CIRA ANNUAL REPORT FY 2013/2014

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE

DIRECTOR'S MESSAGE

The Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University (CSU) is one of a number of cooperative institutes (CIs) that support NOAA's mission. Although this mission continues to evolve, there continue to be strong reasons for partnering between NOAA and the fundamental research being done in the University environment and the students it entrains into NOAA's mission. Strengthening these ties in satellite remote sensing and regional/global weather and climate prediction, as well as application development, education/training, data assimilation, and data distribution technology make CIRA a valuable asset to NOAA. As the Director of CIRA, I have tried to do everything possible to strengthen CIRA's ties not only among CSU's Department of Atmospheric Science, the College of Engineering, and the University, but also the ties among the different groups within CIRA that now covers researchers in Fort Collins and College Park associated with NESDIS, researchers in Boulder working closely with OAR and researchers in Kansas City working with the National Weather Service. With a renewed emphasis on interactions and joint initiatives, we hope to expand our excellence beyond historical areas of strength in Satellite Applications and Model Development to bring the diverse CIRA activities to bear on important problems related to Data Fusion and how they transition into contemporary applications in areas as diverse as air quality, solar energy forecasts or quantitative precipitation estimations. With this, we hope to fulfill the promise of being the conduit for developing ground breaking research to address socially-relevant problems that face NOAA and our society today as well as to help train a new work force that has a broader perspective needed for transitioning to operational stakeholders research concepts that are at the cutting edge of science.

CIRA is fortunate in that its corporate culture and proximity to many of the Nation's top research institutions have allowed it to work with talented researchers and support staff who continue to perform at the highest possible level. There are many important accomplishments that are highlighted in this report and summarized in the executive summary. Not as obvious, but equally important, are the activities that CIRA carries out with the Department of Defense through the Center for Geosciences, the activities with the National Park Service, and the activities with NASA through the CloudSat data processing facility and OCO algorithm development. While not funded by NOAA, these activities are highly synergistic in the areas of algorithm development, modeling and data distribution. They allow CIRA researchers working on exciting new satellite data such as Suomi/NPP's VIIRS instrument to have access to other experts whom they can consult as they develop their own projects. As we finish the current 5-year grant with NOAA and prepare for the next 5 years, we re-establish our commitment to the maintenance and growth of a strong collaborative relationship among NOAA, the Department of Atmospheric Science at CSU, other Departments of the University, and the other programs within CIRA.

Christian D. Kummerow

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VISION AND MISSION

The overarching Vision for CIRA is:

To conduct interdisciplinary research in the atmospheric sciences by entraining skills beyond the meteorological disciplines, exploiting advances in engineering and computer science, facilitating transitional activity between pure and applied research, leveraging both national and international resources and partnerships, and assisting NOAA, Colorado State University, the State of Colorado, and the Nation through the application of our research to areas of societal benefit.

Expanding on this Vision, our Mission is:

To serve as a nexus for multi-disciplinary cooperation among CI and NOAA research scientists, University faculty, staff and students in the context of NOAA-specified research theme areas in satellite applications for weather/climate forecasting. Important bridging elements of the Institute include the communication of research findings to the international scientific community, transition of applications and capabilities to NOAA operational users, education and training programs for operational user proficiency, outreach programs to K-12 education and the general public on environmental literacy, and understanding and quantifying the societal impacts of NOAA research.

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE

The Cooperative Institute for Research in the Atmosphere (CIRA) was established in 1980 at Colorado State University (CSU). CIRA serves as a mechanism to promote synergisms between University scientists and those in the National Oceanic and Atmospheric Administration (NOAA). Since its inception, CIRA has expanded and diversified its mission to coordinate with other Federal agencies, including the National Aeronautics and Space Administration (NASA), the National Park Service (NPS), the U.S. Forest Service, and the Department of Defense (DoD). CIRA is a multi-disciplinary research institute within the College of Engineering (CoE) and encompasses several cooperative agreements, as well as a substantial number of individual grants and contracts. The Institute's research for NOAA is concentrated in five theme areas and two cross-cutting research areas:

Satellite Algorithm Development, Training and Education - Research associated with development of satellite-based algorithms for weather forecasting, with emphasis on regional and mesoscale meteorological phenomenon. This work includes applications of basic satellite products such as feature track winds, thermodynamic retrievals, sea surface temperature, etc., in combination with model analyses and forecasts, as well as in situ and other remote sensing observations. Applications can be for current or future satellites. Also under this theme, satellite and related training material will be developed and delivered to a wide variety of users, with emphasis on operational forecasters. A variety of techniques can be used, including distance learning methods, web-based demonstration projects and instructor-led training.

Regional to Global Scale Modeling Systems - Research associated with the improvement of weather/climate models (minutes to months) that simulate and predict changes in the Earth system. Topics include atmospheric and ocean dynamics, radiative forcing, clouds and moist convection, land surface modeling, hydrology, and coupled modeling of the Earth system.

Data Assimilation - Research to develop and improve techniques to assimilate environmental observations, including satellite, terrestrial, oceanic, and biological observations, to produce the best estimate of the environmental state at the time of the observations for use in analysis, modeling, and prediction activities associated with weather/climate predictions (minutes to months) and analysis.

Climate-Weather Processes - Research focusing on using numerical models and environmental data, including satellite observations, to understand processes that are important to creating environmental changes on weather and short-term climate timescales (minutes to months) and the two-way interactions between weather systems and regional climate.

Data Distribution - Research focusing on identifying effective and efficient methods of quickly distributing and displaying very large sets of environmental and model data using data networks, using web map services, data compression algorithms, and other techniques.

Cross-Cutting Area 1: Assessing the Value of NOAA Research via Societal/Economic Impact Studies - Consideration for the direct and indirect impacts of weather and climate on society and infrastructure. Providing metrics for assessing the value of NOAA/CI research and tools for planners and decision makers. Achieving true 'end-to-end' systems through effective communication of information to policy makers and emergency managers.

Cross-Cutting Area 2: Promoting Education and Outreach on Behalf of NOAA and the University - Serving as a hub of environmental science excellence at CSU for networking resources and research activities that align with NOAA mission goals throughout the University and with its industrial partners. Engaging K-12 and the general public locally, regionally, nationally and internationally to promote both awareness and informed views on important topics in environmental science.

Annually, CIRA scientists produce over 200 scientific publications, 30% of which appear in peer-reviewed publications. Among the important research being performed at CIRA is its support of NESDIS' next-generation satellite programs: GOES-R and NPOESS. These two multi-billion dollar environmental satellite programs will support weather forecasting and climate monitoring for the next 2-3 decades. They will include vastly improved sensors and will offer higher-frequency data collection. CIRA research is building prototype products and developing training, based on the new sensor technology, to assure maximum exploitation of these data when the sensors are launched.

CIRA EDUCATION, TRAINING AND OUTREACH ACTIVITIES: 2013-2014

From the CIRA Mission Statement: *"Important bridging elements of the CI include the communication of research findings to the international scientific community, transition of applications and capabilities to NOAA operational users, education and training programs for operational user proficiency, outreach programs to K-12 education and the general public for environmental literacy, and understanding and quantifying the societal impacts of NOAA research."*

Education and Outreach: Focus for 2013-2014

The Education and Outreach Program at CIRA during 2013 began to implement some of the planned strategies detailed in previous Annual Reports. Beginning with the 5-year review of the Cooperative Institute, which occurred in the first months 2013, the E&O program was given the opportunity to demonstrate the increasingly important role of education, outreach, public relations, and professional development plays in the community at large, and how CIRA E&O programs address these important opportunities. Funding difficulties at the federal level stalled three planned CIRA proposals in the E&O realm, but work towards development of flood/drought education, fire weather professional development, and standards-based geoscience teacher professional development programs continue in anticipation of future funding opportunities.

Front Range Flooding and CIRA: Impacts and Opportunities

As with the fires that ravaged Colorado in 2012, the historic flooding in September of 2013 had a major impact on the CIRA community. The Boulder campus of CIRA experienced more directly the impact of the heavy floods from overflowing mountain streams in the Front Range, with CIRA employees capturing images of high water levels rushing through the streets of Boulder (Figure 1). In Fort Collins, the Foothills Campus location of CIRA once again became part of a command-and-control center for rescue operations, with helicopters from the National Guard departing to and returning from damaged properties in the mountains, landing at nearby Christman Field with loads of evacuees stranded by rising waters (Figure 2).

From a scientific perspective, opportunities to study the meteorological conditions leading to the flooding were extremely compelling, and several images from CIRA researchers became notable for demonstrating the impact of the flood. Two images from the VIIRS instrument aboard Suomi NPP stand out as examples – a before-and-after image of the rivers of Colorado, showing significant swelling due to the discharge of floodwater. Communicating these images through CIRA's social media presence helped draw attention to these powerful forces of nature (Figure 3).

Figure 1. Flooded roads on the way to CIRA's Boulder campus (courtesy of Ed Szoke.)

Figure 2. A CH-47 Chinook helicopter of the U.S. Army's 4th Combat Aviation Brigade lifts off from near the CIRA Foothills Campus, conducting rescue operations. (Courtesy of Matt Rogers.)

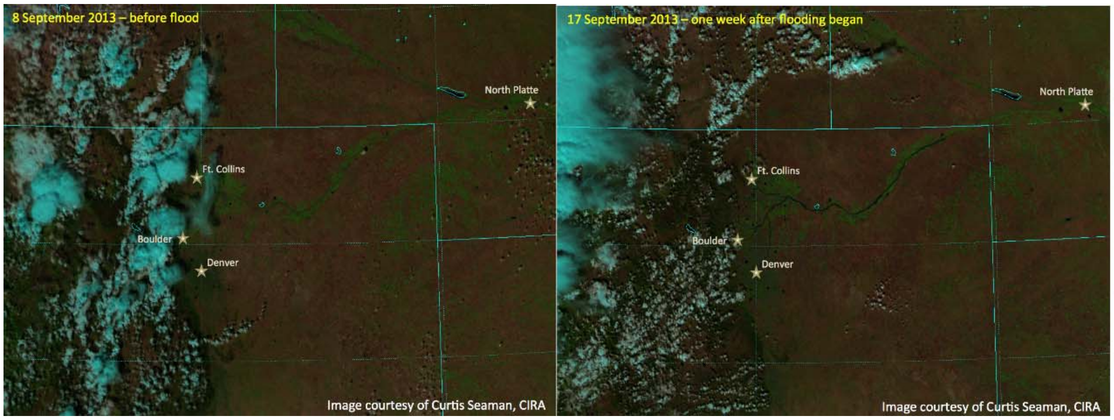


Figure 3. Comparison of the Platte River drainage before (left) and after (right) the flooding of September 2013. (Courtesy of Curtis Seaman.)

Super Typhoon Haiyan at Night: CIRA DNB Imagery Continues to Inform

The passage of Super Typhoon Haiyan over the Philippines in November of 2013 caused an incredible amount of damage and loss of life. CIRA researchers, using the ability of the Day-Night Band (DNB) sensor aboard the Suomi NPP Mission, compared nighttime imagery from the Philippines prior to and immediately after the passage of the typhoon (Figure 4) detailing locations where power and infrastructure in the island nation were destroyed by the typhoon. Information from these kinds of analyses were broadcast through CIRA's social media presence, attracting the attention of, among other things, insurance companies interested in the capabilities of NOAA sensors to document natural disasters.

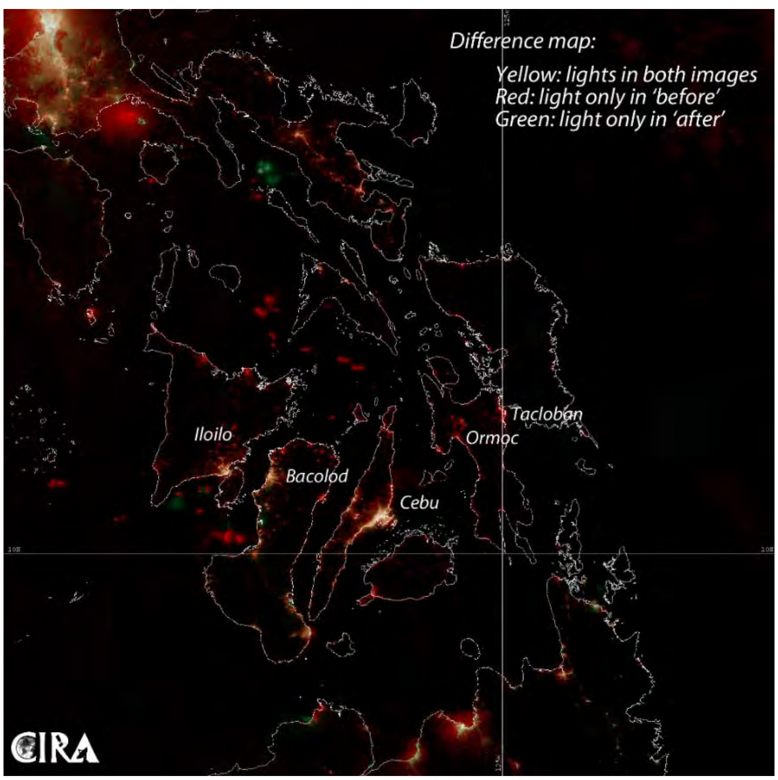


Figure 4. Difference map of lights in the Philippines prior to and after the passage of Super Typhoon Haiyan.

Meteor Tracking and Publicity: Seeing the Chelyabinsk Event from Space

CIRA once again found itself in the unique position of providing research at the cutting edge when the meteor event over Chelyabinsk, Russia in February 2013 captured the world's attention. Using Earth-observing satellites, CIRA researcher and Deputy Director Steve Miller developed a novel technique to triangulate the meteor's path through the atmosphere using observations from two satellite platforms. By comparing the satellite-derived observations against ground observations, a new technique to study meteors was developed (Figure 5), and this research project, borne out of a public relations request to CIRA for information about the meteor, was published in the Proceedings of the National Academies of Science. As with the previous CIRA publication in the Proceedings, a coordinated media campaign on the research results led to CIRA being interviewed internationally.

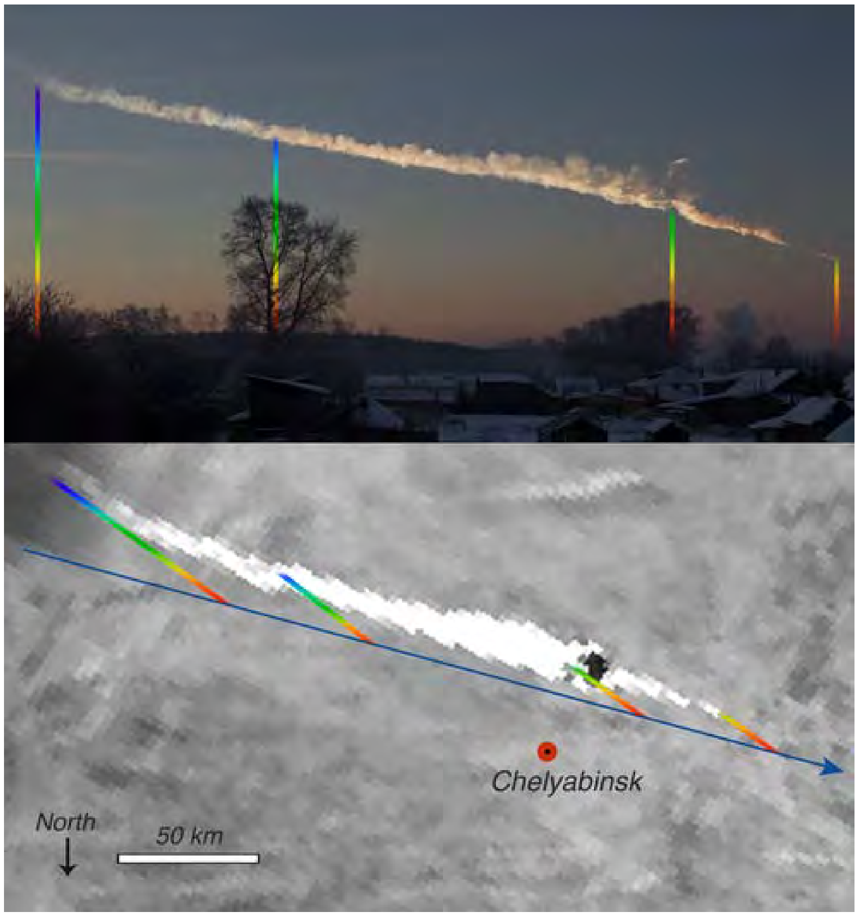


Figure 5. Comparison and triangulation of the Chelyabinsk meteor trail as seen from the ground (top) and from space (bottom) as detailed by CIRA researcher Steve Miller. (Image courtesy of Steve Miller and Maureen Murray.)

FORTCAST: Professional Opportunities for Education and Outreach

In the fall of 2013, CIRA's E&O coordinator, Matt Rogers, was elected as the education and outreach chair for the newly-formed local chapter of the American Meteorological Society (AMS) hosted by Colorado State University. Called 'FORTCAST' (from 'FORT Collins Atmospheric Scientists') the local chapter emerged from the previously-organized student AMS chapter. With the assistance of student, professional, and faculty AMS members, the opportunity to provide a much larger degree of staffing for E&O events became available. The first joint CIRA-FORTCAST E&O activity will take place on Earth Day 2014, with an atmospheric-science themed program hosted at the Fort Collins Museum of Discovery.

Interactions between CIRA and other E&O Organizations – Fort Collins

In addition to the developing organizational structure of the CIRA E&O program, CIRA began to foster more solid relationships with local E&O programs in 2013.

Little Shop of Physics

CIRA continued to work alongside the Little Shop of Physics in 2013. Supported by the NSF-funded Center for Multiscale Modeling of Atmospheric Processes and the CSU Physics Department, the Little Shop of Physics, located online at: http://littleshop.physics.colostate.edu develops hands-on demonstrations of physical concepts for the K-12 audience and supports professional development and science education for K-12 teachers. Utilizing undergraduate and graduate student volunteers, the Little Shop of Physics tours nationally bringing science demonstrations to a large audience. CIRA is annually represented at the Little Shop of Physics Open House where it presents interactive demonstrations of satellite remote sensing techniques and radiative transfer basics, including scattering, absorption, and emission of light.

Soaring Eagle Ecology Center

The Soaring Eagle Ecology Center (SEEC) is a community-led program based in Red Feather Lakes, Colorado, designed to provide that community with education programs for both K-12 and adult audiences. CIRA has provided assistance with both the K-12 and adult programs, and CIRA E&O committee members Teresa Jiles and Matt Rogers hold positions on the SEEC Advisory Committee. In 2013, CIRA researchers continued to present talks at adult summer forums at the Red Feather Lakes Public Library, and interest in developing SEEC property for hands-on educational use with respect to water cycle observations, fire weather, and astronomy are being pursued with CIRA assistance.

Poudre School District

Collaboration with the Fort Collins-based Poudre School District (PSD) bore much fruit in 2013. CIRA developed a program to assist the district with several weather-, climate- and renewable-energy-related programs, including a program for 5th grade teachers to address the Colorado state standards for weather education, which is currently undergoing evaluation by select teachers in the district. Additionally, through CIRA's interaction with FORTCAST, researchers are being connected to district needs through the PSD's *Share It* program, providing subject matter expertise on a number of science and science education projects in the district.

Direct Outreach at Local Elementary School: After-school Programs

Volunteer work supporting after-school weather club: Bernie Connell and Matt Rogers, along with FORTCAST volunteers, organized a weekly after-school weather club on Mondays for Putnam Elementary (K-5) for 6 weeks during the fall of 2013. Each club lasted 90 minutes and included time for snack, a weather topic, and occasionally homework. Sessions covered snow, wind (speed and direction), clouds, temperature, rain and hail measurement, and rainbows. Plans for future educational programs at this successful program are continuing to be developed as the after-school program evolves.

Interaction with World Meteorological Organization Regional Training Centers through the WMO Virtual Laboratory

CIRA is an active member of the World Meteorological Organization (WMO) Virtual Laboratory (VLab) and collaborates with WMO Regional Training Centers (RTC) in Costa Rica, Barbados, Argentina, and Brazil to promote satellite focused training activities. One of our most productive activities with these RTCs continues to be providing support to monthly virtual weather/satellite briefings. Our group is the WMO Focus Group of the Americas and the Caribbean and we are a model group for other WMO countries. Participation in our monthly virtual satellite weather briefings is an easy and inexpensive way to simultaneously connect people from as many as 32 different countries, view imagery from Geostationary and polar orbiting satellites, and share information on global, regional, and local real time and climatic weather patterns, hurricanes, severe weather, flooding, and even volcanic eruptions. Forecasters and researchers are able to “build capacity” by being able to readily communicate with others in their discipline from different countries and discuss the impacts of their forecasts or impacts of broad reaching phenomena such as El Niño. Participants view the same imagery (geostationary and polar orbiting) using the VISITview tool and utilize GoToWebinar for voice over the Internet.
http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp

See http://rammb.cira.colostate.edu/training/rmtc/ for more information on various RTC activities and the calendar of events.

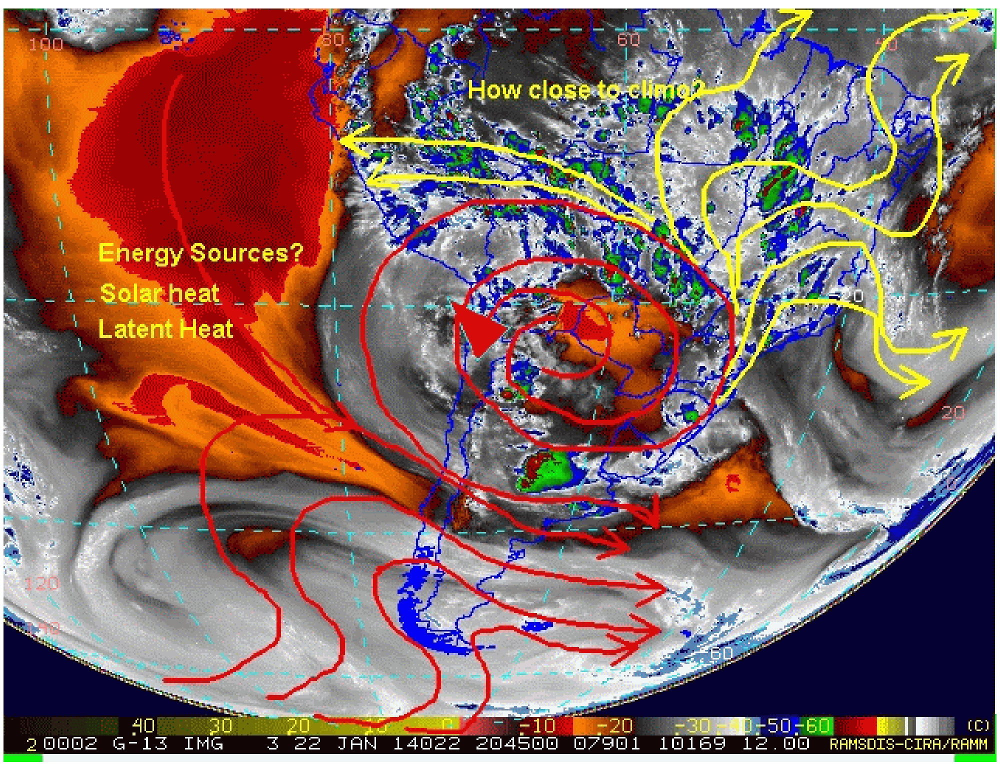


Figure 6. Screen grab during the January 2014 session showing water vapor (6.5 µm) GOES-13 imagery over South America with annotation depicting the location of the Bolivian high. The points addressed during the session focused on whether this the normal climatological position of the high for January and what factors influence the location of the high.

Science on a Sphere® - Michael Biere and Keith Searight

CIRA researchers provide technical support for SOS® new installations. SOS® was installed at the following sites this year:
--E.O. Wilson Biophilia Center - Freeport, FL
--Cyberinfrastructure Building at Indiana University - Bloomington, IN
--Museo delle Scienze - Trento, Italy
--Techmania Science Center - Pilsen, Czech Republic
--NOAA Headquarters - Silver Spring, MD
--Science Central - Fort Wayne, IN
--National Museum of Marine Science and Technology - Keelung City, Taiwan
--Galaxy E3 Elementary - Delray Beach, FL
--NOAA Inouye Regional Center - Honolulu, HI
--Climate Institute - Ciudad Victoria, Mexico
--Dongguan Meteorology and Astronomy Museum - Dongguan, People's Republic of China

The total number of SOS® sites installed is now 104 worldwide. The SOS® team provided regular support to existing SOS® sites by e-mail and telephone. The issues handled included upgrades and problems with the SOS® software, hardware, and equipment, finding and accessing datasets, and questions about operating the SOS® system.

A notable project achievement was the translation of the SOS® website into Mandarin Chinese. SOS® is currently of great interest in Mandarin Chinese speaking nations and this new capability overcomes the unclear descriptions generated by common online translation tools.

The Citizen Weather Observer Program (CWOP) - Leigh Cheatwood and Randall Collander

The CWOP is a public-private partnership with three main goals:

--Collect weather data contributed by citizens.
--Make these data available for weather services and homeland security.
--Provide feedback to the data contributors so that they have the tools to check and improve their data quality.

There are currently 14,147 active stations (citizen and ham radio operator) in the CWOP database (out of a total of 28660 stations in the CWOP database). Of these, approximately 13,076 are sending data based upon an actual count for citizen stations today and application of the same ratio of sending/active (74%) to the ham radio stations. CWOP members send their weather data via internet alone or internet-wireless combination to the findU (http://www.findu.com) server and then the data are sent from the findU server to the NOAA MADIS ingest server every five minutes. The data undergo quality checking and then are made available to users thru the MADIS distribution servers. In 2013, there were approximately 2400 stations added to the database. There were approximately 3000 revisions made to site metadata (note: some sites had multiple change requests, so the number of unique sites that requested changes is less than 3000). Adjustments include latitude, longitude and elevation changes in response to site moves, refinement of site location, and site status change (active to inactive, vice-versa).

NOAA Environmental Information System (NEIS) and TerraViz - Jebb Stewart, Jeff Smith, Randy Pierce, Chris MacDermaid, MarySue Schultz

The objective of the NEIS project is to make data easily accessible to people across the country and around the world. The CIRA team’s objectives are to investigate, prototype and explore. Continued collaboration with the Climate Program Office (CPO) including added tour capability allowing users to create guided presentations of data through the NEIS visualization system TerraViz as well as enhanced collaboration capabilities allowing multiple users to share and interact within a single session of TerraViz at the same time. The team also developed new particle display visualization taking advantage of 3D capabilities to allow users to see wind parameters in motion for gridded forecast data. They added several new data access capabilities including data directly from FTP, HTTP or THREDDS data services. The new THREDDS capability allows users to access multiple vertical levels of gridded data. Created kiosk mode and touchscreen capabilities allowing TerraViz to run in unsupervised mode showing off capabilities and data. This was demonstrated at the AMS Annual Meeting 2013 in Austin TX. Additionally, NEIS/TerraViz is now available on a touch screen in the ESRL Lobby.

Developmental Testbed (DTC) Publications – Edward Tollerud

Through the reporting period, Ed Szoke published quarterly issues of the DTC newsletter. He also presented his information through the Bulletin of the American Meteorological Society as well as at various conferences and workshops.

NWS Virtual Lab (VLab) - Ken Sperow

Continuing his position as NWS VLab technical lead (not to be confused with the WMO VLab project described previously), Ken Sperow assisted with the growth of the NWS VLab's importance and visibility within the NWS. He demonstrated the VLab to both Director of the NWS and to other top-level staff within the NWS. Ken gave separate demos of the VLab to the Warning Coordination Meteorologist (WCM) community, the Information Technology Officer (ITO) community, and the Science and Operations Officer (SOO) community. He maintained web-based services to help manage projects via issue tracking, source control sharing, code review, and continuous integration, VLab Development Services (VLDS) have grown to support 51 projects and 512 developers. Under Ken Sperow's leadership, NCEP used the VLab to check in their 14.2.1 AWIPS II baseline changes. He is currently working with the NOAA CIO's office to move the VLab to a public cloud infrastructure. Ken continues as the technical lead of the Virtual Lab Support Team (VLST). This team currently consists of 10 members to whom Ken provides support and training.

Advanced High Performance Computing - Thomas Henderson, Jacques Middlecoff, James Rosinski, Jeff Smith, Ning Wang

CIRA researchers attended several meetings and gave some talks on GPU and Xeon Phi research at the "Programming Weather, Climate, and Earth Systems Models" Workshop, GPU Technology Conference, the GRIMS Workshop in South Korea (invited), the ACS Program Review, an XSEDE Workshop, the AOLI Meeting at FSU, an RRTMG Meeting at NCAR, and Supercomputing 13.

2013 Summer Weather Experiment, AWC – Dan Vietor, Brian Pettegrew, Larry Greenwood, Adrian Noland, Benjamin Schwedler

The Aviation Weather Center (AWC) in Kansas City, MO hosted the Third AWT Summer Experiment August 12-23, 2013. The primary goal of the experiment was to demonstrate and evaluate new datasets, tools, and deliverables with the participation of AWC forecasters, academia, governments, and industry participants in a simulated operational environment focused on air traffic impact.

There were three primary goals met during the Aviation Weather Testbed (AWT) 2013 Summer Experiment. First, the experiment provided resources to demonstrate and evaluate new capabilities combined with the forging of professional relationships between public, private, and academic entities. Additionally, the 2013 Summer Experiment was a useful training opportunity for AWC forecasters because it exposed them to new data sets, tools, and products, and afforded them the opportunity to discuss them with researchers and developers. Several individuals, both internal and external, gave brown bag lunch seminars that provided valuable information and generated productive discussions. Finally, the experiment played a role in establishing an Operations-to-Research (O2R) link which is critical to the success of developing new products to support existing operations. Tangible successes of the 2013 Summer Experiment are evident by the amount of recommendations and actions that resulted from the interactions of the participants. (Lack, 2014)

The Third AWT Summer Experiment focused on forecasting high-impact convection on multiple scales of interest, from regional to global, however some additional aviation impact variables were considered, such as ceiling, visibility, and winds. Throughout the two weeks, five experimental workstations were set up each with their own individual goals, including: An experimental CCFP desk, an experimental Convective SIGMET desk, a National Aviation Meteorologist (NAM) experimental desk, a global convection desk, and a situational awareness desk (including GOES-R simulated products and a variety of observation and nowcasting datasets). A primary task for the experimental desks was to issue operational products using both operational and experimental guidance available within the AWT. Additionally, some desks were asked to issue modified operational products that provided additional information useful to traffic flow management decision making.

CoCoRaHS and the Colorado Climate Center

CoCoRaHS, the Community Collaborative Rain, Hail and Snow network (http://www.cocorahs.org/) was founded by the Colorado Climate Center at Colorado State University. This citizen-science project started in Fort Collins, Colorado after a devastating flash flood in 1997. The flood caused over $200 million in damages (including major damages to the CSU campus) and the loss of five lives, and also pointed out the need for timely and localized precipitation data. Precipitation is known to be extremely variable; and, with the help of volunteers who are trained and equipped, the gaps between official weather stations are being supplemented by volunteer data. The network quickly grew and now consists of thousands of volunteers in all 50 States, with nearly 10,000 reports submitted daily (Figure 7). One key to the project's success is that the data are used by the public as well as professionals including scientists and meteorologists at the National Weather Service.

CoCoRaHS has implemented new educational materials, including animation based videos. In an effort to promote and facilitate weather and climate literacy, CoCoRaHS released the first in the series, 'The Water Cycle', which not only grabbed the attention of the Jackson Hole Science Media Awards where it became a finalist in the category 'Best Short Program' but has quickly become the single most popular video on the CoCoRaHS YouTube channel reaching over 180,000 views by the end of 2013. Other videos include short training animations including a new series on 'How to Measure Snowfall' (Figure 8): https://www.youtube.com/playlist?list=PLS0EU9SKRY0_liw4Z60q_zodgCz-etYB5

2013 was a great year of growth with CoCoRaHS, especially among schools where teachers and students collect and report precipitation measurements. During 2013 CoCoRaHS presented at 28 professional development workshops, field trips, school visits and water festivals, totaling 1,655 people reached. Twice per year, April and September, CoCoRaHS hosts 'Rain Gauge Week' for all participating schools in the country – nearly 600 by the end of 2013. In September, 2013, 'Rain Gauge Week' happened to coincidentally occur at the same time as the devastating floods along the Front Range of Denver, and participating schools were able to contribute data that is still being analyzed by experts. Figure 9 below shows a precipitation map from the Week of September 8th-12th - including data that was submitted from schools all over the state during Rain Gauge Week.

CoCoRaHS school activities have now been mapped and aligned with state standards for Colorado, Next Generation Science Standards and Common Core. Other states have aligned CoCoRaHS activities to their specific state standards such as Florida and Minnesota.

Thanks to a continuing collaboration with CIRA and the local Poudre School District television studio, the 'Walking Through the Water Year' series now consists of monthly reports from schools participating with CoCoRaHS. Each school that has a rain gauge and reports to CoCoRaHS has the opportunity to select two students to work with professionals in producing their monthly precipitation report. Episodes are aired on local TV and available on line at: http://epresence.psdschools.org/1/Page/Published/3.aspx

Walking Through the Water Year and Rain Gauge Week were both highlighted in a recent publication, 'In the Trenches' – The News Magazine of the National Association of Geoscience Teachers.

Newman, N., 2014: Measuring Rainfall for Science: How a Citizen Science Program Reaches into the Classroom and Across the Curriculum. In The Trenches, National Association of Geoscience Teachers, vol. 4.1, (Jan.) pp. 5-7.

An informal partnership with NASA was formed in conjunction with their Global Precipitation Measurement (GPM) Mission. Two webinars were presented by NASA GPM scientists. Furthermore, educational outreach efforts by GPM education staff have culminated in nearly 35 schools in Maryland and D.C. setting up CoCoRaHS rain gauges for studying ground validation activities.

http://pmm.nasa.gov/education/current-activities/CoCoRaHS

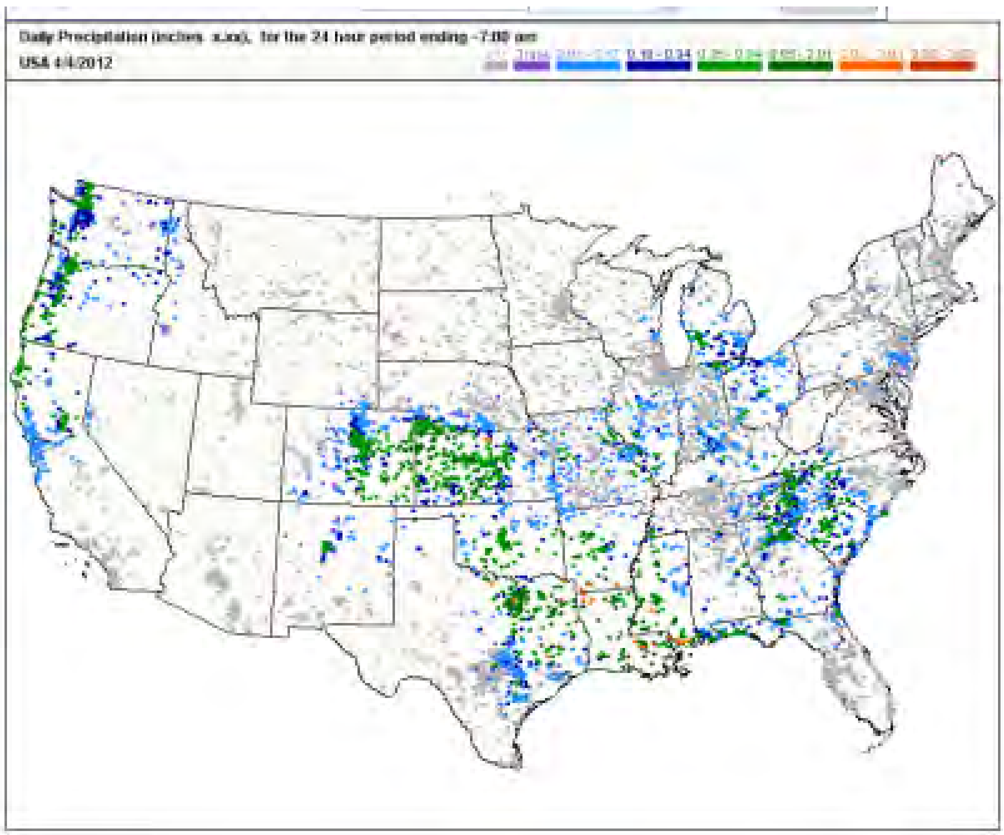


Figure 7

Figure 8. CoCoRaHS Education Video: How to Measure Snowfall.

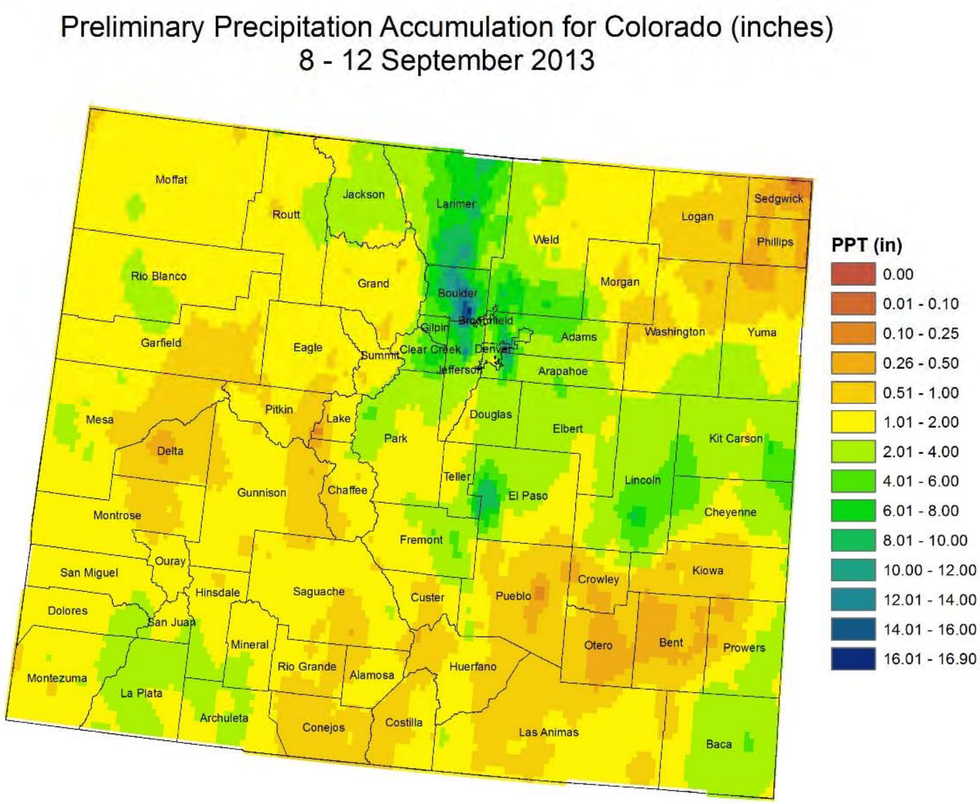


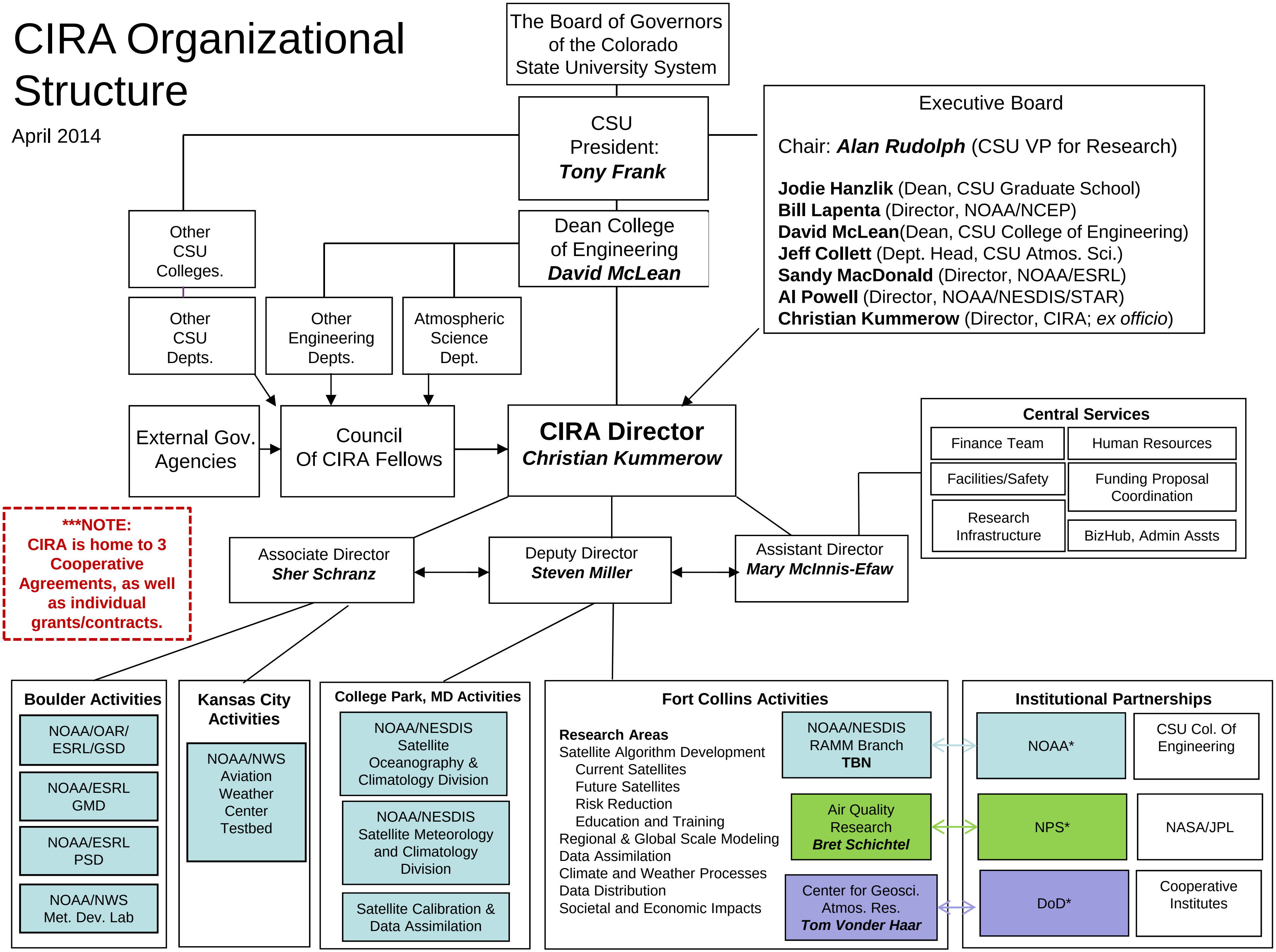
Figure 9. Precipitation Map for Colorado During Rain Gauge Week

NOAA AWARD NUMBERS

Award Number	Identifier	Project Title	Principal Investigators/ Project Directors
NA09OAR4320074	Cooperative Agreement	A Cooperative Institute to Investigate Satellite Applications for Regional/Global-Scale Forecasts	Chris Kummerow (Lead), Steven Miller
NA10SEC0080012	Competitive	CoCoRaHs: Capitalizing on Technological Advancements to Expand Environmental Literacy through a Successful Citizen Science Network	Chris Kummerow (Lead), Nolan Doesken
NA11OAR4310208	Competitive	Development of a Probabilistic Tropical Cyclone Prediction Scheme	Chris Kummerow
NA11OAR4310204	Competitive	Development of a Real-time Automated Tropical Cyclone Surface Wind Analysis	Chris Kummerow
NA13OAR4590187	Competitive	Guidance on Intensity Guidance	Andrea Schumacher
NA11OAR4310203	Competitive	Improvements in Statistical Tropical Cyclone Forecast Models	Chris Kummerow
NA13OAR4310080	Competitive	Improving CarbonTracker Flux Estimates for North Americas Using Carbonyl Sulfide (OCS	Ian Baker
NA12OAR4310077	Competitive	Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models	Eric Maloney
NA10OAR4310103	Competitive	Quantifying the Sources of Atmospheric Ice Nuclei from Biomass Burning Aerosols	Chris Kummerow
NA13OAR4310103	Competitive	Research to Advance Climate and Earth System Models Collaborative Research: A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models	David Randall
NA13OAR4310077	Competitive	Towards Assimilation of Satellite, Aircraft and Other Upper-air CO2 Data into CarbonTracker	David Baker
NA13NWS48300233037	Competitive	Tropical Cyclone Model Diagnostics and Product Development	Wayne Schubert
NA13OAR4590190	Competitive	Upgrades to the Operational Monte Carlo Wind Speed Probability Program	Andrea Schumacher
NA13OAR4310163	Competitive	Use of the Ocean-Land-Atmosphere Model (OLAM) with Cloud System-resolving Refined Local Mesh to Study MJO Initiation	Eric Maloney
NA10NES4400012	Competitive	Utility of GOES-R Instruments for Hurricane Data Assimilation and Forecasting	Chris Kummerow

CIRA Organizational Structure

April 2014



CIRA BOARD, COUNCIL, FELLOWS & BOARD MEETINGS

CIRA EXECUTIVE BOARD

Jeff Collett, Colorado State University
Department Head, Atmospheric Science
Jodie Hanzlik, Colorado State University
Dean, Graduate School
Christian Kummerow (ex officio), Colorado State University
Director, CIRA and Professor of Atmospheric Science
Bill Lapenta, NOAA
Director, National Centers for Environmental Prediction
A.E. "Sandy" MacDonald, NOAA
Chief Science Advisor - NOAA Research and Director, ESRL
David McLean, Colorado State University
Dean, Engineering
Al Powell, NOAA
Director, NOAA/NESDIS/STAR
Alan Rudolph, Colorado State University
Vice President for Research

CIRA COUNCIL OF FELLOWS

V. Chandrasekar, Colorado State University
Department of Electrical and Computer Engineering
Ingrid Guch, NOAA
Chief, NOAA/STAR/CoRP
Don Hillger, Colorado State University
Acting Chief, NOAA/NESDIS/RAMM Branch
Sonia Kreidenweis-Dandy, Colorado State University
Professor, Department of Atmospheric Science
Christian Kummerow, Colorado State University
Director, CIRA and Professor of Atmospheric Science
John Schneider, NOAA
Chief, ESRL/GSD/Technology Outreach Branch
Pieter Tans, NOAA
Senior Scientist, Climate Monitoring and Diagnostics Lab
Fuzhong Weng, NOAA
Chief, NESDIS/STAR/Satellite Calibration and Data Assimilation Branch

CIRA FELLOWS

Mahmood Azimi-Sadjadi, Electrical & Computer Engineering, CSU
Daniel Birkenheuer, NOAA/ESRL/GSD
V. Chandrasekar, Electrical & Computer Engineering, CSU
Jeffrey Collett, Jr., Atmospheric Science Department, CSU
William Cotton, Atmospheric Science Department, CSU
Mark DeMaria, NOAA/NWS/NHC
Scott Denning, Atmospheric Science Department, CSU
Graham Feingold, NOAA/ESRL
Douglas Fox, Senior Research Scientist Emeritus, CIRA, CSU, USDA (Retired)

Ingrid Guch, NOAA/NESDIS/CoRP
Jay Ham, Soil and Crop Sciences, CSU
Scott Hausman, NOAA/GSD
Richard Johnson, Atmospheric Science Department, CSU
Andrew Jones, Senior Research Scientist, CIRA, CSU
Pierre Y. Julien, Civil Engineering, CSU
Stanley Kidder, Senior Research Scientist, CIRA, CSU
Sonia Kreidenweis, Atmospheric Science Department, CSU
Christian Kummerow, CIRA Director, Atmospheric Science Department, CSU
Glen Liston, Senior Research Scientist, CIRA, CSU
Alexander “Sandy” MacDonald, NOAA
Williams Malm, Senior Research Scientist, CIRA; National Park Service (retired)
Roger Pielke, Sr., Senior Research Scientist, CIRES, U of Colorado
James Purdom, Senior Research Scientist, CIRA, CSU
Robert Rabin, NOAA/National Severe Storms Laboratory
Steven Rutledge, Atmospheric Science Department, CSU
John Schneider, NOAA/ESRL/Global Systems Division
George Smith, Riverside Technologies
Graeme Stephens, JPL and Atmospheric Science Department, CSU
Pieter Tans, NOAA/CMDL
Thomas Vonder Haar, CIRA Director Emeritus and Atmospheric Science Department, CSU
Fuzhong Weng, NOAA/NESDIS/STAR
Milija Zupanski, Senior Research Scientist, CIRA

Meeting of the CIRA Fellows May 21-22, 2013
Meeting of the CIRA Executive May 21-22, 2013

Scheduled Meetings:
Meeting of the CIRA Council June 25, 2014
Meeting of the CIRA Executive Board August 27, 2014

EXECUTIVE SUMMARY—Research Highlights

The Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University (CSU) serves as both an active collaborator and formal interface between academic expertise and multiple agencies holding both basic and applied research interests in atmospheric science. Under its capacity as NOAA's Cooperative Institute for exploiting satellite applications for improvements in regional and global-scale forecasting, CIRA provides an important and practical connection between two NOAA line offices—Oceanic and Atmospheric Research (OAR) and the National Environmental Satellite, Data and Information Service (NESDIS). Diverse expertise in satellite remote sensing, science algorithm and application development, education/training, regional/global weather and climate modeling, data assimilation, and data distribution technology make CIRA a valuable asset to NOAA in terms of transitioning research concepts to operational stakeholders.

The CIRA Annual Report provides summaries of the contributions emerging from our research partnership with NOAA, with more detail to be found in the peer reviewed and technical conference publications cited within this report as appropriate. Highlighted below are accomplishments from the current reporting period and drawn from both the NOAA reports contained herein as well as from the broader palette of research conducted at CIRA. These examples underscore intra- and inter-agency partnerships that present opportunities for leveraging activities of other agencies.

- While launches of both GOES-R as well as JPSS in the near future are occupying increasing amounts of time, there is still significant work being conducted to fully exploit existing data. The GOES Improvement and Product Application Program (GIMPAP) has six concurrent research areas that span the gamut of applications from: (1) Combining Probabilistic and Deterministic Statistical Tropical Cyclone Intensity Forecast Models; (2) Developing GOES-Based Tropical Cyclone Recurvature Tools; (3) WFR Cloud Moisture Verification with GOES; (4) Advancing GOES Cloud and Surface Irradiance Products for Applications to Short-Term Solar Energy Forecasting; (5) Enhanced Downslope Windstorm Prediction with GOES Warning Indicators; and (6) Probabilistic Nearcasting of Severe Convection. The Nearcasting of severe convection in particular, has made important strides in the research and shows greater lead times than the NWS severe thunderstorm/tornado warnings in a median sense. Coupled with continued education and training activities such as CIRA's participation in the Virtual Institute for Satellite Integration Training (VISIT), the value of existing data is still being exploited to its fullest.

- CIRA participates actively in the GOES-R and JPSS Risk Reduction activities as well as the GOES-R Satellite Proving Ground Project. The risk reduction activities for GOES-R focus on CIRA-developed techniques to simulate GOES-R data from high-resolution forecast models to help understand the system and its capabilities. Also focused on GOES are substantial activities related to the Algorithm Working Groups where CIRA projects focus on Data Assimilation, Severe Storm Nearcasting; Tropical Cyclone track and intensity analysis and data user preparation. This, of course, is coupled to proving ground activities described in the report to prepare forecasters in the field for these new products. An area of great excitement continues to be the work being done with the Day/Night band of Suomi-NPP in preparation for JPSS. Not only is detection of smoke, dust, and fog possible at night but results appear far better than originally anticipated. Immediate applications such as ash monitoring from Alaska volcanoes is underway as detailed in the project reports. The VIIRS Sensor is also being used extensively for more established applications related to Sea Surface Temperature and Ocean Color products produced by CIRA Research Scientists working directly with NOAA STAR employees in College Park, MD. Perhaps not evident when evaluating a single proposal, however, is the synergy that CIRA provides across projects through its internal communications and collaborations. A careful review of all the activities related to satellite algorithm development, training and education, however, clearly reveals these synergies and the benefits that these create on behalf of NOAA.

- This past year collaborations with the Global Systems Division (GSD), the Physical Sciences Division (PSD), and the Global Monitoring Division (GMD) of the NOAA Earth System Research Lab (ESRL) in Boulder were productive in both continuing and new research areas. CIRA researchers either led or were immersed in every branch and virtually every project in GSD. Project leadership and integral support were provided for: Fire Weather Modeling and Research, the FAA NextGen Network-Enabled Weather (NNEW—now known as CSS-Wx), the NWS NextGen, and Aviation Weather Forecast Evaluation programs; meteorological workstation development, including the AWIPS II Extended Tasks for both Collaboration and Hazard Services, FX-NET Thin Client, AWIPS II Thin Client, and MADIS; high performance computing (especially related to GPU processing); and the design, development and implementation of various regional and global weather and climate models, including the RR, HRRR, WRF-Chem, FIM, and NIM as well as the LAPS/STMAS data assimilation systems and ensemble model post-processing and technology leadership in the Science on a Sphere (SOS®) program and the new NOAA Environmental Information System (NEIS) project. NOAA testbed research resulted in improvements to the ensemble models in the Hydrometeorological Testbed (HMT), downscaled additions to the CONUS Experimental Warning Program (EWP) domain in the Hazardous Weather Testbed (HWT) and changes to the SREF configuration in the Developmental Test Center (DTC) Ensemble Testbed. For program management and proposal development efforts on many of these programs, Sher Schranz won a 2013 CIRA Research Initiative Award.

- As part of the NWS NextGen Program, CIRA researchers at ESRL continued their research into the technology and science of populating a four-dimensional airspace with atmospheric data, extraction methodologies, distribution formats, and input mechanisms to be used by aviation decision support systems. They supported NWS 4D Data Cube by prototyping the iWXXM observation data format required by the international aviation weather community, including the transition of software to NOAA data providers.

- CIRA researchers collaborated on the development of a prototype of TerraViz, a 3D spinning globe application that will be the visualization front end of the new NOAA Environmental Information System (NEIS) initiative. This capability relies on Unity3D—software that has traditionally been used for 3D video games--to present high-volume datasets in stunning displays. TerraViz is also being used to create 3D visualization capabilities for the FIM and NIM models.

- Support for the Science On a Sphere® (SOS) Program continued with the addition of the ability to download global model data in near-real-time via FTP to selected SOS sites. SOS systems were installed at 11 sites this year in Florida (2), Indiana (2), Silver Spring, MD (NOAA HQ), Hawaii, Italy, Czech Republic, Taiwan, Mexico and the People's Republic of China. Worldwide, there are now 104 SOS® sites.

- Vital collaboration with the ESRL Global Monitoring Division continued on CO_2 data assimilation and OSSE research as well as enhancements to the CarbonTracker (CT) Program. Changes to the CT this year included a reworked architecture to separate the transport model from the flux inversion used to assimilate data. Portions of the PCTM and variational carbon data assimilation code were parallelized enabling faster turnaround on model results and analysis. Collaboration with the ESRL Physical Sciences Division was initiated on hydrologic research and applications development for the NOAA HMT, along with water resources applications outreach coordination involving the Russian River and California Integrated Water Resources Science and Services (IWRSS) Pilot and national-level eGIS activities.

- The on-going partnership with the NWS Meteorological Development Lab continued on several fronts. CIRA took the lead in prototyping, setting up, and customizing the Virtual Lab (VLab) using LifeRay's open source java portal framework. The operational VLab continues to be expanded and updated by the CIRA team. The portal component of the VLab provides NWS employees and research partners a web-enabled virtual location to collaborate and innovate. The AWIPS II software development environment has been installed within the Virtual Lab which will become the development environment for all NWS tool development and software management. New development projects in this environment included a new meteogram tool developed by the NASA SPoRT program. Research collaboration was begun to transition the AutoNowcaster (ANC) tool to operations. The CIRA research team members have been added as leaders and/or members of the NWS MDL Configuration Control Board, the VLab support group, the NWS national Impacts Catalog Project and the NWS Systems Engineering Center AWIPS II design team.

- Ensemble model research activities were added to the CIRA collaborations this year. CIRA researchers participated in the development of MET-Based ensemble verification techniques in the NOAA Developmental Testbed Center (DTC) resulting in a BAMS publication. An Ensemble Processor (EP) tool was developed for AWC forecasters (supporting Traffic Flow Management) to allow access to and analysis of the HWRF and SREF ensemble model members. Operational transition work was begun this year as well.

- CIRA researchers continued close collaborations with research and operations personnel at the Aviation Weather Testbed at the NWS Aviation Weather Center in Kansas City, MO. Primary goals of the partnership are to actively engage in the research-to-operations process and to develop, test, and evaluate new and emerging scientific techniques, products, and services in support of the aviation weather community. Research and development efforts have been centered in two research areas; 1) Aviation Impact Variables (AIV's) which are tested during the AWC Summer and Winter Aviation Weather Experiments and include AWRP upgrades to CIP and FIP, and the upgrade to the Collaborative Convective Forecast Product (CCFP); 2) NWS NextGen aviation weather data format prototyping for international standards, and efficient data and product distribution. One member of the CIRA research team (Ben Schwedler) at AWC was nominated, along with his federal collaborators for a NOAA Personnel Advisory Committee (PMAC) award, one administrator was also nominated (Jenna Dalton).

- Project management and planning work was begun in 2013 for the High Impact Weather Prediction Project (HIWPP), part of the Hurricane Sandy Supplemental funding work. Research in OSSE's, high performance computing, information systems, global models, and model verification will be performed in 2014 for this program.

- CIRA's association with the DoD Center for Geosciences / Atmospheric Research (CG/AR) continues and offers promise for the future as both centers focus on substantially the same problem of bringing satellite data to bear on quantifying current conditions and forecasting their future state. The Satellite Data Assimilation effort, in particular, is one in which CIRA PIs work on projects related to both agencies (as well as NSF) and thus benefit from new knowledge gained as a consequence of these efforts.

- Over the past year the CIRA group working with the National Parks Service (NPS) continued its research on issues related to visibility and air quality at our Nation's National Parks. Their research, while focused on issues of importance to the National Park Service, overlaps considerably with a number of new CIRA initiatives related to pollutant transport such as those related to fires that are of great interest to the Park Service and NOAA and thus continues to be an integral partner in what we do as CIRA.

- The CloudSat Mission continues to enjoy strong support from NASA despite some anomalies with the spacecraft during the previous year. The CloudSat Program, with its Data Processing Center running operationally at CIRA on behalf of NASA, has facilitated multiple research activities that are of benefit to NOAA. Chief among these is CIRA's ability to quickly make use of the CloudSat data to provide a unique validation for cloud base height retrievals produced by the VIIRS instrument on Suomi-NPP. In addition, CIRA has compiled a 6-year cloud-class dependent climatology of cloud geometric thickness, partitioned by season, latitude and surface type. This database will serve as an invaluable testbed for VIIRS Cloud retrievals that contains less information than is available for CloudSat.

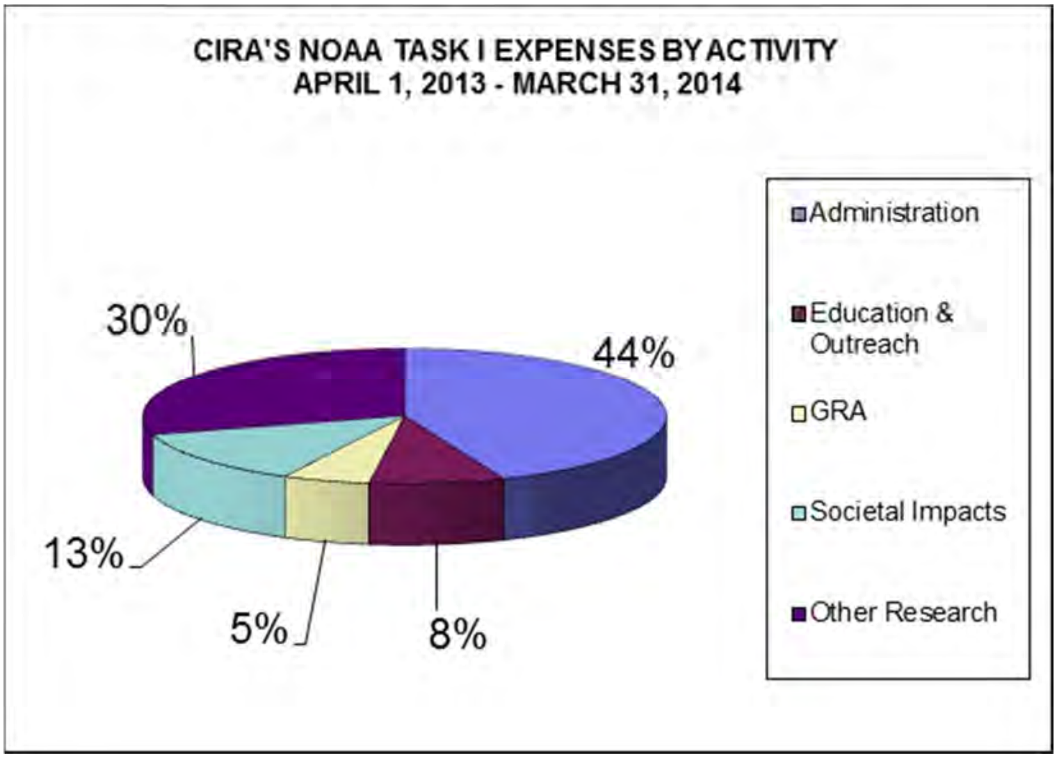
This Annual Report is broken into several chapters which represent the NOAA-defined themes of CIRA's Cooperative Institute. In our *Satellite Algorithm Development, Training and Education* theme, we describe ongoing efforts in developing applications for the current constellation of GOES sensors as well as risk-reduction for the future GOES-R satellite program, work related to estimating tropical cyclone formation probability and the cost-savings of improved track forecasting, and contributions to the VISIT and SHyMET satellite training programs. We continue to expand our activities related to existing NPP and planned JPSS sensors – particularly the VIIRS sensor. Our *Regional to Global-Scale Modeling Systems* theme continues to focus on the development of the Flow-following Finite-volume Icosahedral Model (FIM) and Non-hydrostatic Icosahedral Model (NIM) development along with advanced high-performance computing necessary to run these models efficiently.

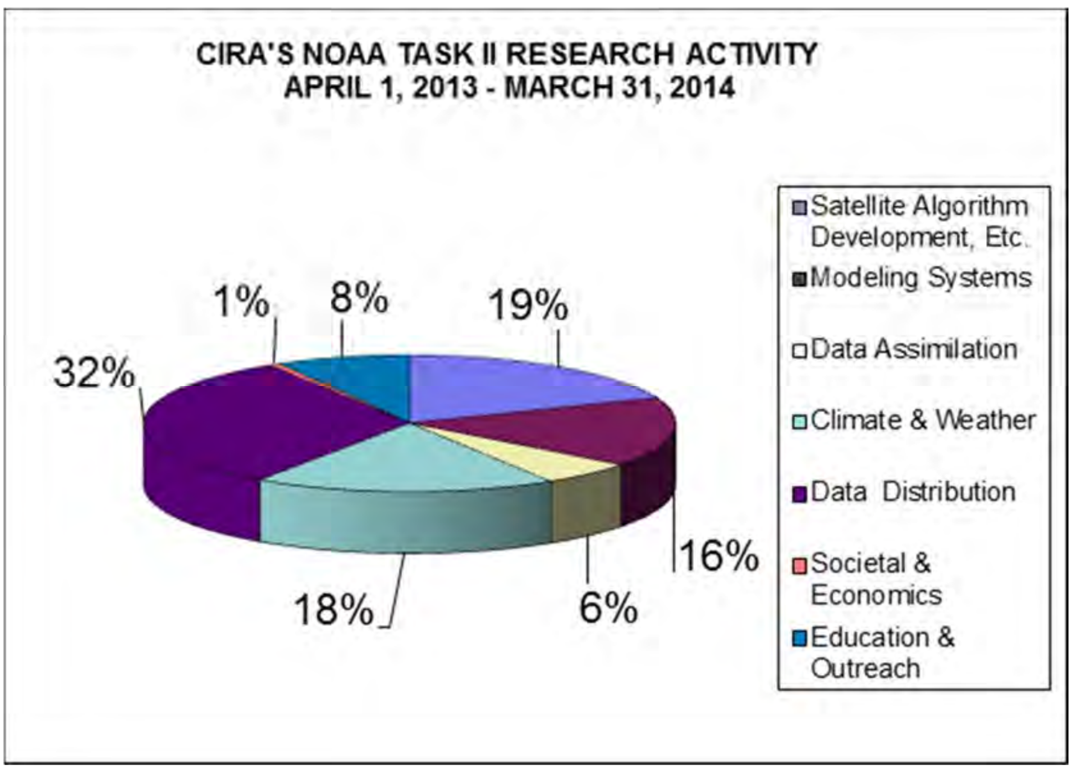
Our *Data Assimilation* theme showcases developments of Ensemble Data Assimilation for Hurricane Forecasting as well as specific applications of these techniques with GOES data. While perhaps not completely evident from this report that focuses on accomplishments related to our NOAA grants, the Data Assimilation activity benefits tremendously from other funding sources that spur the theoretical innovation that is then applied to existing NOAA problems such as CO_2 data assimilation within NOAA's CarbonTracker program or the hybrid Variational-Ensemble Kalman Filter approach used to assimilate lightning data.

Highlighted in CIRA's *Data Distribution* theme is work with the National Weather Service (NWS) Meteorological Development Lab for migration of AutoNowcast to operations for improved convective initiation and situational awareness, multiple efforts toward improving aviation forecast support systems via the FAA NNEW and NWS NextGen projects, preparations for the next-generation AWIPS-II interface, the Meteorological Assimilation Data Ingest System (MADIS) transition to NWS operations, and development of a novel drought early warning system. While a completely separate activity, the severe weather visualization tools connect well with CIRA's support of the CASA Demonstration Network that is intended to predict severe weather through the utilization of many small Doppler radar systems. While it is too early to connect their efforts, it showcases the power of having universities involved that are ultimately interested in exploiting these systems in every way possible.

Interspersed among these major research themes are important contributions from CIRA's NESDIS Environmental Applications Team (NEAT) in data distribution, assimilation, and satellite algorithm development. Located in College Park, MD, and integrated closely with NOAA technical contacts at STAR, these scientists are immersed in research ranging from refinements to the Community Radiative Transfer Model (CRTM), data assimilation of cloudy radiances, satellite-based sea surface temperature (SST) algorithm development, techniques for monitoring and quality control of long-term SST records, and ocean color algorithm development for global climate and coastal/in-land water ecosystem monitoring. Some of the techniques and web interfaces being developed by this outstanding group of Research Scientists is a constant reference source for other CIRA activities with similar objectives.

This Annual Report is the fifth in a series to be completed under CIRA's Cooperative Agreement established with NOAA. As we near completion of our first 5 years of the Cooperative Agreement, we re-establish our commitment to the maintenance and growth of a strong collaborative relationship between NOAA, the Atmospheric Science Department at CSU, other Departments of the University, and the other major programs at CIRA, as well as pursuing new directions of growth within our NOAA research themes. We look forward to the challenges ahead.


CIRA'S NOAA TASK I EXPENSES BY ACTIVITY
APRIL 1, 2013 - MARCH 31, 2014
Administration
Education & Outreach
GRA
Societal Impacts
Other Research
30%
44%
13%
5%
8%


CIRA'S NOAA TASK II RESEARCH ACTIVITY
APRIL 1, 2013 - MARCH 31, 2014
Satellite Algorithm Development, Etc.
Modeling Systems
Data Assimilation
Climate & Weather
Data Distribution
Societal & Economics
Education & Outreach
1%
8%
19%
32%
16%
18%
6%

TASK I – A COOPERATIVE INSTITUTE TO INVESTIGATE SATELLITE APPLICATIONS FOR REGIONAL/GLOBAL-SCALE FORECASTS

Task I activities are related to the administrative management of the CI. As reflected in the pie chart appearing earlier in this report, expenses covered by Task I are primarily salary and benefits, annual report production costs and some travel. This task also includes some support of postdoctoral and visiting scientists.

SEMINARS SUPPORTED BY TASK I

April 4, 2013, D. Randall (CSU ATS). A University Perspective on Climate Modeling.

April 11, 2013, R. Morss (NCAR). Improving Communication of Weather Forecasts and Warnings to Aid Decisions.

April 15, 2013, S-R. Chun and E-J Cha (National Meteorological Satellite Center/Korea Meteorological Administration. KMA's Geostationary Satellite Program.

April 16, 2013. G, Bryan (NCAR). RKW Theory and How It Pertains (and Doesn't Pertain) to the Dynamics of Squall Lines.

April 17, 2013. A.O. Fierro (NOAA/NSSL). A Cloud-scale Lightning Data Assimilation Technique Implemented in the WRF-ARW Model: Performance in Real Time Simulations and Comparisons Against a Cloud-scale 3DVAR Technique.

April 18, 2013, M. Chikira (JAMSTEC/Japan). Impact of Chikira-Sugiyama Cumulus Scheme in Climate and Variability.

April 25, 2013. H. Morrison (NCAR). Improvements and Remaining Challenges in the Parameterization of Microphysics and Its Impact on Deep Convection.

May 2, 2013. L.E.Johnson (CIRA & NOAA/ESRL/PSD). Water Management Applications of Advanced Precipitation Products.

May 2, 2013. T. Peter (Institute for Atmospheric and Climate Science, ETH Zurich). The stratospheric Aerosol Layer: Uncertainties in Our Understanding and Consequences for Climate Change and Geoengineering.

May 3, 2013. N. Oreskes (CSU Monfort Professor-in-Residence). Discussion and Forum "When Knowledge Isn't Power: Science Technology, and Empowerment in the 21st Century".

May 9, 2013. A.G. Hallar (DRI/Storm Peak Laboratory). Chemical, Biological, and Hygroscopic Properties of Aerosol Organics at Storm Peak.

May 10, 2013. G.T.T. Narisma (Manila Observatory, Ateneo de Manila University). Climate Change and Development: Decreasing Resilience and Increasing Risk to Disasters.

May 15, 2013. G. Holl (Lulea University of Technology, Sweden). Using Collocations to Study and Improve IWP Retrievals.

May 17, 2013. Y. Jin (Naval Research Laboratory). Evaluation of Microphysical Parameterizations for Tropical Cyclone Prediction.

June 19, 2013. S. Schranz (CIRA). Wildland Fire Weather Science and Technology Research.

June 21, 2013. M. Pritchard (University of Washington). Critical Sensitivities of the Superparameterized Madden-Julian Oscillation Consistent with Moisture ode Dynamics.

June 25, 2013. R. Roca (Laboratoire d'Etudes en Geophysique et Oceanographie Spatiales). The Precipitation Life Cycle of Tropical Mesoscale Convective Systems from Geostationary and Low Earth Orbit Satellite Observations.

June 27, 2013. M.P. Jensen (Brookhaven National Laboratory). Convective Cloud Life-cycle During the Mid-latitude Continental Convective Clouds Experiment (MC3E).

July 1, 2013. G. Mullendore (University of North Dakota). Mass Transport in Deep Convection: Simulations and Radar Observations.

July 10, 2013. D. Peterson (University of Oklahoma). How Does Lightning Initiate and Propagate?

July 12, 2013. S. Fueglistaler (Princeton University). The Upper Troposphere/Lower Stratosphere – 30-40 Years of Good Data and Still Open Questions?

July 15, 2013. S. Uprety (CIRA). Tracking On-orbit Radiometric Stability and Accuracy of Suomi NPP VIIRS Using Extended Low Latitude SNOs.

August 8, 2013. A.R. Ravishankara (ESRL/CSD). A Tale of Two Chemicals: N_2O and HFCs and Their Potentialo Inclusion in the Montreal Protocol.

September 6, 2013. T. Matsui (Mesoscale Atmospheric Processes Laboratory/NASA). My Personal Journey of Aerosol-Cloud-Precipitation Interactions.

September 11, 2013. J. Courtney (Bureau of Meteorology, Perth). Small Tropical Cyclones: Challenges of Estimating the Intensity Analysis and Prediction.

September 16, 2013. J-D. Jou (National Taiwan University). An Overview of SoWMEX/TIMREX.

September 27, 2013. Members of CSU ATS and CIRA Community. An Early Look at the Historic September 2013 Heavy Rainfall and Flooding in Northern Colorado.

October 4, 2013. A. Andrews (NOAA/GMD). Estimating Greenhouse Gas Emissions and Uptake Using Observations of Atmospheric Distributions and Trends.

October 10, 2013. P. Sellers (Former Astronaut). How Big Organizations Fail: An Example and Gravity.

October 11, 2013. J. Moum (Oregon State University). Why Does SST in the Equatorial Pacific Cold Tongue Exhibit a Seasonal Cycle When the Atmosphere Heats the Ocean Year Round?

October 18, 2013. S. Gleason (Southwest Research Institute). GNSS Remote Sensing from Orbit: UK-DMC to CYGNSS.

October 18, 2013. D. Murphy (NOAA/ESRL/CSD). Using Data Sets to Constrain Aerosol Sources and Radiative Forcing: From Micro to Macro.

October 21, 2013. A. Carrassi (Institut Catala'de Ciencies del Clima, Barcelona). Model Error Treatment in Data Assimilation and the Initialization of Long-term Predictions.

October 25, 2013. R. Hart (Florida State University). Two Perspectives on Meteorological History: Academic Family Trees and Fujiwhara-enhanced U.S. TC Landfall.

November 1, 2013. J.B. Gilman (CIRES). Characterizing the Emissions of Volatile Organic Compounds (VOCs) from Oil and Natural Gas Operations in Several U.S. Shale Basins.

November 8, 2013. F. Zhang (The Pennsylvania State University). Predictability and Data Assimilation of Severe Weather and Tropical Cyclones.

November 15, 2013. R. Johnson (CSU). New Insights on the MJO from DYNAMO.

November 20, 2013. T.N. Krishnamurti (Florida State University). gZ + Cp T+L q and the MONSOON.

November 22, 2013. M. Rocca (Dept. of Ecosystem Science and Sustainability/CSU). Imagining the Future of Colorado's Forests: Beetles, Wildfire, and People.

December 6, 2013. T. Galarneau (NCAR). Intensification of Hurricane Sandy (2012) Through Extratropical Warm Core Seclusion.

January 7, 2014. S. Shige (Kyoto University). Shallow Orographic Heavy Rainfall in the Asian Monsoon Region Observed by TRMM PR.

January 24, 2014. M. DeMaria (NOAA/NESDIS/RAMMB). Generalizing Tropical Cyclone Potential Intensity Estimates to Include Vertical Shear Effects.

January 31, 2014. J. Creamean (NOAA). Dust and Biological Aerosols from the Sahara and Asia Influence Precipitation in the Western U.S.

February 13, 2014. S.S. Zilitinkevich (Finnish Meteorological Institute). Energy – and Flux-budget (EFB) Turbulence-Closure Theory and a Hierarchy of Turbulence-Closure Models for Stably Stratified Atmospheric Flows.

February 14, 2014. S-A. Boukabara (NOAA). Overview of Some of NOAA's Activities in Support of the Joint Center for Satellite Data Assimilation (JCSDA).

February 18, 2014. D. Molenar (NOAA/NESDIS/RAMMB). AWIPS II Demo.

February 21, 2014. R. Viola (CIRA). Unveiling of Proposed CIRA Website.

February 21, 2014. A. Swann (University of Washington). Ecoclimate Teleconnections: Remote Effects of the Interactions Between Ecosystems and Climate.

February 28, 2014. G. Thompson (UCAR). A Study of Aerosol Impacts on Clouds and Precipitation Development in a Large Winter Cyclone.

March 7, 2014. M. Svoboda (National Drought Mitigation Center). Tracking and Talking Drought in a Changing Climate.

March 14, 2014. C. Davenport (U.S. Air Force Academy). A New Idealized Modeling Technique for Approximating Environmental Variability.

March 27, 2014. P. Haertel (Yale). Toward a Lagrangian Climate Model: Fully Lagrangian Simulations of Oceans and Atmospheres.

March 28, 2014. J. Calderazzo and S.E. Campbell (CSU). How to Talk to Non-scientists.

RESEARCH THEME REPORTS

Satellite Algorithm Development, Training and Education 28
NOAA Goal: Serve Society's Needs for Weather and Water Information

Regional to Global-scale Modeling Systems 133
NOAA Goal: Serve Society's Needs for Weather and Water Information

Data Assimilation 147
NOAA Goal: Service Society's Needs for Weather and Water Information

Climate-Weather Processes 170
NOAA Goal: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Data Distribution 192
NOAA Goal: Mission Support

SATELLITE ALGORITHM DEVELOPMENT, TRAINING & EDUCATION

Research associated with development of satellite-based algorithms for weather forecasting, with emphasis on regional and mesoscale meteorological phenomenon. This work includes applications of basic satellite products such as feature track winds, thermodynamic retrievals, sea surface temperature, etc., in combination with model analyses and forecasts, as well as in situ and other remote sensing observations. Applications can be for current or future satellites. Also under this theme, satellite and related training material will be developed and delivered to a wide variety of users, with emphasis on operational forecasters. A variety of techniques can be used, including distance learning methods, web-based demonstration projects and instructor-led training.

PROJECT TITLE: A Study of Precipitation Motion Using Model Winds

PRINCIPAL INVESTIGATOR: Stan Kidder

RESEARCH TEAM: Andy Jones

NOAA TECHNICAL CONTACT: Ingrid Guch (NESDIS/STAR/CRP)

NOAA RESEARCH TEAM: N/A

PROJECT OBJECTIVES:

We propose to study the accuracy of precipitation products, both instantaneous and accumulated, constructed by moving precipitating areas using model winds. In brief, the process we propose is as follows:

1--We will use hourly Stage IV rainfall data to simulate the satellite-observed rain rates.

2--We will use GFS winds to move the rain rates to a later time, and we will accumulate the precipitation.

3--We will compare the moved and accumulated precipitation with later Stage II /IV data to see how well the movement of the precipitation compares to actual.

4--Real precipitating regions change with time. We will also look at whether model trends can be used to indicate an increase/decrease in precipitation during the gaps.

We expect to examine one summer's precipitation data over the CONUS. This should give us a good idea of how well precipitation estimates can be made with infrequent satellite observations.

PROJECT ACCOMPLISHMENTS:

Progress on the first three objectives was made this year. Now we just need to do the number crunching to finalize the project. This will be accomplished by the end of CY 2014.

PROJECT TITLE: Algorithm Development for AMSR-2

PRINCIPAL INVESTIGATOR: Christian Kummerow

RESEARCH TEAM: David Randel (CSU/ATS) & David Duncan (CSU/ATS)

NOAA TECHNICAL CONTACT: Ralph Ferraro (NOAA/NESDIS)

NOAA RESEARCH TEAM: Ralph Ferraro (NOAA/NESDIS)

PROJECT OBJECTIVES:

The Japanese Aerospace Exploration Agency (JAXA) launched the AMSR-2 instrument aboard its GCOM-W satellite in February 2012. This proposal outlines an effort to (1) Assess the quality of the AMSR2 calibration and (b) adapt the Goddard Profiling Algorithm (GPROF) - an existing rainfall retrieval code originally developed for TRMM TMI and Aqua AMSR-E – for use in the NESDIS AMSR-2 processing stream.

PROJECT ACCOMPLISHMENTS:

The calibration assessment work focused on comparing AMSR-E retrievals with AMSR-2 retrievals for ocean parameters (surface wind speed, total column water vapor, cloud water, and precipitation) from ASMR-E and AMSR-2. Because the two sensors do not coincide in time, a double difference technique to SSMIS-F17 was employed. Generally speaking, differences between the two sensors were of a few percent. This was deemed acceptable for operations.

The main work going into the AMSR-2 retrieval algorithm was the construction of the a priori database over land using GPM's NMQ surface radar product and AMSR-2 observations. Early indications are that the algorithm works quite well until the atmosphere gets exceedingly cold and the wind channels are no longer able to sense the small ice crystals associated with snow at temperatures colder than roughly 255K. The successful launch of GPM in February of 2014 will allow comprehensive testing of the algorithm before transfer to operations at NOAA.

Results were presented at ASMR2 as well as GPM science team meetings but no official conference publications have resulted until some additional testing is completed.

PROJECT TITLE: CIRA Support for Feature-based Validation of MIRS Soundings for Tropical Cyclone Analysis and Forecasting

PRINCIPAL INVESTIGATOR: Jack Dostalek

RESEARCH TEAM: Kate Musgrave, Robert DeMaria, Dave Watson, Steve Finley, Kathy Fryer, Renate Brummer

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The purpose of this work is to determine the utility of the Microwave Integrated Retrieval System (MIRS) retrievals for a specific region (the Tropics) and for a specific application (tropical cyclone analysis) to complement the broader Cal/Val activities at STAR. For the 2012 Atlantic hurricane season, the MIRS soundings generated from both the AMSU (Advanced Microwave Sounding Unit) instrument aboard the NOAA and MetOp satellites, and from the ATMS (Advanced Technology Microwave Sounder) instrument aboard Suomi-NPP will be analyzed. The validation of the MIRS soundings will consist of standard error analysis of the thermodynamic profile in addition to comparing their performance in four products relevant to tropical cyclone analysis and forecasting: Maximum Potential Intensity (MPI), vertical velocity profile from an entraining plume model, the Multiplatform Satellite Surface Wind Analysis, and a statistical intensity and wind radii estimate. Comparisons will be made not only between retrievals from the AMSU and the ATMS instruments but also between the AMSU retrievals generated from MIRS and AMSU retrievals generated from an older, statistical algorithm. Dropsondes from tropical cyclone reconnaissance flights will provide the “ground truth” measurements.

This project supports the following NOAA mission goals: Weather and Water.

PROJECT ACCOMPLISHMENTS:

Code, including Fortran programs, Linux shell scripts, Python scripts, and IDL procedures have been written to perform the collocation among three data sources: dropsondes, the statistical AMSU retrievals, and the MIRS AMSU retrievals. Data for the 2012 Atlantic hurricane season has been collected, and the collection of the data for the 2013 season is nearing completion. Figure 1 shows the temperature statistics among the dropsondes and the two AMSU retrieval techniques for Hurricanes Ernesto and Isaac. For these collocations, the satellite retrieval was within 50 km and 1 hour of the dropsonde. Both the bias (dashed) and root mean square error (solid) show that the MIRS retrievals are generally more accurate in the lower and middle levels, but that the statistical technique performs better at the upper levels. A temperature correction which would produce more accurate retrievals from the statistical technique at lower levels, however, was not applied in this instance. Additionally, the number of matchups at each level, given on the right-hand side of the figure, is rather small. More reliable statistics will be produced as more cases are added to the analysis.

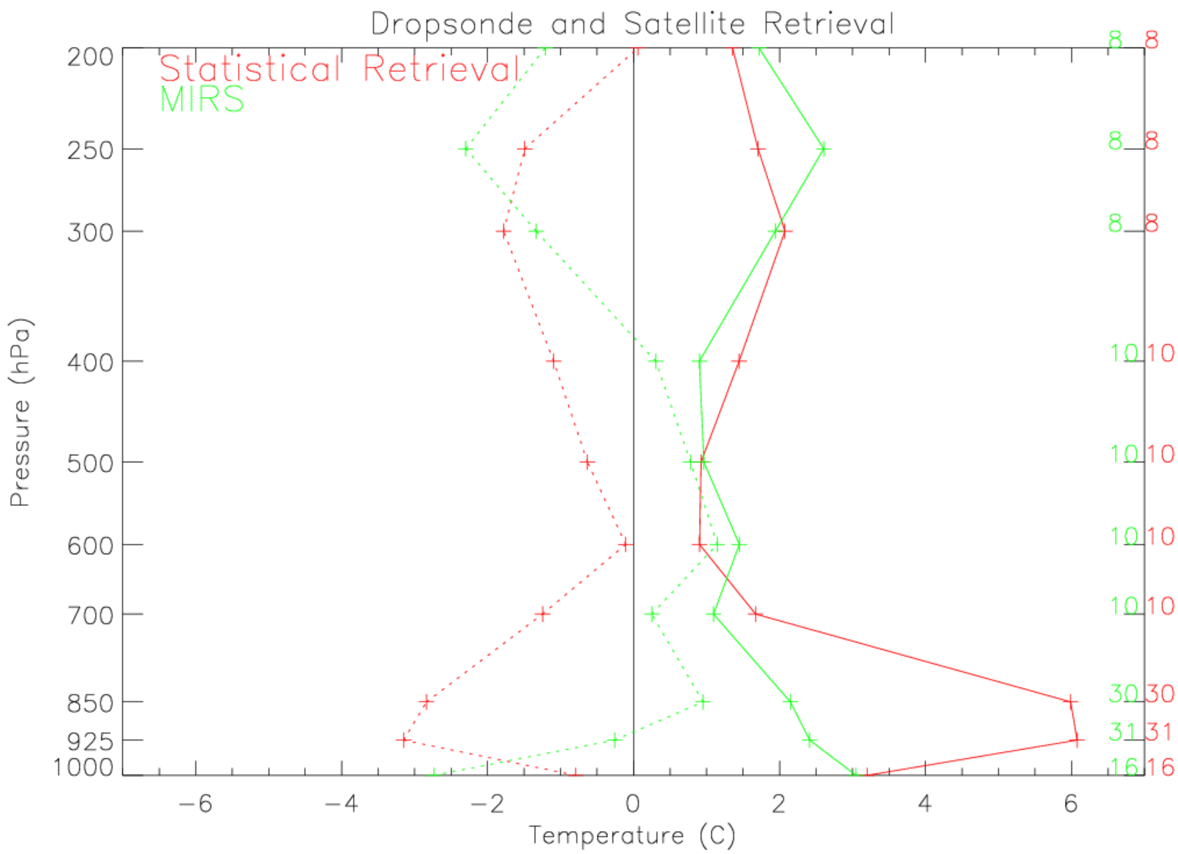


Figure 1. Matchup statistics of AMSU temperature retrievals using a statistical technique (red) and the MIRS algorithm (green) for hurricanes Ernesto and Isaac of the 2012 Atlantic season. The bias is shown in dashed lines and the root mean square error in solid lines. The number of collocations at each level is given on the right.

PROJECT TITLE: CIRA Support for Transition of Tropical Cyclone Forecast Products

PRINCIPAL INVESTIGATOR: Andrea Schumacher and Jack Dostalek

RESEARCH TEAM: Scott Longmore, Robert DeMaria, Galina Chirokova, Kate Musgrave, Natalie Tourville, Steve Finley, Kevin Micke, Dave Watson, Hiro Gosden, Kathy Fryer, Renate Brummer

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Mark DeMaria and John Knaff (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

Tropical cyclones tend to develop and spend a significant portion of their lifecycle over tropical oceans, out of range of aircraft reconnaissance and where in situ observations are sparse. In these regions, meteorologists must rely on satellites to provide data to initialize atmospheric models and monitor TC motion and intensity. The main objective of this project is to develop satellite-based TC guidance products and assist with the integration of these products into NOAA/NESDIS operations. Tropical Cyclone (TC) forecasts affect risk mitigation activities of industry, public and governmental sectors and therefore supports directly NOAA's Weather and Water mission goals.

Project objectives can be divided into the following project areas:

1-- 48-Hour Global Tropical Cyclone Formation Probability (TCFP) Product:

An SPSRB user request (#1003-0003) was submitted by users at the National Hurricane Center to extend the TC formation probabilities from 24 to 48 hours in order to provide TC formation guidance that correspond with the present needs of TC forecasters. This project seeks to address this request by incorporating GFS forecast fields into the Global TCFP algorithm to extend the formation probabilities to 48 hours.

2-- MIRS-Based Tropical Cyclone Intensity and Structure Estimation:

Statistical temperature retrievals along with boundary conditions supplied by NCEP analyses are the basis for the physical retrieval of pressure and wind fields that are statistically corrected to provide estimates of the maximum 1-minute sustained winds, MSLP and radii of 34-, 50- and 64-kt winds. These products are currently being generated operationally at NCEP for the NOAA-15, -16, -18, and -19 satellites, as well as the MetOp-A satellite. Recently, more powerful and flexible methods of retrieving vertical profiles of the atmosphere have become available, such as the Microwave Integrated Retrieval System (MIRS), NESDIS' current operational microwave retrieval system. By switching to the MIRS temperature and water vapor profiles, the wind retrieval program will run more reliably, and likely more accurately. For this project, MIRS retrievals from NOAA-18 and -19, as well as from MetOp-A, and -B satellites will be used. MIRS retrievals are not available for satellites previous to NOAA-18. For each active tropical cyclone the most current AMSU/MIRS retrievals will be ingested and run in the wind retrieval program. The wind and MSLP estimates will be disseminated to users from NESDIS' Office of Satellite and Product Operations (OSPO).

3-- S- NPP Microwave Sounder-based Tropical Cyclone Products:

In addition to the new MIRS retrieval system, data from the next generation of microwave sounders is also available. With the launch of the Suomi NOAA Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (S-NPP) satellite in fall of 2011 comes the opportunity to use data from the Advanced Technology Microwave Sounder (ATMS), the successor to the AMSU. In order to continue providing the best microwave sounder-based TC intensity and structure guidance available, it is necessary to update these products to accept data from the ATMS (SPSRB User Request #1009-0017). This project proposes to do just that by collecting and testing MIRS-processed temperature profiles from the S-NPP ATMS and adapting the operational AMSU-based TC products to utilize this new data source. With its superior spectral and sampling characteristics, it is expected that the ATMS instrument will provide an improvement to the TC products currently based on the AMSU instrument.

PROJECT ACCOMLISHMENTS:

Accomplishments for this fiscal year are listed for each project area below. The time each accomplishment was achieved is in parentheses.

1-- 48-Hour Global Tropical Cyclone Formation Probability (TCFP) Product:
--The 48-Hour Global TCFP was successfully implemented on operational system at NESDIS/OSPO (April 2013).

2-- MIRS-Based Tropical Cyclone Intensity and Structure Estimation:
--Modified operational code to accept MIRS retrievals (May-Aug 2013)
--Developed operational scripts (Aug-Nov 2013)

--Provided modified operational code to OSPO (Nov 2013) --Tested the new products (Mar-Apr 2014)
--Coordinated with OSPO on the operational implementation (Apr-Jun 2014)

3-- S-NPP Microwave Sounder-based Tropical Cyclone Products:
--Evaluated preoperational test results and make final adjustments to algorithm to prepare for operations (Jul-Sep 2013)
--Helped with implementation of operational code at NESDIS. (Jul 2013 - Mar 2014)
--Prepared SPSRB required documentation. (Jul-Sep 2013)
--Monitoring and validating of product quality (Mar-Jun 2014)

PROJECT TITLE: CIRA Support of NOAA's Commitment to the Coordination Group for Meteorological Satellites: Enhancing the International Virtual Laboratory

PRINCIPAL INVESTIGATORS: Bernadette Connell

RESEARCH TEAM: Luciane Veeck

NOAA TECHNICAL CONTACT: Ingrid Guch (NESDIS/STAR) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Anthony Mostek (NOAA/ NWS/OCWWS Training Division)

PROJECT OBJECTIVES:

The World Meteorological Organization (WMO) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) is a collaborative effort joining major operational satellite operators across the globe with WMO regional training centers of excellence in satellite meteorology. Those regional training centers serve as the satellite-focused training resource for WMO Members. Through its cooperative institute for Research in the Atmosphere (CIRA) at Colorado State University (CSU), NOAA/NESDIS sponsors Regional Training Centers of Excellence (CoE) in Argentina, Barbados, Brazil, and Costa Rica.
The top-level objectives of the VLab are:

1--To provide high quality and up-to-date training and supporting resources on current and future meteorological and other environmental satellite systems, data, products and applications;
2--To enable the regional training centers to facilitate and foster research and the development of socio-economic applications at the local level through the National Meteorological and Hydrological Services.

This project provides a Technical Support Officer (TSO) dedicated to support VLab activities, to address the training needs of its evolving audience and to provide strong project coordination and management. This project directly supports NOAA commitments to WMO's Coordination Group for Meteorological Satellites (CGMS) and it supports NOAA's goals of Weather and Water, Commerce and Transportation, and Climate. The international activities proposed in this project also directly address the NOAA Engagement Enterprise Objective for "Full and effective use of international partnerships and policy leadership to achieve NOAA's mission objectives".

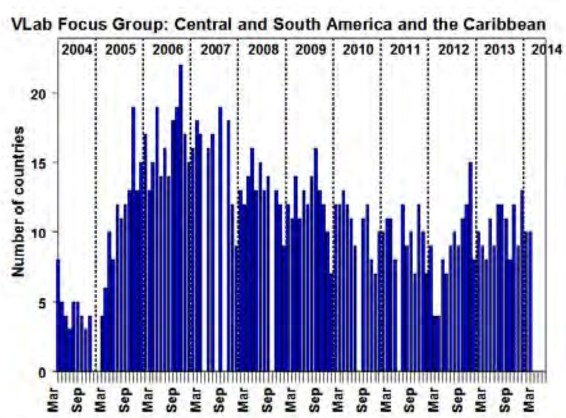
Enhanced training and coordination of training accomplished under this project will prepare forecasters and managers on how to utilize imagery and products to provide services in these areas.

PROJECT ACCOMPLISHMENTS:

1--Provide partial support for organizing and conducting sessions and then processing the recordings of the monthly international virtual Regional Focus Group.
The WMO Virtual Laboratory Regional Focus Group of the Americas and Caribbean conducted 12 monthly bilingual (English/Spanish) weather briefings. The briefings made use of VISITview software to present GOES and POES satellite imagery from CIRA and GoToWebinar for voice communication over the Internet. Over the year, the participants from the U.S. included: CIRA, the NWS International Desk at NCEP, NWS/OCWWS Training Division, the UCAR/NWS International Activities Office, and UCAR/COMET. Twenty-nine countries outside the US participated: Algeria, Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Canada, Cayman, Chile, Colombia, Costa Rica, Croatia, Dominican Republic, El Salvador, Ghana, Haiti, Honduras, Mexico, Niger, Panamá, Peru, St. Kitts and Nevis, St. Lucia, Trinidad and Tobago, Suriname, Uruguay, and Venezuela. M. Davison at the NCEP International Desk led the discussion. Participants offered comments for their regions and tended to also bring interesting questions to the discussion. The number of countries participating each month ranged between 8 and 13 (average 10); and the number of participants each month ranged between 16 and 51 (average 31).

The sessions were recorded (except for August 2013 which experienced technical problems) and can be found here: http://rammb.cira.colostate.edu/training/rmtc/fg_recording.asp

-- We primarily view satellite imagery and products for real-time applications and climatological outlooks. This gives us an opportunity to showcase JPSS products. For example, during the November 2013 session, we highlighted a Mesoscale Convective System (MCS) in Peru with high resolution Infrared I-band imagery along with the day-night band for a case on 17 November.



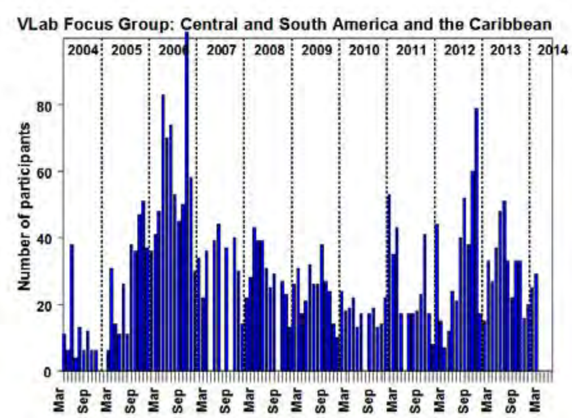


Figure 1. (above left) Number of countries participating each month in the online virtual discussion sessions over the past 10 years.

Figure 2. (above right) Number of participants joining in each month in the online virtual discussion sessions over the past 10 years.

February 2014 is a milestone month for the group leading 10 years of monthly virtual sessions. Up to February 2014, out of a total of 120 possible monthly sessions, we have only missed 5 months: 4 due to leaders not being available and one because of technical problems. That is pretty darn good!
Figure 1 shows the number of countries participating each month over the past 10 years and Figure 2 shows the number of participants joining in each month over the past 10 years.

2-- In 2013, 7 training video clips from the monthly Focus Group Sessions were disseminated through GEONETCast February through July and September.
-- In support of GEONETCast activities, this project also provided partial support for a Train the Trainers GEONETCast workshop in April and a virtual GEONETCast training event in December.
--B. Connell attended the NOAA/WMO Train the Trainers workshop on 6 and 7 April at the NOAA Center for Weather and Climate Prediction in College Park, Maryland prior to the NOAA Satellite Conference. She gave a presentation on “GEONETCast Americas Training Channel: VLab Training”. The workshop focused on all aspects of GEONETCast broadcast including the capability to send training materials. Figure 3 shows the participants at the Train the Trainer Workshop.
--As a follow-up to the WMO NOAA Train the Trainer Workshop on GEONETCast in April 2013, and in response to WMO user surveys CIRA, NOAA, WMO, and the WMO Centers of Excellence in Costa Rica, Barbados, Brazil, and Argentina hosted a virtual training on GEONETCast. It consisted of 3 sessions on the 3rd, 4th, and 5th of December 2013. Regions III and IV have a large percentage of Spanish speaking countries and we wanted to reach both English and Spanish users, so the sessions were presented in both languages (for a total of 6 sessions). The goals of the training were: to make countries more aware of what is available; to expand the use of GEONETCast-Americas; and to start thinking about GOES-R. The topics included an introduction to the capabilities of GEONETCast, disaster mitigation products, and software to view products. The sessions drew a lot of interest as people from 29 countries participated. There were 111 individuals, which included speakers, organizers, and participants. Presentations and session recordings are posted on the web pages

http://rammb.cira.colostate.edu/training/rmtc/geonetcast_event_en.asp

As the GEONETCast Americas web page points out: “This user-driven, user-friendly and low-cost information dissemination service aims to provide global information as a basis for sound decision-making in a number of critical areas, including public health, energy, agriculture, weather, water, climate, natural disasters and eco-systems. Accessing and sharing such a range of vital data will yield societal benefits through improved human health and well-being, environment management and economic growth.” We plan to continue to incorporate this theme in our future training events.

Figure 3. Participants of the NOAA/WMO Train the Trainer Workshop in College Park Maryland in April 2013.

3-- The following coordination activities of Luciane Veeck, VLab Technical Support Officer, were partially supported under this project:
-- Direct Readout events – VLab is organizing a series of online events about the direct readout capabilities of polar orbiting systems. To start the series, two sessions about the EPS/Metop were offered (7 and 8 May 2013). Sessions were organized by the TSO using the Saba conferencing system. A Moodle area was set up to create automatic certificates of participation for those attending the live

sessions and a post-event survey set up for evaluation of the event. A page was created in the VLab website to make the webcast and slides available after the session.
-- Two new Regional Focus Groups (RFG) started in July 2013: Russian RFG and RFG Morocco. The CoE Morocco and CoE South Africa also had sessions in December 2013.
-- Support to Aviation Virtual Round Table Event– Action 12 from VLMG-6 states that VLab should host a set of online events in various languages covering the information on the new WMO regulations and other matters related to aviation. Presentations were done in Spanish (8 May), French (15 May), Russian (5 June), and Portuguese (2 October). Additionally, two follow-up presentations were organized in English (24 September) and in French (25 September).
-- Maintenance of the VLab central website the VLab calendar of events http://vlab.wmo.int
-- Two VLab Newsletters were published: August and December 2013.
-- VLab Report to ET-SUP-7 – A report of the VLab activities was drafted by the TSO and approved by the co-chairs to be submitted to the “Expert Team on Satellite Utilization and Products seventh session” (ET-SUP-7), which took place in Geneva (27-30 May 2013). Slides were also prepared by the TSO and presented at the meeting by Volker Gärtner (VLab co-chair). The full report can be downloaded from the VLab website under Publications/Other reports.
-- VLab Report to CGMS-41 - Based on information collected from CoEs and activities registered in the VLab calendar, the TSO prepared the VLab annual report to CGMS covering September 2012 to June 2013. This report was presented by Volker Gärtner and Kathy-Ann Caesar, VLab co-chairs, at the CGMS-41 Annual Meeting, 8-12 July 2013 in Tsukuba, Japan. The full report can be downloaded from the VLab website under Publications/Other reports.

4-- Virtual Laboratory Management Group web Meetings – CIRA participated in the virtual VLMG meeting on 13 June and 9 October 2013, and 25 March 2014. The meetings were organized by the TSO and the meeting reports can be found in the WMO VLab site http://www.wmo-sat.info/vlab/meeting-reports/

5-- 10th International Conference on Creating Activities for Learning Meteorology (CALMet) – A poster about VLab activities was prepared and presented by the TSO at the CALMet Conference in Toulouse, France (26-30 August). B. Connell (CIRA) prepared and virtually delivered a talk: “Adding the personal touch. A renewed look at presentation, complicated information, and the audience”. The TSO also collaborated in this effort and assisted greatly with the on-site preparations.

Here follows as part of this project report, a report on a related project which is funded by the WMO:

PROJECT TITLE: Tasks related to technical support of the WMO-CGMS Virtual Laboratory for Education and Training in Satellite Meteorology (VLab)

PRINCIPAL INVESTIGATORS: Bernadette Connell

RESEARCH TEAM: Luciane Veeck

NOAA TECHNICAL CONTACT: NA

NOAA RESEARCH TEAM: NA

PROJECT OBJECTIVES:

The World Meteorological Organization (WMO), based on the availability of funds in the WMO Space Program Virtual Laboratory (VLab) trust fund, has signed a contract with CIRA for technical support of the WMO-Coordination Group for Meteorological Satellites (CGMS) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab). The following activities are supported:

1-- Assist the establishment and maintenance of Regional Focus Groups and their activities in WMO member countries;
2-- Support the planning of regional training events by:

-- Ensuring that these events have a virtual component;
-- Providing advanced information for students;
-- Ensuring the appropriate level of student participation;
-- Ensuring that course material is distributed prior to and after the events;
3-- Maintain and enhance the VLab Web presence and Moodle website;
4-- Keep the VLab community updated on evolving training technologies;
5-- Emphasize education, training, and outreach directed towards polar orbiting and geostationary satellites;
6-- Organize the VLMG online meetings in cooperation with the VLMG Co-Chairs;
7-- Based on information collected from VLab Centres of Excellence in Satellite Meteorology (CoEs) and activities registered in the VLab calendar and in coordination with the VLMG Co-Chairs, prepare the VLab annual report to CGMS and WMO (CBS);
8-- Provide any other support to the VLab, as appropriate;
9-- Identify training opportunities, in particular in support of all CoEs;
10-- Provide written quarterly updates on activities.

PROJECT ACCOMPLISHMENTS:

The following coordination activities of Luciane Veeck, VLab Technical Support Officer, support the top level objectives

1-- Two new Regional Focus Groups (RFG) started in July 2013: Russian RFG and RFG Morocco. The CoE Morocco and CoE South Africa also had sessions in December 2013. The TSO helped the groups to organize their sessions. Technical support using Saba conferencing was provided as well as the training of the presenters of the sessions to facilitate the online events.

2-- Support to Aviation Virtual Round Table Event– Action 12 from VLMG-6 states that VLab should host a set of online events in various languages covering the information on the new WMO regulations and other matters related to aviation. The event was called “Aviation Virtual Round Table (AVRT)” and was given in all 6 WMO official languages. A set of information slides was created by Kathy-Ann Caesar and Adanna Robertson-Quinby (CoE Barbados) and revised and validated by WMO. The TSO prepared the files for translation and created the design of the presentation in collaboration with Maja Kuna (EUMETSAT TSO). Saba Centra conferencing system was used to present the AVRT sessions. The TSO set up the system for registration, email reminders/instructions to attend sessions, live presentation/recording, and certificates. The first session of the AVRT was delivered in English (27 March). A page dedicated to the AVRT was also created by the TSO in the VLab central website to keep all the AVRT resources (slides, chat and recordings) available to those who could not participate in the live events. A standard evaluation form (to be sent to participants after the session) was created by the TSO with revision from Kathy-Ann Caesar. The translation of the material to Spanish, French and Russian was made via WMO translators and the translation of the material to Portuguese was coordinated with the VLab CoE Brazil. Coordination with translators was also done to translate all Saba conferencing system messages, evaluation forms and certificates. Saba and Moodle were set up to recognize those languages. Native speakers (Spanish, French, Russian, and Portuguese) were identified within the VLab CoEs (native speakers that work in the topic of aviation) and invited to present the live sessions. Presentations were done in Spanish (8 May), French (15 May), Russian (5 June), and Portuguese (2 October). Additionally, two follow-up presentations were organized in English (24 September) and in French (25 September).

-- Semaine de l’aviation 2013 – This event week was organised in collaboration with CoE Morocco (11-15 November). The TSO was responsible for setting up the Saba system (registration, auto email alerts and live sessions) and offering test/training for the presenters. A Moodle page was also created to deal with the certificates, and a form was created for the post-event evaluation. Technical support was coordinated in collaboration with the EUMETSAT TSO (Maja Kuna). The event was held in the French language. Reports of attendance were produced by the TSO after the event.
-- GEONETCast Event Week – support was given during the English sessions of this event week, helping on the moderation of the online sessions (3-5 December).

3-- Maintenance of the VLab central website http://vlab.wmo.int In order to maintain the VLab website up to date, the TSO has been uploading the VLab Newsletter to the "Publications" area, updating information sent by CoEs' members to the "Centres of Excellence" area, adding news to the "Recent News" and VLab News" areas, and answering the queries that come through the "contacts" form in the website.
-- Maintenance the VLab calendar of events. The online calendar of events is routinely checked by the TSO for events' validation. To increase the visibility of the RFGs' sessions and other major events, the TSO is also emailing alerts of important dates (e.g. submission deadlines and sessions' dates) to the VLab mailing list.

4-- VLab Newsletter – Two VLab Newsletters were published: August and December 2013. Articles were collected from VLab CoEs, WMO Space Programme and Partner Projects. The newsletter was edited by the TSO and made available in the VLab website as well as distributed online using the VLab mailing list
-- TSO keeping updated on evolving training technologies: October 2012 – September 2013 participated in an online course related to the understanding of key theoretical and methodological perspectives of educational enquire and offered by The Open University as part of the post-graduation in Online and Distance and Education Programme.

5-- Direct Readout events – VLab is organizing a series of online events about the direct readout capabilities of polar orbiting systems. To start the series, two sessions about the EPS/Metop were offered (7 and 8 May 2013). Sessions were organized by the TSO using the Saba conferencing system. A Moodle area was set up to create automatic certificates of participation for those attending the live sessions and a post-event survey set up for evaluation of the event. A page was created in the VLab website to make the webcast and slides available after the session

6-- VLMG-web Meetings – Due to the global location of the VLMG members, the VLMG-web meetings occur over two days for "Western" and "Eastern" Groups. These took place on 13-14 June, 9-10 October 2013 and 25-26 March 2013 The organization of these meetings is the responsibility of the TSO, who books the conference system, sends the invitations, contacts presenters, prepares the agenda and slides, and offers training sessions to participants who have not yet used the Centra Conference System. The agenda and action's list from each meeting can be found in the VLab Moodle site. Recorded meetings can also be downloaded from the Moodle site.

7-- VLab Report to ET-SUP-7 – A report of the VLab activities was drafted by the TSO and approved by the co-chairs to be submitted to the "Expert Team on Satellite Utilization and Products seventh session" (ET-SUP-7), which took place in Geneva (27-30 May 2013). Slides were also prepared by the TSO and presented at the meeting by Volker Gärtner (VLab co-chair). The full report can be downloaded from the VLab website under Publications/Other reports.
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8-- CALMET X Conference – A poster about VLab activities was prepared and presented by the TSO at the CALMet Conference in Toulouse, France (26-30 August). The TSO also collaborated with Bernie Connell (CIRA) on another presentation at CALMet, entitled: "Adding the personal touch. A renewed look at presentation, complicated information, and the audience"
-- Conceptual Models for Southern Hemisphere (CM4SH) project was an action from VLMG-6 and is coordinated by Vesa Nietosvaara (EUMETSAT). The TSO created a page for the project in the VLab website and coordinates online meetings for the project with Mr. Nietosvaara as requested.

PROJECT TITLE: CIRA Support of the Virtual Institute for Satellite Integration Training (VISIT)

PRINCIPAL INVESTIGATORS: Dan Bikos, Edward Szoke, and Bernadette Connell

RESEARCH TEAM: Kevin Micke, Holly Kessler, Kathy Fryer

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Mark DeMaria, Dan Lindsey (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The primary objective of the VISIT program is to accelerate the transfer of research results based on atmospheric remote sensing data into National Weather Service (NWS) operations. This transfer is accomplished through web based distance learning modules developed at CIRA and delivered to NWS forecasters. There are two types of distance learning methods. The first is teletraining, which is a “live” training session utilizing the VISITview software and a conference call so that there is interaction between instructor and students. The second type is an audio / video playback format that plays within a web-browser. The later type is popular because it may be taken by a student individually whenever they choose. The combination of live teletraining and audio / video playback versions (Figure 1) reaches out to as broad an audience as possible given the busy schedule of NWS forecasters. Over 24,000 participants have completed VISIT training since April 1999, and most student feedback suggests a direct applicability to current forecast problems. CIRA is also actively involved in tracking of participants, and the collection and summarization of course feedback material. Because the VISIT program has been so successful within the NWS, it is being leveraged for other training activities in the US (Satellite Hydrology and Meteorology Courses (SHyMet), and the GOES-R Proving Ground) and is being utilized by the International community in training programs under the World Meteorological Organization (WMO).

For more information on the VISIT program: http://rammb.cira.colostate.edu/visit/

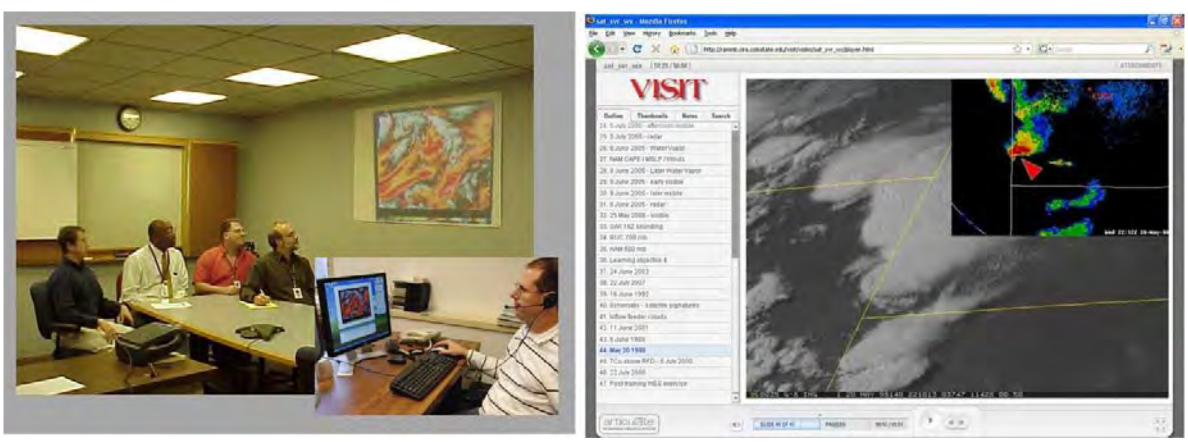


Figure 1. Live VISIT teletraining (left), and audio / video playback VISIT training module (right).

PROJECT ACCOMPLISHMENTS:

1-- VISIT training metrics April 1, 2013 – March 4, 2014:
-- Live teletraining: 46 sessions delivered to 178 participants.
-- Audio / video playback (through NOAA’s Learning Management System as well as directly through CIRA’s web interface): 524 participants.

2--Training sessions:
-- Delivered the training session titled “Identifying Snow with Daytime RGB Satellite Products”.
-- Updated the training session titled “An Overview of Tropical Cyclone Track Guidance Models used by NHC”.
-- Updated the training session titled “An Overview of the Tropical Cyclone Intensity Guidance Models used by NHC”.
-- Updated the training session titled “Synthetic Imagery in Forecasting Low Clouds and Fog”.
-- Support for new training session led by Scott Lindstrom (CIMSS) – “VIIRS Satellite Imagery in AWIPS”.
-- Delivered the training session titled “Orographic Rain Index (ORI)” to San Juan, Puerto Rico WFO in July. The ORI product was requested (in AWIPS) by WFO San Juan which was delivered by CIRA in the summer.
-- D. Bikos was invited by Carven Scott (MIC at Anchorage, AK WFO) to lead teletraining on applications of synthetic imagery from the NSSL WRF-ARW model. Teletraining sessions in May covered extra-tropical cyclogenesis and fog/low stratus applications. Attendees included Alaska WFO’s, WSO’s, and the Anchorage CWSU and VAAC. Interest in synthetic imagery is high in Alaska and are interested in working with CIRA on producing high-resolution synthetic imagery over Alaska.

3--EUMETRAIN World Wide Weather Briefing: D. Bikos was an invited presenter at the EUMETRAIN World Wide Weather Briefing – Event Week 2013 in May. There were multiple presenters from across the globe to focus on weather related forecasting challenges for their particular region. The focus on this presentation was severe thunderstorm forecasting, with an emphasis on satellite imagery interpretation. The web-site for this event includes a recording of all presentations:
http://www.eumetrain.org/events/www_briefing_2013.html

4--VISIT blog:
-- The blog is intended to open the doors of communication between the Operational, Academic and Training Meteorology communities. The blog averages around 300 views per week and is located here:
http://rammb.cira.colostate.edu/training/visit/blog/

5--VISIT Satellite Chat:
-- Since February 2012, the VISIT team has led monthly chat sessions to discuss recent significant weather events with the objective of demonstrating satellite products that can be applied to operational forecasting. These sessions are brief and often lead to products being made available or further discussed in the VISIT blog. For example, during the January chat session, a WFO asked about a recent blowing dust event. Afterwards, a blog entry was put together that discussed this event and the following month the SOO from that WFO discussed the blowing dust event during the chat session. The response was very positive and illustrates the benefits of these monthly sessions: “I would LOVE to see the products such as what was shown on the VISIT webinar (a revisit of the blowing dust/high wind event from 16 January 2014 in southwest NE) to help with the identification of blowing dust.”
Recorded sessions are found here: http://rammb.cira.colostate.edu/training/visit/satellite_chat/

6--Community Outreach:
-- After-school weather club: Scientists at CIRA and CSU students – all members of the local AMS chapter of Northern Colorado) volunteered for the weekly after-school weather club on Tuesdays for Putnam Elementary (Fort Collins, Colorado). The fall session ran for 8 weeks during October through early December 2013. There was a 90 minute session each week. Sessions included helping with homework and leading an activity. The topics covered included rain, wind speed, clouds, temperature, hail, frost (and ice cream!), and things that spin as well as measurements that are associated with these weather occurrences. Volunteers included Bernie Connell, Matt Rogers, Kristi Gebhart, Erin Dagg, and James Ruppert. Putnam has a coordinator who is responsible for matching students with clubs, assigning classrooms, providing snacks, and providing transportation – which is great!
-- B. Connell and Matt Rogers participated in the 22nd Annual Fort Collins Children’s Water Festival held on 15 May 2013. The festival invites 3rd graders from the Poudre School District. We had 20 minutes to entice kids to look up, observe the clouds, name the different types of clouds, and also discover what a cloud feels like. We met with groups from 7 schools.

PROJECT TITLE: CIRA Support to GOES Improvement and Product Assurance Program

PRINCIPAL INVESTIGATOR**:** Steve Miller

RESEARCH TEAM: Dan Bikos, Renate Brummer, Bernie Connell, Jack Dostalek, Hiro Gosden, Louie Grasso, Stan Kidder, Kevin Micke, Andrea Schumacher, Dave Watson

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Mark DeMaria, Donald W. Hillger, John Knaff, Dan Lindsey, Deb Molenar, Michael Pavolonis (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

Over the past several years the Cooperative Institute for Research in the Atmosphere (CIRA) has performed basic and applied research to better utilize data from NOAA Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES). The NOAA/NESDIS GOES Improved Measurements Product Assurance Plan, GIMPAP, has supported CIRA research on the use of GOES data for mesoscale analysis of high-impact weather events, including severe weather and tropical cyclones. A summary of achievements over the past year can be found at: http://rammb.cira.colostate.edu/intranet/GIMPAP_Project/FY12/Index12.htm

During the past year, CIRA's GIMPAP research was divided into the following six project areas:

1-- Combining Probabilistic and Deterministic Statistical Tropical Cyclone Intensity Forecast Models
2-- Developing GOES-Based Tropical Cyclone Recurvature Tools
3-- WRF Cloud and Moisture Verification with GOES
4-- Advancing GOES Cloud and Surface Irradiance Products for Applications to Short-Term Solar Energy Forecasting
5-- Enhanced downslope windstorm prediction with GOES warning indicators
6-- Probabilistic Nearcasting of Severe Convection

PROJECT ACCOMPLISHMENTS:

Project 1: Combining Probabilistic and Deterministic Statistical Tropical Cyclone Intensity Forecast Models

The National Hurricane Center (NHC) uses a range of intensity forecast models including HWRF, GFDL, SHIPS, LGEM, and the Rapid Intensification Index (RII). HWRF and GFDL are coupled ocean-atmosphere prediction systems. SHIPS and LGEM are statistical dynamical models that use GOES SST and GFS forecast fields as input for empirical predictions. The RII uses SHIPS input to estimate the probability of rapid intensification (RI). SHIPS and LGEM have been the most skillful intensity models over the past few years; however, they don't perform as well for rapid intensification (RI) cases. This project focused on improving the LGEM performance for RI cases by developing and testing a version that adjusts the intensity growth rate based on the RII probability.

Accomplishments:
a-- A version of the Rapid Intensification Index (RII) was developed and tested for the Western North Pacific. This is in the process of being combined with the LGEM code so that the growth rate for the first 24 hour can be modified when the probability of rapid intensification exceeds a specific threshold.

b-- Although it was not possible to perform real-time tests, a three year sample of cases for the Atlantic, East Pacific and western North Pacific was assembled, so the version of LGEM with the modified growth rate can be evaluated with a sample large enough to obtain stable statistics. This evaluation is in progress and the results will be presented in next year's report.

c-- The three-year retrospective sample will be used to tune the algorithm. The growth rate adjustment will include two free parameters: (1) the probability threshold for the enhancement and (2) the slope of the relationship between growth rate and RI probability for the RI domain that exceeds the threshold. The first guess will be based on the relationship between the LGEM model bias and RI probability as described in the previous semi-annual report, and then fine-tuned based on the forecast results.

d-- If the tests are successful, the method will be transitioned to operations, possibility with additional support from the Joint Hurricane Testbed, GIMPAP or Hurricane Forecast Improvement Project.

e-- The newly developed (under other funding) West Pacific versions of RII, SHIPS and LGEM is running in real time at NRLMRY and outputs are being provided to the JTWC. This capability will enable future upgrades resulting from this research.

Project 2: Developing GOES-Based Tropical Cyclone Recurvature Tools

This project focuses on the construction of a GOES-based tool that improves forecasts of the short-term (0-48 hours) time of tropical cyclone recurvature for the North Atlantic and Northwest Pacific tropical cyclone basins. Recurvature is defined by the point along the track at which the meridional motion is poleward and the zonal component of motion changes from westward to eastward. This project will make use of GOES/MTSAT water vapor imagery, GFS analysis/forecast fields, and tropical cyclone databases and combining/leveraging objective and subjective methods.

Accomplishments:

a-- GFS analysis fields were used to calculate the deep layer, shallow layer mean winds around tropical cyclones as well as layer means in azimuthal quadrants about the TC. These along with storm motion were used to find predictive relationships with the change in longitude prior to recurvature. We examined 77 recurvature cases in both the Atlantic and western North Pacific. Somewhat surprising the model deep layer means were not useful for anticipation of recurvature, but the observed storm motion was very important. Similar to the findings in Hodanish (1990), the arrival of westerly and southerly winds in the upper and mid-layers at radii between 900 and 600 km preceded recurvature. As the time to recurvature became shorter the model wind fields, particularly westerlies to the north side of the storm preceded recurvature.

b-- The identification of useful predictive features in the water vapor has proven rather difficult. The Harris Corner Detection Algorithm was initially tried, but the features classification was still uncertain with respect to recurvature. In the last six months a simpler algorithm has proven more robust. The method relies on filling regions in the water vapor imagery warmer than a threshold (flood fill), removing “small” filled regions and then estimating both the distance and curvature of the filled features with respect to the TC. Using the 77 recurvature cases, the flood fill algorithm was applied and distances to the TC and curvature of the larger water vapor features were estimated. The algorithm tracks the distance and bearing of each feature with respect to the storm, feature size, and feature curvature. A simplified/filtered example of the algorithm output is shown in Figure 1.

c-- The relationships between the wind field surrounding the TC and recurvature have been identified, but we have yet to combine the information from the water vapor imagery with the GFS derived information.

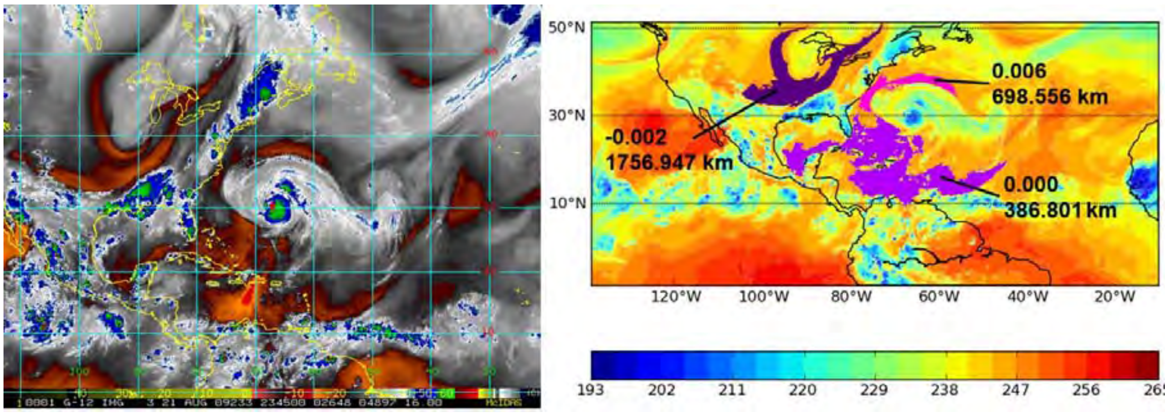


Figure 1. Water vapor image of Hurricane Bill on 21 August 2009 at 2345 UTC (left) and the same image with the output of the flood fill algorithm overlaid in purple and magenta colors (right). For demonstration purposes flood filled features of less than 2000 pixels in size and at distances greater than 2500 km are not highlighted. The feature that eventually steers Bill from the coast is shown in dark purple and has a cyclonic curvature (i.e., negative) and its closest edge is located 1757 km from Bill at this time.

Project 3: WRF Cloud and Moisture Verification with GOES

The purpose of this project is to leverage CIRA's ability to generate synthetic satellite imagery using output from the 4-km NSSL WRF forecast model to valid cloud and moisture forecasts from the NSSL model with observed GOES data. The plan is to provide our quantitative validation statistics to the model developers, who will then use this information to make future model improvements.

Accomplishments:

a-- Compute validation statistics for the 1+ years of archived data and provide the results to NSSL
More than a year of data has been collected and validation statistics have been computed for a portion of it. Currently we are focusing on the largest source of error in the NSSL WRF synthetic brightness temperatures v/s GOES brightness temperatures: the cold clouds. Below (Figure 2) is an example from 16 July 2013, comparing an observed GOES-13 10.7 µm image with the corresponding 27-hour forecast 10.7 µm synthetic image from the NSSL WRF. Note that the convection over northwestern Mexico and Arizona/New Mexico has larger and colder anvils in the observed imagery compared to the synthetic imagery. The corresponding histograms confirm that the observed imagery has more cold pixels than the model-derived synthetic imagery.

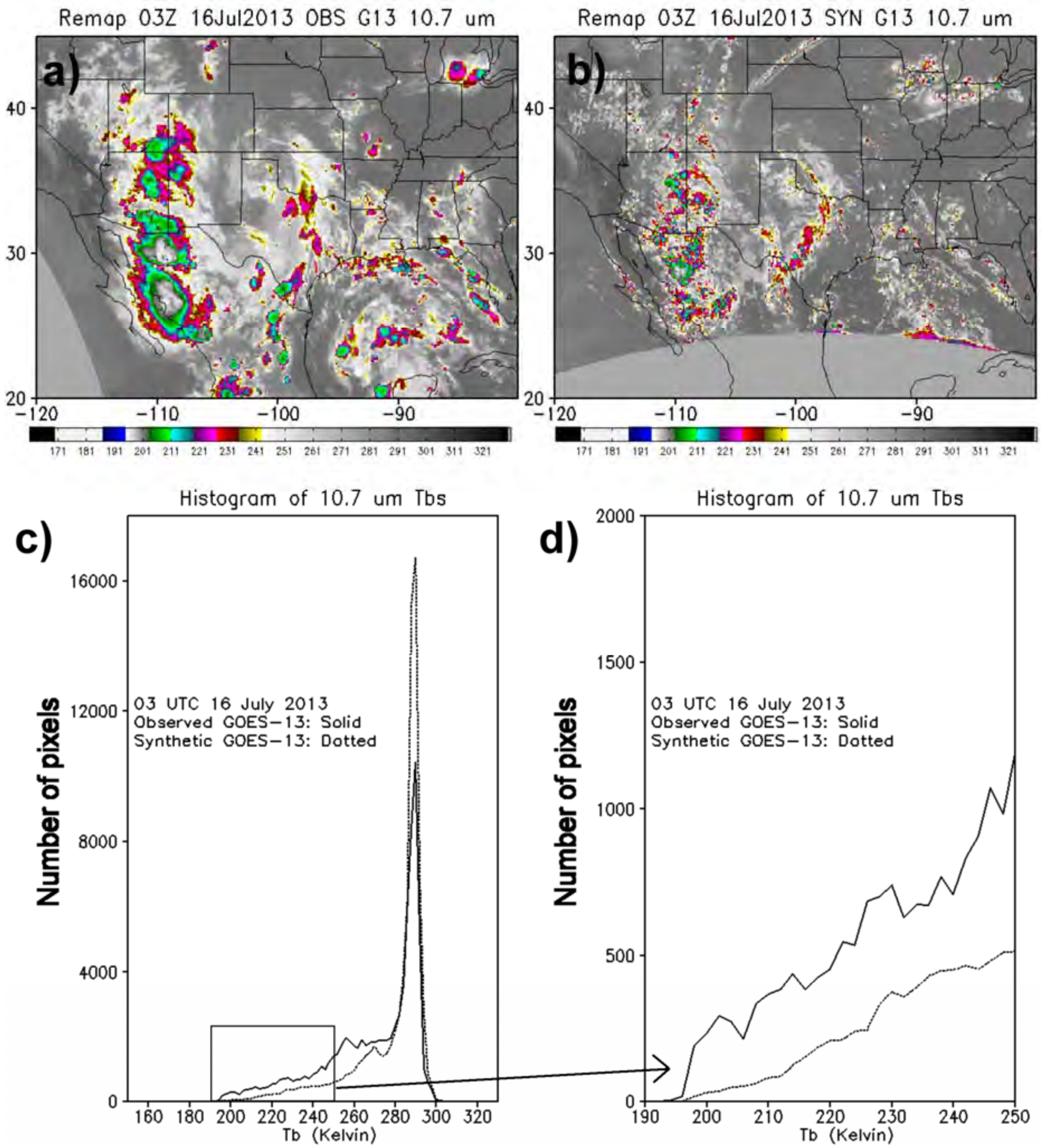


Figure 2. Comparison of observed GOES-13 10.7 µm image (a -- top left) with the corresponding 27-hour forecast 10.7 µm synthetic image from the NSSL WRF (b -- top right) for 16 July 2013. The corresponding histograms confirm that the observed imagery has more cold pixels than the model-derived synthetic imagery.

In order to ensure that this bias is consistent at other times, histograms were created using all forecasts from July 2011 to May 2012 (Figure 3). Indeed, we found more cold pixels (200 – 230 K) in the observed imagery than in the synthetic imagery, confirming that the model has a warm bias in that range.

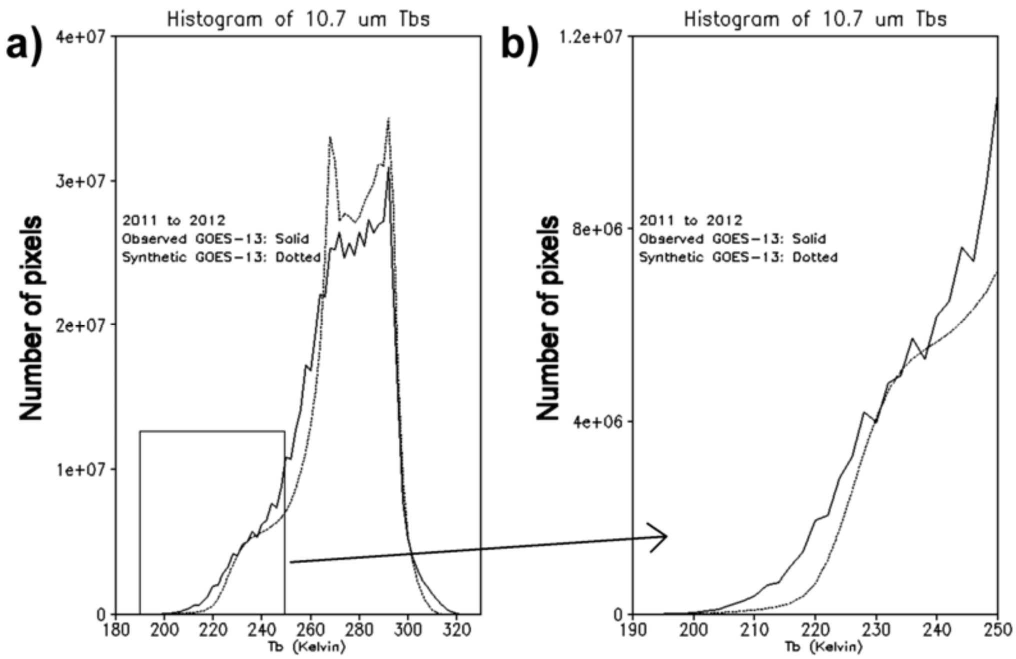


Figure 3. Histograms using all 9- to 36-hour forecast images from July 2011 to May 2012.

Following up on this potentially important finding, the PIs of this project began working with the developers of the WSM-6 microphysics package, Kyo-Sun Lim (Pacific Northwest National Laboratory) and Adam Clark (NSSL). The goal is to test changes to the WSM-6 microphysics routine in order to identify why this warm bias is occurring. These tests are still ongoing.

b-- Begin working toward a real-time verification system.
After getting increasingly involved in this project, we have concluded that a real-time verification system will not benefit forecasters as much as simply viewing the synthetic imagery side-by-side with the corresponding observed imagery (up to the current time), and qualitatively noting areas in which the model has correctly/incorrectly placed the clouds, short waves, jet streaks, etc. A real-time verification system would provide large-scale statistics such as a domain average root mean square error, but knowing the areas in which the model is more on track is far more beneficial.

c-- Compute validation statistics for the fog forecasts using METARS from the select airport locations. Work on this objective began recently and some preliminary statistics have already been computed.

d-- A paper entitled “Evaluation of and Suggested Improvements to the WSM6 Microphysics in WRF-ARW Using Synthetic and Observed GOES-13 Imagery” has been submitted to Monthly Weather Review and is currently in review.

Project 4: Advancing GOES Cloud and Surface Irradiance Products for Applications to Short-Term Solar Energy Forecasting

This project aims to improve the scientific use of GOES data in an area of National priority, and addresses directly some of the needs outlined in the Memorandum of Understanding signed between the DoE and NOAA in January 2011: forecasting the timing and variation of down-welling solar irradiance to assist in its exploitation as a renewable energy resource. CIRA’s research complements and collaborates closely with current research efforts headed by Andrew Heidinger and Istvan Laszlo to couple GOES cloud retrievals from the Pathfinder Atmospheres Extended (PATMOS-x) with Satellite Algorithm for Shortwave Radiation Budget (SASRAB) satellite-based irradiance tools for solar resource assessment.

Other radiative transfer models (e.g., 2-Stream) are also being evaluated. The tools involve physically-based algorithms for projecting GOES-derived cloud information into the short-term future (0-3 hr.), accounting for traditionally ignored details of parallax and cloud shadow projection, and predicting the time series of surface irradiance at selected locations. Account for these details of the satellite perspective and three-dimensional nature of shadow casting and cloud motion are not being done in the solar community, so we regard these elements as advancing the state of the art. The work involves partnerships with federal, university and industry partners.

Accomplishments:

a-- Continue validation experiments at SURFRAD sites, as well as in coordination with research partners. This includes an assessment of the NOAA/NESDIS SASRAB solar irradiance product coupled to the PATMOS-x cloud retrievals.

Collection of forecasted surface irradiance data from our satellite-based forecast algorithm for comparison to SURFRAD data continued in the manner described in the previous progress report. In the interest of developing the software toward possible operational transition, the algorithm has been modified to accept a formatted list of arbitrary surface locations for forecasting purposes, for the eventual comparison of satellite-derived surface irradiance data against research partner sites located in California, southern Colorado, and New York State. This change in forecast site location took effect in January of 2014. Research partner sites in California include PV array locations managed by Southern California Edison and the Sacramento Municipal Utility District; Colorado sites include PV array locations in the San Luis Valley managed by the Public Service Company of Colorado; and New York sites are located on the campus of the Brookhaven National Laboratory. SURFRAD sites being used for comparison include the Desert Rock, Nevada, Table Mountain, Colorado, Sioux Falls, South Dakota, ARM SGP, Oklahoma, and Penn State, Pennsylvania locations.

Validation studies based on these sites are ongoing. Primary issues revealed from validation runs include two major areas of focus: accurately forecasting the beginning and end of solar ‘ramp’ events coincident with shadow passage, and cloud evolution within the 0-3 hour forecast period. An example of a case study illustrating these issues is presented as Figure 4.

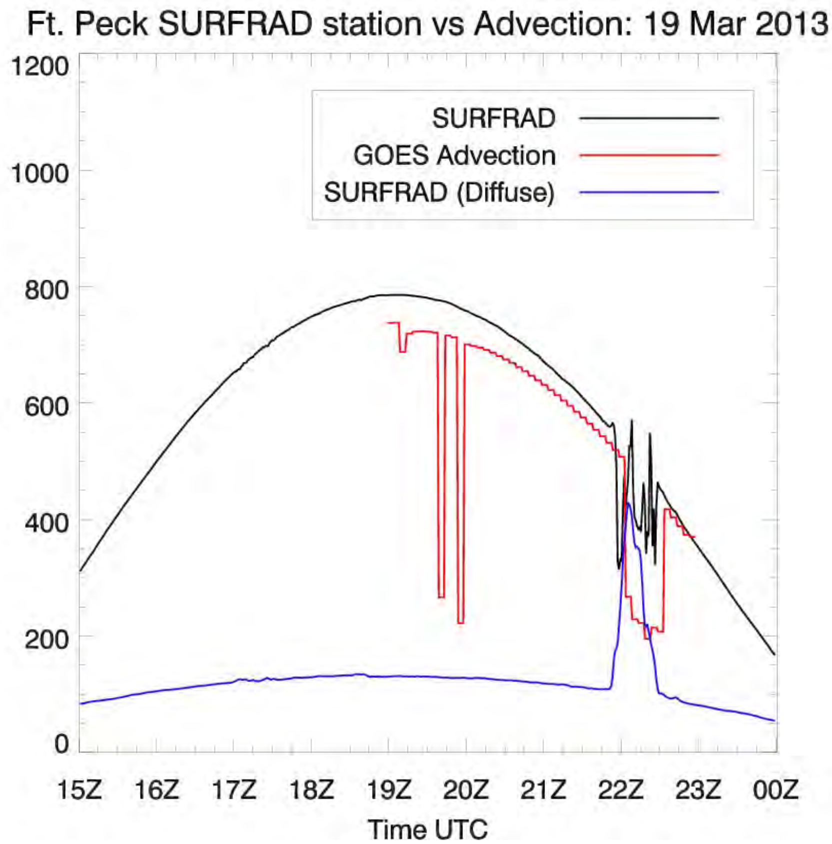


Figure 4. Comparison of satellite advection-derived surface insolation (red line) against surface observations (black line) for the Fort Peck, MT SURFRAD site on 19 March 2013. Two false ramp events were predicted, while one correct ramp event was predicted with an approximate 10-minute lag time between actual event and forecast.

In this forecast, a composite of the 1900UTC and 2100UTC forecasts for the Fort Peck SURFRAD site from 19 Mar 2013, two 'false' ramp events at roughly 1930UTC and 2000UTC are predicted before predicting a ramp event around 2200UTC. The latter event, forecasted by the algorithm to begin at 2200UTC, is shown by the SURFRAD data to have begun around 2150UTC; this ramp event in the SURFRAD data then ends at approximately 2230UTC, while the advection algorithm forecasted the end of the event as occurring shortly before 2245UTC. The roughly 10-minute lag time between the forecasted ramp event and the observed ramp event is thought to be related to choice of model steering winds – continued analysis and correction of the advection algorithm utilizing long-term statistics collected against surface observation will be used to address this timing issue in the forecast.

The prediction of two 'false' ramps around 1930UTC is a result of cloud evolution within the time period of the forecast. Figure 2a presents an observation of cloud optical depth at 1900UTC, which was used as the initialization time for the forecast of the two ramps. In this image, the location of the Fort Peck SURFRAD site is denoted by the cross symbol; a cloud band to the north of the station runs from west-northwest to east-southeast. A small appendage of cloud trails behind the larger cloud band immediately to the north of the SURFRAD site. Cloud motion for these cloud features was identified by the algorithm to be to the southeast; as such, the small appendage was forecasted to transit the SURFRAD site around 1930UTC based on the initial image. Figure 5 presents the observed cloud optical depth for the same location, but at 2000UTC. In this image, it is evident that a large fraction of the cloud mass from the

1900UTC has dissipated, including the small appendage cloud feature that was predicted to pass over the SURFRAD site around 1930UTC. It is possible to address this issue by utilizing additional satellite initialization times; using the PACUS scans at 15- and 45-minutes after the hour on GOES-W, for example, may have picked up the evaporation of the cloud appendage feature from this case study. As part of the DoE SunShot program, we will increase the operational frequency of forecast to every fifteen minutes using combinations of full-disk, CONUS, and sub-CONUS scans from GOES-E and –W observations.

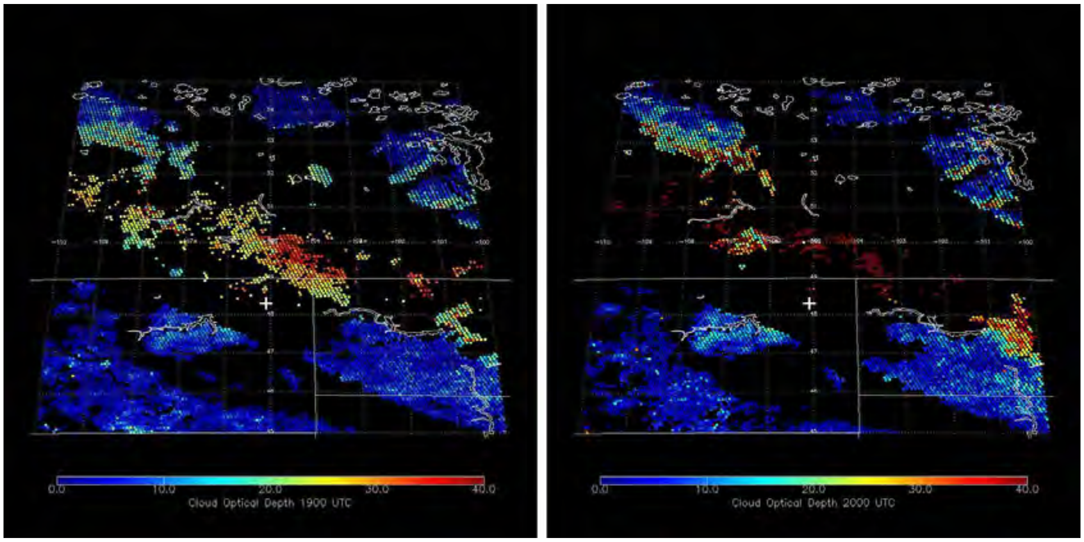


Figure 5. Left: Retrieved cloud optical depth for 1900UTC on 19 March 2013 over the Fort Peck, Montana SURFRAD site (denoted by cross.) Right: Retrieved cloud optical depth for 2000UTC.

b-- Produce automated software for computing surface irradiance component (total/direct/diffuse) time series at an arbitrary location.

The advection forecast algorithm is completely automated, running twice-hourly on one-hour old satellite observations for GOES-W. Automation of GOES-E files was completed by the end of February 2014, and efforts to make the automation run in near-real time are expected to be completed by March 2014 for operational use. Additionally, the software has been modified to provide forecasts over arbitrarily located forecast domains. For GOES-W, those zones encompass an 8x15-degree box centered over Nevada and an 8x15-degree box centered over the central United States. For GOES-E, the central US box is used, along with a 5x10-degree box over the northeastern United States. Additional software has been written to extract surface irradiance forecasts for any GOES pixel within those three zones; the configuration of the zones allows for computation of surface irradiance from the algorithm at any location by appropriately configuring the forecast zones.

c-- Publish findings and package/document all software and datasets.

Preliminary results from the project were presented at the annual Fall Meeting of the American Geophysical Institute, noted below. Additional literature articles describing the algorithm and comparisons against surface data are in preliminary preparations.

Documentation of the algorithm is continuing, and packaging of software and datasets is ongoing as well. Individual surface forecasts are currently being provided as DICAST-formatted ASCII files for selected sites.

We are currently running two case studies which illustrate the importance of variable cloud steering (as opposed to a single advection vector applied to all clouds) and of shadow casting (for a cirrus shield casting a long shadow across eastern Colorado, well ahead of the sub-cloud location) as a way of preparing for a long-overdue algorithm description paper. The paper will be based on numerous conference proceedings, bolstered by these new cases and by forthcoming SURFAD validation results, and submitted to a journal having broad readership by the solar forecasting community (e.g., J. Solar Energy).

Project 5: Enhanced Downslope Windstorm Prediction with GOES Warning Indicators

This project aims to improve the prediction of downslope wind events at select western U.S. locations using a combination of GOES imagery and numerical models. A statistical method has been developed previously to predict downslope windstorms in Ft. Collins, CO using only model output, so we are working to add GOES predictors to the model, as well as to create similar models for other locations that are prone to severe downslope winds.

a-- Optimize the prediction model that combines the GOES-derived algorithm with NWP model fields.

A set of GOES predictors have been selected for the Fort Collins location. The predictors that show the strongest relationship to downslope wind magnitude at 6 and 12 hours into the future are:
--Terrain pattern score – which describes the close correspondence in gradient patterns between the topography and the water vapor channel.
--Fine-resolution downslope drying score – which describes the water vapor channel drying over a mountain slope at the native satellite resolution.
--Regression-based satellite wave score – which describes the coherence of the repeating wave patterns in the water vapor channel in lee of the mountains. The score is calculated by regressing the brightness temperatures around the gravity waves with the brightness temperatures one half-phase apart.

For reference, an example of the regression-based satellite wave score is shown in figure 6 below. The product is sampled at the Fort Collins location to obtain a scalar score value.

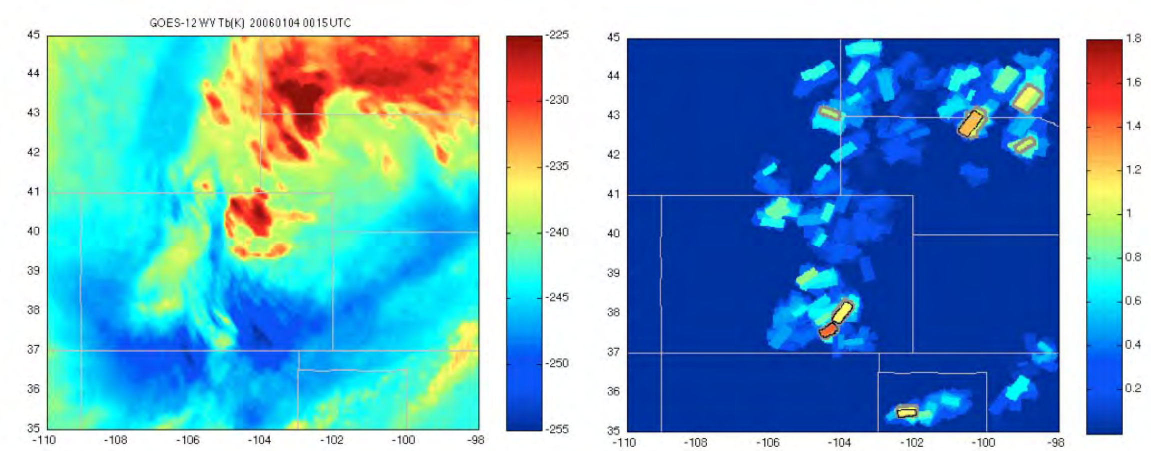


Figure 6. GOES predictor example for 2006-01-04 0015 UTC. Left: GOES Water Vapor Channel brightness temperature for Colorado and the surrounding states. Right: Regression-based satellite wave score, in which hotter colors correspond to stronger signs of repeating wave patterns.

b--Determine whether WRF forecast synthetic imagery is a viable predictor.

WRF forecast synthetic imagery continues to be generated and collected, so after the GOES predictors are finalized, we will test the predictors on the forecast synthetic images to see whether a predictor based on the forecast imagery is viable.

c--Set up an experimental real-time forecast system for the chosen sites.

A real-time forecast system using the environmental predictors already exists for Ft. Collins. Work is in progress to begin processing the GOES predictors in real time from CIRA's satellite ground station. We have set up the changes needed to apply the GOES predictor algorithm to real-time CIRA data streams rather than to University of Wisconsin's SSEC archives. We have also set up the CIRA server account that will run the Matlab code on a crontab, and we performed a successful proof-of-concept test. The remaining work will be to apply the GOES predictor code to real-time data in steps, and troubleshoot. A real-time prediction system will also be set up for the Hill Air Force Base location in Utah.

A Ft. Collins high wind prediction model, currently based only on forecast data from the NAM numerical model, is available online here:
http://rammb.cira.colostate.edu/products/fort_collins_high_wind_probability/
When the new research is sufficiently mature, new versions of the model that include GOES information and/or additional locations will be added to the webpage.

Project 6: Probabilistic Nearcasting of Severe Convection

The goal of this project is to utilize temporal trends in GOES-derived cloud properties (e.g. emissivity, cloud phase, optical depth, etc.), NWP fields (e.g. CAPE and shear, etc.), and NEXRAD to objectively determine the probability that a growing cumulus cloud object will produce severe weather in the near-term (0-1 hours). A flexible probabilistic model is utilized such that additional data sources (e.g., lightning) can be incorporated at a later time. Results achieved thus far indicate that a probabilistic model (a naïve Bayesian classifier) fused together with data from each aforementioned observation source can often predict that severe weather is likely to occur 10 minutes or more prior to the issuance of National Weather Service (NWS) severe weather warnings, without a large increase in false alarms. The end goal of this work is to improve the timeliness and accuracy of severe weather warnings and condense the pertinent information from the "fire hose" of data for NWS forecasters in order to aid in their warning decision. CIRA is a collaborator on this CIMSS project.

a--Optimize cloud object identification and tracking method.
Following the methodology of Sieglaff et al. (2013), we have previously optimized satellite-cloud tracking for developing convection using infrared-derived GOES cloud product imagery. In addition, a radar-object tracking methodology was developed, and the model now associates radar objects with parent satellite objects (after a parallax correction). By doing this, we retain a history of the growth for storms from a satellite perspective and link that development with the evolution of storms on radar, enhancing confidence and lead-time regarding severe potential. This system is being run in real-time at UW-CIMSS.

b--Improve estimation of a priori probabilities and choice of statistical predictors (satellite, NWP, and radar).
The a priori probability required by the statistical model has been improved by selecting criteria based on certain radar thresholds (within satellite objects) in storms, and extracting the most-unstable CAPE and effective shear. 2D kernel density estimation was performed for both severe and non-severe training classes, yielding a smooth a priori probability table based on these two NWP fields. Using archived data from 2013 severe weather days, other NWP fields have been investigated to aid in formulating the a priori, such as the mixed-layer lifted index (MLLI) and 0-1 km bulk shear. Work is on-going to integrate these NWP fields into the a priori probability or as predictors in the model. The model now incorporates the maximum expected size of hail (MESH, Witt et al. 1998), which is a radar-derived parameter that demonstrated skill in discerning severe and non-severe convection. Several other NEXRAD-derived products are being investigated as well (e.g., low-level azimuthal shear, VIL density). Currently, the fused model includes two GOES-derived cloud growth predictors, two NWP predictors (for the a priori), and one radar-derived predictor.

c--Run model in real-time and develop an intuitive display capability (AWIPS-II).
The fused probabilistic model has now been running in real-time at CIMSS with few interruptions since April 2013. There have been many excellent examples where the model exhibits lead-time to NWS warnings (from 10 min up to 60 min), and even examples where the model produces a high probability prior to the occurrence of severe weather, which occurred before an NWS warning was issued. False alarms have not increased substantially, and several NWP fields have been identified to reduce the false alarms that do occur. The probability data may also be ingested into AWIPS-II, in shapefile format, with contours around radar or satellite objects. Development of a real-time plug-in for AWIPS-II ingestion of shapefiles has progressed, and will soon be incorporated into the real-time processing for “live” viewing of the model performance.

d--Make training datasets more robust by expanding them (geographically, seasonally).
The current training sets have been shown in 2013 to generalize reasonably well to independent data (as indicated by the performance). However, the potential inclusion of more predictors may necessitate more training data (due to higher dimensionality). The training is in the process of being expanded using 2013 data, in part to make the satellite growth predictors a function of elapsed time between scans, which should increase the accuracy of the probabilities.

e--Evaluate the model using independent data sets.
The model has been evaluated using two independent days from 2013 where severe weather occurred in various geographic regions of the U.S. The model skill was measured against NWS severe thunderstorm/tornado warnings and local storm reports, and results have been submitted for publication and are currently under review. Based on these preliminary results, the model has comparable skill to NWS severe thunderstorm/tornado warnings while providing greater lead-time (in a median sense) to severe hazards (see FIG. 2). It should be noted that the first severe report or warning was used for the skill analysis, and that this skill may not be representative for all convective modes. Nevertheless, the model has performed skillfully overall, leveraging derived NWP, satellite, and radar data.

PROJECT TITLE: CIRA Support to GOES-R Proving Ground for National Weather Service Forecaster Readiness

PRINCIPAL INVESTIGATORS: Steve Miller and Renate Brummer

RESEARCH TEAM: Ed Szoke, Dan Bikos, Renate Brummer, Bernadette Connell, Greg DeMaria, Robert DeMaria, Jack Dostalek, Kathy Fryer, Hiro Gosden, Lewis Grasso, Stan Kidder, Kevin Micke, Steve Miller, Andrea Schumacher, Dave Watson

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Donald W. Hillger, John Knaff, Dan Lindsey, Deb Molenar (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The next generation GOES environmental satellite systems, beginning with GOES-R, will contain a number of advanced instruments including the Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). National Weather Service (NWS) forecasters and other operational users of satellite data must be introduced to and trained properly on these new capabilities in order to maximize the utility of GOES-R. CIRA is leveraging its existing capabilities to provide this training and experience directly to NWS forecasters through ongoing support of the NOAA Proving Ground project, where simulated and proxy GOES-R products are demonstrated at NWS Weather Forecast Offices (WFOs) in their native Advanced Weather Information Processing System (AWIPS) display systems, as well as at

NOAA Operational Centers such as the National Hurricane Center (NHC), Storm Prediction Center (SPC) and Aviation Weather Center (AWC). This project supports the following NOAA mission goals: Weather and Water, Commerce and Transportation and Climate. Enhanced training will also prepare the forecaster/manager on how to utilize imagery and products to provide services in these areas.

Most CIRA PG products are also made available in real time on the CIRA web page at http://rammb.cira.colostate.edu/ramsdis/online/goes-r_proving_ground.asp. A portion of the web page is shown below in Figure 1.

GOES-R - CIRA Product List

Information

Experimental and operational data are used to demonstrate subsets of what will be available from GOES-R. The real time demonstrations include GOES-R AWG products, product variants, new products and new imagery/visualization techniques. The table below summarizes the products, with a clickable link to more information.

CIRA Product List (click headings to re-sort):

Product	Contact	Related Training	Data Display	WFO / Testbed Feedback	Product Type	Usage
GeoColor Imagery	Steve Miller	Product Description	AWIPS web	WFO	New Imagery / Visualization Technique	Visualization
MODIS Simulated True Color Imagery	Steve Miller	Product Description	web	WFO	New Product	Visualization
GOES Low Cloud / Fog Imagery	Don Hillger	Product Description COMET	AWIPS web	WFO	Product Variant	Cloud determination
MODIS Cirrus Detection	Steve Miller	Product Description	AWIPS web	WFO	New Product	Cloud determination
Orographic Rain Index (ORI)	Steve Miller	Product Description	AWIPS web	HWT	New Product	Rainfall
Marine Stratus Cloud Climatology	Cindy Combs	Product Description VISIT student guide		WFO	New Product	Cloud determination
GOES Blowing Dust	Don Hillger	Product Description COMET COMET EUMETSAT training	AWIPS web	HWT	Product Variant	Volcanic Emissions / Dust
MODIS Based Blowing Dust	Steve Miller	Product Description COMET COMET EUMETSAT training	AWIPS web	HWT	Product Variant	Volcanic Emissions / Dust
MODIS Cloud / Snow Discriminator	Steve Miller	Product Description COMET	AWIPS web	WFO	Product Variant	Snow / Cloud determination
MODIS Cloud Layers & Snow Cover Discriminator	Steve Miller	Product Description COMET	AWIPS web	WFO	Product Variant	Snow / Cloud determination

Figure 1. Web page that provides access to the CIRA Proving Ground products and training.
The web page provides much information on each of the CIRA Proving Ground (PG) products, includes the developer and point of contact as well as a concise but informative "Product Description" that details how the product is made, why it is a PG product, and how it can be used in operations. All of the products are available to forecasters through their AWIPS system if requested, but typically interested National Weather Service (NWS) Weather Forecast Offices (WFOs) who work with CIRA will ingest only a few products at any one time for testing and evaluation. The web page however allows real-time access to all the products for quick viewing, as well as a 4-week archive. This enables forecasters to use them online, or decide if they would like to ingest them into the AWIPS at their WFO (we work with individual WFOs to provide instructions on how to do this). Bandwidth limitations often prevent some WFOs from ingesting too many (or at times any) products, so having the web page presentations can be a useful alternative display mechanism.

CIRA works in collaboration with other Proving Ground partners at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison, the NASA Short-term Prediction Research and Transition (SPoRT) Center located in Huntsville, Alabama, and the GOES-R Proving Ground Satellite Liaisons.

PROJECT ACCOMPLISHMENTS:

Work was conducted in the following six areas:

1--Decision Aid Product Development:
--CIRA continued to generate and serve the following products to the NHC: RGB Airmass, RGB Dust, RII, SRSO, and the new GOES-R Natural Color Imagery Product. CIRA's collaboration with SPoRT continued, with SPoRT making the RGB products available in NAWIPS, the display system at NHC.

--CIRA continued to generate GOES-R ABI synthetic imagery based on output from NSSL's 4-km WRF ARW. Throughout the year, imagery was produced for 6.95 µm, 7.34 µm, 8.50 µm, 10.35 µm, and 12.3 µm for forecast periods out to 36 hours. In addition, CIRA continued to simulate the thermal-only 3.9 µm band (i.e., neglecting the solar reflected component) and the band difference product 10.35 µm - 3.9 µm (referred to as the "fog product" by forecasters) in real-time. Additional band differences created were 10.35 µm – 12.3 µm, 8.5 µm - 10.35 µm, and 8.5 µm - 12.3 µm. CIRA also began generating GOES-R ABI synthetic imagery based on output from the NCEP NAM Nest (CONUS scale 4-km model available to forecasters on AWIPS I/II) 00 UTC run. Bands were generated to produce the standard AWIPS IR and Water Vapor imagery, out to 60 hours. The synthetic imagery continued to receive very favorable feedback from forecasters at many different WFOs, SPC and AWC. Synthetic imagery represents one way to provide Proving Ground products for bands or combinations of bands that do not currently exist with the operational GOES satellites.
-- CIRA produces a variety of Proving Ground products, including GOES blowing dust, MODIS-based dust enhancement, GOES cloud/snow discrimination (3-color technique), MODIS cloud/snow (binary) discriminator, MODIS cloud layers/snow discriminator, MODIS Cirrus, GOES low cloud/fog, GeoColor (with and without city lights, per user request), and the Orographic Rain Index (ORI). These products are generally generated using bands on Polar orbiting satellites, which represents another way to replicate GOES-R type products, since these satellites have many of the bands that will be available on GOES-R (though of course at limited time resolution). Most CIRA PG Decision Aid products were moved into AWIPS and are being served to partnering WFOs.
--The ORI product was delivered with VISIT training per request to WFOs in Hawaii and San Juan, Puerto Rico. Work continued to verify the ORI product as well as making adjustments to the input to ORI per feedback from forecasters.
--The RGB Airmass GOES sounder product was also distributed to the NOAA Weather Prediction Center (WPC) and the Ocean Prediction Center (OPC).

2--Interaction with NWS Forecast Offices and National Centers:
-- Continued close working relationship with partner WFOs at Boulder and Cheyenne. CIRA's WFO Liaison Ed Szoke is also a NOAA/ESRL/GSD employee, and the Boulder WFO is located only two doors down from his GSD office. Ed interacts frequently with the Boulder WFO, including working occasional forecast shifts to gain a better appreciation of operational forecast problems and issues.
-- For the first time Total Lightning evaluation was done at both Boulder and Cheyenne (in cooperation with SPoRT), using lightning data from the Colorado Lightning Mapping Array (CO LMA) maintained by Colorado State University.
--CIRA established a "Front Range Collaboration" effort with SPoRT, and preliminary evaluation of snow/cloud discrimination and Day/Night band products was accomplished. An example of each from the evaluation period last spring and summer is shown in Figures 2 and 3 below.
-- Expanded the distribution of PG products to additional WFOs, which now number 29 that receive CIRA PR products. Many requests come after exposure via VISIT training or evaluation exercises conducted by Satellite Liaison Chad Gravelle.
-- Continued to emphasize the collection of forecaster feedback regarding CIRA PG products. Feedback is being received via email, AFDs, blogs, semi-annual National Center reports, shift logs, verbal communication, and specially created feedback links on our web pages. Feedback comments are being archived.
-- Close interaction with the NWS Scientific Services Divisions (SSDs) ensured that the Regional Headquarters are well informed about PG product distribution to their WFOs.
-- Participation in the SPC Spring Experiment in Norman, Oklahoma in May-June to train forecasters on CIRA's WRF-ARW and NAM Nest based synthetic imagery products.
-- CIRA's close interaction with NHC continued; several visits to NHC offered good opportunities to conduct person-to-person training regarding our NHC PG products.
-- CIRA continued its close interaction with OPC and WPC primarily through their Satellite Proving Ground liaison Michael Folmer. Several products demonstrated to NHC are also demonstrated at OPC and WPC.
-- CIRA provided synthetic imagery for the AWC Winter Experiment. Feedback was very positive.
-- CIRA participated in the AWC Summer Experiment.

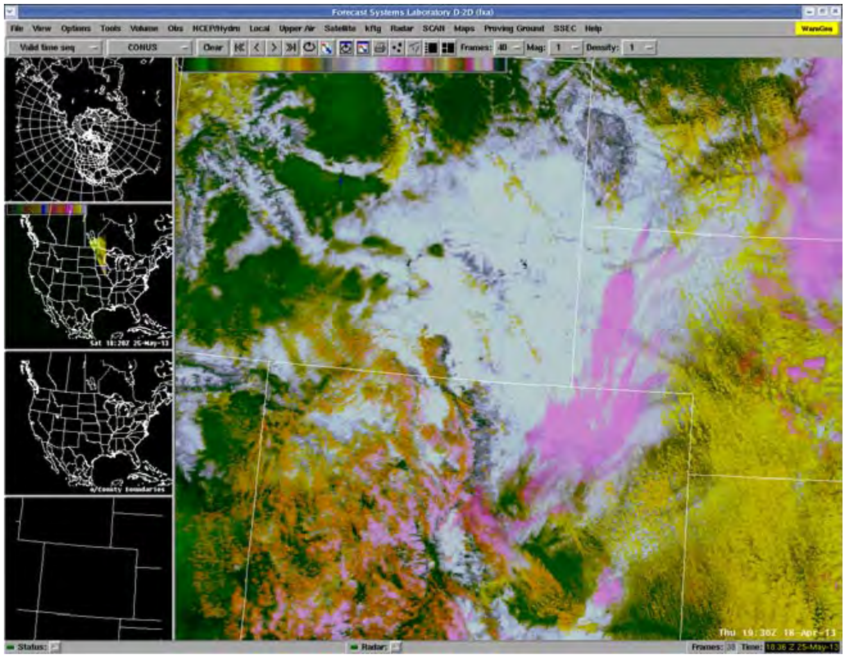


Figure 2. Example of the CIRA snow/cloud layer discrimination product as it appeared on the Cheyenne Wyoming WFO AWIPS display.

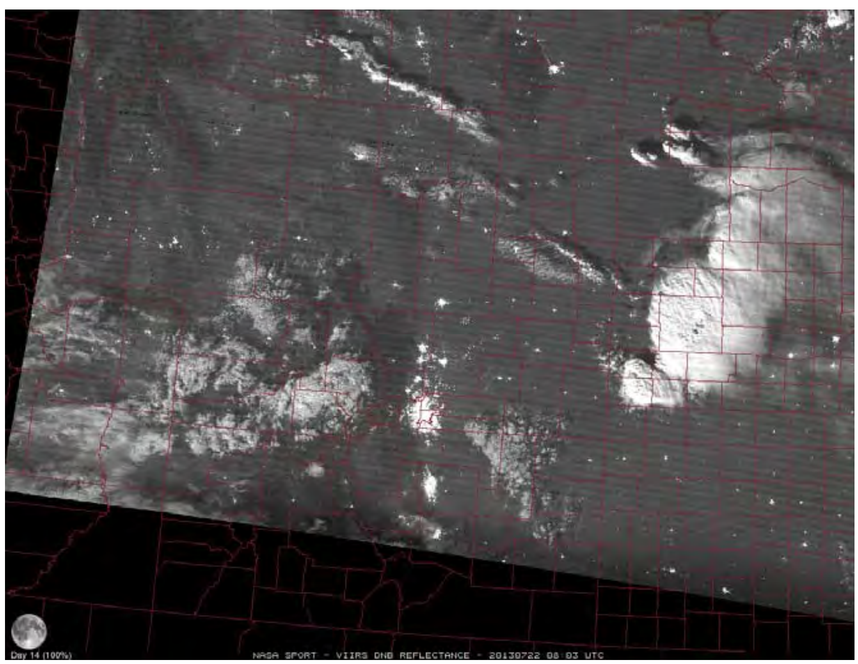


Figure 3. A Day/Night band reflectance image from 0803 UTC on 22 July 2013 (during the period of the Front Range Collaboration evaluation with WFOs in Cheyenne, Boulder and Albuquerque). A complex of thunderstorms in southwestern Nebraska and northwester Kansas appears as it might in a visible satellite image, except that this is in the middle of the night, with the scene illuminated by moonlight using the NPP VIIRS satellite.

3--Proving Ground Website Development:
-- CIRA's real-time PG product webpage is continuously being updated to display the latest products and adhere to presentation formats endorsed by the PG program. New links have been provided to product descriptions and to allow for feedback as well.

4--AWIPS I & II Development:
-- Port of CIRA's AWIPS I geostationary PG products to AWIPS II is complete. Real-time products are being disseminated via the LDM.
-- CIRA's PG products are being demonstrated via AWIPS I, N-AWIPS, web pages, and AWIPS II. Special instruction sets were created for each WFO to facilitate the display of CIRA's Proving Ground products. In addition, CIRA participated in the initial PG Partners working group to develop a standardized AWIPS II product installation template that will be available via the NWS Virtual Lab.
-- CIRA continued to participate in the AWIPS II – Raytheon working group. The bi-weekly group telecons have provided a valuable information channel for Proving Ground AWIPS II developers. A request to Raytheon to add database update capabilities for satellite imagery has been approved. That capability should be available in the May 2014 AWIPS II release. The addition will allow for updated display of CIRA simulated model imagery when new model information becomes available.
-- CIRA continued participation in the monthly NDE-AWIPS Working Group telecons. The meetings provide a framework for technical staff communication regarding problems associated with the establishment of the flow of S-NPP data from NDE into AWIPS II, and allow CIRA to plan for upgrades of NOAAPORT infrastructure that will be needed for GOES-R data ingest.
-- CIRA continued participation in the bi-weekly SPoRT led Experimental Product Development Team telecons. The WebEx sessions provide training on advanced use of the AWIPS II software development capabilities. CIRA sent a representative to the SPoRT EPDT code sprint in Huntsville, AL. Deb Molenar was part of the code sprint team that implemented a beta version of true 24 bit satellite image display capabilities. Scott Longmore also attended the SPoRT EPDT plugin development workshop in Huntsville, AL.
-- AWIPS I product dissemination and client support continued in parallel to AWIPS II product dissemination and client support. An additional AWIPS I LDM product server was procured and implemented to replace the existing seven year old server. Several new AWIPS I sites were added to the CIRA client list.
--Hardware for additional AWIPS II workstations has been procured and configured to expand the CIRA AWIPS II development environment. An AWIPS II workstation has been installed in the CIRA Weather Lab to allow CIRA researchers to become more familiar with the advanced capabilities that are available for additional product development. In addition, 2 64 bit RedHat 6 workstations running the beta 64 bit AWIPS II OB 14.x have been procured and configured. One workstation is used by Scott Longmore for application development. The second workstation has been allocated to facilitate stable transition between builds. Because new build installation and product additions can take 2-3 weeks, a floating upgrade system is needed so that existing work and functionality are not impacted.

5--Product Documentation and User Readiness:
-- CIRA continued to leverage VISIT and SHyMet in-house capabilities to evaluate PG activities. Additional VISIT sessions were created based on CIRA PG products. Special efforts were made to conduct preliminary analysis of the ORI product performance for selected locations, correlating the index with precipitation and stream gauge data and identifying strengths/weaknesses of the algorithm. The algorithm is being reprogrammed to allow for more flexibility in order to address concerns raised by forecasters.
-- CIRA expanded its efforts to post BLOGS on the VISIT webpage.
-- CIRA continued to merge PG modules with on-going activities.
-- CIRA collaborated closely with CIMSS, SPoRT and COMET on training activities.

6--Colorado Lightning Network (CO LMA):
-- During last year's performance period, the CO LMA data stream was taken over by CSU (previously maintained by New Mexico Tech). A communications contract has been established that is working well. A few stations in the network experienced technical problems. Problems included failed hardware and weak back up batteries. All stations are currently on line and operating well. Live CO LMA data are

being ingested into the Boulder and Cheyenne WFOs and are being used by forecasters to help identify severe weather and rapidly evolving convective storms.
-- A M.S. thesis was completed by Brody Fuchs in the Radar Meteorology Group, which used data from the CO LMA network. This thesis compared the characteristics of electrified storms in relation to environmental conditions for storms over Colorado, Oklahoma, Alabama and Washington DC, all of regions having LMA networks.

PROJECT TITLE: CIRA Support to Production of Real-time Nested NAM-based GOES-R Synthetic Imagery

PRINCIPAL INVESTIGATORS: Lewis Grasso and Yoo-Jeong Noh

RESEARCH TEAM: Renate Brummer, Hiro Gosden, Kathy Fryer

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Dr. Dan Lindsey (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

Recent efforts at CIRA to generate GOES-R synthetic imagery in real time from the 4-km NSSL WRF-ARW model have been very successful. Not only is the data being used as a proxy dataset for research into future GOES-R products, but since the output is based on real-time forecast fields, operational forecasters are using the synthetic satellite loops in their daily cloud and convective products.

This past year the CIRA synthetic imagery team began to generate additional synthetic forecast model imagery from the NAM 4-km nest forecast model over the CONUS area. Details of the cloud microstructure, such as cloud particle size, is strongly dependent on the particular microphysics package used in the model, so studying synthetic imagery from more than one cloud model configuration is highly desirable.

The NAM nest imagery will be used for two primary purposes: 1) to assist the NWS with their operational forecasts, and 2) to perform band differencing and other studies for future GOES-R products.

PROJECT ACCOMPLISHMENTS:

CIRA was granted access to the STAR S4 Supercomputer housed in Madison, WI. This machine provided the necessary processing power to efficiently use the 4-km nested NAM model output to create synthetic imagery.

The first portion of this project involved the configuration of the Community Radiative Transfer Model (CRTM). After successfully installing the CRTM on S4 and creating some test images, an automated process was set up so that nested NAM output was being sent to S4. Using output from the NAM-nest 00 UTC run, synthetic imagery was then generated on a daily basis for the GOES 10.7 µm band for the 9- to 60-hour forecast. The plan for 2013 is to begin generating imagery of the GOES water vapor band (6.5 µm) to the daily production process.

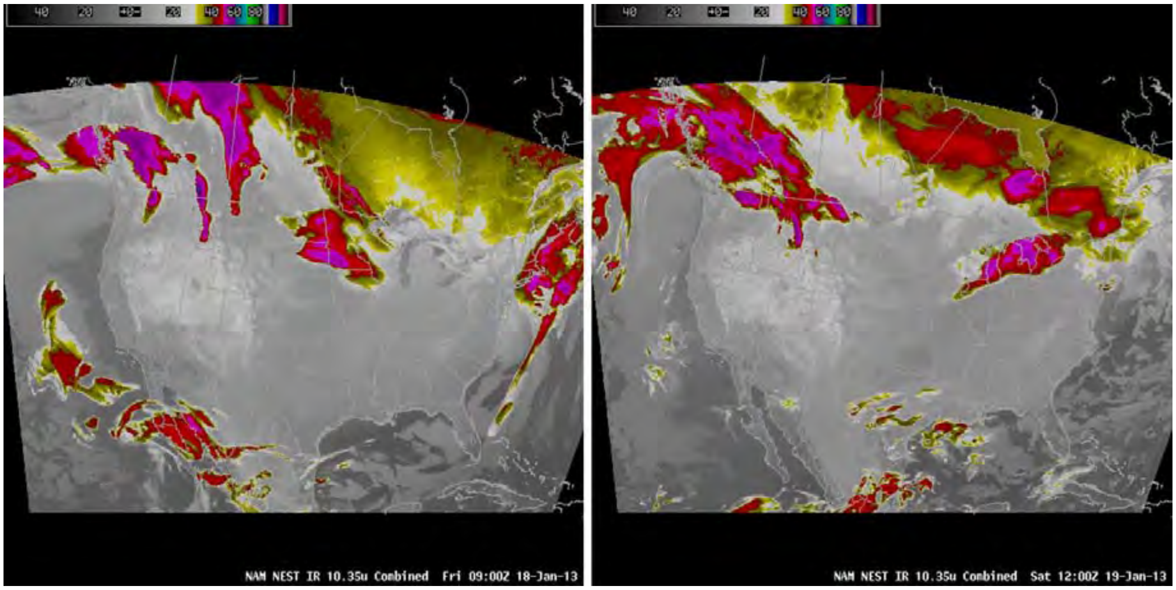


Figure 1. Synthetic 4 km NAM nest 10.7 µm imagery valid on 18 January 2013 at 09 UTC (left) and 19 January 2013 1200 UTC (right), as viewed in AWIPS.

PROJECT TITLE: CIRA Support to Research and Development for GOES-R Risk Reduction for Mesoscale Weather Analysis and Forecasting; and Analysis of Simulated Radiance Fields for GOES-R ABI Bands for Mesoscale Weather and Hazard Events (AWG)

PRINCIPAL INVESTIGATOR**:** Steve Miller

RESEARCH TEAM: Renate Brummer, Cindy Combs, Jack Dostalek, Louie Grasso, Andrea Schumacher, Kevin Micke, Bernie Connell, Dan Bikos, Jeff Braun, Hiro Gosden, Dave Watson, Mike Hiatt

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Mark DeMaria, Donald W. Hillger, John Knaff, Dan Lindsey, Deb Molenar (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The next generation GOES satellites (beginning with GOES-R) will include the Advanced Baseline Imager (ABI) with vastly improved spectral, spatial and temporal resolution relative to the current GOES I-P series satellites. It will also include a Geostationary Lightning Mapper (GLM) which, together with the ABI, offers the potential to significantly improve the analysis and forecasts of mesoscale weather and natural hazards. The GOES-R era will begin in the middle of this decade, and will be part of a global observing system that includes polar-orbiting satellites with comparable spatial and spectral resolution instrumentation. This annual report combines CIRA's different projects conducted in the areas of GOES-R Risk Reduction (R3). The overall goal of these science studies is to contribute to the reduction of time needed to fully utilize GOES-R as soon as possible after launch and to provide the necessary proxy data to the algorithm groups for testing proposed algorithms and therefore to contribute to an improved algorithm selection and algorithm refinement.

GOES-R3 Research Areas
CIRA's GOES-R3 work can be divided into the following eleven different projects:

GOES-R3 Research Areas
Project 1-- Data Assimilation: Utility of GOES-R Geostationary Lightning Mapper (GLM) using hybrid variational-ensemble data assimilation in regional applications.
Project 2-- Precipitation: Improvements to QPE using GOES visible ABI and model data.
Project 3-- Severe Weather: Convective Storm Forecasting 1-6 Hours Prior to Initiation.
Project 4-- Proxy Radiance Data Testbed: Ensemble Simulation of GOES-R Proxy Radiance Data from CONUS Storm-Scale Ensemble Forecasts, Product Demonstration and Assessment at the Hazardous Weather Testbed GOES-R Proving Ground
Project 5-- Tropical Cyclones: Improved Understanding and Diagnosis of Tropical Cyclone Structure and Structure Changes.
Project 6-- Infrastructure - RGB Products in AWIPS II (new task)
Project 7-- User Preparation: National and International Development, Delivery, and Distribution
Project 8-- PCS User Readiness (new task)

AWG Research

Project 9-- GOES–R Proxy Data Application: Development, Evaluation, and Testing.

Supporting Projects
Project 10--Administrative Support
Project 11--Continued Senior Advisory Support for the GOES-R Program (ADEB)

PROJECT ACCOMPLISHMENTS:

Project 1-- Data Assimilation: Utility of GOES-R Geostationary Lightning Mapper (GLM) Using Hybrid Variational-ensemble Data Assimilation in Regional Applications

This is a collaboration project between CIRA and NOAA/NCEP. CIRA's data assimilation team is developing the capability of a prototype hybrid variational-ensemble data assimilation system (HVEDAS) to use GOES-R Geostationary Lightning Mapper (GLM) observations and evaluate its impact in regional data assimilation (DA). In order to enhance the GLM utility, GLM assimilations are being combined with assimilation of all-sky (cloudy) microwave (MW) and infrared (IR) satellite radiance observations. These types of observations have a potential to introduce relevant information related to cloud microphysics and thus impact the analysis and prediction of severe storms and other extreme weather events.

The research focus is on evaluating the impact of GLM observations in data assimilation applications to severe weather. CIRA's development is relying on using the NOAA operational codes for modeling system (e.g., Weather Research and Forecasting Nonhydrostatic Mesoscale Model - WRF-NMM) and observations (e.g., Gridpoint Statistical Interpolation – GSI and Community Radiative Transfer Model – CRTM). Computations are being conducted on the NOAA R&D computer. The development resulting from this research is always immediately available to NOAA researchers and, if warranted, to NOAA operations.

The current operational data assimilation based on GSI has successfully been improved using WWLLN lightning observations and the observation operator. The first important step of this research was to switch to a more complex microphysics in NOAA operations, the development of a cloud hydrometeor-based lightning observation operator. In order to accomplish this step we followed the work of McCaul et al. (2009) that indicates a relevance of graupel flux and vertically integrated cloud ice for lightning detection. Later this year, we will submit manuscript(s) for publication in peer-reviewed scientific journals.

Our results are being presented on our web page (https://www.cira.colostate.edu/projects/ensemble/) as well as at conferences and workshops on this subject.

Project 2-- Precipitation: Improvements to QPE Using GOES Visible ABI and Model Data

This precipitation project is a collaboration project between NSSL, CIMSS, CIRA, and CIMMS. The project addresses the need for remote sensing-based estimates of precipitation in portions of the U.S. and its coastal waters where WSR-88D radar is limited due to the radar beam being blocked and/or overshooting the precipitation. Heavy precipitation poses threats of flash flooding, but existing satellite techniques often perform poorly in pinpointing locations of heavy rain, especially when cloud tops are relatively warm.

Improvements to the existing Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) algorithm was made using high resolution cloud structure from the GOES visible imagery (daytime), estimates of cloud top phase and particle size derived from GOES, and moisture and wind fields from numerical weather model and model and satellite "blended" data. Preliminary work at the National Severe Storms Laboratory (NSSL) indicated that a simple technique to identify small-scale convective cloud tops in visible imagery performs better than IR techniques in matching radar echoes in many situations. GOES-R will provide about twice the resolution of the 1-km observations available from the current GOES. CIRA's contribution to the project was primarily to provide cloud-top effective radius retrievals for selected case studies. This task was completed by the end of last year.

Project 3-- Severe Weather: Convective Storm Forecasting 1-6 Hours Prior to Initiation

This severe weather project is a collaboration effort between NESDIS/STAR, CIRA, CIMSS, Univ. Alabama/Huntsville, CREST, and NSSL. One of the greatest difficulties in severe storm forecasting is deciding where and when storms will initially form. Current numerical models struggle with this problem and often have large errors in their 1-6-hour forecasts for convective initiation (CI). The Advanced Baseline Imager (ABI) aboard GOES-R will provide an unprecedented array of spectral bands at improved spatial and temporal resolution relative to the current geostationary satellites, and offers great promise in improving skill in short-term CI forecasts. In a combined effort among several institutes, we began to examine this problem from several different but related fronts. The overall goal of this proposal is to develop a single objective system that predicts where and when storms will form 1-6 hours prior to initiation. The collaboration includes analysis of chosen case study events over the U.S. (GOES/MODIS) and Europe (MSG SEVIRI), and a sharing of analysis strategies and datasets.

CIRA's portion of the work on this project focused on using GOES-R ABI band differences to identify places where storms are likely to form. Specifically, the 10.35-12.3 µm difference has been shown with MSG observations and model output to highlight low-level convergence of water vapor. Local maxima in the band difference indicate a local pooling of moisture, and convective clouds and sometimes storms often form in these very same areas. CIRA performed additional cloud and radiative transfer model simulations to better understand this process, gathered and analyzed MSG cases, and collected other non-satellite Convective Initiation forecasts, then determined the best way to combine the information into a 1-6 hour CI forecast. As part of this study, data from 20 May 2013, the day of the Moore, Oklahoma tornado, was analyzed closely due to a large region in Texas being cloud free. The NSSL WRF did a good job of simulating this classic dryline case. Simulated ABI 10.35 - 12.3 output showed a well-defined maximum associated with water vapor pooling along the dryline. Vertical cross sections through the dryline confirmed that the largest split window difference values were indeed co-located with deeper low-level moisture. A manuscript on this topic was prepared, submitted, and is currently in review with the Journal of Applied Meteorology and Climatology.

Project 4-- Proxy Radiance Data Testbed: Ensemble Simulation of GOES-R Proxy Radiance Data from CONUS Storm-Scale Ensemble Forecasts, Product Demonstration and Assessment at the Hazardous Weather Testbed GOES-R Proving Ground

This proxy radiance data testbed project is a collaboration project between three cooperative institutes: CAPS, CIMSS, and CIRA. The proposed project employs 4-km storm-scale ensemble forecasts (SSEFs) produced by the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma (OU) for the NOAA Hazardous Weather Testbed (HWT) Spring Experiments. Utilizing national supercomputing resources, synthetic imagery will be generated in real-time, for several infrared channels from 10-15 ensemble members, at hourly intervals. Three radiative transfer model packages were employed in the project. They included the Community Radiative Transfer Model (CRTM) package from NESDIS, the package based on the Successive Order of Interaction (SOI) RTM from CIMSS, University of Wisconsin, and an RTM package from CIRA of Colorado State University. They were used to generate synthetic brightness temperatures for selected Advanced Baseline Imager (ABI) and current GOES infrared channels. Through collaborations, a better understanding of the interaction between cloud microphysics and radiative transfer modeling was achieved so as to provide insights for improving the CRTM system, which is part of the operational data assimilation systems at NCEP.

CIRA scientists collaborated closely with the CAPS proxy data team (Louie Grasso, Ming Xue, Fanyou Kong, and Youngsun Jung) on this project. Ming Xue, the director of CAPS, asked that CIRA provide code that would compute particle size of each of the five habit types (cloud, rain, snow, graupel, and ice) that are available in five microphysical schemes (Morrison, Milbrandt-Yau, NSSL, Thompson, and WDM6) available in WRF-ARW forecast model. This task was accomplished with the additional collaboration of Jason Otkin (CIMSS) and Ted Mansel (NSSL). See Figure 1 below for an example of imagery for each microphysical option of the 23 May 2013 case.

In addition, the performance of the wsm6 microphysical scheme was evaluated for the forecast periods of July 2011 through September 2012 and for summer of 2013. Results indicated that the amount of upper level cloud ice produced by the wsm6 scheme was significantly under predicted when compared to observations. This conclusion was based on histograms we produced of synthetic and observed GOES-13 10.7 µm brightness temperatures for those forecast periods. Further, specific examples of convective events were used for side-by-side comparisons of synthetic and observed GOES-13 imagery. Results have been reported in a peer reviewed manuscript to Monthly Weather Review.

The CIRA team also participated in the Spring Experiment in Norman, Oklahoma (May 2013).

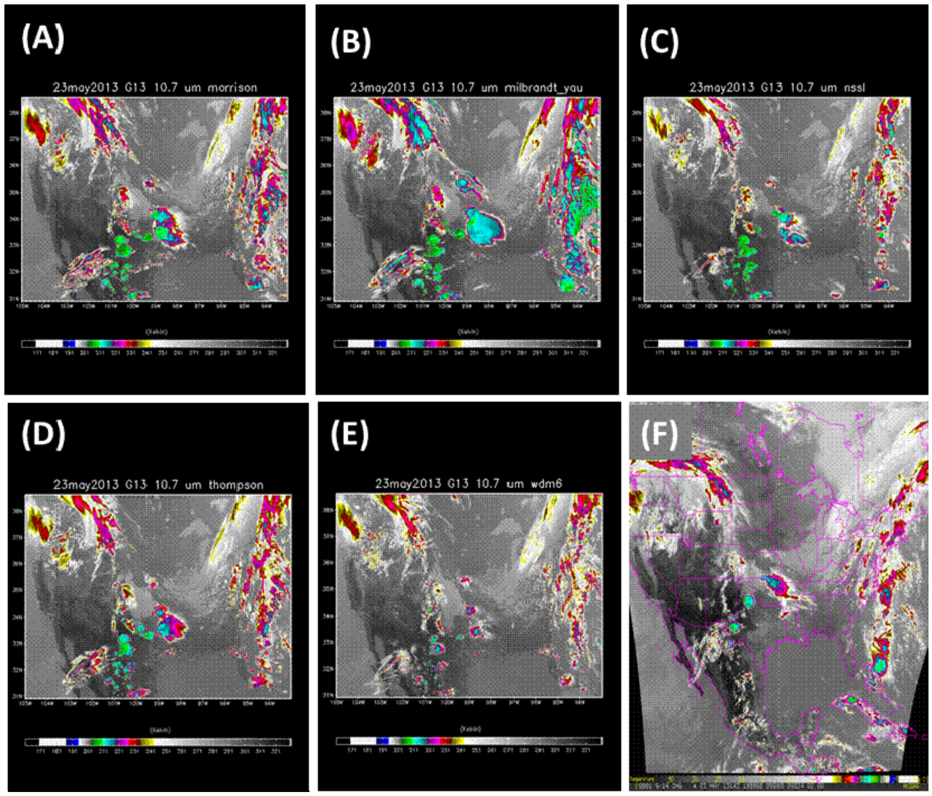


Figure 1. Synthetic GOES-13 imagery from WRF-ARW forecast model output using various microphysical schemes: (A) Morrison, (B) Milbrandt-Yau, (C) NSSL, (D) Thompson, (E) WDM6, and (F) Observations.

Project 5-- Tropical Cyclones: Improved Understanding and Diagnosis of Tropical Cyclone Structure and Structure Changes

This tropical cyclone project is a collaboration project between CIRA, NESDIS/STAR/RAMMB and CIMSS. The goal of this project is to develop new tools that enhance the current capabilities to diagnose tropical cyclone (TC) structure and location using GOES-R advanced baseline imagery (ABI) and GOES lightning mapper (GLM) proxies. The GOES-R Algorithm Working Group presently supports but one TC algorithm, which estimates TC intensity. While intensity is an important operational TC metric, the diagnosis and forecasts of the wind field structure is also an operational requirement and is often considered equally important in determining the impacts of landfalling TCs, initializing numerical weather prediction models, emergency preparedness and disaster mitigation. To directly address the present lack of GOES-R TC structure algorithms, the CIRA/RAMMB team began work on the development of a suite of operationally relevant and pragmatic tools to better diagnose TC structure. This research will lead to a better understanding of the climatological and environmental controls on TC structure variability may allow for the capability to develop a statistical-dynamical TC structure forecast system in the optional third year of funding.

Using current satellite data and GOES-R ABI and GLM proxies the CIRA research contributed to advancing a number of outstanding problems in TC research and forecasting techniques, like the improvement of TC location estimates; an increase in the understanding of the linkages between TC structure, intensity, the TC's environment, and internal dynamics; and the development of improved techniques to estimate the inner-core wind structure and TC-related parameters.

The funding for the development and testing of a Statistical-Dynamical Model which will provide the methods, the historical database, and the knowledge to generate a rudimentary, yet first of its kind, TC structure forecast system was deferred into the next year. This was a management decision made by the GOES-R Risk Reduction NESDIS/STAR Program Office.

The design of this forecast system will now begin in the second half of 2014. It will be a statistical-dynamical system following both the climatology and persistence model detailed in (Knaff et al. 2007) and the Statistical Hurricane Intensity Prediction Scheme (DeMaria et al. 2009). We envision the final statistical-dynamical model to forecast changes in TC structure (RMW, Radii or 34, 50, and 64 kt winds) and MSLP.

Project 6-- Infrastructure - RGB Products in AWIPS II (new task)

For the last several years CIRA has successfully demonstrated RGB products within AWIPS at WFOs and N-AWIPS at National Centers. The products were created from single and multi-band satellite imagery to produce a single 8-bit image file external to the AWIPS environment. A fundamental requirement to augment the AWIPS II capabilities for 24-bit RGB imagery is to develop a satellite visualization plugin or tool that can access individual satellite channels, paired channel differences, or comparable measurements from the AWIPS II database for assignment to the RGB intensities. These intensities must then be combined to display a resulting 24-bit color without assigning transparencies to the individual RGB color inputs themselves.

In addition to band selection, the CIRA and RAMMB team believes that optimal AWIPS II and N-AWIPS II RGB functionality provides an accommodation for the adjustment of threshold temperatures and reflectance that are used in the enhancement of the individual RGB color components.

As a first step, CIRA successfully ported CIRA's AWIPS I geostationary proving ground products to AWIPS II. Other real-time products followed – by the end of this reporting period, the entire CIRA palette of proving ground products was demonstrated in AWIPS II.
-- The CIRA/RAMMB team participated in the initial Proving Ground Partners working group to develop a standardized AWIPS II product installation template that will be available via the NWS Virtual Lab.
-- In addition, CIRA continued to participate in the AWIPS II – Raytheon working group. The bi-weekly group telecons provided a valuable information channel for Proving Ground AWIPS II developers. A request to Raytheon to add database update capabilities for satellite imagery has been approved. That capability should be available in the May 2014 AWIPS II release. The addition will allow for updated display of CIRA simulated model imagery when new model information becomes available.
-- CIRA also continued participation in the monthly NDE-AWIPS Working Group telecons. The meetings provided a framework for technical staff communication regarding problems associated with the establishment of the flow of S-NPP data from NDE into AWIPS II, and allowed CIRA to plan for upgrades of NOAAPORT infrastructure that will be needed for GOES-R data ingest.
-- CIRA continued participation in the bi-weekly SPoRT led Experimental Product Development Team telecons. The WebEx sessions provided training on advanced use of the AWIPS II software development capabilities.
-- CIRA sent a representative to the SPoRT EPDT code sprint in Huntsville, Alabama.

Project 7-- User Preparation: National and International Development, Delivery, and Distribution

1-- This project provided partial support for organizing and conducting sessions and then processing the recordings of the monthly international virtual Regional Focus Group. '
The WMO Virtual Laboratory Regional Focus Group of the Americas and Caribbean conducted 12 monthly bilingual (English/Spanish) weather briefings. The briefings made use of VISITview software to present GOES and POES satellite imagery from CIRA and GoToWebinar for voice communication over the Internet. Over the year, the participants from the U.S. included: CIRA, the NWS International Desk at NCEP, NWS Training Division, the UCAR/NWS International Activities Office, and UCAR/COMET. Twenty-nine countries outside the US participated: Algeria, Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Canada, Cayman, Chile, Colombia, Costa Rica, Croatia, Dominican

Republic, El Salvador, Ghana, Haiti, Honduras, Mexico, Niger, Panamá, Peru, St. Kitts and Nevis, St. Lucia, Trinidad and Tobago, Suriname, Uruguay, and Venezuela. M. Davison at the NCEP International Desk led the discussion. Participants offered comments for their regions and tended to also bring interesting questions to the discussion. The number of countries participating each month ranged between 8 and 13 (average 10); and the number of participants each month ranged between 16 and 51 (average 31)
-- We primarily view satellite imagery and products for real-time applications and climatological outlooks. This gives us an opportunity to showcase GOES-R products. For example, during the summer of 2013, we highlighted the dust RGB product over the Atlantic.
-- The sessions were recorded (except for August 2013 which experienced technical problems) and can be found here: http://rammb.cira.colostate.edu/training/rmtc/fg_recording.asp
-- In 2013, 7 training video clips from the monthly Focus Group Sessions were disseminated through GEONETCast February through July, and September.

February 2014 was a milestone month for the group leading 10 years of monthly virtual sessions. Up to February 2014, out of a total of 120 possible monthly sessions, we have only missed 5 months: 4 due to leaders not being available and one because of technical problems. That is an impressive record!

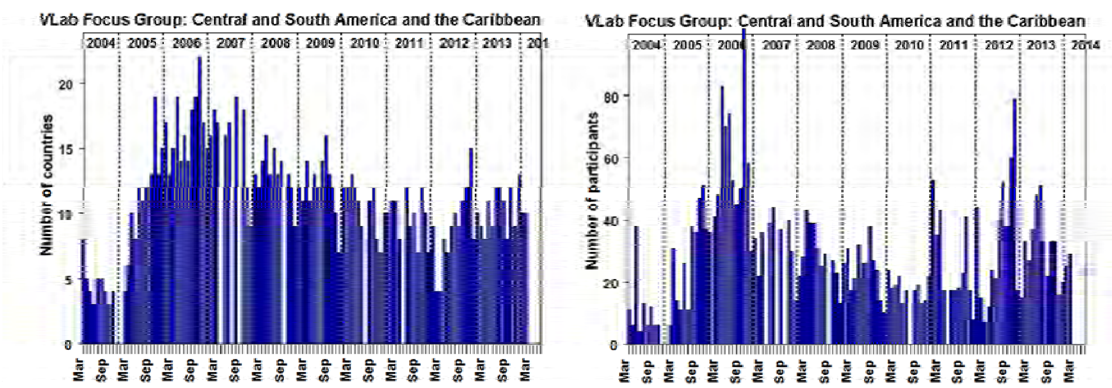


Figure 2. Left: Number of countries participating each month in the online virtual discussion sessions over the past 10 years. Right: Number of participants joining in each month in the online virtual discussion sessions over the past 10 years.

2-- In support of GEONETCast activities, this project provided partial support for a Train the Trainers GEONETCast workshop in April and a virtual GEONETCast training event in December
--B. Connell attended the NOAA/WMO Train the Trainers workshop on 6 and 7 April at the NOAA Center for Weather and Climate Prediction in College Park, Maryland prior to the NOAA Satellite Conference. She gave a presentation on “GEONETCast Americas Training Channel: VLab Training”. The workshop focused on all aspects of GEONETCast broadcast including the capability to send training materials. Figure 3 shows the participants at the Train the Trainer Workshop.

--As a follow-up to the WMO NOAA Train the Trainer Workshop on GEONETCast in April 2013, and in response to WMO user surveys CIRA, NOAA, WMO, and the WMO Centers of Excellence in Costa Rica, Barbados, Brazil, and Argentina hosted a virtual training on GEONETCast. It consisted of 3 sessions on the 3rd, 4th, and 5th of December 2013. The sessions were presented in both English and Spanish (for a total of 6 sessions). The goals of the training were: to make countries more aware of what is available; to expand the use of GEONETCast-Americas; and to start thinking about GOES-R. The topics included an introduction to the capabilities of GEONETCast, disaster mitigation products, and software to view products. The sessions drew a lot of interest as people from 29 countries participated. There were 111 individuals, which included speakers, organizers, and participants. Presentations and session recordings are posted on the web pages http://rammb.cira.colostate.edu/training/rmtc/geonetcast_event_en.asp

3-- Virtual Laboratory Management Group web Meetings – CIRA participated in the virtual VLMG meeting on 13 June and 9 October 2013, and 25 March 2014. The meeting reports can be found in the WMO VLab site http://www.wmo-sat.info/vlab/meeting-reports/

Project 8-- PCS User Readiness (new task)

PCS User Readiness was a new task added to our list of GOES-R3 projects last year. It served to complement activities under the GOES Risk Reduction National and International Training efforts, the JPSS POES training efforts, and work under the Satellite Meteorology and Hydrology (SHyMet) training program. Due to significant budget cuts, the Virtual Institute for Satellite Integrated Training (VISIT) did not receive any funding from the NWS during this past year. The VISIT program has provided the structure for virtual training and we were able to continue to leverage its knowledge and expertise over this past year. One focus of CIRA's proving ground activities was to provide training for the PG products that are being introduced into forecast offices and national centers and solicit feedback from the users. PCS User Readiness activities leveraged VISIT expertise and supported development of training for PG products and of the SHyMet project:

1--Provide PG examples for the VISIT satellite chat
http://rammb.cira.colostate.edu/training/visit/satellite_chat/ and the CIRA PG Blog
http://rammb.cira.colostate.edu/research/goes-r/proving_ground/blog/
Both the VISIT satellite chat and the PG Blog are excellent ways to connect with the forecaster and other users to demonstrate applicability of GOES-R. Funding to develop Synthetic GOES-R imagery has led to a visualization tool that can be used currently. Blog entries on synthetic imagery have focus on low cloud/fog product and orographic cirrus and the influence on temperature forecasts. Many RGB imagery examples using polar orbiting imagery as proxy, have focused on snow/cloud discrimination, fog identification, and dust detection.

In January, an inquiry from a WFO about the availability of imagery to better identify blowing dust led to a blog entry that discussed this event. In February, the SOO from that WFO discussed the blowing dust event during the VISIT Satellite chat session. The response was very positive and illustrates the benefits of these monthly sessions and the blog: "I would LOVE to see the products such as what was shown on the VISIT webinar (a revisit of the blowing dust/high wind event from 16 January 2014 in southwest NE) to help with the identification of blowing dust."

2--New Module developed
"Identifying Snow with Daytime RGB Satellite Products"
Offered as teletraining through the VISIT structure January through March 2014. The session will be recorded after incorporating feedback.
http://rammb.cira.colostate.edu/training/visit/training_sessions/identifying_snow_with_daytime_rgb_satellite_products/

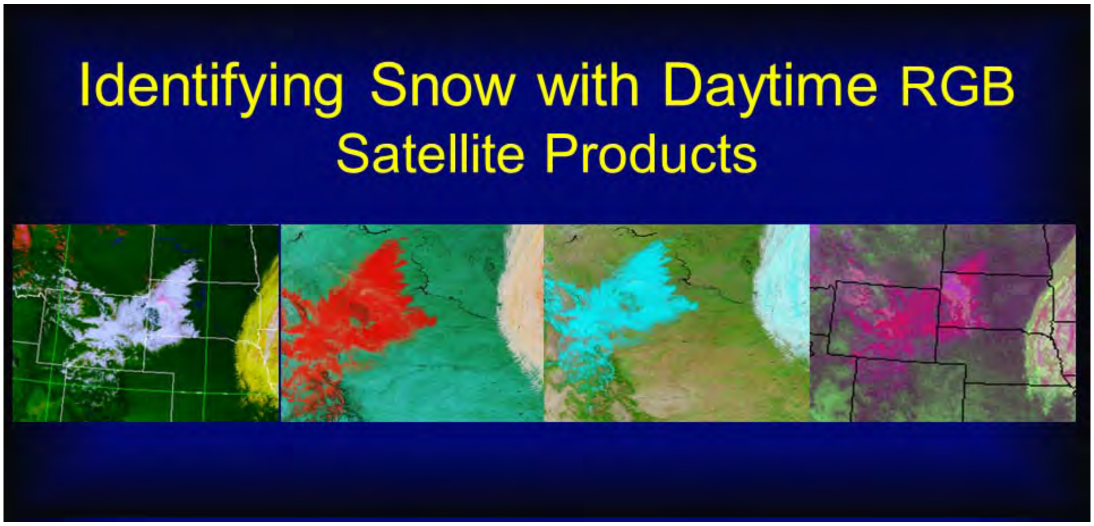


Figure 3. New VISIT Teletraining Module on “Indentifying Snow with Daytime RGB Satellite Products”

Project 9-- GOES–R Proxy Data Application: Development, Evaluation, and Testing

This Algorithm Working Group (AWG) proxy data project is a collaboration project between CIRA, CIMSS, the GOES-R AWG-Visualization Team, and the GOES-R AWG Air Quality Team. Over the past two years, the CIRA proxy data team has gathered considerable amount of experience with producing GOES-R ABI fire proxy data sets for different scenarios (forest fires, agricultural fires, and others).

During this reporting period, the CIRA team generated synthetic dust plume imagery over an area in north-western Texas, which had seen many wildfires in the years before. The synthetic imagery is simulating different GOES-R ABI bands at the typical ABI footprint. Synthetic GOES-R ABI imagery of brightness temperatures and brightness temperature channel differences were produced for five dust plumes which were distinguished by their different mixtures of minerals (quartz, kaolinite, and hematite). The GOES-R ABI synthetic imagery was completed for bands 8.5 µm, 10.35 µm, 11.2 µm, and 12.3 µm.

In addition synthetic GOES-R ABI imagery of the dust plumes was generated for three visible bands: 0.47 µm (blue), 0.55 µm (green), and 0.64 µm (red). The last step in this process of generation of synthetic GOES-R imagery is to combine the three visible bands in order to make an RGB products for this case study.

All CIRA datasets are made available to the NESIDS/STAR GOES-R AWG fire proxy teams and to the AWG-IVT team. In addition the CIRA team has been working closely with Shobha Kondragunta’s (NESDIS/STAR) air quality team. Once completed, the dust plume imagery will aid the air quality team to develop and test their GOES-R dust and smoke detection and retrieval algorithm.

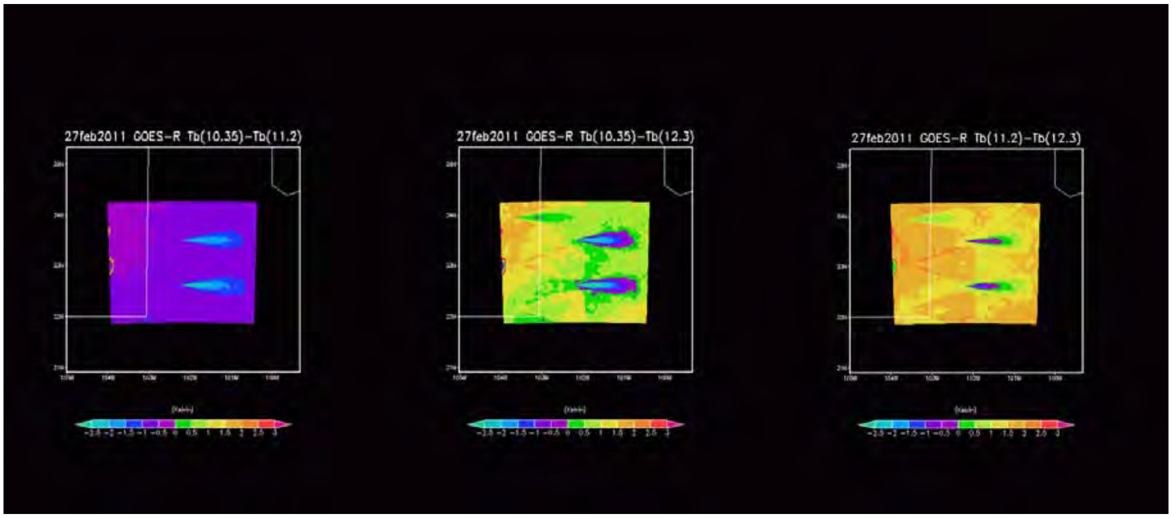


Figure 4. Brightness temperature (Tb) fields for three additional channel differences: 10.35 µm - 11.2 µm, 10.35 µm - 12.3 µm, 11.2 µm - 12.3 µm with five dust plumes (of different mineral compositions) embedded in the Texas 27 Feb 2011 background. Note that each individual image frame covers a total of five dust plumes which are distinguished by their different mixtures of minerals. It is the dust plumes four and five, which are composed of a high percentage of quartz, which show a significant brightness temperature difference for 10.35 µm - 11.2 µm, 10.35 µm - 12.3 µm, 11.2 µm - 12.3 µm.

Project 10--Administrative Support

In a basis consistent with our long-standing Memorandum of Understanding between NOAA and Colorado State University, the CIRA GOES- R3 enclosed budget specifically included support for administrative and clerical personnel directly associated with the technical and managerial administration of this project. This support is “quid pro quo” for the reduced indirect cost rate agreed upon in the long-standing subject memoranda. CIRA’s administrative support person provided communication and collaboration support, assisted in the acquisition and distribution of reference materials relevant to the conception and execution of the project, technical editing of scientific manuscripts, specialized reports and conference papers. In addition, this grant included support for management oversight for the individual GOES-R3 projects. CIRA also provided some administrative support for the wider GOES-R program, including planning for the annual review and tracking of project progress.

Project 11--Continued Senior Advisory Support for the GOES-R Program (ADEB)

Professor Tom Vonder Haar, Member of the National Academy of Engineering, will continue to serve on the Independent Advisory Committee (IAC) for GOES-R. The IAC reports to the GOES-R SDEB and supports tasks assigned to them and by the GOES-R Program Scientist, Dr. Steve Goodman. The range of advisory tasks include all aspects of the Program such as algorithm development and testing; Instrument and Product Cal/Val both before and after launch; User training and outreach; Science and operational applications; and combined products from GOES and JPSS.

PROJECT TITLE: CIRA Support to the JPSS Proving Ground and Risk Reduction Program: Day/Night Band: 'Seeing the Light': Exploiting VIIRS Day/Night Band Low Light Visible Measurements in the Arctic and Advancing Nighttime VIIRS Cloud Products with the Day/Night Band

PRINCIPAL INVESTIGATOR**:** Steve Miller

RESEARCH TEAM**:** Curtis Seaman, Yoo-Jeong Noh, Fang Wang, Scott Longmore, Renate Brummer, Steve Finley

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS/STAR) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Andy Heidinger (NESDIS/STAR/CRPD/ASPB)

PROJECT OBJECTIVES:

Project 1 ('Seeing the Light'—VIIRS/DNB Arctic)

This project focuses on the demonstration of the unique and unprecedented capabilities of the Visible/Infrared Imager/Radiometer Suite (VIIRS) Day/Night Band (DNB) low-light visible nighttime imagery in the Arctic, with a special emphasis on exploiting moonlight illumination during the Winter season when conventional solar illumination is limited or unavailable and where polar-orbiter temporal refresh is most practical to operational users. These demonstrations are being conducted in close cooperation with University of Alaska-Fairbanks (UAF) Geographic Information Network of Alaska (GINA) and its suite of operational partners, and coordinated under the auspices of NOAA's Satellite Proving Ground (and specifically in association with the High Latitude Proving Ground) to ensure a close connection and dialogue with end users. New capabilities for detecting low cloud/fog, snow cover, volcanic ash, sea ice and ice-free passages, auroral boundaries, and other parameters exploiting the 740 m spatial resolution of the VIIRS/DNB low-light visible measurements coupled for the first time with spatially/temporally co-located multi-spectral shortwave and thermal infrared bands, have been demonstrated in near real-time as part of this research project. Application development is leveraging tools and techniques for lunar availability and irradiance prediction as well as hands-on experience with VIIRS/DNB data gained via concurrent participation in the JPSS VIIRS Cal/Val program. Training on DNB imagery capabilities and interpretation for these new observations is an implicit component of this work, and examples derived from this research will provide subject matter for those involved in formal training efforts connected with the Proving Ground and more generally with the environmental satellite user community.

Project 2 (Advancing VIIRS Nighttime Cloud Products)

Clouds are a fundamental meteorological parameter in describing the energy balance of the planet. Knowledge of cloud cover is critical not only to operational users in the context of characterizing current weather-related hazards, but also to the production of high quality climate data records. Beyond the characterization of cloud coverage itself, identification of cloudy scenes is a key first-level filter to numerous other satellite-derived products which must either require cloud-free conditions or knowledge of cloud presence in order to produce accurate retrievals. Without this a priori knowledge, retrievals will contain biases which can propagate to errors in numerical weather prediction models, climate prediction models, and introduce ambiguity to the long-term satellite record of key climate parameters. For these reasons, the critical task of cloud masking resides at a high level in the VIIRS EDR processing chain.

The baseline IDPS algorithms implemented by Northrop Grumman for VIIRS cloud property EDRs draw heritage from MODIS heritage algorithms. While these algorithms were adopted to satisfy the threshold/goal performance requirements, they do not necessarily take full advantage of the new VIIRS observing system which includes additional nighttime lunar reflectance measurements from the Day/Night Band (DNB) low-light visible sensor.

This project modifies the baseline VIIRS cloud mask and properties algorithms to utilize moonlight reflectance, when it is available, in an effort to augment the capabilities of the nighttime cloud products in terms of improved cloud mask, microphysical and macrophysical properties (and indirectly, improving downstream products that are reliant on an accurate cloud mask). The improved performance will be validated using independent, active-based cloud detection from the CALIPSO lidar. Comparisons to the baseline VIIRS cloud parameters will be conducted both in terms of case studies and statistics to infer the benefits of nighttime visible data and postulate implications for the satellite-based climate data records predating the availability of this information.

These projects directly address NOAA's Weather and Water Goal, which seeks to serve society's needs for weather and water information.

PROJECT ACCOMPLISHMENTS:

Project 1 ('Seeing the Light'—VIIRS/DNB Arctic)

1-- Stray light correction:
The stray light correction designed by Raytheon in consultation with various DNB team members was successfully implemented as of 21 August 2013 in the IDPS.

2-- Arctic Region blog:
An Arctic Region blog "Seeing the Light: VIIRS in the Arctic" has been set up as a repository for future case studies illustrating the utility of VIIRS at high latitudes, with an emphasis on the Day/Night Band. A preliminary introduction entry has been included (authored by Curtis Seaman). We intend to populate this blog routinely and opportunistically as appropriate examples emerge, and there is a comment section under each blog to encourage discussion. (http://rammb.cira.colostate.edu/projects/alaska/blog/)

3-- Interactions with operational partners:
- We have provided HDF5→TDF converter software to David J Schneider from the Alaska Volcano Observatory. The software was requested in order to make local use of VIIRS HDF5 data in the Terascan processing environment, which requires the files to be exported from HDF5 to flat files and then imported to Terascan Data Format.
- Day/Night Band imagery processing continues to run in automated fashion at the GINA facility at University of Alaska, Fairbanks, as well as on a local CIRA machine. The GINA processing works on the direct broadcast stream, while the CIRA processing works on the GRAVITE stream (at higher latency). We continue to work with Eric Stevens and Tom Heinrichs (University of Alaska, Fairbanks/GINA) and David J Schneider (USGS) to demonstrate Alaskan DNB imagery.

4-- Version of NCC without banding:
While we awaited correction of the Near Constant Contrast product (NCC) product which handles the scaling dynamically, alternative means to providing a NCC type capability from the radiance SDR data was pursued. It was soon found that the dynamic range from day to night is too extreme to accommodate even under the assumption of log-scaled radiances…resulting either in general loss of detail across the terminator or complete over/undersaturation of most of the scene at the expense of a small component being in a suitable scaling range to show cloud/surface feature details.

Interactions with Eric Stevens (GINA) led to the examination and subsequent correction of terminator DNB radiance imagery by the UW-CIMSS group. The correction involves breakdown of the terminator region into several subsections, each defined by solar zenith angle range, and each having its own dedicated scaling bounds. The result is a superior enhancement to a fixed scaling bound, but results in a banded pattern as shown in Figure 1. Miller also began to work on an alternative handling of this scaling, which implements a sliding scale in log-linear space. The slope of this sliding scale depends on whether there is or is not moonlight present on the night-side of the terminator.

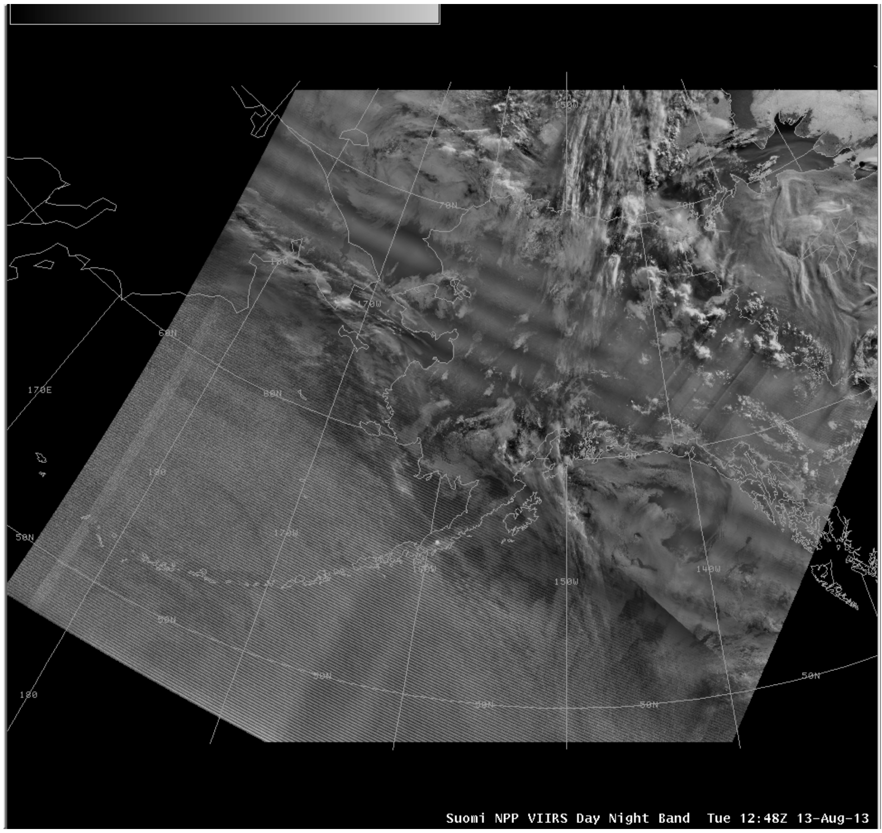


Figure 1. GINA VIIRS DNB imagery from 13 August 2013 at 12:48 UTC. The enhancement across the day/night terminator invokes a series of piecewise scaling ranges which manifests as a wave pattern in the resultant imagery. This artifact was deemed tolerable by users, but we propose here an alternative method which eliminates the banding.

The intended outcome of this method is to reduce the banding artefact. An example of this algorithm, implemented for a case study over Alaska, is shown in Figure 2 for a scene transitioning from daytime at upper right to night time at lower-left. Whereas some brightening near the terminator (in addition to an aurora feature) is seen, it is anticipated that this effect may be mitigated with refined scaling bounds. More importantly, the banding artefacts are not present. Until the official NCC product demonstrates full capability, these SDR-based techniques will remain valuable and may continue as such in the future as they allow more flexibility by the user to select optimized scaling for their regions and features of interest.

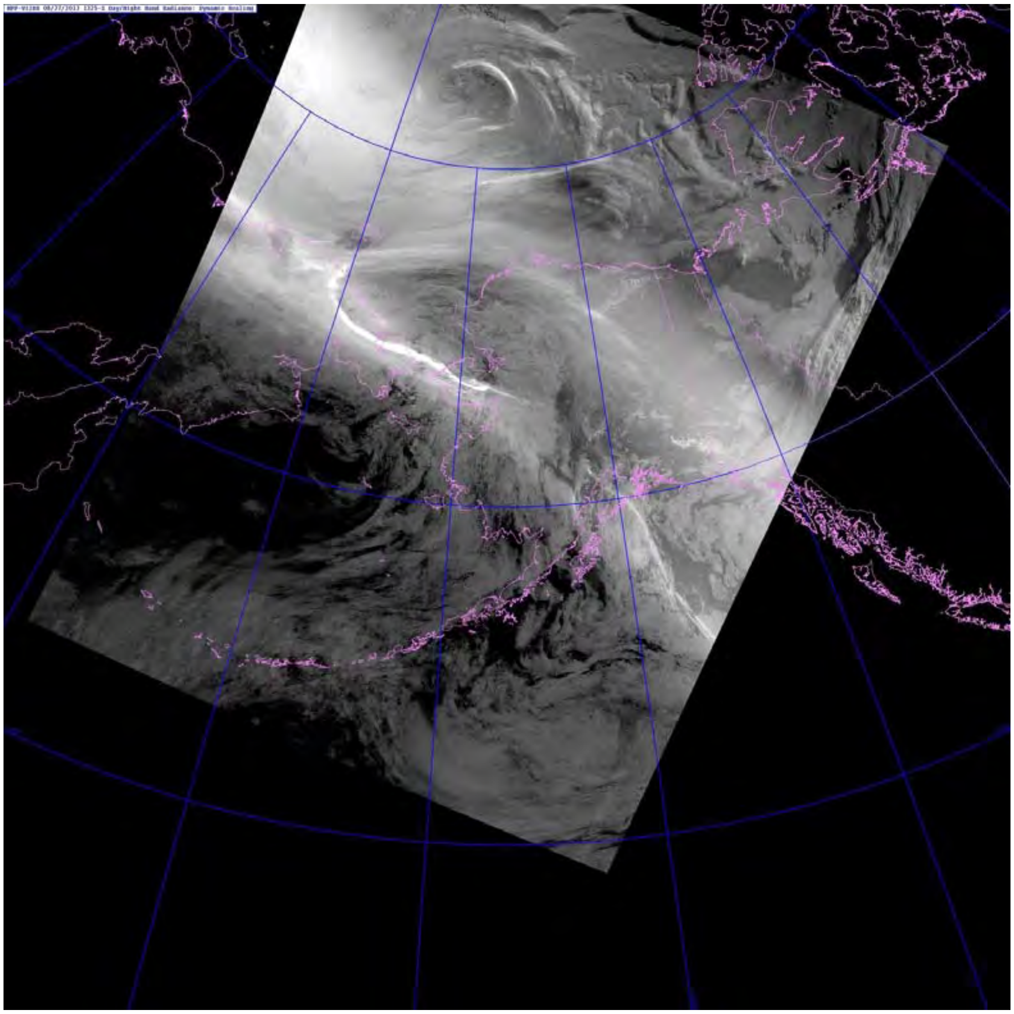


Figure 2. Example of CIRA VIIRS DNB imagery over the Alaska Region spanning the day/night terminator

5-- Interactions with PG Partners:
The project continues to strongly interact with scientists at the University of Wisconsin/CIMSS (in particular with William Straka). The CIMSS team is producing DNB imagery over the Arctic and elsewhere, packaged to display in NWS AWIPS systems. Straka contributed DNB imagery to CIRA's latest Arctic blog (ship lights in the Polar Sea) and served as a co-author on the Day/Night Band Remote Sensing special issue paper. CIRA and CIMSS also interfaced on the Day/Night Band cloud properties work, which enlists the lunar irradiance model mentioned above. Development of those capabilities is ongoing.

6-- Education Materials:
Miller worked with Steve Deyo from the COMET program to update a conceptual illustration of nighttime light sources, to include the nightglow signal during the non-lunar portion of the cycle. Figure 3 shows the results of this interaction. The graphic was used in a DNB capabilities review paper. Miller also composed a set of eight selected examples of multi-spectral VIIRS imagery applications emphasizing operational relevance. Four of these selected examples refer to DNB imagery applications: detection of sea ice, nocturnal tropical cyclone tracking, nocturnal fire lines and biomass smoke, and detection of

power outages. These slides can be used for education and training on VIIRS and particularly also on VIIRS/DNB imagery.

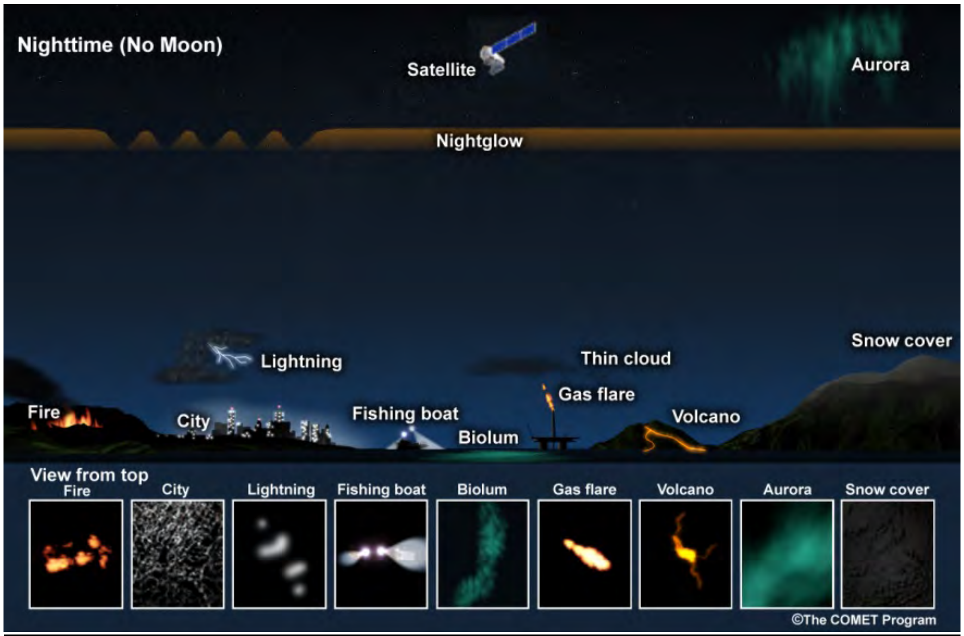


Figure 3. Revision to the nighttime low-light visible source inventory, based on interactions between S. Miller (CIRA) and S. Deyo (COMET). Notably, the presence of nightglow is now illustrated, including its occasional modulation by tropospheric effects such as strong convection.

Project 2 (Advancing VIIRS Nighttime Cloud Products)

1—Delivery of lunar irradiance model:

A core enabling element of this project is the conversion from DNB measurements of radiance to equivalent lunar reflectance. This conversion enlists a lunar irradiance model developed by the project PI in coordination with the Naval Research Laboratory. In the last reporting period we transitioned this software for provisional use in this project, with the understanding that the model would continue to be developed/improved over the course of the project. We confirmed successful implementation of the code, which our CIMSS colleagues have packaged as an interface to the VIIRS H5 format sensor data records.

2-- Lunar phase-angle-dependent albedo correction--Stable Targets:

Work continued on a lunar phase-angle-dependent albedo correction, in coordination Naval Research Laboratory (NRL), Monterey. Need for the correction was realized at the time of original model development, and became apparent when comparing day/night reflectance for stable calibration targets. These targets included White Sands, NM, Salar de Uyuni in Brazil, and selected snow field cases over the United States.

The need for this correction arises from the lunar irradiance model's explicit assumption of a phase-angle-independent albedo. In reality, the lunar disk contains heterogeneous variations in albedo arising from the distribution of brighter Highlands and darker Maria regions. The correction attempts to mitigate departures from the constant albedo (e.g., arising from the mean lunar disk albedo being too dark compared to the waxing moon and too bright compared to the waning moon).

During this period we extended the analysis to Dome C in Antarctica, but found a strong anisotropic scattering behaviour to the surface which confounds the interpretation of phase-dependent albedo biases. We have opted to concentrate squarely on Salar de Uyuni for additional compilation of stable target data, as this location provides a high-altitude (smaller potential for atmospheric contamination), horizontally uniform (as opposed to the dune geometry of White Sands), and ostensibly isotropic reflecting behaviour which is ideal for this analysis.

3-- Lunar phase-angle-dependent albedo correction—MeteoSat SEVIRI Lunar Views:

The original plan focused on pursuing a first-order (linear) correction. In a key development during this reporting period, discussions with UK Met Office colleagues while attending the joint AMS/EUMETSAT Satellite Meteorological Conference in Vienna, Austria, have resulted in access to a MeteoSat Second Generation (MSG) Spin-Enhanced Visible Infrared Imager (SEVIRI) dataset of lunar views between +/- 150˚ phase angle. The wealth of observations at high lunar phase angle sampling resolution is ideal for producing a detailed correction (i.e., a higher-order correction than the linear one we originally proposed).

Analysis of the SEVIRI data will require significant changes to the existing processing. Whereas the lunar irradiance code provides a spectra at 1 nm resolution, which can be re-convolved to the SEVIRI band response functions, additional adjustments must be made to the model in order to re-cast the problem in terms of the Sun/Moon/Satellite geometry as opposed to the default Sun/Moon/Earth system. Differences in the distance between the satellite and Earth position are sufficient to produce non-trivial departures in the lunar irradiance. Even the phase function itself is different, since the satellite is viewing the Moon from a different perspective than a viewer on the surface of the Earth.

We have begun to modify the lunar irradiance software to pursue this valuable new source of validation and bias correction, which we anticipate will enable the production of lunar irradiances to within 5% uncertainty (compared to 5-12% without bias corrections).

4—Porting of Retrieval Code to CIRA

To better assist with the evaluation of the retrievals in the coming year of the project, we have ported the Nighttime Lunar Cloud Optical and Microphysical Properties (NLCOMP) code to CIRA.

5—Assistance with VIIRS Cloud Cal/Val

We provided cross-project assistance to the VIIRS Cloud Cal/Val team by identifying and conducting an analysis of night time cloud optical depth for a 'Golden Night' pass. The results of this comparison between NLCOMP and the operational night-time cloud optical depth (Fig. 4) reveals the limitations of the operational approach in the case of optically thick clouds. Here, the IR-based operational retrieval will saturate, providing no further information despite increasing optical thickness. As a result of this lack of sensitivity, these retrievals saturate at values of ~10. In contrast, the lunar-reflectance-based NLCOMP retrievals are shown to provide a much greater dynamic range of optical depths, based on the retainment of sensitivity to increasing water paths when using a non-absorbing band (here, visible/near-infrared moonlight information).

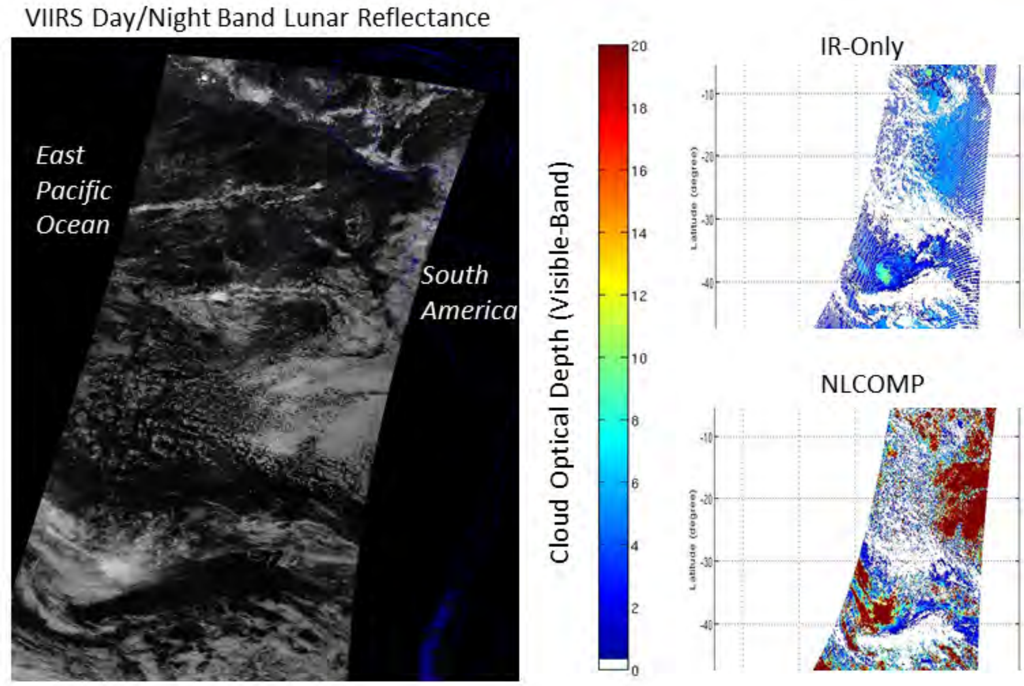


Figure 4. 'Golden Night' example from 29 March 2013 at ~0727 UTC for a nighttime pass over the southeastern Pacific Ocean, used for evaluation of the VIIRS operational nighttime cloud optical depth retrieval. In the left panel is lunar reflectance, the upper-right panel is the conventional (IR-Only) retrieval, and the lower-right panel is the lunar reflectance (NLCOMP) based retrieval. Notice that the conventional retrievals are confined artificially to low (typically, < 10) values due to thermal band saturation, whereas in the NLCOMP retrieval more realistic large values (topping the color scale corresponding to $\tau > 20$ for the range selected) are produced.

PROJECT TITLE: Getting Ready for NOAA's Advanced Remote Sensing Programs: A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal

PRINCIPAL INVESTIGATORS: Bernadette Connell, Dan Bikos

RESEARCH TEAM: Ed Szoke

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The overall objective of the SHyMet program is to develop and deliver comprehensive distance-learning courses on satellite hydrology and meteorology. This project leverages the structure of the VISIT training program but is distinct in that VISIT focuses on individual training modules, while SHyMet organizes modules into courses. SHyMet takes a topic approach and selects content for the topic. It is able to draw on training materials not only within the VISIT program, but outside the program as well. This work is being done in close collaboration with experts at CIRA, the Cooperative Institute for Meteorological Satellite Studies (CIMSS), the Cooperative Program for Operational Meteorology, Education and Training (COMET), the National Weather Service (NWS) Training Center (NWSTC), and the NWS Warning Decision Training Branch (WDTB). The challenge is to provide necessary background information to cover the many aspects of current image and product use and interpretation as well as evaluate data and products available from new satellite technologies and provide new training on the these tools to be used operationally.

This project supports NOAA's goals of Weather and Water, Commerce and Transportation, and Climate. Enhanced training and coordination of training accomplished under this project will prepare forecasters and managers on how to utilize imagery and products to provide improved services in these areas.

PROJECT ACCOMPLISHMENTS:

1-- Maintain existing SHyMet Courses:

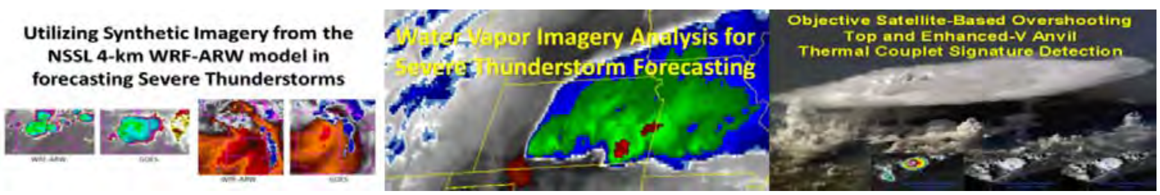


Figure 1. Existing SHyMet courses

The following four courses continue to be administered:
- The SHyMet Intern course touches on Geostationary and Polar orbiting satellite basics (areal coverage and image frequency), identification of atmospheric and surface phenomena, and provides examples of the integration of meteorological techniques with satellite observing capabilities. (http://rammb.cira.colostate.edu/training/shymet/intern_intro.asp).
This continues to be the most popular course.
- The SHyMet for Forecaster course covers satellite imagery interpretation and feature identification, water vapor channels, remote sensing applications for hydrometeorology, aviation hazards, and what to expect on future satellites. http://rammb.cira.colostate.edu/training/shymet/forecaster_intro.asp
- The Tropical track http://rammb.cira.colostate.edu/training/shymet/tropical_intro.asp of the SHyMet Course covers satellite imagery interpretation and application of satellite derived products in the tropics as well as the models used at NHC for tropical cyclone forecasting.
- The Severe Thunderstorm Forecasting Course http://rammb.cira.colostate.edu/training/shymet/severe_intro.asp covers how to integrate satellite imagery interpretation with other datasets in analyzing severe thunderstorm events.

SHyMet metrics are tracked by leveraging the expertise of the VISIT program and the NOAA Commerce Learn Center Learning Management System

SHyMet Course	Total since debut		Jan-Dec 2013		Course Debut
	Completions	Registrations	Completions	Registrations	
Intern	336	437	23	22	April 2006
Forecaster	46	65	1	3	January 2010
Tropical	24	31	3	3	August 2010
Severe	37	58	2	2	March 2011

The numbers we have listed here for total completions since debut have doubled from what were reported last year. This is mainly due to taking a closer look at the completion numbers that come out of NOAA's learning management system. In the past we have asked for participants to send an email to the SHyMet group to register for the course and send another email when they have completed the course. NOAA's LMS currently does not have an ideal way to track completion of a whole course. We retrieve individual module registrations and completions and then sort on those by course and participant. We check this list of course completions against our email registration list. By comparing the two lists, we have found that those that register with CIRA by email account for roughly 66% of those that have completed the course. Of those that register for the course with CIRA and complete it, roughly 50% tell us that they have completed the course. Roughly 33% of those that show they have completed all the modules for a course in NOAA's LMS have not registered with us. It is important to keep this in mind in planning for future courses.

2-- Interact with NWSTC, GOES-R and JPSS Satellite Proving Ground Partners and other education and outreach groups on development of SHyMet GOES-R instruments and products course.
- New Module developed:
Identifying Snow with Daytime RGB Satellite Products
Offered as teletraining through the VISIT structure January through March 2014. The session will be recorded after incorporating feedback.
http://rammb.cira.colostate.edu/training/visit/training_sessions/identifying_snow_with_daytime_rgb_satellite_products/

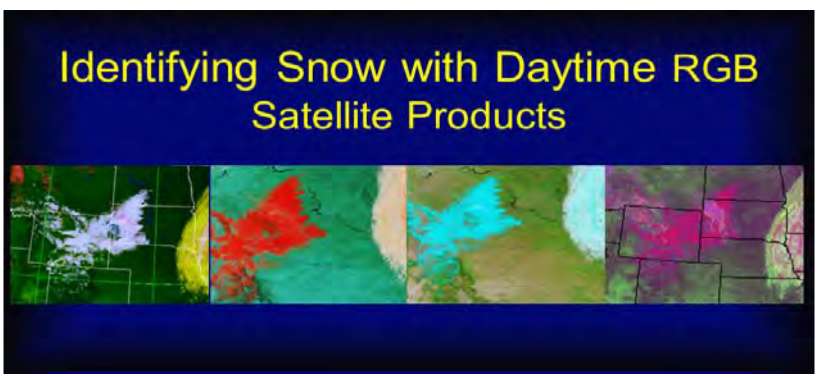


Figure 2. Newly Developed SHyMet Module: Identifying snow with daytime RGB satellite products

- Background on the SHyMet GOES-R instruments and products course
Course structure: A customized / personalized training experience with training needs assessed during signup.

Course execution: Assign the individual modules at the time of registration. The web-pages will group the various topics but we will ask the participant at the time of registration what their training needs are and then determine which modules to assign.

Current list of in-house, COMET, or SPoRT modules (containing 70% or more GOES-R PG product content):
a- Introduction to GOES-R Instruments and Products (updated and abbreviated version of GOES-R 101)
b- Forecaster Training for the GOES-R Fog/low stratus (FLS) Products.
c- GOES-R Severe Weather Applications Demonstrated with synthetic imagery
d- Objective Satellite-Based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection.
e- The UW NearCasting Product.
f- Convective Cloud-top Cooling.
g- GOES-R: Benefits of Next-Generation Environmental Monitoring
h- GOES-R ABI: Next Generation Satellite Imaging
i- Lightning Mapping Array, Part 1, Total Lightning
j- Lightning Mapping Array, Part 2, Applications
k- Pseudo Geostationary Lightning Mapper
l- Identifying Snow with Daytime RGB Satellite Products

Hands on examples:
CIMSS ABI WES case

Planned Modules (from CIRA, CIMSS, COMET, SPoRT, and other organizations

UW Convective Initiation	RGB air mass
Identifying Dust with RGB Satellite Products	Other RGB products
Precipitation	Air Quality simulated GOES-R AQ products
Hydrology	QPE for GOES-R
GOES-R PG fire weather experiment	COMET Companion module for GLM
GOES-R QPE / Rainfall Rate	WFABBA plans / GOES-R simulated fires

Introductory modules are starting to be organized and will briefly address how GOES-R preparations got to where they are now. We will include why there might be more than one product, as well as what to expect before and after satellite launch.

3-- VISIT Satellite Chat:
-- Since February 2012, the VISIT team has led monthly chat sessions to discuss recent significant weather events with the objective of demonstrating satellite products that can be applied to operational forecasting. SHyMet led the sessions during the past year due to VISIT budget shortfalls.
These sessions are brief and often lead to products being made available or further discussed in the VISIT blog. For example, during the January chat session, a WFO asked about a recent blowing dust event. Afterwards, a blog entry was put together that discussed this event and the following month the SOO from that WFO discussed the blowing dust event during the chat session. The response was very positive and illustrates the benefits of these monthly sessions: “I would LOVE to see the products such as what was shown on the VISIT webinar (a revisit of the blowing dust/high wind event from 16 January 2014 in southwest NE) to help with the identification of blowing dust.”
Recorded sessions are found here: http://rammb.cira.colostate.edu/training/visit/satellite_chat/

PROJECT TITLE: NESDIS Environmental Applications Team – Thomas Vonder Haar – Advanced Studies of Global Water Vapor

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Tom Vonder Haar, John Forsythe, Heather Q. Cronk

NOAA TECHNICAL CONTACT: Fuzhong Weng (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Fuzhong Weng (NOAA Team Lead)

PROJECT OBJECTIVES:

The development and subsequent release of the NASA Water Vapor Project (NVAP-M) dataset was supported as part of the NASA Making Earth Science Data Records for Use in Research Environments (MEaSUREs) program. This global (land and ocean) water vapor dataset was created through merging the retrievals of multiple satellites and surface observations spanning the 22-year period from 1988 – 2009. The input data is processed using different paths to create gridded fields of total and layered precipitable water at either daily 1º or 6-hourly 0.5º resolution. The end result is multiple products that allow users to focus on global climate, ocean-only, or weather event water vapor. Because the data is observationally-driven with minimal dependency on numerical models, it is a very useful tool for comparing to model output. The dataset is available to the scientific community via the NASA Langley Atmospheric Science Data Center (https://eosweb.larc.nasa.gov/project/nvap/nvap-m_table) as well as archived along with all the input data on the CIRA mass storage system. A more detailed description of the dataset and its properties is available in Vonder Haar et al. 2012 (doi:10.1029/2012GL052094).

PROJECT ACCOMPLISHMENTS:

Currently, an international effort is underway to investigate the quality and capabilities of the NVAP-M dataset (as well as several other state-of-the-art water vapor products) as part of the Global Energy and Water Exchanges Project (GEWEX) Water Vapor Assessment (G-VAP). Our group was invited to participate in this assessment and helped to host the most recent G-VAP Workshop at CIRA in the fall of 2013. Through support from NOAA/NESDIS, our group is conducting preliminary trend analysis and the investigating time-varying sampling effects on global and regional trends. At this time, we are unable to prove or disprove a robust global trend in total precipitable water due to the challenges that go along with changes in satellite sampling through the time period.

PROJECT TITLE: NESDIS Environmental Applications Team – Marouan Bouali, Research Scientist

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Marouan Bouali

NOAA TECHNICAL CONTACT: Alexander Ignatov (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Alexander Ignatov

PROJECT OBJECTIVE:

Develop and test an algorithm for stripe noise reduction in level 1B Terra/Aqua MODIS and S-NPP VIIRS brightness temperatures (BT), for operational use at NOAA for improved quality of level 2 SST imagery and downstream applications

PROJECT ACCOMPLISHMENTS:

Uncertainties in the estimation of scan-by-scan calibration parameters lead to stripe noise in level 1B BTs acquired by whiskbroom scanners, MODIS and VIIRS. Although the magnitude of these residual errors remains within the sensor pre-launch noise equivalent temperature difference (NEdT) specifications, stripe noise is amplified by level 2 algorithms and propagates into native resolution SST imagery. This in turn highly affects downstream oceanographic applications such as the detection of thermal fronts in SST imagery. A destriping algorithm intended for operational use within NOAA's Advanced Clear-Sky Processor for Oceans (ACSPO) system was developed and tested on both MODIS and VIIRS instruments. The algorithm substantially improves the image quality of ACSPO VIIRS BTs and SST while preserving the sharpness of geometrical structures in the imagery, i.e., no perceptible blur is introduced in the SST images. The algorithm methodology and results of testing with 3 days of global VIIRS data were published in the Journal of Atmospheric and Oceanic Technology ("Adaptive reduction of striping for improved SST imagery from S-NPP VIIRS", Bouali and Ignatov, 2014). The algorithm was also applied to Terra and Aqua MODIS BTs using two weeks of global data, with similarly satisfactory results, including significant improvement in image quality (Figure 1) and front detection (Figure 2). To test the temporal stability of the destriping approach, we defined a new metric, the Normalized Improvement Factor (NIF) which was evaluated for the entire two weeks period (Figure 3). It was shown that for the test period, the NIF is highly stable with values varying between 15±0.5% for Terra and 18±1% for Aqua. We note that these results are in agreement with our previous analysis (Bouali and Ignatov 2012a) which demonstrated that the magnitude of striping is more pronounced for Terra than for Aqua. To ensure that SST data derived from destriped BTs can be used in climate oriented studies, we further analyzed the impact of stripe noise on SST mean values and standard deviations with respect to in situ SST and to the Canadian Meteorological Centre (CMC) L4 SST. Results show that destriping has a negligible effect on SST global validation statistic, a major requirement for its operational use. This study was submitted to Geophysical Research Letters.

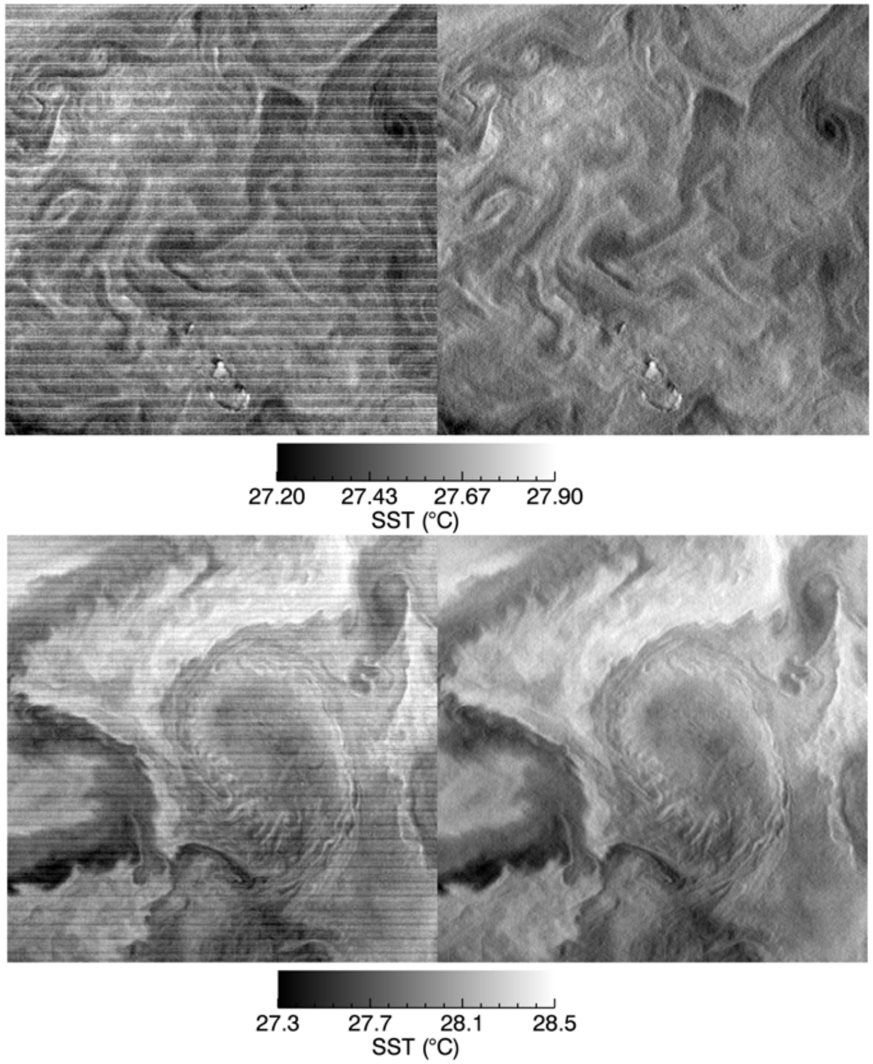


Figure 1. (Left) MODIS SST images (300×300 pixels) generated with ACSPO from original BTs. (Right) Same images generated with ACSPO from destriped BTs. The images were acquired by (Top) Terra MODIS on 20 August, 2013 at 22:10 UTC, over the Timor Sea and (Bottom) Aqua MODIS on 23 August, 2013 at 10:25 UTC, over the Mediterranean Sea.

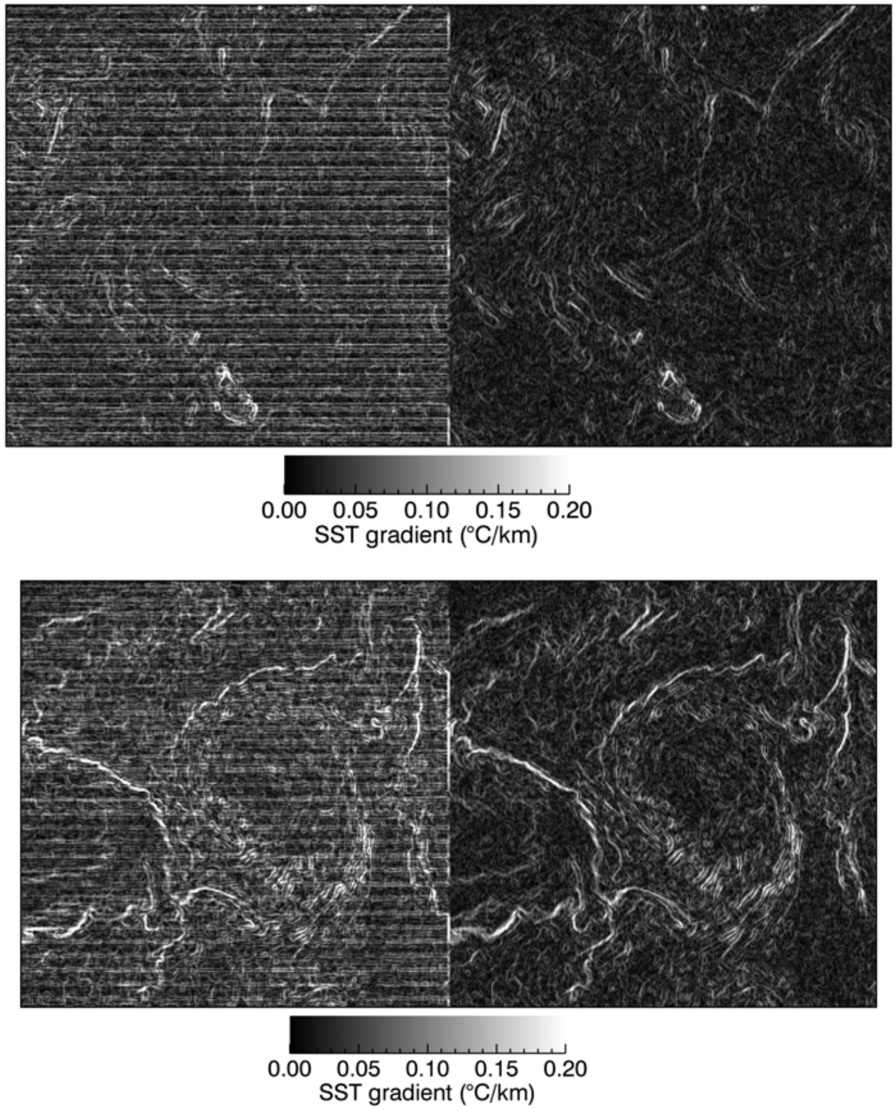


Figure 2. Gradient magnitude (°C/km) of (top) Terra and (bottom) Aqua MODIS SST fields shown in figure 1. Note that the destriping improves substantially the detection of SST submesoscale fronts.

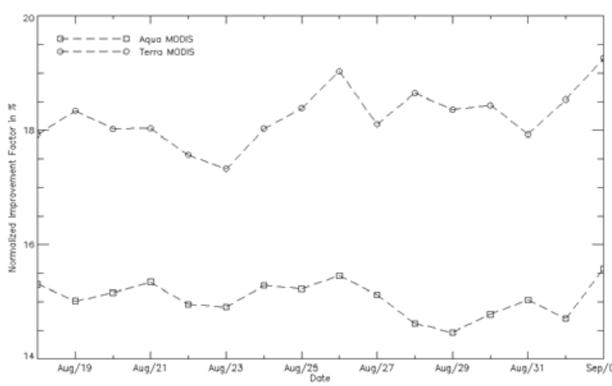


Figure 3: Daily averaged Normalized Improvement Factor for ACSPO Terra and Aqua MODIS SST from 18 August to 2 September 2013.

PROJECT TITLE: NESDIS Environmental Applications Team – Prasanjit Dash, Research Scientist

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Prasanjit Dash

NOAA TECHNICAL CONTACT: Alexander Ignatov (NOAA/NESDIS/STAR) Ocean Sensors Branch

NOAA RESEARCH TEAM: Yury Kihai (GST, Inc.), John Stroup (STG, Inc.)

PROJECT OBJECTIVES:
1--Deep-dive analyses of ACSPO VIIRS SST: Extend the *SST Quality Monitor* (SQUAM) abilities to routinely analyze, monitor and validate ACSPO NPP-S VIIRS SST.

2--Continue analyses equivalent to #1 but for IDPS VIIRS products.

3--Initial implementation of #1 for NAVO VIIRS SST (preliminary).

4--Detect any issues with L4 that is used as a reference in L2-SQUAM (used in #1, 2, 3).

5--Tune SQUAM S/W for analyses of long-term ACSPO GAC re-analysis products, perform analyses and present in web.

6--In situ validation of Level-2 products in SQUAM: Daily *in situ* validation was implemented earlier in the last term; in this term *in situ* validation was extended to *monthly* time range for both GAC (ACSPO global products from five platforms) and High resolution (for seven global products).

7--Initial implementation of #1 for (A)ATSR Reprocessing for Climate (ARC) towards Sentine-3 SLSTR preparation (preliminary)

8--Several functional (technical) improvements

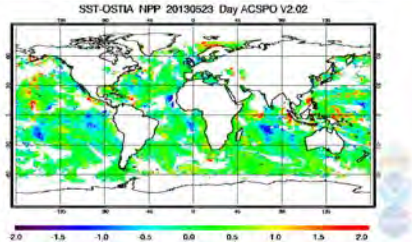
9--Other professional activities (review papers, GHRSST, Eumetsat and other meetings)

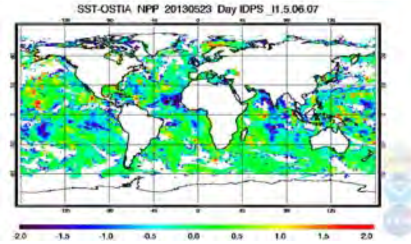
10--Other tasks outside of immediate SST team but for the SST community: provide feedbacks, generated and provide SST coefficients based on request, help external users with technical and scientific requests and participate in potential internal collaborations.

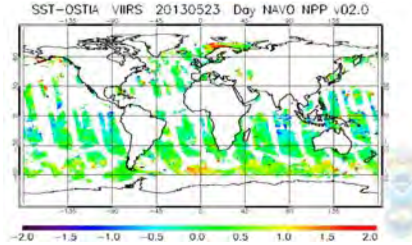
PROJECT ACCOMPLISHMENTS:

Objectives 1, 2 and 3: Analyze VIIRS SSTs ACSPO, IDPS, NAVO

Exhibit -1: Inclusion of NPP VIIRS SSTs from ACSPO, IDPS and NAVO in SQUAM
Extended and fully implemented SQUAM for ACSPO and IDPS Suomi-NPP VIIRS SST products and made initial analyses of NAVO NPP VIIRS products (to be completed next term). This work helps in the development stage or at a matured stage of the products to check for product accuracy and performances of cloud mask and algorithm uniformity across a range of geo-physical variables http://www.star.nesdis.noaa.gov/sod/sst/squam/HR/.







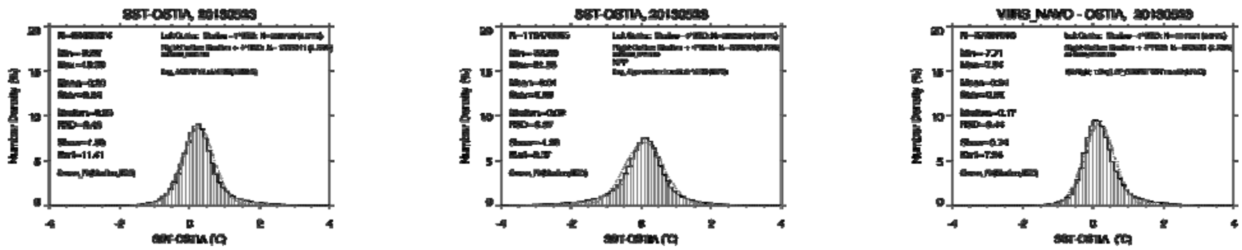


Figure 1. VIIRS Day L2 SST *minus* OSTIA L4 reference, May-23-2013. ACSPO (left), IDPS (middle), NAVO (right). Such diagnostics are routinely performed in SQUAM. Statistical moments and parameters annotated on the histograms are plotted in time series for various combinations to assess relative performances and detection of anomalies. Note a reduced coverage in NAVO and cloud leakage in IDPS products, as compared to ACSPO.

Exhibit -2: Warm-up Cool-down (WuCd) events in VIIRS and effect on SST product

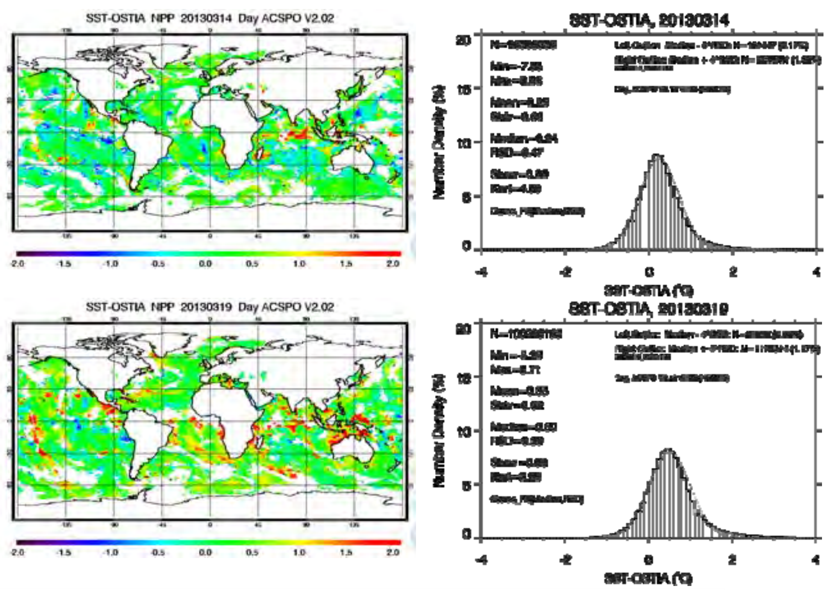


Fig. 2: Sensor calibration team performs Warm-Up Cool-Down (WuCd) experiments on VIIRS black body. This figure shows effect of WuCd events in VIIRS bands on corresponding SST products. Top-panels: a typical regular day (Mar-14 2013). Bottom-panels: WuCd event (Mar-19 2013). Notice the increased mean and standard deviation values in the bottom panel. A time series plot of these values with event dates is shown in the next figure (Fig. 3).

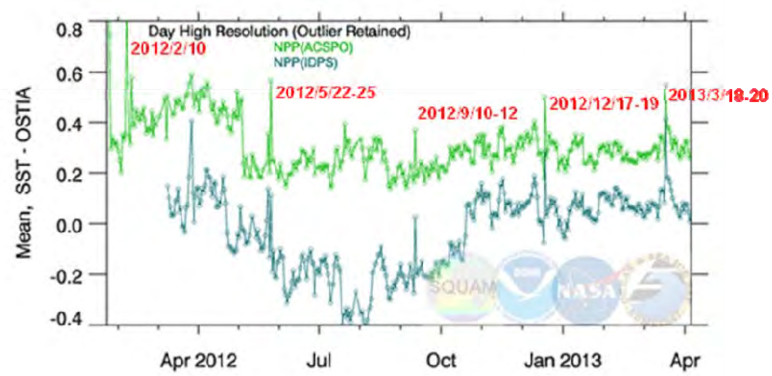
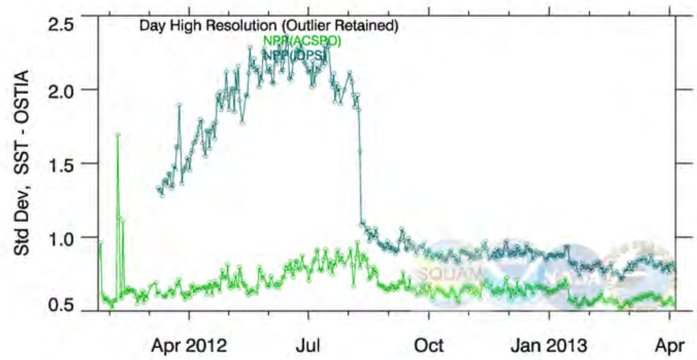


Fig. 3: Time series of "VIIRS SST – OSTIA" showing WuCd events in VIIRS bands for both ACSPO and IDPS products. Top-panel: Mean; Bottom-panel: Std Dev. Initially, large spike is seen in global mean biases (Feb 2012). After code fixes, SST spikes reduced to ~0.2-0.3K. Large spike in global Std Dev (Feb 2012). After code fixes, spikes in Std Dev are not present.



Objective 4: Detect issues with L4 SSTs used as references by relative studies
Exhibit -3: Detect issues with reference L4 SST

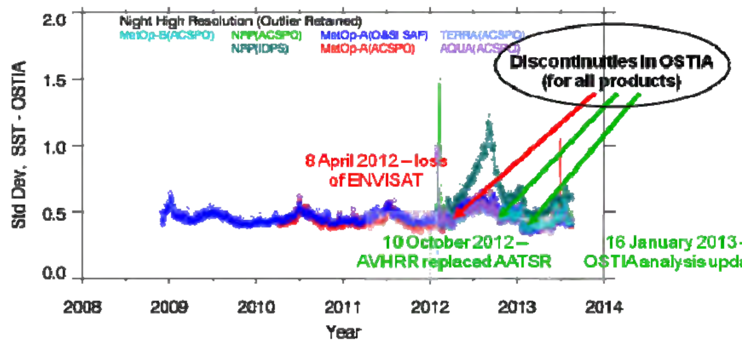


Fig. 4: Std Dev of Satellite SST – OSTIA; which is used as one of the references in L2-SQUAM. Three discontinuities are observed (8-Apr-2012, 10-Oct-2012, 16-Jan-2013) corresponding to loss of Envisat, AVHRR replacing AATSR in OSTIA system and update of OSTIA system, respectively. Text and arrow in RED = increase; GREEN = decrease in Std Dev. SQUAM employs multiple L4 SST fields as references to detect such issues and avoid misleading interpretation of L2 products due to an issue in a given reference field.

Objective 5: Tune SQUAM for long-term ACSPO GAC reanalysis (RAN) products

Recently, the SST team has taken up the task of historical reprocessing of AVHRR GAC data. Accordingly, the SQUAM GAC module had to be tailored to analyze these historical data. A separate set-up (script, IDL code, web design) was established for this purpose and retrospective processing was made. A temporary web that will be merged with the main page later is setup at: http://www.star.nesdis.noaa.gov/sod/sst/squam/ACSPOGAC/index_grp.html. At the request of the NOAA PI, this set-up, along with instructions to run them independently, was shared with another colleague to run for any consecutive reprocessing efforts (a collection mode is envisioned for our reprocessing efforts). Any improvement in the main code will be reflected on the RAN part too but it is expected to be functional with minimal involvement from my side.

Exhibit -4: Validation of ACSPO GAC reanalysis (ACSPO RAN)

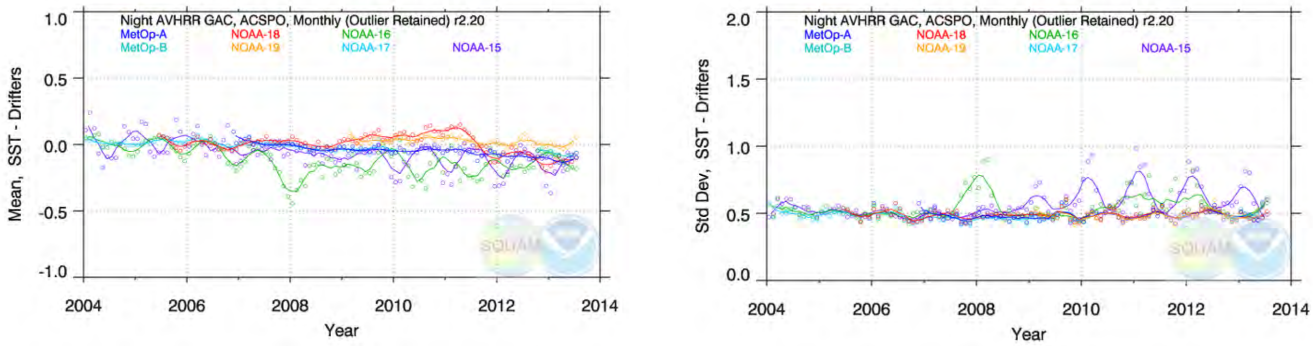


Figure 5: Validation of reprocessed AVHRR GAC SSTs, generated by ACSPO (ACSPO RAN), for seven platforms. Both the figures show nighttime monthly validation against in situ drifters. Left-panel: Mean, Right-panel: Std. Dev.

Objective 6: Monthly *in situ* validation of ACSPO GAC & other HR SST products

Exhibit -5: Monthly in situ validation of high resolution SST products

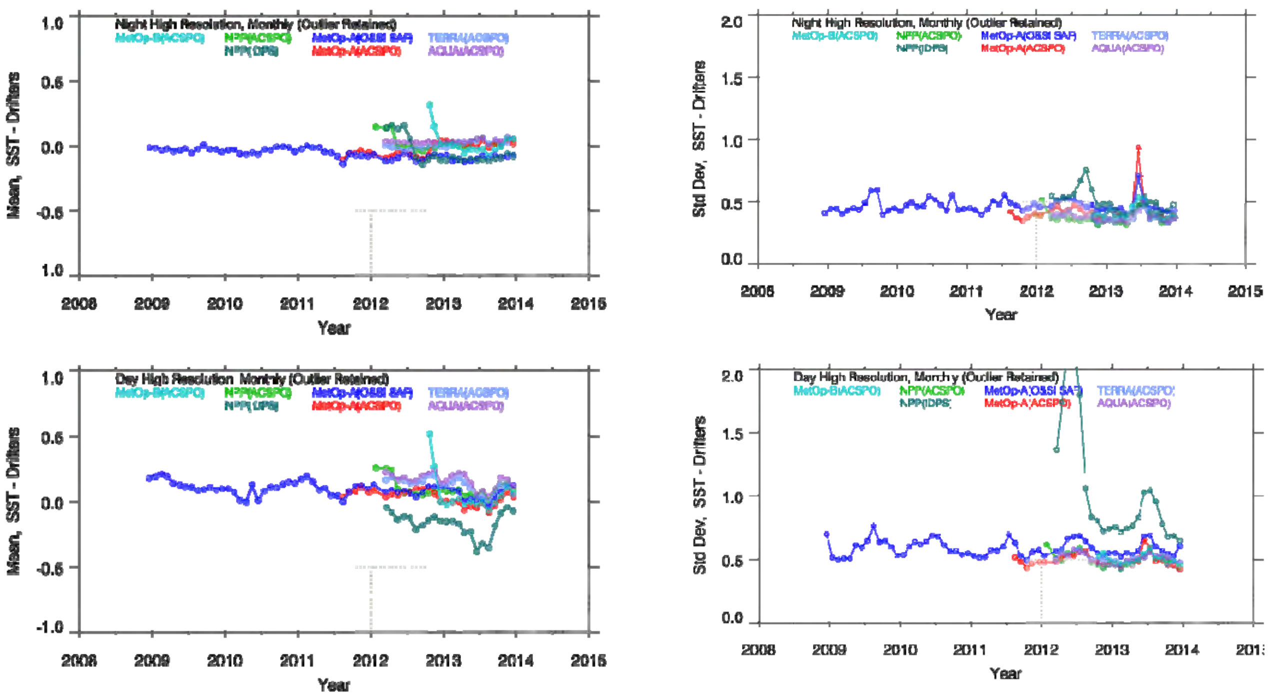


Figure 7. Monthly in situ validation of high resolution SST products. Left-panels: Mean, Right-panels: Std. Dev. Top-panels: Night, Bottom-panels: Day. More at: http://www.star.nesdis.noaa.gov/sod/sst/squam/HR/index.html

Objective 7: SQUAM-implementation of (A)ATSR Reprocessing for Climate (ARC)

NOAA and ESA have made partnership agreements for sharing of Sentinel-3 L2 data and our team will also monitor SSTs from SLSTR, which is designed to continue the heritage of (A)ATSR sensors. Towards this objective, an initial set-up (data access, script, codes, web page) was made to analyze ARC data (as a proxy for Sentinel-3 SLSTR SST).

Disclaimer: This work is preliminary (and not conclusive) and we are discussing with the data producers to improve our analyses. The data shown below should not be used to draw any conclusions until an official release of SQUAM analyses for ARC SST is made (likely by the next reporting term).

Exhibit -6: Initial analyses of (A)ATSR Reprocessing for Climate (ARC) SST products.

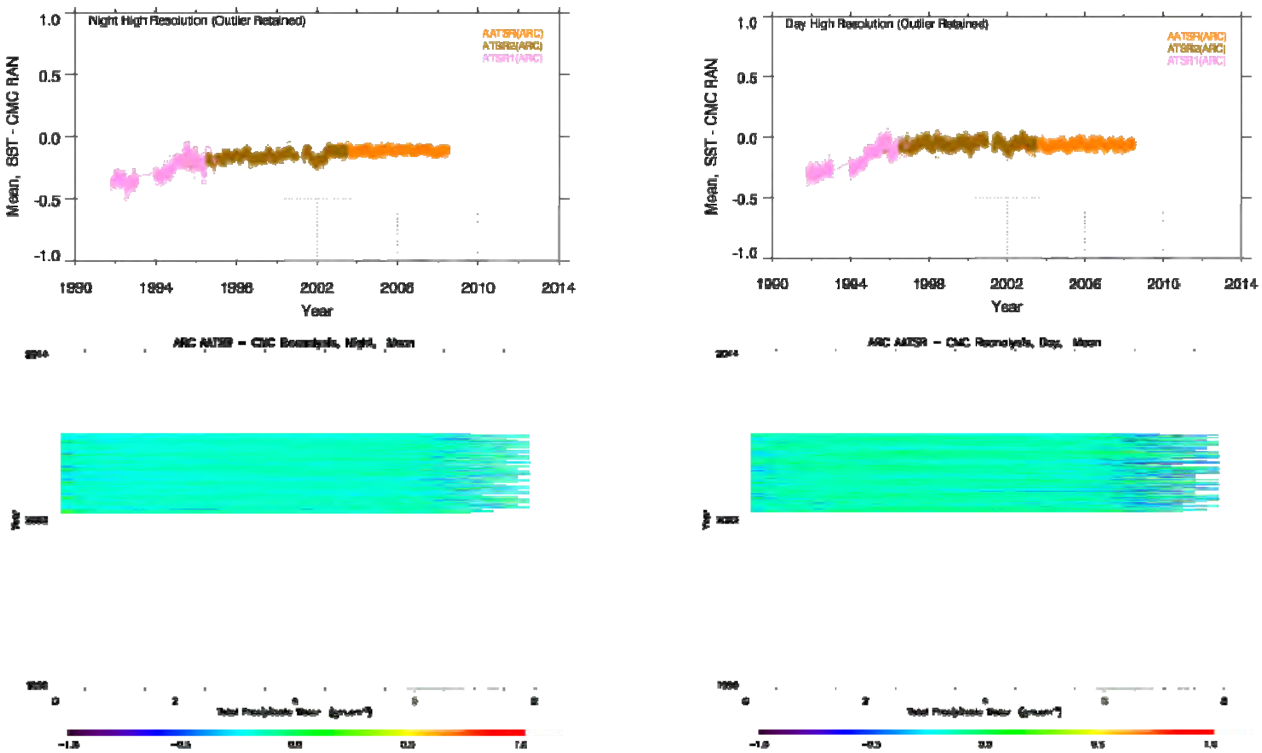


Figure 6. Mean of “ARC SST *minus* Canadian Meteorological Centre (CMC) L4 SST”. Left-panels: Night, Right-panels: Day. Top-panels: Time series scatter plots, Bottom-panels: Time series of mean as a function of total precipitable water (TPW). Note that the ATSR1 product shows anomalous values (top-panels) because of sensor issues.

Objective 8: Functional improvements in SQUAM

--CMC was included as an additional reference in L2-SQUAM. This was decided based on the performance and long-term availability of CMC data. As a first step, it has been included in the ACSPO GAC module and will be added in HR module later (next term).

--Initially, SQUAM showed maps and dependences only after removing outliers (histogram and time series are shown with and without outliers). For dependence plots and maps, the results are almost identical only except for extreme conditions. Therefore it was decided, based on observations for some extreme WuCd cases (*cf*., Exhibit-2), to include maps and dependences in both ways: *with* and *without* outliers. This implementation has been successfully made in ACSPO GAC SQUAM module, recently, and will be extended to High Resolution SQUAM module at a later stage (next term).

Above items are implemented at: http://www.star.nesdis.noaa.gov/sod/sst/squam/ACSPOGAC/

Objective 9:	Professional activities

--Reviewed papers for: IEEE JSTARS, IEEE TGRS, IJRS
--GHRSST member: IC-TAG, ST-VAL, AUS-TAG; serve as co-chair for AUS-TAG.
--As GHRSST AUS TAG co-chair, proactively took part in GHRSST booth preparation at the Ocean Sciences Meetings (Honolulu, February 2014) in collaboration with colleagues from JPL and Universities of Leister and Reading, e.g., deciding the logistics and presentations.
--Presented at: Meteo France Workshop, GHRSST XIV, Eumetsat 2013, NSC 2013.

Objective 10:	Tasks outside of immediate team, based on request to the group

--Provide feedback to Level-4 SST producers; in general L4-SQUAM operations have been suspended due to technical issues (will be resumed during the next term) but provided feedback for specific cases.
--Generated and provided SST coefficients for specific forms of SST equations based on external requests (e.g., UK PML, Sea Space).
--Provided technical help, based on requests, for dealing with VIIRS SSTs.
--Took part in internal collaboration based on divisional visions, e.g., discussed possible extension of SQUAM for Sea Surface Salinity (SSS) monitoring with SSS lead and participated in interviewing process of a new hire.

PROJECT TITLE: NESDIS Environmental Applications Team – Robert Hale, Research Scientist - Satellite Land Surface Temperature Validation

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Robert Hale

NOAA TECHNICAL CONTACT: Yunyue Yu, Environmental Monitoring Branch (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Yunyue Yu (STAR), Yuling Liu (STAR), Zhuo Wang (STAR), Peng Yu (STAR), Dan Tarpley (Short and Associates)

PROJECT OBJECTIVES:

The primary objective of this project is to support validation efforts for the Land Surface Temperature (LST) product resulting from the Geostationary Operational Environmental Satellite Series R (GOES-R) mission. This project specifically seeks to develop and analyze a variety of statistical regression models for “upscaling” *in situ*, ground-based measures of LST to make them more appropriate for use in validating coarse resolution satellite data like those derived from the GOES-R Advanced Baseline Imager (ABI). Current ground-based measurements of LST typically incorporate fields-of-view two to three orders of magnitude smaller than the ABI resolution, making their use in validation efforts problematic due to heterogeneity of the landscape and its insolation, with resulting spatial variability of LST. Statistical models such as those being explored through this project have the potential to improve the representativeness of ground-based LST measurements for larger areas with minimal costs in terms of computational time and needs for ancillary data inputs.

This project supports NOAA’s goals of Weather and Water, Commerce and Transportation, and Climate.

PROJECT ACCOMPLISHMENTS:

Previous work on this project utilized data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) as a source of high-resolution LSTs for development of regression-based upscaling models. While these proved effective in some cases, the paucity of scenes available greatly reduced the ability to produce statistically robust models. This was particularly problematic when trying to produce unique models for each ground site and season. To overcome this limitation, work in the past year has focused on acquiring, subsetting, and utilizing data from the Landsat Enhanced Thematic Mapper Plus (ETM+) sensor. Additionally, models were created and analyzed based on aggregation by NDVI and dominant land cover type, and the effects of view angles on model performance analysis were evaluated.

Thermal (band 6) data from the ETM+ has a 60-m resolution (resampled to 30-m as used here) with a repeat interval of 16 days. Over 10,000 Landsat scenes coincident with 26 ground sites were obtained, including brightness temperatures (BTs), NDVI, cloud cover assessment, and sensor saturation. These data, in combination with *in situ* measurements and NDVI data from the Moderate Resolution Imaging Spectroradiometer (MODIS), provided the foundation for nearly 15,000 new upscaling models.

The standard deviation of the differences (SDDs) between unscaled *in situ* and MODIS LSTs were compared with the SDDs between scaled *in situ* and MODIS LSTs as a metric of model performance. Here, MODIS LSTs serve as a source of coarse-resolution data comparable to the operational GOES-R product. Figure 1 shows the significance of the reduction in the SDDs after model application for the best-performing models for each site and season. Significance below 0.1 indicates statistically significant improvement resulting from model application, and marker size correlates with the number of MODIS scenes used in analyzing performance. As can be seen, model performance varied considerably between sites, and also between seasons at those sites. At some sites, such as the paired Wolf Point USCRN sites, no model provides significant improvement following upscaling. However, in many cases, such as wintertime at the paired Newton sites, highly significant reduction of the SDDs is seen. It is these cases where upscaling of *in situ* LSTs is most beneficial in providing a more representative measurement for validation of coarse-resolution satellite data.

Exploration of methods to potentially refine models and improve their performance included changes in both the source of NDVI data used and their method of use. Utilization of high-resolution NDVI data from the ETM+ was compared with using coarser resolution NDVI from MODIS, however differences in model performance were negligible. Also, models were produced for specific ranges of NDVI values rather than on a seasonal basis. Despite the expectation that vegetation amount might be a better predictor for upscaling of *in situ* LSTs, it was found that aggregation by season proved more effective. This may be a result of physical rather than biological factors, such as prevalence of snow cover.

Performance of models derived from scenes aggregated by the dominant land cover type present at each site was also evaluated. It was found that a higher percentage of models resulted in statistically significant reduction of SDDs when the models were based on dominant land cover type rather than specific sites. This was an unexpected result, suggesting that land cover type may be such an influential factor in upscaling of LSTs that it overrides some of the other site-specific features that would be expected to impact model performance. A possible explanation for this lies in the relatively static nature of the dominant land cover type, which is not subject to the inter-annual variation of other measures (e.g., NDVI).

Finally, since MODIS LSTs are utilized in analyzing model performance, the potential influences of their view angles were evaluated. (It should be noted that the ETM+ sensor has a narrow view angle, and thus impacts of off-nadir viewing are minimal.) By grouping models into MODIS view angle bins, it was found that view angle effects on model evaluation were minimal.

The creation and analysis of models based on Landsat ETM+ LST data has revealed many insights into how best to upscale *in situ* LSTs to make them more representative of the broader areas encompassed by coarse-resolution satellite sensors. The findings of the past year will be incorporated into the GOES-R validation tool to provide high quality data for validation of the ABI.

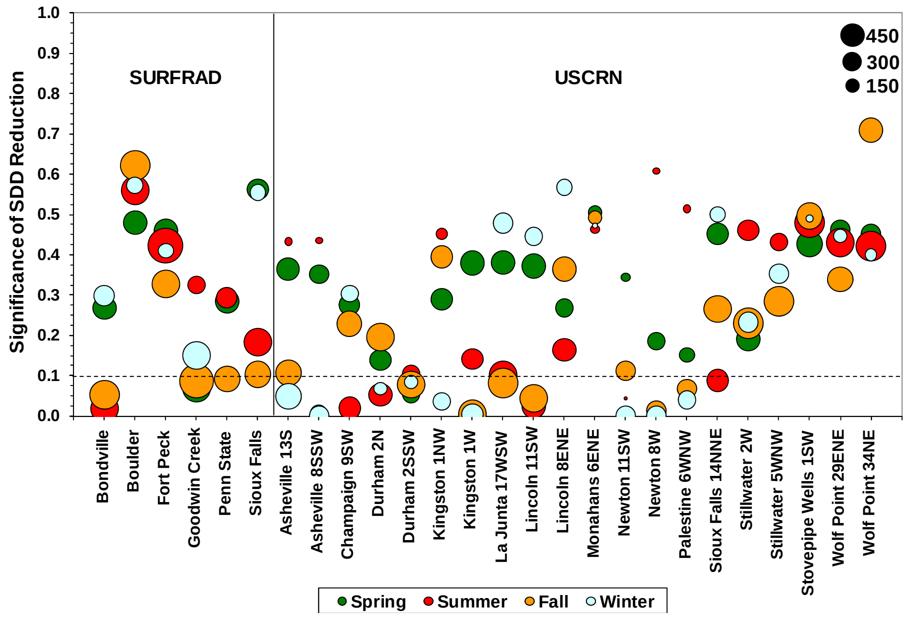


Figure 1.

PROJECT TITLE: NESDIS Environmental Applications Team – Lide Jiang, Post Doc

PRINCIPAL INVESTIGATOR**:** Steve Miller

RESEARCH TEAM: Lide Jiang

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS/STAR/SOCD/MECB)

NOAA RESEARCH TEAM: Menghua Wang

PROJECT OBJECTIVES:

1--VIIRS Suomi-NPP global data routine retrieval, archiving and imagery distribution;
2--NOAA-MSL12 ocean color Level-1B to Level-2 new sensor support and processing algorithm development and improvement;
3--VIIRS ocean color global Level-1B to Level-2 and Level-2 to Level-3 routine data processing and distribution;
4--NPP VIIRS OCC EDR Cal/Val support and OCC EDR re-processing using ADL;
5--Near-real-time ocean color data support

PROJECT ACCOMPLISHMENTS:

1--Developed a command-line true-color software package (Figure 1) for VIIRS based on original MODIS package by NASA MODIS Rapid Response team and University of Wisconsin, Madison, using the VIIRS Rayleigh-corrected reflectance software from NASA Direct Readout Laboratory;
2--Implemented new products in the NOAA-MSL12 processing software, including PAR from Dr. Frouin (Figure 2); IOPs (various absorption and backscattering coefficients) from Dr. Lee (QAA algorithm); and chlorophyll-a concentration with Ocean Color Index (OCI) algorithm from Dr. Hu; implemented detect-based vicarious gain and Rayleigh correction; implemented daily true ice-mask;
3--Developed and implemented a new near-infrared water reflectance estimation model (BMW for Bailey, MUMM, and Wang: Figure 3);
4--Re-derived MODIS-Aqua vicarious gains for NOAA-MSL12 processing package;
5--Developed a processing code to derive Level-3 binned products IOPs and chlor_oci directly from Level-3 binned water-leaving radiances;
6--Provided near-real-time support for VIIRS Suomi-NPP regional chlorophyll-a imageries to NOAA National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) for their summer research cruises around Gulf of Mexico, Key West, and Bahamas during May~June

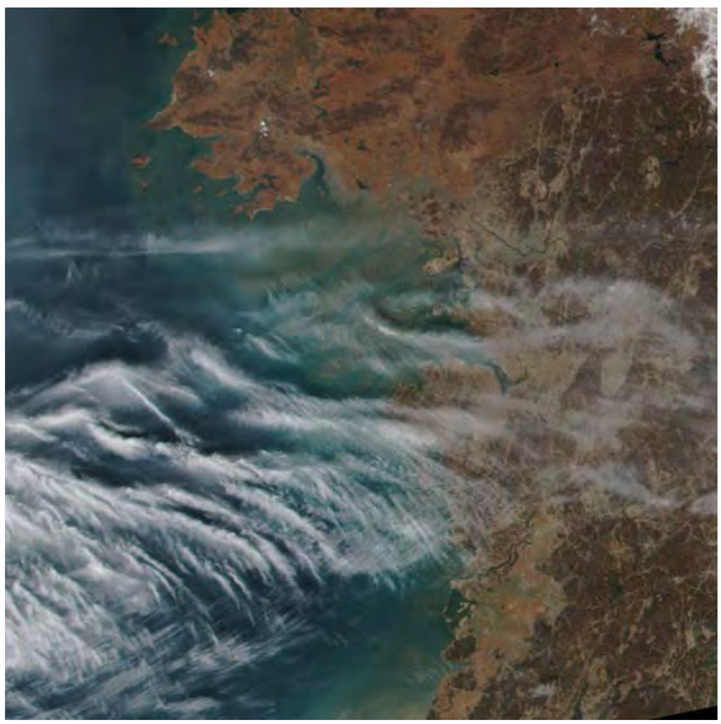


Figure 1. A true color image from VIIRS near Korean west coast

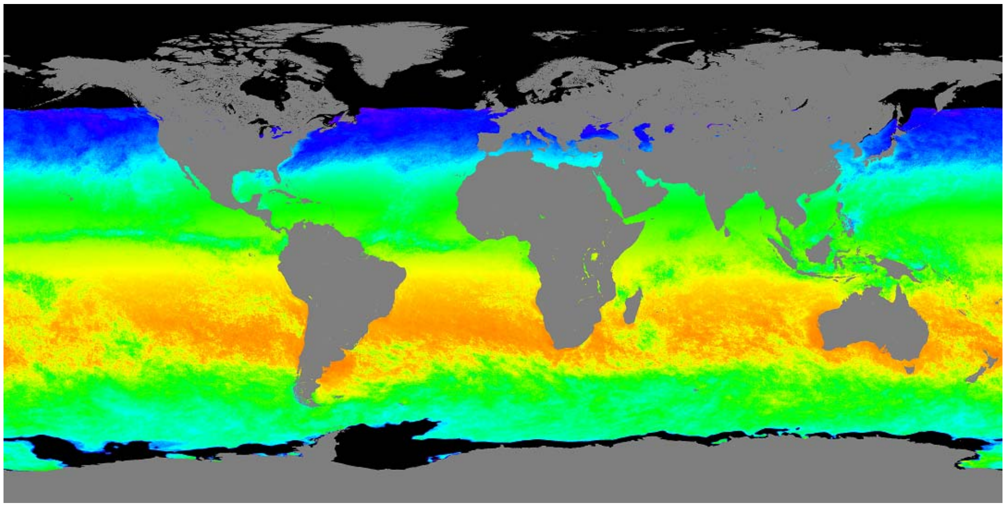


Figure 2.   Monthly composite image of PAR from VIIRS in January 2014

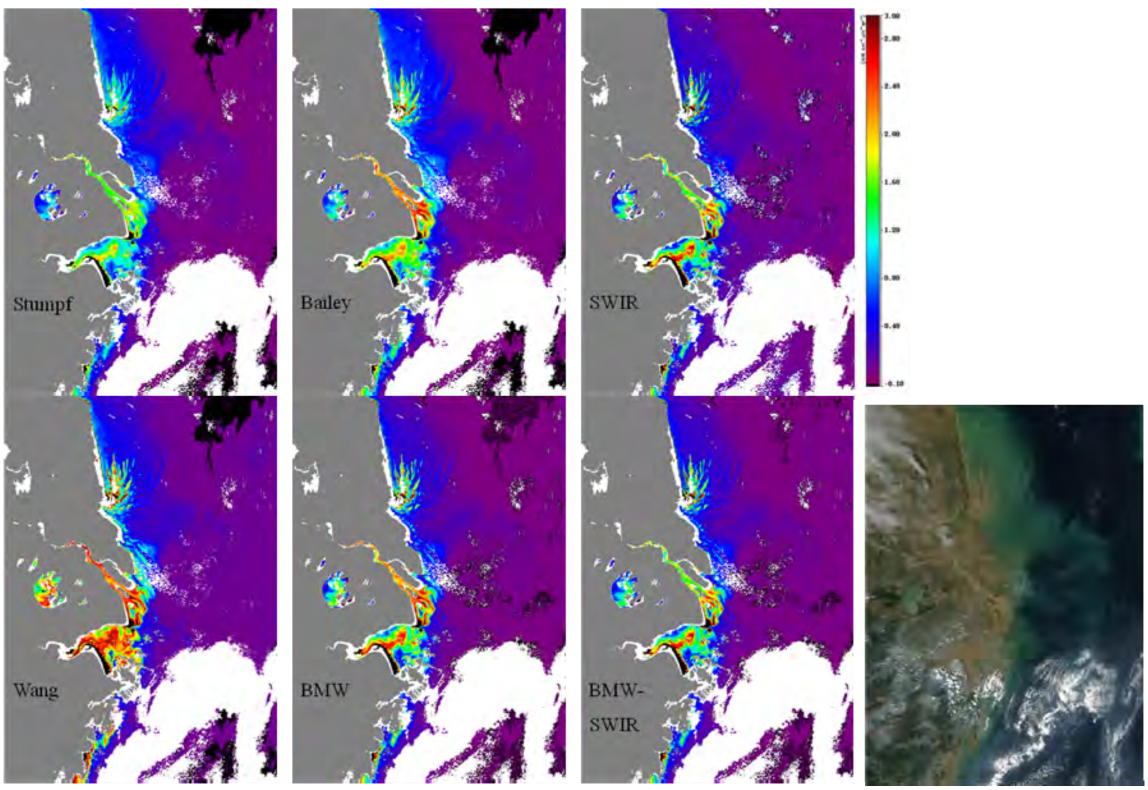


Figure 3. nLw(748) from MODIS-Aqua on October 19, 2003 at 0515Z over East China Sea

PROJECT TITLE: NESDIS Environmental Applications Team – Xingming Liang, Research Scientist

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Xingming Liang

NOAA TECHNICAL CONTACT: Alexander Ignatov (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Alexander Ignatov, John Sapper, John Stroup, Xinjia Zhou, Korak Saha, John Stroup, Boris Petrenko, Yury Kihai of STAR/OSPO.

PROJECT OBJECTIVES:

1--Analyze and publish in the Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS; http://www.star.nesdis.noaa.gov/sod/sst/micros/) web system results of reanalysis of 12-years of AVHRR GAC Advanced Clear-Sky Processor for Ocean (ACSPO) ACSPO data
2--Analyze effect of consistent CRTM coefficients on Model minus Observation (M-O) biases and double differences (DD) in MICROS
3--Test European Center for Medium Range Forecast (ECMWF) vs. the US National Centera for Environmental Prediction (NCEP) Global Forecast System (GFS) profiles as input into fast Community Radiative Transfer Model (CRTM), to improve accuracy of M-O biases and their potential to monitor various sensors for stability and cross-platform consistency

PROJECT ACCOMPLISHMENTS:

1--Twelve years (from 2002-2014) of AVHRR GAC data (reprocessed in ACSPO by X. Zhou) have been displayed in MICROS. NOAA-15 was added in this reprocessing, in addition to six AVHRRs (Metop-A, -B, NOAA16,-17,-18, and -19) regularly monitored in MICROS in near-real time (Figure 1). The sensor stability ranked from best to worst are: Metop-A, NOAA-17, Metop-B, NOAA-19, NOAA-18, NOAA-16, and NOAA-15. The largest cross-platform inconsistencies are 0.14 K in IR37 and 0.3 K in IR11 between Metop-A and Metop-B, likely due to suboptimal Metop-B AVHRR sensor calibration and CRTM coefficients. Part of this work has been presented on AGU Ocean Sciences 2014 conference (February 2014, Honolulu). This work will continue to be presented on GSICS 2014 (March 2014, Darmstadt, Germany) and SPIE 2014 (October 2014, Beijing, China)

2--Sensitivity analyses are being performed with respect to using CRTM Coefficients on M-O biases and double differences (DDs) (in collaboration with Dr. Yong Chen). The objective is to understand and improve cross-platform M-O consistency. Four sets of consistent CRTM coefficients, representing various combinations of transmittance calculation (optical depth in absorption space, ODAS, and optical depth in pressure space, ODPS), and two ways of broad-band parameterizations (ordinary, ORD, and plank-Weighted, PW) were generated and used to produce CRTM model BTs. Comparison of the M-O mean, STD, and DD for four combinations of CRTM coefficients suggests that ODPS-PW overall provides a better combination for the use in CRTM simulation. CFC absorption is a major factor affecting MICROS DDs in the longwave bands centered at 11 and 12µm (IR11&12). Its inclusion for some platforms and discarding for others result a major source of error in the accurate interpretation of DDs in MICROS. Uncertainties in sensor response functions are another major factor. The result has been presented at the NOAA Satellite Conference in College Park (Apr 2013), and an updated analysis will be presented in SPIE 2014 (May 2014, Baltimore). Peer-reviewed manuscript is currently under internal review.

3--To minimize M-O biases and improve sensor stability and cross-platform consistency analyses, ECMWF (0.25° spatial resolution, 97 vertical levels) atmospheric profiles were used as input into CRTM and compared with GFS (1°, 26 levels) using MICROS functionality. Based on analysis of one month of global data for several AVHRR, MODIS and VIIRS sensors, a superior ECMWF performance is observed. The number of clear sky pixels slightly, but consistently, increases for all sensors and resolutions. In IR37, the global mean M-O biases (~0.2K) and standard deviations (STD<0.5K) remain largely unchanged, as expected. However, in IR11 & IR12, the GFS numbers for mean biases (0.5-0.7K) and STDs (~0.55K) are reduced, and become closer to those in IR37. This suggests that ECMWF has more moisture than GFS, which mainly affects the longwave bands. The large warm spots in M-O biases in the tropics seen with GFS implementation are reduced and even reverted to negative M-O biases, suggesting that ECMWF may slightly overestimate water vapor. The DDs are not significantly affected by ECMWF implementation, as expected, but sensor stabilities get improved for all three bands and SST (Figures 3-6). A mirror website was established to monitor the ECMWF results and compare them with official MICROS based on GFS. Results are currently being documented, and will be presented at GSICS 2014 annual meeting (March 2014, Darmstadt, Germany), and the WWOSC – 2014 conference (August 2014, Montreal).

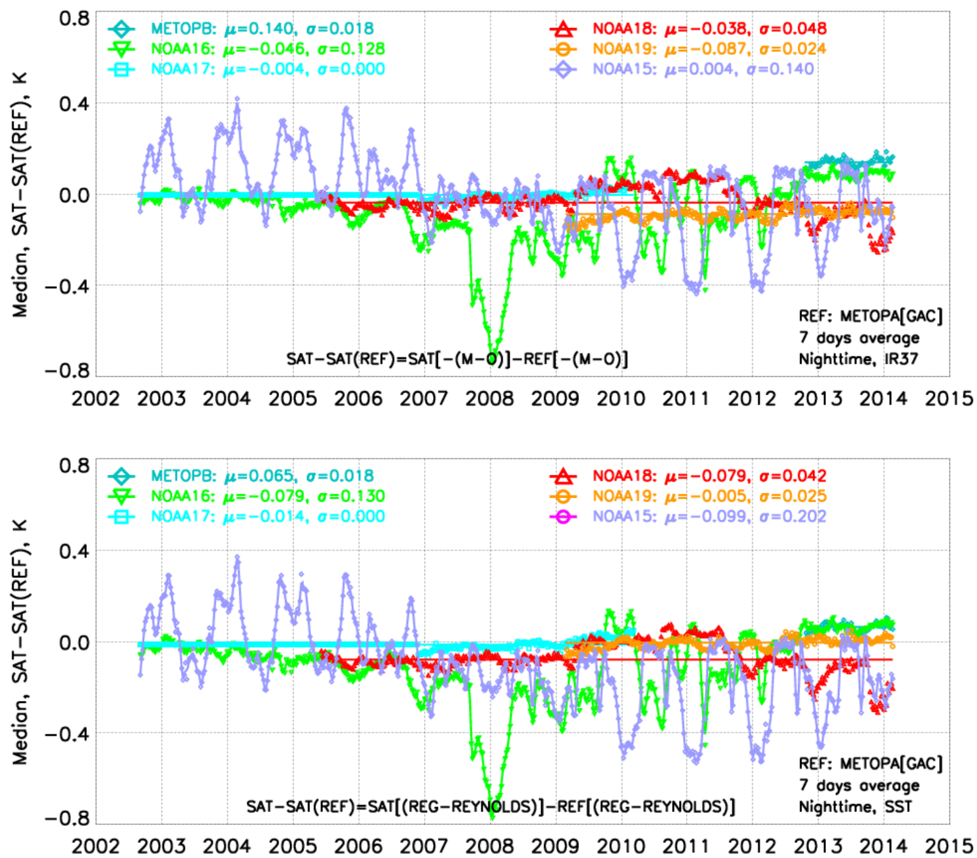


Figure 1. Double differences for (upper panel) M-O biases in IR37; and (bottom panel) SST biases, form 12-year AVHRR AGC reprocessing. Note high correlation of SST artifacts with sensor radiances artifacts.

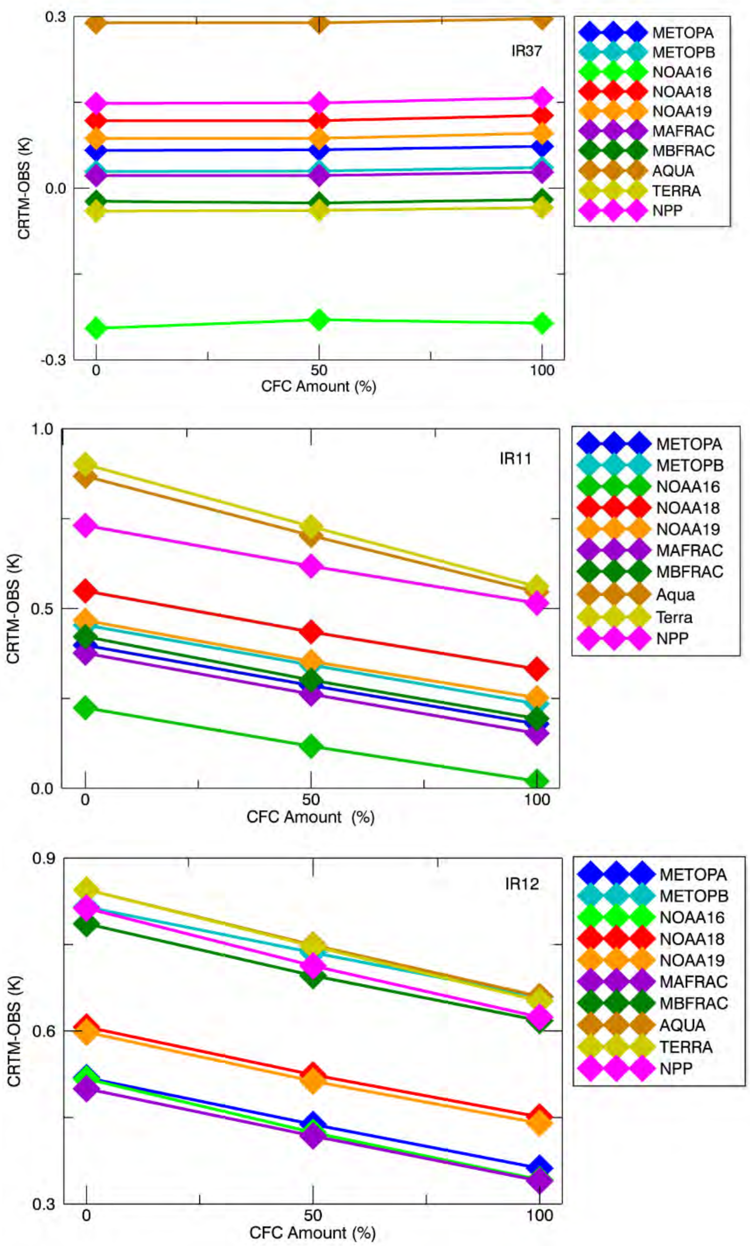


Figure 2. The effect of Chlorofluorocarbon (CFC) on M-O biases in IR37, IR11 and IR12 bands.

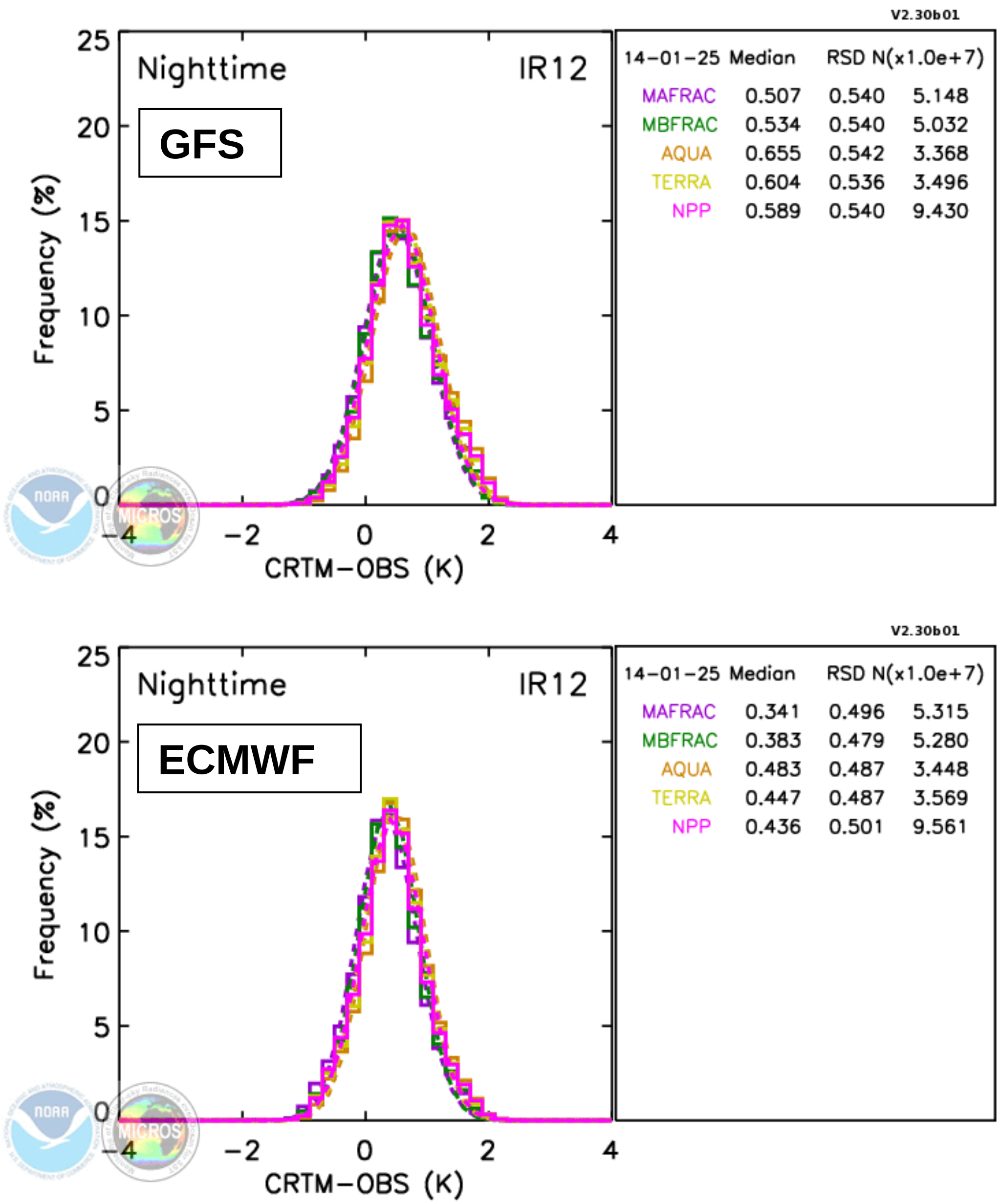


Figure 3. Histograms of M-O biases between GFS and ECMWF as Input to CRTM for IR12.

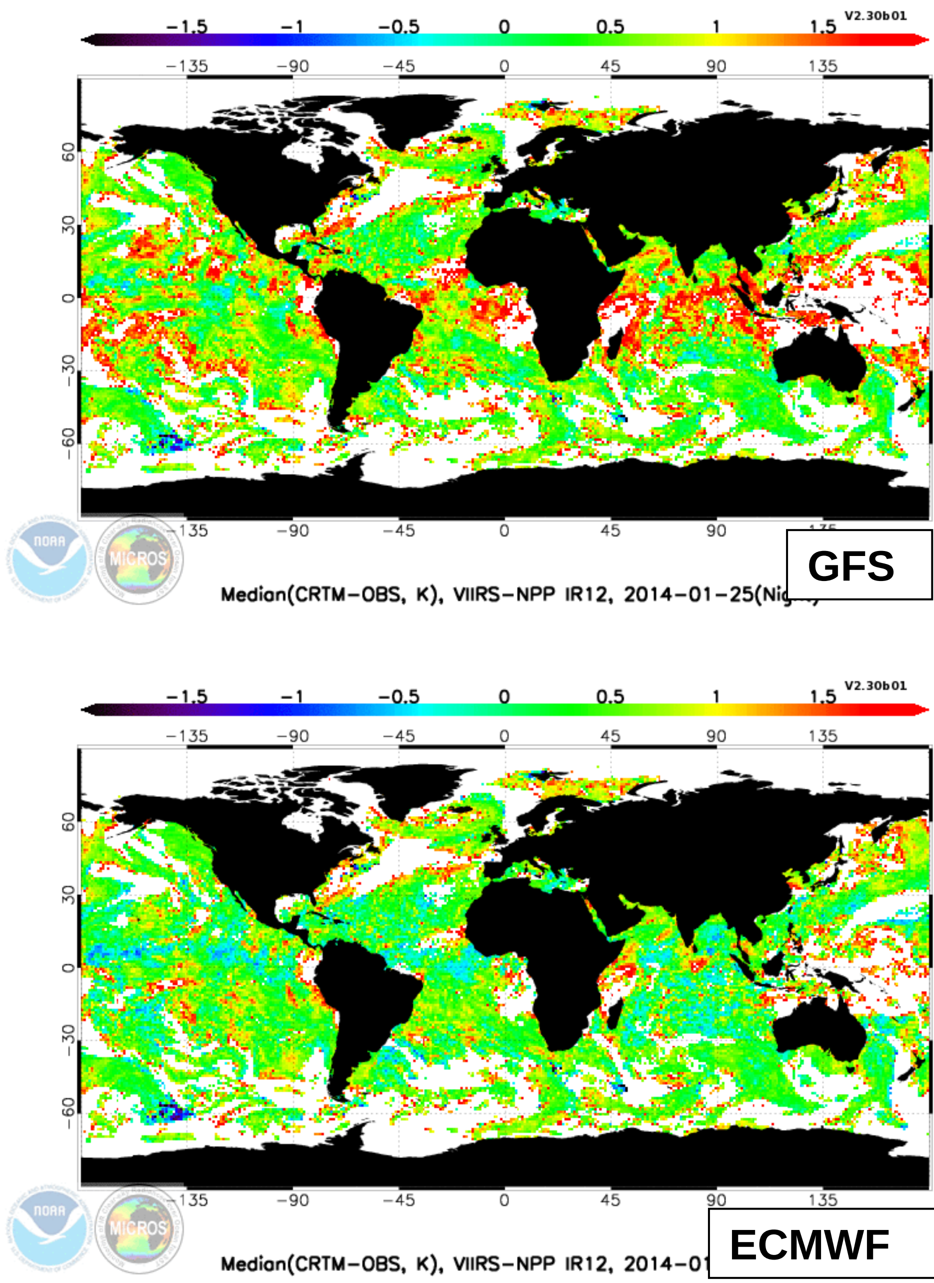


Figure 4. Global distribution of M-O biases for GFS and ECMWF inputs into CRTM in IR12.

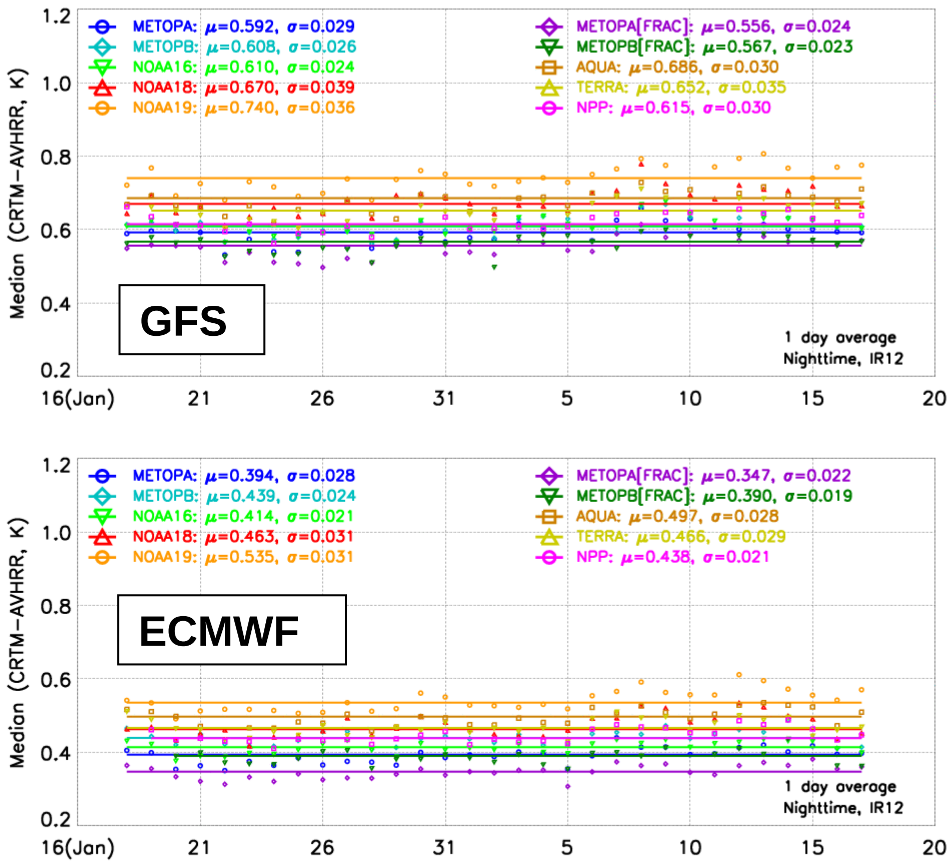


Figure 5. Time series of M-O bias for GFS and ECMWF as CRTM input in IR12.

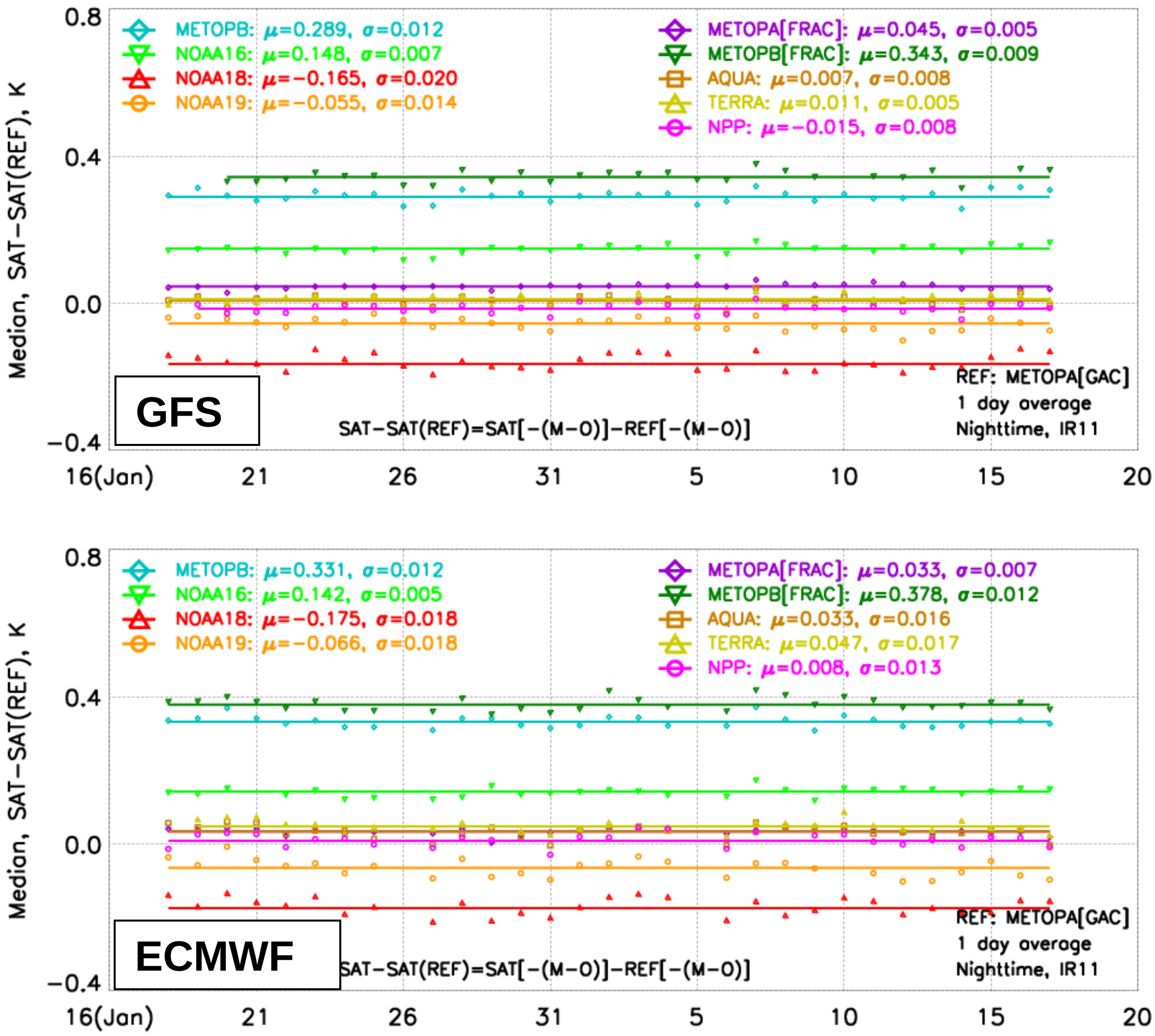


Figure 6. Double Differences corresponding to M-O biases in Figure 5.

PROJECT TITLE: NESDIS Environmental Applications Team – Xiaoming Liu, Research Scientist - Ocean Color Algorithm Development and Ocean Process Study with Satellite Ocean Color Remote Sensing

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Xiaoming Liu

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Menghua Wang

PROJECT OBJECTIVES:

1--Calibration and Validation of VIIRS ocean color products
2--Improve VIIRS IDPS ocean color data processing algorithms
3--Conduct ocean color related applications and research

PROJECT ACCOMPLISHMENTS:

1--VIIRS Cal/Val
--Continue monitoring the VIIRS ocean color products and compare with in situ measurements and MODIS measurements. These processes are automated on our Linux servers and posted on the web weekly: (http://www.star.nesdis.noaa.gov/sod/mecb/color/validation/).
--Set up VIIRS SDR monitoring for bands M1-11 at Libya and the South Pacific Gyre. (This is also an automated process, and the results are posted on our internal web sites.)
--Evaluated the VIIRS ocean color products based on different SDR versions to study the impact of SDR on the ocean color products. This is part of contributions to the publication on JGR-Atmosphere (2013) listed below.
--Analyzed the time series of global oligotrophic water chlorophyll concentration from MODIS (2002-2013) and VIIRS (2012-2013), to evaluate the difference between 2012 and 2013 found in VIIRS ocean color products (Figure 1). This study is parts of IDPS VIIRS SDR review for Validated Maturity Status.

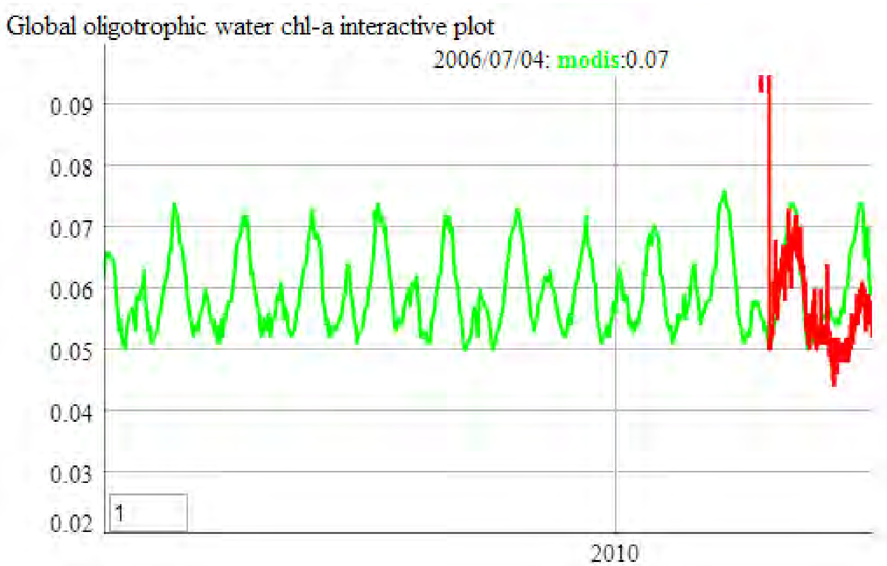


Figure 1. Time series of global oligotrophic water chlorophyll concentration from MODIS (green line) and VIIRS (red line). MODIS shows a very good consistency from 2002 to 2013, but VIIRS has significant difference between 2012 and 2013.

--Contributed to the report for IDPS VIIRS ocean color EDR products review and assessment for Provisional Maturity Status.

2--Evaluated the sun glint algorithm in the IDPS ocean color processing, and fixed a bug in the processing code. A discrepancy report (DR 7384) has been filed to IDPS for correction.

3--Studied the MODIS derived climatology and monthly Total Suspended Sediment (TSS) in the Chesapeake Bay, and its correlation to the Susquehanna River discharge. Numerical sediment model are used to simulate the sediment transport process from the Susquehanna River to the upper Chesapeake Bay. This study was presented on the 2014 Ocean Sciences Meeting.

PROJECT TITLE: NESDIS Environmental Applications Team – Puneeta Naik, Post Doc

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Puneeta Naik

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Menghua Wang

PROJECT OBJECTIVES:

In-situ data quality control and Satellite Ocean color products validation for MODIS and VIIRS.

PROJECT ACCOMPLISHMENTS:

1--In-situ marine optical data quality control from various oceanic regions e.g. MOBY site, BOUSSOLE site, Chesapeake Bay, Aeronet-OC sites, HOT site, northern Gulf of Mexico.
2--Assessed performance of VIIRS and MODIS primary ocean color products for various in-situ data (e.g. MOBY, BOUSSOLE, Chesapeake Bay, Aeronet-OC, HOT, Gulf of Mexico).
3--Determined effective band center wavelengths for MODIS and VIIRS (Figure 1) using MOBY data.
4--Compared total band and in band averages for MOBY data.
5--BRDF corrections recommended by Gordon, 2005 Applied Optics paper and Morel & Gentili, (1991, 1993, 1996), implemented for application to in-situ normalized water leaving radiance. (Figure 2)
6--Provided MODIS and VIIRS weighted normalized water leaving radiance spectra from hyperspectral data for MOBY from 2002-present, Chesapeake Bay and Florida keys to the group for calibration and validation purposes.
7--Submitted abstract to SPIE Ocean Sensing and Monitoring VI for oral presentation.

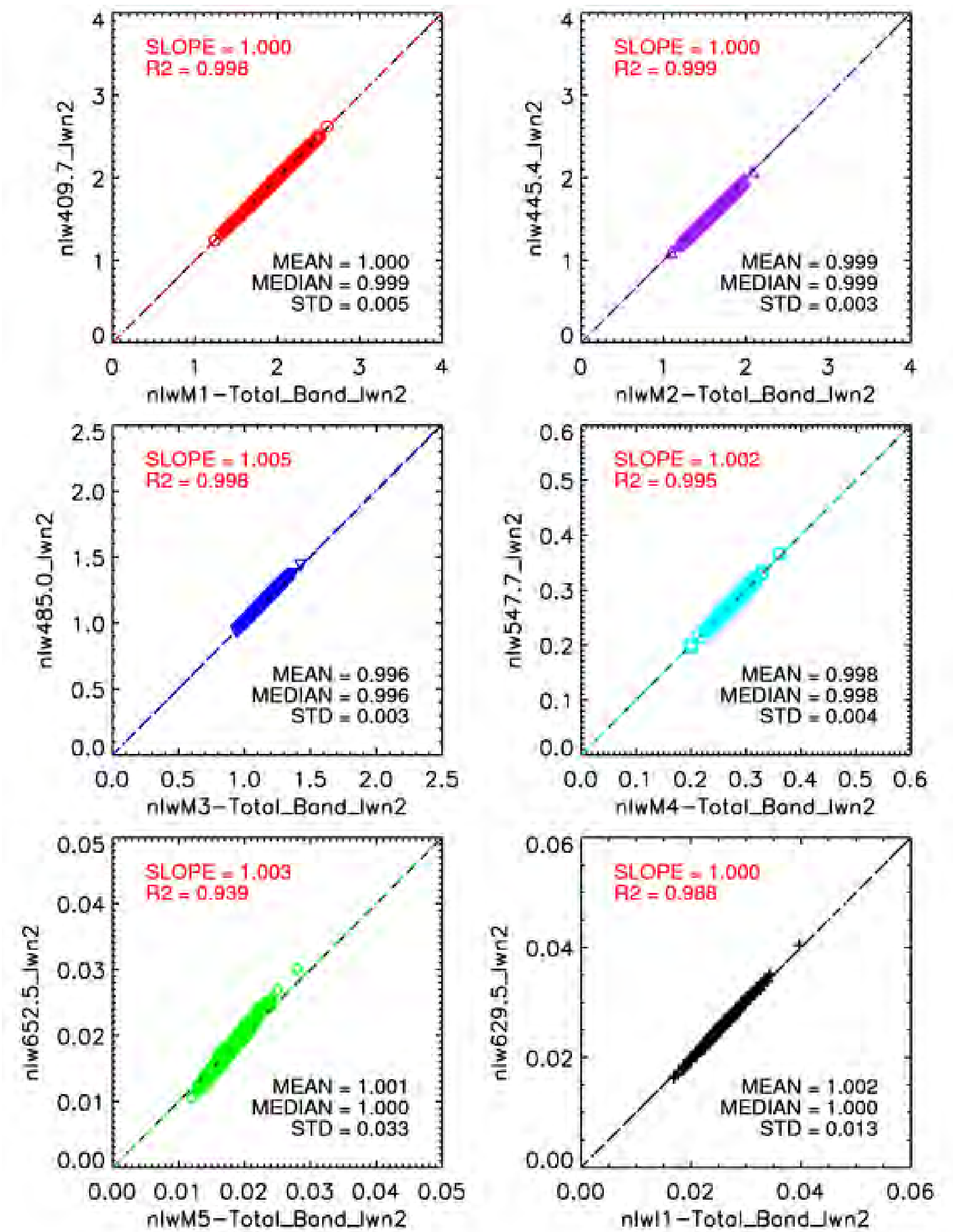


Figure 1. Effective band center wavelengths for VIIRS ocean color bands at MOBY site.

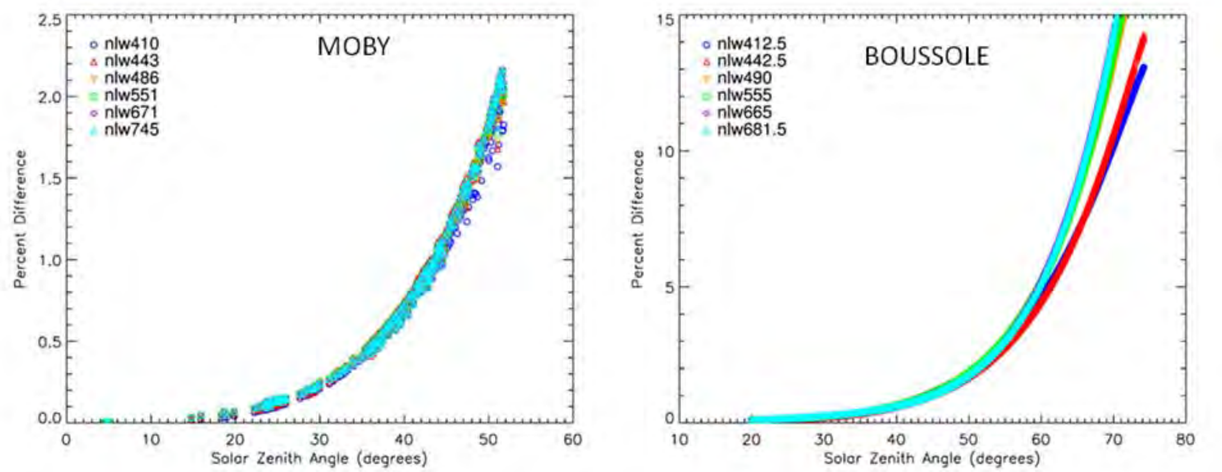


Figure 2. Percent difference between measured and surface BRDF corrected normalized water leaving radiance (nLw) in relation to solar zenith angle for MOBY (left panel) and BOUSSOLE (right panel) sites.

PROJECT TITLE: NESDIS Environmental Applications Team – Korak Saha, Post Doc

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Korak Saha, Xingming Liang

NOAA TECHNICAL CONTACT: Alexander Ignatov (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Alexander Ignatov, Yuri Kihai, John Stroup

PROJECT OBJECTIVES AND ACCOMPLISHMENTS:

1--Effect of ambient cloud on clear-sky ocean brightness temperatures and SSTs

In this study, ambient/residual cloud effect on the clear-sky BTs (at 3.7, 11 and 12µm) and SSTs obtained from Advanced Clear Sky Processor for Oceans (ACSPO) is quantified. Pixels identified in ACSPO as cloud-free, may be still affected by their cloudy neighbors. Currently used threshold based ACSPO clear-sky tests may identify (or not) pixels that are difficult to classify (mostly transient states), thus affecting ACSPO clear-sky BTs and SSTs. Number of clear-sky ocean pixels (NCSOP) around each clear-sky pixel, calculated using sliding window technique, is used as (an inverse) proxy of these ambient cloud. SST and BT differences are calculated in each clear-sky pixel, by subtracting the Canadian CMC 0.2 SST (first guess) and BTs (simulated using a radiative transfer model). These SST and BT differences decrease exponentially with NCSOP, and asymptotically approach their “confidently clear-sky” limits, when NCSOP is large enough. Figure 1 shows an example of a NCSOP dependence of BT (11 *µm*) and SST differences for AVHRR onboard Metop-A, NOAA-18 and NOAA-19. The corresponding number distribution (%) is shown in Figure 2, which confirms that the majority of the clear-sky pixels for all the platforms has clear-sky conditions in the 100 km x 100 km sliding window, followed by a second maxima at 50% of pixels being clear-sky.

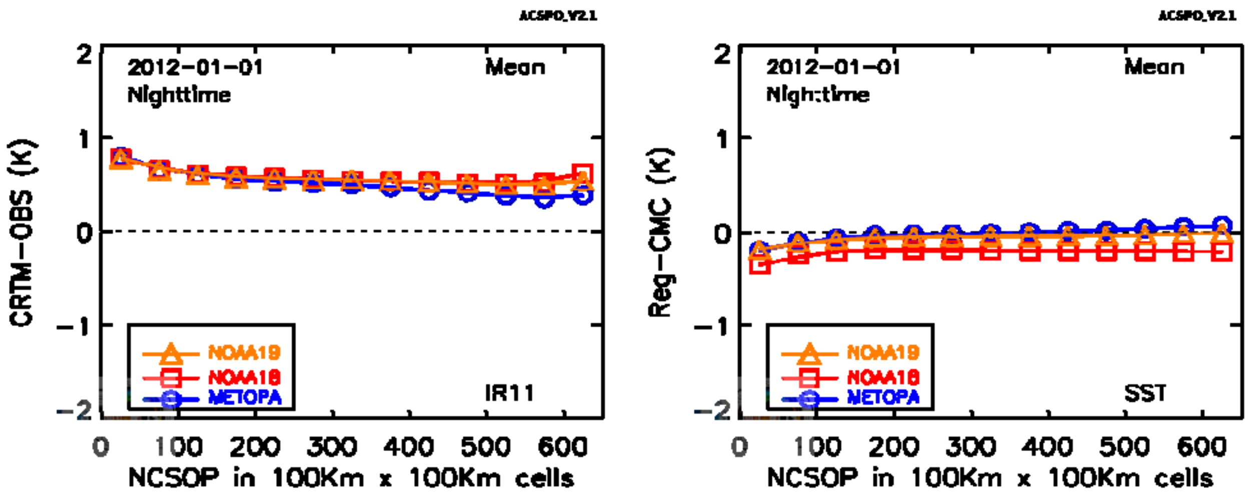


Figure 1. Dependence of “Model – Obs” BT@11*μm* & “Retrieved – Reynolds” SST on NCSOP.

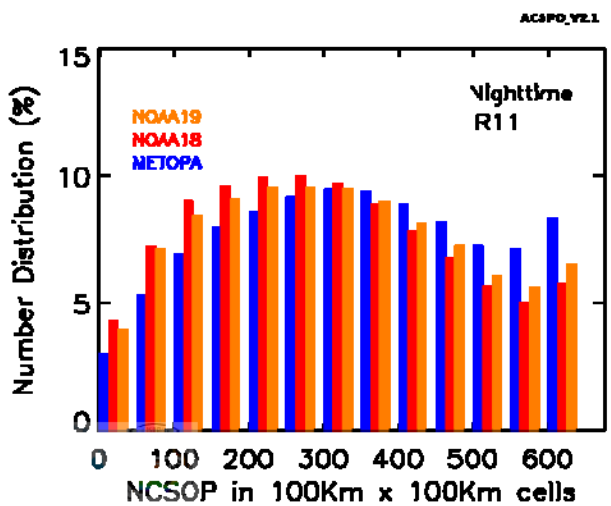


Figure 2. Number density distribution of the corresponding NCSOP dependency

In this study, we fit an exponential curve with three fit parameters to approximate this curve as:

$$\Delta T \equiv f_N(X) = A_0 + A_1 \exp(-A_2 \times X)$$

Here, *X*=NCSOP; with two asymptotic regimes of interest: (1) confident clear sky (NCSOP $\rightarrow\infty$), described by the parameter A_0, and (2) entire cloud (NCSOP$\rightarrow$0), described by the (A_0+A_1) aggregate, respectively. Parameters A_1 and A_2 represent the amplitude of the M-O bias and its drop-off rate with NCSOP, respectively.

Using a modified Levenberg-Marquardt least-square minimization technique, termed MPFIT, this exponential fit is implemented. Figure 3 shows monthly mean fitted dependency curves mean bias of Channel 3.7 (IR37), 11 (IR11), 12 (IR12) µm and SST for Metop-A (M2), NOAA-18 (NN) and NOAA-19 (NP). The monthly values of Ao, A1 and A2 are printed in each plot. All these fits are obtained by several iterative process until the chi-square values obtained from the residuals is minimized. The values of Ao, A1 and A2 for each months does not vary much and is more or less constant. In this analysis, it is concluded that fixing the apriori values for Ao, A1 and A2 can provide best fit results for any given day.

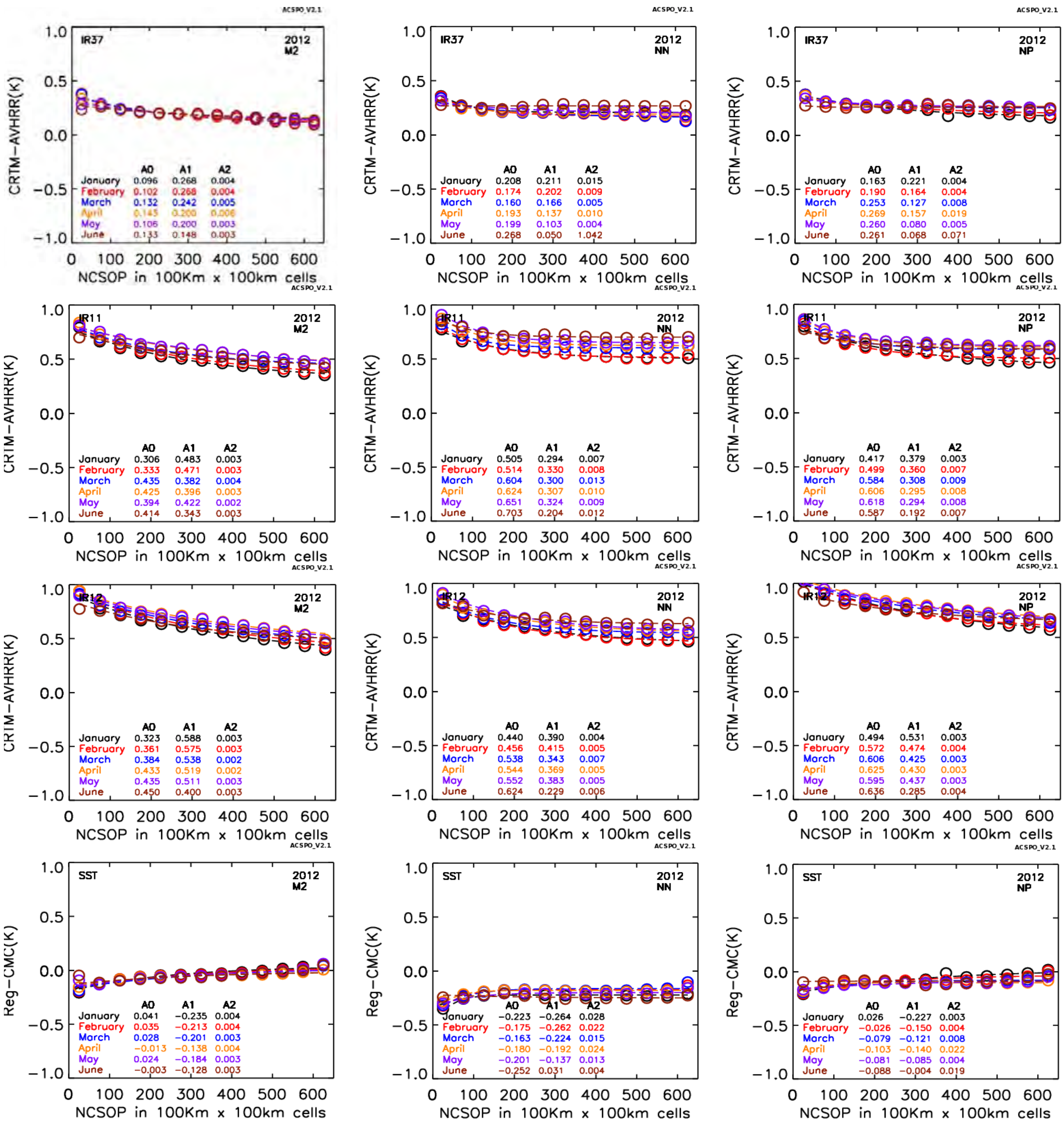


Figure 3. Exponential fit for the Model-Obs (mean_diff) vs. NCSOP for Metop-A Ch3B (3.7 *μm*), Ch4 (11 *μm*), Ch5 (12 *μm*) and SST.

Using MPFIT, the non-linear curve fit is developed on a day-to-day basis for the NCSOP dependencies of Metop-A, NOAA-18, and NOAA-19. The stability of the fitting is investigated by trending the fit parameters with time. The accuracy and precision of satellite retrieved BT and SST can be improved by associating the uncertainty due to residual clouds to each pixel.

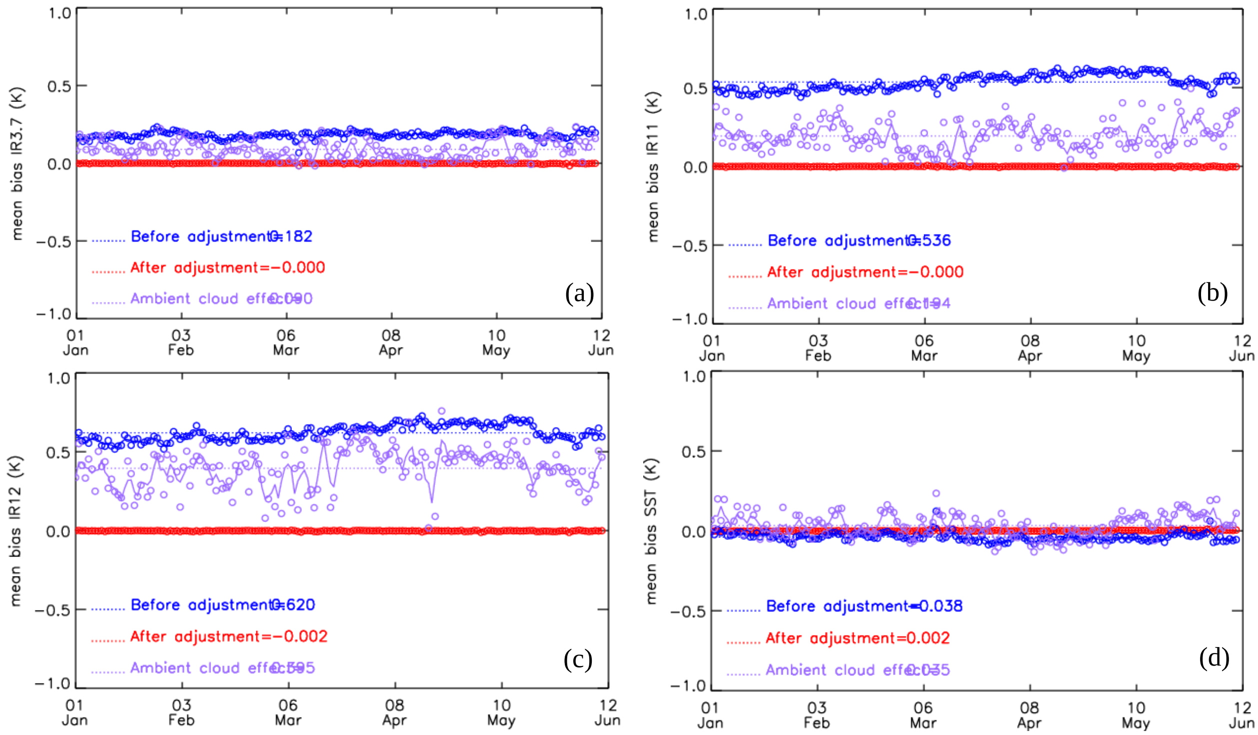


Figure 4. Time series of mean M-O biases before (blue) and after (red) bias adjustment for 3.7 (a), 11 (b) and 12 μm (c) BT channels. Same for the mean Reg-CMC SST bias (d). The contribution from ambient cloud is also presented (purple) in each plot.

To evaluate the effectiveness of this error characterization due to the residual clouds, bias adjustment was applied at pixel level using the global fitting coefficients generated for every day. A time series of mean M-O biases before (blue) and after (red) bias adjustment for 3.7, 11 and 12 µm BT channels and SST are presented in Figure 4(a-d). The global mean bias is centered close to zero after the bias adjustment. The contribution to M-O biases due to residual cloud is also plotted in each plot and is quantified using the term involving the amplitude (A1) and drop-off rate coefficient (A2) in eq. (1). Overall error due to ambient cloud presence corresponds to ~30% of total M-O bias for Channels 3.7 and 11 μm, where as it is about 50% in 12 μm and in SST biases.

PROJECT TITLE: NESDIS Environmental Applications Team – Wei Shi, Research Scientist - Ocean Color Algorithm Development and Ocean Process Study with Satellite Ocean Color Remote Sensing

PRINCIPAL INVESTIGATOR: Steven Miller

RESEARCH TEAM: Wei Shi

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS)

NOAA RESEARCH TEAM: Menghua Wang

PROJECT OBJECTIVES:

--Development of new ocean color algorithm
--Application of satellite ocean color for coastal and in-land water ecosystem monitoring

PROJECT ACCOMPLISHMENTS:

During this period, we studied the ocean reflectance spectra at the red, near-infrared, and shortwave infrared from highly turbid waters, and developed a NIR-based algorithm for satellite IOP retrievals in the highly turbid waters. This is a major contribution the satellite ocean color remote sensing. In addition, we also conduct research on the tide-related ecosystem changes in the Chesapeake Bay. Research was also conducted to study the quality of VIIRS SDR products in the VIIRS ocean color EDR products.

--Ocean reflectance spectra at the red, near-infrared, and shortwave infrared from highly turbid waters: A study in the Bohai Sea, Yellow Sea, and East China Sea
--Tidal effects on ecosystem variability in the Chesapeake Bay from MODIS-Aqua
--Ocean color products from the Korean Geostationary Ocean Color Imager (GOCI)
--Impacts of VIIRS SDR performance on ocean color products

Publication Abstracts:

Title: Ocean reflectance spectra at the red, near-infrared, and shortwave infrared from highly turbid waters: A study in the Bohai Sea, Yellow Sea, and East China Sea
Author(s): Shi, Wei; Wang, Menghua
Limnol. Oceanogr., 59(2), 2014, 427–444, 2014

Abstract: Normalized water-leaving radiance spectra $nL_w(\lambda)$ at the red, near-infrared (NIR), and shortwave infrared (SWIR) are quantified and characterized in highly turbid waters of the western Pacific using three-year (2009–2011) observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the satellite Aqua. $nL_w(645)$ (red), $nL_w(859)$ (NIR), and $nL_w(1240)$ (SWIR) were higher in the coastal region and river estuaries, with SWIR $nL_w(1240)$ reaching up to ~0.2 mW cm^{-2} μm^{-1} sr^{-1} in Hangzhou Bay during winter. The NIR ocean reflectance spectral shape represented by the ratio of the normalized water-leaving reflectance $\rho_{wN}(\lambda)$ at the two NIR bands $\rho_{wN}(748)$:$\rho_{wN}(869)$ is highly dynamic and region-dependent. The NIR spectral feature associated with the sediment source from the Yellow River and Ancient Yellow River is noticeably different from that of the Yangtze River. There are non-negligible SWIR $nL_w(1240)$ contributions for waters with the NIR $nL_w(859)$ > ~2.5 mW cm^{-2} μm^{-1} sr^{-1}. Estimation of the NIR ocean reflectance with iterative approaches might only be accurate for turbid waters with $nL_w(859)$ < ~1.5 mW cm^{-2} μm^{-1} sr^{-1}. Thus, the SWIR atmospherics correction algorithm for satellite ocean color data processing is indispensable to derive accurate $nL_w(\lambda)$ for highly turbid waters. Current existing satellite algorithms for chlorophyll *a*, diffuse attenuation coefficient at the wavelength of 490 nm ($K_d(490)$), total suspended matter (TSM), and inherent optical properties (IOPs) using $nL_w(\lambda)$ at the red band for coastal waters are limited and can only be applied to turbid waters with $nL_w(859)$ < ~1.5 mW cm^{-2} μm^{-1} sr^{-1}. Thus, the NIR $nL_w(\lambda)$ measurements are required to characterize water properties for highly turbid waters.

Based on the fact that pure water absorption is significantly larger than other absorption components in the NIR wavelengths, we show that it is feasible to analytically derive accurate IOP data for turbid waters with combined sate

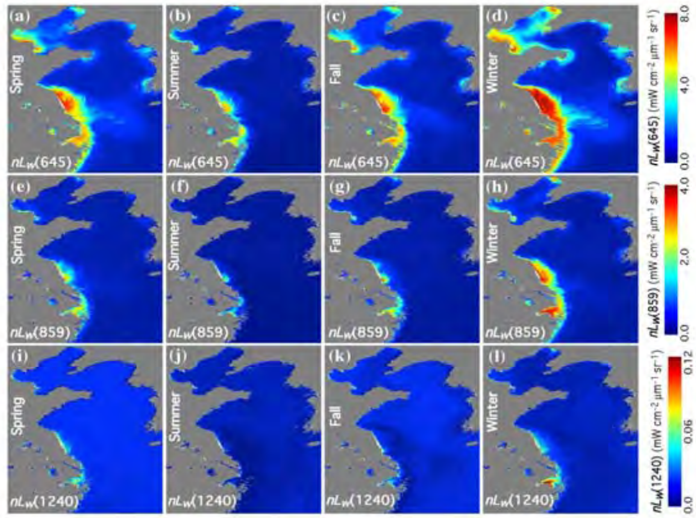


Fig. 2

Figure. Three-year mean seasonal images of (a–d) nL_w(645), (e–h) nL_w(859), and (i–l) nL_w(1240) derived from MODIS-Aqua observations between 2009 and 2011 in the Bohai Sea, Yellow Sea, and East China Sea for the season of (a, e, i) spring (March–May), (b, f, j) summer (June–August), (c, g, k) fall (September–November), and (d, h, l) winter (December–February).

Title: Tidal effects on ecosystem variability in the Chesapeake Bay from MODIS-Aqua

Author(s): Shi, Wei; Wang, Menghua

Remote Sensing of Environment Volume: 138 Pages: 65-76, 2013

Abstract: Eight-year ocean color observations between 2002 and 2009 from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the satellite Aqua are used to quantitatively assess the tidal effects on variability of ocean's optical, biological, and biogeochemical properties in the Chesapeake Bay. We demonstrate that tidal variation in the lower Chesapeake Bay is one of important ocean processes that drive significant changes of the ocean's optical and biogeochemical properties. Normalized water-leaving radiance spectra ($nL_w(\lambda)$), water diffuse attenuation coefficient at the wavelength of 490 nm (K_d(490)), and total suspended sediment (TSS) concentration show significant tidal variations in the lower Chesapeake Bay. Indeed, in the lower Bay region, K_d(490) increases from 0.9 m^{-1} under low tidal current conditions at 0.10–0.15 m/s to 1.35 m^{-1} under high tidal current conditions at 0.45–0.50 m/s, while chlorophyll-a concentration in the lower Bay region decreases slightly with increase of the tidal current. Tide-driven variability in K_d(490) and TSS in the lower Bay is similar to and slightly larger than the seasonal variability in the region. On the other hand, different from the variability in the lower Bay, the tidal effects on the ecosystem are small and negligible in the middle and a large part of upper Chesapeake Bay regions.

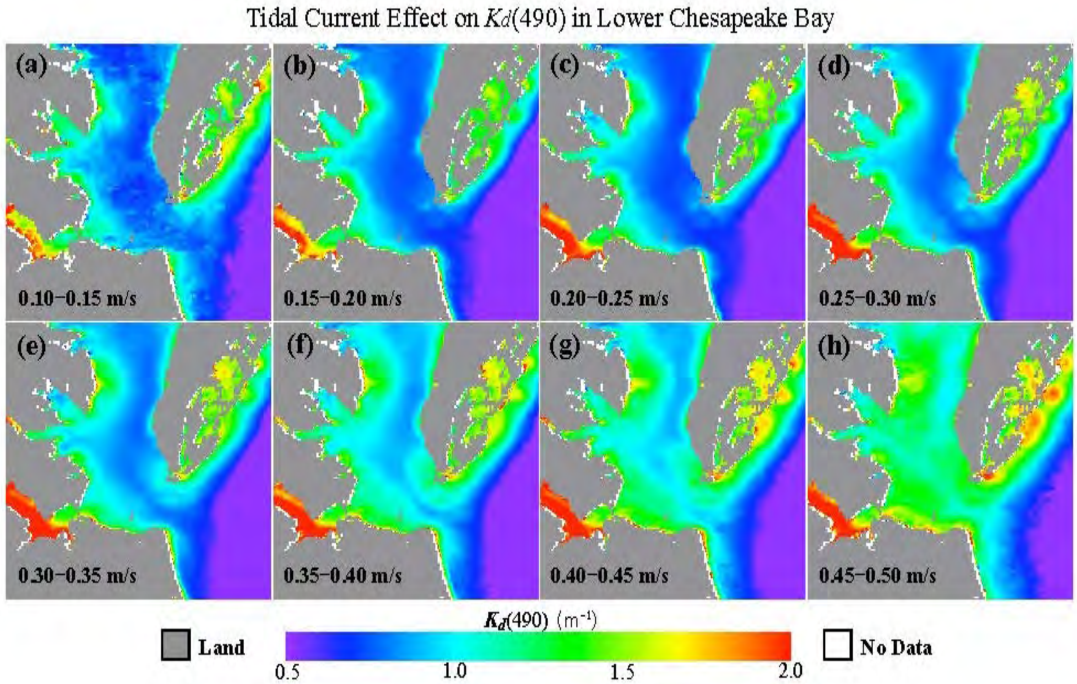


Figure. Composite $K_d(490)$ images in the lower Chesapeake Bay derived from MODIS-Aqua measurements from 2002 to 2009 for the tidal current (at the station CB0201) of (a) 0.10–0.15 m/s, (b) 0.15–0.20 m/s, (c) 0.20–0.25 m/s, (d) 0.25–0.30 m/s, (e) 0.30–0.35 m/s, (f) 0.35–0.40 m/s, (g) 0.40–0.45 m/s, (h) 0.45–0.50 m/s.

Title: Ocean color products from the Korean Geostationary Ocean Color Imager (GOCI)
Author(s): Wang, Menghua; Ahn, Jae-Hyun; Jiang, Lide; Wei Shi
Optics Express: Volume: 21 Issue: 3 Pages: 3835-3849, 2013

Abstract: The first geostationary ocean color satellite sensor, Geostationary Ocean Color Imager (GOCI), which is onboard South Korean Communication, Ocean, and Meteorological Satellite (COMS), was successfully launched in June of 2010. GOCI has a local area coverage of the western Pacific region centered at around 36 degrees N and 130 degrees E and covers similar to 2500 x 2500 km(2). GOCI has eight spectral bands from 412 to 865 nm with an hourly measurement during daytime from 9: 00 to 16: 00 local time, i.e., eight images per day. In a collaboration between NOAA Center for Satellite Applications and Research (STAR) and Korea Institute of Ocean Science and Technology (KIOST), we have been working on deriving and improving GOCI ocean color products, e.g., normalized water-leaving radiance spectra (nL(w)(lambda)), chlorophyll-a concentration, diffuse attenuation coefficient at the wavelength of 490 nm (K-d(490)), etc. The GOCI-covered ocean region includes one of the world's most turbid and optically complex waters. To improve the GOCI-derived nL(w)(lambda) spectra, a new atmospheric correction algorithm was developed and implemented in the GOCI ocean color data processing. The new algorithm was developed specifically for GOCI-like ocean color data processing for this highly turbid western Pacific region. In this paper, we show GOCI ocean color results from our collaboration effort. From in situ validation analyses, ocean color products derived from the new GOCI ocean color data processing have been significantly improved. Generally, the new GOCI ocean color products have a comparable data quality as those from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the satellite Aqua. We show that GOCI-derived ocean color data can provide an effective tool to monitor ocean phenomenon in the region such as tide-induced re-suspension of sediments, diurnal variation of ocean optical and biogeochemical properties, and horizontal advection of river discharge. In particular, we

show some examples of ocean diurnal variations in the region, which can be provided effectively from satellite geostationary measurements.

Title: Impacts of VIIRS SDR performance on ocean color products
Author(s): Menghua Wang, Xiaoming Liu, Liqin Tan, Lide Jiang, SeungHyun Son, Wei Shi, Kameron Rausch, and Kenneth Voss
J. Geophys. Res.: ATMOSPHERES, VOL. 118, 1–14, doi:10.1002/jgrd.50793, 2013

Abstract: One of the primary goals for the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi National Polar-orbiting Partnership is to provide the science and user communities with the data continuity of the Environmental Data Records (EDR) (or Level-2 products) over global oceanic waters for various research and applications, including assessment of climatic and environmental variations. The ocean color EDR is one of the most important products derived from VIIRS. Since ocean color EDR is processed from the upstream Sensor Data Records (SDR) (or Level-1B data), the objective of this study is to evaluate the impact of the SDR on the VIIRS ocean color EDR. The quality of the SDR relies on prelaunch sensor characterizations as well as on-orbit radiometric calibrations, which are used to develop the sensor F-factor lookup tables (F-LUTs). VIIRS F-LUTs derived from solar and lunar calibrations have been used in processing data from the VIIRS Raw Data Records (or Level-0 data) to SDR. In this study, three sets of F-LUTs with different generation schemes have been used to reprocess the SDR and then the ocean color EDR for product evaluations. VIIRS ocean color products are compared with in situ data from the Marine Optical Buoy and products from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the satellite Aqua. It is found that the data quality of VIIRS operational ocean color products before 6 February 2012 is poor due to the inappropriate use of the at-launch F-LUTs for the SDR calibration, and that the recently updated VIIRS F-LUTs have significantly improved the SDR and ocean color EDR. Using reprocessed SDR with updated F-LUTs and including vicarious calibration, VIIRS ocean color EDR products are consistent with those from MODIS-Aqua in global deep waters. Although there are still some significant issues with VIIRS ocean color EDR, e.g., poor data quality over coastal regions, our results demonstrate that VIIRS has great potential to provide the science and user communities with consistently high-quality global ocean color data records that are established from heritage ocean color sensors such as MODIS-Aqua.

PROJECT TITLE: NESDIS Environmental Applications Team – SeungHyun Son, Research Scientist

PRINCIPAL INVESTIGATOR: Steven Miller

RESEARCH TEAM: Seunghyun Son

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS/STAR/SOCD/MEB)

NOAA RESEARCH TEAM: Menghua Wang

PROJECT OBJECTIVES:

1--Processing and validation/evaluation of the JPSS VIIRS data
2--Processing and Validation/evaluation of the Geostationary Ocean Color Imager (GOCI) data
3--Development of bio-optical and biogeochemical algorithms for the satellite ocean color data use in the coastal and inland waters
4--Validation/evaluation of the MODIS-Aqua ocean color data

PROJECT ACCOMPLISHMENTS:

1--The two VIIRS data sets from IDPS-EDR and NOAA-MSL12 processing have been being processed over the various ocean waters (Hawaii region, South Pacific Gyre, US east coast, Yellow & East China seas, Mediterranean Sea, etc.). In situ bio-optical data were compared for validation of the VIIRS data in various regions.

2--The first geostationary ocean color imager (GOCI) data in 2011, derived using a new atmospheric correction algorithm, were processed and compared with in-situ bio-optical data. The results were presented at the international meeting and published in international scientific (peer-reviewed) journal.

3--Regional algorithms for total suspended sediments in the Chesapeake Bay, and turbidity in China's Lake Taihu and Lake Okeechobee have been developed. The results were submitted to a international scientific (peer-reviewed) journals (1 published and 1 in press).

4--Regional algorithms for Sea-Ice mask and turbidity for use of satellite ocean color data in the Great Lakes are developed, and the optical properties in the Great Lakes are characterized. The results will be submitted to a peer-reviewed journal.

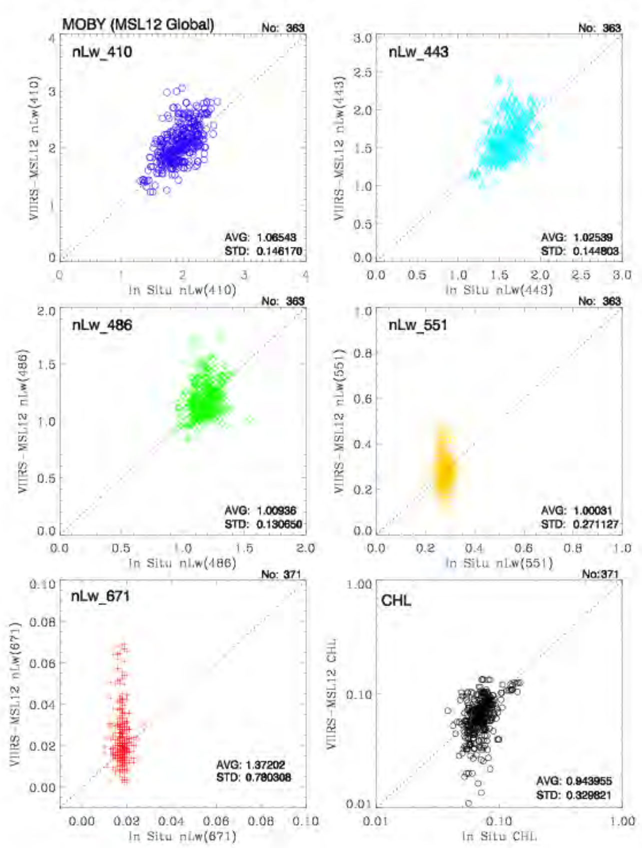


Figure 1. Matchup comparison between MOBY in-situ and VIIRS NOAA-MSL12 processing *nL*$_{w}$(λ) and Chl-a measurements.

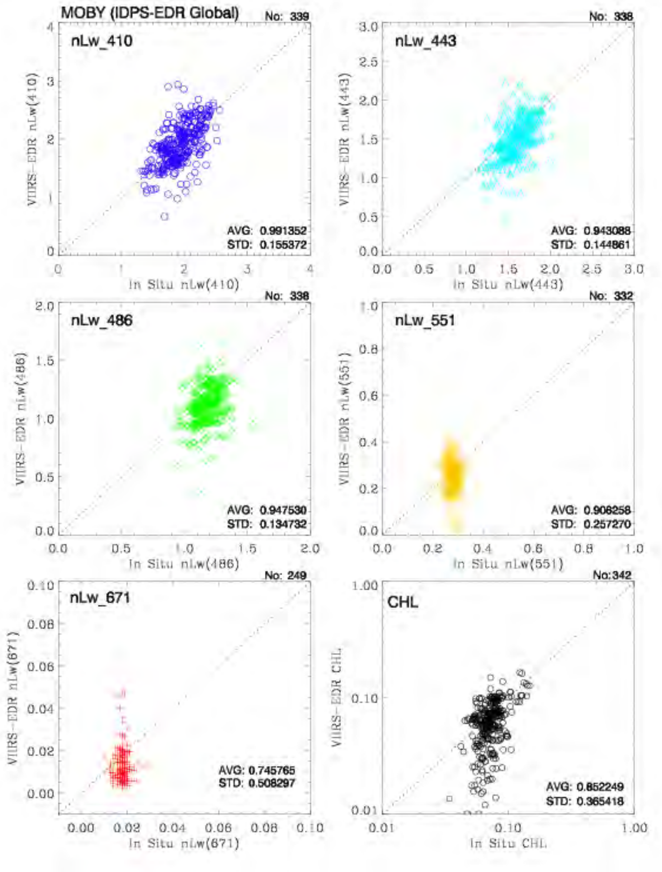


Figure 2. Matchup comparison between MOBY in-situ and VIIRS IDPS-EDR processing $nL_w(\lambda)$ and Chl-a measurements.

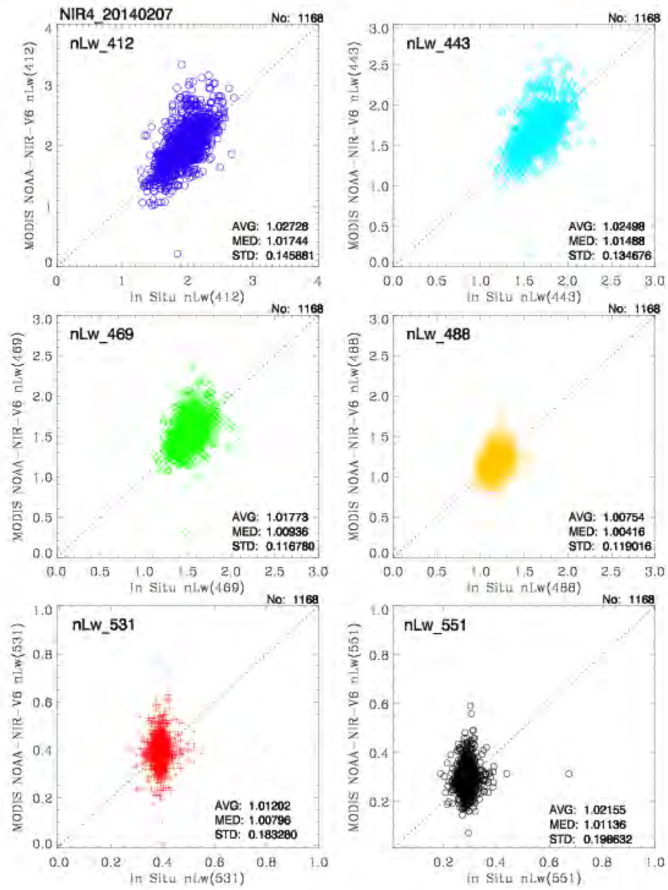


Figure 3. Matchup comparison between MOBY in-situ and MODIS NOAA-MSL12 processing $nL_w(\lambda)$ and Chl-a (using MODIS collection 6 and new vicarious gain) measurements.

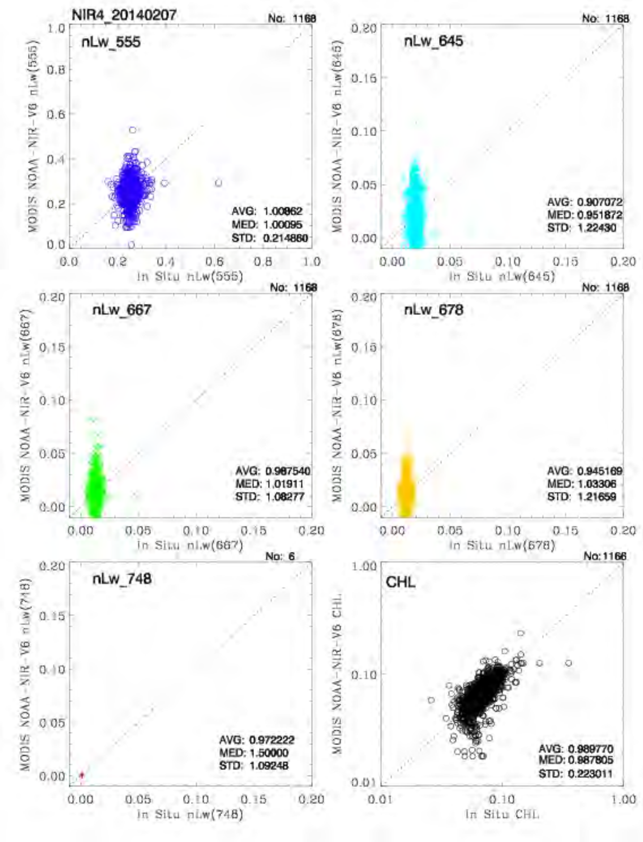


Figure 3 continued.

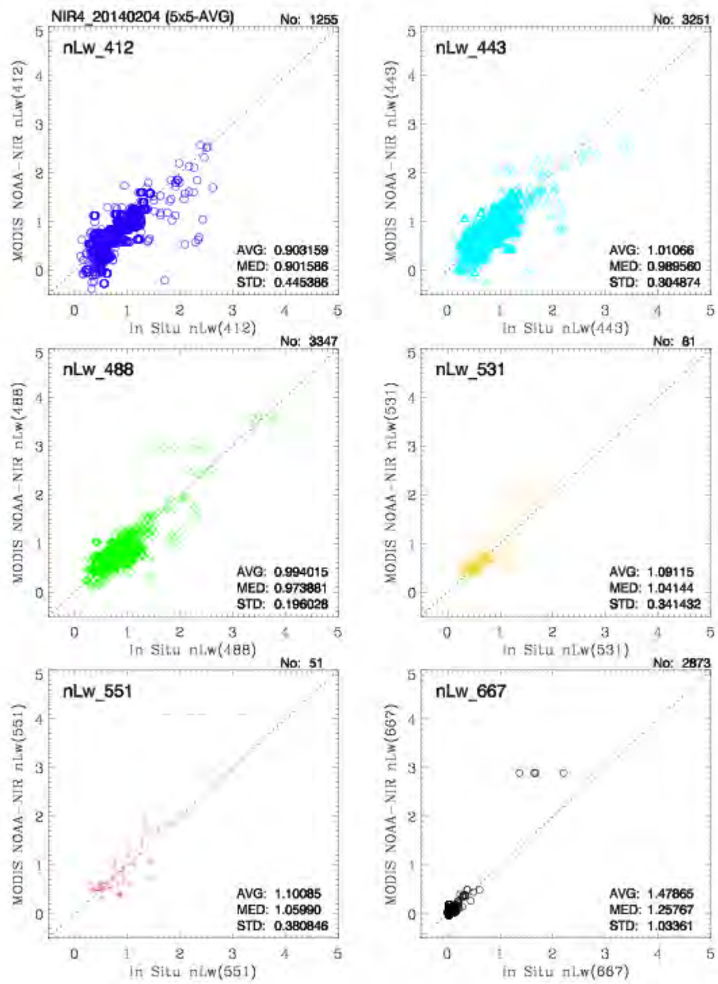


Figure 4. Matchup comparison between NASA SeaBASS in-situ and MODIS NOAA-MSL12 processing $nL_w(\lambda)$ and Chl-a (using MODIS collection 6 and new vicarious gain) measurements.

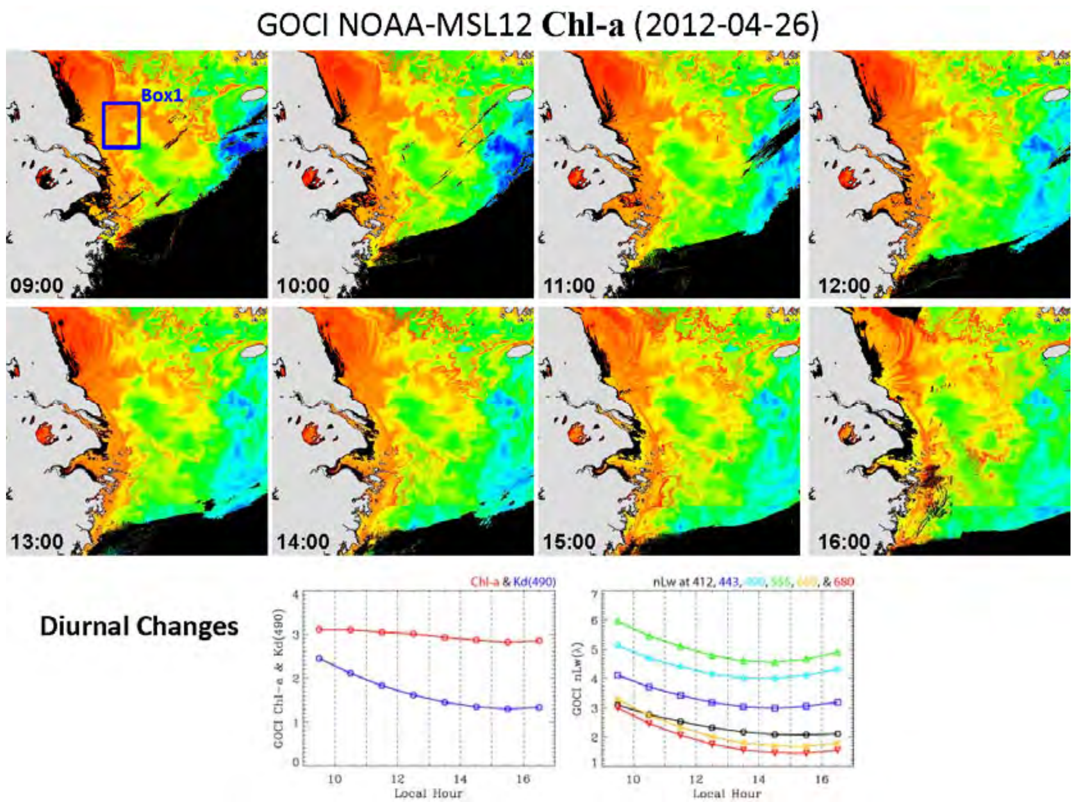


Figure 5. GOCI-derived Chl-a images from 9:00 to 16:00 o'clock in local time near the Yangtze River mouth in April 26th, 2012. Diurnal variations of Chl-a, $K_d(490)$, and $nL_w(\lambda)$ for Box1 are shown.

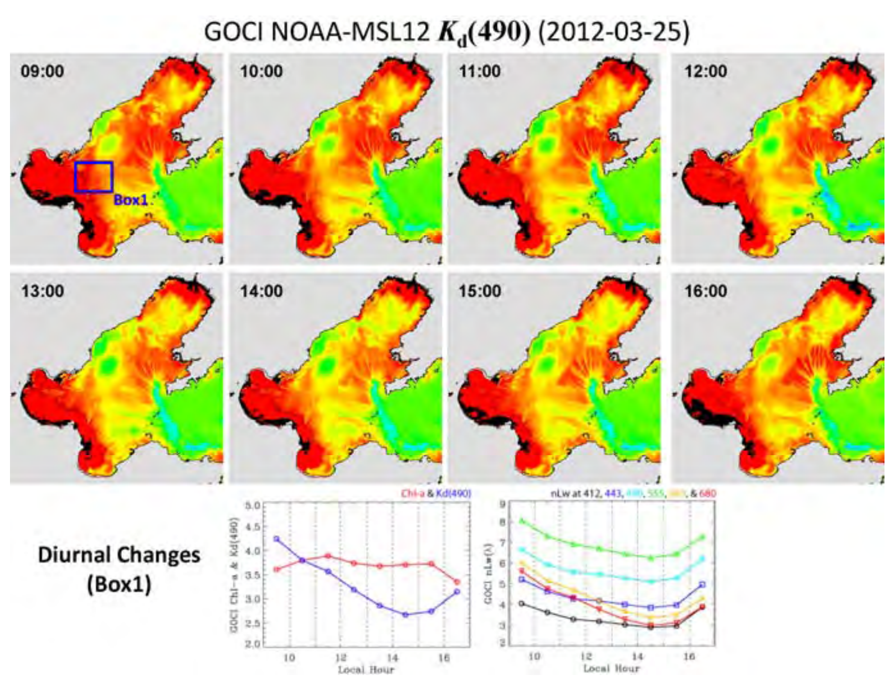
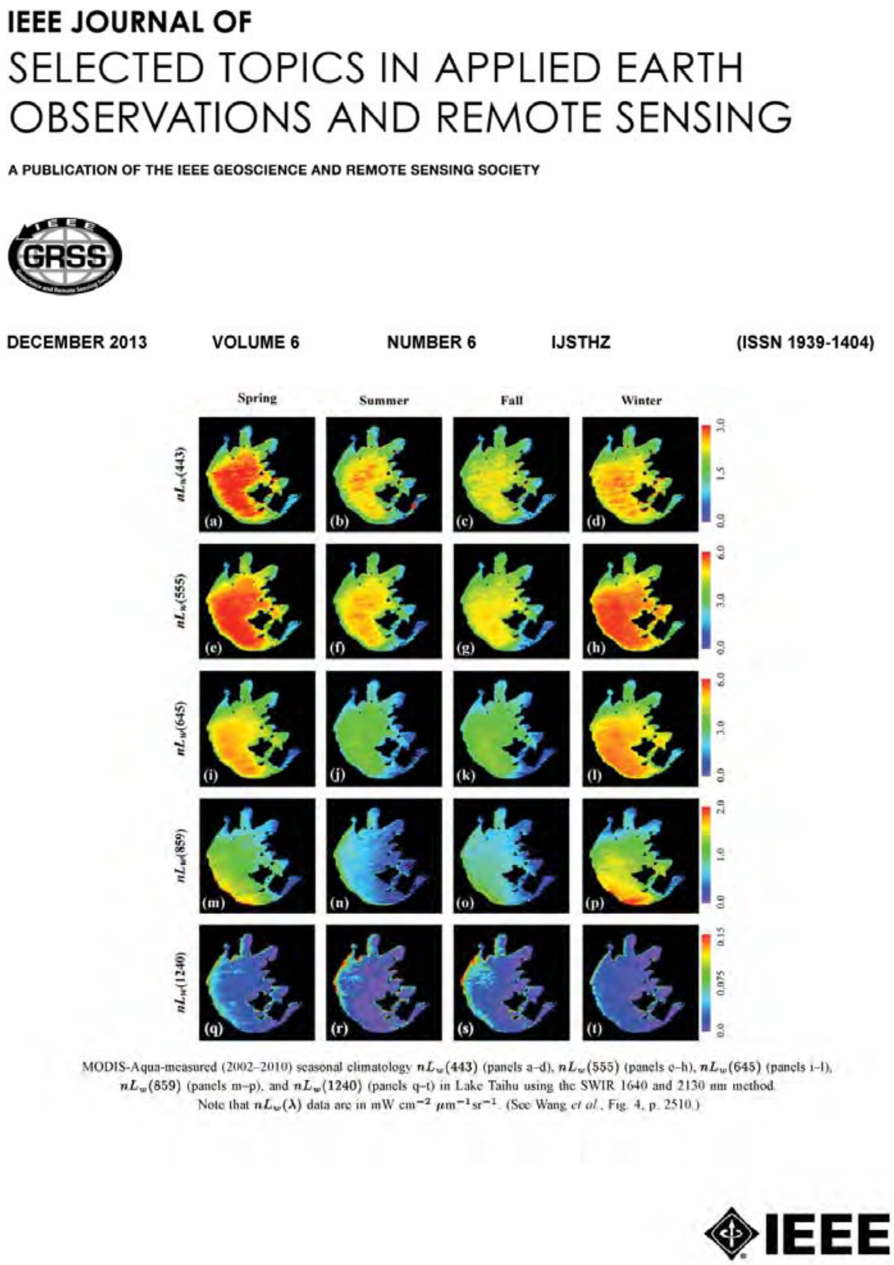


Figure 6. GOCI-derived $K_d(490)$ images from 9:00 to 16:00 o'clock in local time in the Bohai Sea in March 25th, 2012. Diurnal variations of Chl-a, $K_d(490)$, and $nL_w(\lambda)$ for Box 1 are shown.



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MODIS-Aqua-measured (2002–2010) seasonal climatology $nL_w(443)$ (panels a–d), $nL_w(555)$ (panels e–h), $nL_w(645)$ (panels i–l), $nL_w(859)$ (panels m–p), and $nL_w(1240)$ (panels q–t) in Lake Taihu using the SWIR 1640 and 2130 nm method. Note that $nL_w(\lambda)$ data are in mW cm^{-2} μm^{-1}sr^{-1}. (See Wang *et al.*, Fig. 4, p. 2510.)

IEEE

Figure 7. MODIS-Aqua-derived climatology seasonal $nL_w(\lambda)$ spetra maps of Lake Taihu (from Wang et al., 2013).

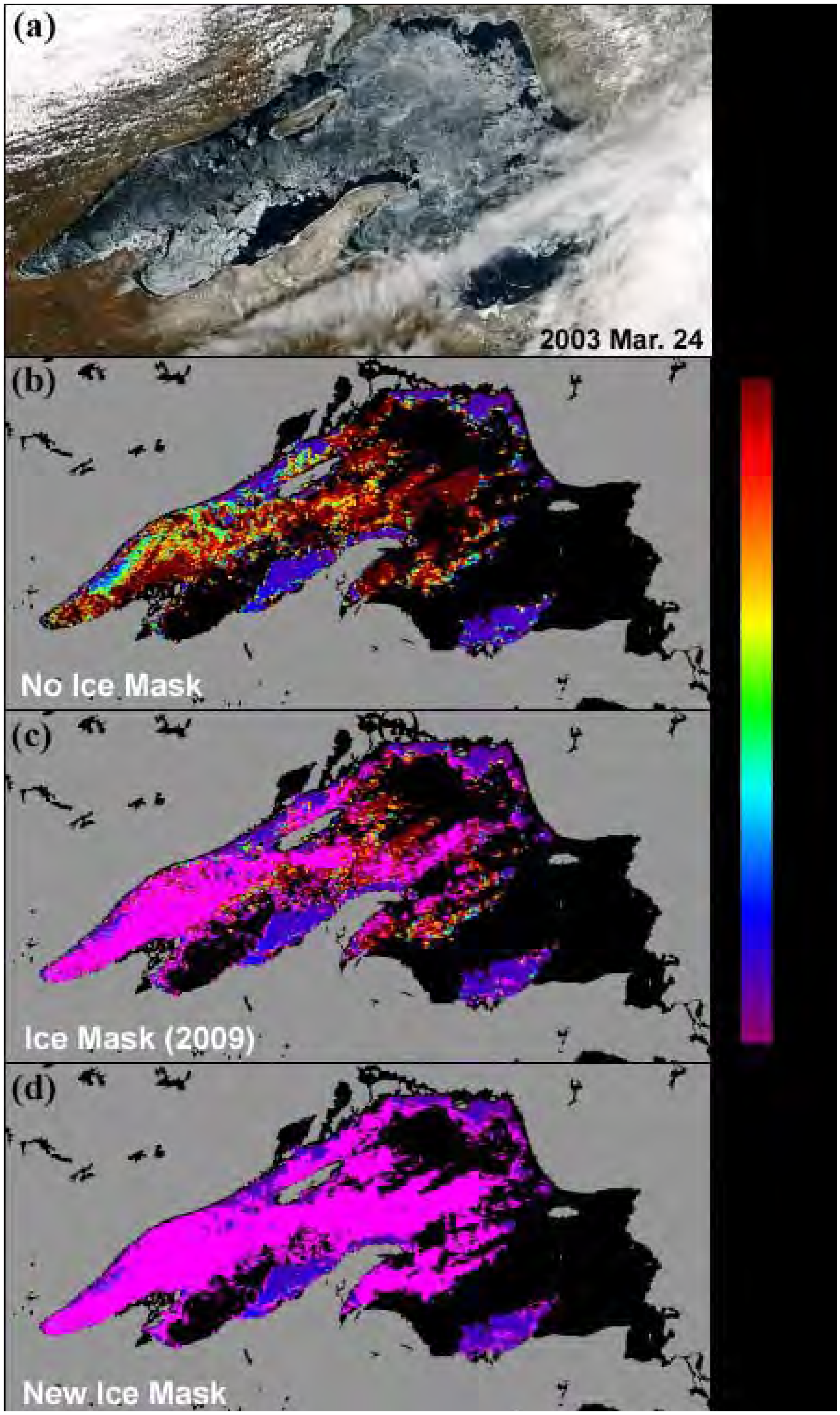

Figure 8. MODIS-Aqua-derived (a) true color image, and normalized water-leaving radiance at 551 nm, $nL_w(551)$ using (a) without an ice masking method, (b) with ice detection masking from Wang and Shi (2009) (pink), and (d) a new ice masking (pink) in the Great Lakes acquired on March 4, 2003.

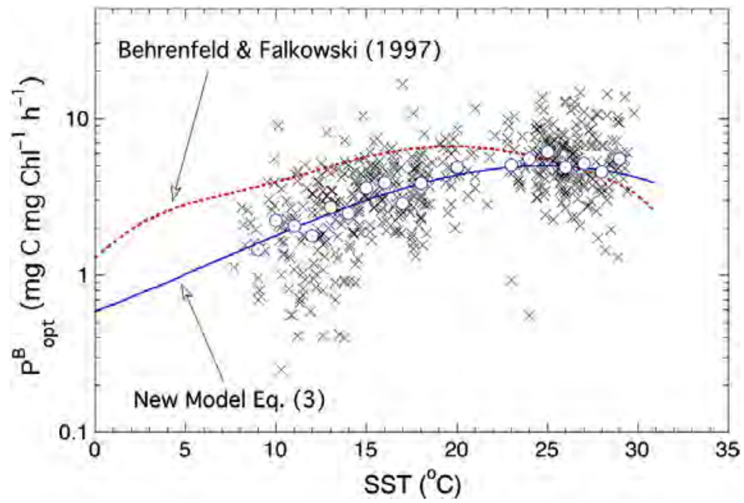

Figure 9. Optimal photosynthetic carbon fixation rate (P^B_{opt}) as a function of SST for the Chesapeake Bay.

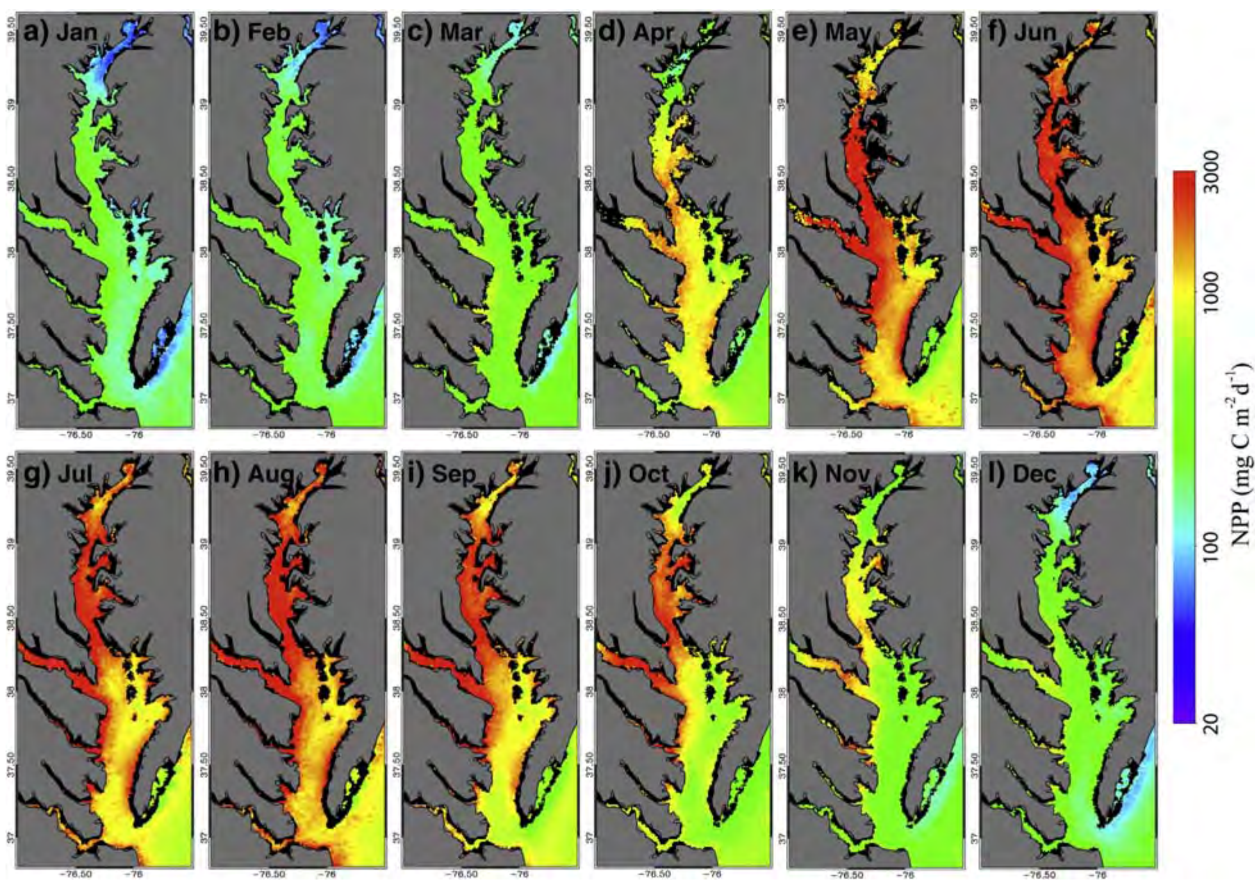

Figure 10. MODIS-Aqua-derived monthly climatology Net Primary Production images for the Chesapeake Bay for months of January to December.

PROJECT TITLE: NESDIS Environmental Applications Team – Liqin Tan, Research Associate

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Liqin Tan

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Menghua Wang (NOAA team lead)

PROJECT OBJECTIVES:

--Performing VIIRS instrument characterization and calibration for ocean color (OC) data processing and applications. Evaluating the effect of VIIRS instrument performance on the science data quality and quantify the impact
--Understanding, evaluation, and refining VIIRS ocean color (OC) data processing system

PROJECT ACCOMPLISHMENTS:

--Compiled and tested two updates of JPSS Algorithm Development Library (ADL) software (ADL4.1_Mx7.1 and ADL4.2) on NOAA STAR server. Improved our internal ADL based off-line VIIRS RDR to SDR data process system for VIIRS RDR to Ocean Color EDR reprocess at selected regions and global scale, based on algorithm changes and calibration coefficient Look-up-table (LUT) update . Studied the new IDPS Mx8 SDR code and LUTs updates of RSBAutoCal.

--Contributed to the research of the impact of VIIRS SDR performance on ocean color products. Completed four months (Jan/Apr/Jul/Oct, 2012) global historic VIIRS RDR to SDR data reprocessing using ADL4.1 with the updated F factor LUT (provided by Aerospace on 20130130) for this study. Co-authored the JGR paper for this study.

--Contributed to the development and testing of a more efficient new F factor ratio method for VIIRS SDR data reprocessing from old SDR data and updated F factor. Co-authored the paper for this result. Applying this method will significantly reduce the required CPU time and data storage for mission-long global VIIRS SDR reprocessing.

--Developed tools to retrieve VIIRS gain status data from the raw VIIRS RDR. Generated the VIIRS gain status data since the beginning of VIIRS mission, as input required by the new F factor ratio method for VIIRS SDR data reprocessing.

--Continue performed Hawaii MOBY site historical VIIRS RDR to SDR data reprocessing, using the different updated calibration algorithms and F LUTs from VIIRS SDR team (AEROSPACE), for OCC EDR reprocessing and situ data calibration. Completed the historical VIIRS RDR to SDR data reprocessing for other selected data validation match-up sites (SPG, AERONET-OC, BOUSSOLE, USEC, YECS, etc.) to support VIIRS SDR and OCC EDR data evaluation using both IDPS and NOAA-MSL12 .

--Provide VIIRS Level 1 technical support to the team by cooperation with the VIIRS SDR team. Participated in VIIRS SDR team weekly teleconference. Provided feedback to VIIRS SDR team for SDR improvement. Monitoring JPSS algorithm collaboration activities, IDPS operation code builds status, and Discrepancy Record (DR). Continue retrieved the most updated IDPS VIIRS calibration coefficient LUTs from the Raytheon Common CM VOB of FastTrack. Conducted VIIRS SDR calibration F LUT comparison and SDR evaluation, IDPS SDR all granule information retrieving, VIIRS verified RDR generation from raw RDR, IDPS SDR anomaly tracking during government shutdown, and VIIRS OCC EDR DR submitting, etc.

Publication Abstracts:

Title: Impacts of VIIRS SDR performance on ocean color products

Author(s): Menghua Wang, Xiaoming Liu, Liqin Tan, Lide Jiang, SeungHyun Son, Wei Shi, Kameron Rausch, and Kenneth Voss

Status: Published. J. Geophys. Res. Atmos., 118, 10,347–10,360, 2013.

Abstract:
One of the primary goals for the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi National Polar-orbiting Partnership is to provide the science and user communities with the data continuity of the Environmental Data Records (EDR) (or Level-2 products) over global oceanic waters for various research and applications, including assessment of climatic and environmental variations. The ocean color EDR is one of the most important products derived from VIIRS. Since ocean color EDR is processed from the upstream Sensor Data Records (SDR) (or Level-1B data), the objective of this study is to evaluate the impact of the SDR on the VIIRS ocean color EDR. The quality of the SDR relies on prelaunch sensor characterizations as well as on-orbit radiometric calibrations, which are used to develop the sensor F-factor lookup tables (F-LUTs). VIIRS F-LUTs derived from solar and lunar calibrations have been used in processing data from the VIIRS Raw Data Records (or Level-0 data) to SDR. In this study, three sets of F-LUTs with different generation schemes have been used to reprocess the SDR and then the ocean color EDR for product evaluations. VIIRS ocean color products are compared with in situ data from the Marine Optical Buoy and products from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the satellite Aqua. It is found that the data quality of VIIRS operational ocean color products before 6 February 2012 is poor due to the inappropriate use of the at-launch F-LUTs for the SDR calibration, and that the recently updated VIIRS F-LUTs have significantly improved the SDR and ocean color EDR. Using reprocessed SDR with updated F-LUTs and including vicarious calibration, VIIRS ocean color EDR products are consistent with those from MODIS-Aqua in global deep waters. Although there are still some significant issues with VIIRS ocean color EDR, e.g., poor data quality over coastal regions, our results demonstrate that VIIRS has great potential to provide the science and user communities with consistently high-quality global ocean color data records that are established from heritage ocean color sensors such as MODIS-Aqua.

Title: An Efficient Approach for VIIRS RDR to SDR Data Processing

Author(s): Junqiang Sun, Menghua Wang, Liqin Tan, and Lide Jiang

Status: Submitted to JGR

Abstract:
The Visible Infrared Imaging Radiometer Suite (VIIRS) Raw Data Records (RDR) (or Level-0 data) are processed using the current standard Algorithm Development Library (ADL) to produce Sensor Data Records (SDR) (or Level-1B data). The ocean color Environmental Data Records (EDR), one of the most important product sets derived from VIIRS, are processed from the SDR of the visible and near-infrared (NIR) moderate resolution (M) bands. As the ocean color EDR are highly sensitive to the quality of the SDR, the bands from which the EDR data arise must be accurately calibrated. These bands are calibrated on-orbit using the on-board Solar Diffuser (SD) and the derived calibration coefficients are called F-factors. The F-factors used in the forward operational process may have large uncertainty due to various reasons, and thus to obtain high quality ocean color EDR, the SDR needs to be reprocessed with improved F-factors. The SDR reprocessing, however, requires tremendous computational power and storage space, which is about 27 terabytes for one year of ocean color related SDR data. In this letter, we present an efficient and robust method for reduction of the computational demand and storage requirement. The method is developed based on the linear relationship between the SDR radiance/reflectance and the F-factors. With this linear relationship, the new SDR radiance/reflectance can be calculated from the original SDR radiance/28 reflectance and the ratio of the updated and the

original F-factors at approximately 100th or less of the original CP requirement. The produced SDR with this new approach fully agrees with those generated using the ADL package. This new approach can also be implemented to directly update the SDR in the EDR data processing, which eliminates the hassle of a huge data storage requirement as well as that of intensive computational demand. This approach may also be applied to other remote sensors for data reprocessing from raw instrument data to science data.

PROJECT TITLE: NESDIS Environmental Applications Team – Sirish Uprety, Research Associate - Suomi NPP VIIRS Calibration and Validation

PRINCIPAL INVESTIGATOR: Steven Miller

RESEARCH TEAM: Sirish Uprety

NOAA TECHNICAL CONTACT: Changyong Cao (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Changyong Cao

PROJECT OBJECTIVES:

On-orbit calibration and validation of Suomi NPP VIIRS
1--Evaluate the radiometric performance of S-NPP VIIRS by doing inter-comparison at SNO and SNO-x with MODIS
2--Develop automated system to estimate the S-NPP VIIRS radiometric bias at high latitudes (SNO) and at low latitudes (SNO-x)
3--Evaluate the Radiometric consistency of VIIRS and NOAA series AVHRR

PROJECT ACCOMPLISHMENTS:

1--Evaluate the radiometric performance of S-NPP VIIRS by doing inter-comparison at SNO and SNO-x with MODIS

S-NPP VIIRS has undergone through extensive calibration and validation since launch. There are a number of events when the cal/val look-up tables has been modified or changed to account for instrument degradation and increase the radiometric accuracy. One of the crucial technique in evaluating the calibration stability and absolute radiometric accuracy is by comparing VIIRS with other well calibrated instruments such as MODIS. VIIRS and MODIS intercomparison has been continuously analyzed to monitor the radiometric performance of VIIRS. Figure 1 shows the radiometric bias time series of VIIRS blue bands relative to matching MODIS bands estimated using SNO-x over desert. The time series indicates the calibration stability and accuracy of VIIRS since early launch.

2--Develop automated system to estimate the S-NPP VIIRS radiometric bias at high latitudes (SNO) and at low latitudes (SNO-x):

The development of automated system to monitor VIIRS radiometric performance using SNO and SNO-x is ongoing. The automated system saves time needed for manual steps during collection and processing of the data. The automated system for high latitude SNO is nearly complete and is undergoing testing. For low latitude extended SNOs, adaptive algorithm is needed to accurately generate the valid region of interests for comparison. This tool lets users monitor and analyze the VIIRS radiometric accuracy continuously over time. The similar technique can be used in the future to evaluate the radiometric consistency of VIIRS with other instruments as well.

3--Evaluate the Radiometric consistency of VIIRS and NOAA series AVHRR:

Multiple independent cal/val studies since launch have suggested that the VIIRS absolute radiometric accuracy for most of the RSB bands is within 2%. VIIRS is a follow on mission for MODIS and AVHRR. It is very important to perform cross-comparison between VIIRS and NOAA series AVHRR to establish data continuity to multi-decadal Earth observation from AVHRR with VIIRS for global climate change studies. The study is done using extension of SNOs to low latitudes (SNO-x). The impact due to spectral differences of the matching bands of the two instruments is analyzed using hyperspectral measurements and MODTRAN. Figure 2 shows the observed bias time series of NOAA-19 AVHRR compared to VIIRS for AVHRR bands 1 and 2. The large bias for both channels is mainly due the spectral differences between AVHRR and matching VIIRS band and uncertainty in AVHRR calibration. The study has been done using nearly six months of data. The ultimate plan is to use the technique to expand the analysis over longer time period in an effort to establish data continuity between VIIRS and AVHRR data.

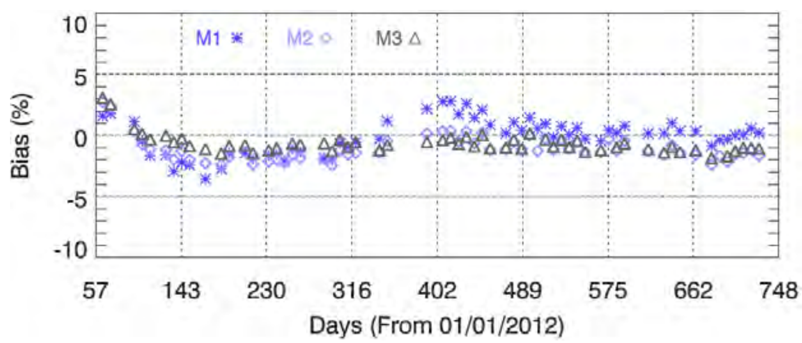

Figure 1. VIIRS bias time series relative to MODIS

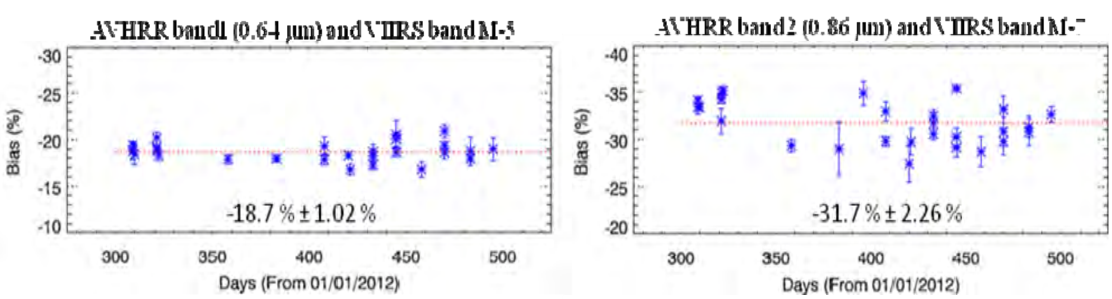

Figure 2. Bias time series estimated for NOAA-19 AVHRR relative to VIIRS.

PROJECT TITLE: NESDIS Environmental Applications Team – Xiao-Long Wang, Research Associate - Software Development for Satellite Data Analysis and Processing

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Xiao-Long Wang, Lide Jiang, Xiaoming Liu, Wei Shi, Liqin Tan and SeungHyun Son

NOAA TECHNICAL CONTACT: Menghua Wang (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Xiao-Long Wang, Lide Jiang, Xiaoming Liu, Wei Shi, Liqin Tan and SeungHyun Son (NOAA SOCD)

PROJECT OBJECTIVES:

Develop satellite data visualization and processing system to support NPP VIIRS, MODIS, MERIS, SeaWiFS, GOCI Ocean color products.

PROJECT ACCOMPLISHMENTS:

Actively made progresses on VIIRS image visualization for various products (SDR, EDR, L3bin, Quality Flags, Masks, etc.) and data analysis/processing.

1--Continuously integrated and realized VIIRS SDR and EDR image data display with IDL based satellite data processing system. Supported all VIIRS Ocean Color products in image visualization, image data manipulation, multiple band image difference computation, geo-registration, image mapping/re-projection, graphic output,

2--Enhanced system functions to display and overlay all VIIRS cloud mask, product quality flags, environmental flags (coastal turbid water, sun-glint, shallow water, bright pixels, etc.) to support image analysis. Supported VIIRS SDR I-band data in image visualization and data manipulation.

3--Performed global L3 data regional data extraction and computation to monitor trends of various ocean-color products (from multiple sensors or different algorithms). Enabled automatic routine operation to support VIIRS data analysis and validation.

4--Realized VIIRS true-color image creation and using multiple band data. Added this program as new processing function into the image visualization & analysis tool package. Made GUI design to allow analysis tool users to easily generate high quality true-color images with simple steps.

5--Upgraded image visualization tools with new ocean bathymetry data with higher resolution and better data coverage.

6--Implemented L3bin function to support VIIRS L3 binning processing.

7--Provided GUI mode and command mode support to perform above image band data computations and image data analysis / processing system for group user's batch jobs and command scripts.

8--Conducted test for possible VIIRS data archive or distribution in web-based THREDDS data server with NetCDF format.

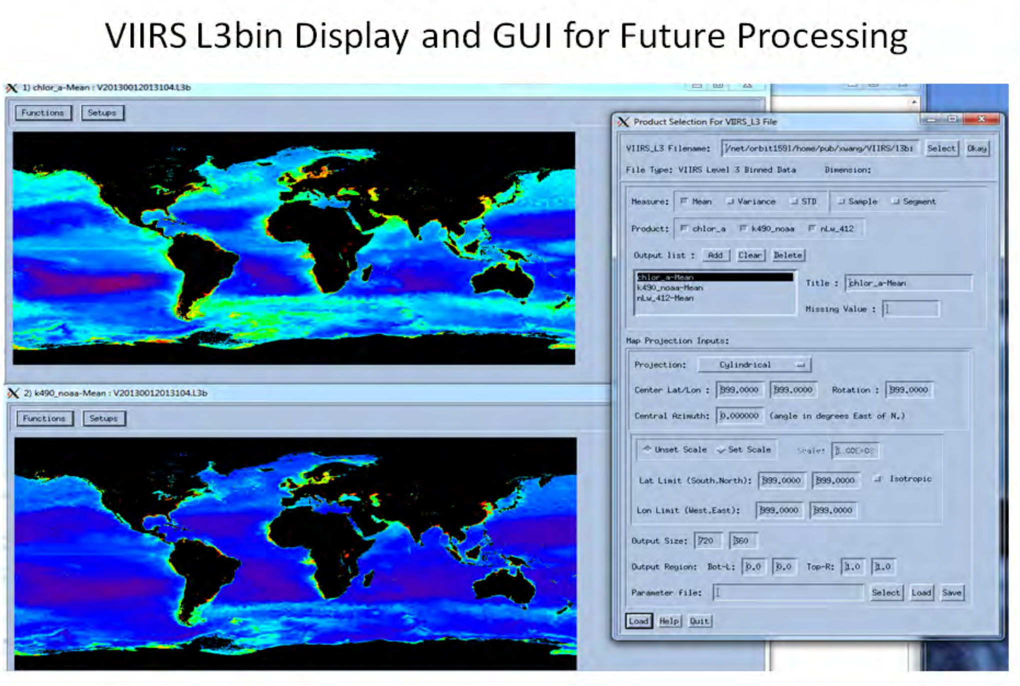

Figure 1. Enabled VIIRS L3bin Function for Data Binning and Processing.

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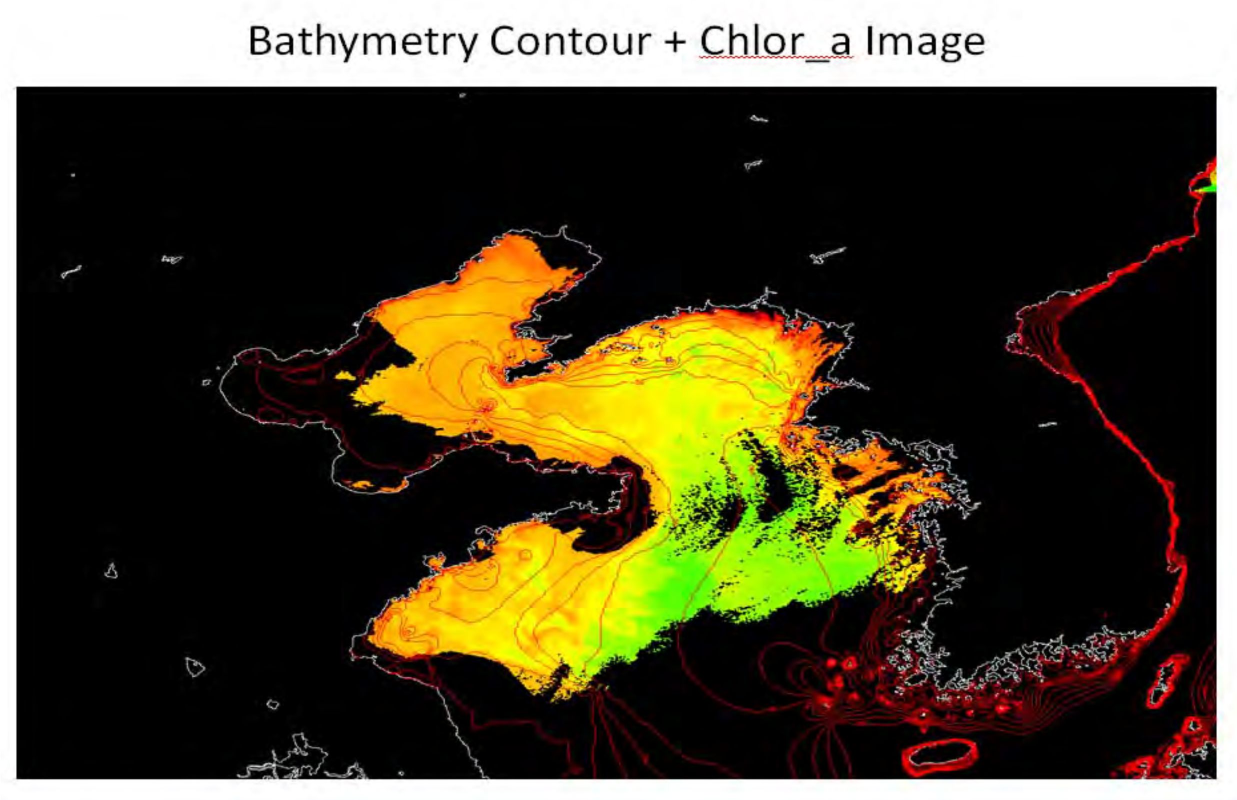


Figure 2. Updated Bathymetry Database to High Resolution

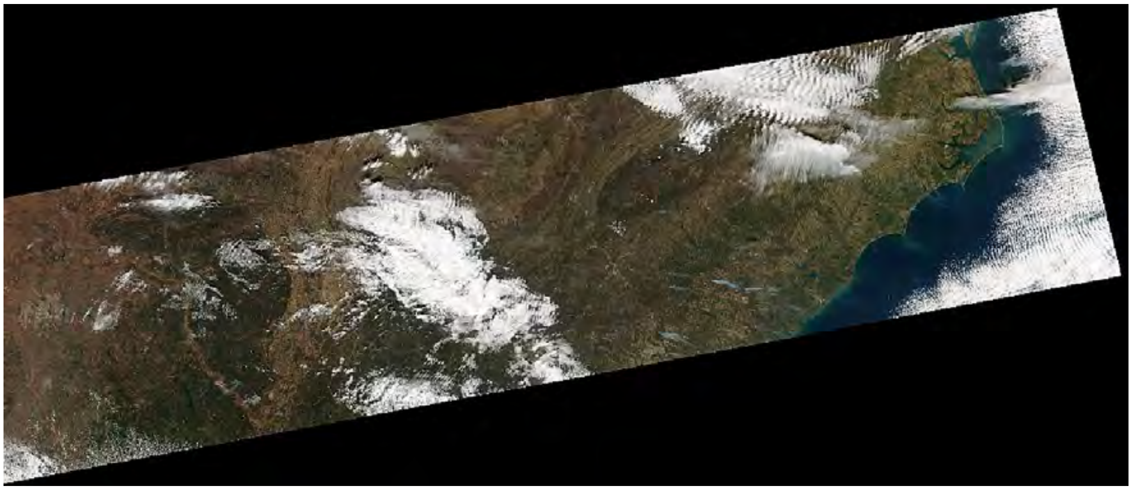


Figure 3. Mapped True-color Image from VIIRS SDR Granule Data

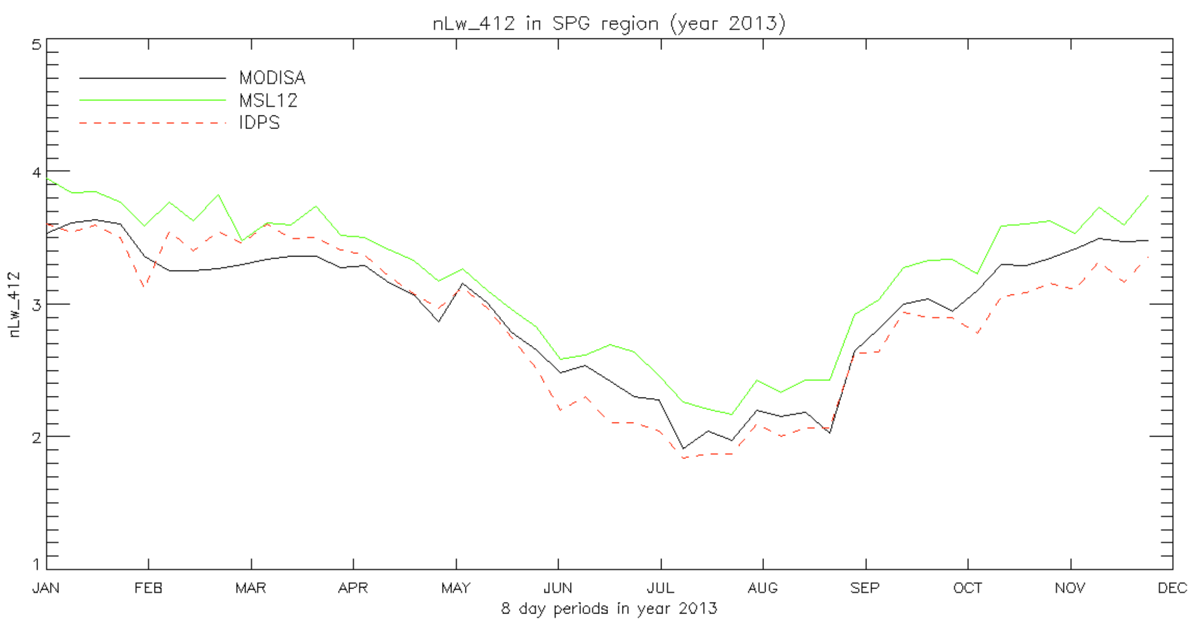


Figure 4. Regional extracted L3 product changes during Year 2013

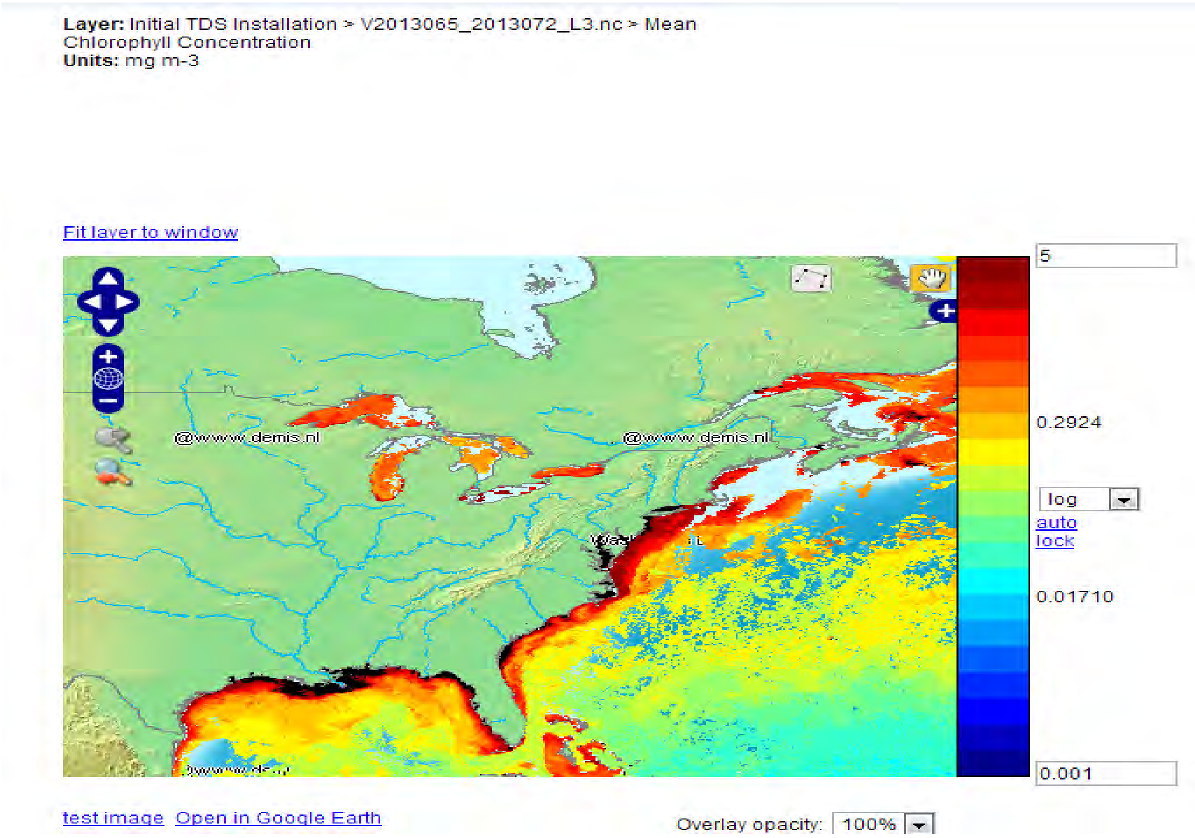


Figure 5. Test on THREDDS data server for possible VIIRS global data distribution.

PROJECT TITLE: NESDIS Environmental Applications Team – Xinjia Zhou, Research Associate

PRINCIPAL INVESTIGATOR(S) (CIRA/CSU PI): Steve Miller

RESEARCH TEAM: Xinjia Zhou, Prasanjit Dash, XingMing Liang

NOAA TECHNICAL CONTACT: Alexander Ignatov (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM: Alexander Ignatov (STAR), Feng Xu (GST, Inc.), Boris Petrenko (GST, Inc.), Yury Kihai (GST, Inc.), John Stroup (STG, Inc.)

PROJECT OBJECTIVES:

1--Build processing infrastructure for long-term Advanced Clear-Sky Processor for Oceans (ACSPO) Reanalysis (RAN) of AVHRR GAC SST products, perform ACSPO-RAN1, including match-ups with in situ data and publishing results on the web.

2--Perform analyses of NASA MODIS MO/YD28 SST products, publish results on the web.

3--Adapt SQUAM to publish new long-term L2 SST dataset (used in #1, 2).

4--Assume ownership of the in situ Quality Monitor (iQuam; http://www.star.nesdis.noaa.gov/sod/sst/iquam/); work towards IQuam version 2.

5--Sustain and manage the NOAA GOES-POES blended SST online monitoring system.

6--Develop ACSPO source code to add geostationary satellite data capability (SEVIRI sensor on board MSG satellite).

PROJECT ACCOMPLISHMENTS:

Objective 1: Generate, Analyze and Publish ACSPO-RAN AVHRR/GAC Product

Working with A. Ignatov, B. Petrenko, P. Dash, X. Liang, and Y. Kihai, ACSPO-RAN1 of AVHRR GAC SST product (2002-14) has been generated from NOAA-15, -16, -17, -18, -19, and Metop-A and -B, matched with iQuam in-situ data, and analyzed and displayed in SQUAM (www.star.nesdis.noaa.gov/sod/sst/squam/ACSPOGAC/index_rp.html) and in MICROS system (www.star.nesdis.noaa.gov/sod/sst/micros).

Based on lessons learned from RAN1, RAN2 is planned in 2014, pending updates in ACSPO and SQUAM, and release of iQuam v2.

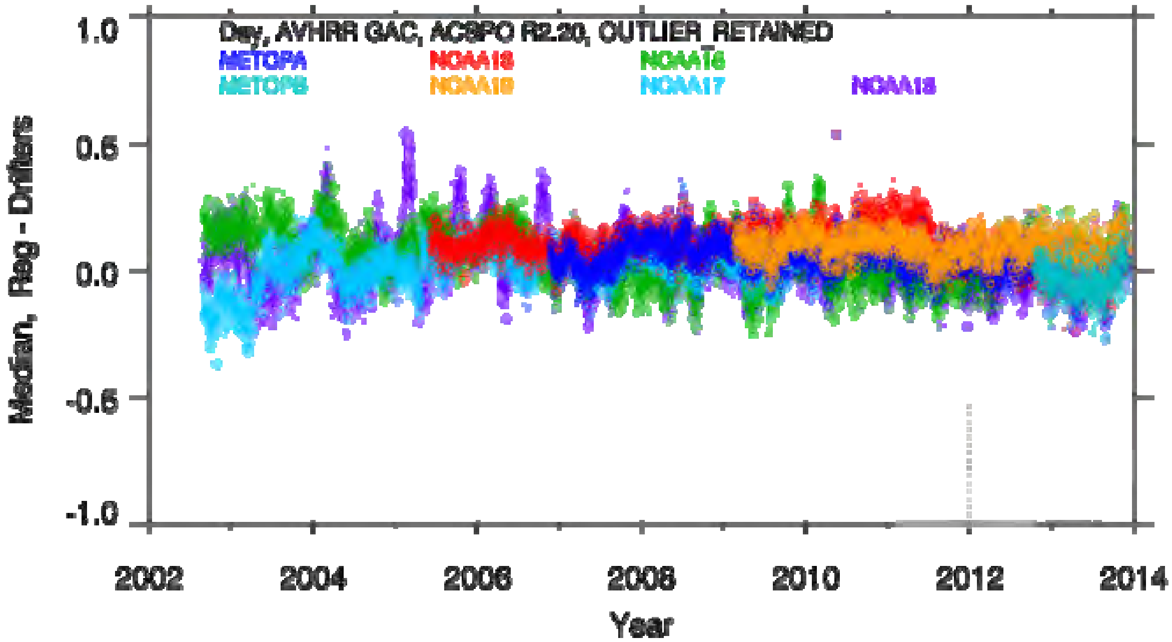
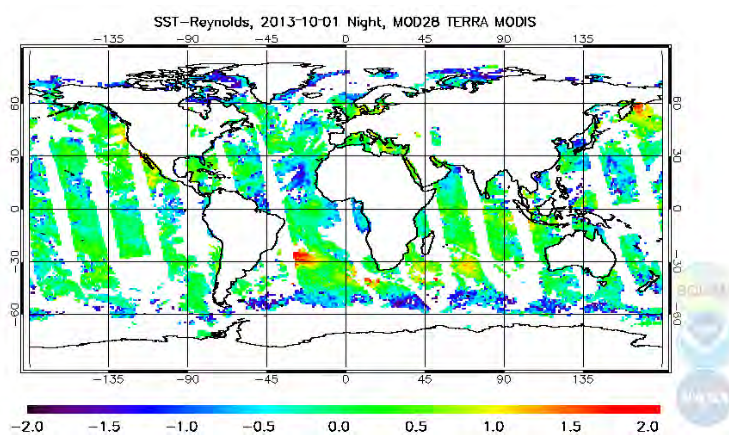


Figure 1. Time series of daytime ACSPO GAC L2 SST *minus* in-situ drifter SST daily mean biases.

Objective 2: Analyses of NASA MOD28 SST Dataset

Figure 2. Global map of mean bias (NASA MOD28/TERRA – Reynolds L4 SST) for 1 Oct 2013 (nighttime). Analysis was done to evaluate the NOAA ACSPO SST in L2-SQUAM. The plan is to extend the diagnostics and include full SST records for Terra (2000-pr) and Aqua (2002-pr).



NASA MOD28 SST product is an important level 2 sea surface temperature dataset. Work is underway to include it in L2-SQUAM, and comprehensively evaluate its performance in context of other available L2 SST products such as ACSPO. Preliminary results for 1 Oct 2013 have been processed and displayed in SQUAM.

Objective 3: Adapt SQUAM for long-term ACSPO reanalysis (RAN) products

SQUAM system developed by P. Dash was adapted to ACSPO-RAN project. Several new functions were added in SQUAM L2 RAN webpage, including 1), adding monthly statistic (aggregates of daily statistics); 2), adding outliers retained/removed radio button in all tabs; 3), reorganizing the buttons.

Objective 4: IQUAM Version 2 Development Is In Progress

The NOAA iQuam system developed by F. Xu was transition to X. Zhou for maintenance and development. Work is underway with F. Xu and A. Ignatov, to transition to version 2, which includes several major developments, including extending time series back ~1980 (from current 1991), including ARGO floats, ships in trackob format, and GHRSST drifting buoys. Quality controls will be improved. Back-up processing will be added to improve stability, and provide automatic gap-filling. Output format will change to netcdf4, which is the accepted standard in the SST community, occupies less disk space. The expected release time is Apr-May 2014.

Objective 5: Manage POES-GOES Blended SST Monitor Tool

The management includes control of these 4 web pages below,
http://www.star.nesdis.noaa.gov/sod/mecb/blended_validation/

http://www.star.nesdis.noaa.gov/sod/mecb/goes_validation/test/index.php

http://www.star.nesdis.noaa.gov/sod/mecb/mtsat_validation/index.php

http://www.star.nesdis.noaa.gov/sod/mecb/msg_validation/index.php

Objective 6: Development of Adding New Function Geostationary Satellite Data

Develop ACSPO source code to adopt geostationary satellite data (SEVIRI sensor on board MSG satellite).

PROJECT TITLE: NESDIS Environmental Applications Team – Tong Zhu, Research Scientist - Satellite Observation System Assessment and Optimization

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Tong Zhu

NOAA TECHNICAL CONTACT: Sid Boukabara (NOAA/NESDIS/JCSDA)

NOAA RESEARCH TEAM: Masutani (ESSIC@NOAA/NWS/NECP/EMC)
Jack Woollen (IMSG@NOAA/NWS/NECP/EMC)

PROJECT OBJECTIVES:

--Support the impact assessment of the global observing system at both global and regional scales,
--Support the JPSS data gap mitigate study,
--Support OSSE experiments through radiance simulations,
--Proxy data generation to improve future satellite data assimilation readiness,
--Support research in cloudy/raining data assimilation with an emphasis on extreme weather events.

PROJECT ACCOMPLISHMENTS:

1--Impacts of Satellite Data and Lateral Boundary Condition on Superstorm Sandy Forecast with HWRF

The geostationary satellite sensors can provide high spatial and temporal resolution observations, which are of great benefit in monitoring and forecasting severe weather events. To optimize the usage of geostationary satellite data in numerical weather prediction and study the potential impact of the Joint Polar Satellite System (JPSS) data coverage gap, a series of impact experiments were designed for the simulation of Superstorm Sandy by the Hurricane Weather Research and Forecasting Model (HWRF).

Limited area numerical models usually take global model input as initial and lateral boundary conditions. Before study the satellite data impact, it is necessary to first evaluate the impact of lateral boundary condition on the forecast skill. In the first group of sensitivity experiments, 5 different HWRF domain-1 sizes were employed for performing forecasts without the assimilation of satellite data. The second group experiments were the same as first group's but with the assimilation of satellite data. It was found that, for the 3-5 days forecasts, the forecasted storm track errors increased with the increase of domain-1 size up to BIG2 size for the experiment without satellite data, and the track errors increased up to BIG1 size experiment with the assimilation of satellite data. The forecast track errors and uncertainty of track errors (STD) were reduced with the assimilation of satellite data. The maximum wind and MSLP forecast errors were not affected by the changing of domain-1 size. These results indicate that the lateral boundary condition impact decreases with the increase of HWRF domain size, and the impact is reduced after assimilating satellite data. The next step is to study the geostationary satellite data impact with global GSI system by increasing the usage of satellite data in HWRF domain.

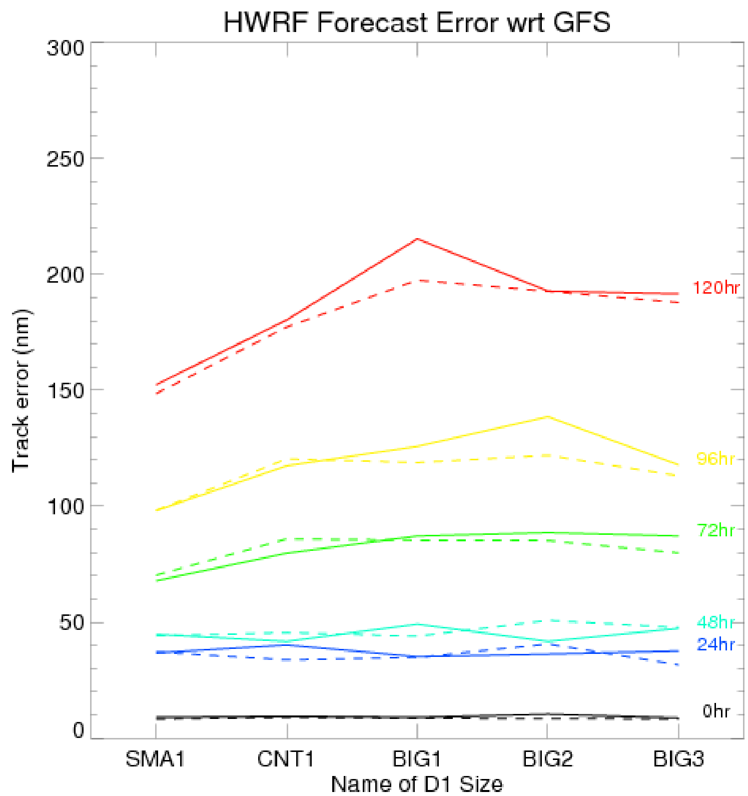


Figure 1. The 22 forecast cycles averaged forecast track errors w.r.t. GFS operational forecast from five different domain experiments. The solid and dashed curves are for the experiments without and with the assimilation of satellite data, respectively.

2--Adding OBS Error to Synthetic Radiances for Joint OSSE Study

To support JCSDA Joint OSSE project, we worked on adding observation errors to the synthetic radiance simulated from natural run for 2012 data base. The GMAO's observation error simulation package was connected to JCSDA radiance simulation tool. We found an error in the GMAO's package and fixed it by using a new seeding method for generating random errors. Figure 2 shows the comparison of biases and standard deviations between the simulated radiances before and after adding biases and/or random errors. It is found that the new error simulation package works well for adding biases and random errors to synthetic radiances.

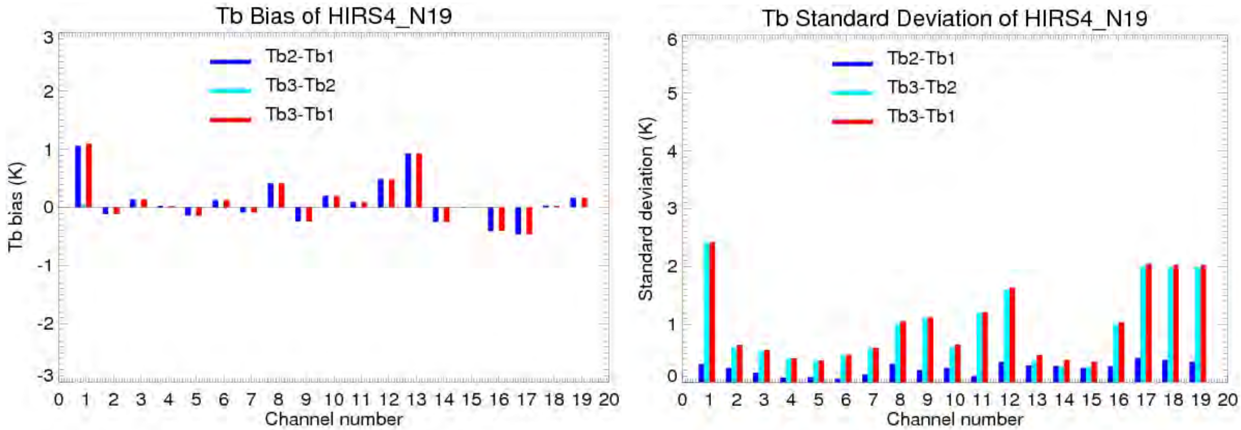


Figure 2. The (a) bias, and (b) standard deviation between original simulated radiance data (***T1***), after adding GSI bias to T1 (***T2***), after adding random error to T2 (***T3***) for HIRS4 sensor on NOAA-19 satellite.

PROJECT TITLE: RAMMB Infrastructure for Product Development, Demonstration and Operational Transition at CIRA/CSU

PRINCIPAL INVESTIGATOR**:** Renate Brummer

RESEARCH TEAM: Scott Longmore, Hiro Gosden, Steve Finley, Natalie Tourville

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM**:** Deb Molenar, Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

CIRA and RAMMB are key players in the GOES-R and JPSS Proving Ground. A large number of different Proving Ground products have been successfully demonstrated over the past years. We continued to upgrade and expand computer infrastructure to support our Proving Ground efforts. The National Weather Service (NWS) demonstrations required that CIRA/RAMMB products be created in compatible AWIPS II formats. The main focus during this reporting period was completion of the conversion of existing AWIPS I geostationary satellite Proving Ground products to AWIPS II, the development of new AWIPS II- compatible products, and the implementation of new real-time display and software development systems. Now that our additional AWIPS II development systems are in place, we are in a position to utilize the advanced AWIPS II capabilities to demonstrate the use of satellite data sets in AWIPS II at NWS offices and National Centers.

PROJECT ACCOMPLISHMENTS:

We received the necessary funds to continue our upgrade and expansion of the AWIPS II infrastructure at CIRA. Conversion of all of the AWIPS I geostationary satellite Proving Ground products to AWIPS II format has been completed. These products are currently being distributed to several NWS Forecast Offices (FO) that are on the leading edge of the new NWS AWIPS II deployment schedule. Conversion of the remaining AWIPS I MODIS products is now underway. CIRA successfully implemented several additional AWIPS II computer resources. The addition of a real-time AWIPS II workstation ingesting products from the NOAAPORT SBN has allowed research staff to obtain familiarity with the advanced capabilities provided by AWIPS II and to begin formulation of new research products which can take advantage of those capabilities. In addition, new systems were implemented to replace the 7 year old workstation (and backup system) that distribute AWIPS I products to the field so support to the extensive AWIPS I NWSFO and National Center clients can continue without interruption .

The addition of new AWIPS II ADE development workstations has provided the infrastructure for additional EPDT training of programming staff. RAMMB/CIRA staff attended several EPDT training sessions hosted by SPoRT, and continue participation in the Experimental Products Development Team (EPDT) working group projects and bi-weekly telecons. Software development staff is collaborating with other Proving Ground partners to implement a standardized AWIPS II product installation template that will be supported through the NWS Virtual Lab.

REGIONAL TO GLOBAL SCALE MODELING SYSTEMS

Research associated with the improvement of weather/climate models (minutes to months) that simulate and predict changes in the Earth system. Topics include atmospheric and ocean dynamics, radiative forcing, clouds and moist convection, land surface modeling, hydrology, and coupled modeling of the Earth system.

PROJECT TITLE: CIRA Support to Tropical Cyclone Model Diagnostics and Product Development

PRINCIPAL INVESTIGATOR: Wayne Schubert

RESEARCH TEAM: Kate Musgrave, Scott Longmore, Andrea Schumacher, Louie Grasso, Robert DeMaria, Chris Slocum, Kathy Fryer

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS/STAR) and Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: John Knaff, Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The National Oceanic and Atmospheric Administration (NOAA) initiated the Hurricane Forecast Improvement Project (HFIP) to reduce the errors in tropical cyclone track and intensity forecasts. This reduction will be accomplished through improved coupled ocean-atmosphere numerical hurricane models, better use of observations through advanced data assimilation techniques and ensemble forecasts. Model diagnostic techniques will also be developed to determine the sources of model errors and guide future improvements. The CIRA team performed seven tasks that contribute to this HFIP effort. Details on these tasks are described in the next section, focusing on the tasks that overlapped the reporting period (April 2013 – June 2013).

The CIRA HFIP activities directly address NOAA's Weather and Water goal, which seeks to serve society's needs for weather and water information. This research falls within the NOAA-defined CIRA thematic area of Satellite Algorithm Development.

PROJECT ACCOMPLISHMENTS: Covering April 2013 – June 2013 by Objective:

1—Continue development of large scale diagnostic code, run diagnostic code, and conduct verification for EMC for 2012 HWRF pre-implementation tests and during 2012 season

--Work continued on the development of diagnostic code, with emphasis on the HWRF and GFDL regional hurricane models. The emphasis was on parameters related to the storm environment, and a version was provided to the NCEP Environmental Modeling Center to assist with the model inter-comparison and pre-season testing and evaluation of the HWRF model. The latest version of the diagnostic code was delivered to EMC and several other modeling groups in 2013, for use in the next round of pre-implementation tests and during the season. CIRA continued to develop new capabilities for model diagnostics in order to enhance the code. In continuation of last year's work, these studies included the adapting balance model theory and vortex structure evaluation capabilities, using the vortex profile originally developed by Holland (1980).

2—Experimental product development including ensemble product tests

--Work on the CIRA SPICE (Statistical Prediction of Intensity with a Consensus Ensemble) project included an updated version of SPICE with new HFIP model inputs including ensembles. The updated version of SPICE with three model inputs was run in stream 1.5 during the 2012 season, and was evaluated at the end of the season. The version of SPICE including ensembles was tested for limited cases for the 2009-2012 seasons. SPICE was run on the 2010-2012 seasons as part of the retrospective testing process for stream 1.5, and the results are shown in Figure 1.

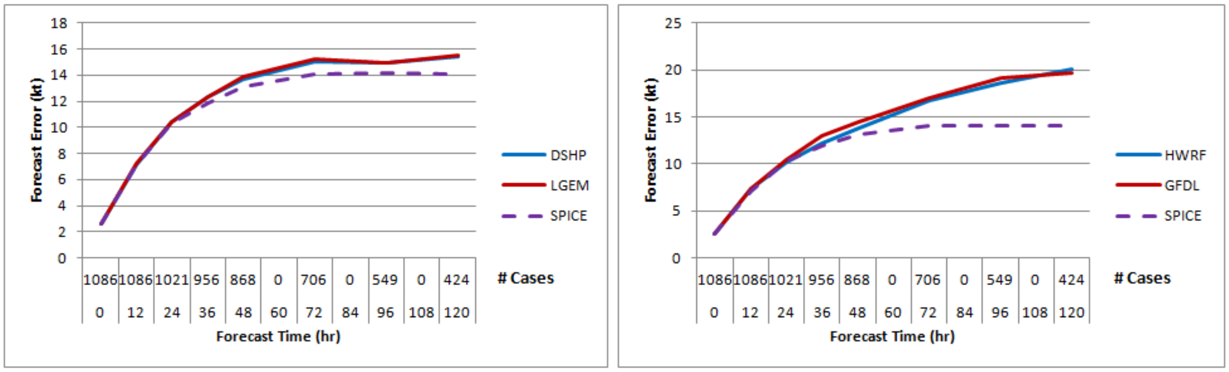


Figure 1. Mean absolute error (in kt) for forecast intensity for the retrospective runs of the 2010-2012 Atlantic hurricane seasons. The left panel features Decay-SHIPS (blue), LGEM (red), and SPICE (purple dashed), while the right panel festures HWRF (blue), GFDL (red), and SPICE (purple dashed).

3—Support of hurricane observations

--CIRA/RAMMB continued to maintain and to populate its real-time TC website. In addition we developed geostationary datasets and Fortran90 code for reading: Storm-scale, Mercator projection (Atlantic, East Pacific, Central Pacific), IR channels 2-6; and full-disk, satellite projection, channels 3 and 4, both from GOES-East and West.

4-- Develop and implement a comprehensive TC tracking scheme

--CIRA developed and implemented a comprehensive TC tracking scheme that provides detailed TC parameters for the LGEM and DSHIPS model and for operational forecasting applications and for use in SPICE. We also applied global-only ensembles consisting of GFS and FIM members for improved consensus intensity prediction. We compare raw model versus statistically post-processed intensity. This work was performed in coordination with ESRL.

PROJECT TITLE: EAR - Rapid Update Cycle (RUC)/WRF (RAP) Model Development and Enhancement

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Kevin Brundage, Tracy Smith

NOAA TECHNICAL CONTACT: Stanley Benjamin (NOAA/OAR/ESRL/GSD/AMB Chief)

PROJECT OBJECTIVES:

The primary focus of the GSD Assimilation and Modeling Branch is the refinement and enhancement of the Rapid Refresh, High Resolution Rapid Refresh (RAP and HRRR) and development of the Weather Research and Forecast (WRF) model. The RAP replaced the operational Rapid Update Cycle (RUC) 1 May 2012, becoming the operational short-range model at the NOAA/NWS National Centers for Environmental Prediction (NCEP). RAP Version 2 was implemented at NCEP on 25 February 2014. In addition to refinement and enhancements of the RR and HRRR, CIRA researchers collaborate on the development of the Weather Research and Forecast (WRF) model used by CIRA and GSD researchers.

CIRA staff is also involved in development and support of the Finite-volume Flow-following Icosahedral global NWP model (FIM/iHYCOM). The FIM model utilizes an icosahedral horizontal grid structure and an adaptive hybrid isentropic-sigma vertical coordinate and finite-volume horizontal transport mechanism. A coupled ocean model, based on the National Ocean Partnership Program's (NOPP) HYCOM model with a horizontal structure compatible with FIMs was incorporated in 2012. The 15km version of the FIM provided guidance forecasts to the National Hurricane Center again during 2013 and is scheduled to participate in 2014.

PROJECT ACCOMPLISHMENTS:

The operational Rapid Refresh (RAP) short range (0-18h) forecasting system was upgraded in February of 2014. This WRF-based model provides enhanced resolution and has proven to improve forecasts of winds aloft and precipitation—two critical elements required by aviation forecasters. Several parallel research versions of the RAP and the HRRR are also run in real time to test new data sources and algorithms. A robust retrospective system to evaluate seasonal effects as well as new algorithms and data sources is also a key part of our research. The RUC has continued to be supported at the request of the Storm Prediction Center.

The global FIM model provided experimental guidance at the National Hurricane Center as part of the NOAA Hurricane Forecast Improvement Project (HFIP) during the 2013 hurricane season. Storm track data generated by the FIM provided predicted hurricane tracks as part of this important experiment. Experience gained from this active season provided important feedback used to improve the model physics utilized in this model.

In addition to the important model development work conducted during 2012, CIRA personnel also provided integration testing, support and consulting expertise for the recently installed Zeus NOAA R&D computational facilities. This 382 Tflop high performance computing system was installed at the NOAA Environmental Security Computing Center (NESCC) in late 2011. This system provides over 27,600 computational cores to support the R&D efforts throughout NOAA.

Please see the real time products and additional information available at:
http://rapidrefresh.noaa.gov/RR/
http://rapidrefresh.noaa.gov/hrrr/
http://fim.noaa.gov

PROJECT TITLE: EAR - Rapid Update Cycle (RUC) Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) Models Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Brian Jamison, Ed Szoke

NOAA TECHNICAL CONTACT: Steven Weygandt (NOAA/OAR/ESRL/GSD/AMB)

PROJECT OBJECTIVES:

Tasks for this project include: creation and management of automated scripts that generate real-time graphics of output fields, management of web sites for display of those graphics, and management of graphics for hallway public displays.

PROJECT ACCOMPLISHMENTS:

Each of the web pages for RAP http://rapidrefresh.noaa.gov/RAP/ , HRRR http://rapidrefresh.noaa.gov/HRRR/ , and RUC http://ruc.noaa.gov/RUC/ have been refined with new developmental model versions, better graphics and new fields.

Two new developmental models have been added for the HRRR and one for the RAP, including all subdomains and soundings. New soundings locations were also added to the web page with sounding plots http://rapidrefresh.noaa.gov/soundings/ .

Many improvements and some new products were added to the model suites, including cross sections of potential temperature, wind, and total condensate for the HRRR. New processing techniques provide faster production of graphics and better use of space saving applications allow for more products to be added and managed.

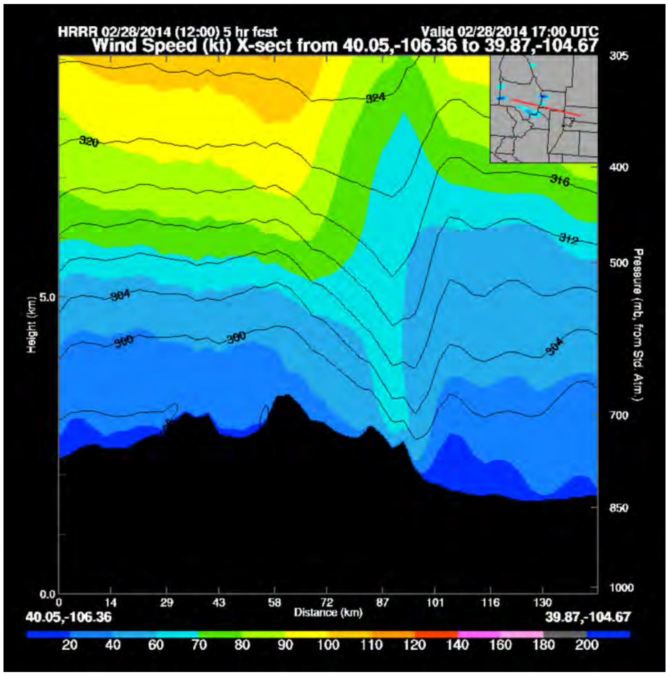


Figure 1. HRRR cross section of wind speed and potential temperature through Boulder. The inset is composite reflectivity and shows the plan view transect line.

A dual-monitor hallway display on the second floor of the David Skaggs Research Center (DSRC) displays HRRR model graphics for public viewing. Currently, a montage loop of four output fields is regularly displayed and updated automatically.

PROJECT TITLE: EAR - Advanced High Performance Computing

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Thomas Henderson, Jacques Middlecoff, James Rosinski, Jeff Smith, Ning Wang

NOAA TECHNICAL CONTACT: Mark Govett (NOAA/OAR/ESRL/GSD/ACE)

PROJECT OBJECTIVES:

--Collaborate with ESRL meteorologists with the objective of running the Non-hydrostatic Icosahedral Model (NIM) at sub 5KM global resolution. Running at 5KM resolution requires accelerator technology and research in the area of grid generation and optimization, pre- and post-processing, and development of numerical algorithms. Running NIM at 5KM resolution also requires the enhancement of the software suite known as the Scalable Modeling System (SMS).
--Provide software support to ESRL scientists including software design advice and expertise on a variety of software/web/database technologies. CIRA researchers continue to modify the Flow-following, Finite volume Icosahedral Model (FIM) software to enhance interoperability with NCEP's NEMS architecture implemented via the ESMF and continue to collaborate closely with Tom Black and others at NCEP to further generalize the NEMS ESMF approach so it meets requirements of NCEP models (GFS, NMMB) as well as FIM.
--Interact with the ESMF Core development team to specify requirements for features needed by FIM, NIM, and other NOAA codes.
--Serve on the National Unified Operational Prediction Capability (NUOPC) Common Model Architecture (CMA) and Content Standards subcommittees.
--Fine-tune software engineering processes used during FIM development, ensuring that these processes remain suitable for a candidate production NWP code, optimize FIM run-time performance, port FIM to new machines, and incorporate new features such as the ongoing integration of WRF-CHEM and WRF-ARW physics into FIM.
--Collaborate with the Developmental Testbed Center Ensemble Team (DET) to modify WRF Portal to support running complex WRF ensembles on the GSD Jet and TACC Ranger supercomputers. Also develop, improve, and support WRF Portal, FIM Portal, and WRF Domain Wizard.
--Develop improved capabilities in the (NextGen) CSS-Wx Testing Portal—a Flash web application (with server side Java) that tests NextGen OGC web services (WFS, WCS, and RegRep), performs load tests, generates graphs and reports, and enables guided ad-hoc querying of these web services.
--Serve on the GSD program review committee and the NOAA Earth Information System (NEIS) committee (a project listed in NOAA's 2011 Annual Guidance Memorandum as a priority for NOAA).
--Collaborate with CIRES researchers to develop TerraViz—a 3D visualization application for environmental datasets (similar in some respects to Google Earth) that is a core component of NEIS.
--Assist the Space Weather Prediction Center in maintaining the Ionosphere Plasmasphere Electrodynamics (IPE) code.

PROJECT ACCOMPLISHMENTS:

CIRA researchers continued to optimize serial and parallel NIM on NVIDIA GPU, Intel Xeon Phi, and CPUs from Intel and AMD. They continued to use NIM as a test case to investigate the stability and features of new commercial OpenACC GPU compilers from CAPS, Portland Group, and Cray and for the

Intel compiler for the Xeon Phi. Note that Xeon Phi is the Intel product that competes directly with NVIDIA's GPUs in the massively parallel fine-grained (MPFG) arena. Several stand-alone test cases were created and shipped to vendors to illustrate specific shortcomings of vendor products. Many compiler bugs and limitations were found and fed back to the vendors yielding improved products that better address our needs. CIRA researchers improved I/O and OpenMP performance of NIM. They repeatedly integrated major changes from the model developers onto the NIM trunk and parallelized for both distributed-memory parallel and MPFG architectures.

CIRA researchers created a NIM dynamics benchmark for the HIWPP procurement (in support of the NOAA CIO). This effort included porting and tuning, creating input and output datasets and assessment criteria, creating documentation for vendor benchmarkers, and answering vendor questions. This is the only benchmark in the procurement that is performance-portable to Intel CPU, AMD CPU, NVIDIA GPU, and Intel Xeon Phi architectures.

CIRA researchers enhanced the capabilities of SMS including processor-to-processor communication (exchange). The SMS exchange function was completely redone including allocating buffers as mapped pinned memory to utilize zero-copy, completely re-writing the pack and unpack routines in CUDA, and pre-calculating and caching initialization variables for each exchange type. As a result of the exchange enhancements, NIM exchanges on the GPU went from 51% of the total time to 14% and showed significant improvement on the Xeon Phi and some improvement on the CPU. CIRA researchers guided and advised CIRES researchers who replaced the SMS pre-processor with a new pre-processor based on modern compiler technology that understands Fortran90. They continue to assist SMS users and to find and fix bugs.

CIRA researchers supported ongoing development of the IPE code by adding periodic boundary conditions and periodically updating to the latest version of SMS. They worked with SWPC IPE developers and the ESMF core team to define requirements for WAM-IPE coupling.

CIRA researchers assisted FIM developers with integration, parallelization errors, test suite issues, I/O issues, repository issues, interruptions in real-time runs, and general debugging. They assisted the FIM team to set up high-profile 10km FIM runs used by Sandy MacDonald in an AMS talk.

CIRA researchers continued collaborating with NCEP, Navy, NCAR, and NASA to define aspects of a Common Modeling Architecture (CMA) for the National Unified Operational Prediction Capability (NUOPC). The primary objective of the NUOPC's CMA is to reduce long-term costs of integrating and sharing software between the nation's three operational global weather prediction centers—AFWA, FNMOC, and NCEP. They also served on the NUOPC Content Standards Committee (CSC) to define meta-data conventions to be shared by operational NWP models. CIRA researchers visited NCEP to discuss progress on GPU work with NCEP model developers and managers. They began collaborating with NCEP's John Michalakes on porting NWP codes to Intel Xeon Phi. And they continued attending NCEP's weekly UMIG meetings to discuss ongoing upgrades to NEMS and ensure that FIM continues to be NEMS-compliant.

CIRA researchers continued evaluating Intel's Xeon Phi (a.k.a. MIC, a.k.a. KNC) for the FIM and NIM models. OpenMP was used initially to port NIM dynamics and physics to the Xeon Phi and NIM was ported to TACC "stampede" and internal Intel machines. This required addition of WRF-style "tiling" loops to GRIMS physics. We worked closely with an Intel team led by Mike Greenfield to tune performance of NIM on Xeon Phi without adversely impacting performance on traditional CPU architectures. Performance was tuned for hybrid ("symmetric") runs made on combinations of CPU and Xeon Phi hardware. Adopted "cache-blocking" scheme from John Michalakes' work on WSM5 microphysics scheme to WSM3 scheme used in GRIMS physics in NIM. Tuned performance with assistance from Mike Greenfield's group.

CIRA researchers continued to improve software engineering processes for FIM and NIM. Assisted NIM users from CSU.

CIRA researchers worked with NIM scientists to integrate new GRIMS physics packages and extend test suite coverage to include them. Discovered a bug in the GRIMS physics informed GRIMS authors (Yonsei University) who applied the bug fix to their repository. CIRA researchers assisted NIM scientists with implementation of model restart. They assisted NIM scientists with MPAS build and run issues as they began integrating MPAS physics packages into NIM. CIRA researchers created a double-precision version of NIM for evaluation by NIM scientists.

CIRA researchers ported NIM to gaea and titan and optimized NIM for the NVIDIA K20X GPU and AMD CPU. CIRA researchers ported the NIM test suite to gaea and verified bitwise-exact match between NIM dynamics-only runs made on NVIDIA GPU, AMD CPU, Intel CPU, and Intel Xeon Phi. CIRA researchers ported the NIM trunk to the PGI compiler and worked with Cray to port NIM to the Cray compiler.

CIRA researchers attended several meetings and gave some talks on GPU and Xeon Phi research at the "Programming Weather, Climate, and Earth Systems Models" workshop, GPU Technology Conference, the GRIMS workshop in South Korea (invited), the ACS program review, an XSEDE workshop, the AOLI meeting at FSU, an RRTMG meeting at NCAR, and Supercomputing 13.

PROJECT TITLE: EAR - Flow-following Finite-volume Icosahedral Model (FIM) Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Brian Jamison, Ning Wang, Ed Szoke

NOAA TECHNICAL CONTACT: Stanley Benjamin (NOAA/OAR/ESRL/GSD/AMB Chief)

NOAA RESEARCH TEAM: Jian-Wen Bao, OAR/ESRL/PSD; Mark Govett, OAR/ESRL/GSD/ACE

PROJECT OBJECTIVES:

Tasks for this project include: developing and improving FIM for global and continental scale weather prediction, developing and implementing accurate and efficient numerical schemes for FIM on massive parallel computer systems, generating graphics of output fields, creation and management of websites for display of those graphics, and creation and management of graphics for hallway public displays, including software for automatic real-time updates.

PROJECT ACCOMPLISHMENTS:

Several efforts were achieved to improve FIM model numerics and its implementation on the sphere. An improved Spherical Linear INTerpolation (SLINT) was implemented which provides direct interpolation to subdomain regions from the native icosahedral grid, instead of the 0.5 degree grid. This improves processing speed and provides more accurate output fields. A new icosahedral grid construction algorithm for horizontal grid generation was implemented, as was a native grid plot utility, plot icos, to help icosahedral model debugging.

A web site for display of FIM model output http://fim.noaa.gov/FIM/ was updated and currently has 10 separate versions of FIM with 46 products available in 21 regions for perusal with 6-hourly forecasts going out to 14 days. Many new regions are available, including an expanded Arctic region, a region centered on Cambodia, and subregions of the continental United States. Also available are GFS model forecast plots, FIMX (a version with chemistry, for which 10 more products are available for viewing), and higher resolution versions at 15km and 10km grid spacing. Difference plots are generated and are available, as are plots of forecast error. Cross sections are also being generated and are available at http://fim.noaa.gov/FIMxs/ .

Many improvements and some new products were added to the model suites, including 12 and 24-hour total precipitation, shortwave and longwave radiation, and products from potential vorticity based fields.

New processing techniques were installed to efficiently generate GRIB and binary data on multiple grids and provide faster production of graphics and better use of space saving applications to allow for products to be added and managed.

A dual-monitor hallway display on the second floor of the David Skaggs Research Center (DSRC) displays FIM model graphics for public viewing. Currently, a montage loop of four output fields is displayed and updated regularly.

PROJECT TITLE: EAR - Nonhydrostatic Icosahedral Model (NIM) Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Ning Wang, Ka Yee Wong, Jung-Eun Kim, Thomas Henderson, Jacques Middlecoff, and James Rosinski

NOAA TECHNICAL CONTACT: Jin Luen Lee (NOAA/OAR/ESRL/GSD/OD)

NOAA RESEARCH TEAM: Jian-Wen Bao, (OAR/ESRL/PSD), Mark Govett (OAR/ESRL/GSD/ACE)

PROJECT OBJECTIVES:

--Develop Nonhydrostatic Icosahedral Model (NIM) for kilometer-scale resolution on multiple graphical processing units
--Explicit prediction of small-scale weather systems such as topographic precipitation as well as convective macro-phenomenon like the Madden-Julian Oscillation (MJO)
--Diagnose and resolve atmospheric phenomenon using the NIM modeling system

PROJECT ACCOMPLISHMENTS:

--Prepared dynamics and physics software for parallel CPU and GPU processing
--Improved and prepared pre-processing and post-processing software for parallel CPU and GPU processing
--Performed and analyzed NIM/GRIMs aqua-planet simulation due to different vertical resolutions (32, 64, and 96 layers)
--Upgraded the debugging and diagnostic package for NIM output analysis and visualization in aqua-planet case and real data case

PROJECT TITLE: EAR - Fire Weather Modeling and Research

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Sher Schranz

NOAA TECHNICAL CONTACT: Elliot Jacks (NOAA/NWS/OCWWS)

NOAA RESEARCH TEAM: Pete Roohr (NWS/OS&T), Heath Hockenberry, Robyn Heffernen, (NWS/OCWWS)

PROJECT OBJECTIVES:

Funding for this project is still pending. A new proposal and updated status on other CIRA fire weather projects have been provided to the NOAA collaborators. The NWS and OAR directors will be presented the external project research status and a NOAA research proposal on March 25, 2014.

PROJECT ACCOMPLISHMENTS:

No fire weather presentations were reported this year. A NASA ROSES Proposal sustained this effort and results will be presented to NOAA at the March 25th meeting.

PROJECT TITLE: Severe Weather/Aviation Impact from Hyperspectral Assimilation

Project Title: Improving Mesoscale Forecasts of Severe Weather and Aviation Weather from Enhancements to Hyperspectral Satellite Data

PRINCIPAL INVESTIGATOR: Haidao Lin and Cliff Matsumoto

RESEARCH TEAM: Haidao Lin

NOAA TECHNICAL CONTACT: Steven Weygandt (NOAA/OAR/ESRL/GSD/AMB)

PROJECT OBJECTIVES:

Investigate the impact from satellite hyperspectral data on severe storm forecasts in the Rapid Refresh and the increase in accuracy of short-range mesoscale model forecasts from the assimilation of satellite data into the Rapid Refresh.

PROJECT ACCOMPLISHMENTS:

In the past year, work has included a radiance data impact study with the hybrid variational/Ensemble Kalman Filter (EnKF) data assimilation system within the Rapid Refresh (RAP) model, as well as updates for radiance assimilation within RAP v3 for NCEP operational implementation in 2015. As new data to the operational RAP, the AIRS and GOES sounder data are assimilated within the full mix of observation within the RAP hybrid assimilation system.

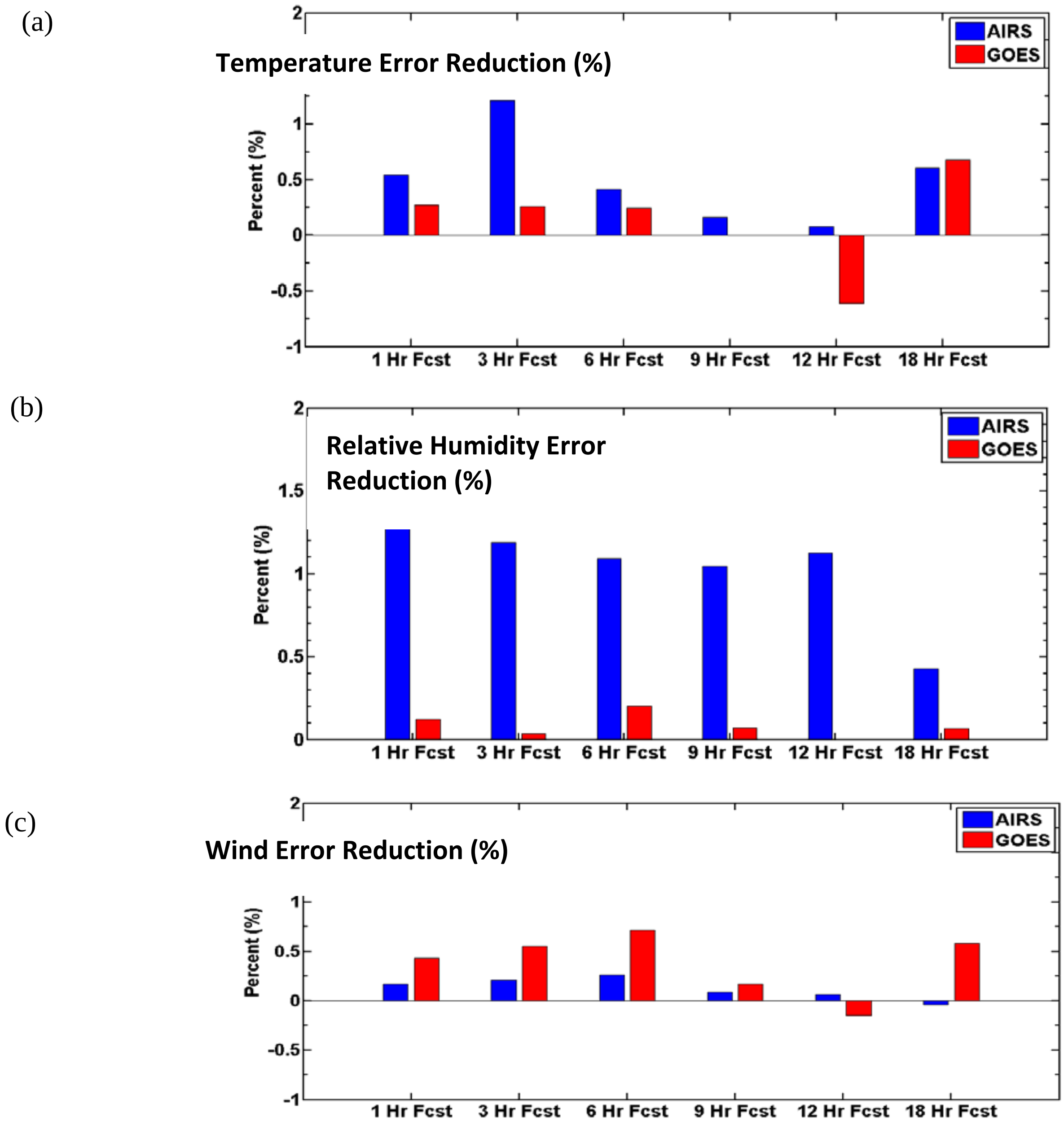


Figure 1. Normalized error reduction [(CNTL – EXPT)/CNTL] (%) from AIRS data (blue) and GOES sounder data (red) for (a) temperature, (b) relative humidity, and (c) wind. The control run uses conventional data only. Statistics are computed for 1000-100-hPa layer over the RAP domain. The retrospective period is from May 28 to June 04 2012.

Figure 1 shows the mean percent reduction in forecast error [(CNTL – EXPT)/CNTL], computed against radiosonde observations, with positive values indicating reduced error, for retrospective experiments in which AIRS data (blue) and GOES sounder data (from GOES-15, red) are assimilated, respectively. The control run uses conventional data only, which is also the case for all later experiments. The RAP has a very short observation cut-off time of about +35 minutes (after the model initial time) for a given model run. For satellite data, the very short observation cut-off time combined with the long data latency result in very limited data coverage for real-time applications. The retrospective runs are conducted with an ideal condition (no data latency and no cut-off issues). Additional experiments have examined the impact from the satellite radiance data when assimilated in a real-time configuration (less coverage than the idealized configuration). In order to improve the real-time satellite data coverage, we have also examined the possible use of short latency direct readout data for the real-time RAP. As part of this process, the Regional ATOVS Retransmission Services (RARS) real-time data files for the RAP are assimilated in addition to the real-time data set.

(a) (b) (c)

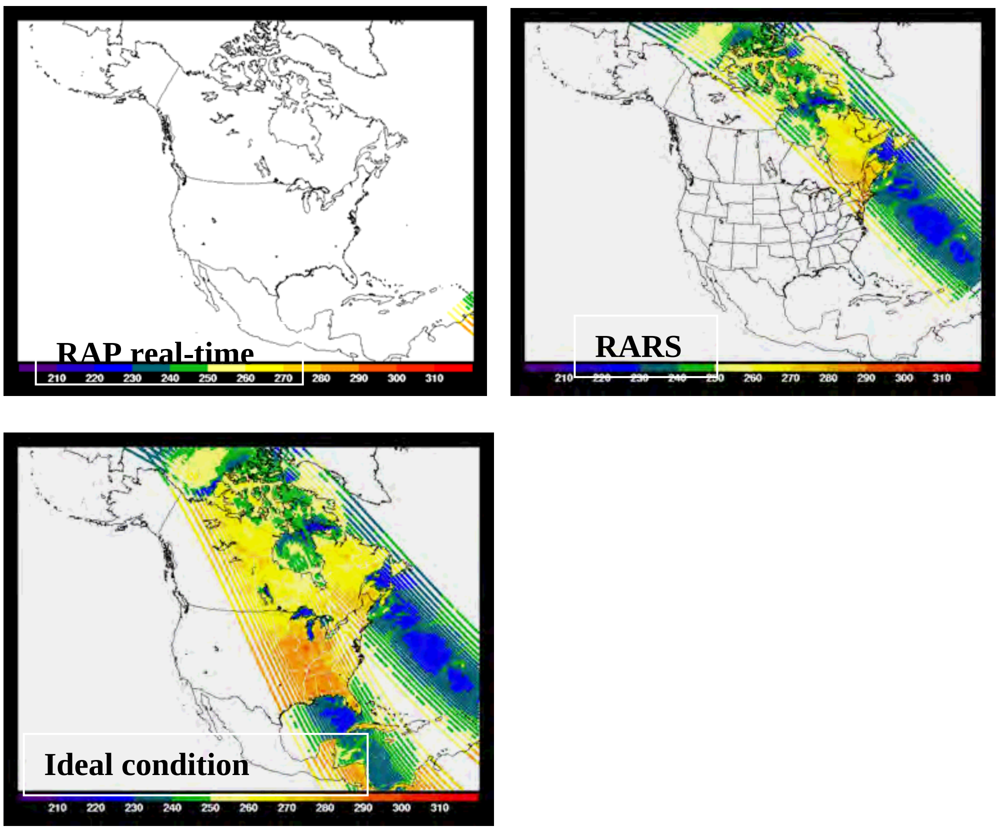


Figure 2. AMSU-A channel 3 brightness temperature from NOAA-19 at 18Z May 29 2012 with +/- 1.5 hour time window for (a) RAP real-time data file (used operationally), (b) RAP RARS file (not used operationally yet), and (c) the ideal condition (no data latency and no cut-off issue).

Figure 2 shows the NOAA-19 AMSU-A data coverage at 18Z May 29, 2012 for the RAP real-time data file, a RARS data file for RAP, and the ideal condition. As Fig. 2 shows, for this cycle time, there is a very limited amount of data in the data use window for the RAP real-time file (Fig. 2a, note that the coverage is somewhat better for some times, but still markedly worse than the other two files – RARS and ideal conditions). In contrast, data coverage from the RARS file (Fig. 2b) is much better, due to the earlier availability of the direct readout data. Figure 2c shows the coverage for the ideal condition. The radiance data used in these retrospective experiment runs are AMSUA, MHS, HIRS4, and GOES sounder data. A set of channels for all of these data has been selected specifically for RAP with 10-hPa model top before the assimilation. The forecast impacts from these retrospective runs are shown in Fig. 3.

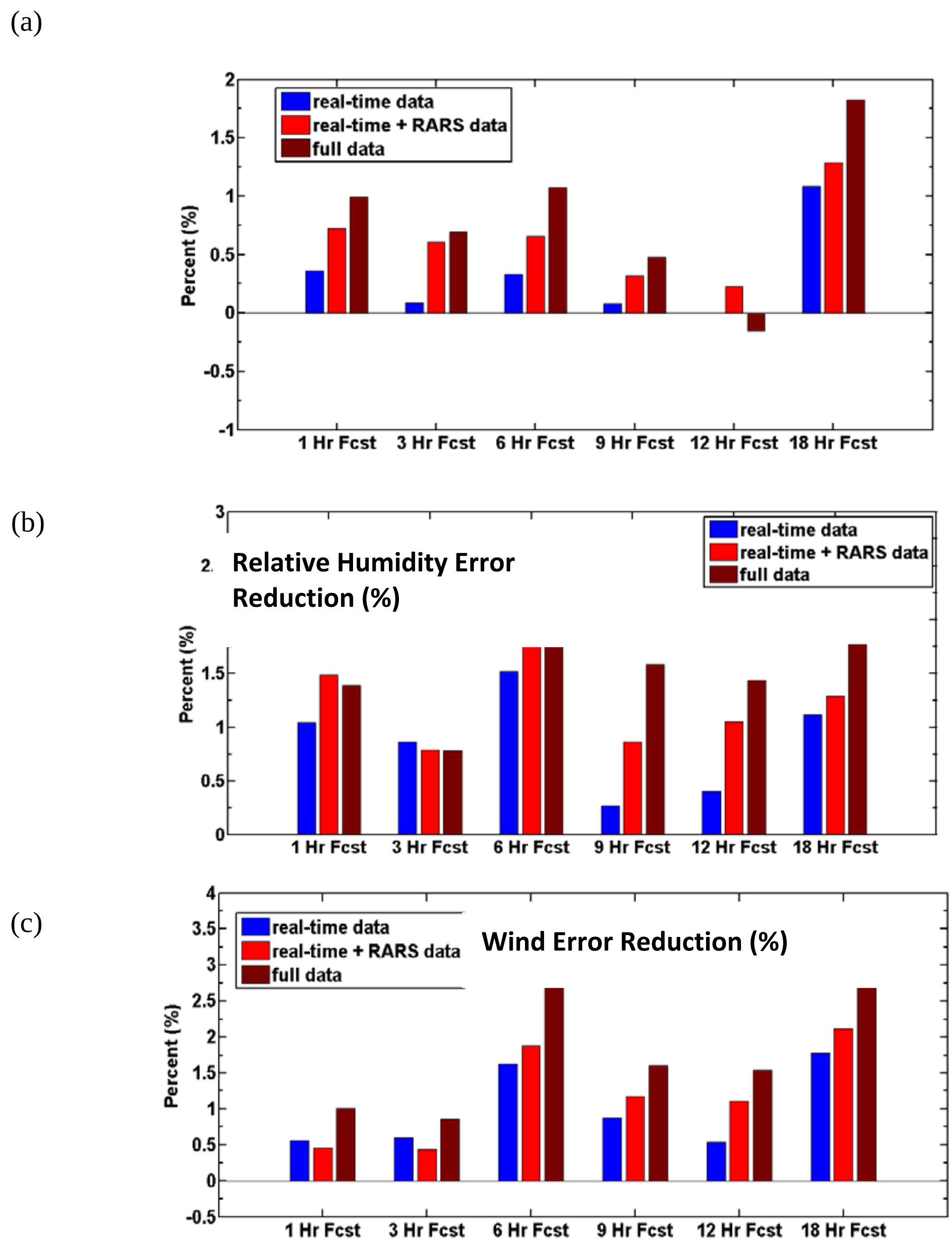


Figure 3. Normalized error reduction [(CNTL – EXPT)/CNTL] (%) from RAP real time data (blue), real time data plus RARS data (red), and full data (ideal condition, dark red) for (a) temperature, (b) relative humidity, and (c) wind. The control run uses conventional data only. Statistics are computed for 1000-100-hPa layer over the RAP domain. The retrospective period is from May 28 to June 04 2012.

Overall, a slight positive impact is seen almost for all forecast hours and for all variables, with the largest impact (1.5% for temperature at 18-h; 2.5% for relative humidity at 6-h; and 3.5% for wind at 18-h) from the full data sets. To further investigate the overall radiance data impact for the real-time situation, real-time hybrid RAP runs with and without radiance data have been set up on Zeus.

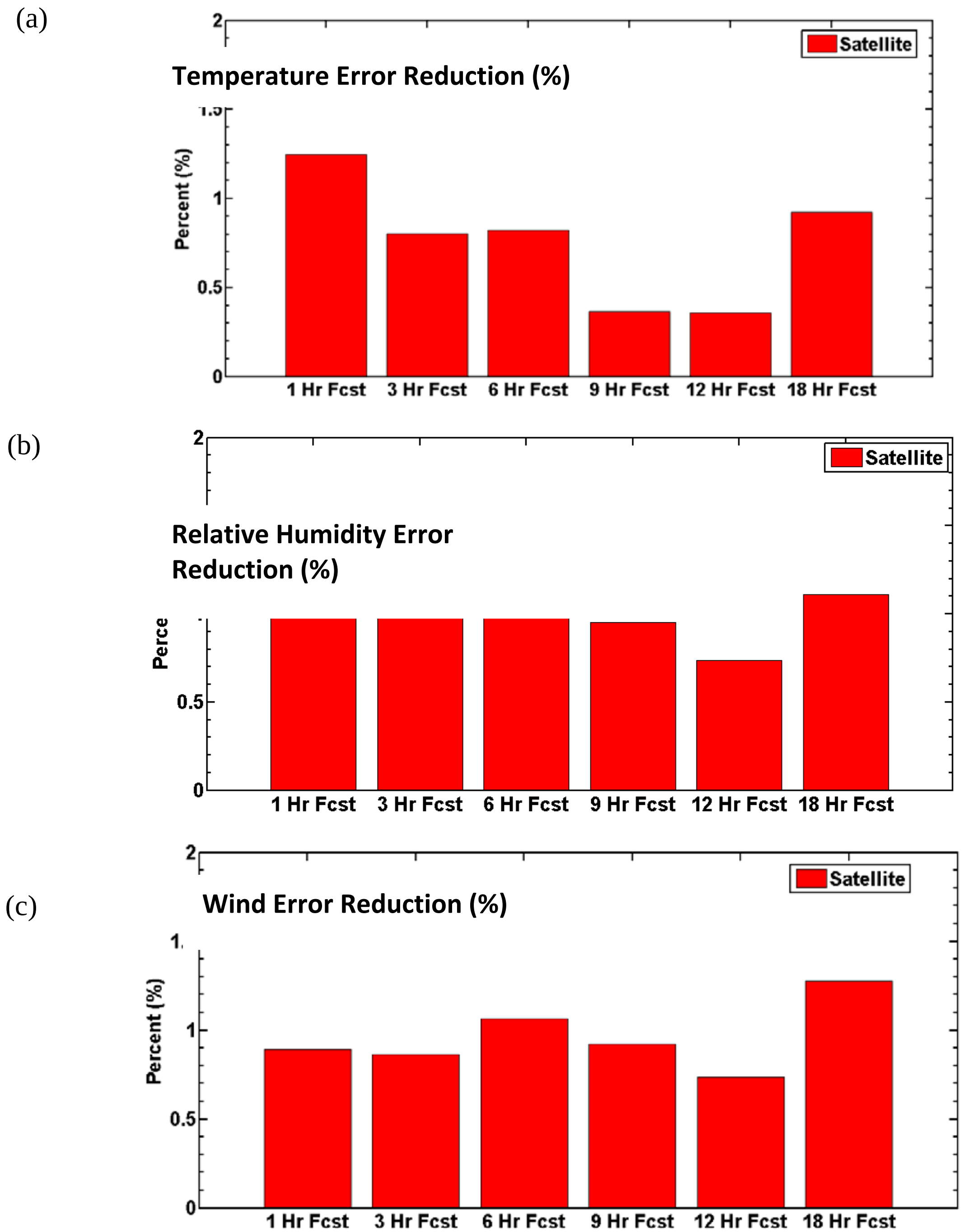


Figure 4. Normalized error reduction [(CNTL – EXPT)/CNTL] (%) from RAP real time runs using radiance data for (a) temperature, (b) relative humidity, and (c) wind. The control run uses conventional data only. Statistics are computed for 1000-100-hPa layer over the RAP domain. The 6-month real-time period includes June-July, October-December, 2013 and January 2014.

Figure 4 shows the mean percent reduction in forecast error from radiance data from a 6-month period of real-time RAP runs. Although the impact is modest compared with the retrospective runs with full data, the results are very encouraging, as obtaining positive impact from satellite data assimilation in this real-time (short data cutoff), limited-area model configuration is difficult. Very consistent positive impact has been seen for all forecast hours and for all variables with the maximum impact around 1%. Based on these promising radiance data impact study results and the investigation from extensive retrospective and real-time runs, radiance updates (bias correction, new data, channel selection etc.) have been incorporated into the RAP v3, which will be operationally implemented at NCEP in 2015.

DATA ASSIMILATION

Research to develop and improve techniques to assimilate environmental observations, including satellite, terrestrial, oceanic, and biological observations, to produce the best estimate of the environmental state at the time of the observations for use in analysis, modeling, and prediction activities associated with weather/climate predictions (minutes to months) and analysis.

PROJECT TITLE: CIRA Research Collaborations with the NOAA Earth System Research Lab/Global Monitoring Division on Carbon Tracker Model Enhancements

Project Title: Towards Assimilation of Satellite, Aircraft, and Other Upper-air CO_2 Data into CarbonTracker

PRINCIPAL INVESTIGATOR: David Baker

RESEARCH TEAM: Michael Trudeau, David Baker

NOAA TECHNICAL CONTACT: Pieter Tans (NOAA/OAR/ESRL/GMD)

NOAA RESEARCH TEAM: Andrew Jacobson (CIRES)

PROJECT OBJECTIVES:

In collaboration with Andy Jacobson and the CarbonTracker (CT) -team at NOAA ESRL/GMD, Colorado State researchers are modifying the flux inversion method used by CarbonTracker to allow it to make good use of CO_2 concentration data taken away from the surface, in the mid- to upper-troposphere. Column-integrated CO_2 concentration measurements taken from satellites and by surface-based sun-viewing spectrometers, as well as vertical profiles taken from aircraft, are examples of such data. Currently, the link between surface fluxes and their perturbations in the interior of the atmosphere is cut off after 5 weeks of transport in the CT ensemble Kalman smoother (EnKS) method. This time window is too short to allow most CO_2 data located in the mid- to upper-column to be attributed to fluxes at the proper location and emission time. Longer EnKS time windows and the addition of an “outer loop” inversion for correcting broader spatial scales and longer time scales will be explored to correct this. In addition, different flux parameterizations than those currently used by CT will be experimented with: this could permit the fluxes to be estimated at finer spatial scales, for example. Finally, the sensitivity of flux estimates to vertical transport errors when assimilating (or not assimilating) upper column CO_2 data in CT will be explored through the use of a second transport model in CT.

PROJECT ACCOMPLISHMENTS:

A number of modifications to CT have been made in the past year that affects this project. First, under separate funding, Andy Jacobson reworked the architecture of CT to separate the underlying transport model (TM5) from the flux inversion method (the EnKS) used to assimilate data. Previously, the code for the two had been mixed together. This made it possible to replace TM5 with different transport models in CT, or even to replace the EnKS with a different inversion method. Other changes allowed different *a priori* CO_2 fluxes and measurement types to be added. David Baker ported both the PCTM transport model and his variational carbon data assimilation method to NOAA’s “Zeus” computer, and modified

PCTM to locate *in situ* measurements vertically using geopotential height, as is done in TM5. Andy Jacobson has modified the CT code to allow EnKS time windows of longer than 5 weeks to be used (before, issues with the driving meteorology had caused this to be longest span possible).

Under this project, Michael Trudeau modified TM5 to accept measurement information in the new ObsPack format that NOAA is now using to distribute its *in situ* CO_2 data. Andy Jacobson added the ability to sample full columns of CT output, for use in comparing to satellite data offline. Michael Trudeau has gone further to develop code that will allow CT to read in satellite data for use in CT's inversion method. This code convolutes modeled CO_2 concentrations with a vertical averaging kernel appropriate for a column measurement, combines it with *a priori* CO_2 information used in the retrieval process that produced the measurement itself, and then compares this modeled measurement with the true measurement, for use in the measurement update step of the CT EnKS.

With these developments, CT now has the ability to ingest upper-column data into its inversion method and can be run with longer time windows than 5 weeks. We are now in a position to begin the simulation experiments outlined in our proposal that will determine what changes to the CT inversion approach are necessary to yield accurate flux estimates with satellite and other "upper air" data.

Project Title: Expand Capabilities of CarbonTracker

PRINCIPAL INVESTIGATOR**:** David Baker

RESEARCH TEAM: Michael Trudeau, Tomohiro Oda

NOAA TECHNICAL CONTACT: Pieter Tans (OAR/ESRL/GMD)

NOAA RESEARCH TEAM: Andrew Jacobson (CIRES)

PROJECT OBJECTIVES:

In collaboration with Andy Jacobson and the CarbonTracker team at NOAA ESRL/GMD, Colorado State University researchers are working to expand the capabilities of CarbonTracker by adding new carbon flux models, atmospheric transport models, meteorological driving data, and inversion methods. The range of results given by these alternative models will allow the accuracy of the flux and concentration estimates from CarbonTracker to be characterized better.

PROJECT OBJECTIVES:

The computer previously used to do the runs for the annual CarbonTracker release changed this year (from "jet" to "zeus"). Michael Trudeau transferred the complete set of ECMWF-based meteorological drivers needed to run the TM5 atmospheric transport model to the new platform, ensured their integrity, and set up the routine transfer of new driver files to "zeus" as they are produced. Michael modified CarbonTracker to accept measurements from multiple data types in the new ObsPack format, to accept input of Tom Oda's latest ODIAC fossil fuel emissions, and to output columns of CO_2 concentrations at the location of satellite and other "upper air" CO_2 measurements. He ran TM5 to simulate the impact of placing Tom Oda's aircraft-related FF emissions in upper layers of the TM5 model, to allow this to be compared to the impact of placing these at the surface, as had been done previously.

Tom Oda provided his latest version of the ODIAC FF emissions module to CarbonTracker (including the 3-D version with the aircraft emissions injected at upper layers of the model) for use in simulations.

PROJECT TITLE: EAR - Assimilation of Aerosol Observations Using GSI and EnKF with WRF-Chem

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Mariusz Pagowski

NOAA TECHNICAL CONTACT: John Brown (NOAA/OAR/ESRL/GSD/AMB)

NOAA RESEARCH TEAM: Georg Grell (CIRES)

PROJECT OBJECTIVES:

1--Improve aerosol data assimilation methods for air quality forecasting.
2--Perform evaluation of forecasts.

PROJECT ACCOMPLISHMENTS:

Gridpoint Statistical Interpolation is a 3D-Var assimilation tool that is used at National Centers for Environmental Prediction in operational weather forecasting. In collaboration with NCAR we implemented an extension to the GSI for assimilating surface measurements of PM2.5, PM10, and MODIS Aerosol Optical Depth at 550 nm with WRF-Chem. In the past the aerosol assimilation system has been employed to issue daily PM2.5 forecasts at NOAA/ESRL. To GSI community and new users we provide a package that, in addition to augmented GSI, consists of software for calculating background statistics and converting in-situ and satellite data to BUFR format plus sample input files for an assimilation exercise. Thanks to the flexibility of the GSI and coupled with the meteorology-chemistry of WRF-Chem, assimilation of aerosol observations can be carried simultaneously with meteorological data assimilation.

In North America, continuous measurements of surface aerosol concentrations at hourly resolution are made available thanks to monitoring stations participating in US EPA AIRNow program. The observations are available from a free ftp feed and are processed with minimal delay making them suitable for real-time assimilation. There are over 600 sites measuring PM2.5 and over 150 sites measuring PM10. In the package we provide a computer code to convert this data to BUFR format as required by the GSI.

AOD data come from Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on board Terra and Aqua satellites. Retrievals over land and sea are derived from the dark target product (Remer et al., 2005) and deep blue product over bright land surface (Hsu et al., 2004, 2006). Currently, the dark target ocean and land AOD products are available from both Terra and Aqua, but deep blue retrievals are only available from Aqua. MODIS retrieved AOD is provided at seven wavelengths: 470, 550, 660, 870, 1240, 1630, and 2130 nm. In our implementation, only Level 2 AOD retrievals at 550 nm are used. These data come in HDF-EOS format at 5 min segments of the satellite's orbit that corresponds to 10 km $\times$ 10 km resolution at the surface. Computer code is available in the package to convert HDF to BUFR for the GSI.

Simulations were performed in summer 2012 for a 24-km resolution domain that is shown in Figure 1. GOCART aerosol parameterization was employed. Fire emission inventory was used to account for wild fires and results from a global model MOZART provided lateral boundary conditions for WRF-Chem simulations.

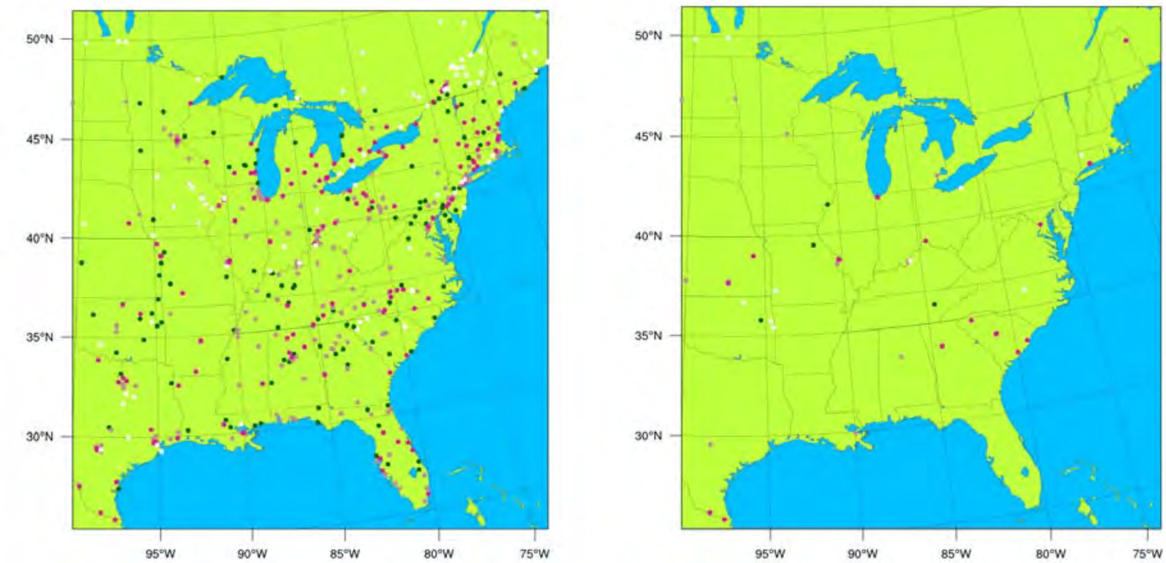
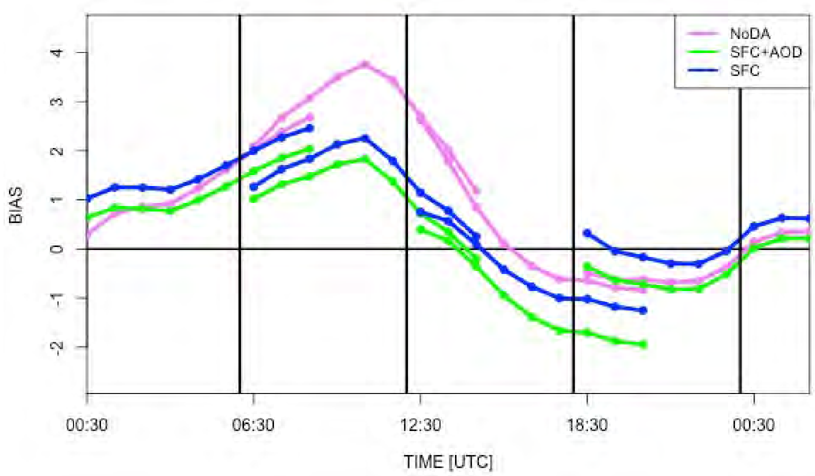
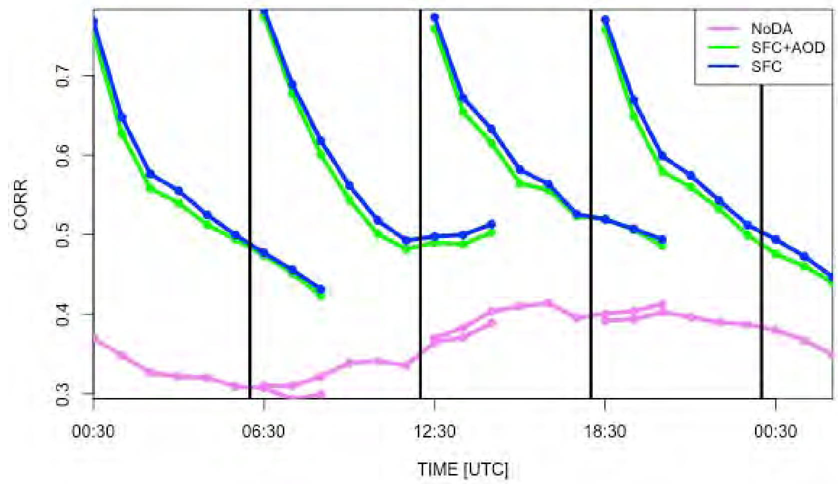


Figure 1. Maps of the PM2.5 and PM10 sites in the simulation domain. Color of dots is related to site location: dark brown – urban, light brown – suburban, green – rural, white – unknown.

Comparison of bias, spatial correlation, and pattern RMSE for simulations with and without data assimilation is shown in Figure 2. Impact of AOD can also be assessed by comparing simulations with the complete data assimilation against those with only surface observations. It can be noted that for the evaluations against surface observations effect of AOD alone is rather small and assimilation of AIRNow observations is crucial for air quality forecasting. In all the experiments also standard meteorological observations are simultaneously assimilated with chemistry. Overall, it can be seen that data assimilation has very significant impact on the accuracy of the forecasts.





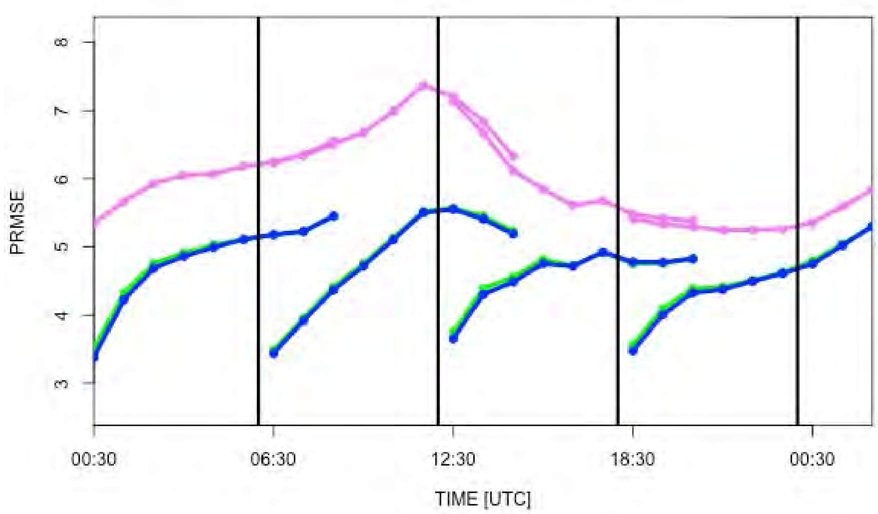


Figure 2. Bias, pattern RMSE, and correlation of PM2.5 forecasts for experiments with assimilation of surface observations and AOD, with assimilation of surface observations only and without data assimilation evaluated against AIRnow observations. Black vertical lines are plotted at assimilation times.

An article on the implementation of aerosol assimilation in the GSI is being reviewed for publication in EGU's journal, Geoscientific Model Development.

Separately, a publication on an impact of aerosol assimilation on weather forecasts in the boundary layer is being prepared.

PROJECT TITLE: EAR - Implementation of EnkF Assimilation in FIM model

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Mariusz Pagowski

NOAA TECHNICAL CONTACT: John Brown (NOAA/OAR/ESRL/GSD/AMB)

PROJECT OBJECTIVES:

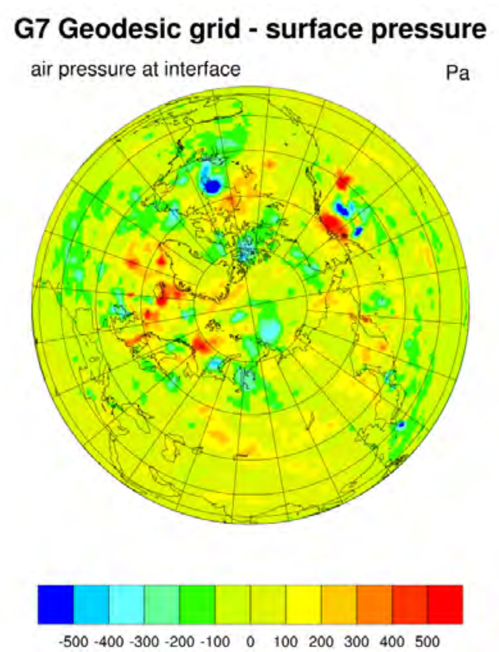
Implementation of EnKF data assimilation in FIM.

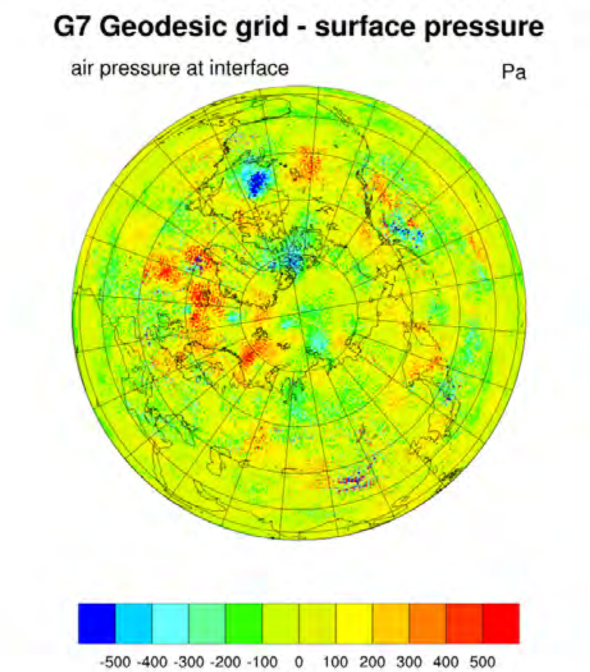
PROJECT ACCOMPLISHMENTS:

EnKF assimilation has been implemented in FIM but its application faces significant challenges related to the performance of the model itself.

FIM model currently has two dynamical cores. The hybrid sigma p-Theta core is being run operationally. It has been demonstrated that this core has numerical noise problems that makes it unsuitable for data assimilation. Sigma p dynamical core has numerical noise but the signal to noise ratio is manageable and, currently, for practical purposes assimilation is only possible with this core.

Illustration of the problem is shown in Figures 1 and 2. Figure 1a shows the initial difference between two ensemble members obtained on input from GFS. Differences between two members for FIM forecasts after six hours are shown in Figure 1b for sigma p –Theta and Figure 1c for sigma p.





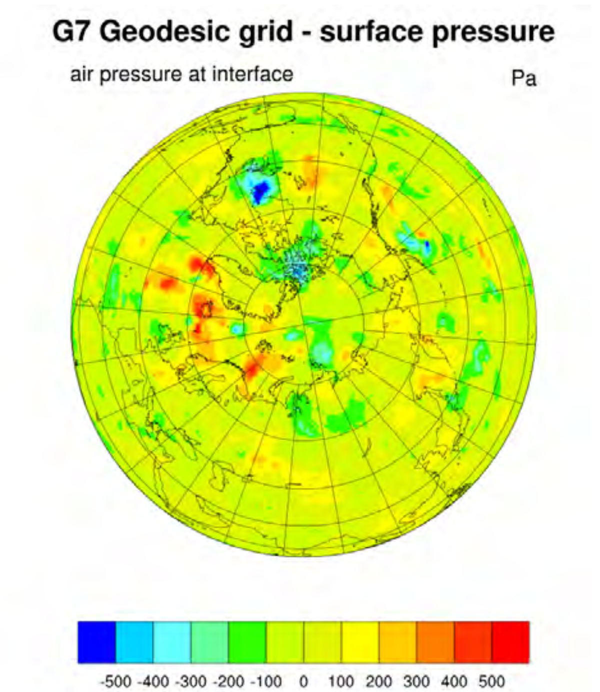


Figure 1. a) The initial difference between two ensemble members obtained on input from GFS. b) Differences between two members for FIM forecasts after six hours are shown in Figure 1b for sigma p. c) as "b" but for sigma p.

Also, surface pressure 9-hr timeseries for a member forecast at a point 60N 37.5 W is shown for two dynamical cores in Figure 2. Considering sigma p –Theta first, it can be seen that grid-scale noise (on the order of ten timesteps) is accompanied by a large amplitude wave which is artificial as can be seen by comparison with sigma p curve. Since different ensemble members will be out-of-phase it is transparent that model error estimated based on the ensemble spread will not reflect reality but be dominated by artifacts. Sigma p core also displays grid-scale noise and external gravity wave (with period of the order of several hours) but their magnitudes are much smaller than for sigma p –Theta.

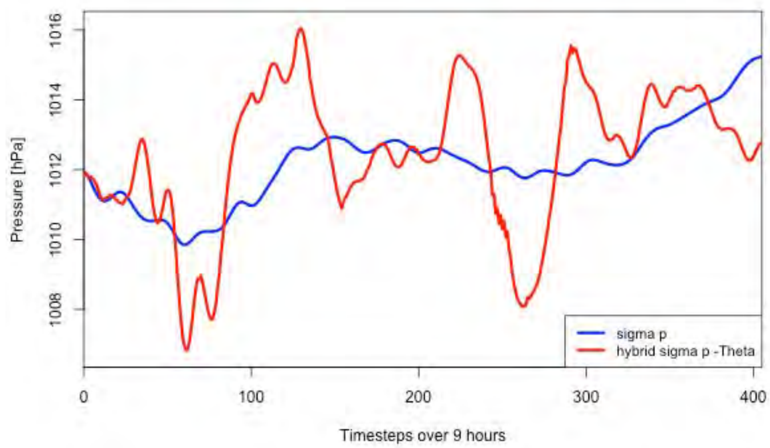


Figure 2. Timeseries of surface pressure for FIM 9-hr forecasts using two dynamical cores.

Another problem related to EnKF assimilation for FIM using sigma p is related to increasing growth of pressure increments over time and temperature drift in the tropics. In Figure 3, FIM increments are shown at the initial time and after approximately one week of assimilation. It can be seen that over North America there is a large surface pressure increment which is a persistent feature of the assimilation at this time and also other times of the assimilation. Different approaches have been attempted with the assimilation that failed to solve the problem.

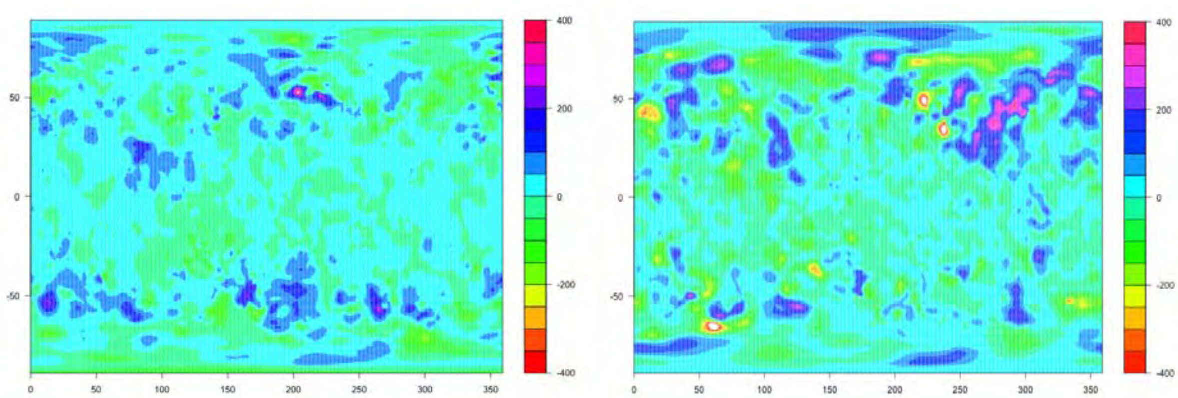


Figure 3. Surface pressure increments: a) initial b) after one week of assimilations.

Biases of pressure and temperature are shown in Figure 4 where timeseries are plotted for a month-long period. It can be noted that biases for surface pressure are strongest in the Northern hemisphere and biases in model's temperature are strongest in the tropics. The pressure bias is possibly a result of inconsistency between FIM and GFS/GSI/EnKF vertical discretization and or integration of the hydrostatic equation. Temperature drift is possibly due to physical parameterizations.

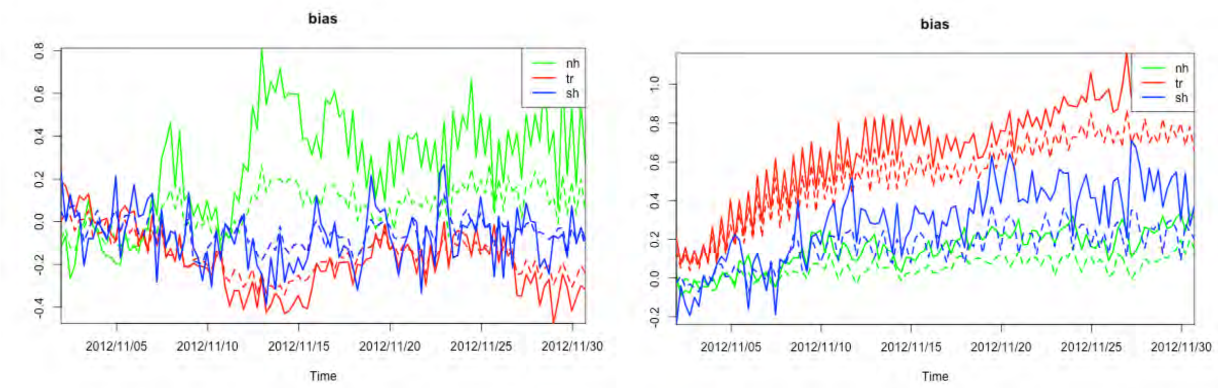


Figure 4. Timeseries of a) pressure and b) temperature. Solid lines - prior, dashed lines – posterior; nh – northern hemisphere, sh- southern hemisphere, tr- tropics.

It is unlikely that until these issues are resolved in FIM, data assimilation will be successful so that for the time being FIM forecasts need to be initialized from the GFS.

PROJECT TITLE: EAR - Local Analysis and Prediction System

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Steven Albers, Isidora Jankov, Hongli Jiang, Hongli Wang

NOAA TECHNICAL CONTACT: Zoltan Toth (NOAA/OAR/ESRL/GSD/FAB Chief)

PROJECT OBJECTIVES:

Improvement and enhancement of the LAPS in providing real-time, three-dimensional, local-scale analyses and short-range forecasts for domestic and foreign operational weather offices, facilities, and aviation and other field operations.

Examine and evaluate issues associated with model initialization and cycling process, and work towards improvement of these processes.

Study improvements to analysis techniques, diabatic initialization and balance package, WRF model initialization, ensemble forecasting techniques as well as model forecast verification at the Taiwan Central Weather Bureau.

Continue long-term collaboration with GSD to have LAPS and variational LAPS (aka STMAS, or VLAPS) software running in the National Weather Service Weather Forecast Offices (WFOs) for evaluation and use by operational forecasters in both AWIPS and AWIPS II.

Support HMT operations in California as part of HMT-WEST legacy. Similar efforts, including support of the analysis and modeling system, will continue in support of the California Dept. of Water Resources (DWR). Furthermore, CIRA will participate in support of the analysis and forecast systems as well as model forecasting, including ensembles, for the HMT-EAST field project.

Participate in Hazardous Weather Testbed (HWT) Experimental Warning Program (EWP), and Warn on Forecast activities.

PROJECT ACCOMPLISHMENTS:

1--Within the Forecast Applications Branch (FAB), CIRA personnel continue to play a leading role in development and implementation of meteorological analyses (e.g. wind, clouds, temperature, and precipitation), data ingest, and auxiliary processing, and web displays within the LAPS. This includes overall management of the configuration, updates, and distribution of the LAPS (including VLAPS) system. We've thus been highly motivated to lead the coordination of new ideas for development in LAPS including VLAPS. For LAPS and VLAPS, we worked to improve the analyses in the following areas:
--First Guess Processing
--Observational Data Sets
--Surface Observations
--Upper Air Observations
--Surface Analysis
--Radar Processing
--Wind / Temperature Analyses
--Cloud / Precipitation Analyses
--LAPS/VLAPS Model Initialization/Post Processing
--General Software Improvements & Portability
--LAPS Implementation

We maintain the LAPS software distribution and the associated web site. This involves more than 100 users both in the U.S. and internationally.

A high-resolution 1-km LAPS 3D analysis was set up to run with a 15-min cycle. A global analysis is also being run.

WWW LAPS Interface
Web pages were significantly improved for plotting analysis and forecast fields for LAPS including VLAPS. The "on-the-fly" page has additional available fields and improved animation capability. Our achievements for this project compare favorably with the goals projected in the statement of work.

2--VLAPS-3D Development and Improvements
2.1--Analysis and Data-Assimilation improvements
We are running a hybrid system with VLAPS where analysis modules from both the new VLAPS software are combined with some from “traditional” LAPS. This provides an ideal testing platform as we phase in VLAPS improvements. As the VLAPS analysis is embedded within the overall LAPS software package, most improvements mentioned regarding LAPS have a direct benefit to VLAPS. There are also items we will highlight that are more specific to VLAPS analysis development.

One LAPS improvement relates to the variational cloud analysis where some improved cost function routines were developed to help improve the fit to visible and 11-micron IR satellite imagery. Cloud analysis improvements were made on several additional fronts. Satellite parallax correction was introduced to improve the accuracy of the traditional LAPS cloud analysis (used as a first guess for the variational cloud fields). We are looking at the use of satellite products such as cloud optical thickness and liquid water path to help provide input to the variational cost function. Examples of cloud optical depth observation distribution and cloud ice water analysis produced by VLAPS assimilating cloud optical depth are demonstrated in Figure 1.

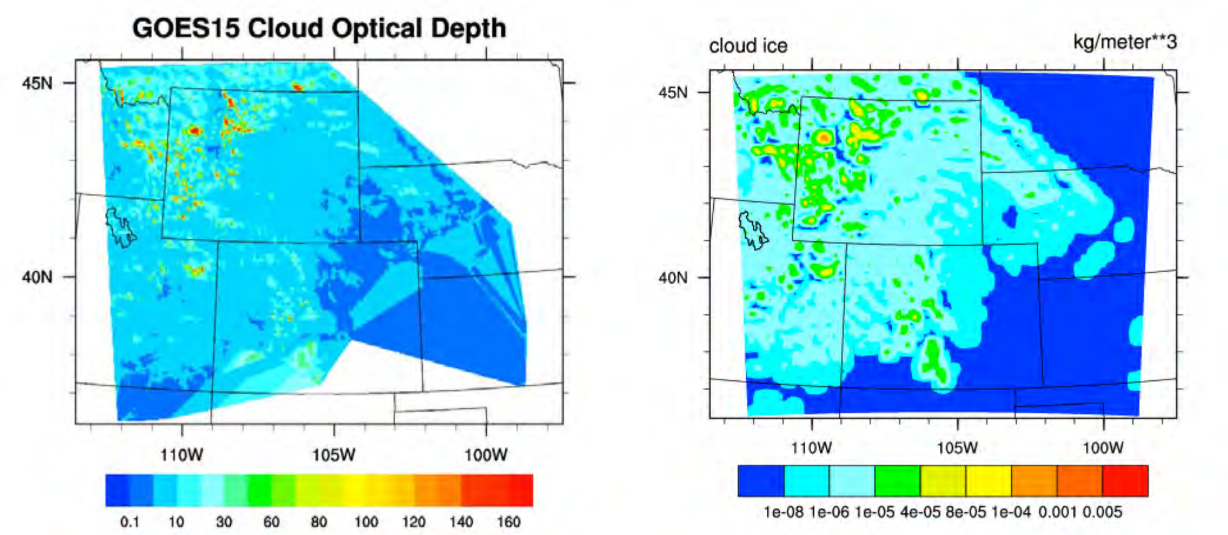


Figure 1. (a) Cloud optical depth observations from GOES15 satellite, (b) Cloud ice water analysis (kg/kg) produced by VLAPS at 250hPa. Analysis time is 2200 UTC DEC 30 2013.

A visualization package to produce simulated visible light all-sky imagery from the gridded fields was developed and used to validate the analyses, along with some forecasts. There is an all-sky camera mounted on the roof of the DSRC (along with cameras on Mount Evans and near Longmont) to assist in doing side by side comparisons (Fig 2).

Figure 2. Simulated All-Sky image generated from 1km LAPS analysis data (top) compared with all-sky image from the DSRC rooftop camera (bottom).

Similar visualization techniques were developed to display clouds (seen from an Earth orbiting perspective) from the global FIM model in a successful presentation at the AMS 2014 conference. These can be displayed either with Science On A Sphere® or with TerraViz.

Our verification software and website were improved, particularly in the area of precipitation. Forecasts of radar reflectivity and solar radiation can now be produced by advection (extrapolation) using the wind field. These are being included in the verification mix, along with persistence and various reference models.

2.2--Model Ensembles and Ensemble Post Processing

Ensemble forecast system testing and implementation continued in support of the Hydrometeorological Testbed and the project supported by California's Department of Water Resources. The ensemble design in terms of dynamic cores and physics stayed the same as previous years (3 WRF-ARW runs with various microphysics and one WRF-NMM run). The additional variety has been added by using the GFS ensemble members to provide lateral boundary conditions for the HMT/DWR ensemble members.

A model run with an hourly cycle and 12-hr forecast length this season has been run over a large domain covering basically the entire West Coast. The increase in the integration domain resulted in coarsening horizontal grid spacing from 5 to 10 km. Ensemble mean products were developed for the HMT experiment. As during the earlier seasons, the output from this run was used as input to a moisture flux tool developed by colleagues from PSD.

A high resolution analysis and forecast was run for the Hazardous Weather Testbed (HWT) Spring 2013 experiment.

3--Range Standardization and Automation (RSA) Project

We coordinated with federal personnel to give support to the western launch range (WR) at Vandenberg, CA to use a recently updated version of the LAPS analysis along with the WRF forecast model.

4--Taiwan Central Weather Bureau (CWB)

We continued to operate real-time LAPS runs both at GSD and at the CWB. We added the model run with 6-hour cycle and 12-hr forecast for CWB domain. Our achievements for this project compare favorably with the goals projected in the statement of work, given the available funding. We have accomplished additional task compared to the objectives since Hongli Jiang joined the team.

5--NWS Interaction

5.1--AWIPS and AWIPS-II

We continue a long-term effort to have LAPS software running in the National Weather Service WFO's (on AWIPS) for evaluation and use by operational forecasters. Discussions are being held about ongoing efforts to upgrade LAPS and introduce LAPS and VLAPS in the new AWIPS-II workstations running in National Weather Service WFOs.

A new version of the VLAPS surface is nearing the end of development and testing, which is:

--Multivariate analysis
--Topography incorporated
--Background flow dependent
--Simple surface constraints used

The test version of VLAPS is presently being evaluated at the Boise WFO. A high resolution (1-km horizontal grid spacing) WRF-ARW model run is available four times per day for potential use by the local NWS office in Boulder.

5.2--EFF Activities

We continued our interaction with the local NWS WFO in Boulder, located within the David Skaggs Research Center. CIRA researchers take part in presenting and producing weather briefings.

6--Hydrometeorological Testbed (HMT) / California Department of Water Resources (DWR)
EXRef ensemble model runs over the North American domain and California sub-region have continued during 2013 and into 2014. We are evaluating real-time precipitation verification of our runs. Variational LAPS is among the ensemble members, along with a diversity of runs having different boundary conditions and microphysics.

Ensemble forecast system testing and improvement continues. One of the issues with the ExREF ensemble forecasts was a lack of spread. This resulted in focusing on development of a new approach to Initial Condition Perturbations in order to increase the ensemble spread and general performance. The new method for dynamical downscaling has been developed and recently implemented into the ExREF production. Some results indicating increase in spread while keeping the error the same (or lower) are shown in Figure 3.

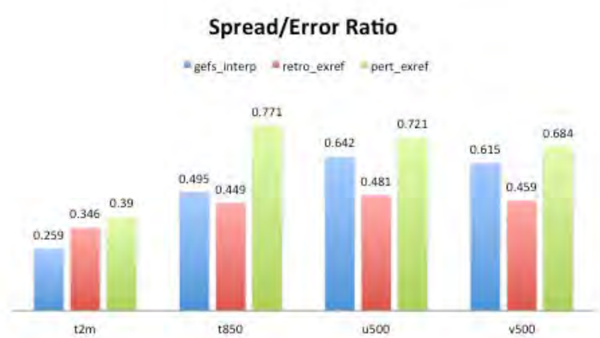


Figure 3

Figure 3. Spread/Error ratio for three ExREF experiments having IC provided by interpolating GEFS, using production version, and using new dynamical downscaling method.

7--Hazardous Weather Testbed (HWT) Experimental Warning Program (EWP)
At FAB, three domains were set up for participating in the HWT EWP 2013. One is a CONUS domain (surface analysis only) with 2.5km resolution, the second is a regional 3km domain, and the third is sub-regional 1km domain for 3-D analyses and forecasts. All three domains generate output at 15 min frequency.

The 1km resolution forecast was initialized hourly, and forecast out 3 hours, while the 3km resolution forecast was initialized every 3 hours, and forecast out to 4 hours. Both domains were initialized using VLAPS. A list of meteorological variables of interest generated and derived from VLAPS was transferred to National Severe Storm Laboratory (NSSL) in Norman, OK and evaluated by the forecasters over the three-week period of EWP 2013. These results are used in experimental warning preparation and comparison among several models and observations. Hongli Jiang, Isidora Jankov, and Steve Albers each spent one week in Norman to participate the daily activities during the HWT 2013 Spring Forecast

Experiment (EWP). Hongli presented the results of the experiment at the AMS 2014 annual meeting. Forecaster feedback was positive and very valuable.

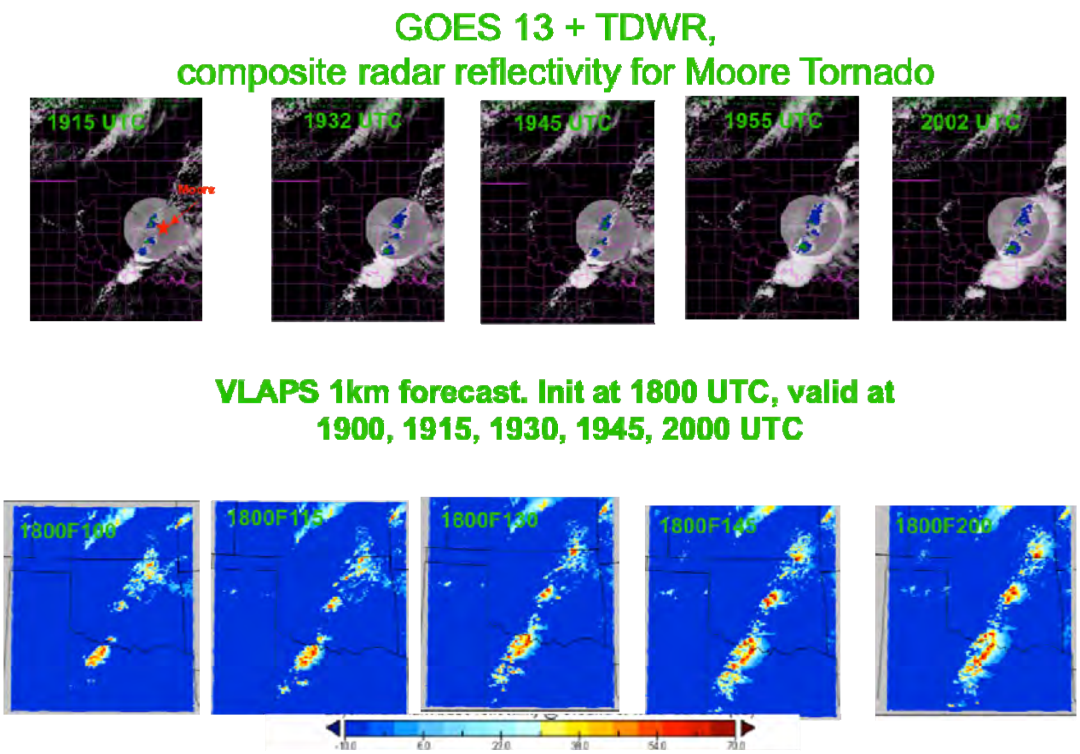


Figure 4. Comparison of composite reflectivity between GOES 13 overlaid with Terminal Doppler Weather Radar (TDWR) and 2h forecast from VLAPS initialized at 1800 UTC. VLAPS captured the three distinctive storms very well.

Real-time verification was further developed and made available online so we can look at the quality of radar reflectivity and other forecasts.

8--Investigative Modeling Research

8.1--Finnish Meteorological Institute (FMI)
We continued to work with the FMI on various LAPS topics including the use of radar data and the model first guess in the LAPS analyses. Improved methods of using rain gauge to refine radar-estimated rainfall are being investigated and a paper (Gregow et. al. 2013) has been published.

8.2--Windsor Tornado Case Study
We are collaborating with Radiometrics Corporation, UCAR, and others to study the analysis and short-range forecasting of the May 2008 Windsor, CO tornado. This includes gathering the real-time LAPS analyses, as well as all available in-situ and remotely sensed observational data for rerun LAPS and VLAPS, together with WRF forecasts. There is a CIRA-managed special project dedicated to continued research on this topic. For this project, we ran short-term 1-hour and 3-hour LAPS/WRF forecasts of the Windsor Tornado. We made careful comparisons of model runs initialized from both LAPS and VLAPS analyses. Resolutions ranged from 5km down to 800m. We also performed some data denial experiments for the LAPS humidity analysis with and without radiometer data.

Radiometrics Corporation is experimenting with using LAPS soundings as input to a forward model. The forward modeled brightness temperatures are then compared with radiometer measurements in several frequency bands. Results show reasonable consistency, though with a bias at one of the highest frequency bands. A paper has been published on this research.

8.3--Renewable Energy

We've informally been doing some experiments with verifying analyses and forecasts of solar radiation, with excellent results. Verification includes the use of Global Horizontal Irradiance (GHI) analysis, hot-start forecasts, and advected cloud forecasts. Several research labs and companies have an ongoing interest in our LAPS / GHI software, as well as real-time gridded output.

9--Developmental Test Center (DTC) Ensemble Testbed

During the period of interest the Ensembles Team has completed establishment of a functionally similar operational environment for NCEP's Short-Range Ensemble Forecast (SREF) system on NOAA's Zeus supercomputer. This preparatory work was necessary to allow planned testing activities in the context of NOAA's Hydrometeorology Testbed (HMT) that focuses on evaluating the impact of changes, in ensemble initialization, physics options, and horizontal grid spacing using the ARW subset of SREF.

Through close communication and working collaboration with the EMC colleagues, we have learned about EMC's priorities to help us prioritize and adjust our plans. High priority has been focused on changes to the SREF configuration. Particularly, there was interest in evaluation of the impact that changes in grid spacing and microphysics options have on the SREF. To address these questions two tests are run:

1--SREF run with 9km grid spacing and

2--SREF runs with HMT microphysics options were performed.

For these tests the focus was on the WRF-ARW SREF members with the ensemble being comprised of a control member, three members with a negative initial condition perturbation, and three members with a positive initial condition perturbation. These members are initialized from the same initial data as the SREF. The tests were performed during the transition month of May 2013 and captured one of the most active severe weather months in recent history hence providing an interesting dataset for future in-depth studies. Evaluation and verification will be performed using the DTC's Model Evaluation Tools (MET) and utilizing both single-value and probabilistic measures aggregated over the entire month of study. One example of the results is presented in Figure 5.

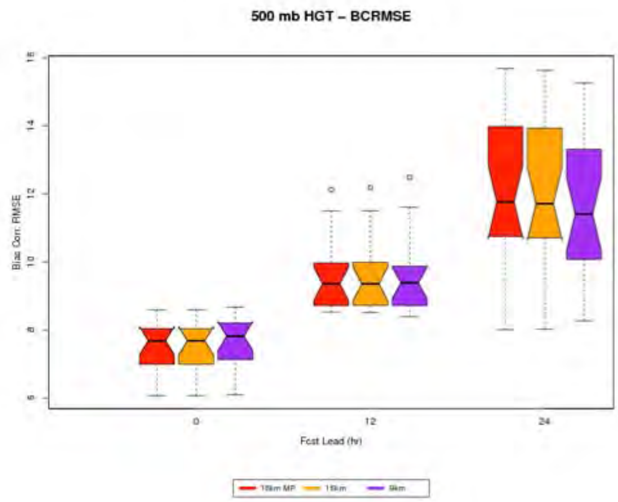


Figure 5

Figure 5. Bias Corrected Root Mean Squared Error with lead time for the three SREF experiments.

Also, recently through the DTC Visitor Program, the Ensemble Team hosted Dr. Sai Ravela, Massachusetts Institute of Technology. Dr. Ravela developed a Field Alignment technique that potentially can be very useful for assessment of forecast errors and bias correction. The code has been ported on the Zeus super-computer and is available for the community use. Use of this technique for error decomposition, as well as for bias removal in a real time setting has been evaluated. This resulted in a manuscript that will be soon submitted to a peer-reviewed journal. An example of use of the method for the error decomposition is presented in figure 6.

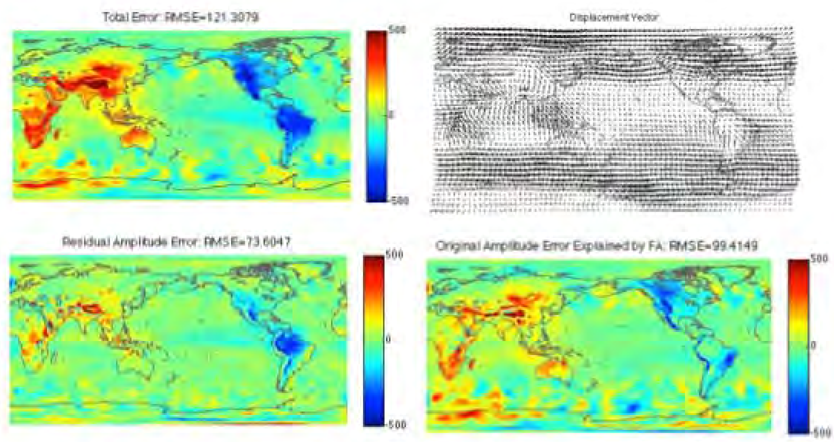


Figure 6

Figure 6. Calculated a) Total error and RMSE, b) Estimated displacement vector, c) Amplitude error and RMSE, and d) change between the original and “aligned” forecast after the FA technique was applied on GEFS Control member 12h MSLP forecast initialized at 00Z for the month of September 2011.

10. Other activities

Proposals were submitted for GOES-R in areas related to lightning, fire weather, and severe storm data assimilation.

PROJECT TITLE: Impact Assessment and Data Assimilation of NOAA NPP/JPSS Sounding Products and Quality Control Parameters

PRINCIPAL INVESTIGATOR: Steven J. Fletcher

RESEARCH TEAM: Steven J. Fletcher

NOAA TECHNICAL CONTACT: Sid-Ahmed Boukabara (NOAA/NESDIS/JCSDA)

NOAA RESEARCH TEAM:

PROJECT OBJECTIVE:

To investigate the differences between the humidity and temperature products of the MIRS 1-D VAR retrieval system using NPP-ATMS brightness temperature observations against the first guess and the analysis equivalent fields from the GFS-GSI.

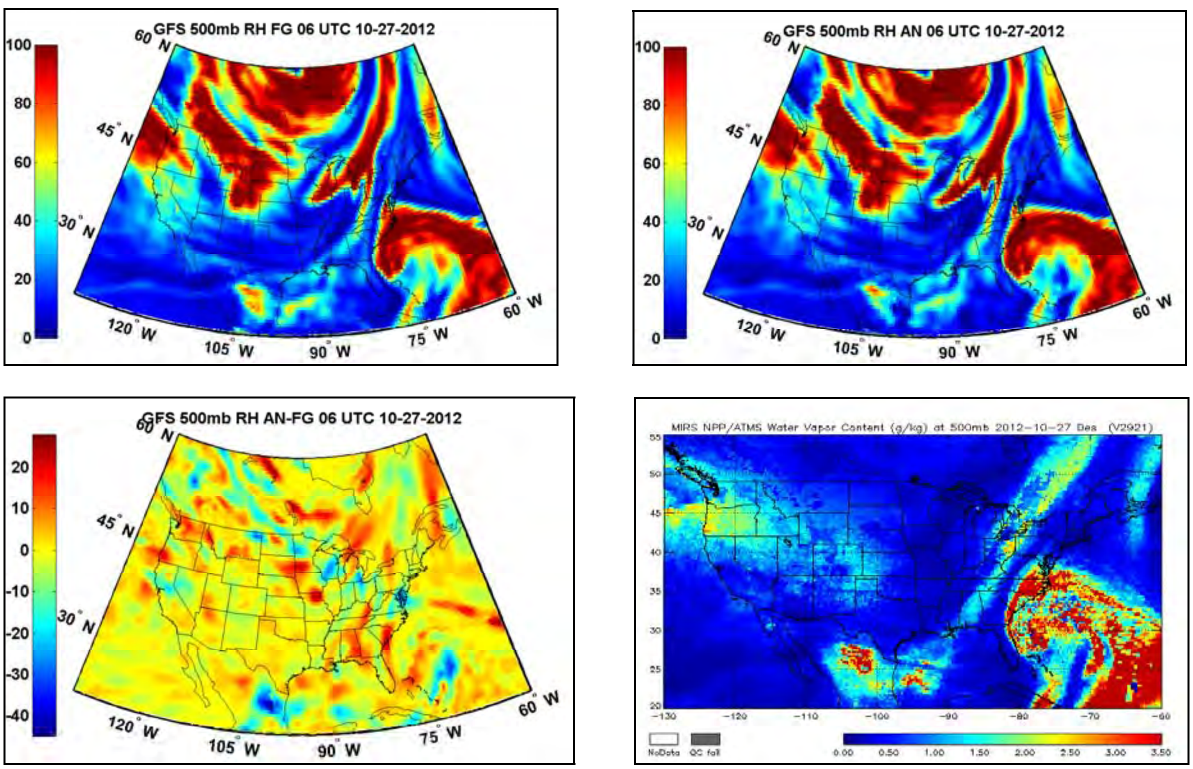
The comparison metric is the observation quality control gross error measure and the chi-squared goodness of fit of the equivalent retrieved brightness temperature to the original observations.

Before the end of this project the GDAS first guess and final solution will be compared to the MIRS retrieved values to compare with the metric mentioned above.

PROJECT ACCOMPLISHMENTS:

--So far this year the GDAS data has been obtained and been mapped into a projection that can be compared with the MIRS retrieval values.

--The MIRS binary files still need to be written into a format that can be compared to the output from GDAS.



PROJECT TITLE: NESDIS Environmental Applications Team – Tanvir Islam, Post Doc

PRINCIPAL INVESTIGATOR: Steve Miller

RESEARCH TEAM: Tanvir Islam

NOAA TECHNICAL CONTACT: Sid Boukabara, (NOAA/NESDIS/JCSDA)

NOAA RESEARCH TEAM: Sid Boukabara, Xiwu Zhan, Christopher Grassotti, Kevin Garrett, Pan Liang, Viktor Zubko, Craig Smith

PROJECT OBJECTIVES:

1--Extend and enhance the capability and performance of the Microwave Integrated Retrieval System (MiRS) for SAPHIR onboard Megha-Tropiques Satellite

2--Extend and enhance the capability and performance of the Microwave Integrated Retrieval System (MiRS) for AMSR2 onboard GCOM-W1 Satellite

3--Implementation of a new *a priori* database and an updated version of forward model (CRTM 2.1.1) in the retrieval system

4--Extend and enhance the capability and performance of the Microwave Integrated Retrieval System (MiRS) for high resolution products

PROJECT ACCOMPLISHMENTS:

Objective 1: Extend and enhance the capability and performance of the Microwave Integrated Retrieval System (MiRS) for SAPHIR onboard Megha-Tropiques Satellite

A recent effort is made to extend the MiRS algorithm to SAPHIR humidity sounder for the inversion of total precipitable water vapor (TPW) and atmospheric moisture profiles. The unique challenge for inverting atmospheric moisture from SAPHIR is that, the instrument carries six channels in which all the channels are centered at similar frequency near 183 GHz absorption line. The lack of window channels in the instrument makes the retrieval relatively challenging in the lower troposphere. It has been found that the algorithm performs reasonably well when estimating TPW over ocean and land surface backgrounds as well as under clear and cloudy sky conditions, although less accurate than what is achieved by sensors with both sounding and imaging capabilities. The moisture profiling performance was found to be reasonable as well. The assessment of these performances has been conducted by comparing the retrievals to ECMWF and GDAS water vapor analyses.

Providing an example, we demonstrate a comparison of the TPW estimate between the MiRS retrieved and ECMWF produced fields in Figure 1. This example is taken from 1st August 2013. It is encouraging to see that the MiRS has managed to capture the global distribution of TPW, almost similar to the ECMWF field.

Although, the SAPHIR instrument is primarily designed for vertical water vapor profiling, research has demonstrated that the 183 GHz band is not fully transparent to clouds. In the presence of ice particles aloft, the upwelling radiation gets impacted causing brightness temperature depression. In other words, these frequencies contain reasonable information of scattering properties, enough to transfer them into surface rain rate information.

Since the MADRAS instrument is currently out of operation, the only option for retrieving rain rate from Megha-Tropiques mission is through utilizing the SAPHIR channels at 183 GHz. We investigate the MiRS algorithm to retrieve rain rate solely from SAPHIR channels at 183 GHz. Note that, unlike other algorithms, MiRS algorithm does not use any rain/no rain detection method in an ad-hoc fashion. The MiRS is an iterative approach, and within its 1DVAR framework, initially, rain and ice free condition is assumed without retrieving rain and ice profiles in the state vector. If, the convergence is not reached, "multiple scattering feature" is then turned on to retrieve hydrometeors. Figure 2 provides the comparison of SAPHIR rain rate retrieval against TRMM 2A12 radiometer algorithm. Overall, the MiRS/SAPHIR rain rate agrees reasonably well with the TRMM 2A12 algorithm.

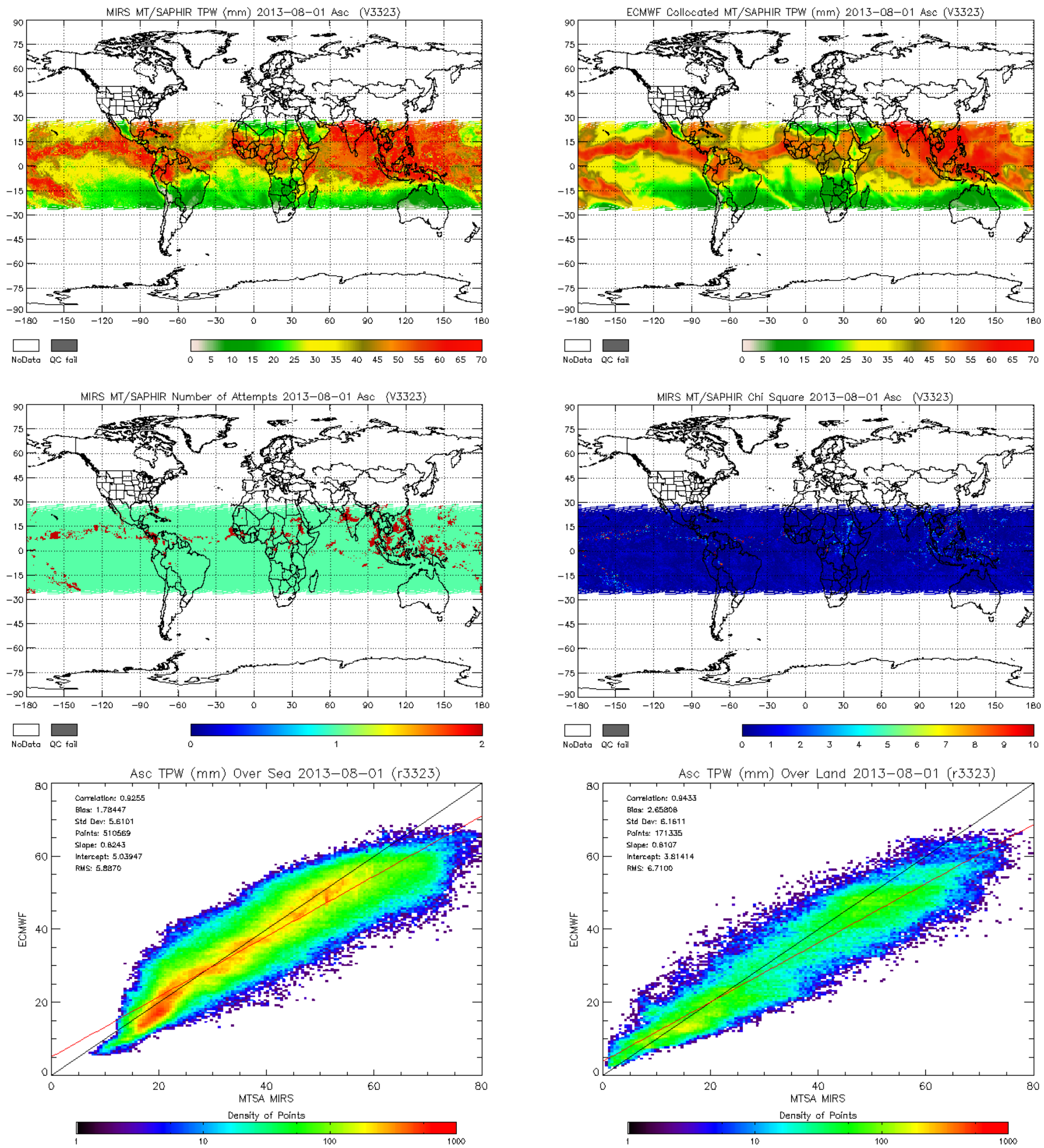


Figure 1. The performance of MiRS/SAPHIR retrieved TPW in comparison with the ECMWF TPW. The ECMWF analyses fields are collocated to SAPHIR measurements for the comparison. The global distribution of MiRS based TPW compares favourably with ECMWF field in non-precipitation region (top). The precipitation contaminated areas are shown as "2nd attempt" in the figure (middle left). The chi-square distribution is also shown (middle right). The corresponding scatter plots for non-precipitating conditions are given in the bottom panel.

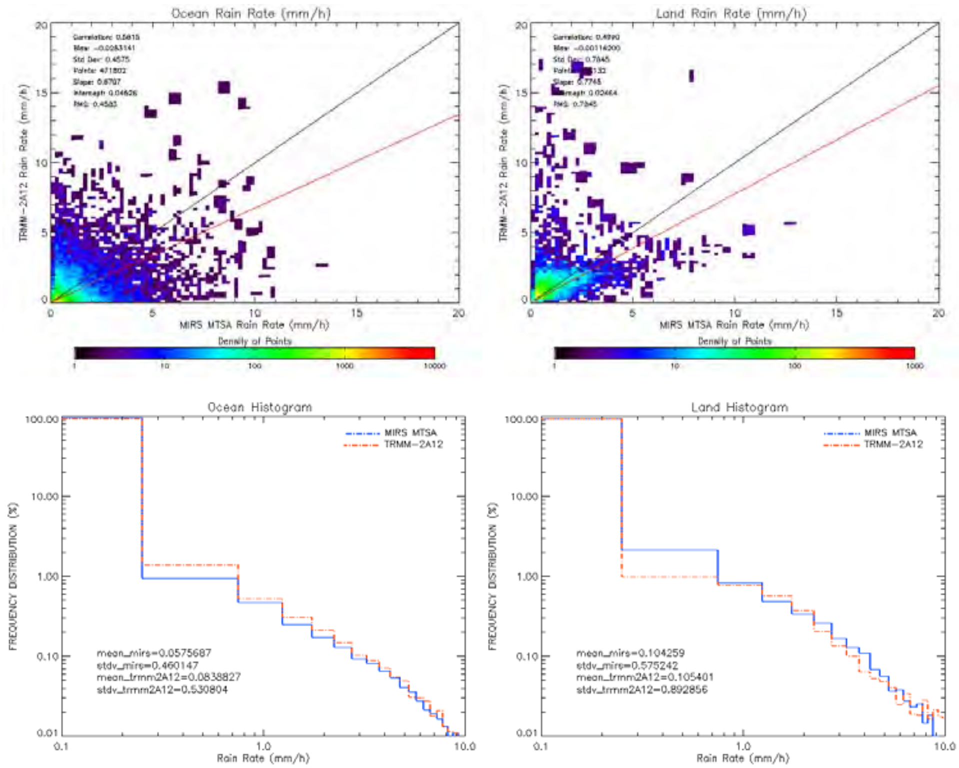


Figure 2. Independent assessment of MiRS SAPHIR rain rate retrieval against TRMM GPROF algorithm (March – August 2013 validation period).

Objective 2: Extend and enhance the capability and performance of the Microwave Integrated Retrieval System (MiRS) for AMSR2 onboard GCOM-W1 Satellite

Very recently, the MiRS algorithm has been extended to AMSR2 instrument onboard GCOM-W1 Satellite. A comprehensive set of sounding, surface, hydrometeor, and cryosopheric products are generated from AMSR2 using the MiRS algorithm. The products include atmospheric temperature, moisture and vertically-integrated total precipitable water (TPW), the surface skin temperature, emissivity, snow water equivalent and sea ice concentration, as well as the hydrometeor products of non-precipitating cloud liquid water (CLW), rain and ice water paths, and rain rate.

We show an example illustrating the validation of AMSR2 TPW product in comparison with the ECMWF analyses fields (Figure 3, left panel). In this figure, the AMSR2 retrieved TPW estimate is compared with the ECMWF analyses data for the day 1st August 2013. The comparison is shown in clear condition and over sea region. It can be seen that the MiRS retrieval agrees favorably with the ECMWF reference dataset. The correlation coefficient is calculated as 0.98 with RMSE of 2.94 and standard deviation of 2.37 mm. The emissivity retrieval at 18 GHz channel is also compared in Figure 3 (right panel). The MiRS produced cryospheric products are also routinely compared with the NASA team algorithm. Figure 4 provides such an example constructed from one day AMSR2 data (27th October 2012). It can be seen that both products (MiRS and NASA Team) agree reasonably well.

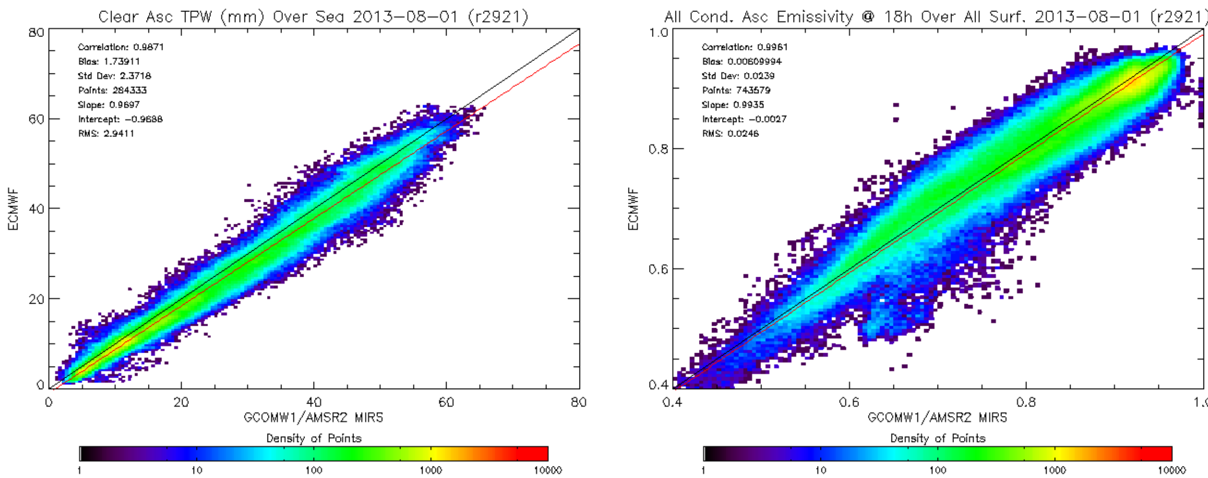


Figure 3. An example illustrating the preliminary performance of MiRS/AMSR2 geophysical fields in comparison with the ECMWF analysis fields, TPW (left), and emissivity at 18 GHz (H-pol) (right).

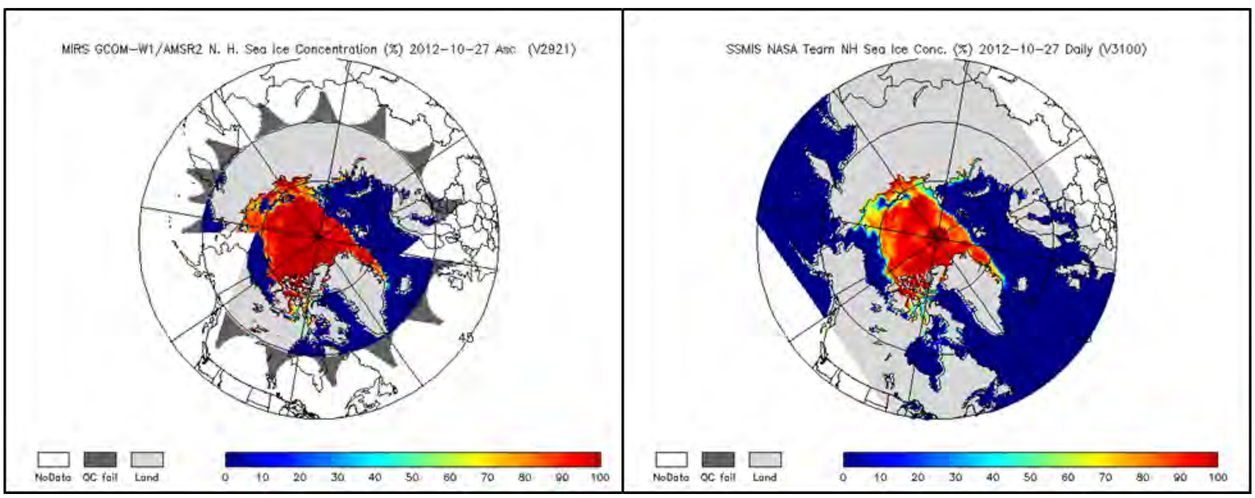


Figure 4. Illustration of inter-comparison between the MiRS/AMSR2 and NASA/SSMIS sea ice concentration retrievals.

Objective 3: Implementation of a new *a priori* database and an updated version of forward model (CRTM 2.1.1) in the retrieval system

The *a priori* state plays a critical role in MiRS retrievals, especially when there is limited number of radiometric measurements. A spatially and temporally varied database of temperature and water vapor fields is constructed from the ECMWF analyses fields. The database is constructed for every month to represent the temporally varied atmosphere, and gridded to 5 x 5 degrees box with 10 degrees moving average window (see Figure 5 for schematic illustration), in order to take care of the temporally and spatially varied dynamic atmosphere for the entire globe. The diurnal cycle is also considered while preparing the database (time of the day- 0, 6, 12, 18 UTC). In turn, during 1D-variational run, the dynamic geophysical fields are interpolated to the footprint matched radiance measurements, in which the solution will be fitted. Note that this *a priori* database is different from the one used in earlier version of the MiRS package. Previously, MiRS utilized constant *a priori* state vectors based on a global climatology. This new *a priori* database has been successfully implemented in the MiRS system, and the retrieval results are validated with reference datasets. It is found that this new addition in the system has significant positive impact in the geophysical retrievals.

Besides, an updated version of a radiative transfer model, CRTM 2.1.1, is implemented as the forward and Jacobean operators in the retrieval system.

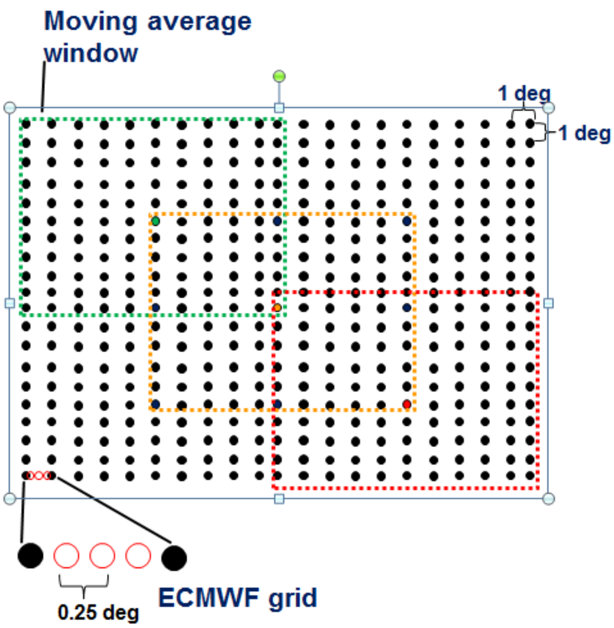


Figure 5. Schematic illustration of the development of spatially and temporally varied “Dynamic” *a priory* database for temperature and water vapor fields. The database is constructed from the ECMWF analyses fields.

Objective 4: Extend and enhance the capability and performance of the Microwave Integrated Retrieval System (MiRS) for high-resolution products

Scientific study is currently underway to optimize the hydrometeor retrieval for high-resolution products (POES and DMSP satellites) with new forward model (CRTM 2.1.x), and further, validate them with *in situ* data. The results will be reported at a later stage.

CLIMATE-WEATHER PROCESSES

Research focusing on using numerical models and environmental data, including satellite observations, to understand processes that are important to creating environmental changes on weather and short-term climate timescales (minutes to months) and the two-way interactions between weather systems and regional climate.

PROJECT TITLE: Application of Joint Polar Satellite System (JPSS) Imagers and Sounders to Tropical Cyclone Track and Intensity Forecasting

PRINCIPAL INVESTIGATOR**:** Renate Brummer

RESEARCH TEAM**:** Galina Chirokova, Robert DeMaria, Jack Dostalek, Kate Musgrave, Andrea Schumacher, Hiro Gosden, Dave Watson, Kevin Micke, Renate Brummer, Kathy Fryer

NOAA TECHNICAL CONTACT**:** Ingrid Guch (NOAA/NESDIS) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM**:** Mark DeMaria and John Knaff (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The time scale of tropical cyclone track and intensity changes is on the order of 12 hours, which makes JPSS instruments well suited for the forecasting of these parameters. Two tropical cyclone applications of JPSS data are currently being developed. The first uses the imager and sounder data for improving center location estimates of tropical cyclones, which is the starting point for tropical cyclone forecasts. Methods are being developed to use multi-spectral imagery from VIIRS, in combination with sounder data for this purpose. The second is to use temperature and moisture retrievals from **the** Advanced Technology Microwave Sounder **(**ATMS) in the near storm environment to improve intensity analysis and forecasting. This new information is being incorporated into existing intensity estimation techniques and to an operational statistical-dynamical intensity forecast model to improve their performance. The goal is to make these new products available in the satellite Proving Ground to operational forecasters at the National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC) for evaluation and feedback.

Tropical Cyclone (TC) forecasts affect risk mitigation activities of industry, public and governmental sectors and therefore supports directly NOAA's Weather and Water mission goals. Improving forecasts of tropical cyclone track and intensity is a top NOAA/DoD priority.

PROJECT ACCOMPLISHMENTS:

1**--** Develop Database of AMSU MIRS Temperature and Moisture Retrievals and VIIRS Data for Global Tropical Cyclones

A large database of VIIRS data is now available at CIRA. An automated procedure for extracting VIIRS and MIIRS data centered on global tropical cyclones has been in place since 2012, and continued to run in 2013 and 2014. The MIRS temperature and moisture retrievals became operational on the NPP Data Exploitation (NDE) system on Feb 6, 2014, however the data are not yet available via DDS feed. A large sample of cases was obtained from NESDIS/STAR using the same algorithm and in the same format as will be available from the NDE system. This sample includes 28 days for 23 TCs from 2012, providing about 200 TC cases from global tropical cyclones. This dataset is being used for the majority of the algorithm testing described below.

2-- Begin Development of Center Fixing Routine from AMSU, VIIRS, and GOES

The center-fixing algorithm was developed and tested with proxy AMSU retrievals. The algorithm was adapted to use ATMS inputs, and a comparison with the AMSU version was made. Figure 1 shows the results of the comparison for the 206 cases from the ATMS MIRS dataset. The blue bars show the first guess center position errors (left bar) and those after the first guess is updated using the quadratic discriminant analysis technique (right bar) for the AMSU cases from 2006-2011 which was used to develop the algorithm. The red bars show the same two sets of errors for the case where the algorithm, trained on the 2006-2011 AMSU cases, was run on the 206 ATMS cases from 2012, and the green bars show the results where the algorithm was trained on the 2012 ATMS cases and run with the 2012 ATMS input. The red and green bars show that when the ATMS input is used, there is a greater improvement over the first guess than when the algorithm is run with AMSU input. The next step is to refine the ATMS center estimates with VIIRS data.

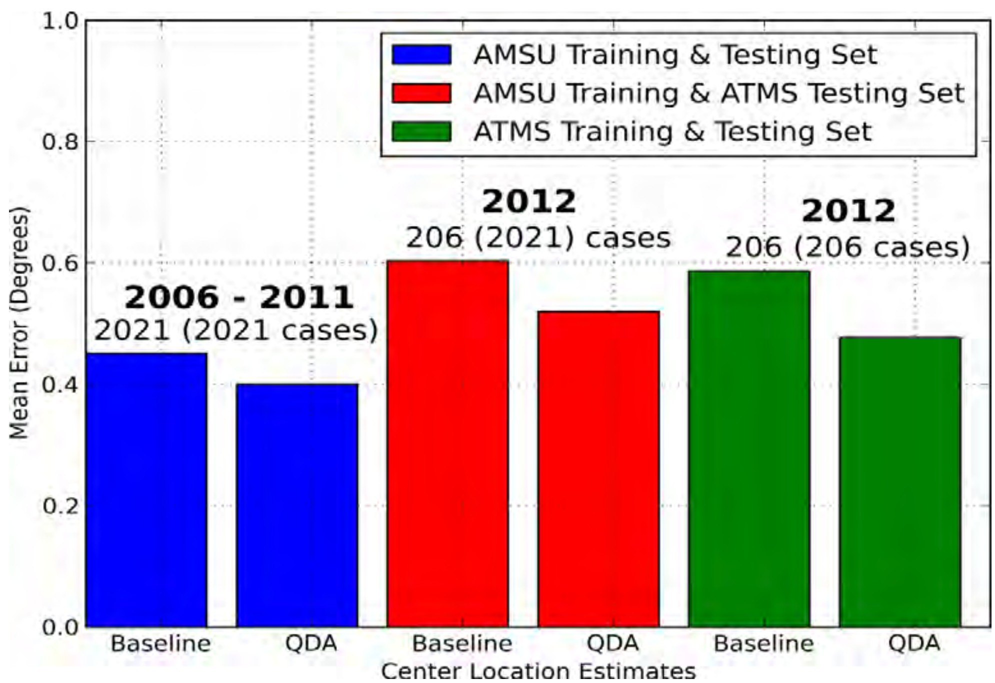


Figure 1. Errors in the center location estimate using the NHC best track positions interpolated to the time of the microwave pass. For each pair of bars (blue, red green), the left bar is the error of the first guess position and the second one is the error after the first guess has been updated using the quadratic discriminant analysis (QDA) technique. Results show that using the ATMS data provides a bigger improvement than the AMSU data, even for the case where the algorithm trained on AMSU data is used with ATMS input. The QDA will then be refined using the much higher resolution VIIRS data.

The utility of an image processing technique called the circular Hough transform algorithm for finding tropical cyclone centers from infrared imagery was evaluated. In the field of computer vision, the circular Hough transform is a commonly used algorithm for identifying circular or nearly circular features within images. An implementation of the algorithm was produced and run on 135 infrared images containing tropical cyclones at various points in their lifetimes. The distance between the center location reported by the algorithm and the best-track location was computed for each image. Additionally, the distance between the real-time location produced by the NHC, extrapolated to the time the IR image was created, and the best-track was used as a baseline comparison. The results can be seen in Figure 2. While the algorithm performed fairly well on images containing an eye, greater error was experienced when no eye was present. However in cases without an eye, the algorithm was able to effectively find the center of the cloud shield. Relating the center of the cloud shield to the rotational center of the storm may be an effective method of performing automated center-fixing and further work will be performed to investigate this possibility. For the weaker systems, additional information will be needed such as spiral cloud lines from visible and day-night band imagery, circulation centers and vertical wind shear estimates from ATMS wind retrievals.

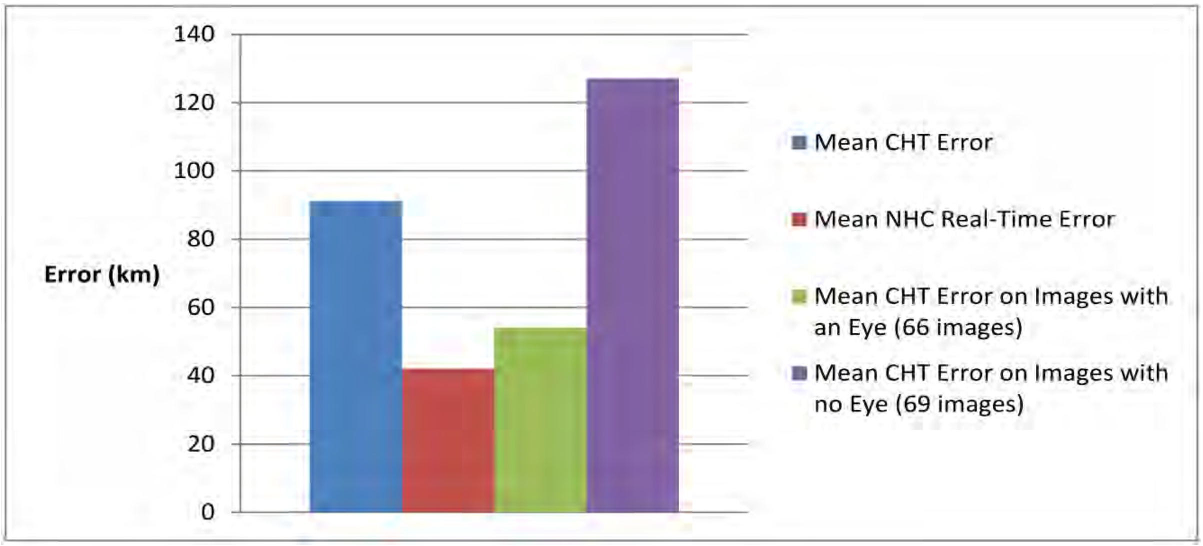


Figure 2. Mean errors reported from using the circular Hough transform on IR images to perform automatic center fixing.

3-- Begin Testing of Maximum Potential Intensity Estimate with MIRS Retrievals for Improved LGEM

An analysis of the MIRS moisture profiles was performed. These are needed along with the temperature profiles for the MPI algorithm. The water vapor is retrieved in terms of mixing ratio, and methods were developed to convert to relative humidity (RH), analyze the data in storm-centered coordinates, perform azimuthal averages, and generate perturbation fields. Figure 3 shows an example of a 700 hPa RH field for Hurricane Leslie from the 2012 Atlantic season. Also shown are radial-height cross sections of the azimuthally averaged RH, T anomaly, and RH anomaly fields. The structure of the moisture field looks very reasonable, with increasing RH near the storm center. These should provide good input to the MPI algorithm.

The maximum potential intensity (MPI) algorithm was successfully adapted to using the ATMS retrievals as input. Values were calculated for all 206 cases in the preliminary MIRS dataset described above. Figure 4 shows a comparison of the MPI estimates from three methods, including the empirical MPI currently used by NHC's statistical intensity models (dark blue circles), the MPI calculated from Bister and Emanuel's theoretical formula with storm environmental soundings from the GFS analysis (green circles), and the MPI calculated from Bister and Emanuel's formula with environmental soundings from ATMS (red circles). Also shown in this figure are two SST values (the weekly Reynolds SST and that from the Navy's daily NCODA analyses). The Reynolds SSTs were used in all of the MPI calculations. There are significant differences between the MPI results, with the MIRS input resulting in higher values for warmer SSTs and lower values for colder SSTs. The LGEM and SHIPS statistical intensity models are being run with empirical and ATMS inputs and the results are being compared.

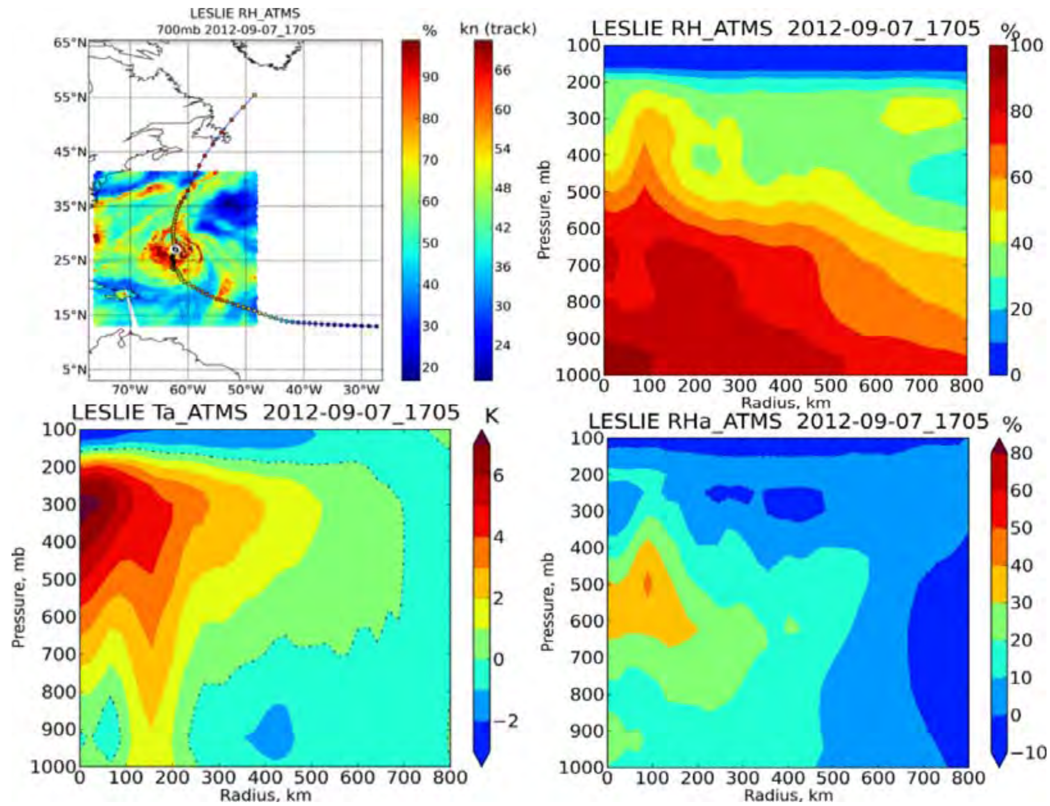


Figure 3. ATMS MIRS temperature and moisture retrievals for a case from Hurricane Leslie, including the 700 hPa relative humidity field (RH) (upper left), and radial-height cross sections of RH (upper right), temperature anomaly (lower left) and RH anomaly (lower right).

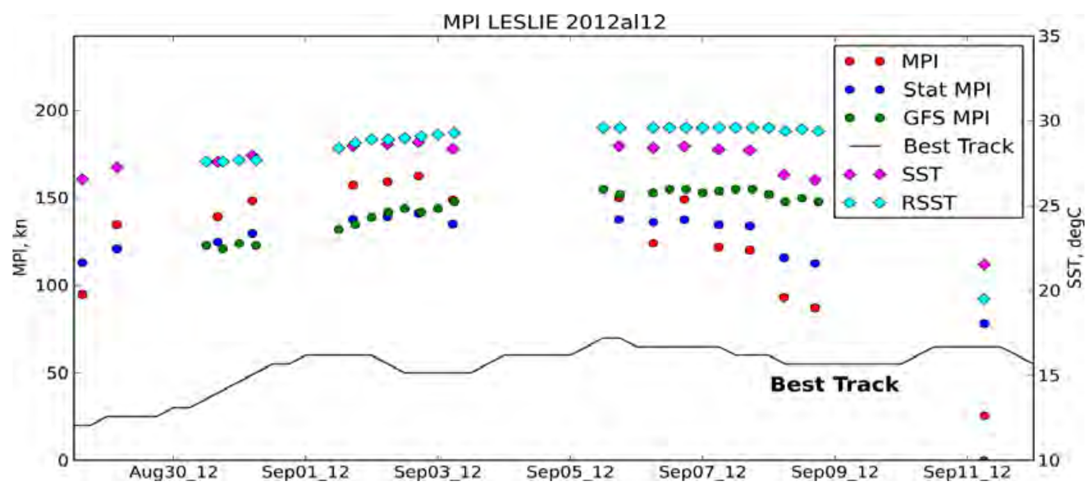


Figure 4. Comparison of MPI estimated from the empirical formula used in NHC' statistical models (Stat MPI), from a theoretical formula with NCEP global model input (GFS MPI) and from a theoretical formula with the ATMS MIRS retrieval input (MPI) for Hurricane Leslie from the 2012 Atlantic hurricane season. Also show are the observed maximum wind (Best Track) and SST from two different analyses, Reynolds weekly (RSST) and Navy NCODA daily (SST).

4--Apply Maximum Potential Intensity and Stability Analysis to all MIRS Tropical Cyclone Cases from 2012 and 2013

The stability parameter described in DeMaria (2009) was successfully adapted to using ATMS retrievals as input. The stability parameter is more general than the standard CAPE calculations because it includes the effect of entrainment, the ice phase, and the weight of the condensate on the buoyancy of a lifted parcel. The stability parameter is the vertically averaged vertical velocity (VVAV) of a parcel lifted from the surface to the level where the vertical velocity first becomes negative. Both Bister and Emanuel (1998) Maximum Potential Intensity (MPI) and VVAV were calculated for all 2012 cases in the preliminary MIRS dataset. Both calculations are very sensitive to SST used as input. In order to separate the effect of the SST input from the effect of different atmospheric profiles, as calculated from GFS model and ATMS, all estimates were reprocessed using the same weekly Reynolds SST temperature that was used in the operational version of SHIPS and LGEM. Figures 5a and 5b show the scatter plots of MPI and VVAV with GFS versus ATMS sounding input. The T, q profiles and sea level pressure (SLP) for all calculations were averaged between 200 km and 800 km to represent near-storm environment. The weekly Reynolds SST, used in all calculations, is a single point value at the storm center. The ATMS MPI has positive bias relative to GFS MPI for weaker storms for both Atlantic and East Pacific Basins. For MPI greater than about 100 kt, in some cases GFS MPI is larger than ATMS MPI, and in some cases that relationship is reversed. The reasons for these differences are being investigated. The ATMS VVAV tends to have negative bias in the low VVAV range and small positive bias in the high VVAV range.

The differences shown in Figure 5 indicate that the replacement of the GFS soundings with those from ATMS will have some impact on the LGEM forecasts, since MPI is used in the operational version, and VVAV is used in a new version under development. The related Rapid Intensification Index (RII) will also be impacted by this change. The forecast impact on the RII is being evaluated.

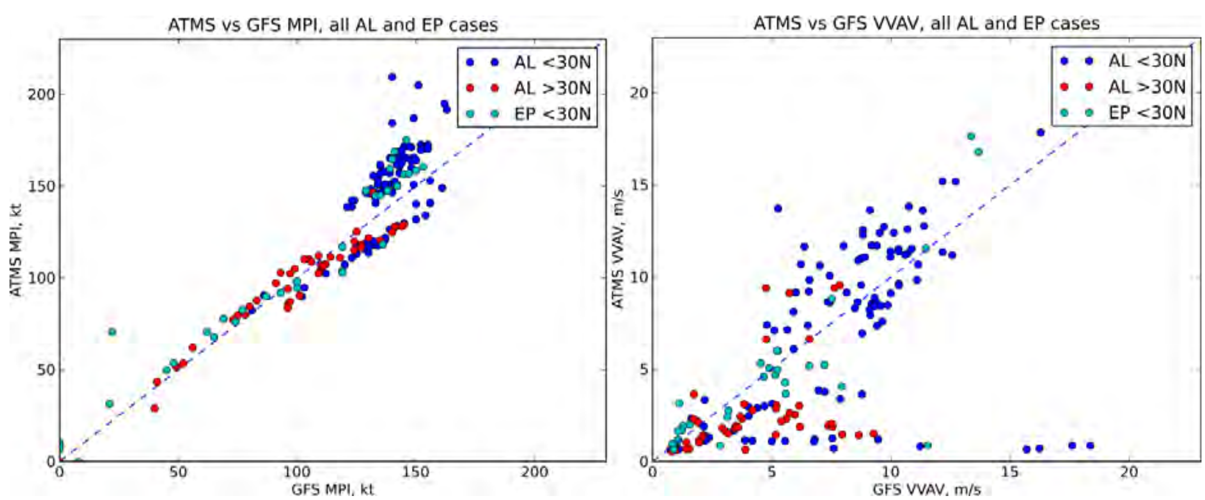


Figure 5. a) Left panel: Bister and Emanuel (1998) MPI(kt) calculated from ATMS and GFS profiles, with all other parameters identical. b) Right panel: average vertical velocity (m/s) from DeMaria (2009) generalized CAPE calculation. For both a) and b) blue and red dots show Atlantic Basin storms south and north of 30^o N, correspondingly, and magenta dots correspond to East Pacific Basin. For both plots the atmospheric profiles, including temperature and moisture profiles, and sea level pressure (SLP) are calculated from either ATMS or GFS, while all other parameters, including SST, are kept identical. T, q, SLP are averaged between 200 and 800 km for all calculations.

5-- Begin Investigation of NPP Input Into the Rapid Intensification Index (RII)

Preliminary estimates of the RII changes from ATMS profiles have been obtained. Considerable RII forecast sensitivity to the MPI calculation was found in some cases (not shown). Figure 6 shows the RII forecast change for 2012 Atlantic Hurricane Michael (AL13). Green dots show observed RII index, which is 0 if no RI occurred, and 100% if RI occurred. Red line with stars shows RI forecast based on operational GFS model fields, and blue line with triangles shows RI forecast with MPI calculated from ATMS data. Both forecasts are somewhat late in predicting the rapid intensification period; however, the ATMS version shows improvement by the significantly faster decrease in RII probability after the RI event was completed. The bias of ATMS data is 1.67 compared to 1.87 bias from GFS.

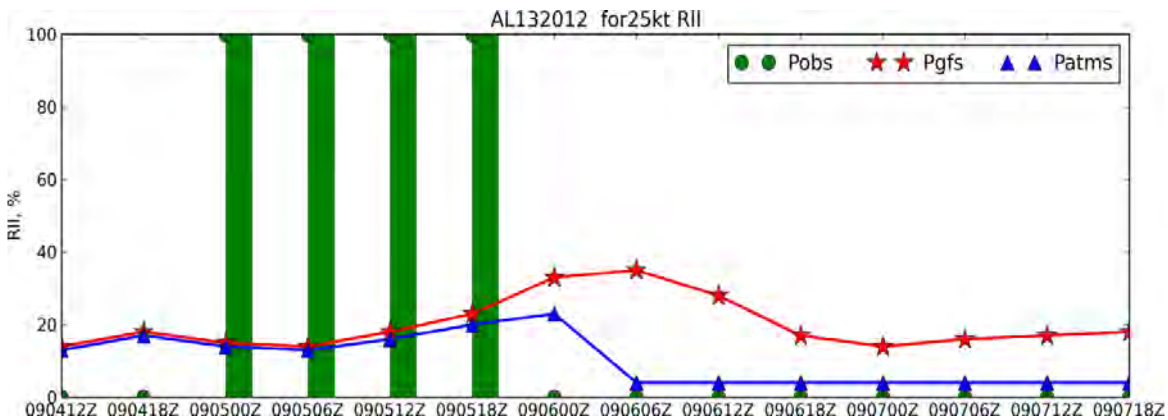


Figure 6. RII for 25 knots for Hurricane Michael, AL13 2012. Green bars show observed RII index, which is 0 if no RI occurred, and 100% if RI occurred. Red line with stars shows RI forecast based on operational GFS model fields, and blue line with triangles shows RI forecast with MPI calculated from ATMS data. The bias of ATMS data is 1.67 compared to 1.87 bias from GFS.

PROJECT TITLE: CIRA Collaboration with ESRL Physical Sciences Division on Hydrologic Research and Water Resources Applications Outreach Coordination

Project Title: Hydrologic Research and Water Resources Applications Outreach

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Lynn Johnson

NOAA TECHNICAL CONTACT: Rob Cifelli (NOAA/OAR/ESRL/PSD/WCB)

NOAA RESEARCH TEAM: Chengmin Hsu (CIRES), Robert Zamora (OAR/ESRL/PSD/WCB), Tim Schneider (NWS/HD)

PROJECT OBJECTIVES:

Hydrologic Research and Applications Development

Objective: Provide expert guidance and consultation on hydrologic applications in HMT.
Major activities include:
--Assist in the design, coordination and development of hydrological modeling and water resources management applications for regional demonstrations with the HMT, NWS/OHD, WWA and NIDIS programs;
--Provide guidance and leadership in carrying forward the hydrological research agenda defined in the HMT Hydrological and Surface Processes (HASP) plan, including publication in peer-reviewed journals;
--Support the HMT Project Manager in identifying and tracking candidate (and past) tools, techniques and knowledge transfers to NWS and key stakeholders.

Water Resources Applications Outreach Coordination

Objective: Provide support to and coordination between HMT and NOAA Partners and Stakeholders.
Major activities include:
--Assist in coordination with water management stakeholders such as the Corps of Engineers, U.S. Geological Survey, and other federal, state, and local water management agencies.
--Act as a liaison across NOAA Line Offices, particularly between OHD, PSD, CNRFC, NMFS and Line Office Headquarters;
--Provide guidance related to technical aspects of the national water resources information system, including system interoperability and data exchanges, eGIS and geo-Intelligence, integrated information delivery, the acquisition and management of observations and surveillance, and technological research and development;
--Support the planning for an HMT/IWRSS Russian River and California Pilot Study;
--Develop briefings and reports related to high-level needs (NOAA, Other Agency, and Legislative).

PROJECT ACCOMPLISHMENTS:

--On the topic of hydrologic research and applications development for the HMT, several sub-topics were addressed, including development of the HMT Hydrologic Research Plan and various hydrologic research extensions for companion PSD Water Cycle Branch (WCB) projects. The HMT Hydrologic Research Plan is intended to address the HMT major activity area on Hydrological and Surface Processes (HASP) research activities. The near-term focus is on the HMT-West where a priority requirement is to enhance the coupling of atmospheric and hydrologic models. There are several companion WCB projects which involve a hydrological research dimension. These include the North Fork of the American River, the Russian and Napa Rivers, the San Francisco Bay Regional system, and other activities in the Pacific Northwest and the HMT Southeast (HMT-SE).

Distributed hydrologic model (DHM) of the Russian River, CA accounts for the spatial distribution of rain, topography, soils, land use and runoff. It is a primary tool to assess the quality of precipitation nowcasts and forecasts products, and is being prototyped for deployment in real time forecast operations. The DHM has been calibrated for several tributary watersheds in the Russian-Napa river basins for the full range of flows – flood peaks and volumes, and low flows.

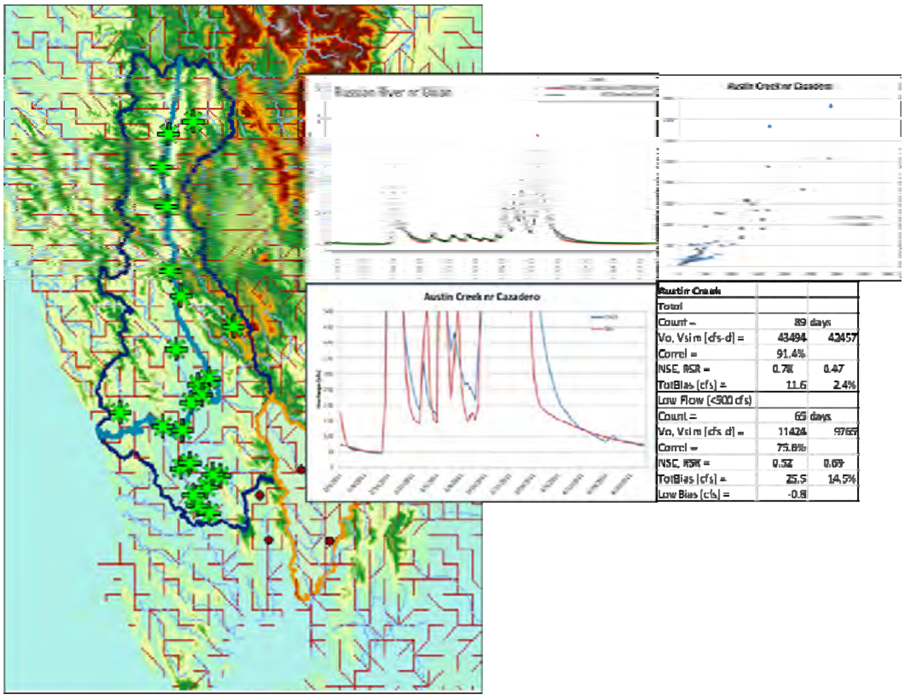


Figure 1. Calibration comparison between DHM simulated and observed flows is generally characterized as good to excellent.

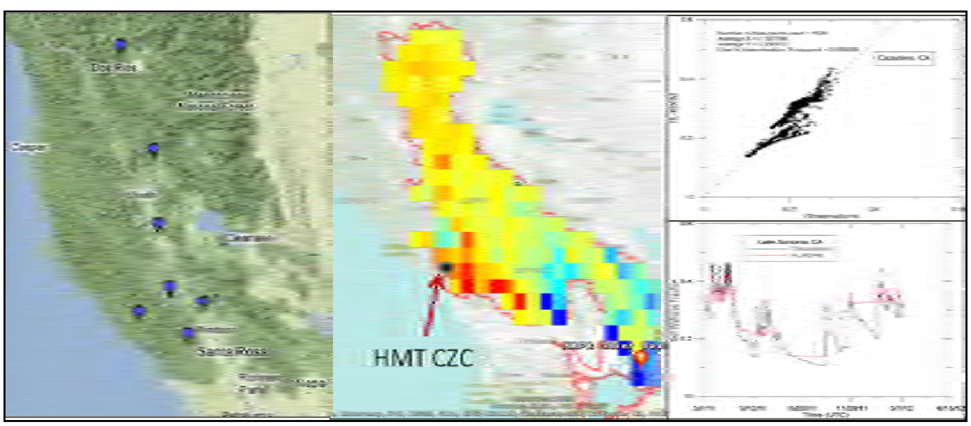


Figure 2. Soil moisture observations compared to DHM simulated values show good correlation in time but are biased due to sensor mis-calibration.

--On the topic of water resources applications outreach, there are several sub-topics being addressed, including the Russian River and California Integrated Water Resources Science and Services (IWRSS) Pilot and national-level eGIS (enterprise Geographical Information Systems) activities. The IWRSS program is a national-level initiative seeking interoperability of water resources information within NOAA and other federal agencies. The Russian River IWRSS Pilot involves representatives from federal, state and local agencies assembled to consider approaches and benefits that could accrue through coordinated water data exchange and decision support. Coordination activities are directed to a multi-agency focus on the Russian River as an IWRSS pilot demonstration; extensions to other sites in California, the Pacific NW and other regions are expected. Identified activities include HMT research applications for distributed hydrologic modeling, Sonoma County Water Agency hydrologic index decision support and US Army Corps of Engineers (ACE) and US Geological Survey (GS) data interoperability.

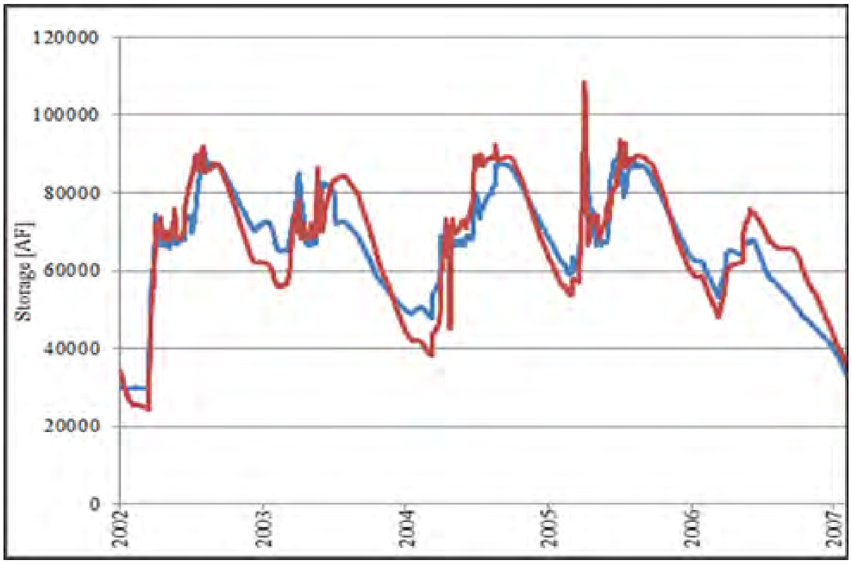


Figure 3. Reservoir operations model (FldOps) has been developed to assess alternate forecast-based operations policies. FBO policies have potential to mitigate floods and enhance water supply.

PROJECT TITLE: CIRA Support to JPSS Science Program: NPP VIIRS EDR Imagery Algorithm and Validation Activities and NPP VIIRS Cloud Validation

PRINCIPAL INVESTIGATOR**:** Steve Miller

RESEARCH TEAM: Stan Kidder, Yoo-Jeong Noh, Curtis Seaman, Steve Finley, Hiro Gosden, Dave Watson, Kevin Micke, Renate Brummer, Kathy Fryer

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS) and Phil Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: Don Hillger, John Knaff, Dan Lindsey, Mark DeMaria (NOAA/NESDIS/STAR/RAMMB)

PROJECT OBJECTIVES AND ACCOMPLISHMENTS:

The Suomi National Polar-orbiting Partnership mission (NPP), serving as risk-reduction to the Joint Polar Satellite System (JPSS) and providing continuity to the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS) climate mission, was launched successfully on 28 October 2011.

The Visible Infrared Imager Radiometer Suite (VIIRS) on board Suomi NPP provides atmospheric, cloud, and surface imagery for both weather and climate applications. VIIRS is the next-generation to the Advanced Very High-Resolution Radiometer (AVHRR) which has flown on board the Polar-Orbiting Environmental Satellites (POES) since NOAA-15 in 1998. VIIRS was originally designed to merge the capabilities of the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) and the NASA Moderate-resolution Imaging Spectroradiometer (MODIS).

This is a multi-agency research project with teams involved from NOAA/NESDIS/STAR, CIRA, CIMSS, NRL, NGDC, NGAS, and Aerospace. CIRA's research in this area is divided in into two distinct elements: I) VIIRS Imagery Algorithm and Validation Activities and II) VIIRS Cloud Base Height (CBH) and Cloud Cover/Layers (CCL) Validation.

These projects directly address NOAA's Weather and Water goal, which seeks to serve society's needs for weather and water information. This research also falls within the NOAA-defined CIRA thematic area of Satellite Algorithm Development, Training and Education, as calibration/validation is an integral and critical first step in the algorithm development process. Outcomes of the current research may in some cases lead to adjustments in the original algorithm to correct issues discovered during the calibration/validation analysis.

Project I: VIIRS Imagery Algorithm and Validation Activities

Objectives:
1--Continue the collection of near real-time Imagery EDRs (and SDRs as needed) from available sources (e.g. GRAVITE and Atmos PEATE).
2--Create VIIRS imagery and image products on special weather events like tropical cyclones, severe weather events, and mid-latitude cyclones.
3--Generate and analyze data and examine selected higher-order image products. These include multi-spectral image combinations, such as those used in the detection of fog/stratus, blowing dust, fires and smoke, aerosols, etc.
4--Demonstrate true-color applications for assessing land and atmospheric phenomena (such vegetation, blowing dust, smoke, haze, etc.). Adapt true color processing techniques customized for VIIRS R/G/B bands.
5--Leverage the real-time web displays of VIIRS imagery and higher-order image products as a source of material for training of NWS and other meteorologists, especially for those spectral bands that are new to the operational satellite data stream (i.e., in comparison to AVHRR).

Research Conducted:
1--CIRA received (in near real-time) and archived (some permanently and some on a rotating basis) in an automated fashion a large amount of VIIRS data during FY13, including both Imagery EDRs and SDRs from available sources (GRAVITE, Atmos PEATE, and Direct Broadcast imagery from UW/CIMSS). CIRA continued and expanded the processing of the VIIRS imagery via automated scripts. The imagery generated serves as a repository for quality-control as well as case study examples for highlighting various multi-spectral capabilities. Refinements to processing scripts have enabled the mapping and display of imagery at I-band (375 m resolution), producing high-quality graphics suitable for JPSS public relations and general media consumption. The agility of the automated processing, combine with access to global data from Suomi NPP, provide a mechanism for rapid response to environmental events occurring worldwide.

2--Display/visualization tools (such as McIDAS-V, IDL, and Terascan) were used for analysis of VIIRS imagery and imagery products for cases involving tropical cyclones, blowing dust, aerosols, snow, as well as regional depictions (e.g., Antarctica) created and shared with NESDIS managment both proactively and upon special request. VIIRS imagery was depicted and discussed in detail on CIRA's online display, CIRA's NPP Blog, the Seeing the Light: VIIRS in the Arctic Blog, and occasionally on the NESDIS and

STAR pages. The team has also spearheaded efforts to determine alternative pathways and/or bent-pipe solutions within the current processing framework in an effort to overcome ~7 hour data latency for imagery products. We anticipate that the fruits of this effort will be global data at a latency of ~2 hours, making the data operationally viable.

3--Activities with other VIIRS EDR and SDR Teams were coordinated to accomplish the checkout of imagery and image product quality. Monthly telecons were conducted to discuss the VIIRS imagery, including such things as: data access, image quality, image and data processing problems, and discrepancy reporting. CIRA scientists continue to participate in the identification of EDR Imagery issues, although mostly resolved for non-NCC Imagery. However, among the imagery EDRs, the product with the most challenges was the Day/Night Band (DNB (SDR)) or Near Constant Contrast (NCC (EDR)) product. CIRA participated in discussions/decisions surrounding specific issues with this product, including interactions with both the software developers (Northrop Grumman) and operations (Raytheon) related to NCC's limitations in producing nighttime imagery, as well as necessary corrections to reduce stray light contamination. These interactions resulted in the implemented of the necessary software corrections for the full and proper implementation of VIIRS NCC Imagery. CIRA continued to select insightful case studies that illustrate the strong potential of VIIRS imagery to assist in the interpretation of the meteorological situation via our VIIRS satellite blog site (http://rammb.cira.colostate.edu/projects/npp/blog/). The site connects Suomi imagery to current events, such as Super Typhoon Haiyan's landfall in the Philippines (Figure 1) the major floods in Colorado in September 2013, and the massive wild fires across the western U.S. earlier that summer. The blogs are delivered in a unique blend of technical and laymen language in an effort to entrain the general public and 'citizen scientists,' while providing sufficient information to serve as an informative training tool for operational uses in NOAA. VIIRS true-color imagery is also being used as training and proxy data for the future geostationary-based capabilities.

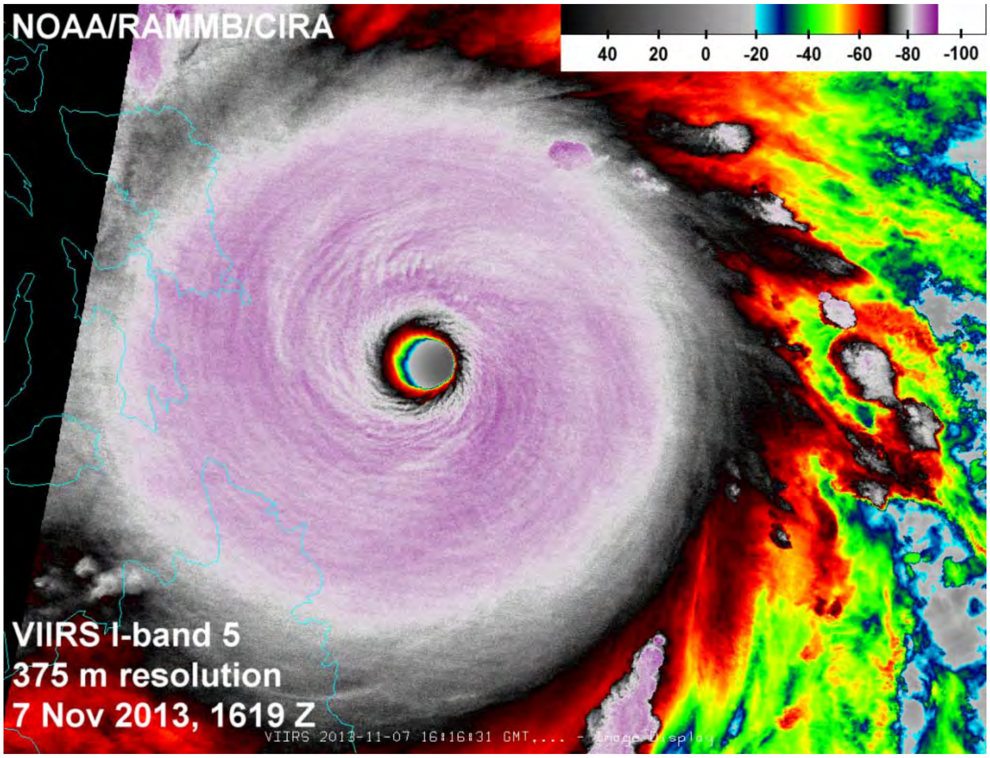


Figure 1. VIIRS infrared (I-5) image of Super Typhoon Haiyan (Yolanda) taken 16:16 UTC 7 November 2013. Brightness temperatures are given in degrees Celsius. From the 14 Nov 2013 CIRA VIIRS blog.

4--Several multi-spectral and RGB products (including true-color imagery) were generated for many different atmospheric events (tropical cyclones, severe thunderstorms, dust, fires, smoke, volcanic ash, fog, smog, ocean currents, etc.) An example is shown in figure 2 below.

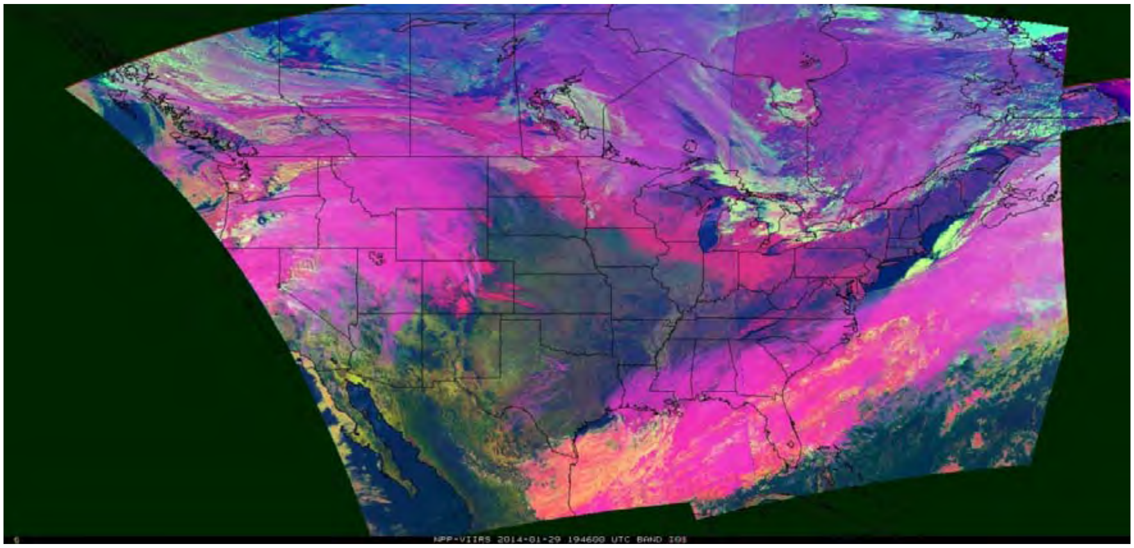


Figure 2. RGB composite (DNB/Shortwave Albedo/Longwave IR) produced from daytime VIIRS direct-broadcast imagery captured from the University of Wisconsin and displayed on CIRA's "Suomi NPP VIIRS Online". Land surfaces are basically green, ocean surfaces are blue, and low clouds are white or off-white. The magenta-based colors for snow (more red) and ice cloud (more purple) are similar, but users can easily learn to distinguish between the two.

The team also submitted a science paper describing the status of its imagery cal/val activities to the Journal of Geophysical Research (JGR). It summarizes research that has helped resolve several imagery-related issues, including missing geo-location information, as well as missing radiance measurements. In particular, the Near Constant Contrast (NCC) imagery product, derived from the Day/Night Band, has had a large number of issues to overcome, including numerous missing or blank-fill images, mis-navigation issues, and a stray-light leakage problem that require software-based corrections. The paper also includes multispectral imagery examples, based on some of the same techniques highlighted in the VIIRS blog entries. This paper is in review.

5--NPP VIIRS Imagery is being used as training/proxy data for the application new spectral bands, some of which will appear in geostationary data in the GOES-R era. Real-time web displays of VIIRS imagery and image products are updated regularly at http://rammb.cira.colostate.edu/ramsdis/online/npp_viirs.asp and blogs are being posted regularly at http://rammb.cira.colostate.edu/projects/npp/blog/ and http://rammb.cira.colostate.edu/projects/alaska/blog/

In addition, the team engages in monthly tag-ups teleconferences to keep abreast of developments with imagery, discuss and craft Discrepancy Reports when applicable, and strategize on best practices in evaluating imagery related issues. The team also contributed results to the JPSS Provision Review in January 2014. A full status on the imagery cal/val activities as well as key imagery examples were supplied.

Project II: Support of the VIIRS Cloud Validation Activities

Objectives

1--Continue to collect co-location datasets for CloudSat/CALIPSO/Suomi-NPP, coordinating with Univ. Wisconsin to ensure common protocols are followed for footprint matching and formats.

2--Validate CCL/CBH Intermediate Products (IPs; pixel-level, unaggregated results) against CloudSat and CALIPSO data as available, matched in space/time to VIIRS, for selected case studies to gain insight on instantaneous performance for various cloud types (e.g., optically thin ice-phase clouds, or optically thick low-level liquid phase clouds).

3--Compile statistics on EDR performance as a function of cloud optical and microphysical properties, season, region, etc., using CloudSat and CALIPSO.

4--In coordination with NOAA and CIMSS, install and test PATMOS-x cloud property retrieval software, applied to VIIRS Level-1B measurements, as an end-around to the issues currently faced in the operational IDPS processing stream.

5--Implement a local version of the CBH software based on the CBH ATDB, as described above.

Research Conducted

1--Work continued on validation of VIIRS Cloud Cover Layers (CCL) and Cloud Base Height (CBH) products against CloudSat data and CALIPSO data as available, matched in space/time to VIIRS. Since the EDRs are aggregated from the Intermediate Products (IPs), the latter are the initial focus of this cal/val effort as they are available at the native sensor resolution of VIIRS M-bands. Many methods of validation were conducted, including stratification on cloud type and cloud optical depth. As an additional layer of quality control, a version of the comparisons was done under the constraint that cloud top height retrievals were within performance specifications.

2--We discovered an issue with the pixel matching between CloudSat and VIIRS in team-supplied software which occasionally resulted in attempts to extract information from the ‘bow tie deletion’ zones of the VIIRS swath. We modified this code to select nearest good neighbor and re-ran all the statistics, recapturing about 7.5% of the total data.

3--The team participated in bi-weekly tag-up teleconferences, where various issues were discussed as related to the cloud EDRs, crafting of Discrepancy Reports (DRs), and plan/strategy for overcoming issues and evaluating the performance of algorithm changes.

4--Among the DRs mentioned, a number of issues with up-stream products which feed into CBH were identified by the cal/val team, rendering dubious the quality of the CBH retrievals. In particular, a major issue with radiative transfer look-up tables resulted in significant errors to retrieved optical depth, particle size, and water path which are critical inputs to the CBH algorithm. Each new fix made to these upstream products requires reprocessing of the CloudSat/VIIRS comparisons. Toward the end of the period, a topic of debate became to what extent the science team should continue to devote its attention to remedying the IDPS products when there exist alternative processing that provides consistency with MODIS and heritage NOAA algorithms is available.

5--In anticipation of a possible switch to NOAA-heritage processing, we completed work on porting CBH from IDPS to local processing and confirmed correct operation. The algorithm has been coupled to our local copy of PATMOS-X (which maintains consistency with the NOAA operational version via SVN checking). We are currently in a position to switch seamlessly to the PATMOS-X based CBH product upon receipt of JPSS Program Office direction.

6--The current performance of the IDPS CBH algorithm leaves considerable room for improvement. In preparation for introducing CloudSat-based geometric cloud thickness (conditioned on cloud type), we have reprocessed the CloudSat full-mission data statistics on geometric thickness using VIIRS cloud typing logic applied to Aqua MODIS data. Since CloudSat and Aqua both fly in the NASA A-Train, porting the VIIRS cloud type algorithm to MODIS enables compilation of an enormous, statistically-robust dataset. The statistics will allow us to constrain cloud geometric thickness by representative distributions for each VIIRS cloud type encountered, as a way of quality controlling results and potentially weighing the likelihood of results produced by different Cloud Base Height algorithmic approaches.

7--We assisted in nighttime cloud base height comparisons using cloud optical depth derived from moonlight instead of the standard (operational) thermal-infrared method. This is a future-focused research direction for the project, as nighttime lunar-based Cloud Optical Properties is not yet part of the NOAA operational processing plan.

8--The team also contributed numerous results to the Beta Maturity review in June 2013 and to the Provisional Review in January 2014.

9--In addition, we participated in the analysis of IDPS and PATMOS-x CBH retrievals for the months of September 2012 and September 2013, which represent 'golden months' for comparisons after updates to the IDPS cloud property codes.

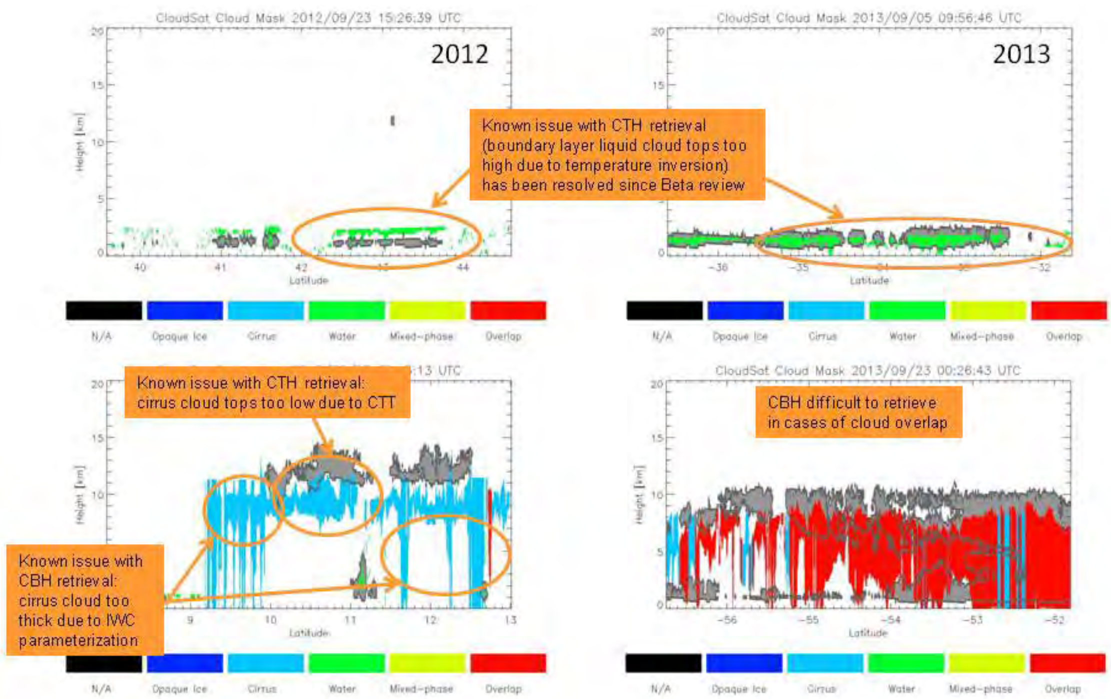


Figure 3. Examples of CloudSat geometric profiles (gray cross-sections) vs. matched VIIRS retrievals as a function of cloud type, illustrating various issues that have come to light over the course of this analysis. Most issues tie back to discrepancies in the various upstream VIIRS cloud property retrievals.

PROJECT TITLE: Design, Development, Evaluation, Integration and Deployment of New Weather Radar Technology

PRINCIPAL INVESTIGATOR: V. Chandrasekar

RESEARCH TEAM: Francesc Junyent

NOAA TECHNICAL CONTACT: Robert Cifelli (NOAA/OAR/ESRL/PSD/WCB)

NOAA RESEARCH TEAM:

PROJECT OBJECTIVE:

Site Identification Report for Potential Future Radar Sensors for the City and County of San Francisco

The San Francisco Advanced Quantitative Precipitation Information System project would be an iterative approach of data collection, analysis, and system improvements to assure accurate data and operational reliability. One of the principal tasks is to collect data that would feed the AQPI to develop Radar-based Nowcast for short-term prediction (30 minutes) and Quantitative Precipitation Forecast (QPF) for up to 12 hours. The key aspect of obtaining the accurate and timely update of the rainfall map over the SF area is to install new modern dual-polarization X band and C band radars in the appropriate locations to provide coverage to the city in terms of rainfall monitoring. Towards this goal a small study was initiated to select and evaluate sites for possible deployment of one X band and one C band radar. This report presents results from the X Band and C band radar deployment study.

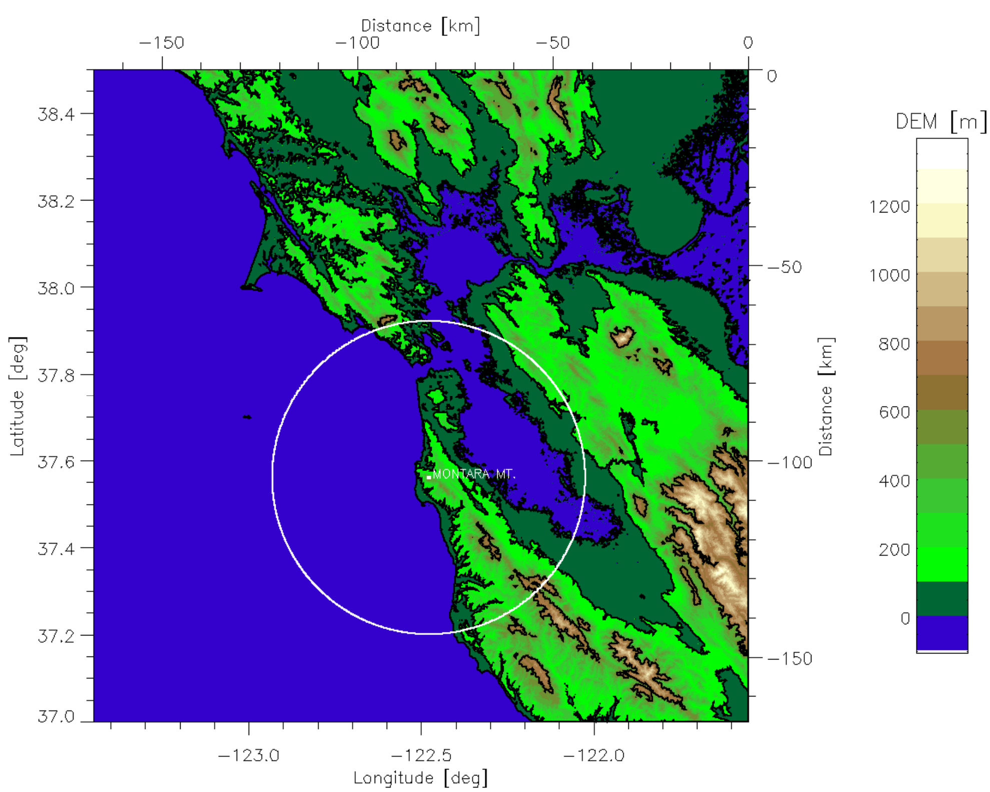


Figure 1. An example of Digital elevation model based radar beam height study.

PROJECT ACCOMPLISHMENTS:

The results and recommendation from this project are primarily based on scientific and engineering considerations. Some additional tradeoffs and modifications can be made on these recommendations based on further considerations. For example, radar deployment at any location will be dependent on securing a license to transmit from the FCC, which may depend on other existing equipment on site.

A major comprehensive NOAA report was prepared titled: Preliminary Site Identification Report for Potential Future Radar Sensors for the City and County of San Francisco.

PROJECT TITLE: eTRaP Upgrade – Shear, Topography, Storm Rotation, and Rainfall Climatology & Persistence Model (R-CLIPER)

PRINCIPAL INVESTIGATOR: Stan Kidder

RESEARCH TEAM: Stan Kidder

NOAA TECHNICAL CONTACT: Bob Kuligowski (NOAA/NESDIS/STAR/SMCD/EMB)

NOAA RESEARCH TEAM: Liquin Ma (NESDIS/OSPO/SPSD/SPB), Bob Kuligowski (NESDIS/STAR/SMCD/EMB) Michael Turk (NESDIS/OSPO/SPSD/SAB), Sheldon Kusselson (NESDIS/OSPO/SPSD/SAB), Beth Ebert (Australian Bureau of Meteorology); Clay Davenport (contractor, NESDIS/OSPO/SPSD), Bob Glassberg (contractor, NESDIS/OSPO/SPSD/SPB)

PROJECT OBJECTIVES:

1--If appropriate, insert R-CLIPER “TRaPs” as ensemble members in eTRaP

2--Investigate the effects of shear and topography on eTRaP

3--Try to apply rotation to satellite rainfall estimates (instead of just keeping the pattern fixed for 24 hours).

PROJECT ACCOMPLISHMENTS:

Good progress was made this year, in spite of major computer problems at STAR:

1--Found a way to “disaggregate” the 24-hour R-CLIPER rainfall estimates into 6-hour chunks, which can then be used in eTRaP, just as the microwave TRaPs (and soon the HydroEstimator TRaPs) are used. Efforts are nearly complete to pin down the SensorWeight and SensorBias to be applied to the R-CLIPER TRaPs.

2--Beginning the task of determining how the sheared R-CLIPER rainfall estimates can be used either with or in place of the non-sheared R-CLIPER rainfall estimates to go into eTRaP. I expect this work to be completed by the end of June.

3--Bob Kuligowski has done initial calculations on storm rotation on HydroEstimator TRaPs. First results don’t look promising. It may be decided that the added computational burden of storm rotation (which was developed for storms striking Taiwan) may not be warranted for eTRaP for Atlantic tropical cyclones.

PROJECT TITLE: POES-GOES Blended Hydrometeorological Products

PRINCIPAL INVESTIGATOR: Stan Kidder

RESEARCH TEAM: John Forsythe, Andy Jones

NOAA TECHNICAL CONTACT: Limin Zhao (NOAA/NESDIS/OSPO/SPSD/SPB)

NOAA RESEARCH TEAM: Limin Zhao (NESDIS/OSPO/SPSD/SPB), Sheldon Kusselson (NESDIS/OSPO/SPSD/SAB), John Paquette (NESDIS/OSPO/SPSD), Ralph Ferraro (NESDIS/STAR/CRPD/SCSB), and others

PROJECT OBJECTIVES:

1--Test real-time ATMS/S-NPP in TPW and RR products when they become available from MIRS. (Note: This objective and the following three objectives are repeated from last year because (1) the reporting year doesn't coincide with the time when the work can be done, and (2) the time when data actually become operationally available to us often slips into the following reporting period.)

2--Deliver the updated products for operational implementation (repeated from last year)

3--Develop a snow & ice mask to eliminate problems with retrievals over snow or ice-covered areas (repeated from last year)

4--Ensure Metop-B readiness (repeated from last year)

5--Add GCOM-W1 AMSR-2 observations to Blende TPW and Blended RR (new this year)

PROJECT ACCOMPLISHMENTS:

1--NESDIS decided that new data from MIRS ATMS/S-NPP (and Metop-B) would be in netCDF format instead of the HDF-EOS format that we have been using. This required a major rewrite of our processing engine, DPEAS (which we are calling DPEAS Version 3). This was accomplished, and has been transferred to OSPO for implantation. New ingest routines for the ATMS/NPP data have been written and are in use at CIRA to produce Blended TPW and Blended RR (see http://cat.cira.colostate.edu). The ATMS data are still not operational at OSPO. When they become operational, we will complete testing and transfer the routines to OSPO for operational implementation.

2--Product delivery is an on-going process. It depends on (1) when operational products are ready to be ingested by DPEAS, (2) when we have finalized testing, and (3) when OSPO is ready to receive them. Currently OSPO is installing DPEAS Version 3.

3--This has turned out to be a more complicated (and less necessary) task than previously thought. MIRS retrieves TPW and RR over snow-covered land, so the surprise raining areas and TPW bull's-eyes are not as distracting as they once were. But there are still problems with undetected sea-ice and also with anomalously high TPW over cold land, which was not part of the snow & ice mask concept. We are rethinking this objective.

4--We have written the Metop-B netCDF ingest routine and are including Metop-B data in Blended RR and Blended TPW. Delivery of these routines to OSPO awaits OSPO's implementation of DPEAS Version 3.

5--GCOM-W1 AMSR-2 TPW and RR retrievals are not yet operationally available. Using test data, we have developed ingest routines and are now investigating how best to include the data in Blended RR and Blended TPW. The biggest problem is that the AMSR-2 data have different resolutions for different fields, and they are not in the same file; thus, a somewhat different blending strategy will be necessary.

6--The current operational blended TPW product does not account for topography over land, nor does it exploit the full capabilities of GOES-E and GOES-W TPW retrievals. An improved Blended TPW merge procedure was developed at CIRA, and is slated to be implemented as an upgrade at OSPO in 2014. Side-by-side near-real time animations of the two products are available at http://amsu.cira.colostate.edu/gpstpw/.

7--CIRA participated in ongoing monitoring of the operational products at OSPO and the developmental products at CIRA. The capability of CIRA to run a shadow system using the same software as the operational OSPO system is a valuable troubleshooting tool. This led to feedback to OSPO to adjust the timing of their GPS data pulls for increased product quality, and comments to the MiRS team on retrieval performance.

Publications Note: Our PSDI grant doesn't have publication costs or travel money.

PROJECT TITLE: Quantitative Precipitation Estimation (QPE)

PRINCIPAL INVESTIGATOR: V. Chandrasekar

RESEARCH TEAM: V. Chandrasekar, Delbert Willie, Haonan Chen

NOAA TECHNICAL CONTACT: Robert Cifelli (NOAA/OAR/ESRL/PSD/WCB)

NOAA RESEARCH TEAM: Robert Cifelli

PROJECT OBJECTIVE:

QPE in the NOAA's West Hydrometeorology Testbed (HMT-West)

PROJECT ACCOMPLISHMENTS:

1--Impact of a commercial C-band radar for QPE in an area of poor NEXRAD radar coverage and to determine the relative performance of different QPE methods Hydrometeor classification
2--Evaluation of MPE
3--Evaluation of NOAA Q2 product

This study aims to evaluate the impact of a commercial C-band radar for QPE in an area of poor NEXRAD radar coverage and to determine the relative performance of different QPE methods. The primary area of interest in this study is concentrated around the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorology Testbed (HMT) in the Russian River basin north of San Francisco, CA (Figure 1). This watershed covers approximately 1500 square miles and has an annual average discharge of around 1,600,000 acre-feet. In this mountainous terrain, the challenge of obtaining reliable QPE's is limited by beam blockage and overshooting (Maddox et al. 2002), and orographic enhancement (Kitchen et al. 1994). Even if a perfect empirical Z-R relation can be applied, the accuracy is subject to factors such as: radar calibration, ground clutter, attenuation, beam blockages, bright bands and anomalous propagation, etc. (Fulton et al. 1998). In development of Z-R algorithms, rain gauges provide ground truth to the estimation of Z-R coefficients for a given region. In this study, radar data is taken from the surrounding NEXRAD WSR-88D radars (KMUX, KDAX, KBHX, and KBBX) as well as the C-band TV station radar KPIX. The KPIX radar scans the same area of interest but, unlike the NEXRADs, is closer and has a nearly unobstructed view of the Russian River basin. Rain gauge data from the

California Data Exchange Center (CDEC) was used for ingest into QPE processing, and the rain gauges used for validation came from the NOAA HMT and Sonoma County winery gauges (Figure 2).

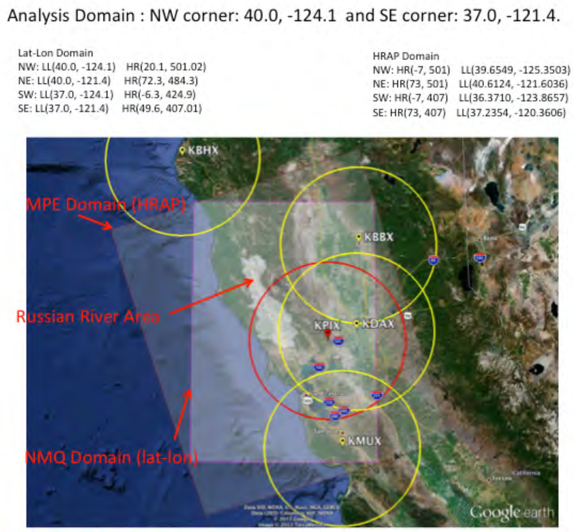


Figure 1

Figure 2

The QPE precipitation fields, generated by NMQ, evaluated in this analysis include: gauge only, multiple radar-only, and multiple radar with VPR and gauge correction. Along with radar input, 52 gauges are used by NMQ for gauge analysis.

To illustrate the impact of the KPIX radar on the NMQ QPE products, several scenarios were evaluated by varying the NMQ radar input parameters. The first was to use KPIX as the only NMQ radar input. Then use all radars which include the four local NEXRAD radars along with KPIX. The final scenario was to only use the four NEXRAD radars into the mosaic. With each radar input, the NMQ QPE products of interest were gauge only, radar only, and radar with VPR and gauge correction. Along with the NMQ

QPE, a simple KPIX QPE was calculated directly from the raw reflectivity using the Z-R relationship. These QPE results were also compared to the independent gauge QPE.

References:

Fulton, R., J. Breidenbach, D. J. Seo, D. Miller, and T. O'Bannon, 1998: The WSR-88D rainfall algorithm. Wea. Forecasting, 13, 377-395.

Kitchen, M., R. Brown, and A. G. Davies, 1994: Real-Time Correction of Weather Radar Data for the Effects of Bright Band, Range and Orographic Growth in Widespread Precipitation. Quart. J. Roy. Meteor. Soc., 120, 1231-1254.

Maddox, R., J. Zhang, J. Gourley, and K. Howard, 2002: Weather Radar Coverage over the Contiguous United States. Weather Forecasting, 17, 927-934.

Martner B. E., S. E. Yuter, A. B. White, S. Y. Matrosov, D. E. Kingsmill, and F. Martin Ralph, 2008: Raindrop Size Distributions and Rain Characteristics in California Coastal Rainfall for Periods with and without a Radar Bright Band. J. Hydrometeor., 9, 408–425.

Seo, D. J., 1998: Real-time estimation of rainfall fields using radar rainfall and rain gage data. J. Hydro., 208, 37–42.

Simanton J. R., and H. B. Osborn, 1980: Reciprocal Distance Estimate of Point Rainfall. J. Hydraul. Div. Amer. Soc. Civ. Eng., 106, 1242-1246.

Zhang, J., and Coauthors, 2011: National Mosaic and Multi-Sensor QPE (NMQ) System: Description, Results, and Future Plans. Bull. Amer. Meteor. Soc., 92, 1321–1338.

PROJECT TITLE: PROJECT TITLE: Summer School on Atmospheric Modeling

PRINCIPAL INVESTIGATOR: David Randall

RESEARCH TEAM: David Randall

NOAA TECHNICAL CONTACT: Cecelia DeLuca (NOAA/OAR/ESRL)

NOAA RESEARCH TEAM:

PROJECT OBJECTIVES AND ACCOMPLISHMENTS:

1—Summer School on Atmospheric Modeling

The time frame covered by this report is April 1, 2013 – March 31, 2014.

We developed and conducted a Summer School on Atmospheric Modeling (SSAM 2013), which was held at the National Centers for Environmental Prediction, on July 29-August 1, 2013. The focus of the class was GFS, the global forecast model. Information about the class is available here:

https://docs.google.com/spreadsheet/ccc?key=0AulUXafaNxz0dDMzWnZVLTNSNkpYLWtyTFJiQ1Y0Q3c&usp=sharing#gid=0

	Course Schedule			
	Mon, July 29	**Tue, July 30**	**Wed, July 31**	**Thur, Aug 1**
8:30 AM	Introductions & Syllabus	Physics	Climate	Ensemble
8:45 AM				
9:00 AM	Logistics	SAS	Land Surface	WAM
9:15 AM				
9:30 AM	NEMS/GFS Overview	RAS	Ocean/Sea Ice Surface	Aerosols
9:45 AM		**BREAK**		
10:00 AM	**BREAK**	Radiation	**BREAK**	**BREAK**
10:15 AM	Parallel Computing		DA	Future plans
10:30 AM				Q/A Session
10:45 AM	Dynamics - Eulerian	Turbulence / PBL	Verification	
11:00 AM				WPC wx briefing
11:15 AM		Gravity Wave Drag	Post	
11:30 AM	Semi-Lagrangian			MEG meeting
11:45 AM	Q/A Session	Q/A Session	Q/A Session	
12:00 PM	**LUNCH**	**LUNCH**	**LUNCH**	
12:15 PM				
12:30 PM				**LUNCH**
12:45 PM				
1:00 PM	TUTORIAL	TUTORIAL	TUTORIAL	
1:15 PM				
1:30 PM				Feedback Session
1:45 PM				
2:00 PM				TUTORIAL DISCUSSIONS
2:15 PM				
2:30 PM				
2:45 PM				
3:00 PM				
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4:30 PM				
4:45 PM				

Participation was limited to students; a list of the students is available upon request.

SSAM 2013 was made possible through the efforts of NCEP scientists, whose participation was authorized by the then Acting Director of the Environmental Modeling Center, William Lapenta.

2--Class Materials on Global Atmospheric Modeling

David Randall's graduate-level book "An Introduction to the Global Circulation of the Atmosphere" has been delivered to Princeton University Press. Publication is expected in early 2015

PROJECT TITLE: Variability in Snow Sublimation Across Basin Scale Systems

PRINCIPAL: Nolan Doesken

RESEARCH TEAM: Morgan Phillips, Nolan Doesken

NOAA TECHNICAL CONTACT: Chad McNutt (NOAA/ESRL)

NOAA RESEARCH TEAM: Chad McNutt

PROJECT OBJECTIVE:

Provide reasonable estimates of local and regional sublimation losses over a 10-year time period including wet and dry years to quantify the seasonal cycle, year-to-year variations and spatial differences in snow sublimation.

PROJECT ACCOMPLISHMENTS:

Morgan Phillips completed this research project (described fully in last year's annual report) during the spring and early summer of 2013 and successfully defended his thesis. This was a modelling study that utilized SnowModel driven by a ten year data set processed through the Local Data Assimilation System applied to a large area of the Upper Colorado River Basin in Colorado and eastern Utah. From this modelling effort, estimates were made of the absolute magnitude of snow sublimation, the temporal variability of sublimation throughout the 10 years of simulations, and the spatial patterns associated with both the absolute magnitude, the rate and the contribution to sublimation from static, canopy and blowing snow sublimation. SnoTel data from dozens of sites across the basin provided a degree of validation.

One publication was completed and accepted, a newsletter article was submitted to the NIDIS program office, and a live webinar was held for interested stakeholders in the Upper Colorado River Basin with around 50 water managers in attendance.

This project then launched the first year of a new M.S. research project supporting NIDIS and Drought Early Warning in the Upper Colorado River Basin. Peter Goble began work during the fall of 2013 assessing available soil moisture monitoring locations in and near the basin and the type of instrumentation used. This will form the basis of a new study on improving drought early warning through better use of modeled and observed soil moisture.

DATA DISTRIBUTION

Research focusing on identifying effective and efficient methods of quickly distributing and displaying very large sets of environmental and model data using data networks, using web map services, data compression algorithms, and other techniques.

PROJECT TITLE: CIRA Research Collaborations with the NWS Meteorological Development Lab on AutoNowCaster and AWIPS II Projects

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Kenneth Sperow, John Crockett

NOAA TECHNICAL CONTACT: Stephan Smith (NOAA/NWS/OST/MDL)

NOAA RESEARCH TEAM: Mamoudou Ba (NWS/OST/MDL), Lingyan Xin (NWS/OST/MDL)

PROJECT OBJECTIVES:

1--Virtual Lab (VLab)
The NWS is creating a service and IT framework that will enable the NWS and its partners to share ideas, collaborate, engage in software development, and conduct applied research from anywhere. The VLab will help to:
a--Reduce the time and cost of transitions of NWS field innovations to enterprise operations;
b--Minimize redundancy and leverage complementary, yet physically separated, skill sets;
c--Forge scientific and technical solutions based on a broad, diverse consensus; and
d--Promote a NWS culture based on collaboration and trust.

2--AWIPS II
The NWS is in the process of evolving AWIPS to an open source, service oriented architecture (SOA). The major objective of this project is to provide the functionality of AWIPS build OB9 in this new SOA infrastructure.

The MDL is not directly responsible for the migration of its applications from AWIPS to AWIPS II; this is the responsibility of Raytheon, the prime contractor. However, the MDL will be overseeing the migration of its current applications, developing new applications in the new framework, and enhancing existing applications beyond OB9, which falls outside the scope of Raytheon's migration. AWIPS II uses many technologies (JAVA, Mule, Hibernate, JavaScript, JMS, JMX, etc.) that are new to the MDL and the NWS. In order for the MDL to be in a position to add value, they need people who have a working understanding of these technologies.

3--AutoNowCaster (ANC)
Originally developed by the Research Applications Laboratory (RAL) at the National Center for Atmospheric Research (NCAR), ANC nowcasts convective initiation. It is currently experimental and runs solely at the MDL. The project's objectives are the following:

a--Develop a more complete understanding of ANC's architecture and configuration, and document that understanding b--Where possible and/or necessary, optimize ANC's software and streamline its configuration

c--Contribute to experiments designed to improve, better understand, or showcase ANC

d--Transition ANC to operations so that its nowcasts of convective initiation are available to interested entities

4--Impacts Catalog
The National Weather Service's Weather-Ready Nation Roadmap calls out the creation of a national Impacts Catalog, a system whereby the NWS can improve its Impact-based Decision Support Services (IDSS) to its core partners by providing those partners information regarding the impacts which relevant meteorological variables will have on those partners' operations. The project's objective is to provide leadership and technical expertise.

PROJECT ACCOMPLISHMENTS:

1--VLab
a--Ken Sperow continued to be the VLab technical lead, as well as the technical lead of the Virtual Lab Support Team (VLST). This team currently consists of 10 members to whom Ken provides support and training.

b--Under Ken Sperow's and Stephan Smith's (the NOAA PI) leadership, the VLab continues to grow in importance and visibility within the NWS.

--Ken Sperow demonstrated the VLab both to the Director of the NWS and to other top-level staff within the NWS.
--Separate demos of the VLab were given to the Warning Coordination Meteorologist (WCM) community, the Information Technology Officer (ITO) community, and the Science and Operations Officer (SOO) community.
--Providing web-based services to help manage projects via issue tracking, source control sharing, code review, and continuous integration, VLab Development Services (VLDS) have grown to support 51 projects and 512 developers.

c--Under Ken Sperow's leadership, NCEP used the VLab to check in their 14.2.1 AWIPS II baseline changes.

d--Ken is working with the NOAA CIO's office to move the VLab to a public cloud infrastructure.

2--AWIPS II
a--Ken Sperow assisted NWS Systems Engineering Center management with the high-level design of AWIPS II tasks being assigned to GSD, Raytheon, NCEP, and the MDL. This assistance included co-leading several meetings in which all the organizations participated
.
b--Continued to provide AWIPS II support to MDL developers and to install new releases of the AWIPS II software on the system for knowledge transfer and development activities.

c--Lead the development of a meteogram tool within AWIPS II in coordination with the NASA Short-term Prediction Research and Transition Center (SPoRT) within the VLab. Ken applied for and received an ATAN to install and test the tool in a real-time environment at the Huntsville, AL forecast office as well as the NHDA test facility. Ken is working with NASA SPoRT to have the tool tested within the NWS Operations Proving Ground in Kansas City, MO and also at the Hazardous Weather Testbed (HWT) in Norman, OK. Ken led the design review and is working with the team to have the code checked into the AWIPS II baseline in late spring, 2014.

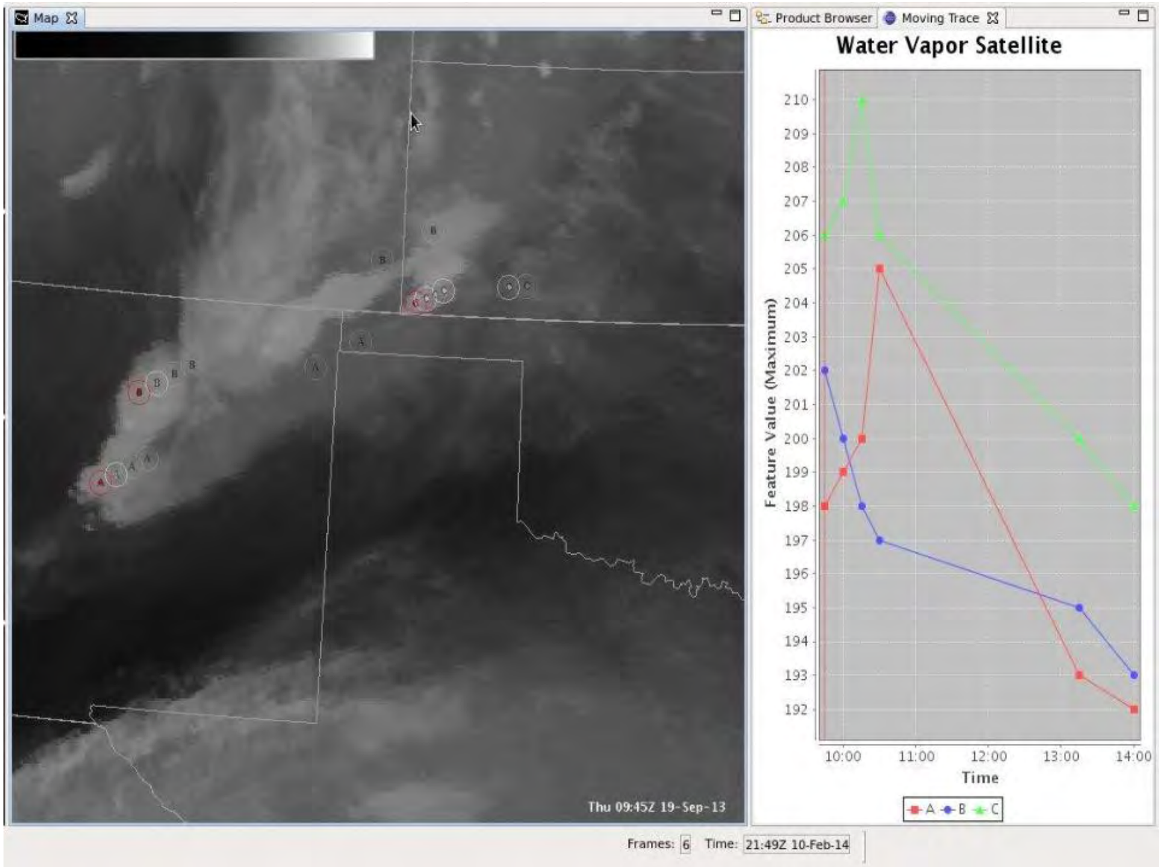

Figure 1. Tracking Meteogram tool within AWIPS II Cave.

3--ANC
a--John Crockett continued to support the day-to-day running of ANC at the MDL.

b--Maintained and updated all of the documentation related to ANC.

c--Modified a number of ANC applications in order to reduce overall CPU and disk usage, and he found and fixed software bugs as needed.

d--John Crockett contributed to an as yet unpublished journal article, Evaluation of NCAR's AutoNowCaster as a Tool for Nowcasting Thunderstorms, the final product of an experiment which began in August, 2011. The experiment focused on using ANC over the eastern third of the United States—an area of great importance to the Federal Aviation Administration (FAA) in regards to air traffic—and it included testing the use of a genetic algorithm developed by the National Severe Storms Laboratory (NSSL) to tune ANC objectively. John was responsible for almost all of the setup needed to use the algorithm.

e--Reconfigured ANC so that its domain covers the CONUS. As part of this work, John created a simple web site in order to display two CONUS-wide ANC output fields (http://www.mdl.nws.noaa.gov/ancView/conus/).

f--Modified ANC in order to enable it to ingest and use both the 3-D Multi-Radar/Multi-Sensor (MRMS) radar reflectivity data from the NSSL and the experimental Rapid Refresh (RAP) model data from the Earth System Research Laboratory's Global Systems Division (GSD).

g--Along with NOAA research team member Mamoudou Ba, John Crockett took part in the Summer 2013 Experiment held at the Aviation Weather Center (AWC) in Kansas City, MO. After a very favorable review by the AWC of ANC's 60-minute nowcast of convective initiation, John took the steps needed to send those nowcasts to the AWC in real-time for ingest by the AWC's NAWIPS.

h--John Crockett began the process of transitioning ANC from an experimental system at the MDL to an operational system at the National Centers for Environmental Prediction (NCEP). As part of this process, John simplified ANC's source code structure, and CIRA research team member Ken Sperow moved ANC to the Virtual Laboratory's development environment.

i--Created documentation and training material for the Central Weather Bureau (CWB) of Taiwan. The material focused on the mechanics and methodology which underlay the MDL's process for tuning ANC objectively. John sent the requisite software to the CWB and, assisted by NOAA research team member Lingyan Xin, provided the corresponding training to two visitors from the CWB. John responded accordingly to questions and problems as they arose.

4--Impacts Catalog
a--John Crockett helped draft the high-level presentation given to the Director of the NWS as a prerequisite for project authorization.

b--John was made Technical Lead of the National Impacts Catalog Project, he was made a member of the project's Integrated Working Team (IWT), and he also became the manager of VLab's Impacts Catalog Community.

c--John Crockett coordinated a high-level presentation at the MDL from the Impact Computing Corporation regarding that company's Weather Impact Probability Forecast (WIPCast) software.

d--John Crockett conducted all of the informational interviews with the project's Operational Test and Evaluation (OT&E) sites as part of the requirements collection and analysis process. Two such interviews were conducted on-site: one at the Sterling, VA Weather Forecast Office (WFO) and the other at the Charleston, WV WFO. John drafted the initial set of requirements and presented them to the project's IWT for review and consensus voting.

5--NWS Technical leadership
Ken Sperow:
--Continues to serve as a member of the MDL's Configuration Control Board (CCB), the body responsible for reviewing requests for changes to the MDL's IT infrastructure.
--Is the technical leader of the Virtual Lab Support Team (VLST). This team currently consists of 11 members, 8 of whom are government FTEs.
--Heads an effort to shift all AWIPS II distributed development within the VLDS.
--Is co-lead and technical lead of the VLab.
--Manages development of an AWIPS II tracking meteogram tool.
--Assists the NWS Systems Engineering Center management with the high-level design of AWIPS II tasks.

John Crockett is the technical lead of the national Impacts Catalog Project and also manages the VLab's Impacts Catalog Community.

PROJECT TITLE: CIRA Support to the CASA Dallas Fort Worth Urban Demonstration Network

PRINCIPAL INVESTIGATOR: Brenda Philips

RESEARCH TEAM: V. Chandraskear (CSU), Bechini (CSU), Haonan Chen (CSU), Westbrook (U Mass) (1 month), Lyons (U Mass)

NOAA TECHNICAL CONTACT: Tim McClung (NOAA/NWS/OST) and Curtis Marshall (NOAA,/OST)

NOAA RESEARCH TEAM:

PROJECT OBJECTIVES:

The National Weather Service is partnering with the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) in leveraging a five-year proposal for the CASA Dallas Fort Worth Urban Demonstration project to research the utility and impact of fusing short-wavelength polarimetric, networked radar and other observations to improving convective and hydrologic warnings, nowcast, and numerical forecast performance linked to user decision making in the Fort Worth-Dallas metropolitan area.

PROJECT ACCOMPLISHMENTS:

Research accomplishments listed by thematic areas:

Objective 1: Data Fusion

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In this project, we follow data fusion at different three levels: Namely, 1) data fusion for QPE, 2) data fusion for CASA and KFWS data and 3) fusion of radar and lightning observations.

Accurate and efficient temporal interpolation and fusion of radar data from multiple sources is necessary for applications requiring characterization of atmospheric conditions. Interpolation is a fundamental data processing problem and several well-known interpolation techniques exist. The Dynamic Radar Tracking of Storms (DARTS) model is a Lagrangian persistence-based nowcasting model that has previously shown utility in nowcasting a variety of radar data in severe weather and aviation decision support applications. DARTS also provides an inherent means to perform temporal interpolation, fusion of both CASA and WSSR-88D radar observations. DARTS represents the general continuity equation modeling the motion of an observed precipitation field represented by a sequence of radar data fields as a discrete spatiotemporal linear model that is formulated in the Fourier domain and solved using linear least squares estimation. In this context, interpolation can be accurately and efficiently performed by appropriately windowing the assimilated data and evaluating an interpolating trigonometric polynomial using the Fast Fourier Transform (FFT). The utility of this interpolation methodology was demonstrated and performance compared to linear and cubic spline interpolation methods. The use of DARTS-based extrapolation to perform interpolation was also investigated. Rainfall rates derived from data collected by the KFWS WSR-88D S-band radar and the CASA X-band radar located at the University of Texas at Arlington in the Dallas-Fort Worth Testbed were used for demonstration purposes. The results also show that the FFT-based approach within the context of the DARTS model yielded normalized standard error values within about 8% of the forward-backward extrapolation approach and ran about 2–3 orders of magnitude faster in terms of CPU time. The error structure of the interpolation/ fusion methods in the context of the presence of noise and atmospheric scales represented in the data is also evaluated.

Results to Date:

<u>Fusion in QPE</u>

Figure 1 shows the fusion of temperature and the radar fields are used to create a QPE product that is robust.

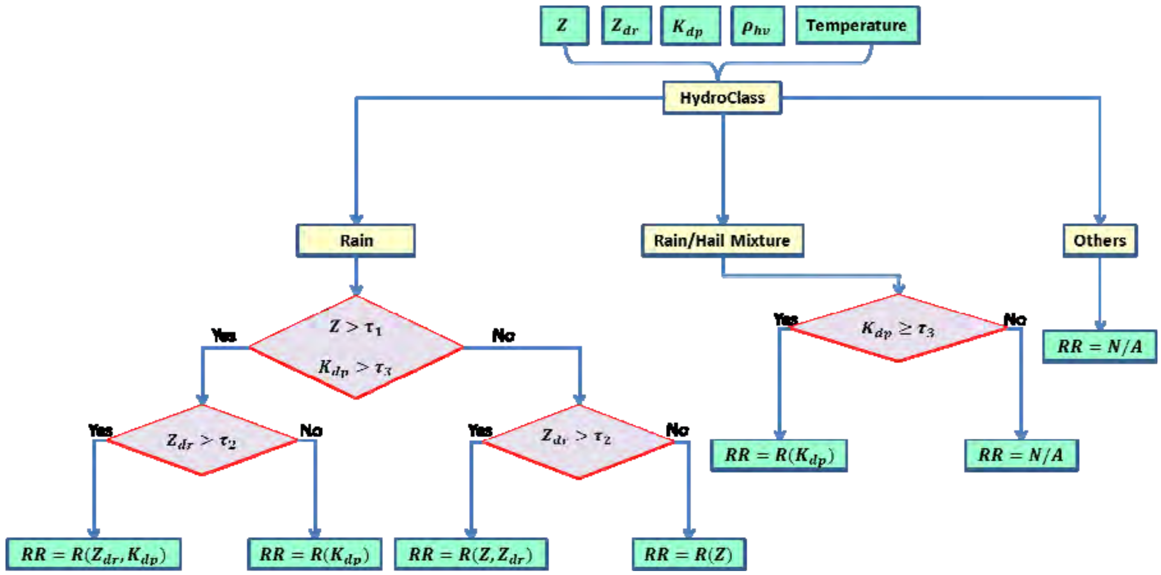


Figure 1. Flowchart of the blended rainfall rate retrieval algorithm τ_1,τ_2,τ_3 thresholds on the respective measurements.

The performance of this algorithm is discussed in the report on QPE.

Fusion of CASA and KFWS Observations

The need for high-temporal-resolution radar data (~1 min) to better depict, understand, and warn of hazardous weather phenomena has been demonstrated by CASA. Due to the distributed processing environment and relatively large high-resolution datasets used by the CASA system, the Dynamic and Adaptive Radar Tracking of Storms (DARTS) nowcasting method was developed as a fast nowcasting algorithm to meet the operational nowcasting requirements to provide useful products to the end users of the system. DARTS represents the general continuity equation modeling the motion of an observed precipitation field represented by a sequence of radar data fields as a discrete spatiotemporal linear model that is formulated in the Fourier domain via the Discrete Fourier Transform (DFT) and solved using linear least squares estimation. In this context, the Fast Fourier Transform (FFT) allows for computationally efficient motion estimation for nowcasting or interpolation, scale filtering to improve nowcasting accuracy, and interpolation by appropriately windowing the assimilated data and zero-padding the FFT of the assimilated data.

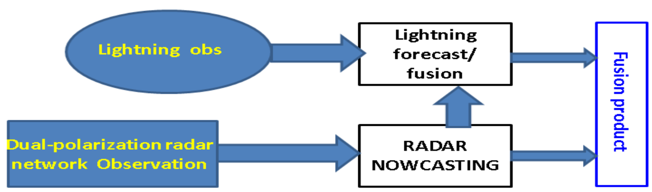
A new method to perform temporal interpolation by appropriately windowing the assimilated data and evaluating an interpolating trigonometric polynomial using the FFT has been incorporated into the DARTS model. The utility of this methodology for fusing radar rainfall fields will be demonstrated and performance compared to linear and cubic spline interpolation methods. Rainfall rate fields derived from data collected by the KFWS WSR-88D S-band radar and the X-band radar located at the University of Texas at Arlington in the Dallas-Fort Worth Testbed were used for the analyses.

The contributions of this work are summarized as follows:
1--Introducing a new option for temporal interpolation of multiple source radar data by adapting and evaluating the DARTS based method to 3-D using real radar data sequences of short length.
2--Extending the DARTS model previously used for nowcasting to perform interpolation/fusion within the structure of the nowcasting model.
3--Assess the utility of small precipitation scales in the interpolation methods.

Fusion of Radar and Lightning Observations

Lightning warnings are important to airports, defense, and large- venue operations (sporting events, etc.). Extended lead time of accurate warnings is particularly desirable. Weather radar provides data products with favorable measurement range to provide these warnings. Therefore fusion of radar and lightning data would be useful for improved decision support applications.

Relationships between ground-based radar reflectivity and lightning onset have been investigated and have shown potential value for nowcasting electrification. Prior studies show the relationship of C-G locations and the vertical structure of reflectivity above the 0^{o} C height in stratiform regions. It is well known that the presence of graupel is a key component of the electrification process that produces lightning. Work on the development of relationships between radar-estimated graupel and lightning activity is emerging as dual-polarization weather radar data becomes more prevalent and hydrometeor classification technology progresses. Evidence has been seen in support of the idea that hydrometeors with wet growth carried less net space charge than neighboring hydrometeors with a drier growth. In summary the hydrometeor classification product is a viable mechanism to fuse information from radar and lightning. This project is preparing the infrastructure towards that direction. We have just completed the development of hydrometeor classification system (see report) and the future development is described in the following diagram.



NWS STRATEGY ALIGNMENT

Data fusion is a critical part of NWS strategy. DFW has data fusion at multiple levels and three of those examples are demonstrated here. High quality hydrometeor classification is an important product of DFW radar observations. The information fusion link between lightning and radar is through the detection of dry and wet ice particles, which is a critical product. The Hydrometeor identification also provides hail product that will be used by Emergency mangers. This is also a product with current polarimetric upgraded version of KFWS. We are working with Vaisala to obtain the lightning observations.

Objective 2: Integration of CASA Data into AWIPS Platforms

The goal of the project was to create a live feed of CASA data and products into AWIPS2 in the Fort Worth NWS forecast office to facilitate forecaster data evaluation. Eric Lyons is meeting with Southern Region Headquarters and Raytheon who is in of programming AWIPS II to create a CASA plug in for spring 2014. The Fort Worth Weather Forecast office will view the data on a “thin client”. See attached sample visualization of CASA data from one of the DFW radars.

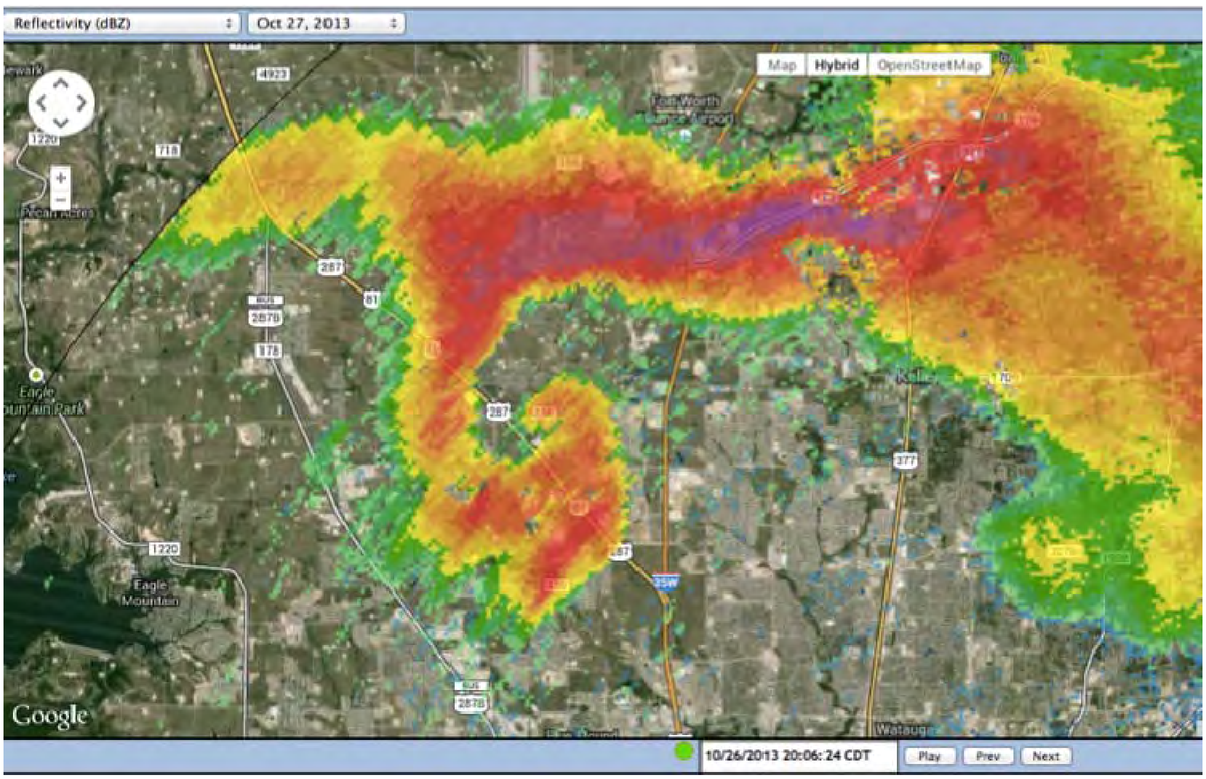
Objective 3: User-relevant Metric Development

--Continued development draft methods for evaluating geographic specificity of CASA data based on meetings with Fort Worth NWS Forecast Office.

--Conducted analysis of Fort Worth NWS Forecast office warning performance to determine how we would measure improvements in the warning system in CASA.
--Began content analysis of NWS chat to see how geographic specificity and uncertainty are expressed to EMs and other on chat.

Objective 4: Project Management

--PI telecons and meetings with research team to address progress.
--PI telecons with NOAA technical contacts



High Resolution view of brief tornado and hail event in north Tarrant county Texas as seen by the CASA Arlington radar. A Severe Weather Warning was in place.

Tornado F-Scale	0	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	30 - 40	40 - 50	Total
EF0										
# Events	15	10	20	6	17	12	9	18	6	**113**
# Injuries	0	0	2	0	0	0	0	0	0	**2**
EF1										
# Events	11	3	5	4	2	3	2	4	.	**34**
# Injuries	3	8	3	0	1	0	0	6	.	**21**
EF2										
# Events	2	.	1	2	.	1	3	2	.	**11**
# Injuries	0	.	4	1	.	3	17	3	.	**28**
EF3										
# Events	.	.	.	.	1	1	.	.	.	**2**
# Injuries	.	.	.	.	7	7	.	.	.	**14**
EF4										
# Events	.	.	.	.	.	1	.	.	.	**1**
# Injuries	.	.	.	.	.	54	.	.	.	**54**
Tot. Events	**28**	**13**	**26**	**12**	**20**	**18**	**14**	**24**	**6**	**161**
Tot. Injuries	**3**	**8**	**9**	**1**	**8**	**64**	**17**	**9**	**0**	**119**

Tornados in the DFW County warning area by lead time, tornado strength and number of injuries.

This was a building phase of the project and publications will be coming along soon.

PROJECT TITLE: EAR - Aviation Weather Forecast Impact and Quality Assessment

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Melissa Petty, Paul Hamer, Michael Turpin, Michael Leon

NOAA TECHNICAL CONTACT: Michael Kraus (NOAA/OAR/ESRL/GSD/ACE Chief)

NOAA RESEARCH TEAM: Brian Etherton (OAR/ESRL/GSD/ACE), Matt Wandishin, Geary Layne, Joan Hart, Michael Rabellino, Laura Paulik (CIRES)

PROJECT OBJECTIVES:

The objectives of this project are to provide program management and engineering support for the NOAA/ESRL/GSD/ACE/Forecast Impact and Quality Assessment Section (FIQAS) in
1--Scientific research and quality assessment activities
2--Technology development

PROJECT ACCOMPLISHMENTS:

Objective 1--Scientific Research and Quality Assessments
Program management and engineering support was provided to FIQAS scientific research and quality assessment activities. Major accomplishments include:

--Evaluation of the Graphical Turbulence Guidance Version 3 (GTG3): FIQAS was tasked with an evaluation of version 3 of the GTG algorithm, which incorporated several new features, including mountain wave forecasts, extension of the forecast to include low altitude levels in addition to the current mid and upper altitude levels, and extension of the forecast from 12 out to 18 hrs. The 2013/14 activities for the evaluation included adaptation of forecast verification techniques to new features; code implementation to support the assessment; and preliminary analysis of results. Preliminary results indicated lower performance of the GTG3 product as compared to the previous version. The transition timeline for the GTG3 product is currently being re-evaluated.

--Evaluation of the Current Icing Potential (CIP) and Forecast Icing Potential (FIP) HiRes products: FIQAS was tasked with an evaluation of the latest 'HiRes' version of the CIP and FIP products, which incorporated several enhancements, including an increase in the horizontal resolution from 20 km to 13 km, an increase in the vertical resolution from 1000 ft. to 500 ft., and an extension of the FIP forecast from 12 out to 18 hrs. The 2013/14 activities for the evaluation included: developing verification techniques to address algorithm enhancements; incorporating a new technique using satellite data to determine inferences of icing in areas where PIREPs are not available; developing and finalizing the overall approach for the assessment; performing analysis of results; and providing a formal report of assessment results. The final report was presented to a Technical Review Panel in Oct 2013, which approved the new version for transition into operations.

--Preparation for Evaluation of Icing Product Alaska (IPA): FIQAS has been tasked with an evaluation of the IPA product, which is a new forecast product of in-flight icing, based on the FIP algorithm but adapted to the Alaska domain. Preparatory activities for the evaluation occurred, including the investigation of a new technique using polar orbiting satellite data to determine inferences of icing in areas where PIREPs are not available; developing and finalizing the overall approach for the assessment; and review and approval of the formal verification plan. Implementation of techniques will begin in May 2014, with completion of the evaluation in Nov 2014.

--Preparation for Evaluation of CIP/FIP 1.1: FIQAS has been tasked with independent assessments of CIP/FIP upgrades in accordance with the CIP/FIP semi-annual upgrade cycle. As part of this cycle, an upgrade to the HiRes (1.0) products was completed Dec 2013, resulting in the new minor version 1.1. FIQAS will evaluate version 1.1 as compared to the 1.0 products, to ensure the product quality was not negatively impacted by the changes. Because this is a minor version, the evaluation will be more limited. The 2013/14 activities for this evaluation included development and approval of the verification plan, data collection for the assessment, and implementation. The evaluation is expected to be completed in June 2014.

--Preparation for Evaluation of CIWS and MRMS products: Preparatory activities occurred for an evaluation of differences between the MRMS and CIWS convective forecast and analysis products. Activities for 2013/14 included investigation of the MRMS product, identification of the techniques to be used in the assessment, development and review of the formal verification plan, and data collection for the assessment. Preliminary results will be presented in July 2014, with a final analysis completed October 2014.

--Verification Technique Research and Development: Core verification technique development occurred in 2013/14 to support current and future assessments. This included the development of verification techniques to measure product skill with respect to its ability to forecast impactful events, which involved the definition and characterization of events and determining measures of accuracy with respect to event spatial and temporal displacement. Additional activities included enhancements to constraint-based verification techniques from the en-route to terminal domain for aviation; investigating the use of polar orbiting satellite data and dual pol radar to augment other observation sets for verification use; and investigation of observation sources in the Alaska region as alternatives or supplements to PIREPs.

--Objective 2--Technology Development
CIRA was responsible for application development in support of FIQAS activities, including FIQAS assessments as well as the development of technologies for external users. Accomplishments include: Verification Requirements and Monitoring Capability (VRMC; Figure 1): The VRMC currently provides ongoing verification metrics for the operational GTG and CIP/FIP products, as well as results from the FIQAS assessments performed prior to the transition of these products into operations. The VRMC was extended in 2013/14 to support the GTG3, CIP/FIP ‘HiRes’ (1.0) and CIP/FIP 1.1 quality assessments.

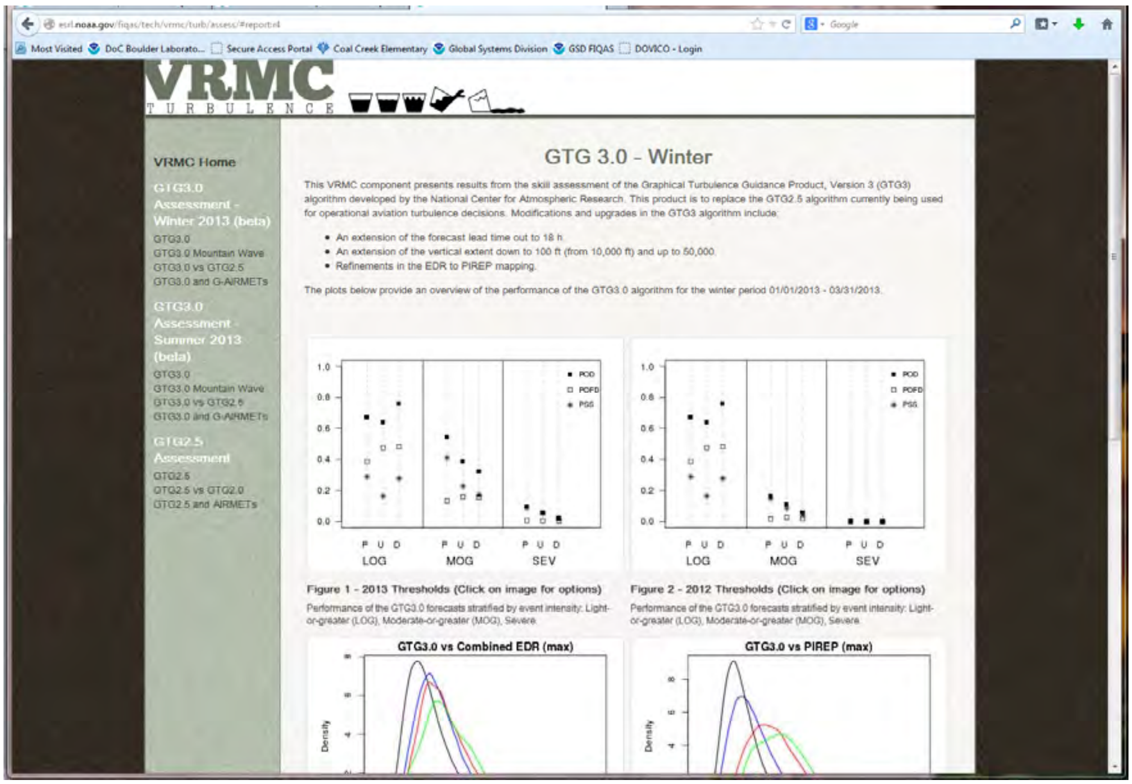


Figure 1. The Verification Requirements and Monitoring Capability.

Activities for 2013/14 included: incorporating automated processing and the verification modules necessary to produce intermediate verification results for the GTG and CIP/FIP products; extension and adaptation of the intermediate data storage to incorporate the intermediate verification results; and extension of the web interface with additional plotting capabilities as needed.

--Enhancements to the Event-based Verification and Evaluation of NWS gridded products Tool (EVENT; Figure 2): EVENT, developed in 2012/13, is a prototype web application providing ongoing performance metrics of convective products with respect to performance requirements as defined by the Traffic Flow Management Weather Requirements Working Group (TRWG).

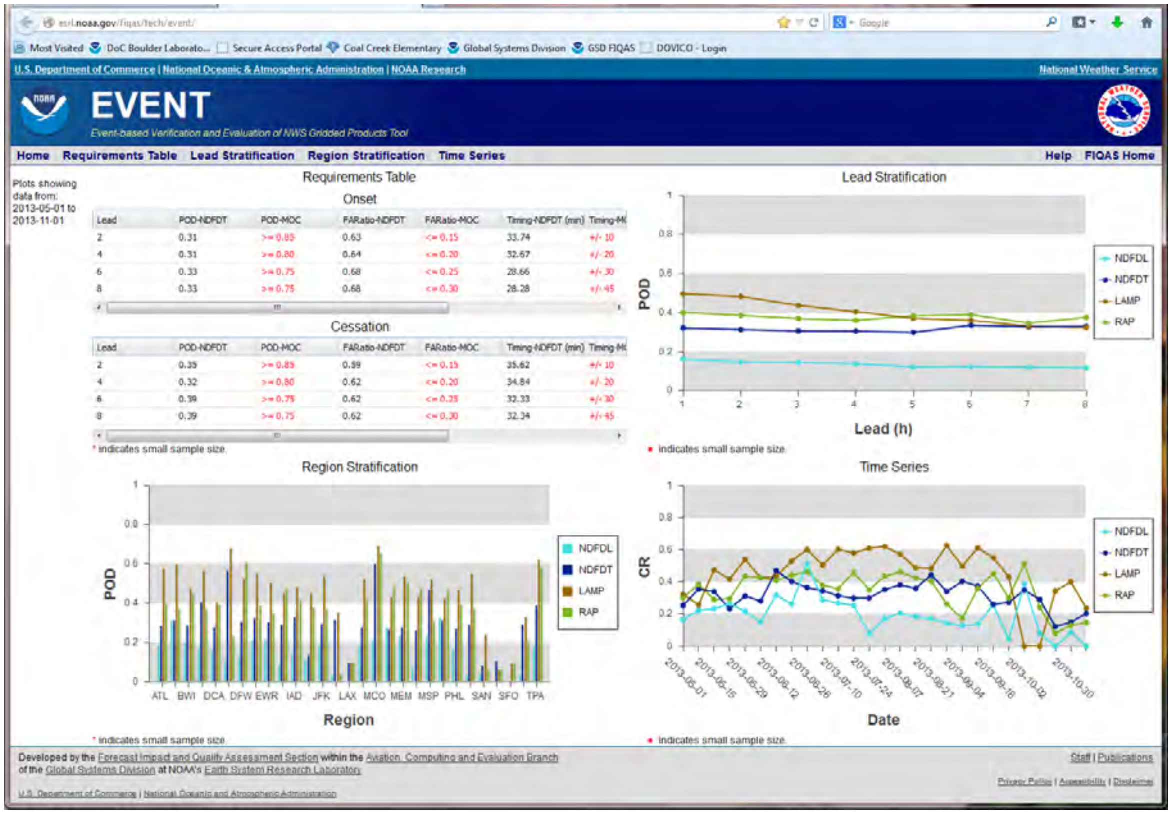


Figure 2. Event-based Verification and Evaluation of NWS gridded products Tool.

Development activities for 2013/14 involved extensions to the current application, including: addition of performance results for the HRRR forecast product, incorporation of the MRMS as an observation product, and extensions to existing verification techniques implemented in the tool. Enhancements are targeted for completion in May 2014.

--Integrated Support for Impacted air-Traffic Environments (INSITE; Figure 3): INSITE is a web-based application developed for use in the convective weather forecast process. The tool provides guidance to forecasters by providing detailed information on the potential impacts of forecast convective weather to en-route aviation operations. INSITE (2.0) was made available for NWS forecaster use and evaluation throughout the 2013 convective season. User feedback was gathered in Nov 2013, which included positive reviews as well as requests for enhancements. Funding for further development of INSITE was renewed to incorporate enhancements. The development plan for enhancements has been established, with a target date of May 2014 for release of INSITE version 3.0.

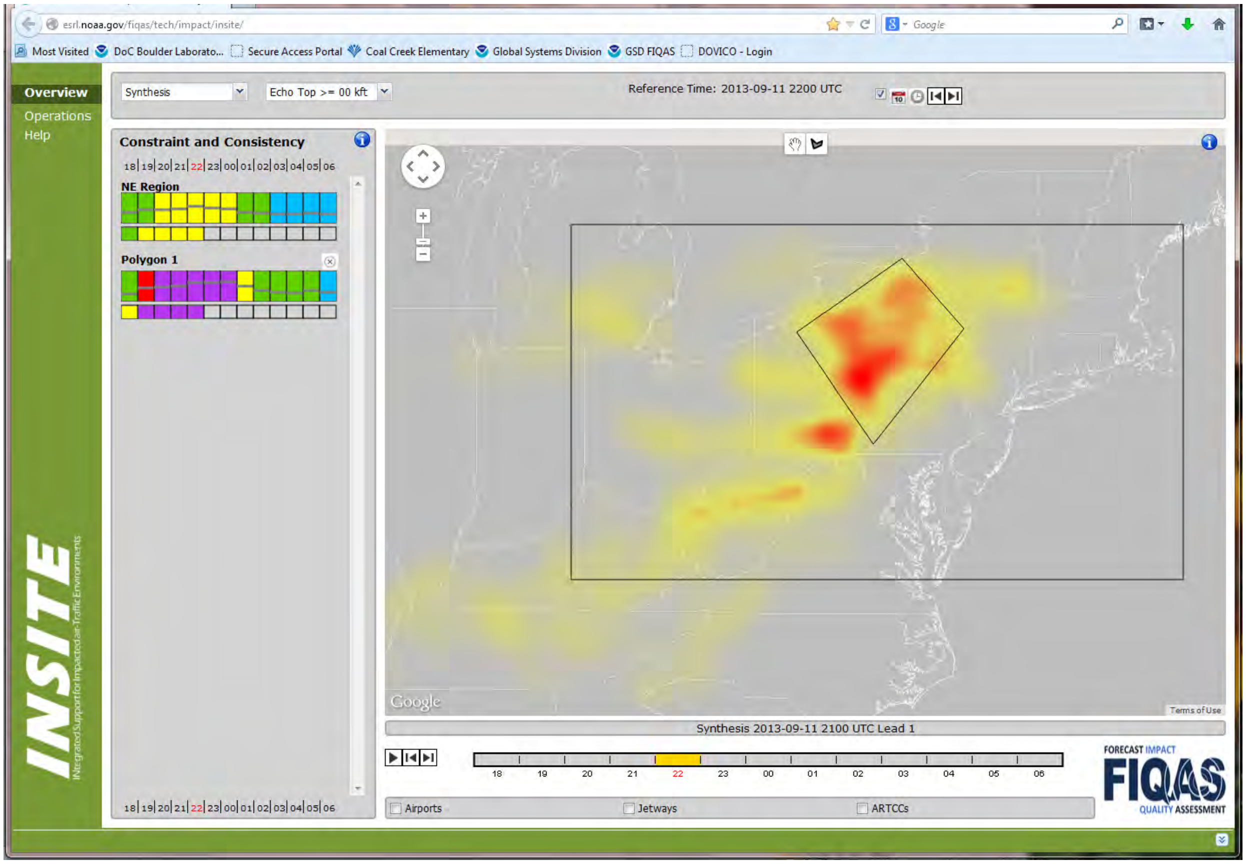


Figure 3. Integrated Support for Impacted air Traffic Environments.

--Aviation Forecast Verification Tools: Preparatory work has occurred to support several NWS processes, including the verification of CWSU weather briefings and TRACON approach and departure gate forecasts. Activities for 2013/14 included research to gain knowledge of the terminal decision-making and weather forecast process, and technique development for verification metrics in this terminal context.

PROJECT TITLE: EAR - AWIPS II Workstation Development

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Daniel Schaffer, James Ramer, U Herb Grote, Evan Polster

NOAA TECHNICAL CONTACT: Woody Roberts (NOAA/OAR/ESRL/GSD/ISB)

PROJECT OBJECTIVES:

The long-term objective of this project is to develop a forecast workstation with advanced interactive display capabilities that includes inter-office and external collaboration, and integrates existing hazard services. The collaboration capability can improve forecast consistency between offices and permit better coordination with external partners.

The goal of the hazard services project is to integrate current AWIPS applications that are used to generate hazard weather watches, warnings, and advisories. These discrete applications are WarnGen, Graphical Hazard Generator, RiverPro, and the NWS National Center hazard generation functionality.

PROJECT ACCOMPLISHMENTS:

AWIPS II Extended Task - Collaboration
The envisioned collaboration capability allows NWS forecasters to collaborate with each other and with external collaborators. This year, work focused on external collaboration. Development continued on a prototype web-browser based collaboration client that enabled external users to communicate with an "internal" AWIPS II workstation. The collaboration capabilities included text chatting, graphic display and animation of weather data, and drawings such as polygons and lines. The look and feel of the web-client was improved by adding the capability for the map background to be selected and for the transparency of the overlaid images to be adjusted dynamically.

Work then commenced on an operational version of external collaboration. One need was to assist in the process of gathering requirements for the operational version. Working with Lisa Kriederman, a Boulder IMET, CIRA staff prepared a video demonstrating the how the prototype works. This video was made available to other forecasters and NWS personnel involved in the requirements gathering process. In preparation for developing an operational capability, several design options were prepared for NWS and the AWIPS II contractor (Raytheon) that would integrate the external and internal collaboration capabilities. Components in these designs included the web-client graphical user interface and a web-server contained component that exchanges messages between the client and Common AWIPS Visualization Environment (CAVE).

At this point, the team received feedback from potential users that indicated there is not currently sufficient interest in the external collaboration capability to warrant continued development. The project has been put on hold indefinitely.

AWIPS II Extended Task – Hazard Services
The hazard services project is a multi-year effort to integrate the various warning, watch, and advisory tools used by the NWS. In the process, CIRA staff sought to transition the current hazard generation programs from a paradigm of issuing products to one of decision support.

This effort is multi-faceted. The first facet is the continued vetting of requirements with Hazard Services users. CIRA personnel participated in weekly discussions including the presentation of code designs and implementations. Some visits to nearby weather forecast offices were also made for day-long in-person discussions.

A second facet is the continued development of code that implements the requirements for Hazard Services. CIRA personnel assisted in this development process. One such requirement is the capability for Hazard Services to alert forecasters when a hazard event nears expiration. A second is to provide graphical user interface (GUI) components that enable forecasters to configure filters that control which hazards are visible. This allows forecasters to focus on hazard events of critical interest in a weather scenario. A third is to provide a permanent storage mechanism for hazard event information. CIRA personnel modified the existing prototype version of Hazard Services to leverage a relational database storage solution provided by Raytheon.

A third facet is to transition the code from prototype to operational. CIRA personnel helped to re-factor the code base; making it cleaner, easier to read and easier to maintain.

A fourth component is the creation of a configuration management scheme to be used during the development of hazard services. The scheme put in place by Raytheon uses the Git repository system and a package called Gerrit used in code review. CIRA personnel assisted in the process of bringing Hazard Services under configuration management. This work included training of GSD personnel in the use of Git and Gerrit and developing/maintaining a streamlined install process for Hazard Services that leverages the Git-based configuration management approach. CIRA personnel also participated in many reviews of code produced by various members of the Hazard Services Team.

A fifth aspect is to establish a testing process for Hazard Services. This is particularly important as the code undergoes additional development and re-factoring. The testing process CIRA personnel designed is multi-pronged. For integration level testing, a collection of written functional tests that exercise Hazard Services Capabilities were developed with the help of CIRA personnel. These are particularly useful when, as is the case with GUI software, it is difficult to write automated tests. In many places, it was possible to write automated tests. CIRA personnel designed an automated integration test framework and helped write many of the tests. The test framework allows developers, with one push of a button inside Hazard Services, to execute integration level tests that exercise many key aspects of the software. The test framework leverages a Model/View/Presenter framework in Hazard Services that was recommended by CIRA personnel. The automated tests stub out the "View" (GUI) components; replacing them with simple java "beans" that can be queried to see if the right information is being sent to the views. A collection of unit tests was also developed to cover some of the functionality at a lower level. Finally, the testing process calls for this entire suite of tests to be executed on a test bed machine by personnel other than the developer of the particular code modification so as to provide an independent look. Only when all of these regression tests pass is code allowed to be committed to the repository.

The team collaborates closely with the AWIPS II contractor, who is responsible for developing specific portions of the code and also for ensuring that the software will work in the AWIPS II environment. Regularly scheduled coordination meetings allow all members of the team to be properly informed on the software development tasks.

AWIPS II Transition Task - Migrate LAPS and MSAS to AWIPS-II
Last year CIRA staff mostly completed this task. Keeping this work up to date and fixing the occasional bug is an ongoing effort, which this year has focused mostly on improving the install and domain change scripting. Some work was also required to make the Laps data conversion work in a 64 bit operating system, and to properly configure Laps and MSAS to interoperate with upgrades to the GRIB decoder.

The changes made in response to the updated GRIB decoder have been very positive, making it possible to change the geographic domain for Laps and MSAS without restarting EDEX. Access to gridded data was also improved for both Laps and MSAS, avoiding ASCII encoding and thus retaining the full precision of the data stored in EDEX.

CIRA staff also began work on a new version of A-II LAPS that will no longer rely on cron based data conversion; the Laps programs will read the EDEX data they need directly in real time. This new version of LAPS will also have a graphical user interface for domain changes.

This task is a joint effort with government staff from the Forecast Applications Branch and the Information Systems Branch.

AWIPS II Transition Task - Migrate existing user created procedures and color tables.
Last year CIRA staff mostly completed this task. Keeping this work up to date and fixing the occasional bug is an ongoing effort, which this year has focused mostly on color tables. Some work was also required to make the programs that support procedure and color table conversion work in a 64 bit operating system, and to configure the procedure conversion to inter-operate with upgrades to the GRIB decoder.

PROJECT TITLE: EAR - Meteorological Assimilation Data Ingest System (MADIS)

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Tom Kent, Leigh Cheatwood-Harris, Randall Collander, Jim Frimmel, and Amenda Stanley

NOAA TECHNICAL CONTACT: Greg Pratt (NOAA/OAR/ESRL/GSD/ISB)

NOAA RESEARCH TEAM: Leon Benjamin, Gopa Padmanabhan (CIRES), Michael Vrencur (ACE Info Sol.)

PROJECT OBJECTIVES:

MADIS is dedicated toward making value-added data available for the purpose of improving weather forecasting by providing support for data assimilation, numerical weather prediction, and other hydro-meteorological operations. This includes over 170 surface networks producing nearly 13 million observations per day, 450,000 aircraft observations per day, 154 profiler sites, as well as global radiosonde and satellite observations.

The objectives are:
--To continue to add new functionality and data sources to MADIS.
--To provide support to the user community.
--Transition to operations at NWS NCEP.

PROJECT ACCOMPLISHMENTS:

MADIS is in the process of transitioning its software to the NWS National Centers for Environmental Prediction (NCEP) Central Operations (NCO). The first big step in this process was met in 2010 with the acceptance of Initial Operating Capability (IOC) on the CCS super computer. Final Operating Capability (FOC) is expected in late 2014 or early 2015 and will have all 3 components of MADIS (ingest, processing, distribution) in a virtual machine environment at the NCO. This streamlines the current IOC configuration of ingest and distribution at the TOC and just processing at NCO. Another change for FOC is that GSD will no longer be an operational backup and instead will go back to its mission of research. Other enhancements include adding CLARUS into MADIS to transition Department of Transportation (DoT) data, metadata, and QC algorithms for FOC and beyond. Agreements are also in place for a NWS-FAA partnership for a direct feed of real-time 1 minute ASOS data. MADIS is also a partner in the National Mesonet program and working with various providers on data and metadata standards for easier delivery and decoding. As the project moves forward to meet FOC there are still many exciting challenges for CIRA personnel to meet.

In 2013 all the MADIS software was ported from the NCO CCS super computer to the new NCO WCOSS super computer. This meant porting 64-bit code from an AIX OS to RH6 with diff compilers and platforms. Many new data providers were added during this process as well. Numerous tools were written to measure performance metrics for ingest, decoding, distribution and to add better recovery from provider data that is badly formatted or old in time. With an emphasis for performance on the NCEP super computer, many pieces of the decoding and QC code were streamlined to reduce system load. A large amount of time was spent on training NCEP personnel on MADIS Support help so they could take over larger chunks of the help desk each month leading up to FOC. Numerous web documents were written for end-to-end information for each network. A monitoring mechanism is also in place for all the data and communication processes. MADIS team members are notified when issues arise and were contacted during off hours when it is warranted. CIRA staff play a key role in providing MADIS support such as solving user problems, data delivery problems, data archive requests, firewall issues, LDM set-up, new accts, password resets and a host of other issues. Many new scripts were written to automate some of the account maintenance as well as for performance metrics and graphical displays.

An agreement for NWS to partner with the FAA to do a direct feed for the 1 minute ASOS data was reached and several months of testing between GSD and FAA was performed to pass over 200 formalized comms and data delivery tests.

More new enhancements to the MADIS Web Surface Display using Google Maps were put into production. This tool allows users to see all the data points as well as some of the metadata in a concise manner and allowing for easy subsetting of data over the web. A new Google Map display of aircraft data was also developed.

PROJECT TITLE: EAR - Citizen Weather Observer Program (CWOP)

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Leigh Cheatwood-Harris, Randall Collander, and Tom Kent

NOAA TECHNICAL CONTACT: Greg Pratt (NOAA/OAR/ESRL/GSD/ISB)

NOAA RESEARCH TEAM: Leon Benjamin, Gopa Padmanabhan (CIRES),
Michael Vrencur (ACE Info Sol.)

PROJECT OBJECTIVES:

The Citizen Weather Observer Program (CWOP) database is now maintained by the MADIS Staff. CIRA researchers administer the CWOP through database updates (adding new stations, removing stations no longer reporting data, and maintaining accurate site location information), interactions with CWOP members (answering questions and discussing suggestions, and investigating data ingest and dissemination issues), refreshing related web pages and documents, verifying that station listings and other reference data required by MADIS are complete and accurate, and confirming that routine backups of database and related files are performed.

The CWOP is a public-private partnership with three main goals:
1--Collect weather data contributed by citizens.
2--Make these data available for weather services and homeland security.
3--Provide feedback to the data contributors so that they have the tools to check and improve their data quality.

PROJECT ACCOMPLISHMENTS:

There are currently 14,147 active stations (citizen and ham radio operator) in the CWOP database (out of a total of 28660 stations in the CWOP database). Of these, approximately 13,076 are sending data based upon an actual count for citizen stations today and application of the same ratio of sending/active (74%) to the ham radio stations. CWOP members send their weather data via internet alone or internet-wireless combination to the findU (http://www.findu.com) server and then the data are sent from the findU server to the NOAA MADIS ingest server every five minutes. The data undergo quality checking and then are made available to users thru the MADIS distribution servers.

Database procedures were streamlined through development and implementation of scripts to auto-correct missing and typographical errors in new member sign-up requests, and through introduction of automated site geographic location and elevation verification algorithms. Interactions occurred with users via email regarding site setup, data transmission issues, quality control and general meteorology.

Various web-based documents and databases were updated on a daily, weekly or monthly basis depending on content, and statistics and other informational graphics revised and posted.

In 2013, there were approximately 2400 stations added to the database. There were approximately 3000 revisions made to site metadata (note: some sites had multiple change requests, so the number of unique sites that requested changes is less than 3000). Adjustments include latitude, longitude and elevation changes in response to site moves, refinement of site location, and site status change (active to inactive, vice-versa).

PROJECT TITLE: EAR - Aviation Tools: Aviation Initiative (AI) Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Jim Frimel

NOAA TECHNICAL CONTACT: Lynn Sherretz (NOAA/OAR/ESRL/GSD/ACE)

NOAA RESEARCH TEAM: Chris Masters, Huming Han, David Hagerty (ACE Info Sol), SSG Staff

PROJECT OBJECTIVES:

This project was officially terminated by NWS Program Management at the end of the federal government's Fiscal Year, September 30, 2013.

Consistent with the FAA's Air Traffic Organization's (ATO) philosophy to review, upgrade, and create efficiencies in various functions, in January 2006, the National Weather Service (NWS) Corporate Board agreed to prototype the FXC AI system to demonstrate a more effective and efficient forecast process to support Air Route Traffic Control Center (ARTCC) operations.

The Aviation Initiative was a short-term effort that took place from July through September of 2006. It was a rapid response development and prototyping effort with an extremely demanding schedule. This effort was in support of a NWS proposal for transforming the agency's aviation weather service program to meet the FAA requirements of reducing costs and enhancing services. The initiative focuses on services provided by NWS Center Weather Service Units (CWSU).

The participants in the demonstration were the Leesburg, Virginia CWSU and the Sterling, Virginia Weather Forecast Office (WFO). System and server support was from Boulder's ESRL/Global Systems Division. The purpose of the FXC Aviation Initiative was to demonstrate the capability to perform collaboration between the CWSU and the WFO to produce new forecast and decision aid products that translate weather impact on en-route and terminal air operations and that provide common situational awareness to all prototype participants; additionally to demonstrate the capability of the WFO to remotely support ARTCC weather information requirements when the CWSU is unavailable.

During the summer of 2006, CIRA researchers in the Global Systems Division's Aviation Branch, along with FXC engineers from the Information Systems Branch, concentrated its efforts on Aviation Initiative development. This development was based on the Earth System Research Laboratory (ESRL) technologies and services being developed by CIRA engineers at the Prototyping Aviation Collaborative Effort (PACE) facility at the Fort Worth ARTCC. For a description of PACE and related FXC Development, refer to the FXC TMU project description. The FX-Collaborate (FXC) software developed at NOAA's ESRL was the major software system used in the Aviation Initiative demonstration. The FXC Aviation Initiative offers on-demand services, remote briefing capabilities, new graphical products, and tactical decision aids.

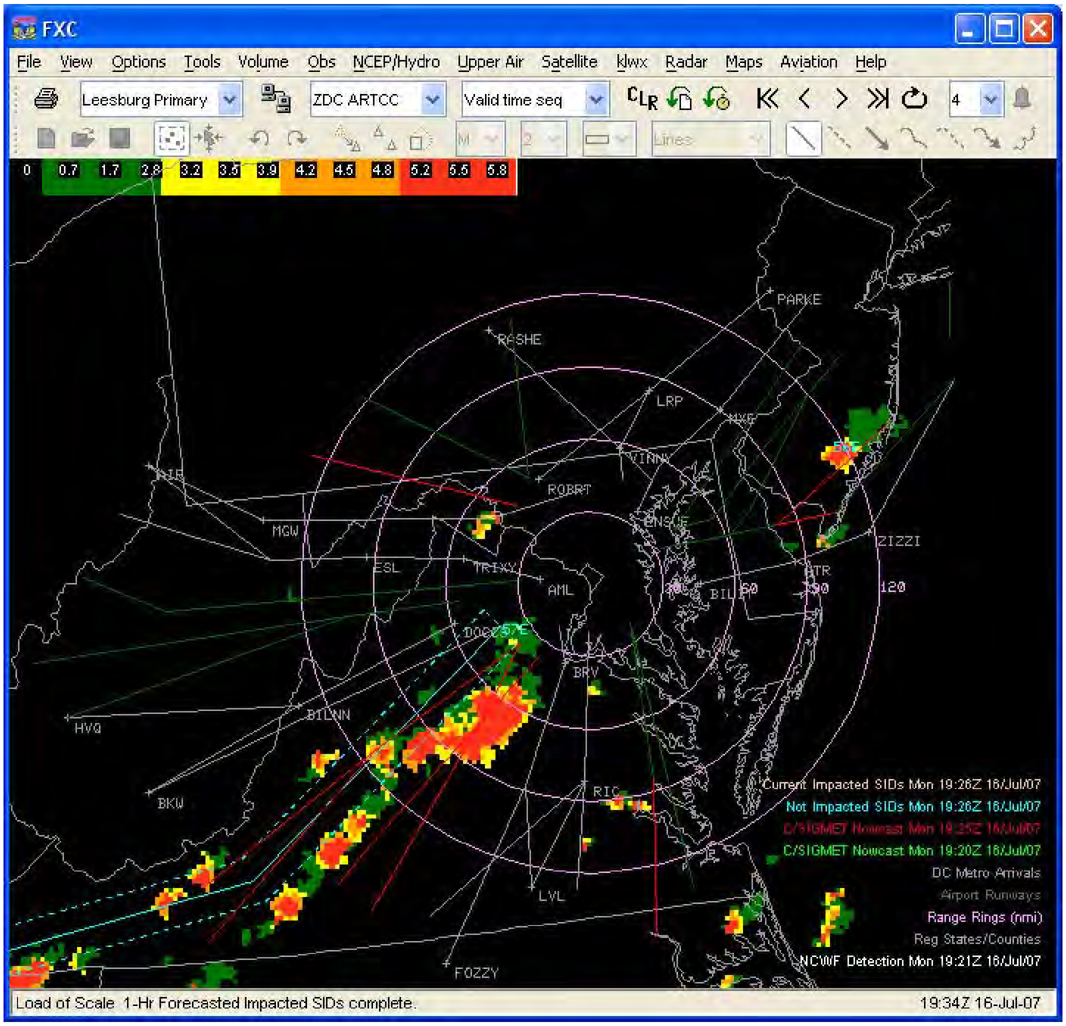


Figure 1. View of the FXC AI Brief EE display with map enhancements and impacted DC Metro departure routes.

As of May 2007, the AI project has been operating in software/system maintenance and support mode since the project research funding had ended. As of March 2009, the original federal manager of this project left to work for another branch within GSD. In Feb 2010, a Letter of Agreement between GSD and the NWS Office of Climate, Water, and Weather Services (OCWWS) was drafted in order to specify some funding and understanding to support and maintain these systems until the transition to AWIPS II extended clients for the CWSU's occurs.

PROJECT ACCOMPLISHMENTS:

Due to a lack of funding support, this project was officially terminated by NWS Program Management at the end of the federal government's Fiscal Year, September 30, 2013. The work this past year was for the Systems Support Group (http://esrl.noaa.gov/gsd/its/ssg/) and CIRA engineers to support the AI project systems, "as they are", until one of the following occurs; Aviation Tools capabilities and requirements that were developed are implemented and replaced by AWIPS II extended tasks; the occurrence of an irreparable hardware failure; or the project's maintenance funding is discontinued.

The maintenance and support addressed this past year included items related to:
--RHEL 5 Operating System patches
--Hardware failures

--Client Rebuilds
--Failed Disks and Recovery
--Data Volume increases
--Field support and recovery for client problems.
--Support and Recovery for server and connection problems.
--Various Discussions and Responding to Management inquires.

Due to the AWIPS II deployment schedule and limited resources in Eastern Region, the AI Project tools were not replaced with an AWIPS II client, prior to decommissioning. There was no planned or definitive Leesburg, CWSU AWIPS II client delivery timeline as of the decommissioning. However, prior to the shutdown, the Leesburg CWSU forecasters had transitioned and started using a generic Web Briefing application for their daily briefings to the Traffic Managers. The web based tool lacked the functionality and customization that was provided by the AI Project software, such as: Remote briefings briefer briefee capability, the collaboration tool and the annotation drawing tool functionality.

Currently, there are no future plans for the software tools developed for the AI project or continuing and developing all the AI project capabilities in to AWIPS II.
The project hardware, systems and software have been fully decommissioned and dismantled.

It is important to mention that the AI project systems were used at the Leesburg, Virginia CWSU for the daily weather briefings to the Traffic Managers, up to the time of their decommissioning. The reason these systems had continued to be maintained and supported is a testimony to the project success and utility by the end users. This is a noteworthy example of the AI project research being used in operations.

The AI project played a vital role in bringing to the forefront of NWS management, aviation and CWSU centric importance and needs. The lessons learned, concepts discussed, and ideas generated will continue forward to the next generation of software tools.

Project Website: http://www.esrl.noaa.gov/gsd/ab/asdad/

PROJECT TITLE: EAR - Federal Aviation Administration (FAA) Prototyping and Aviation Collaboration Effort (PACE) – Traffic Management Unit (TMU) Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Jim Frimel

NOAA TECHNICAL CONTACT: Lynn Sherretz (NOAA/OAR/ESRL/GSD/ACE)

NOAA RESEARCH TEAM: Chris Masters, Huming Han, David Hagerty (ACE Info Sol), SSG Staff

PROJECT OBJECTIVES:

This project was officially terminated by NWS Program Management at the end of the federal government's Fiscal Year, September 30, 2013.

Prototyping and Aviation Collaboration Effort (PACE) is an operational test area located within the Fort Worth Air Route Traffic Control Center's (ARTCC) CWSU for developing innovative science and software technology used to directly provide weather support for the ARTCC Traffic Management Unit (TMU).

The TMU project, staged at this facility, is researching the weather information needs and developing innovative software technology used to directly provide weather support for the ARTCC TMU. A major objective is to investigate aviation data sets and forecast products specifically tailored for the ARTCC air traffic weather forecasting environment among operational weather forecasting facilities and to investigate the utilization of collaborative weather forecasting.

The objectives came from the necessity to research and investigate software tools and data products for minimizing adverse weather disruptions in air traffic operations within the National Airspace System (NAS). Requirements and needs can be found in the study performed by FAA ARS-100 on "Decision-Based Weather Needs for the Air Route Traffic Control Center (ARTCC) Traffic Management Unit".

PROJECT ACCOMPLISHMENTS:

The TMU project is currently using convective weather products to address the weather information needs of the TMU relating to weather-related hazards impacting air traffic, originally planned to be followed by icing, turbulence, and ceiling/visibility. Each phase will address the tactical (0-1 hour) and the strategic (2-6 hour) application of the above products to help the TMU decision maker in directing air traffic into and out of the ARTCC airspace. All phases will be subjected to the iterative process of defining, developing, demonstrating, and evaluating the weather related hazard graphic and its presentation to the Traffic Manager.

The FX-Collaborate (FXC) software, developed at NOAA's Earth System Research Lab at the Global Systems Division's Information Systems Branch, is a major component of the TMU project. The major system used to acquire, distribute, create and provide the required data sets for FXC is the AWIPS Linux data ingest and display system. The FXC and AWIPS software is being tailored, modified, extended, enhanced, and utilized in the TMU project. The FXC software allows for the remote access and display of AWIPS data sets over the Internet, a collaboration capability among participants at physically different locations, remote weather briefings and the ability to utilize tools to aid in discussing forecasts. Additionally, the TMU project relies on the AWIPS system for generating the content available on the TMU Project TCHP and ADA web site.

The TMU Project is comprised of a suite of systems that consists of a database to house tactical decision aids, a web presence to display this content to traffic managers, and a FXC TMU system capable of overriding the impact information. The FXC TMU end-to-end capability allows forecasters to edit and override aviation route impacts. The override information is propagated back through the system and made available to update AWIPS, FXC, and the TMU Web Content displays. The initial design and structure of the decision aids relational database was populated with map background information for the ZFW arrival/departures, high-use jet routes, and TRACON arrival/departure gates. Following were changes to the AWIPS impact decoders to create impact information based on the NCWF2 data sets that would then be stored in the database and server side processing and generation of the web content generation.

A goal of the TMU web site is to consolidate all tactical aviation weather hazards information into a suite of products for presentation to TMU decision-makers in an easily understood format (A, GO-NO-GO, approach to air traffic route and flow information). What is important to understand about the Weather Information Decision Aids (WIDA) web content page is that it is a complete end-to-end system, not just a simple web display that provides useful information assisting in tactical and strategic decision making. It is an extremely complex suit of systems that involves AWIPS, FXC, content generation for the web, and a database backend. This is an end-to-end decision aid tool centered on the forecaster in the loop concept for helping to keep and create a more consistent, relevant, and accurate Weather Information Decision Aid (WIDA) product available for TMU managers. The consistency and power comes from the fact that all these systems are now tied and share the same data source.

The two images below show current impact with no Forecaster Edits. ZFW TRACON departure gates are displaying green (no impact) and yellow (partial impact).

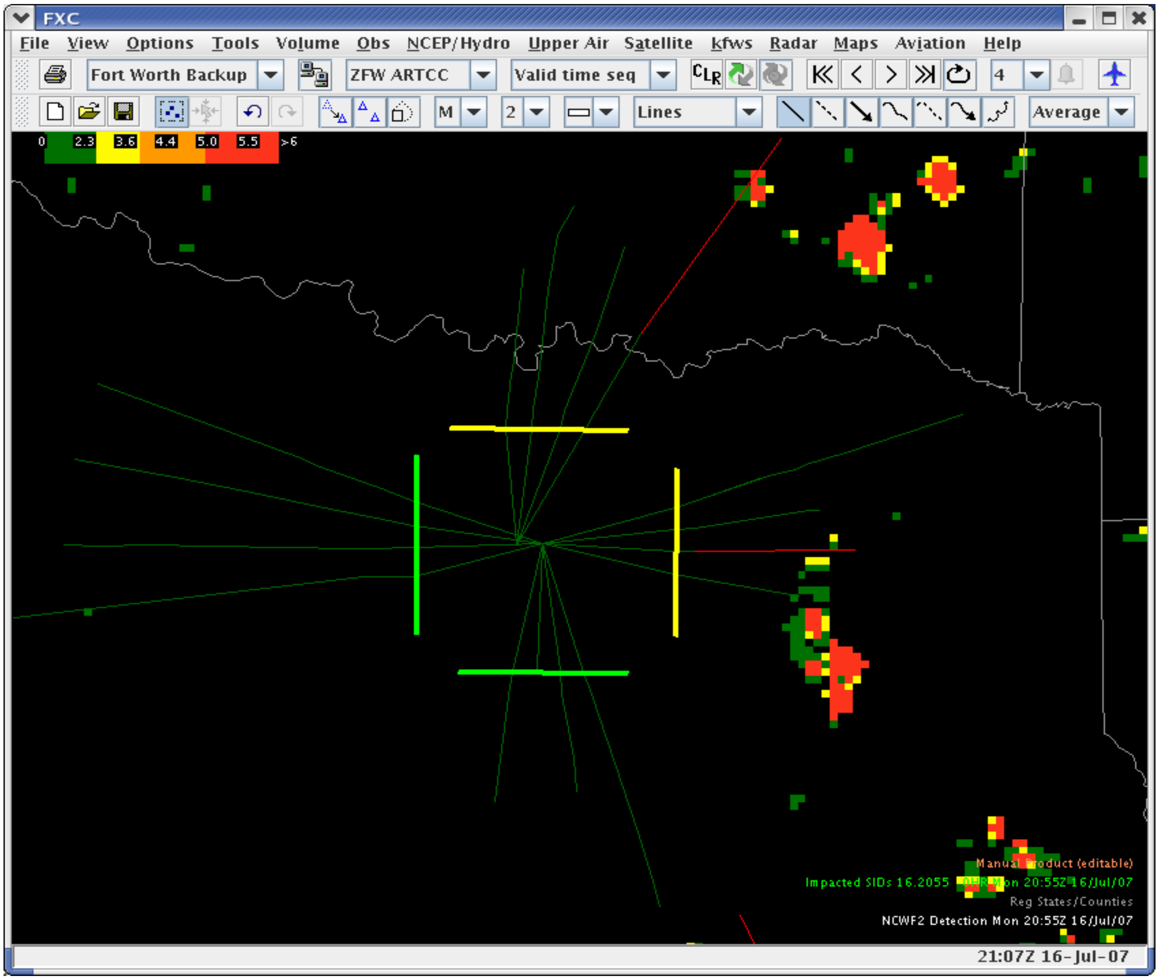


Figure 1. Forecaster FXC tool showing current ZFW TRACON Departure Gate impacts with NCWF2.

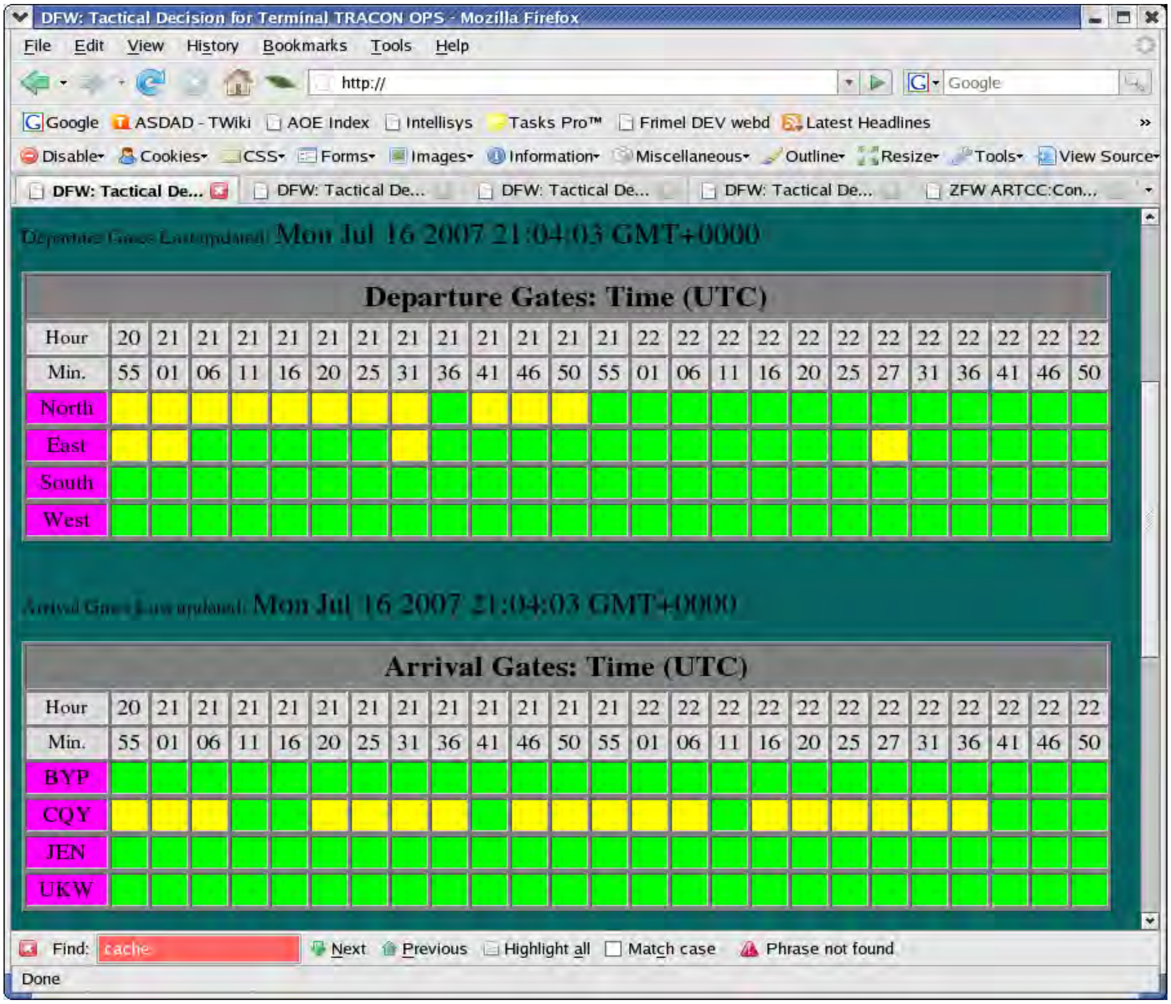


Figure 2. Traffic Manager (WIDA) Web Display showing concurrent Red-light/Green-light Departure Gate Impact information.

As of May 2007, the TMU project has been operating in software/system maintenance and support mode since the project research funding had ended. As of March 2009, the original federal manager of this project left to work for another branch within GSD. In Feb 2010, a Letter of Agreement between GSD and the NWS Office of Climate, Water, and Weather Services (OCWWS) was drafted in order to specify some funding and understanding to support and maintain these systems until the transition to AWIPS II extended clients for the CWSU's occurs.

PROJECT TITLE: EAR - Aviation Tools: Volcanic Ash Coordination Tool (VACT) Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Jim Frimel

NOAA TECHNICAL CONTACT: Lynn Sherretz (NOAA/OAR/ESRL/GSD/ACE)

NOAA RESEARCH TEAM: Chris Masters, Huming Han, David Hagerty (ACE Info Sol), SSG Staff

PROJECT OBJECTIVES:

This project was officially terminated by NWS Program Management at the end of the federal government's Fiscal Year, September 30, 2013.

The VACT project is an experimental client/server based application utilizing the Internet and is based on the FX-Collaborate (FXC) system architecture. The participating agencies are currently the National Weather Service Alaska Region Headquarters (NWSARH), Anchorage Volcanic Ash Advisory Center (VAAC), Alaska Volcano Observatory (AVO), and the Anchorage Air Route Traffic Control Center, Center Weather Service Unit (CWSU).

The FX-Collaborate (FXC) software developed at NOAA's Earth System Research Lab in the Global Systems Division's Information Systems Branch is a major component of the VACT project. The major system used to acquire, distribute, create and provide the required data sets for FXC is the AWIPS Linux data ingest and display system. The FXC and AWIPS software is being tailored, modified, extended, enhanced, and utilized in the VACT project. The FXC software allows for the remote access and display of AWIPS data sets over the Internet, a collaboration capability among participants at physically different locations, and the ability to utilize tools to aid in discussing forecasts.

The VACT project is a research and development effort in direct response to investigating the collaborative approaches and needs of agencies involved in generating Volcanic Ash Advisories. The Volcanic Ash Coordination Tool is being tested at each of these operational sites to investigate forecaster productivity tools and collaboration capabilities in response to aviation hazards posed by volcanic eruptions. The system is designed to help locate and determine the extent and movement of volcanic ash so that more accurate, timely, consistent, and relevant ash dispersion and ash fallout watches, warnings, and forecasts can be issued. These watches, warnings, and forecasts can be disseminated using current approaches and standards (societal impact statements) but will also be tailored for end user needs in the form of societal impact graphics (i.e. jet routes or runways turning red when ash is present). Graphics tailored to aviation needs focus on making the National Airspace System (NAS) safer and more efficient during a volcanic ash event. Efforts are focused on integrating the latest advancements in volcanic ash detection and dispersion from the research community, allowing users to overlay and manipulate this information in real-time; developing tools to generate end user impact statements and graphics; and disseminating the impact statements in a timely fashion so that hazard mitigation plans can be activated.

The VACT system allows users at different sites and with different expertise to simultaneously view identical displays of volcanic ash and other related data sets (i.e. shared situational awareness) and collaborate in near real-time. The expertise from all participating agencies is used in the determination of location, extent, and movement allowing for forecasts of fallout and dispersion to be consistent and more accurate. Relevant data on local agency systems and on the Internet can be pulled into the VACT system during collaborative sessions among the agencies to help in the analysis phase of an event. Societal impact forecasts can be disseminated faster through the development of a smart-system, which will automatically center on the area of eruption and display or highlight all key data sets for the volcanic ash event. Users of the VACT system aren't tasked with determining which data is relevant and can focus their attention on location, extent, dispersion, and societal impact. Societal impact statements can be disseminated following current standards and practices or by interactive briefings tailored to meet the needs of the end user (i.e. the public, emergency managers, FAA, airlines, armed services, state agencies, etc.). All volcanic ash events are captured and archived to help improve detection and dispersion methodologies, train new users on VACT functionality, detect and eliminate problems with multiple agencies collaborating in real-time on volcanic ash events, and improve dissemination techniques.

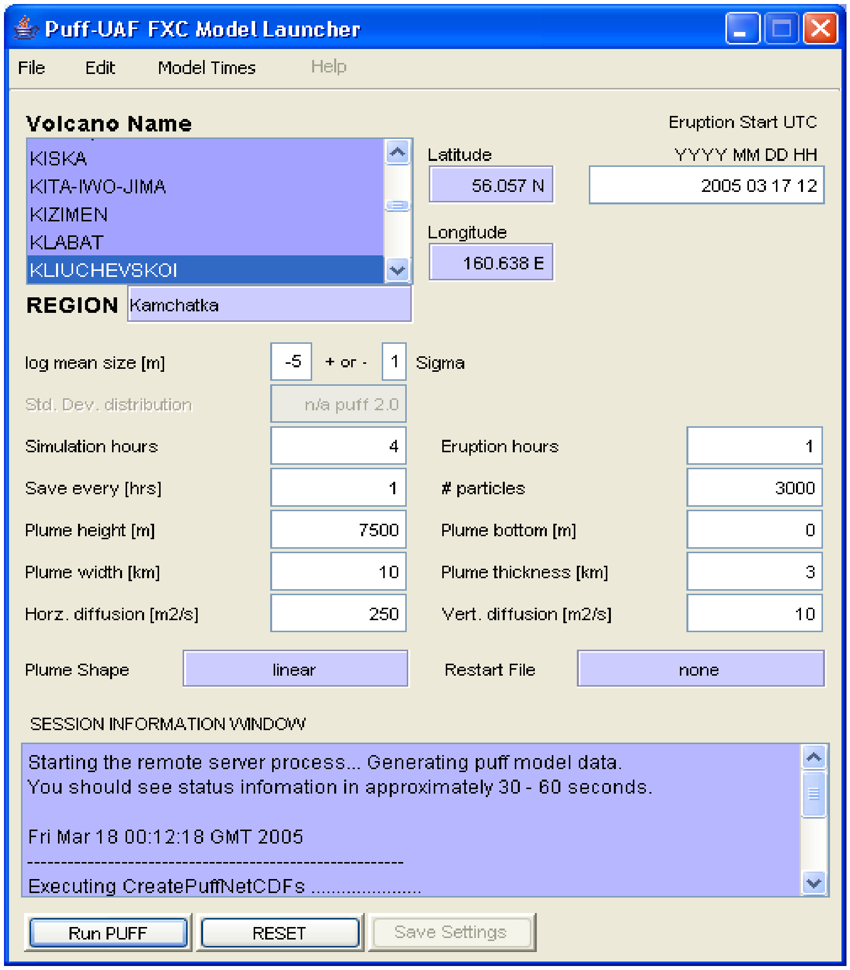


Figure 1. VACT PUFF Interface.

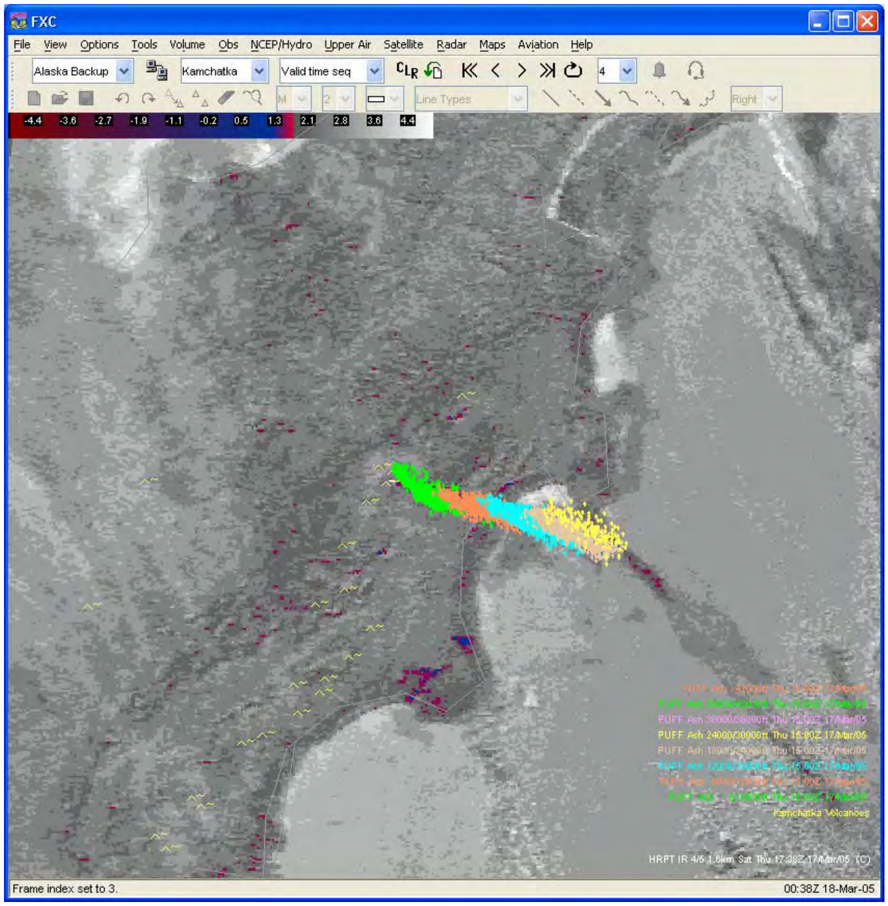


Figure 2. Example output from running the PUFF model over the 17 March 2005 eruption of Kliuchevskoi.

As of May 2007, the VACT project has been operating in software/system maintenance and support mode since the project research funding had ended. As of March 2009, the original federal manager of this project left to work for another branch within GSD. In Feb 2010, a Letter of Agreement between GSD and the NWS Office of Climate, Water, and Weather Services (OCWWS) was drafted in order to specify some funding and understanding to support and maintain these systems until the transition to AWIPS II extended clients for the CWSU's occurs.

PROJECT ACCOMPLISHMENTS:

Due to a lack of funding support, this project was officially terminated by NWS Program Management at the end of the federal government's Fiscal Year, September 30, 2013.
The work this past year was for the Systems Support Group (http://esrl.noaa.gov/gsd/its/ssg/) and CIRA engineers to support the VACT project systems, "as they are", until one of the following occurs; Aviation Tools capabilities and requirements that were developed are implemented and replaced by AWIPS II extended tasks; the occurrence of an irreparable hardware failure; or the project's maintenance funding is discontinued.

The maintenance and support addressed this past year included items related to
--RHEL 5 Operating System patches
--Hardware failures
--Client Rebuilds
--Failed Disks and Recovery
--Data Volume increases
--Field support and recovery for client problems.

--Support and Recovery for server and connection problems.
--Various Discussions and Responding to Management inquires.

As of the decommissioning, there was no known or planned replacement of the VACT Project systems and capabilities, such as interagency collaboration, the running and sharing of custom PUFF dispersion models, and issuing graphical Meteorological Impact Statements.

Currently, there are no future plans for the software tools developed for the VACT project or continuing and developing all the VACT project capabilities in to AWIPS II.
The project hardware, systems and software have been fully decommissioned and dismantled.

It is important to mention that the VACT project systems were available up to the time of their decommissioning. The reason these systems had continued to be maintained and supported is a testimony to the project success and utility by the end users. This is a noteworthy example of the VACT project research being used in operations.

The VACT project played a vital role in bringing to the forefront of NWS management, aviation and CWSU centric importance and needs. The lessons learned, concepts discussed, and ideas generated will continue forward to the next generation of software tools.

Project Website: http://www.esrl.noaa.gov/gsd/ab/asdad/

PROJECT TITLE: EAR - Research Collaborations with Information and Technology Services

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Leslie Ewy, Patrick Hildreth, Robert Lipschutz, Chris MacDermaid, Glen Pankow, Randy Pierce, Richard Ryan, MarySue Schultz, Amenda Stanley, and Jennifer Valdez

NOAA TECHNICAL CONTACT: Scott Nahman (NOAA/OAR/ESRL/GSD/ITS Chief)

NOAA RESEARCH TEAM: Chris Masters and Alex Mendoza (ACE Info Sol.)

PROJECT OBJECTIVES:

CIRA researchers in Information and Technology Services (ITS) develop and maintain systems that acquire, process, store, and distribute global meteorological data in support of weather model and application R&D projects throughout GSD. CIRA researchers collaborate with ITS and other GSD researchers to provide services that meet the specified requirements. CIRA researchers also develop methods to provide and maintain user access to the NOAA R&D High Performance Computing System's (RDHPCS) Hierarchical Storage Management System (HSMS), and develop and maintain the GSD web site.

PROJECT ACCOMPLISHMENTS:

--GSD Central Facility - CIRA researchers managed the 6-host data processing cluster, extending the configuration to handle a variety of new data sets, including from two global lightning data providers and several wind farm operators. Also, CIRA staff provided support to numerous external collaborators using GSD data sets, including the Rapid Refresh (RAP), the High-Resolution Rapid Refresh (HRRR), and the Flow-following finite-volume Icosahedral Model (FIM). A new method was implemented for capturing real-time data sets targeted for storage in GSD's Facility Data Repository. This capability dramatically reduced storage system resource utilization that previously had resulted in incomplete storage of some large data sets.

--GSD Enterprise Storage project - CIRA researchers implemented methods for mirroring real-time data from GSD's legacy storage server to a new enterprise storage system. After considerable testing and planning, we successfully transitioned all data processing to the new Central Storage Server, resulting in substantial capacity, performance and reliability gains for GSD.

--NOAA Earth Information System (NEIS) - CIRA researchers collaborated on the NEIS demonstration program, developing a set of services for metadata management and searching, web proxying and data caching. The CIRA team specified and implemented services on a collection of Virtual Machines following best System Development Life Cycle practices for setting up build, test, and production environments and establishing rigorous testing, maintenance, and promotion procedures. Software development included extending services to meet new requirements for secure connections, curated metadata, and Web Map Tile Services (WMTS), as well as integrating monitoring methods into GSD's System Support Group systems.

--FAA Common Support Services-Weather (CSS-Wx) - CIRA researchers collaborated with CSS-Wx researchers in GSD, NCAR, and MIT/Lincoln Lab on weather services to improve the quality, safety and cost of air traffic by more effectively making decision makers aware of current and upcoming weather.

--HIWPP High-Impact Weather Prediction Project (HIWPP) - CIRA researchers collaborated with researchers across NOAA and with researchers in the atmospheric sciences outside NOAA to address the severe weather needs of the nation through the development of one to two-week global weather models. CIRA researchers have begun developing the services and infrastructure for this project.

--GSD Web Services - Jennifer Valdez, serves as GSD Webmaster, providing numerous services to GSD scientists, RDHPCS management, and external community members. Activities included establishing a new publications database for GSD, developing an Account Information Management system for RDHPCS, serving on the NOAA Web Committee, and collaborating on developing a website and portal for the High Impact Weather Prediction Project (HIWPP).

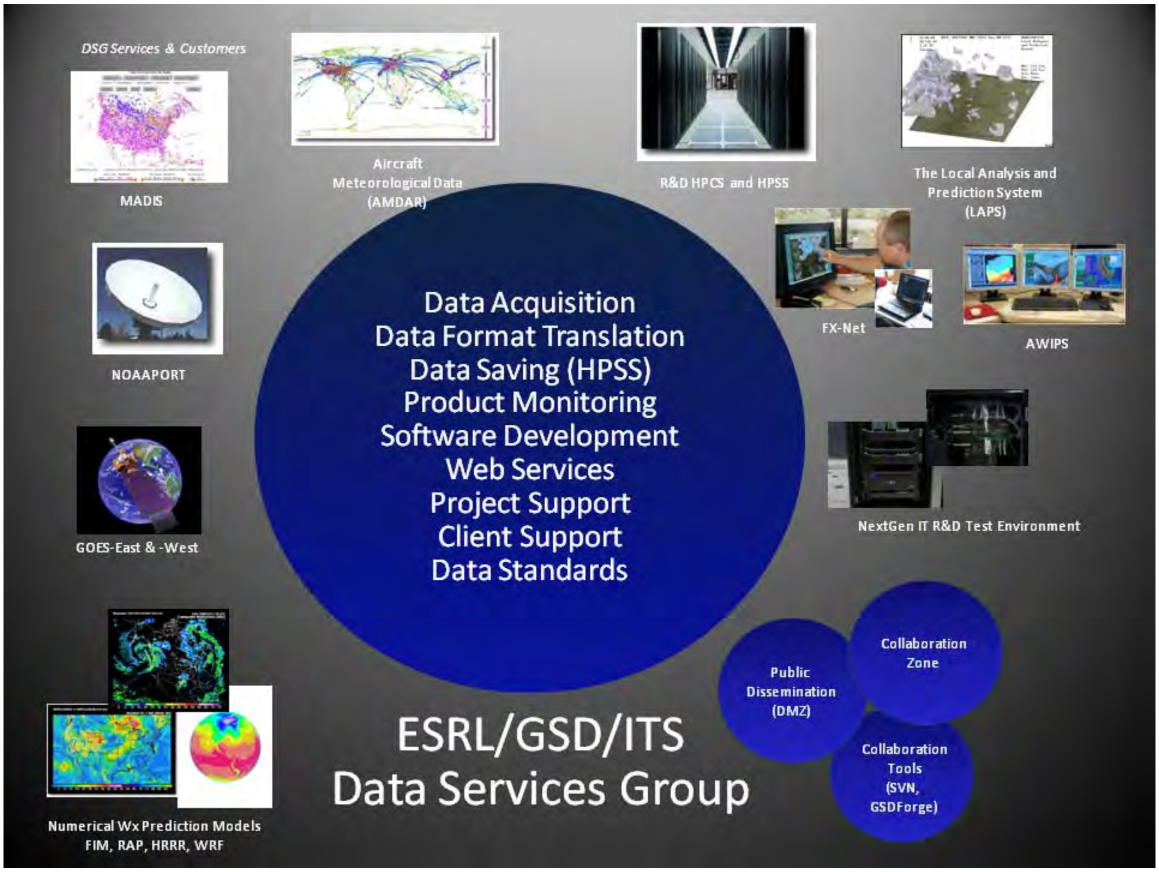


Figure 1. DSG Marketing Slide.

PROJECT TITLE: EAR - Common Support Services – Weather (CSS-Wx)

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Jim Frimel, Patrick Hildreth, Michael Leon, Chris MacDermaid, Glen Pankow, Sher Schranz

NOAA TECHNICAL CONTACT: Lynn Sherretz (NOAA/OAR/ESRL/GSD/ACE)

NOAA RESEARCH TEAM: Charles Burton (Ace Info Sol.)

PROJECT OBJECTIVES:

1--Enable the Federal Aviation Administration (FAA) to interface with NOAA Services
2--Establish foundation for a Weather Service-Oriented Architecture (SOA)
3--Work with the NextGen Joint Planning and Development Office (JPDO) to establish interagency SOA.

PROJECT ACCOMPLISHMENTS:

The primary goal of NextGen is to address and meet the rapidly changing needs of the United States aviation industry, including the ever-increasing demand for air traffic services. Expanding airspace capacity, optimizing efficiency, and improving safety, are key components of NextGen. As noted in the NextGen Weather Concept of Operations (13 May 2006), weather has a considerable impact on aviation operations. Acquisition, management, dissemination, and use of weather-related information and data will play a vital role in the success of NextGen. Consequently, exploring, identifying, and employing methods and techniques that will help facilitate the flow of operation-specific, weather-related information to end-users is critical.

The CSS-Wx System is a key component of the NextGen weather system. The CSS-Wx Program will create the weather standards to be used by the CSS-Wx System and by NOAA Web Services for data dissemination purposes.

The CSS-Wx Program is dedicated to using and developing technologies and standards that will support effective weather data dissemination within the NextGen environment. Among the CSS-Wx team members are National Center for Atmospheric Research, Research Applications Laboratory (NCAR/RAL), Massachusetts Institute of Technology/Lincoln Laboratory (MIT/LL), NOAA Earth Systems Research Laboratory/ Global Systems Division (GSD), MITRE, and the FAA's William J. Huges Technical Center (WJHTC). Together, these organizations are working in partnership to lay the foundation for NextGen weather data distribution.

In conjunction with other agencies that support JPDO, FAA is planning a NextGen weather Initial Operating Capability (IOC) for the 2016 timeframe.

Supporting and maintenance of the CSS-Wx Web Service Testbed
CIRA researches supported and maintained the Open Geospatial Consortium (OGC) Web Feature Service Reference Implementation (WFSRI), OGC Web Coverage Service Reference Implementation (WCSRI), and the OGC Web Map Service Reference Implementation (WMSRI). CIRA researchers also maintained the Testing Portal for testing the FAA's and NOAA Web Services. These efforts included conducting functional and performance testing, enabling the services to use real-time data and ensuring the services adhered to OGC standards.

Technical Support to CSS-Wx Program Office
CIRA researchers attended technical meetings with other agencies and the JPDO and responded to ad-hoc requests for information from the CSS-Wx Program Office.

Product Data Descriptions (PDDs)
CIRA researchers created PDDs in accordance with FAA Std 65A for GOES (Geostationary Satellite Server) data, METAR station data, HRRR (High-Resolution Rapid Refresh) and RAP (Rapid Refresh) numerical weather prediction models.

PROJECT TITLE: EAR - FX-Net Forecaster Workstation Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Evan Polster, Sher Schranz

NOAA TECHNICAL CONTACT: John Schneider (NOAA/OAR/ESRL/GSD/TOB Chief)

NOAA RESEARCH TEAM: Eli Jacks (NOAA/NWS/OCWWS), Robyn Heffernan (NOAA/NWS/Fire Weather Program, Boise, ID WFO)

PROJECT OBJECTIVES:

The FX-Net Thin Client has been supporting NWS Incident Meteorologists, USFS Predictive Services Fire Weather Forecasters, NOAA Research field studies, university meteorological education programs and the US Air Force's Air Force One weather forecasting operations. The FX-Net team continued to support these programs in FY13/14.

The purpose of the AWIPS Thin Client project is to develop and deploy an integrated thin client solution that will satisfy the NWS enterprise requirements for remote access to baseline AWIPS-II capabilities. Included in this project is the effort to transition from maintenance and support of the FX-Net thin client workstation to delivery of the AWIPS II Common AWIPS Visualization Environment (CAVE) thin client workstation.

The CIRA team's objective is to continue supporting FX-Net for the US Forest Service and to conduct an investigation in this fiscal year to determine and evaluate the best approach to transitioning them from FX-Net to the AWIPS II Thin Client. As the AWIPS II thin client is not yet operational, the existing version of FX-Net will be supported while determining the best transition method.

1--Thin Client development and support for NWS and US Forest Service
2--Evaluate AWIPS II for use by USFS National Interagency Fire Center

PROJECT ACCOMPLISHMENTS:

The FX-Net client workstation was upgraded to version 6.0 in the Spring 2013. This release included new capabilities to display product inventory and creation times, enhanced color bars to more closely emulate existing AWIPS, revised and updated documentation, upgraded installer package with new support for Linux and Mac users, and transition clients to port 80 to improve network availability.

Continued development and support of capability to ingest new third-party model data including the Rocky Mountain Center (RMC) MM5 For-Flux 15km, RMC WRF Fire model 8km, High Resolution Rapid Refresh (HRRR) Chem model 4km.

Maintained working production server systems within ESRL/GSD for FX-Net (including communications processors, data servers, application servers, and load balancers) as well as provided support for NWS regional headquarters currently deployed FX-Net servers, including Western, Southern, Alaska and Pacific regions

Provisioned and maintained most current release of the EDEX standalone server from OB 11.6 to OB 14.1.1.

Furthered research of the Application Development Environment (ADE) for continual investigation into developing specialized tools to integrate with the Common AWIPS

Visualization Environment (CAVE) workstation

Initiated investigation into a tool to enhance CAVE capabilities providing access and basic processing of raw model data. This tool will provide capabilities to replace the existing Grid Extraction Tool-Web Interface (GETwi) and will support the migration of current Gridded FX-Net users to the new AWIPS II Thin Client application.

PROJECT TITLE: EAR - GRIDDED FX-Net Forecaster Workstation Project

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Evan Polster, Sher Schranz

NOAA TECHNICAL CONTACT: John Schneider (NOAA/OAR/ESRL/GSD/TOB Chief)

PROJECT OBJECTIVES:

Maintain existing Gridded FX-Net and Grid Extraction Tool, Web-Interface (GET-WI) system capabilities for USFS, BLM and Dept. of Agriculture National Interagency Fire Center (NIFC) Predictive Services Fire Weather forecasters.

The USFS NIFC Geographical Area Coordination Centers (GACC's) rely heavily on the gridded data delivered by the Gridded FX-Net system. The AWIPS II Remote system has a different storage format data extraction technology. As a result, the forecasters do not want to give up their existing systems as it will require a change in their fire index algorithm processes. It is the goal of the Gridded FX-Net team to explore methods to deliver the grids needed in the existing AWIPS I format.

PROJECT ACCOMPLISHMENTS:

Maintained production server systems for Gridded FX-Net and GETwi and provided support to field meteorologist for NICC, NIFC, and GACC offices.

Delivered field personnel survey to Ed Delgado who gathered information on which models were preferred.

Additional accomplishments regarding transition to AWIPSII were combined and listed as part of FX-Net Forecaster Workstation Project.

PROJECT TITLE: EAR - NOAA Environmental Information System (NEIS)

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Jebb Stewart, Jeff Smith, Randy Pierce, Chris MacDermaid, Mary Sue Schultz

NOAA TECHNICAL CONTACT: John Schneider (NOAA/OAR/ESRL/GSD/TOB Chief)

NOAA RESEARCH TEAM: Alexander MacDonald (OAR/ESRL Director), Eric Hackathorn (OAR/ESRL/GSD/TOB), Tracy Hansen (OAR/ESRL/GSD/ISB), Chris Golden and Julien Lynge (CIRES)

PROJECT OBJECTIVES:

NOAA is challenged to ingest, manage, generate and provide reliable access to the increasing volume of data associated with their high caliber environmental systems. The objective of the NEIS project is to make data easily accessible to people across the country and around the world. NOAA can benefit from leveraging an existing information management and storage solution to allow easy and open information sharing of big data services throughout the user community. NOAA can use proven Portals, Apps, App Chaining, Collaboration Tools, Information Management & Storage, and Business Analytics within NEIS. http://www.esrl.noaa.gov/neis/

The core capabilities of this new system will meet requirements to:
1--Provide discovery and access to all information and data for all time scales.
2--Provide the information when the user needs it.
3--Provide the information in a form the user can interpret.
4--Make information available on all platforms.

The CIRA team's objectives are to investigate, prototype and explore:
--Improving data discoverability and access,
--Data management capabilities,
--How interoperable processing and analysis services are integrated into the system.

The CIRA team is also dedicated to conduct this research with a collaborative team of NOAA, University and private sector developers.

PROJECT ACCOMPLISHMENTS:

Continued collaboration with the Climate Program Office (CPO) including the following:
--Lead interoperability experiment with other partners of CPO to evaluate what an interoperable system would need and look like taking a handful of target datasets through discovery, access, visualization, and integration using NEIS framework. This effort concluded with a document and presentations describing success and failures of the interoperable systems as well as a road map to implement an interoperable system building off the NEIS infrastructure.
--Added tour capability allowing users to create guided presentations of data through the NEIS visualization system TerraViz.
--Enhanced collaboration capabilities allowing multiple users to share and interact within a single session of TerraViz at the same time.
--Developed new particle display visualization taking advantage of 3D capabilities to allow users to see wind parameters in motion for gridded forecast data.

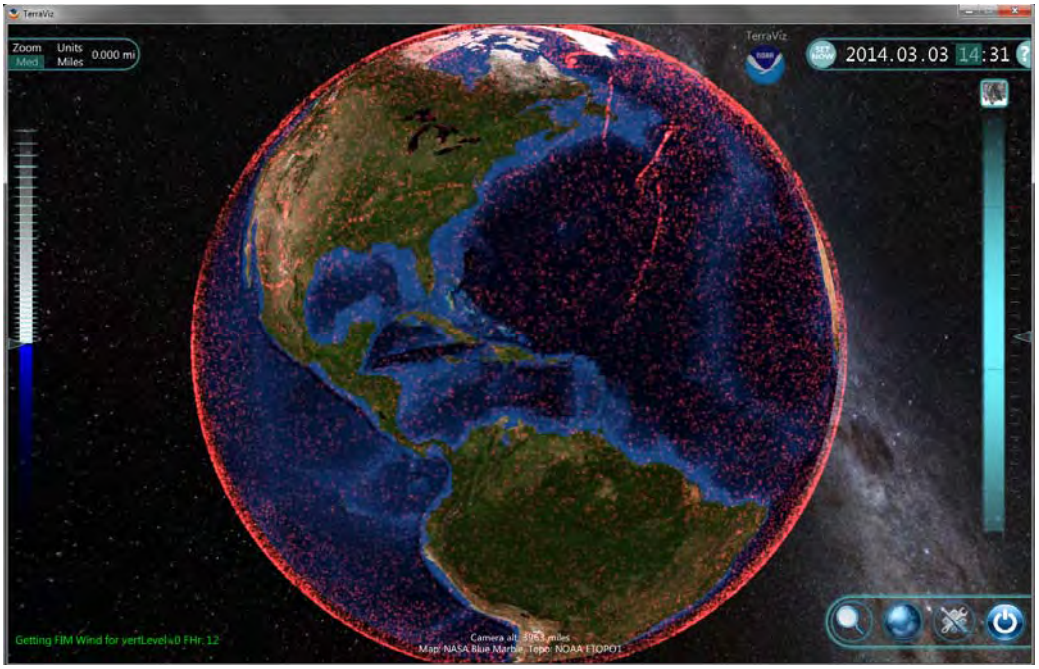


Figure 1. NEIS.

--Added several new data access capabilities including data directly from FTP, HTTP or THREDDS data services. The new THREDDS capability allows users to access multiple vertical levels of gridded data.

--Created kiosk mode and touchscreen capabilities allowing TerraViz to run in unsupervised mode showing off capabilities and data. This was demonstrated at the 2013 AMS Annual Meeting in Austin TX. Additionally, NEIS/TerraViz is now available on a touch screen in the ESRL Lobby.

Various enhancements and performance improvements to NEIS and TerraViz visualization including:
--Incorporating a web browser to allow the display of additional content and easier content creation
--The ability to curate tags for datasets allowing enhanced usage and categorization of data.
--Implementation of a secure proxy allowing NEIS/TerraViz to display data and other content from remote sources not hosted by ESRL.

PROJECT TITLE: EAR - Science on a Sphere® (SOS) Development

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Keith Searight, Michael Biere, Jebb Stewart, Steve Albers

NOAA TECHNICAL CONTACT: John Schneider (NOAA/OAR/ESRL/GSD/TOB Chief)

PROJECT OBJECTIVES:

1--Continue to develop and enhance near-real-time global data sets for SOS museum sites.
2--Continue software and technical support for both the existing installed base of SOS systems, as well as new and proposed SOS installations.

3--Release version 4.1 of the SOS system software, with planned features including display of Google KML and WMS data sets, a web-based playlist editor, a SphereCast user interface, and an automatic alignment capability.
4--SphereCast capabilities will be further enhanced.
5--Track the level of usage of specific SOS data sets across the SOS network.

PROJECT ACCOMPLISHMENTS:

The Science on a Sphere® Development project addresses NOAA's cross-cutting priority of promoting environmental literacy. The NOAA Science on a Sphere® (SOS) project displays and animates global data sets in a spatially accurate and visually compelling way on a 6-foot spherical screen. CIRA provides key technical support to the project, particularly research into effective user interfaces for the system, new visualization techniques, and new data sets.

1--Near-real-time global data sets

The SOS team supported the automated transfer of large volumes of near-real-time weather model data to SOS sites via private FTP. Recently collected statistics documented a monthly average of 3.5 TB data volume downloaded.

In addition to the large quantity if near-real-time data sets, the CIRA research team created some other notable SOS content, including:

--A global cloud visualization from a high resolution FIM model forecast that was demonstrated by the ESRL director at the AMS conference. This "animated Blue Marble" forecast will soon be made available on SOS.

--A "future paleo" dataset that interpolates/morphs between 5 newly available frames from Ron Blakey. Thus a smooth animation was created that shows plausible future continental drift over the next 250 million years.

--A dataset that shows general atmospheric circulation for the Earth. This utilizes a more flexible IDL procedure that places text and icons at arbitrary locations on the sphere with the correct spherical distortion. Text now has the option of being shaded for better visibility.

2--Software and technical support for new and existing sites
--The SOS team provided regular support to existing SOS sites by e-mail and telephone. The issues handled included upgrades and problems with the SOS software, hardware, and equipment, finding and accessing datasets, and questions about operating the SOS system.
--A notable project achievement was the translation of the SOS website into Mandarin Chinese. SOS is currently of great interest in Mandarin Chinese speaking nations and this new capability overcomes the unclear descriptions generated by common online translation tools.

Figure 1. SOS website translated in Mandarin.

During this reporting period, 11 new SOS systems were installed at the following sites:
E.O. Wilson Biophilia Center - Freeport, FL
Cyberinfrastructure Building at Indiana University - Bloomington, IN
Museo delle Scienze - Trento, Italy
Techmania Science Center - Pilsen, Czech Republic
NOAA Headquarters - Silver Spring, MD
Science Central - Fort Wayne, IN
National Museum of Marine Science and Technology - Keelung City, Taiwan
Galaxy E3 Elementary - Delray Beach, FL
NOAA Inouye Regional Center - Honolulu, HI
Climate Institute - Ciudad Victoria, Mexico
Dongguan Meteorology and Astronomy Museum - Dongguan, People's Republic of China

The total number of SOS sites installed is now 104 worldwide.

3--Version 4.1 release

SOS 4.1 was successfully released in December 2013. Most of the objectives for this release were met, although the desktop playlist editor was simply enhanced rather than being replaced by a web interface and the initial research conducted on using machine vision approaches to automated projector alignment will require additional effort before providing a robust solution.

Here are the 4.1 release highlights:

--A new SOS security feature that requires a separate key provided by the SOS team in order for each SOS installation to operate.

--A new ability to view KML (Keyhole Markup Language) files on SOS. KML is very popular and actively used with Google Earth to display data on a sphere. The initial SOS KML capability in SOS includes the KML features typically used in Google Earth.

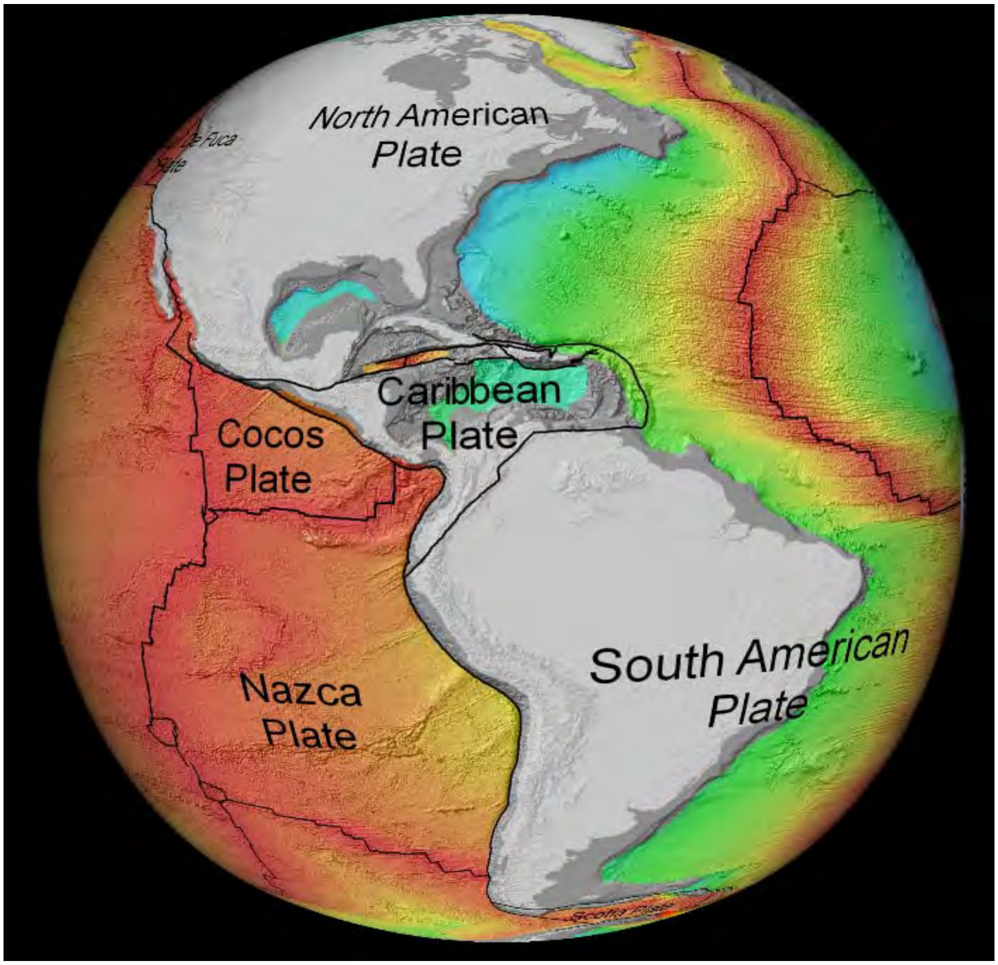


Figure 2. SOS KML Features.

--A new experimental capability to specify and load images directly from an Open GeoSpatial Consortium (OGC) Web Mapping Service (WMS). SOS takes advantage of the “progressive zooming” functionality in WMS to provide more image detail at higher zoom levels inside the magnifying glass on the sphere.

--An updated Playlist Editor, with many updates to handle newer SOS functionality, including layers, annotation, KML, and WMS.

--A new SOS Utilities graphical user interface to address some common support issues.

--A new SphereCast graphical user interface accessed from the SOS Stream GUI to make receiving a SphereCast easier.

--15 bug fixes made since the 4.0 release to address issues such as crashes that occur infrequently, better error messaging, updates for operating system changes, some PIP-related behavior, and better alignment support.

4--SphereCasting enhancements

Improvements to SphereCasting are currently in development and are expected to be part of the next SOS release, planned for May 2014. Targeted upgrades include having the audio/video of the presenter appear in a PIP on the sphere during a SphereCast and supporting the transmission of more SOS features from host to viewing sites, such as layer visibility and transparency.

5--Dataset usage tracking

Tracking and report for dataset usage at SOS sites are currently in development and are expected to be part of the SOS 4.2 release. Anticipated functionality includes top 10 lists of data sets played on spheres per site, type of site, and for all sites, made available on the SOS website.

PROJECT TITLE: EAR - Developmental Testbed Center (DTC) Support

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Edward Tollerud

NOAA TECHNICAL CONTACT: Zoltan Toth (NOAA/OAR/ESRL/GSD/FAB)

PROJECT OBJECTIVES:

1--Publish DTC Newsletter
2--Publications for HMT/DTC collaborations
3--NWP Verification Technique Development

PROJECT ACCOMPLISHMENTS:

1--Four issues of quarterly DTC newsletter (Transitions) published
2--Presentations at AMS annual meeting, NOAA Testbeds Workshop, and WRF Users Workshop; see publications below.
3--Presentation at AMS WAFS/NWP Conference; Ensemble Workshop w/NUOPC meeting report published in BAMS; Proposal for MET-based verification paper accepted by BAMS; paper on object-oriented verification techniques for atmospheric rivers in progress; technical report on CCPA/Stage IV precipitation estimates comparison in progress.

PROJECT TITLE: Effective Collaborative NIDIS Drought Monitoring and Early Warning in the Upper Colorado Basin

PRINCIPAL INVESTIGATOR: Nolan Doesken

RESEARCH TEAM: Nolan Doesken, Zachary Schwalbe, Wendy Ryan, Henry Reges, Noah Newman, Rebecca Bolinger (formerly Smith), Morgan Phillps (funded by a different NOAA project but also contributing until he completed his M.S.), Peter Goble (funded by a different NOAA project but began contributing to this project since December 2013)

NOAA TECHNICAL CONTACT: Allan Schmidt (NOAA/OAR Cooperative Institutes Office)

NOAA RESEARCH TEAM: Roger Pulwarty, Jim Verdin, Lisa Darby, Chad NcNutt, Veva DeHeza (NIDIS Program Office, Boulder CO) and Mike Brewer (Drought.gov development work at the National Climatic Data Center)

PROJECT OBJECTIVES:

1--Develop and improve drought monitoring for the purpose of providing timely status reports and drought early warning information for stakeholders and information providers and also to coordinate input for the USDM weekly update cycle

2-- Expand active participation and strategically engage multiagency expertise from Utah and Wyoming to improve the quality and cross-border consistency of USDM products

.

3)--Systematically conduct formative and summative evaluation with emphasis on stakeholder impact and changes in confidence and use of drought products and information over time

PROJECT ACCOMPLISHMENTS:

The focus of our work this past year was directed at objective 1. The extreme and widespread drought of 2012 continued, although less extreme, over many parts of the Upper Colorado River Basin in 2013. As a result, we directed most of our project staff time towards aggressive drought monitoring and information outreach.

We have now conducted weekly “Climate, Water and Drought Assessments” every week since February 2010.

http://ccc.atmos.colostate.edu/drought_webinar.php

Beginning in mid-April 2013 we moved from a weekly power point format for data delivery and display to more of a “Dashboard” approach. Narrative interpretation is embedded in graphics for all the key components of water supply and demand (precipitation, snowpack, runoff, reservoir storage, evapotranspiration, soil moisture, etc.). This change was accompanied by a transfer to the NIDIS ”Constant Contact” communications system to better track the engagement of stakeholders receiving our weekly assessments. Overall, this transition and the more versatile graphics was very well received by users. We do have a concern, however, that the migration of communication to nicely formatted “Constant Contact” messages rather than the previous ugly but personal e-mail communication may have improved some aspects but also taken away the sense of personal direct weekly communication. We’re only seeing about a 1/3 open rate for those receiving our weekly message through “Constant Contact” based on their feedback metrics. Of those that open the e-mail it looks like only about half seem to be clicking through the weekly updates to explore the detailed hydroclimatic information. Considering that the e-mail list is composed only of individuals who specifically asked to be on the mailing list, this seems like a small number (usually less than 70 users per week). But again, those who have provided feedback have been almost universally positive and enthusiastic. More evaluation may be appropriate to better understand this response. Also, the “Constant Contact” metrics are known to be conservation and actual view rates may be higher.

Bob Kimbrough, USGS, joined the webinar team as our streamflow content expert.   National Weather Service offices have remained dedicated to the periodic webinars and weekly electronic updates. We considered doing short video clips, similar to the Southern Climate Impacts group, but as drought conditions softened a bit, we did not see a big enough demand to justify the time spent perfecting this.

We worked with consultants from Riverside Technology Incorporated to develop more drought monitoring and visualizations tools to help automate the weekly assessment process. Several tools were developed and tested by RTI as a part of a small business innovation effort funded separately. We found their reservoir analysis and display tools very helpful. For our weekly assessment reports and periodic webinars, we still crave better expertise on reservoir operations since this is a human-decision-driven variable that can’t always be explained from physical data.

Despite improving conditions beginning in April and May 2013 over Wyoming and Northern Colorado in April-May 2013 and then expanding southward later in the summer and early fall, drought still has a grip on parts of the region – notably in SE Colorado but also over other parts of southern Colorado and parts of Utah. The process of accurately depicting drought severity through the well-developed mechanism of the U.S. Drought Monitor remains a tedious and sometimes mildly disagreeable process. Drought severity is viewed differently by recreation and tourism interests compared to agriculture. Our staff, in collaboration with the National Weather Service and state and local experts have navigated this process well enough and have enjoyed close working relationships with most of the USDM weekly authors. There have been occasional disagreements, however. The lack of sufficient long-term precipitation data in many parts of the Colorado- Utah – Wyoming adds to this challenge.

We have also continued to face difficulties in working across state lines through this weekly assessment process. While integrated in situ data and regional analyses has been straight forward, participation in a Colorado-lead 3 state discussions has not drawn much help from UT and only limited (but very helpful) input from Wyoming. There is opportunity for improvement here but it will take personal relation-building time to build a multistate team. For a number of reasons, it may be most efficient to just encourage each state to contribute individually to the USDM weekly update process, but regionalizing this a bit would really help the drought monitor author deal with time limitations. This needs more discuss and strategy.

Evaluation (Objective 3): During the summer of 2013, NIDIS and the Western Water Assessment (WWA) hired a full time evaluator, Elizabeth McNie. Rather than duplicating assessment efforts, we have teamed up and are proceeding with a robust, professional evaluation.   Dr. McNie has spent many hours with our full project staff, documenting the project history, progress, and reasons for various decisions and priorities. Dr. McNie has sat in on several Webinars and reviewed our products and services.   She is currently preparing a stakeholder drought information survey to be distributed to hundreds in the next few weeks. We are very grateful for the assistance on this important aspect of our project.

This link shows a recent example of the automated reservoir tracking tool and graphic developed for NIDIS collaboratively through Riverside Technology, INC here in Fort Collins. http://climate.colostate.edu/~drought/weeklypics/teacups.png

In addition to formal presentations, Becky submitted another manuscript for review and rapped up most of her PhD research. She will be defending her dissertation in April 2014.   There were other conferences, workshops, and task force presentations highlighting drought monitoring and communicating drought to stakeholders in Colorado and the Upper Colorado River Basin. From regional meetings such as the PROGreen EXPO to watershed protection and local irrigation district meetings, we had many opportunities to share drought information and invite more participation in the weekly monitoring and assessment process.

https://www.signup4.net/public/ap.aspx?EID=PROG129E&TID=TFBqm44BdIyRuIbkcdNQqA%3d%3d

PROJECT TITLE: Legacy Atmospheric Sounding Data Set Project

PRINCIPAL INVESTIGATOR: Richard H. Johnson

RESEARCH TEAM: Richard H. Johnson and Paul E. Ciesielski, ATS

NOAA TECHNICAL CONTACT: William L. Murray (NOAA CPO)

NOAA RESEARCH TEAM: None (Collaboration is with NCAR)

PROJECT OBJECTIVES:

1--Identify past field programs for which central collections of sounding data do not exist,

2--Track down existing holdings of sounding data for those field programs, to the extent they exist, at centers, laboratories, and universities,

3--Extract sounding data that are found on old storage media (i.e., 9-track tapes, printouts, etc.), and place into a consistent, easily-read, digital format,

4--Carry out standard quality control of the sounding data including objective gross limit and vertical consistency checks, and

5--Prepare a catalog and a central, publicly accessible archive of the sounding data (probably at NCAR and/or NCDC).

PROJECT ACCOMPLISHMENTS:

No funding was made available for this project during the reporting period, so no additional progress has been made nor have there been any new publications. The project web site is http://www.eol.ucar.edu/projects/legacy/.

PROJECT TITLE: Research Collaboration at the NWS Aviation Weather Center in Support of the Aviation Weather Testbed, Aviation Weather Research Program, and the NextGen Weather Program

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Daniel Vietor, Chad Hill, Larry Greenwood, Adrian Noland, Anders (Mick) Ohrberg, Brian Pettegrew, Lee Powell, Guohua Liu, Sher Schranz, Jenna Dalton

NOAA TECHNICAL CONTACT: David Bright (NOAA/AWC)

NOAA RESEARCH TEAM: David Bright (AWT Program Manager, NWS/AWC), Steven A. Lack (NWS/AWC)

PROJECT OBJECTIVES:

The Aviation Weather Center (AWC) Support Branch (ASB) is primarily responsible for providing support to the www.aviationweather.gov web site, providing support and maintenance to the network and server infrastructure at the AWC as well as supporting the research to operations processes.

The primary goal of the ASB is to maintain the internal network, servers and workstations at the AWC to ensure continuity of operations. The 24x7 support is critical to AWC forecast and web operations. The ASB collaborates with the other NCEP centers and the NWS to provide data and research to operations support. The branch supports the research operations at the AWC, headed by a team of Technique Development Meteorologists (TDMs). This includes support for the Aviation Weather Testbed (AWT) as well as support for the FAA Aviation Weather Research Program (AWRP). The AWRP products include CIP, FIP (Current and Forecasted Icing Products) and GTG (Graphical Turbulence Guidance). The ASB also supports the AWC web site which includes ADDS, WAFS Internet File service (WIFS) and the International Flight Folder (IFFDP) project.

As part of the CIRA effort, the ASB has close links to the research and development projects going on at the AWC. This includes:
--supporting NextGen and AWRP,
--providing better tools to decrease weather impacts to the National Airspace System (NAS) including efforts at the FAA Command Center and the Traffic Flow Management (TFM) project,
--providing direct support to the TDMs at the AWC for ongoing research projects including GOES-R, ensemble model diagnostics and product verification,
--expanding its collaboration efforts with the other testbeds within NOAA and the NWS focusing on R2O projects.

PROJECT ACCOMPLISHMENTS:

In the past year efforts have been centered on three primary projects: the upgrade of the www.aviationweather.gov web site, the AWC Summer Weather Experiment, and the Production Dashboard.

The www.aviationweather.gov Web Site Upgrade
In the summer of 2012, the new version of Java by Oracle started breaking the Java code on the web site. Starting in the winter of 2012-13, research into replacements for the Java applets led to the use of OpenLayers, a Javascript API for access geospatial data and Mapserver, a backend WMS server.

At the same time, the National Weather Service (NWS) unveiled its new web site www.weather.gov. This featured a new layout and more streamlined view of the data. Over time, all NWS sites will have to adopt the new layout.

It was decided that the new layout and the new OpenLayers tools would create the opportunity to upgrade other legacy parts of the web site. The design goals are:

--Update to the weather.gov layout - This provides a cleaner, more modern look and feel.
--Add in the OpenLayers views for METARs, TAFs, PIREPs, SIGMETs to replace the existing ADDS Java applets - This eliminates the Java on the client support issues and provides a better tool for accessing the data.
--Streamline the user experience - The idea is to simplify the pages and provide a common layout for all pages. The legacy web site had several user interfaces and each page had a different layout. Moving to a common look and feel should make it easier for users to find data and access the pages they need to access.
--Streamline the back-end web code - This was an opportunity to rewrite much of the back-end code and move it all into a more modern scheme. Zend Framework is a MVC (Model, View, Controller) API for developing web sites. Using this framework separates functionality and should make the web site easier to support and upgrade in the future.
--Moving ADDS into the open geospatial world - The move to OpenLayers also requires the development of back-end services to support geospatial formats and protocols. Scripts needed to be written to output GeoJSON for point and polygon data as well as WMS for imagery. This should position the web site for future geospatial efforts.
--Support for mobile devices - The aviation world is moving toward the use of tablets to display data. Supporting iPads and Android tablets is a must, and many of the design features of the new web site were aimed specifically at mobile support. The idea is to provide a web site that gives the user the same functionality whether it's on a tablet or a desktop browser. In addition, a new mobile website was developed specifically for small screen devices such as iPhones.

Dan Vietor is the lead on the project with substantial help from Adrian Noland and Larry Greenwood. The prototype web site went live in the summer of 2013 and was displayed at the Oshkosh air show. The pilots loved the new web site and especially the tablet support. User feedback has been critical in tailoring the web site to ensure it fits user needs. The final version will become operational at the end of March 2014. A screenshot of the new web site is seen in Figure 1.

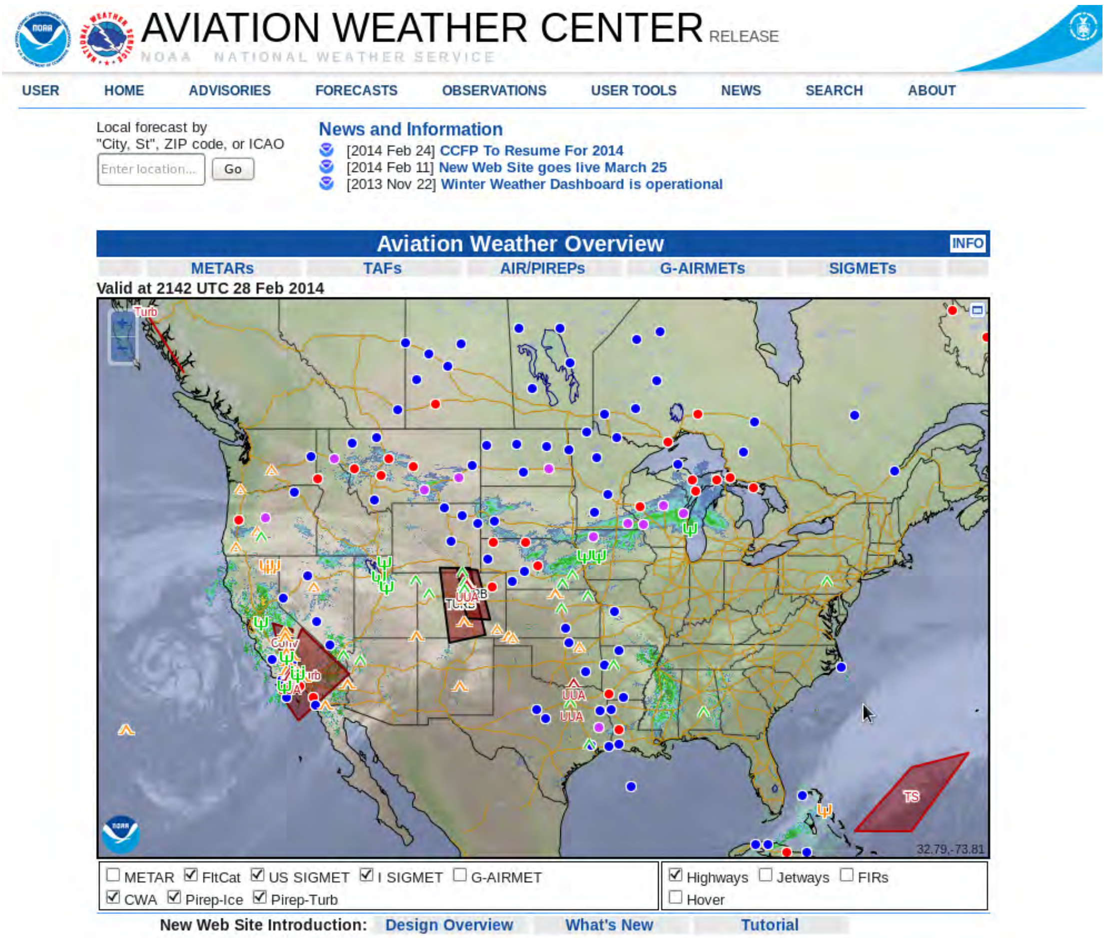


Figure 1. The upgraded AviationWeather web site with new weather.gov layout and OpenLayers interactive tools.

2014 Summer Weather Experiments

The Aviation Weather Center (AWC) in Kansas City, MO hosted the Third AWT Summer Experiment August 12-23, 2013. The primary goal of the experiment was to demonstrate and evaluate new datasets, tools, and deliverables with the participation of AWC forecasters, academia, governments, and industry participants in a simulated operational environment focused on air traffic impact. A description of each of the main objectives and methodologies for both experiments will be presented along with a brief summary of findings.

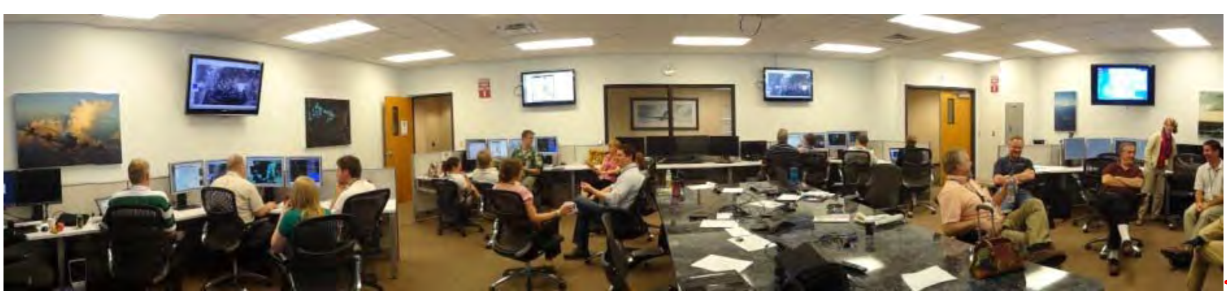

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Figure 2. Participants collaborating on forecasts during the summer experiment. There are five forecaster desks each with a different goal and set of products to view.

The Third AWT Summer Experiment focused primarily on forecasting high-impact convection on multiple scales of interest, from regional to global, however some additional aviation impact variables were considered, such as: ceiling, visibility, and winds. Throughout the two weeks, five experimental workstations (see Fig. 2) were set up each with their own individual goals, including: an experimental CCFP desk, an experimental Convective SIGMET desk, a National Aviation Meteorologist (NAM) experimental desk (See Fig, 3), a global convection desk, and a situational awareness desk (including GOES-R simulated products and a variety of observation and nowcasting datasets). A primary task for the experimental desks was to issue operational products using both operational and experimental guidance available within the AWT. Additionally, some desks were asked to issue modified operational products that provided additional information useful to traffic flow management decision making.

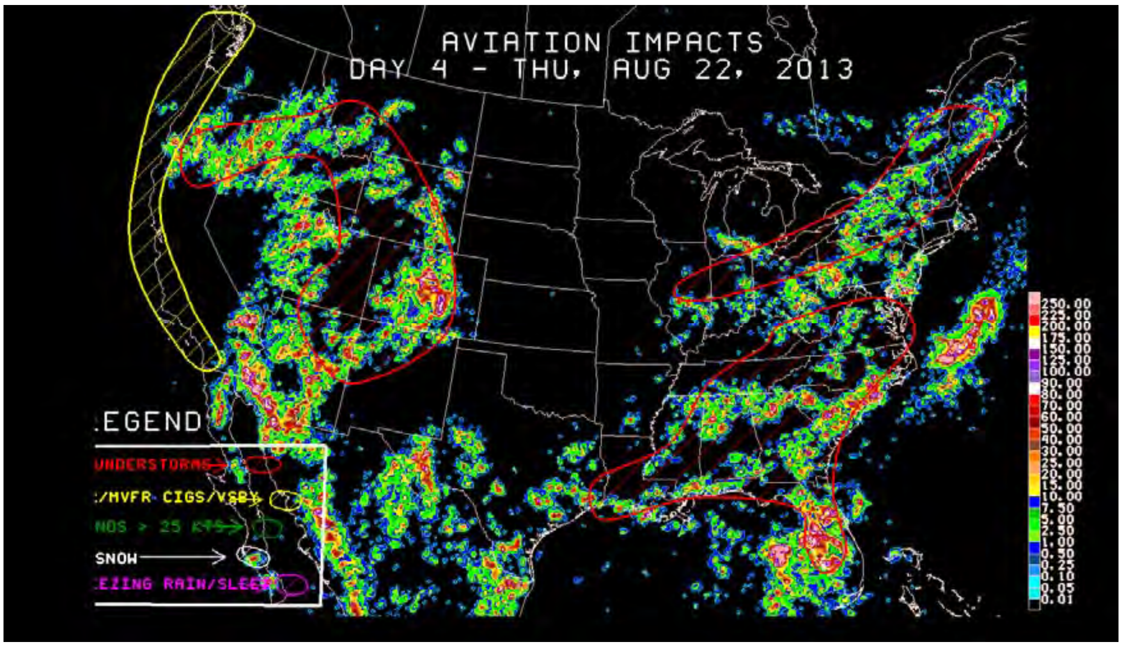


Figure 3. Example long range planning forecast for the FAA Command Center issued by the NAM participating in the experiment. Overlaid is gridded lightning density showing how well the forecast turned out.

Brian Pettegrew was part of the AWC team and participated in the daily running of the experiment. He developed several of the products used in the experiment and provided support for some of the lightning products. The rest of the ASB team provided data, server and hardware support for the experiment.

Production Dashboard

One of the high priority recommendations that came out of the ISO 9001 Quality Management certification was the need to track the timeliness of the operational product delivery. Larry Greenwood was the lead developer on the production timeliness dashboard web site. Development was done in the fall and winter of 2013 and the site went operational in January 2014. The dashboard (see Fig. 4) shows a list of products, both pending and sent. Completed products are shown shaded in green if sent on time, yellow or red based on thresholds for lateness.

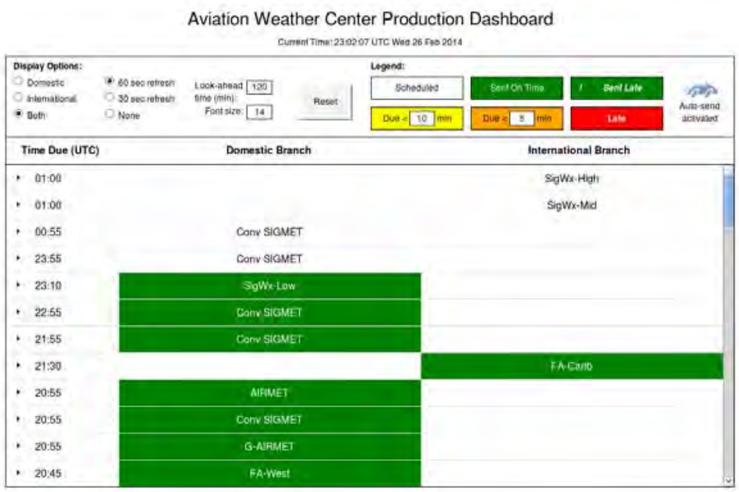


Figure 4. The AWC Production Dashboard. This displays both pending and completed products. Completed products are color coded as to whether they were sent out on time or late.

Several options were added into the interface to allow users to:
--filter for various product sets (domestic versus international),
--configure the time thresholds,
--set the refresh time,
--access NWS databases to confirm product was transmitted to NWS.

Traffic Flow Management Project
The Center Weather Service Units (CWSUs) provide several services to their users. Many of these could be provided on a broader scale at the Aviation Weather Center. The goal of the TFM project is to transfer some of these tools to the operational AviationWeather.gov web site. During 2013, Dan Vietor and Larry Greenwood worked on ports of the TDA (Tactical Decision Aid) tool (See Fig. 5) and gate and enroute forecasting tools. Many of these tools are slated to go operational in 2014.

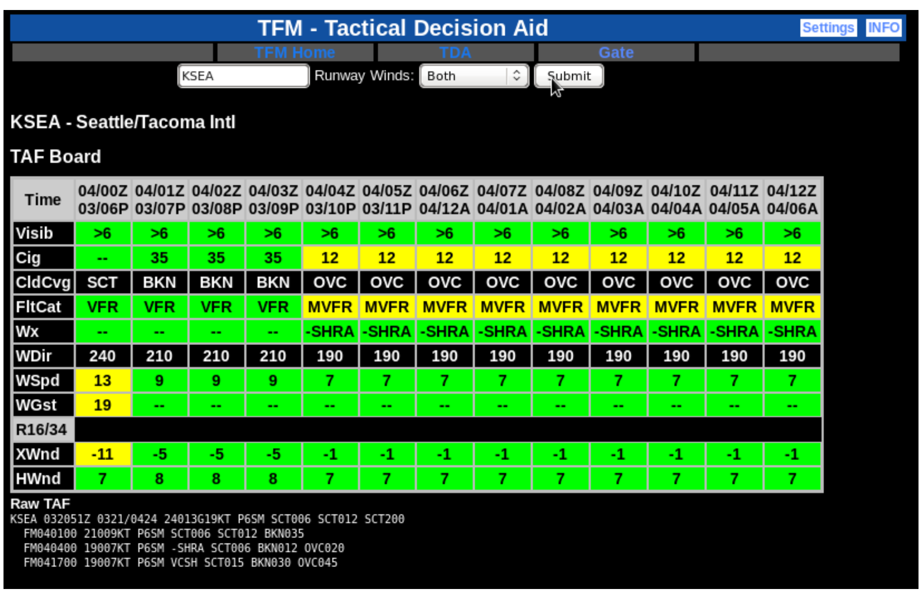


Figure 5. This is the TFM Tactical Decision Aid tool which shows TAF information out to 12 hours along with runway crosswinds and head winds.

ADDS Convergence Process

In the past five years, NCAR's development version of ADDS has diverged from the production version of ADDS, which has made the transition of development code to the AWC more difficult. To rectify the problem, an effort began in 2013 to converge code bases between the AWC and NCAR. This included updates to decoders, folding AWC changes into the NCAR code set, and initial testing of the newest tools from NCAR. In the fall of 2013, Dan Vietor led efforts to deploy the latest FlightPath and HEMS (Helicopter and Emergency Medical Services) tools to AWC for initial testing with the goal of deploying these tools to operations in late 2014.

Aviation Weather Research Program Update

Brian Pettegrew has been leading the efforts to move turbulence and icing products to the NCEP Weather and Climate Operational Supercomputing System (WCOSS). Initial efforts have concentrated on moving the new GTG (Graphical Turbulence Guidance) version 3.0 to the supercomputer. Brian is also investigating what is needed to move the CIP (Current Icing Potential) and FIP (Forecast Icing Potential) products to the supercomputer.

ASB Support for Collaboration Efforts

Adrian Noland and Mick Ohrberg conducted efforts to upgrade the collaboration tools used in operations. Due to Java issues, a new collaboration tool using Groupboard's HTML5 client software was installed for use with the CCFP (Convective Forecast) and SIGWX (Significant Weather) collaboration web sites.

Network Infrastructure

A major overhaul of the entire AWC network infrastructure kicked off in the fall of 2013. It was determined that the current infrastructure was out-of-date and deteriorating. The project consists of three phases:

--Phase 1 replaces all network cables AWC wide. New Category 6 cables have been run from two new patch panel server racks in the server room to all AWC workstation locations (see Fig. 6), Management offices, OPS, AWT (test bed), etc.

--Phase 2 implements new top of the line Cisco Nexus networking hardware. The new hardware will give the AWC a 10GB (up to 40 GB) backbone for server to server communication. The current average is 1GB to 4GB. Client to server throughput will be a full 1GB connection. Moving all servers and clients to the new hardware will be a difficult and delicate task which has been months in the planning. Unfortunately, funding for the new hardware has been delayed, and the ASB has been requested to utilize the existing hardware. This challenge is needed to meet contractual obligations so Phase 3 can be completed on time. The team has been working tirelessly to create a virtual test environment, and has a well-documented plan "B" in the works.

--Phase 3 will be to remove all old unused cable AWC wide, and is slated to be completed July 2014.

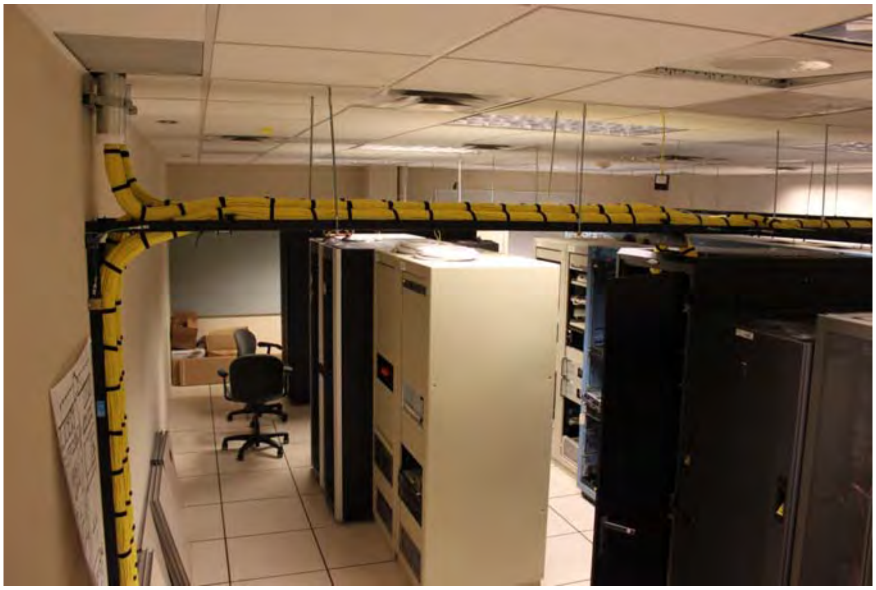


Figure 6. New cabling infrastructure at AWC.

Virtualization
ASB implemented virtualization in the datacenter, and successfully virtualized 95% of the Windows server infrastructure. There are short term hardware upgrades planned to facilitate long term plans to stay ahead of emerging technologies. Capacity planning and baseline utilization reports have been completed to prepare for future virtual requirements.

Monitoring of Virtual and Physical Servers
System Center Operations Manager which is a part of the vSphere 5.5 environment (virtual environment) monitors all servers. It provides infrastructure monitoring that allows for flexible alerting and response. It helps ensure predictable performance and availability of vital applications, and offers comprehensive monitoring for all AWC virtual and physical systems.

Other Accomplishments
--Adrian Noland and Mick Ohrberg conducted efforts to replace the shift log software with Wordpress blogging software.
--Adrian Noland assisted with the testing and release of the Winter Weather Dashboard (WWD) code in November 2013.
--Brian Pettegrew has been developing new ensemble based clear air turbulence products.
--Brian Pettegrew continued to work on global lightning display products and verification tools for use with operational global products (See Fig. 7).

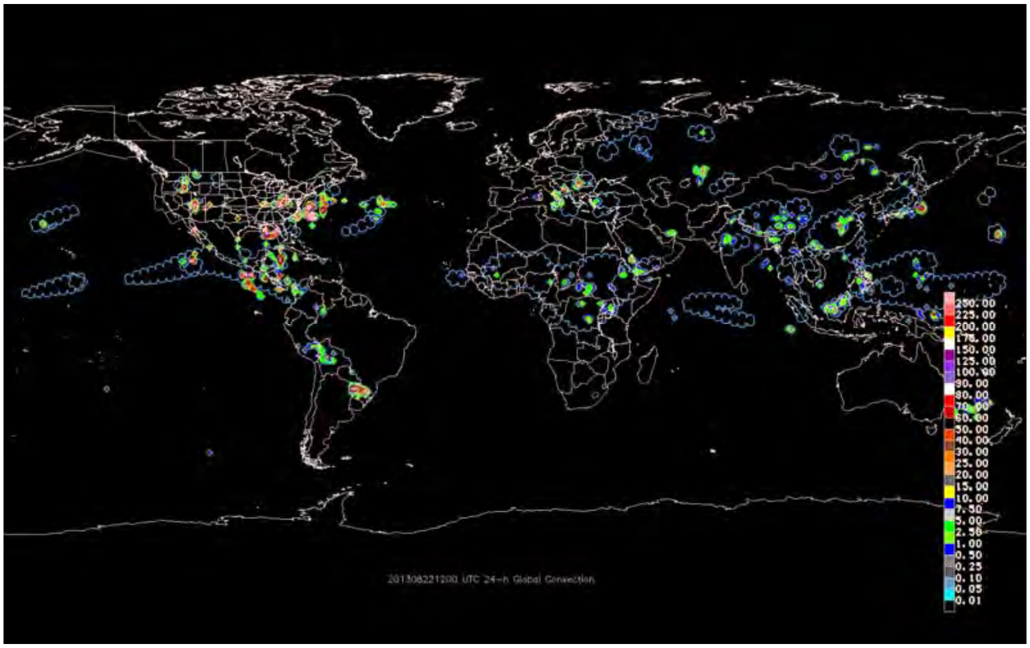


Figure 7. The 1200 UTC Experimental Global convection forecast valid for 23 Aug. 2013 overlaid with gridded lightning density using experimental ENTLN.

--Larry Greenwood assisted development of an automated area forecast guidance web page over the summer of 2013.
--Dan Vietor and Larry Greenwood have been developing WIFS (WAFS Internet File Service) usage and timeliness statistics.
--Mick Ohrberg implemented LDAP authentication on operational servers and workstations to migrate off of the old and insecure NIS authentication method.
--Lee Powell upgraded all Windows workstations from Windows XP to Windows 7 to meet Windows XP end-of-lifecycle drop off date.
--The IT group streamlined and secured endpoints with McAfee ePO server upgrade and System Center Configuration Manager 2012 R2 upgrade.
-Mick Ohberg helped create a plan to reconfiguration the satellite dishes in case of a GOES outage. This was implemented with the temporary failure of GOES 13 and the required repointing of the dish at GOES 15 (See Figure 8).
--Jenna Dalton provides ADDS, WIFS, TFM and AWRP project support at the AWC to ensure continuity of operations through procurement, budgetary analysis and administrative efforts throughout FY13.

Figure 8. GOES satellite dishes at AWC

Project Title: Research Collaboration with the NWS Aviation Weather Center (AWC) in Support of the Ensemble Model Processor and WRF Domain Wizard (WRF Portal) for the Aviation Weather Testbed (AWT)

PRINCIPAL INVESTIGATOR: Sher Schranz

RESEARCH TEAM: Jeff Smith

NOAA TECHNICAL CONTACT: David Bright (NOAA/NWS/AWC/AWT Program Manager)

PROJECT OBJECTIVES:

The Aviation Weather Center Aviation Weather Testbed developers support the AWC mission to deliver consistent, timely and accurate weather information for the world airspace system. The Center is dedicated to working with customers and partners to enhance safe and efficient flight. This is a Decision Support project for Traffic Flow Management to mitigate the impacts of various severe weather phenomena. The project objective is to create innovative tools and techniques that are needed to fill the gap between strategic planning and tactical planning (2hours). The guidance information this tool provides will help blend deterministic and ensemble output.

PROJECT ACCOMPLISHMENTS:

The CIRA effort created a WRF Domain Wizard for HWRF, a special version of the software that creates domains for the latest version of Hurricane WRF. New versions of WRF Portal and WRF Domain Wizard were released, and talks were given on using the software at NCAR's WRF Winter Tutorial and Summer Tutorial in Boulder, Colorado.

Research efforts improved the Ensemble Processor (EP) to import thousands of grib2 files forming the operational NCEP Short Range Ensemble Forecast (SREF) into a geospatial database in real time as the files become available. The billions of database rows are indexed (for performance) and available to be queried either via web services or the web application (The SREF Query Tool) that guides forecasters in selecting and subsetting the desired data. For maximum performance, EP also supports simple query syntax for directly querying (reading) and aggregating the grib2 files based on user supplied constraints. EP data visualizations include animated wind particles flowing over the North American landscape, wind speed and direction over airport runways, images and contours superimposed over Google Maps, animating forecasts over time, diff'ing members against the ensemble mean, etc. The EP also creates derived products such as low level wind shear and mountain obscuration, outputting the results as grib2 files available for import into NMAP and GEMPAK. Making the SREF and other weather forecast ensembles available for easy data mining will empower forecasters to create new data products (such as mountain obscuration) and perhaps find new insights into the underlying weather models themselves. Figure 1 shows the UI for this tool.

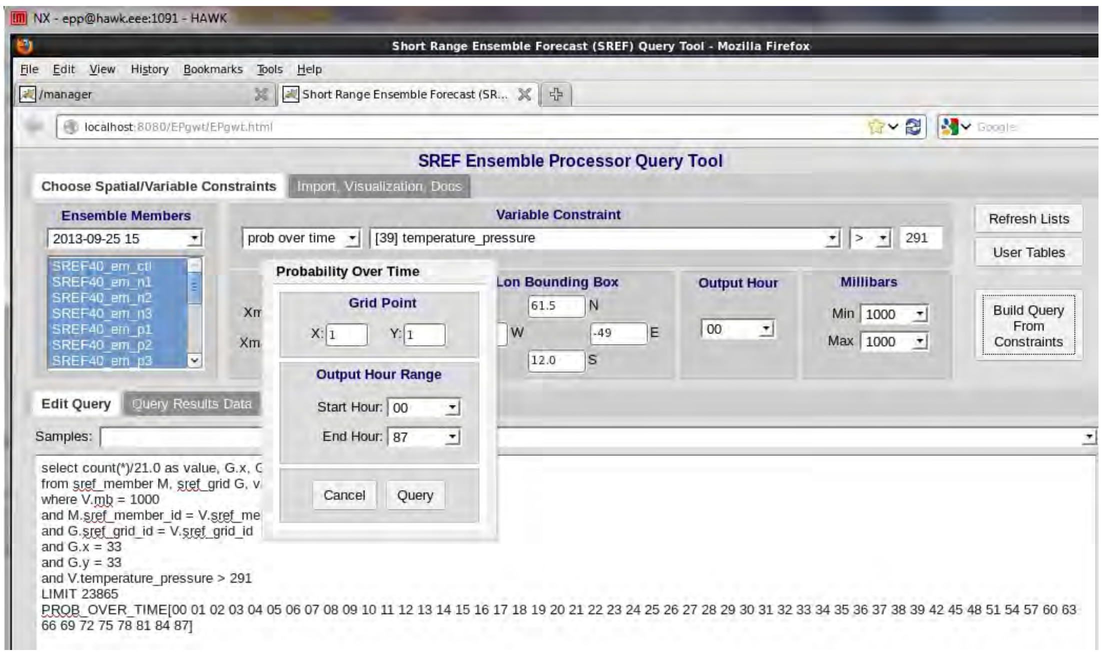


Figure 1. SREF Ensemble Processor Query Tool User Interface.

PROJECT TITLE: Research Collaboration with the Aviation Weather Testbed in Support of the NWS NextGen Weather Program

Project Title: National Weather Service NextGen 4D Data Cube

PRINCIPAL INVESTIGATOR: Cliff Matsumoto

RESEARCH TEAM: Benjamin Schwedler, Sher Schranz

NOAA TECHNICAL CONTACT: David Bright (NOAA/NWS/AWC)

NOAA RESEARCH TEAM: Jason Levit (NWS/OST), Mark Miller (NWS/OST)

PROJECT OBJECTIVES:

Objective 1
Conduct research into the technology and science of populating a four-dimensional airspace with atmospheric data, extraction methodologies, distribution formats and input mechanisms to be used by aviation decision support systems. The GSD appointed Sher Schranz as the Deputy Program Manager for the ESRL/GSD projects. Members of the FX-Net team will conduct research projects as a part of this program.

Objective 2
Continue the integration and testing of all web services development by NWS and FAA collaborative labs. Develop tests and evaluations for NWS 4D Data Cube prototypes, demonstrations and capability evaluations (CE's) - including the transition of technology, as required, to web-enable NOAA data providers.

Objective 3
CIRA is now a member of the Open Geospatial Consortium and, as a part of this project, is an active member of the working groups and committee that develop standards for the web services and web-enabled data formats such as WXXM.

PROJECT ACCOMPLISHMENTS:

Objective 1
CIRA staff at the Aviation Weather Center continue to support the Aviation Weather Testbed efforts to infuse new science and technology into AWC operations. A major focus of this effort is ensuring that AWC operations evolve with and complement the NextGen paradigm.

During the last year, the AWT conducted its summer experiment during the two weeks in Aug 12-23 2013. Various experimental data sets were evaluated within mock AWC operations. An experimental convective SIGMET issued during the experiment is shown in Figure 1. A large focus was on the use of probabilistic guidance within the forecast process. While the forecasts made by experiment participants were not probabilistic in nature, the experiment allowed developers, forecasters, and air traffic managers to have candid discussions about how particular uncertainty information was developed, and how it is interpreted by those using it for air traffic planning purposes. As a result, several tools are slated for transition into AWC operations to supplement the suite of guidance currently available to operational forecasters. For additional information, please visit
http://testbed.aviationweather.gov/page/public?name=2013_Summer_Experiment

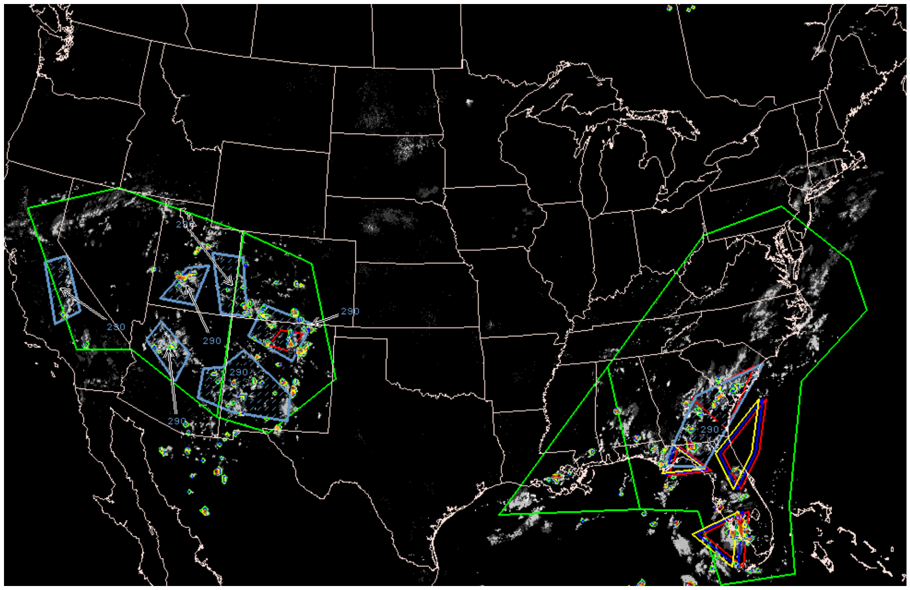


Figure 1. Comparison of Operational and Experimental Convective Sigmet Issuances at 17Z on 20 Aug 2013. Light blue areas are 2-hour convective outlooks, red/blue/yellow areas are operational convective SIGMETs (red=0hr, blue=+1hr, yellow=+2hr), green areas are operational convective 2-6hr outlooks, composite reflectivity is shown in grey-scale and filled contours are Earth Networks Total Lightning 10-min density.

AWC staff continues to apply “air traffic and weather together” concept as applied to moving toward the goals of NextGen. One such example is the development of the Aviation Summer Weather Dashboard. This tool provides ensemble forecast information along specified air traffic jet routes in the northeast United States. Developed in conjunction with the AWC meteorologists at the FAA Air Traffic Control System Command Center as well as air traffic planners, this tool represents AWC’s venture into providing model-derived forecast information specific to air traffic patterns. An illustration of the dashboard can be found in Figure 2. The experimental dashboard is available at http://testbed.aviationweather.gov/summerdashboard/

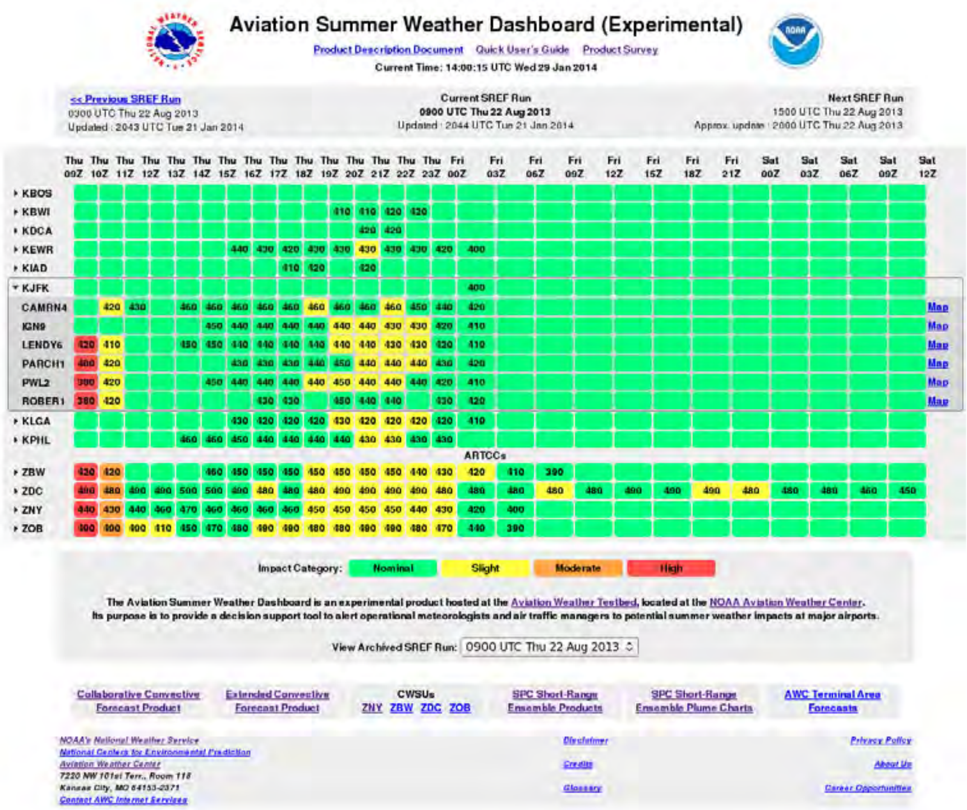


Figure 2. Illustration of the Aviation Summer Weather Dashboard, with terminal impacts expanded to show New York Kennedy Airport.

Additional tools are being developed by CIRA staff to provide enhanced probabilistic guidance and decision support information. In conjunction with CIRA software engineering staff, meteorologists at the AWC are building an ensemble post-processing system that is used to produce aviation-specific forecasts including uncertainty information. This tool is being designed so that it can be applied to any ensemble forecasting system and compute post-processed guidance information for forecasters and decision support tools.

Along with forecast tools, CIRA staff at AWC helped to develop a case archive system to allow AWC forecast staff to easily save and view specific cases for forensic investigation. This effort allows forecasters on admin shifts to assess their performance and determine how to improve forecasts for events that were particularly difficult to forecast or had a large impact on air traffic that day. This system now houses over 100 cases and is being used on a nearly daily basis.

Objective 2
The Aviation Weather Center continues to provide a real-time feed of products originating at the AWC using NextGen data dissemination technologies. AWC continues to host installations of the Web Coverage Service Reference Implementation (WCSRI) and the Web Feature Service Reference Implementation (WFSRI). These data continue to be provided to partner labs including the FAA. As part of the joint NWS-FAA Capability Evaluation, the data provided by the AWC web services were used to demonstrate display capabilities in ground and cockpit systems. Specifically, the Graphical Turbulence Guidance, SIGMETs, and G-AIRMET were used to populate an iPad display that provided a real-time feed to an FAA test flight. Ben Schwedler, AWC NextGen Development Meteorologist, attended the Joint CE at the FAA Tech Center on June 26th 2013. During this demonstration, interaction between the developers using AWC's forecast products and AWC development staff provided insight into

improvements needed in future development in the web service software as well as the formats of the XML documents used to transfer these data.

A large volume of data to the public though the operational AWC website. As NextGen data dissemination technologies mature, it will be possible entities outside the FAA to leverage the same formats due to the network-enabled architecture. In addition to providing data to partner labs utilizing NextGen dissemination technologies, the AWC also began to provide public access to their WCSRI and WFSRI installations. This allows customer to access the same data that is provided to the FAA Tech Center.

Objective 3
Over the past year, the AWC has made a concerted effort to become more involved in the development of the XML schema used to represent aviation weather forecast data. In the past schema like the Weather Exchange Model (WXXM) had been developed without input from or collaboration with the AWC. Since AWC is one of the primary providers of the data that will be made available using these schemas, it needs to be a stakeholder guiding and developing future versions. As such, AWC is actively involved in the development of WXXM version 2.0 and USWX version 2.0, which will include products like AIRMET, G-AIRMET, CCFP, and other US-specific forecast products.

At the World Area Forecast Center (WAFC) coordination meeting in October 2013, the WAFCs at the UK Met Office and the US National Weather Service agreed to move forward and work towards distributing the SIGWX forecasts in XML. AWC's NextGen Development Meteorologist participated in these meetings, offering guidance in how to transition from distributing these products in BUFR to producing the forecasts in XML. An example of the SIGWX forecasts can be seen in Figure 3. AWC staff is currently coordinating efforts to develop the logical model and XML schema which will describe the SIGWX forecasts. These changes will eventually be folded into IWXXM, the international schema that is approved by the International Civil Aviation Organization (ICAO).

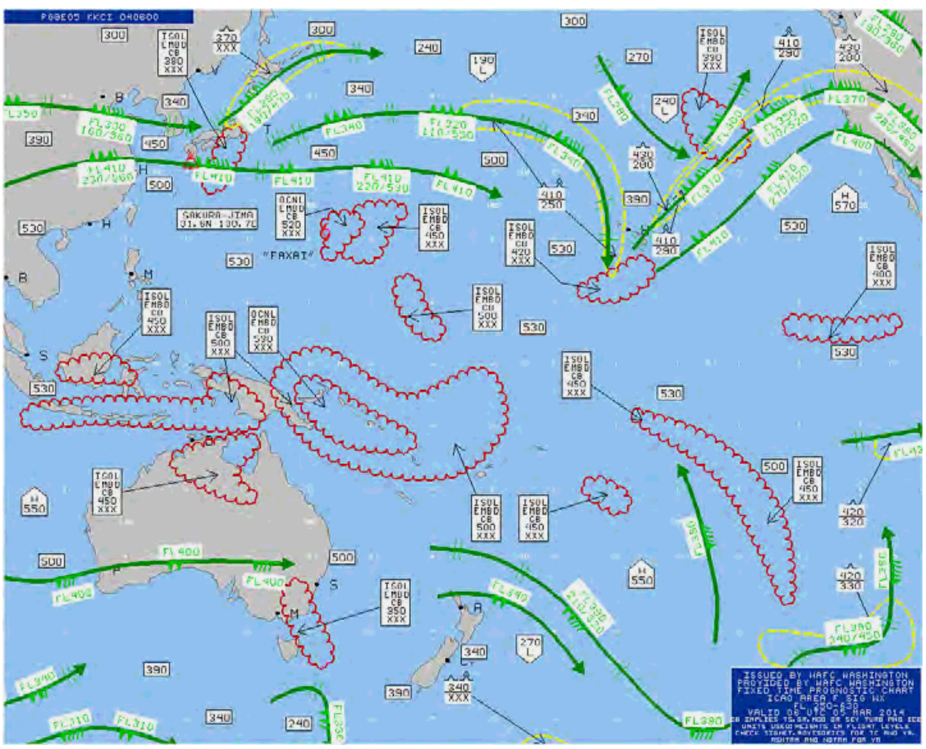


Figure 3. Example of a World Area Forecast System High-Level SIGWX forecast that will start to be issued in XML.

PROJECT TITLE: SSMI and SSMIS Fundamental Climate Data Record Sustainment and Maintenance

PRINCIPAL INVESTIGATOR: Christian Kummerow

RESEARCH TEAM: Wes Berg, ATS

NOAA TECHNICAL CONTACT: Candace Hutchins (NOAA/NESDIS/NCDC)

NOAA RESEARCH TEAM: Hilawe Semunegus

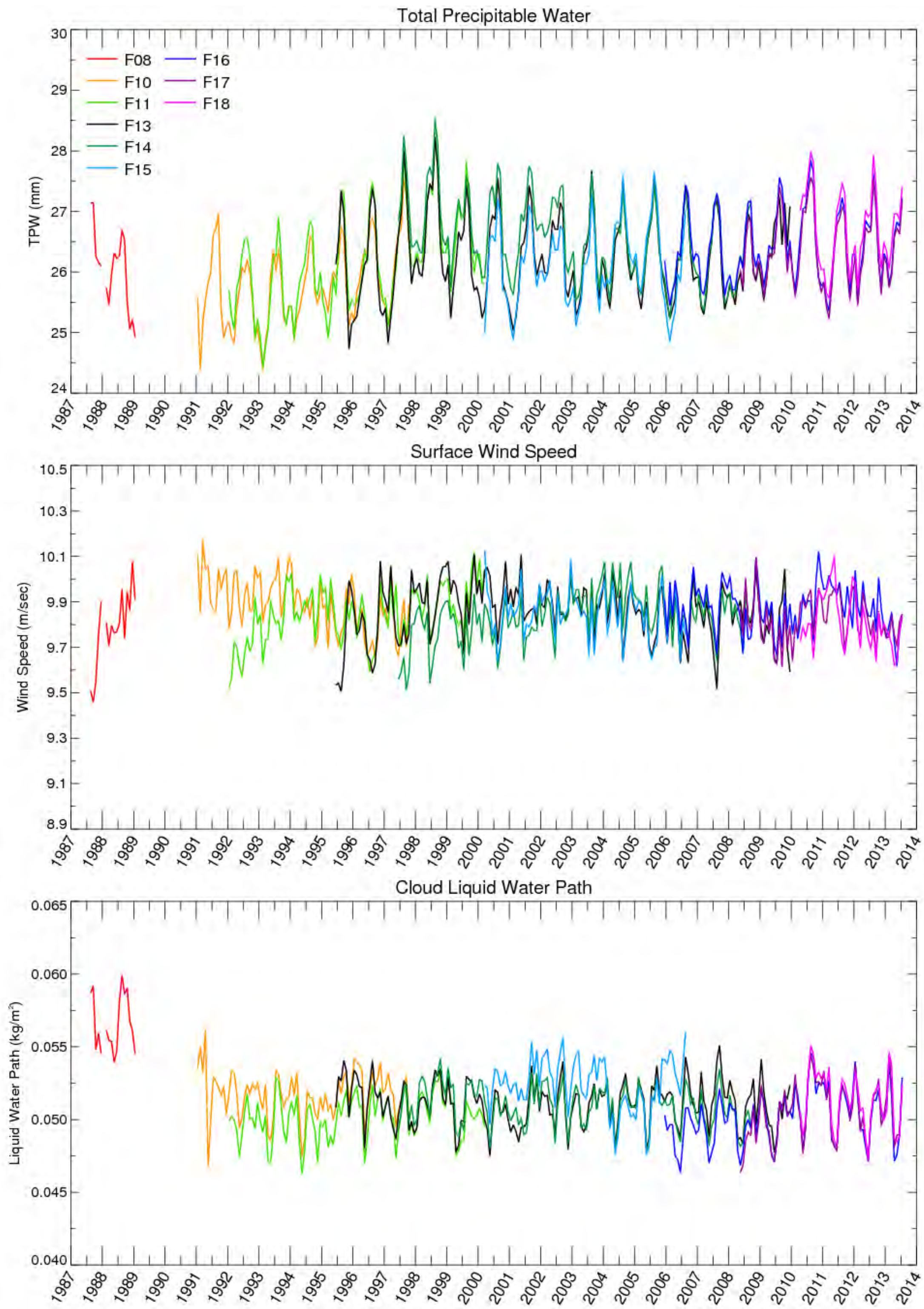
PROJECT OBJECTIVES:

The Climate Data Record Program (CDRP) leads NOAA's development and provision of authoritative satellite climate data records (CDRs) for the atmospheres, oceans and land. This project's objective is to provide NOAA with a fundamental climate Data record of Special Sensor Microwave/Imager (SSMI) and Special Sensor Microwave Imager and Sounder (SSMIS) data records. For the currently orbiting SSMIS sensors, the records are broken into Interim Climate Data Records (ICDR) produced rapidly using automated QC and trending information as well as the fundamental data record (FCDR) produced roughly six months after acquisition. The objectives further relate to distribution of data, interface for the community, and including new satellite data streams when these become available.

PROJECT ACCOMPLISHMENTS:

We delivered the SSMI(S) Brightness Temperature Implementation Plan that describes, in detail, how ICDRs and FCDRs will be created and submitted to NCDC. The plan is dated October 29, 2013 and specifies that ICDRs will be provided within 10 days of data collection while FCDRs will be produced on a 6-month cycle. It details the external dependencies (we requite 2-line elements for orbit characteristics) from NORAD that has not been 100% reliable in the past, and details the quality control procedure we have implemented.

We also provided a quality assurance document that highlights the progress made in monitoring the quality of the intercalibrated Tb. Retrieval of ocean parameters (Figure below) illustrates this monitoring capability, as well as user information to NCDC upon request.



Total Precipitable Water
TPW (mm)
F08
F10
F11
F13
F14
F15
F16
F17
F18
Surface Wind Speed
Wind Speed (m/sec)
Cloud Liquid Water Path
Liquid Water Path (kg/m²)

PROJECT TITLE: Weather Satellite Data and Analysis Equipment and Support for Research Activities

PRINCIPAL INVESTIGATORS: Chris Kummerow and Michael Hiatt

RESEARCH TEAM: Michael Hiatt

NOAA TECHNICAL CONTACT: Ingrid Guch (NOAA/NESDIS/STAR)

NOAA RESEARCH TEAM:

PROJECT OBJECTIVES:

1--Earthstation: Operations and maintenance for 4 antennas and associated telemetry, network, ingest, processing, distribution, and archive
2--Data Collection: All direct readout GOES including special collections via 3 GOES systems, MSG via 7M DOMSAT system, and 19 project products via Internet
3--Data Archive: Blu-ray media, archive writers, and online RAID storage
4--Personnel Salary: Part time coverage for one Electrical Engineer

PROJECT ACCOMPLISHMENTS:

1--All data sets collected, processed, cataloged, distributed, and archived at 99.9% level. Online archive now spans from 1992-2014 with approximately 330TB online data.
2--2 RAID NAS units added for additional storage
1--1 processing server upgraded

AWARDS

CIRA Board Member Appointed AMS President-elect
CIRA Executive Board Member, Dr. Alexander E. "Sandy" MacDonald, who serves as NOAA Chief Science Advisor and ESRL Director, was recently named as the American Meteorological Society President-elect. Dr. MacDonald's selection to lead the Nation's principal scientific society promoting the advancement of atmospheric and related sciences, technologies, applications and services recognizes his pre-eminent scientific accomplishments, visionary nature, and reflects the high esteem held for him by his scientific colleagues.

AGU Research Spotlight
John Haynes, a CIRA Research Scientist, will have the "spotlight" trained on his work in an upcoming publication. A recent Haynes et al. (2013) paper has been selected by the American Geophysical Union for their "AGU Research Spotlight" on the back page of an upcoming edition of their widely-read EOS publication. The paper titled, "Radiative heating characteristics of earth's cloudy atmosphere from vertically resolved active sensors," describes research using instruments onboard the CloudSat and CALIPSO satellites to study the radiative heating and cooling characteristics of the layers of the cloudy atmosphere. Among the co-authors is CIRA Director Emeritus Thomas H. Vonder Haar.

CIRA-NOAA Team Receives OAR Employee of the Year Award
A collaboration between CIRA and NOAA staff known as the "Rapid Refresh Team" received an estimable commendation for its work. The announcement occurred on February 7th and honored the OAR RAP team responsible for the development, integration, and transition of the next generation of NOAA's hourly North American prediction, a foundation for realizing NOAA's "Weather Ready Nation" strategies as well as positioning NOAA for emerging service areas.

The following CIRA employees were recognized as part of this group effort: Brian Jamison, Haidao Lin, Kevin Brundage, Tracy Lorraine Smith and Bob Lipschutz. Director Christian Kummerow told them "I wanted to send my sincerest congratulations. Not only does this award recognize your personal accomplishments, it also reflects positively upon all CIRA employees who are ultimately elevated by your efforts."

CIRA Staff Recognized for Website Design
"Webbies" recognize "VERIFIED' and "SOS" Websites. Every year, NOAA Global Systems Division staff nominate and vote on the "Webbies" or web awards to recognize outstanding websites. CIRA folks that were honored by their co-workers include those involved with two of the five winning sites called "VERIFIED" and "SOS".

Verification of Impact-translated Forecasts for Integrated Decision-making.
http://esrl.noaa.gov/figas/tech/impact/verified/
The team included Missy Petty and Paul Hamer of CIRA, along with Geary Layne and Matt Wandishin of NOAA.

SOS – Science on a Sphere®
http://sos.noaa.gov/
The web team includes Irfan Nadiadi (lead) and Michael Biere of CIRA, as well as Shilpi Gupta and Beth Russell of NOAA.

Dr. Mark DeMaria Finalist for Prestigious Award

Dr. Mark DeMaria, a nationally known research scientist and Branch Chief for the Regional and Mesoscale Meteorology Branch (RAMMB), hosted at CIRA, was listed as a finalist for the 2013 Samuel J. Heyman Service to America Career Achievement Medal. The RAMMB team, part of the National Oceanic and Atmospheric Administration's Center for Satellite Applications and Research (STAR) office, conducts cutting-edge research on the use of satellite data to improve analysis, forecasts, and warnings for regional-scale weather events.

The Samuel J. Heyman Service to America medals celebrate the accomplishments of the Nation's foremost public servants. Known sometimes as the 'Oscars of government service', the medals are awarded annually at a gala event which occurred October 3, 2013. Recipients of the medal, according to President Obama, "exemplify the spirit of service that marks our federal workforce." Dr. DeMaria was one of five finalists announced for the Career Achievement Medal.

More information about the award and Dr. DeMaria's nomination can be found online at: http://servicetoamericamedals.org/SAM/finalists/cam/demaria.shtml

GSD Employee of the Month- December 2013

Jebb Stewart – Technology Outreach Branch/CIRA Research Associate - was designated as GSD's Employee of the Month for December 2013. He received this in recognition for a number of outstanding efforts in assisting HIWPP - High Impact Weather Prediction Project and SOS- Science on a Sphere®.

The HIWPP Project Manager was in the process of hiring a project manager and Test Program lead when the HIWPP Project Plan was due to OAR. As this hire was not completed before the Plan due date, Jebb stepped in to develop the HIWPP project plans for both the NEIS - (NOAA Environmental Information System), and the Test Program. NEIS and the Test Program are important and integral components of the HIWPP project. Jebb successfully worked with many groups in ESRL and other NOAA labs to develop the needed project plans and the budgets.

Jebb has done an excellent job leading the NEIS development since its inception. He has led a diverse team of researchers from groups across GSD to produce a system that has been demonstrated to groups around the country. NEIS has received funding from outside agencies and NOAA to continue developing this geophysical data delivery, analysis and display system.

Jebb has made substantial contributions to the SOS program during the past year. He has developed KLM and WMS software that enhances the overall SOS activity. He has also provided excellent customer support, answering specific questions that have arisen at customer sites, to get the SOS systems back up and running smoothly.

CoCoRaHS Wins AMS Special Award- February 2014

CIRA has had a long running partnership with The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS). We are pleased to share the news that CoCoRaHS was selected to receive an American Meteorological Society Special Award "For building a community of over 15,000 volunteer observers dedicated to providing high quality, reliable observations of daily precipitation across the United States." Congratulations to CoCoRaHS Director Nolan Doesken and the entire CoCoRaHS team.

Wayne Schubert Winner of College of Engineering's Abell Outstanding Research Faculty Award

Professor Schubert was recognized for his continued record of outstanding research in the field of atmospheric dynamics. Over the past few years he has graduated many PhD students, published numerous ground-breaking papers with his research group, and successfully directed several projects sponsored by NSF, NOAA and ONR.

University Distinguished Professor David Randall Recipient of 2014 AMS Jule G. Charney Award. This award, one of the highest honors bestowed by the AMS, is granted to individuals in recognition of highly-significant research or development achievement in the atmospheric or hydrologic sciences. Prof. Randall's selection was given in recognition of his transformative research into atmospheric convection and cloud processes and their improved representation in global weather and climate models.

CIRA Research Initiative Award Winners Announced

Ken Sperow's technical leadership on a number of high-visibility NWS projects—one of which is specifically spelled out in the National Weather Services' Weather-Ready Nation Roadmap—provided ample evidence and outstanding examples of team leadership/mentoring capability and achievements that result in substantial impact within and external to a member's workplace worthy of the Research Initiative Award.

Sirish Uprety, an up-and-coming Research Associate with the STAR Satellite Meteorology and Climatology Division/Sensor Physics Branch, was recognized for his innovative and creative approaches and techniques in support of the Suomi-NPP VIIRS sensor data record radiometric calibration and validation efforts. His noteworthy list of contributions to the NOAA satellite mission as well as his publication record led to his selection as a recipient of this year's Research Initiative Award.

Sher Schranz's long list of critical responsibilities and outstanding accomplishments across a myriad of high-visibility programs and projects—fire weather research, NextGen aviation weather, unmanned aircraft systems, NEIS, FX-Net--told the story of her contributions. Her involvement in all of the above provided evidence that she more than earned recognition for her outstanding service in administrative oversight, project management, and outreach.

Kudos to the following CIRA staff who earned service milestones in 2013

--Kathy Fryer – 20 years
--Jennifer Hand – 10 years
--Michael Hiatt – 25 years
--Lynn Johnson – 10 years
--Laura Leinen – 10 years
--Mike Leon – 10 years
--Cliff Matsumoto – 15 years
--Shawn McClure – 10 years
--Maureen Murray – 15 years
--Andrea Schumacher – 10 years
--Natalie Tourville – 20 years
--Mike Turpin – 10 years
--Sharon Wittstock – 45 years

PUBLICATIONS MATRIX

	Institute Lead Author						NOAA Lead Author						Other Lead Author					
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Peer-Reviewed	37	24	24	21	31	23	21	17	16	23	25	28	35	31	20	29	30	31
Non Peer-Reviewed	58	6	45	71	114	98	34	0	33	70	69	40	49	5	20	35	43	33

PUBLICATIONS & PRESENTATIONS

PUBLICATIONS

(All publications fall under Award Number NA090AR4320074 unless otherwise noted)

CIRA Research Collaborations with the NOAA Earth System Research Lab/Global Monitoring Division on Carbon Tracker Model Enhancements

The research and development work outlined here over the past year has not yet resulted in publications in the peer-reviewed literature. The work is reflected in the on-line CarbonTracker documentation at**:** http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/

CIRA Collaboration with ESRL Physical Science Division on Hydrologic Research and Water Resources Applications Outreach Coordination

Johnson, L. E., 2013: Applications and values of advanced precipitation products. Report prepared for NOAA-HMT-ESRL in support of San Francisco Bay Advanced Quantitative Precipitation Information project. NOAA-HMT-ESRL. 55 pp.

Johnson, L. E., 2013: Flood Operations Simulation Model (FldOps). Computer program prepared for evaluation of Russian River reservoirs operations policies. NOAA-HMT-ESRL.

Johnson, L. E., 2013: HMT Training Plan. Concept paper on design to establish an on-going training program on HMT research and outcomes in order to enhance the transition of research to operations. NOAA-HMT-ESRL. 10 pp.

Johnson, L. E., 2013: Improve precipitation and river flow forecasting to maximize water capture for fisheries. Concept paper prepared for National Marine Fisheries Service Habitat Blueprint Focus Area program. 10 pp.

Johnson, L. E. 2013: Russian River tributaries water budget - High resolution characterization of historical, current and future conditions. Concept paper prepared for National Marine Fisheries Service Habitat Blueprint Focus Area program. 10 pp.

Johnson, L. E., 2013: Verification of distributed hydrologic model for low flows, Russian River Basin. Report prepared for National Marine Fisheries Service. Santa Rosa, CA. 37 pp.

Johnson, L. E., R. Cifelli, A. White, G. Pratt, Z. Toth, 2013: Accelerated development of an advanced quantitative precipitation information system for the San Francisco Bay Region: a) Project description. b) Addendum A – Budget. Prospectus prepared for Bay Area Integrated Regional Water Management Program. NOAA-HMT-ESRL. 51 pp.

Johnson, L. E., R. Cifelli, A. White, D. Reynolds, 2013: Improving quantitative precipitation information for the San Francisco Bay Region. Prospectus prepared for Bay Areas Flood Protection Agencies Association (BAFPAA) in support of Proposition 84 IRWM Planning Grant Application Round 1, Project Title: San Francisco Bay Area IRWM Plan Update.

Johnson, L.E., C. Hsu, R. Cifelli, R. Zamora, 2013: Assessment of distributed hydrologic modeling Russian-Napa River Basins Case Study. Report prepared for California Dept. Water Resources (Draft). 70 pp.

White, A.B., M. L. Anderson, M. D. Dettinger, F. M. Ralph, A. Hinojosa, D. R. Cayan, R. K. Hartman, D. W. Reynolds, L. E. Johnson, T. L. Schneider, R. Cifelli, Z. Toth, S. I. Gutman C. W. King, F. Gehrke, P. E. Johnston, C. Walls, D. Mann, D. J. Gottas, and T. Coleman, 2013: A Twenty-First-Century California observing network for monitoring extreme weather events. J. Atmos. Oceanic Technol., 30, 1585–1603. doi: http://dx.doi.org/10.1175/JTECH-D-12-00217.1

CIRA Support for Transition of Tropical Cyclone Forecast Products

DeMaria M, J.A. Knaff, R. Zehr, 2013: Assessing hurricane intensity using satellites. Satellite-based applications to climate change. J.J. Qu, A. Powell, and M.V.K. Sivakumar, Eds, Springer, New York, pp 151-163. doi: http://dx.doi.org/10.1007/978-94-007-5872-8_10

CIRA Support of the Virtual Institute for Satellite Integration Training (VISIT)

Grasso, L., Lindsey, D.T., Lim, K., Clark, A., Bikos, D., 2014: Evaluation of and suggested improvements to the WSM6 Microphysics in WRF-ARW using synthetic and observed GOES-13 imagery. Mon. Wea. Rev., in review.

CIRA Support to a GOES-R Proving Ground for National Weather Service Forecaster Readiness

Grasso L.D, D.W. Hillger, C. Schaaf, Z. Wang, R.L. Brummer, and R. DeMaria, 2013: Use of MODIS 16 day albedos in generating GOES-R Advanced Baseline Imager (ABI) Imagery. *J. Appl. Remote Sens.*, **7**:1, 073584; doi: 10.1117/1.JRS.7.073584

Hillger, D.W., T. Kopp, T. Lee, D.T. Lindsey, C. Seaman, S.D. Miller, J. Solbrig, S.Q. Kidder, S. Bachmeier, T. Jasmin, and T. Rink, 2013: First light imagery from Suomi NPP VIIRS. Bulletin of the American Meteorological Society. 94:7, 1019-1029, plus cover images. doi:10.1175/BAMS-D-12-00097.1

Lang, T.J., S.A. Rutledge, B. Dolan, P. Krehbiel, W. Rison, and D.T. Lindsey, 2014: Lightning in wildfire smoke plumes observed in Colorado during summer 2012. *Mon. Wea. Rev.*, 142, 489-507. doi: http://dx.doi.org/10.1175/MWR-D-13-00184.1

Lindsey, D.T., T.J. Schmit, W.M. MacKenzie, Jr., C. P. Jewett, M.M. Gunshor, L.D. Grasso, 2013: 10.35 µm: atmospheric window on the GOES-R Advanced Baseline Imager with less moisture attenuation Journal of Applied Remote Sensing, 6:1, 12 pp.

Schmit, T.J., S.J. Goodman, D.T. Lindsey, R.M. Rabin, K.M. Bedka, M.M. Gunshor, J.L. Cintineo, C.S. Velden, A.S. Bachmeier, S.S. Lindstrom, and C.C. Schmidt, 2013: GOES-14 Super Rapid Scan operations to prepare for GOES-R. J. Appl. Remote Sens. **7**:1, 073462 doi: 10.1117/1.JRS.7.073462

CIRA Support to GOES Improvement and Product Assurance Program

DeMaria, M., J.A. Knaff, M. Brennan, D. Brown, R. Knabb, R.T, DeMaria, A.B. Schumacher, C. Lauer, D. Roberts, C. Sampson, P. Santos, D. Sharp, and K. Winters, 2013: Improvements to the operational tropical cyclone wind speed probability model. Wea. Forecasting, 28, 586-602. doi: http://dx.doi.org/10.1175/WAF-D-12-00116.1

Miller, S. D., J. Forsythe, P. T. Partain, J. Haynes, R. Bankert, M. Sengupta, C. Mitrescu, J. D. Hawkins, and T. H. Vonder Haar, 2014: Estimating three-dimensional cloud structure from statistically blended active and passive sensor observations. J. Appl. Meteor. Clim., 53(2), 437-455.

CIRA Support to JPSS Science Program: NPP VIIRS EDR Imagery Algorithm and Validation Activities and NPP VIIRS Cloud Validation

Hillger, D., C. Seaman, C. Liang, S. D. Miller, D. Lindsey, and T. Kopp 2014: Suomi NPP VIIRS imager calibration and validation. Submitted to J. Geophys. Res. Atmos.

Hillger, D.W., T. Kopp, T. Lee, D.T. Lindsey, C. Seaman, S.D. Miller, J. Solbrig, S.Q. Kidder, S. Bachmeier, T. Jasmin, and T. Rink, 2013: First light imagery from Suomi NPP VIIRS. Bull. Amer. Meteor. Soc.. 94:7, 1019-1029, plus cover images. doi:10.1175/BAMS-D-12-00097.1

Seaman, C. J. and S. D. Miller, 2013: VIIRS captures Aurora motions. Bull. Amer. Meteor. Soc., 94, 1491-1493, doi:10.1175/BAMS-D-12-00221.1.

Walther, A., A. K. Heidinger, and S. Miller, 2013: The expected performance of cloud optical and microphysical properties derived from Suomi NPP VIIRS day/night band lunar reflectance, J. Geophys. Res. Atmos., 118, 13,230–13,240.

CIRA Support to Research and Development for GOES-R Risk Reduction for Mesoscale Weather Analysis and Forecasting and Analysis of Simulated Radiance Fields for GOES-R ABI Bands for Mesoscale Weather and Hazards Events

Grasso, L.D., D.W. Hillger**,** C. Schaaf, Z. Wang, R.L. Brummer, R. DeMaria, 2013: Use of MODIS 16 day albedo values in the generation of synthetic GOES-R natural color imagery. J. Appl. Remote Sens. **7**:1, 073584 (February 22); doi: 10.1117/1.JRS.7.073584

Grasso, L.D., D. T. Lindsey, K.-S. Lim, Adam Clark, and Dan Bikos, 2013: Evaluation of and Suggested Improvements to the WSM6 Microphysics in WRF-ARW Using Synthetic and Observed GOES-13 Imagery. Mon. Wea. Rev. (Accepted with revision).

Knaff, J.A., S.P. Longmore, D.A. Molenar, 2014: An Objective Satellite-Based Tropical Cyclone Size Climatology. *J. Climate*, **27**, 455-476. doi: http://dx.doi.org/10.1175/JCLI-D-13-00096.1

Lindsey, D.T., T.J. Schmit, W.M. MacKenzie, Jr., C. P. Jewett, M.M. Gunshor, L.D. Grasso, 2013: 10.35 µm: atmospheric window on the GOES-R Advanced Baseline Imager with less moisture attenuation Journal of Applied Remote Sensing, 6:1, 12 pp.

Setvak, M., K. Bedka, D.T. Lindsey, A. Sokol, Z. Charvat, J. Stastka, P.K. Wang, 2013: A-Train observations of deep convective storm tops. Atmospheric Research, 123**,** 229-248. http://dx.doi.org/10.1016/j.atmosres.2012.06.020

Sitkowski, M., J.P. Kossin, C.M. Rozoff, and J.A. Knaff, 2013: Hurricane eyewall replacement cycle thermodynamics and the relict inner eyewall circulation. Mon. Wea. Rev., 140, 4035–4045. doi: http://dx.doi.org/10.1175/MWR-D-11-00349.1

CIRA Support to the CASA Dallas Fort Worth Urban Demonstration Network

V. Chandrasekar, 2013: Comprehensive report to NOAA. Preliminary site identification report for potential future radar sensors for the City and County of San Francisco.

CIRA Support to the JPSS Proving Ground and Risk Reduction Program

Hillger, D.W., T. Kopp, T. Lee, D.T. Lindsey, C. Seaman, S.D. Miller, J. Solbrig, S.Q. Kidder, S. Bachmeier, T. Jasmin, and T. Rink, 2013: First light imagery from Suomi NPP VIIRS. Bull. Amer. Meteor. Soc.. 94:7, 1019-1029, plus cover images. doi:10.1175/BAMS-D-12-00097.1

Kuciauskas, A. J. Solbrig, T. Lee, J. Hawkins, S. D. Miller, M. Surratt, K. Richardson, R. Bankert, and J. Kent, 2013: New satellite meteorology technology unveiled, Bull. Amer. Meteor. Soc., 94, 1824-1825.

Liang, C. K., B. I. Hauss, S. Mills, and S. D. Miller, 2014: Improved VIIRS day/night band imagery with near constant contrast. IEEE TGRS, In Press.

Miller, S. D., W. Straka, III, S. P. Mills, C. D. Elvidge, T. F. Lee, J. Solbrig, A. Walther, A. K. Heidinger, and S. C. Weiss., 2013: Illuminating the capabilities of the Suomi NPP VIIRS Day/Night Band. Rem. Sens., 5, 6717-6766; doi:10.3390/rs5126717.

Seaman, C., and S. D. Miller, 2013: Aurora motion VIIRS day/night band, Bull. Amer. Meteor. Soc., Nowcast, 94(10), 1491-1493; doi: 10.1175/BAMS-D-12-00221.1.

Solbrig, J. E., T. F. Lee, and S. D. Miller, 2013: Advances in remote sensing: imaging the Earth by moonlight, Trans. EOS, 94(40), 349-350.

Walther, A., A. K. Heidinger, and S. Miller, 2013: The expected performance of cloud optical and microphysical properties derived from Suomi NPP VIIRS day/night band lunar reflectance, J. Geophys. Res. Atmos., 118, 13,230–13,240.

CIRA Support to Tropical Cyclone Model Diagnostics and Product Development

DeMaria, M., J.A. Knaff, M. Brennan, D. Brown, R. Knabb, R.T DeMaria, A.B. Schumacher, C. Lauer, D. Roberts, C. Sampson, P. Santos, D. Sharp, and K. Winters, 2013: Improvements to the operational tropical cyclone wind speed probability model. *Wea. Forecasting*, 28, 586-602. doi: http://dx.doi.org/10.1175/WAF-D-12-00116.1

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Knaff, J.A., M. DeMaria, C.R. Sampson, J.E. Peak, J. Cummings, W.H. Schubert, 2013: Upper oceanic energy response to tropical cyclone passage. J. Climate, 26, 2631-2650. doi: http://dx.doi.org/10.1175/JCLI-D-12-00038.1

Knapp, K.R., J.A. Knaff, C. Sampson, G. Riggio, and A.D. Schnapp, 2013: A pressure-based analysis of the historical western North Pacific tropical cyclone intensity record, Mon. Wea. Rev., 141, 2611-2631.

Lin, I-I, G.J. Goni, J.A. Knaff, C. Forbes, M.M. Ali, 2013: Tropical cyclone heat potential for tropical cyclone intensity forecasting and its impact on storm surge. *Journal of Natural Hazards*. 66, 1481-1500. doi:10.1007/s11069-012-0214-5

Effective Collaborative NIDIS Drought Monitoring and Early Warning in the Upper Colorado Basin

Ryan, W., and N. Doesken, 2013: Drought of 2012 in Colorado. Climatology Report 13-01. Dept. of Atmos. Sci., CSU, Fort Collins, CO. June, 2013.

Smith, R.A., C.D. Kummerow, 2013: A Comparison of in situ, reanalysis, and satellite water budgets over the Upper Colorado River Basin. J. Hydrometeor, 14, 888–905

Environmental Applications Research (EAR)

Gregow, E., E. Saltikoff, S. Albers, and H. Hohti, 2013: Precipitation accumulation analysis - assimilation of radar-gauge measurements and validation of different methods. Hydrol. Earth Syst. Sci., 17, 4109-4120.

Hong, S.-Y., M.-S. Koo, J. Jang, J.-E. Kim, H. Park, M.-S. Joh, J.-H. Kang, and T.J. Oh, 2013: An evaluation of the software system dependency of a global atmospheric model. Mon Wea. Rev., 141, 4165-4172.

Hong, S.-Y., H. Park, H.-B. Cheong, J.-E. Kim, M.-S. Koo, J. Jang, S. Ham, S.-O. Hwang, B.K. Park, E.-C. Chang, and H. Li, 2013: The Global/Regional Integrated Model System (GRIMs). Asia-Pacific J. Atmos. Sci., 49, 219-243.

Pagowski, M., Z. Liu, G. A. Grell, M. Hu, H.-C. Lin, C. S. Schwartz, 2014: Implementation of aerosol assimilation in Gridpoint Statistical Interpolation and WRF-Chem. Geosci. Model Dev., in review

Sandgathe, S., B. G. Brown, B. Etherton, and E. I. Tollerud, 2013: Designing multimodel ensembles requires meaningful methodologies. Bull. Amer. Meteor. Soc., 94, 12, ES183–ES185. doi: http://dx.doi.org/10.1175/BAMS-D-12-00234.1

Tollerud, E. I, B. Etherton, Z. Toth, I. Jankov, T.L. Jensen, H. Yuan, L.S. Wharton, P.T. McCaslin, E. Mirvis, B. Kuo, B.G. Brown, L. Nance, S.E. Koch, F.A. Eckel, 2013: The DTC ensembles task: A new testing and evaluation facility for mesoscale ensembles. Bull. Amer. Meteor. Soc., Vol. 94, Issue 3, 321-327.

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Ware, R., D. Cimini, E. Campos, G. Giuliana, S. Albers, M. Nelson, S.E. Koch, P. Joe, and S. Cober, 2013: Thermodynamic and liquid profiling during the 2010 Winter Olympics. Atmos. Res., 132-133, 278-290. http://dx.doi.org/10.1016/j.atmosres.2013.05.019

NESDIS Environmental Applications Team (NEAT and NEAT Expanded)

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Towards Assimilation of Satellite, Aircraft, and Other Upper-air CO_2 Data into CarbonTracker (NA13OAR4310077)

Details on CarbonTracker-CO_2 may be found at: http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/

Tropical Cyclone Model Diagnostics and Product Development (NA13NWS48300233037)

DeMaria, M., J.A. Knaff, M. Brennan, D. Brown, R. Knabb**,** R.T DeMaria, A.B. Schumacher, C. Lauer, D. Roberts, C. Sampson, P. Santos, D. Sharp, and K. Winters, 2013: Improvements to the operational tropical cyclone wind speed probability model. *Wea. Forecasting*, 28**,** 586-602. doi: http://dx.doi.org/10.1175/WAF-D-12-00116.1

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Upgrades to the Operational Monte Carlo Wind Speed Probability Program (NA13OAR4590190)

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Utility of GOES-R Instruments for Hurricane Data Assimilation and Forecasting (NA10NES4400012)

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PRESENTATIONS

(All publications fall under Award Number NA090AR4320074 unless otherwise noted)

Application of JPSS Imagers and Sounders to Tropical Cyclone Track and Intensity Forecasting

Chirokova G., M. DeMaria, R. T. DeMaria, and J.F. Dostalek: Applications of JPSS imagers and sounders to tropical cyclone track and intensity forecasting. 2013 EUMETSAT Meteorological Satellite Conference, 19th AMS Satellite Meteorology, Oceanography, and Climatology Conference, September 16-20 2013, Vienna, Austria. Chirokova G., M. DeMaria, R. T. DeMaria, and J. F. Dostalek: Tropical cyclones thermodynamic analysis using satellite microwave soundings. NCAR/NOAA/CSU TC Workshop, May 16, 2013, Fort Collins, CO.

Chirokova G., M. DeMaria, R. T. DeMaria and J.F. Dostalek: Applications of JPSS imagers and sounders to tropical cyclone track and intensity forecasting. 2013 EUMETSAT Meteorological Satellite Conference, 19th AMS Satellite Meteorology, Oceanography, and Climatology Conference, September 16-20 2013, Vienna, Austria.

Chirokova G, M. DeMaria, and J. Dostalek: Rapid intensification index estimates with ATMS profiles. NCAR/NOAA/CSU Tropical Cyclone Workshop, Jan 8, 2014, Boulder, CO.

DeMaria M, J. Knaff, F, Weng, C. Velden, J. Li, C. Rozoff, G, Chirokova, R. DeMaria, J. Beven, and M. Brennan: NOAA Satellite Science Week tropical storms/hurricanes science achievements. NOAA Satellite Science Week, 18-22 March 2013.

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Slocum, C., K. D. Musgrave, L. D. Grasso, G. Chirokova, M. DeMaria, and J. Knaff: Satellite applications to hurricane intensity forecasting." CoRP Science Symposium, 23-24 July 2013, Madison, WI.

CIRA Collaboration with ESRL Physical Science Division on Hydrologic Research and Water Resources Applications Outreach Coordination

Hsu, Chengmen, L. E. Johnson, R. Cifelli, 2013: Assessment of precipitation mappings using distributed hydrologic modeling. Proceed., 27th Conference on Hydrology, Austin, TX, Amer. Meteor. Soc.

CIRA Research Collaborations with the NOAA Earth System Research Lab/Global Monitoring Division on Carbon Tracker Model Enhancements

The research and development work outlined here over the past year has not yet resulted in publications in the peer-reviewed literature. The work is reflected in the on-line CarbonTracker documentation at**:** http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/

CIRA Support for Transition of Tropical Cyclone Forecast Products

Chirokova, G., M. DeMaria, R. DeMaria, J.F. Dostalek, 2013: Applications of JPSS imagers and sounders to tropical cyclone track and intensity forecasting. NOAA Satellite Science Week, 18-22 March 2013.

CIRA Support of NOAA's Commitment to the Coordination Group for Meteorological Satellites: Enhancing the International Virtual Laboratory

Connell, B., 2013: GEONETCast Americas training channel: VLab training. WMO train the trainer GEONETCast Workshop, College Park, Maryland, 6-7 April, 2013. Presentation.

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, B. Motta, T. Schmit, M. Davison, K. Caesar, V. Castro, L. Veeck, 2014: Satellite training activities: VISIT, SHyMet, and WMO VLab. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems at the 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2014. Poster.
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Veeck, L., 2013: Opening doors to education and training in satellite meteorology. 10th International Conference on Creating Activities for Learning Meteorology (CALMet), Toulouse, France, 26-30 August 2013. Poster.

CIRA Support of the Virtual Institute for Satellite Integration Training (VISIT)

Bikos, D., Connell, B., Szoke, E., Bachmeier, S., Lindstrom, S., Mostek, A., DeMaria, M., 2013: The SHyMet GOES-R instruments and products training course, and other related satellite training for operational forecasting, 38th Annual Meeting, Charleston, South Carolina, 12-17 October, 2013, National Weather Association. Poster.

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, B. Motta, T. Schmit, M. Davison, K. Caesar, V. Castro, L. Veeck, 2014: Satellite training activities: VISIT, SHyMet, and WMO VLab. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems at the 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2914.
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CIRA Support to a GOES-R Proving Ground for National Weather Service Forecaster Readiness

Bikos, D., B. Connell, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, M. DeMaria, 2013: The SHyMet GOES-R instruments and product training course, and other related satellite training for operational forecasting, 38th Annual Meeting, Charleston, South Carolina, 12-17 October, 2013, National Weather Association. Poster.

Bikos, D., D.T. Lindsey, and L.D. Grasso, 2013: Synthetic imagery of fog and wave clouds, NOAA Satellite Science Week virtual conference, 18-22 March 2013.

Bikos, D., E. Szoke, S.Q. Kidder, and S.D. Miller, 2013: Recent examples of the Orographic Rain Index (ORI) satellite product, NOAA Satellite Science Week virtual conference, 18-22 March, 2013.

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, T. Mostek, M. Davison, K.-A. Caesar, V. Castro, and L. Veeck, 2013: Satellite training activities: What's new and what's ongoing? 2013 NOAA Satellite Conference, College Park, MD, 8-12 April, 2013. Poster http://www.goes-r.gov/downloads/AMS/2014/posters/session02/692.pdf

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, B. Motta, T. Schmit, M. Davison, K. Caesar, V. Castro, L. Veeck, 2014: Satellite training activities: VISIT, SHyMet, and WMO VLab. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems at the 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2914. Poster.http://satelliteconferences.noaa.gov/2013/docs/Tuesday%20Poster%20Session%20Final%20Posters/T72_NSC_April2013_T72_Connell_SatTrainingActivities_poster.pdf

Knaff, J.A. 2013: CIRA/RAMMB NHC Proving ground products, National Hurricane Center, 24 April, 2013.

Lindsey, D.T., and L.D. Grasso, 2013: Simulated ABI data and convective initiation, Warn-on-Forecast and Hazardous Weather Workshop, *4-8 February, Norman, OK.*

Lindsey, D.T., L.D. Grasso, D. Bikos, E. Szoke, 2014: Using simulated satellite Imagery to visualize model forecasts. AMS 26th Conference on Weather Analysis and Forecasting, 2-6 February, Atlanta, GA.

Lindsey, D.T., L.D. Grasso, E. Szoke, 2014: A new look at the GOES-R ABI split window difference for convective initiation forecasting. AMS 10th Annual Symposium on New Generation Operational Environmental Satellite Systems, 2-6 February, Atlanta, GA.

Miller, S.D., 2013: A dynamic enhancement background reduction algorithm (DEBRA) applicable to GOES-R ABI, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

Molenar, D.A., 2013: RAMMB/CIRA's current AWIPS2 capabilities and on plans for AWIPS2 RGB product development and evaluation, NOAA Satellite Science Week virtual conference, 18-22 March.

Seaman, C., R.L. Brummer, D.T. Lindsey, L.D. Grasso, D.W. Hillger, 2013: Synthetic satellite imagery development at CIRA, 2013 EUMETSAT Meteorological Satellite Conference & 19th American Meteorological Society AMS Satellite Meteorology, Oceanography, and Climatology Conference 16-20 September, Vienna, Austria.

Seaman, **C.**, S. Miller and D.W. Hillger, 2013: RGB applications of VIIRS imagery in support of a weather-ready Nation*,* CoRP Symposium 201*3,* Madison, WI, 23-*24 July 2013.*

Seaman, C., and D.A. Molenar, 2013: Use of RGB composite imagery in AWIPS-II, NOAA Satellite Science Week virtual conference, 18-22 March 2013.

Seaman, C., D.W. Hillger and S.D. Miller: VIIRS imagery: Applications and outreach at CIRA, NOAA 2013 Satellite Conference, 8-12 April 2013, College Park, MD.

Seaman, C., D.W. Hillger, S.D. Miller, 2013: VIIRS Imagery: Applications and outreach at CIRA, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

Seaman, C., D.W. Hillger and S.D. Miller, 2013: Suomi-NPP VIIRS imagery: RGB applications and product development at CIRA, NOAA Satellite Science Week virtual conference, 18-22 March 2013.

Seaman, C., D.W. Hillger, S.D. Miller, D.T. Lindsey, 2013: Suomi-NPP VIIRS imagery: RGB applications and product development at CIRA, 2013 EUMETSAT Meteorological Satellite Conference & 19th American Meteorological Society AMS Satellite Meteorology, Oceanography, and Climatology Conference 16-20 September, Vienna, Austria.

Szoke, E., D. Bikos, R. Brummer, H. Gosden, S. Miller, M. DeMaria, D. Lindsey, D. Hillger, C. Seaman, and D. Molenar, 2014: More opportunities for forecaster interaction for future operational satellite products – CIRA's activities in the GOES-R and JPSS Proving Grounds, 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2014, 4th Conference on Transition of Research to Operations. Talk.

Szoke, E., D. Bikos, D. Lindsey, D. Molenar, H. Gosden, R Brummer, S. Miller, and M. DeMaria, 2013: An overview of CIRA proving ground NWS interactions, 38th Annual Meeting, Charleston, South Carolina, 14-18 October, 2013, National Weather Association. Poster and Talk.

CIRA Support to GOES Improvement and Product Assurance Program

Lindsey, D.T., L.D. Grasso, D. Bikos, E. Szoke, 2014: Using simulated satellite imagery to visualize model forecasts. AMS 26th Conference on Weather Analysis and Forecasting, 2-6 February, Atlanta, GA.
DeMaria, M., 2013: Generalizing tropical cyclone potential intensity estimates to include vertical shear effects. Seminar at CSU Atmospheric Science Department, 24 January 2014.

Rogers, M., S. Miller, J. Haynes, A. Heidinger, S. Benjamin, M. Sengupta, S.-E. Haupt, and T. Auligne, 2013: Results from a satellite-derived short-term insolation forecast technique: Comparison against surface observations, NWP predictions, and challenges. 2013 Annual Fall Meeting of the American Geophysical Institute, A14-E2, San Francisco, CA 9 Dec 2013.

Seaman, C, R.L. Brummer, D.T. Lindsey, L.D. Grasso, D.W. Hillger, 2013: Synthetic satellite imagery development at CIRA, 2013 EUMETSAT Meteorological Satellite Conference & 19th American Meteorological Society AMS Satellite Meteorology, Oceanography, and Climatology Conference 16-20 September, Vienna, Austria.

CIRA Support to JPSS Science Program: NPP VIIRS EDR Imagery Algorithm and Validation Activities and NPP VIIRS Cloud Validation

Hillger D.W., T. Kopp, S.D. Miller, D.T. Lindsey, C. Seaman, 2013: Suomi NPP VIIRS imagery after 1 Year, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

Hillger, D.W., C. Seaman, C. Liang, S.D. Miller, D.T. Lindsey, T. Kopp, 2014: Suomi NPP VIIRS Near Constant Contrast (NCC) Imagery. AMS Tenth Annual Symposium on New Generation Operational Environmental Satellite Systems. 2-6 February, Atlanta, GA.

Miller, S. D., 2013: Suomi NPP's day/night band sheds new light on the nocturnal environment, invited Oral Presentation, NOAA Science Day, May 2013, Silver Spring, MD

Seaman, C., D.W. Hillger and S.D. Miller, 2013: VIIRS imagery: Applications and outreach at CIRA, NOAA 2013 Satellite Conference, 8-12 April 2013, College Park, MD.

Seaman, C., D.W. Hillger, S.D. Miller, and D. Lindsey, 2013: Suomi-NPP VIIRS imagery: RGB applications and product development at CIRA, 2013 EUMETSAT Meteorological Satellite Conference and 19th AMS Satellite Meteorology, Oceanography and Climatology Conference. Vienna, Austria, 16-20 September 2013.

Seaman, C. and D.T. Lindsey, 2013: Suomi-NPP VIIRS Imagery: High-resolution views of thunderstorms and tropical cyclones, NOAA Satellite Science Week virtual conference, 18-22 March 2013.

Seaman, C., S. Miller and D.W. Hillger, 2013: RGB applications of VIIRS imagery in support of a weather-ready Nation, *CoRP Symposium 201*3, Madison, WI, 23-24 July 2013.

Seaman, C., D. Molenar, D. Hillger, S. Miller and M. DeMaria, 2013: RGB Imagery: Applications and decision aids in AWIPS II, NOAA Satellite Science Week virtual conference, 18-22 March 2013.

Walther, A., S. Miller, and A. Heidinger., 2013: Nighttime cloud microphysical products with the VIIRS day/night band, Joint AMS/EUMETSAT Satellite Conference, Vienna.

CIRA Support to Research and Development for GOES-R Risk Reduction for Mesoscale Weather Analysis and Forecasting and Analysis of Simulated Radiance Fields for GOES-R ABI Bands for Mesoscale Weather and Hazards Events

Connell, B., 2013: GEONETCast Americas training channel: VLab training - WMO train the trainer GEONETCast Workshop, College Park, MD, 6-7 April, 2013. Presentation.

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, T. Mostek, M. Davison, K.-A. Caesar, V. Castro, and L. Veeck, 2013: Satellite training activities: What's new and what's ongoing? 2013 NOAA Satellite Conference, College Park, MD, 8-12 April, 2013. Poster.
http://satelliteconferences.noaa.gov/2013/docs/Tuesday%20Poster%20Session%20Final%20Posters/T72_NSC_April2013_T72_Connell_SatTrainingActivities_poster.pdf

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, B. Motta, T. Schmit, M. Davison, K. Caesar, V. Castro, L. Veeck, 2014: Satellite training activities: VISIT, SHyMet, and WMO VLab. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems at the 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2014. Poster.
http://www.goes-r.gov/downloads/AMS/2014/posters/session02/692.pdf

Connell, B., P. Seymour, K.-A. Caesar, and L. Veeck, 2013: Training videos through GEONETCast? What will they think of next! 2013 NOAA Satellite Conference, College Park, MD, 8-12 April, 2013. Poster. http://satelliteconferences.noaa.gov/2013/docs/Tuesday%20Poster%20Session%20Final%20Posters/T73_NSC_April2013_T73_Connell_GEONETCast_TrainingChannel_poster.pdf

Lindsey, D.T. and L.D. Grasso, 2013**:** Simulated ABI data and convective initiation. 2013 Warn-on-Forecast and High Impact Weather Workshop, 4-7 February, Norman, OK.

Lindsey, D.T., L.D. Grasso, D. Bikos, E. Szoke, 2014: Using simulated satellite imagery to visualize model forecasts. AMS 26th Conference on Weather Analysis and Forecasting, 2-6 February, Atlanta, GA.

Lindsey, D.T., L.D. Grasso, E. Szoke, 2014: A new look at the GOES-R ABI split window difference for convective initiation forecasting. AMS 10th Annual Symposium on New Generation Operational Environmental Satellite Systems, 2-6 February, Atlanta, GA.

Seaman, C., R. Brummer, D.T. Lindsey, L.D. Grasso, D.W. Hillger, 2013: Synthetic satellite imagery development at CIRA, 2013 EUMETSAT Meteorological Satellite Conference & 19th American Meteorological Society AMS Satellite Meteorology, Oceanography, and Climatology Conference 16-20 September, Vienna, Austria.

CIRA Support to the JPSS Proving Ground and Risk Reduction Program

Hillger D.W., T. Kopp, S.D. Miller, D.T. Lindsey, C. Seaman, 2013: Suomi NPP VIIRS imagery after 1 year, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

McCarthy, J.K., E. J. Jacobson, T. M. Kilduff, R. W. Estes, P. A. Levine, S. D. Mills, C. Elvidge, and S. D. Miller, 2013: On the potential to enhance the spatial resolution of the day-night band (DNB) channel of the visible and infrared imaging radiometer suite (VIIRS) for the second joint polar satellite system (JPSS-2) and beyond. Proc. SPIE 8866, Earth Observing Systems XVIII, 88661Q (September 23, 2013); doi:10.1117/12.2024407

Miller, S.D., 2013: A dynamic enhancement background reduction algorithm (DEBRA) applied to MSG/SEVIRI observations of dust storms, Joint AMS/EUMETSAT Satellite Conference, 16-20 September, Vienna, Austria.

Miller, S. D., 2013: Light amidst the shadows: A new paradigm of nocturnal environmental application capabilities from the Suomi NPP VIIRS day/night Band, Joint AMS/ EUMETSAT Satellite Conference, 16-20 September, Vienna, Austria.

Miller, S. D., NOAA Science Day, May 2013: Suomi NPP's day/night band sheds new light on the nocturnal environment, invited Oral Presentation, Silver Spring, MD

Miller, S.D., OCONUS Proving Ground, June 2013: VIIRS day/night band Off-CONUS topics, Oral Presentation, Anchorage, AK

Miller, S. D., 2014: Northern Colorado Astronomical Society, Invited, Nighttime applications and the Chelyabinsk Meteor, Ft. Collins Discovery Museum, January 2014.

Miller, S.D., Panelist: User Feedback Session, VIIRS day-night band, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, College Park, MD, April 2013

Miller, S. D., W. Straka, and D. Pettit, 2014: Man in the loop—Benefits of the ISS platform for characterizing low-light visible observations from the Suomi NPP day/night band. Oral Presentation, 30th AMS Conf. Env. Inf. Proc. Tech., Atlanta, GA. Abstract 241957.

Seaman, C., D.W. Hillger and S.D. Miller, 2013: Suomi-NPP VIIRS imagery: RGB applications and product development at CIRA, NOAA Satellite Science Week virtual conference, 18-22 March 2013.

Seaman, C., D.W. Hillger, and S.D. Miller, 2013: VIIRS imagery: Applications and outreach at CIRA, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

Straka, W., T. Jasmin, T. Rink, D.T. Lindsey, D.W. Hillger, S.D. Miller, T. Achtor, 2013: McIDAS-V, visualization and data analysis for Suomi National Polar-orbiting Partnership, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

Szoke, E., R.L. Brummer, H. Gosden, C. Seaman, D. Bikos, S.D. Miller, M. DeMaria, D.T. Lindsey, D.W. Hillger, and D.A. Molenar, 2014: More opportunities for forecaster interaction for future operational satellite products – CIRA's activities in the GOES-R and JPSS Proving Grounds. AMS 4th Conference on Transition of Research to Operations, 2-6 February, Atlanta, GA.

CIRA Support to Tropical Cyclone Model Diagnostics and Product Development

Musgrave, K. D., M. DeMaria, B. D. McNoldy, Y. Jin and M. Fiorino, 2013: Further development of a statistical ensemble for tropical cyclone intensity prediction. 67th Interdepartmental Hurr. Conf., March 5-7, College Park, MD. Available online at: http://www.ofcm.gov/ihc13/Presentations/6-Session/07-S6-Musgrave_IHC_2013.pptx

Effective Collaborative NIDIS Drought Monitoring and Early Warning in the Upper Colorado Basin

Doesken, N., 2013: Regional Drought Early Warning System: Lessons learned from the Upper Colorado. NIDIS Missouri Basin Project Kickoff Meeting, Feb. 26-27, 2014, Nebraska City, NE

Environmental Applications Research (EAR)

Albers, S., H. Jiang, D. Birkenheuer, I. Jankov, Z. Toth, 2013: The Variational version of the Local Analysis and Prediction System (LAPS): Hot-start data assimilation of convective events. Presentation, 14th WRF-users Workshop, Boulder, CO, UCAR.

Albers, S. C., Y. Xie, V. Raben, Z. Toth, K. Holub, 2013: The Local Analysis and Prediction System (LAPS) cloud Analysis: Validation with all-sky imagery and development of a variational cloud assimilation, Abstract A43B-0246 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.

Bernardet, L. R.,I. Jankov, S. Albers, K. Mahoney, T. Workoff, F. Barthold, W. Hogsett, D. Reynolds, and J. Du, 2014: The Experimental Regional Ensemble Forecast System (ExREF). Poster, 26th Conf. Weather Analys. Forecasting/22nd Conf. Num. Weather Pred., Atlanta, GA, Amer. Meteor. Soc.

Fowler, T., E. I. Tollerud, T. Jensen, W. Clark, E. Gilleland, L. Bernardet, and B. G. Brown, 2013: WRF verification for specific needs: The DTC connection with NOAA testbeds. Present., 14th Annual WRF User's Workshop, Boulder, CO, UCAR.

Hackathorn, E., J. Q. Stewart, J. Lynge, J. Smith, 2013: Interactive visualization using NOAA's Earth Information System (NEIS) and TerraViz. Global Monitoring Annual Conference, Boulder, CO, ESRL Global Monitoring Division.

Jankov, I., 2013: Initial condition perturbations for the Hydrometerological Testbed ensemble forecasting system. Presentation, 4th NOAA Testbed User Workshop, College Park, MD, NOAA HMT.

Jankov, I., T. L. Jensen, J. Du, G. DiMego, Y. Zhu, B. G. Brown, E. Mirvis, and Z. Toth, 2014: An evaluation of the impact of increased horizontal grid spacing on SREF performance. Poster, 26th Conf. Weather Analys. Forecasting/22nd Conf. Num. Weather Pred., Atlanta, GA, Amer. Meteor. Soc.

Jensen, T.L., T. L. Fowler, I. Jankov, J. H. Gotway, R. Bullock, E. I. Tollerud, and B. G. Brown, 2014: Understanding ensemble behavior using the Method for Object based Diagnostic Evaluation (MODE). Proceed., 26th Conf. Weather Analys. Forecasting/22nd Conf. Num. Weather Pred., Atlanta, GA, Amer. Meteor. Soc.

Jiang, H., S. Albers, I. Jankov, Y. Xie, Z. Toth, and R. M. Rabin, 2014: Case studies of severe storms during HWT 2013 using variational LAPS. Proceed., Special Symposium on Severe Local Storms, Atlanta, GA, Amer. Meteor. Soc.

Kim, J.-E., J.-L. Lee, and S.-Y. Hong, 2013: Sensitivity of horizontal and vertical resolution in a non-hydrostatic global model: An aquaplanet study, Abstract A31A-0014 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.

Layne, G.J., M. S. Wandishin, B. J. Etherton, and M. A. Petty, 2014: Use of the Flow Constraint Index: Combining weather and traffic Information to identify constraint. Poster, Fourth Aviation, Range, and Aerospace Meteorology Special Symposium, Atlanta, GA, Amer. Meteor. Soc.

Pagowski, M., G. A. Grell, 2013: Assimilation of fine aerosols using WRF-Chem and Ensemble Kalman Filter methods. Proceedings, 33rd International Technical Meeting on Air Pollution Modeling and Its Application, Miami, FL, NATO.

Pagowski, M., G. A. Grell, J. Berner, K. Smith, M. Hu, 2013: Assimilation of fine aerosols using WRF-Chem and ensemble Kalman Filter. 14th Annual WRF User's Workshop, Boulder, CO, UCAR.

Pagowski, M., G. A. Grell, M. Hu, 2013: Assimilation of fine aerosols using WRF-Chem, 3D-VAR and ensemble Kalman Filter methods. Traversing New Terrain Meteorology Conference, Davis, CA, UC-Davis.

Petty, Melissa A., G. J. Layne, M. S. Wandishin, B. J. Etherton, P. Hamer, and B. Lambi, 2014: INSITE, Integrated Support for Impacted air Traffic Environments. Poster, Second Symposium on Building a Weather-Ready Nation: Enhancing Our Nation's Readiness, Responsiveness, and Resilience to High Impact Weather Events, Atlanta, GA, Amer. Meteor. Soc.

Smith, T. L., S. S. Weygandt, C. R. Alexander, M. Hu, H. Lin, and J. R. Mecikalski, 2014: Assimilation of GOES satellite based convective initiation data into the Rapid Refresh and HRRR systems to improve aviation forecast guidance. Poster, 4th Aviation, Range, and Aerospace Meteorology Special Symposium, Atlanta, GA, Amer. Meteor. Soc.

Stewart, J., 2013: NOAA Earth Information System. Presented at Internet2 Annual Meeting, Arlington, VA, Internet2.

Stewart, J., 2013: Interoperability: What does it mean and how do we improve it? ESIP Summer Meeting, Chapel Hill, NC, ESIP Federation.

Stewart, J., 2013: Improving data discovery and access through an interoperable system in Climate.gov. Presented at ESIP IT & I Rave and Rant for May, Virtual Meeting, May 2, 2013.

Stewart, J., 2013: NOAA Earth Information System and TerraViz. Presented at May 21 2013 Monthly Meeting, Boulder, CO, BESSIG.

Stewart, J. Q., D. L. Davis, E. Hackathorn, J. Lynge, C. MacDermaid, R. Pierce, and J. S. Smith, 2013: Introduction to the NOAA Earth Information System (NEIS). Proceedings, 29th Conference on Environmental Information Processing Technologies, Austin, TX, Amer. Meteor. Soc.

Stewart J. Q., E. J. Lynge, E. Hackathorn, C. MacDermaid, R. Pierce, and J. S. Smith 2013: Exploring interoperability: The advancements and challenges of improving data discovery, access, and visualization of scientific data through the NOAA Earth Information System (NEIS), Abstract IN34A-08 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.

Stewart, J. Q., D. Davis, J. Lynge, E. Hackathorn, C. MacDermaid, R. Pierce, and J. Smith, 2013: Introduction to the NOAA Earth Information System. 29th Conference on Environmental Information Processing Technologies (EIPT), Austin, TX, Amer. Meteor. Soc., CD-ROM, 5.1 Jan. 5 – 10 2013.

Stewart, J. Q., J. Lynge, E. Hackathorn, C. MacDermaid, R. Pierce, and J. Smith, 2013: NOAA Earth Information System (NEIS). NOAA Scientific Review of CIRA, Fort Collins, CO, CIRA, May 21-22 2013.

Stewart, J. Q., J. Lynge, E. Hackathorn, C. MacDermaid, R. Pierce, and J. Smith, 2013: Exploring interoperability: The advancements and challenges of improving data discovery, access, and visualization of scientific data through the NOAA Earth Information System (NEIS). Abstract IN34A-08 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.

Tollerud, E. I., T. Fowler, T. L. Jensen, W. L. Clark, E. Gilleland, L. R. Bernardet, and B. G. Brown, 2014: NWP testing and evaluation for specific needs: The DTC connection with NOAA testbeds. Poster, 26th Conf. on Weather Analys. Forecasting/22nd Conf. Num. Weather Pred., Atlanta, GA, Amer. Meteor. Soc.

Tollerud, E. I., T. Jensen, T. L. Fowler, J. H. Gotway, B. G. Brown, and R. Bullock, 2014: The model evaluation Tools: How to use its statistical output to understand model performance. Proceed., 26th Conf. Weather Analys. Forecasting/22nd Conf. Num. Weather Pred., Atlanta, GA, Amer. Meteor. Soc.

Wandishin, M.S., G. J. Layne, B. J. Etherton, and M. A. Petty, 2014: Challenges of incorporating the event-based perspective into verification techniques. Proceedings, 22nd Conference on Probability and Statistics in the Atmospheric Sciences, Atlanta, GA, Amer. Meteor. Soc.

Xie, Y., S. Albers, H. Jiang, D. Birkenheuer, Z. Toth, 2013: Variational cloud analysis Using CRTM in a multiscale analysis. Poster, Special Symposium on Advancing Weather and Climate Forecasts: Innovative Techniques and Applications, Austin, TX, Amer. Meteor. Soc.

Getting Ready for NOAA's Advanced Remote Sensing Programs: A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal

Bikos, D., Connell, B., Szoke, E., Bachmeier, S., Lindstrom, S., Mostek, A., DeMaria, M., 2013: The SHyMet GOES-R instruments and products training course, and other related satellite training for operational forecasting, 38th Annual Meeting, Charleston, South Carolina, 12-17 October, 2013, National Weather Association. Poster.

Connell, B., 2013: Introduction to GOES-R. GEONETCast Event Week. 3-5 December 2013. Virtual Presentation. Presentation and recording can be found on the Thursday, 5 December session. Rosario Alfaro translated and presented a Spanish version.
http://rammb.cira.colostate.edu/training/rmtc/geonetcast_event_en.asp

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, T. Mostek, M. Davison, K.-A. Caesar, V. Castro, and L. Veeck, 2013: Satellite training activities: What's new and what's ongoing? 2013 NOAA Satellite Conference, College Park, MD, 8-12 April, 2013. Poster.
http://www.goes-r.gov/downloads/AMS/2014/posters/session02/692.pdf

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, B. Motta, T. Schmit, M. Davison, K. Caesar, V. Castro, L. Veeck, 2014: Satellite training activities: VISIT, SHyMet, and WMO VLab. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems at the 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2014. Poster.
http://satelliteconferences.noaa.gov/2013/docs/Tuesday%20Poster%20Session%20Final%20Posters/T72_NSC_April2013_T72_Connell_SatTrainingActivities_poster.pdf

Connell, B., Veeck, L., and Caesar, K-A, 2013: Adding the personal touch. A renewed look at presentation, complicated information, and the audience. 10th International Conference on Creating Activities for Learning Meteorology (CALMet), Toulouse, France, 26-30 August 2013. Virtual presentation.

Szoke, E., Bikos, D., Brummer, R., Gosden, H., Miller, S., DeMaria, M., Lindsey, D., Hillger, D., Seaman, C., and Molenar, D., 2014: More opportunities for forecaster interaction for future operational satellite products – CIRA's activities in the GOES-R and JPSS Proving Grounds, 94th AMS Annual Meeting, Atlanta, Georgia, 2-6 February, 2014, 4th Conference on Transition of Research to Operations. Talk.

Szoke, E., Bikos, D., Lindsey, D., Molenar, D., Gosden, H., Brummer, R., Miller, S., and DeMaria, M., 2013: An overview of CIRA Proving Ground NWS interactions, 38th Annual Meeting, Charleston, South Carolina, 14-18 October, 2013, National Weather Association. Poster and Talk.

Community Outreach

--After school weather club: Scientists at CIRA and CSU students, all of which are members of the local AMS chapter of Northern Colorado Fort Collins Atmospheric Scientists (FORTCAST), volunteered for the weekly after school weather club on Tuesdays for Putnam Elementary (K-5). The fall session ran for 8 weeks during October through early December 2013. There was a 90 minute session each week. Sessions included helping with homework and leading an activity. The topics covered included rain, wind speed, clouds, temperature, hail, frost (and ice cream!), and things that spin as well as measurements that are associated with these weather occurrences. Volunteers included Bernie Connell, Matt Rogers, Kristi Gebhart, Erin Dagg, and James Ruppert. Putnam has a coordinator who is responsible for matching students with clubs, assigning classrooms, providing snacks, and providing transportation – which is great!

--B. Connell and Matt Rogers participated in the 22nd Annual Fort Collins Children's Water Festival held on 15 May 2013. The festival invites 3rd graders from the Poudre School District. We had 20 minutes to entice kids to look up, observe the clouds, name the different types of clouds, and also discover what a cloud feels like. We met with groups from 7 schools.

Impact Assessment and Data Assimilation of NOAA NPP/JPSS Sounding Products and Quality Control Parameters

Fletcher, S. J., 2013: A quality control of NOAA MIRS cloud retrievals during Hurricane Sandy. Annual Fall Meeting of the American Geophysical Union, San Francisco, 9 – 13 December.

Fletcher, S. J., 2013: A quality control study of the distribution of NOAA MIRS Cloudy retrievals during Hurricane Sandy. 6th WMO International Symposium on Data Assimilation, University of Maryland, College Park, 7 – 10 October.

NESDIS Environmental Applications Team (NEAT and NEAT Expanded)

Bouali M. and Ignatov A., 2013: Towards improved ACSPO SST imagery, NOAA Satellite Conference, College Park, MD, USA, April 2013.

Bouali M. and Ignatov A., 2013: Reduction of stripe noise for improved ACSPO SST, SPIE Security, Defense and Remote Sensing, Baltimore, Maryland, USA, May, 2013

Bouali M. and Ignatov A., 2013: Mitigation of striping in ACSPO clear-sky radiances and SST products, 14th GHRSST meeting, Woods Hole, MA, June, 2013.

Boukabara, K., J. Garrett, C. Grassotti, F. Iturbide-Sanchez, W. Chen, Z. Jiang, S. A. Clough, X. Zhan, F. Weng, P. Liang, Q. Liu, T. Islam, V. Zubko, and A. M. Mims, 2014: A physical approach for a simultaneous retrieval of sounding, surface, hydrometeor and cryospheric parameters from SNPP/JPSS ATMS. 94th AMS Annual Meeting, January 2014. Atlanta, USA.

Chang, T., X. Wu, F. Weng, W. Guo, F. Kogan, X. Liang, A. Ignatov, 2013: On-orbit testing of MetOp-B AVHRR, 2013 NOAA Science Conf., College Park, April 2013 (Poster.)

Dash, P., A. Ignatov and Y. Kihai, 2013: GHRSST SST Quality Monitor (SQUAM) updates: Progress since GHRSST-13 and future work. 2013 Annual Meeting, Woods Hole, MA Jun 17-21 2013 (poster)

Dash, P., A. Ignatov and Y. Kihai, 2013: SST Quality Monitor (SQUAM): Intercomparison of Metop-A SSTs from O & SI SAF and ACSPO. OSI-SAF Workshop on SST from Polar Orbiters: Use of NWP Outputs, Lannion, France Mar 5-6 2013 (oral)

Dash, P., A. Ignatov and Y. Kihai, 2013: SST Quality Monitor (SQUAM) updates: Progress since GHRSST-13 and future work. GHRSST 2013 Annual Meeting, Woods Hole, MA Jun 17-21 2013 (poster)

Dash, P., A. Ignatov, Y. Kihai, B. Petrenko, J. Stroup and J. Sapper, 2013:   Preliminary analyses of Metop AVHRR, MODIS and VIIRS SST products in SQUAM. GHRSST 2013 Annual Meeting, Woods Hole, MA Jun 17-21, 2013 (oral)

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Lin, H., S. S. Weygandt, M. Hu, S. G. Benjamin, C. Alexander, and P. Hofmann, 2013: Evaluation of radiance data assimilation impact on Rapid Refresh forecast skill for retrospective and real-time experiments. Present., 11th Workshop on Satellite Data Assimilation, College Park, MD, Joint Center for Satellite Data Assimilation.

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Variability in Snow Sublimation Across Basin Scale Systems

Phillips, M., 2013: Variability of Snow Sublimation in the Upper Colorado River Basin. Western Snow Conference. 81st Annual Meeting (April 15-18, 2013), pp. 91-102

Presentations - Competitive Projects

CoCoRaHS: Capitalizing on Technological Advancements to Expand Environmental Literacy Through a Successful Citizen Science Network (NA10SEC0080012)

Webinar #17 - Thursday, April 18, 2013
Forecasting the Ferocious: The How, What, Where and Why of Tornadoes
Greg Carbin, NOAA/Storm Prediction Center, Norman, OK

Webinar # 18 - Thursday, May 9, 2013
At the Cutting Edge: Harry Wexler and the Emergence of Atmospheric Science
Jim Fleming, Colby College, Waterville, ME

Webinar #19 - Thursday, June 13, 2013
Monitoring the Earth's Climate
Deke Arndt, NOAA/National Climatic Data Center, Asheville, NC

Webinar #20 - Thursday, July 25, 2013
Rainwater Harvesting - Catching and Using It
Billy Kniffen, Vice President and Education Coordinator, American Rainwater Catchment Systems Association (ARCSA), Menard, TX

Webinar #21 - Thursday, August 15, 2013
Atlantic basin seasonal hurricane prediction and the forecast for the 2013 Atlantic hurricane season
Phil Klotzbach, Colorado State University, Fort Collins, CO

Webinar #22 - Thursday, September 12, 2013
The Hundred Hunt for the Red Sprite
Walt Lyons, FMA Research, Inc., Fort Collins, CO

Development of a Probabilistic Tropical Cyclone Prediction Scheme (NA11OAR4310208)

Dunion, J., 2014: Development of a probabilistic tropical cyclone genesis prediction scheme, National Hurricane Center Briefing, 3 March, 2014, Miami, FL.

Development of a Real-time Automated Tropical Cyclone Surface Wind Analysis (NA11OAR4310204)

Knaff, J.A., R.L. Brummer, M. DeMaria, C. Landsea, M. Brennan, R. Berg, J. Schauer, 2013: Development of a real-time automated tropical cyclone surface wind analysis: A Year 2 joint hurricane testbed project update. 67th Interdepartmental Hurricane Conference, 4-8 March, College Park, MD.

Guidance on Intensity Guidance (NA13OAR4590187)

Bhatia, K.T., D.S. Nolan, and A.B. Schumacher, 2014: Predicting tropical cyclone intensity forecast error, Tropical Cyclone Research Forum / 67th Interdepartmental Hurricane Conference, 3-6 March 2014, Miami, FL.

Improvements in Statistical Tropical Cyclone Forecast Models (NA11OAR4310203)

DeMaria, M., A.B. Schumacher, J.A. Knaff, R. Brummer, 2013: Improvements in statistical tropical cyclone forecast models: A Year 2 joint hurricane testbed project update. *67th Interdepartmental Hurricane Conference, 4-8* March, College Park, MD.

Quantifying the Source of Atmospheric Ice Nuclei from Biomass Burning Aerosols (NA10OAR4310103)

DeMott, P. J., 2011: Insights into the roles of different aerosol types as ice nuclei (Invited), Gordon Research Conference on Atmospheric Chemistry, July 27, 2011, Mt. Snow, VT.

DeMott, P. J., 2011: Progress and needs for in-situ measurements of atmospheric ice nuclei sources, DOE ASR Fall Working Group Meeting, September 12 – 14, 2011, Annapolis, MD (http://asr.science.energy.gov/meetings/fall-working-groups/presentations).

DeMott, P. J., 2012: (Invited) Studies of sources of inorganic and organic ice nuclei, Telluride Science Center's Workshop - Aerosols and Clouds: Connections from the Laboratory to the Field to the Globe, Telluride, CO, 7-10 August.

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DeMott, P. J., A. J. Prenni, G. R. McMeeking, R. C. Sullivan, T. C. Hill, G. Franc, A. Sullivan, E. Garcia, Y. Tobo, K. A. Prather, K. Suski, A. Cazorla, J. R. Anderson, and S. M. Kreidenweis, 2012: (Invited) Ice nuclei sources, concentrations, and relation to aerosol properties, 16th International Conference on Clouds and Precipitation, Leipzig, Germany, 30 July – 3 August, IAMAS/ICCP, Pap. 10.3.1 [Available online].

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DeMott, P. J., A. J. Prenni, A. P. Sullivan, G. R. McMeeking, G. D. Franc, T. C. Hill, J. Anderson, Y. Desyaterik, R. C. Sullivan, and S. M. Kreidenweis, 2011: Investigations of atmospheric ice nuclei produced from biomass burning , American Association for Aerosol Research Annual Meeting, Abstract 9F.1, October 6, 2011, Orlando, FL (http://aaar.conference2011.org/content/program).

DeMott, P. J., R. C Sullivan, G. R. McMeeking, A. J Prenni, T. C. Hill, G. D. Franc, A. P. Sullivan, E. Garcia, Y. Tobo, K. A Prather, K. Suski, A. Cazorla, J. R. Anderson, S. M. Kreidenweis, 2011: Recent field measurements of ice nuclei concentration relation to aerosol properties (Invited), Abstract A21E-01, 2011 AGU Fall Meeting, December, 6-10, 2011, San Francisco, CA.

Levin, E. J.T., G.R. McMeeking, C. McCluskey, P.J. DeMott, and S.M. Kreidenweis, 2013: A unique approach to determine the ice nucleating potential of soot-containing aerosol from biomass combustion, Abstract A33C-0240, 2013 AGU Fall Meeting, December, 9-13, 2013, San Francisco, CA.

McCluskey, C. S., P. J. DeMott, A. J. Prenni, G. R. McMeeking, A. P. Sullivan, E. Levin, S. Nakao, C. M. Carrico, G. D. Franc, T. C. Hill, and S. M. Kreidenweis, 2012: The production and characteristics of ice nuclei from biomass burning in the US, Geophysical Research Abstracts, Vol. 15, EGU2013-11190, EGU General Assembly, Vienna, Austria.

McCluskey, C. S., P. J. DeMott, A. J. Prenni, A. P. Sullivan, G. McMeeking, Y. Desyaterik. G. Franc, T. C. Hill, and S. M. Kreidenweis, 2012: Ice nuclei produced from prescribed fires in Southeastern United States. American Association for Aerosol Research Annual Meeting, Abstract 2CC.12, October 3, 2012, Minneapolis, MN.

Prenni, A. J., P. J. DeMott, A. P. Sullivan, R. C. Sullivan and S. M. Kreidenweis, 2010: Quantifying the sources of atmospheric ice nuclei from biomass burning aerosols, International Aerosol Conference 2010, Helsinki, FI, 29 August – 3 September (www.iac2010.fi/).

Tropical Cyclone Model Diagnostics and Product Development (NA13NWS48300233037)

DeMaria, M., J. Knaff, K. Musgrave, A. Schumacher, R. DeMaria, L. Grasso, S. Longmore, and C. Slocum, 2013: 2013 NESDIS HFIP activities. HFIP conference call, October 23.

DeMaria, M., K. Musgrave, A. Schumacher, L. Grasso, J. Knaff, and D. Lindsey, 2013: NESDIS/CIRA diagnostics - 2013. 2013 HFIP Diagnostics Workshop, November 22, College Park, MD.

DeMaria, M., A. Schumacher, and K. Musgrave, 2013: A reformulation of the logistic growth equation model (LGEM) for ensemble and extended range intensity prediction. HFIP conference call, August 7.

Slocum, C. J., K. D. Musgrave, L. D. Grasso, G. Chirokova, M. DeMaria, and J.A. Knaff, 2013: Satellite applications to hurricane intensity forecasting. CoRP Science Symposium, July 23-24, Madison, WI.

Upgrades to the Operational Monte Carlo Wind Speed Probability Program (NA13OAR4590190)

Schumacher, A.B. and M. DeMaria, 2014: Upgrades to the operational Monte Carlo Wind Speed Probability Program, Tropical Cyclone Research Forum / 68th Interdepartmental Hurricane Conference, 3-6 March 2014, Miami, FL.

Utility of GOES-R Instruments for Hurricane Data Assimilation and Forecasting (NA10NES4400012)

Apodaca, K., M. Zupanski, M. DeMaria, J. A. Knaff, and L. D. Grasso, 2013: Assessing the impact of lightning observations in a hybrid data assimilation system. The Sixth WMO Symposium on Data Assimilation, October 7-11, 2013, College Park, MD.

Zhang, M., M. Zupanski, and J. A. Knaff, 2013: Direct assimilation of al-sky SEVIRI IR10.8 radiances in TC core area using an ensemble-based data assimilation method. The Sixth WMO Symposium on Data Assimilation, October 7-11, 2013, College Park, MD.

Zupanski, M., 2013: Extracting maximum information from GOES-R ABI and GLM instruments in regional data assimilation applications to high-impact weather. Joint Centers for Satellite Data Assimilation Seminar, June 4, 2013, NCWCP, College Park, MD.

Zupanski, M., 2013: Utility of GOES-R ABI and GLM instruments in regional data assimilation for high-impact weather. JCSDA Science Workshop on Satellite Data Assimilation, June 5-7, 2013, NCWCP, College Park, MD.

Zupanski, M., K. Apodaca, and M. Zhang, 2013: Utility of GOES-R Geostationary Lightning Mapper (GLM) using hybrid variational-ensemble data assimilation in regional applications. Warn-on-Forecast and High-Impact Weather Workshop, Feb 6-7, 2013, National Weather Center, Norman, OK.

CIRA EMPLOYEE MATRIX

Employees who received 50% support or more		Degree				
Category	**Number**	**Doctorate**	**Masters**	**Bachelors**	**Associates**	**Non-Degreed**
Research Scientists	26	26	0	0	0	0
Visiting Scientists	0	0	0	0	0	0
Postdoctoral Fellows	7	7	0	0	0	0
Research Support Staff*	78	6	28	30	0	14
Administrative Personnel	6	1	2	3	0	0
Total	117	40	30	33	0	14

Employees who received less than 50% support	Degree				
Number	**Doctorate**	**Masters**	**Bachelors**	**Associates**	**Non-Degreed**
61	20	13	19	0	9

Students who received less than 50% support		Degree		
Category	**Number**	**Doctorate**	**Masters**	**Bachelors**
Undergraduate	5	0	0	5
Graduate	6	0	6	0
Total	11	0	6	5

Employees located at NOAA Laboratories		GSD	MDL	PSD	GMD	NGDC	AWC
Total	64	48	1	1	4	2	8

Obtained NOAA Employment within the last year	
Total	3

***Equivalent to Research Associate in CIRA/CSU parlance**

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2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
A Collaborative Effort to Improve Geostationary Products of Hydrologic Variables	Yonsei Univ	5-367420	Kummerow	x						
A Study of Precipitation Motion Using Model Winds	NOAA	5-311250	Kidder	x						
A Global High-resolution fossil fuel CO2 Inventory Built From Assimilation of in situ and Remotely-sensed Datasets to Advance Satellite Greenhouse Gas	NASA	5-355320	Baker		x		x			
A Multisensor 4-D Blended Water Vapor Product for Weather Forecasting	NASA	5-319490	Kidder, Forsythe, Jones				x			
AFWA Coupled Assimilation and Prediction System Development at CIRA	UCAR/ NCAR	5-319380	Jones, Fletcher	x	x	x	x			
Algorithm Development for AMSR-2	NOAA	5-312790	Kummerow	x						
Analyzing the Impacts of Non-Gaussian Errors in Gaussian Data Assimilation Systems	NSF	5-346920	Fletcher			x				
Application of "A-Train" Satellite Observations to Support Decision Support Systems for Operational Aviation Weather Products (NASA)	NASA	5-319070	Miller	x						
Application of JPSS Imagers and Sounders to Tropical Cyclone Track and Intensity Forecasting	NOAA	5-311270	Miller				x			
Assistance for Instrument Development to Measure the Relationship of Air Quality with Night Sky Visibility	NPS	5-341840	Hand			x				

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
Assistance for Night Sky Visibility Data Collection, Analysis and Presentation and Web-based Environmental Database Supporting Air Resource Management	NPS	5-317040	Hand					x		
Assistance for Visibility Data Analysis and Image Display Techniques	NPS	5-341070/ 5-310940	Hand		x			x		
CIRA Collaboration with ESRL Physical Science Division Hydrologic Research and Water Resources Applications Outreach Coordination	NOAA	5-312870	Matsumoto				x			
CIRA Contributions in Formulating GeoCARB	Lockheed	5-363680	Polonsky	x						
CIRA Data Processing Center Support for the CloudSat Mission	JPL	5-339760	Miller					x		
CIRA Research Collaborations with the NWS Meteorological Development Lab on AutoNowcaster and AWIPSII Projects	NOAA	5-311150	Matsumoto					x		
CIRA Research Collaborations with the NOAA Earth System Research Lab/Global Monitoring Division on Carbon Tracker Model Enhancements	NOAA	5-312760	Baker			x				
CIRA Support for Feature-based Validation of MIRS Soundings for Tropical Cyclone Analysis and Forecasting	NOAA	5-311160	Dostalek	x						
CIRA Support for Transition of Tropical Cyclone Forecast Products	NOAA	5-312490	Schumacher	x						
CIRA Support of NOAA's Commitment to the Coordination Group for Meteorological Satellites: Enhancing the International Virtual Laboratory	NOAA	5-312680	Connell	x						x
CIRA Support of the Virtual Institute for Satellite Integration Training (VISIT)	NOAA	5-312560	Bikos, Connell	x						

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
CIRA Support to GOES Improvement and Product Assurance Program	NOAA	5-311190	Miller	x						
CIRA Support to GOES-R Proving Ground for National Weather Service Forecaster Readiness	NOAA	5-312570	Miller, Brummer	x						
CIRA Support to JPSS Science Program: NPP VIIRS EDR Imagery Algorithm and Validation Activities and NPP VIIRS Cloud Validation	NOAA	5-311240	Miller				x			
CIRA Support to Production of Real-time Nested NAM-based GOES-R Synthetic Imagery	NOAA	5-312930	Grasso, Noh	x						
CIRA Support to Research and Development for GOES-R Risk Reduction for Mesoscale Weather Analysis and Forecasting and Analysis of Simulated Radiance Fields for GOES-R ABI Bands for Mesoscale Weather and Hazard Events	NOAA	5-312740	Miller	x						
CIRA Support to the CASA Dallas Fort Worth Urban Demonstration Network	NOAA	5-312810	Chandra V.					x	x	
CIRA Support to the JPSS Proving Ground and Risk Reduction Program	NOAA	5-311220	Miller	x						
CIRA Support to Tropical Cyclone Model Diagnostics and Product Development	NOAA	5-312070	Schubert		x					
Climate Science Connections to Vulnerability Assessments	USGS	5-346930	Liston		x					

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
CoCoRaHs: Capitalizing on Technological Advancements to Expand Environmental Literacy Through a Successful Citizen Science Network (Competitive)	NOAA	5-311010	Doesken				x			x
Collaborative Research - AON: A Snow Observing Network to Detect Arctic Climate Change - SnowNet II	NSF	5-338800	Liston, Hiemstra				x			
Collaborative Research: Sensitivity of Regional Climate Due to Land-Cover Changes in the Eastern U.S. Since 1650	NSF	5-345940	Lu				x			
Collaborative Research: Linking Inuit Knowledge and Synoptic- to Local-scale Meteorology to Investigate Changing Winds and Human Impacts at Clyde River, Nunavut	NSF	5-336100	Liston				x			
Data Warehouse for Air Quality Modeling in the Oil and Gas Region of Wyoming, Utah, and Colorado	NPS	5-341820	McClure			x		x		
Design, Development, Evaluation, Integration and Deployment of New Weather Radar Technology	NOAA	5-312770	Chandra V.				x			
Development of a Probabilistic Tropical Cyclone Prediction Scheme (Competitive)	NOAA	5-312890	Schumacher	x						
Development of a Real-Time Automated Tropical Cyclone Surface Wind Analysis (Competitive)	NOAA	5-312850	Brummer				x			

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
DoD Center for Geosciences/Atmospheric Research at CSU	DoD		Vonder Haar	x		x	x	x		
Downscaling NCEP Global Climate Forecast System (CFS) Seasonal Predictions for Hydrologic Applications Using Regional Atmospheric Modeling System (RAMS) (CU/CIRES)	CU/ CIRES	5-311130	Lu		x	x	x			
EAGER: Collaborative Research: Interoperability Testbed-Assessing a Layered Architecture for Integration of Existing Capabilities	NSF	5-312840	Matsumoto					x		
Effective Collaborative NIDIS Drought Monitoring and Early Warning in the Upper Colorado River Basin	NOAA	5-311280	Doesken				x	x	x	x
Enabling the Use of NASA and NAAPS Products in the Air Quality Decision-making Processes Involved in Daily Forecasting, Exceptional Event Analysis, and Development of Standards	NASA	5-319010	McClure			x		x		
Ensemble Data Assimilation for Nonlinear and Nondifferentiable Problems in Geosciences	NSF	5-331190	Zupanski, Zupanski			x				
Ensemble-based Assimilation and Downscaling of the GPM-like Satellite Precipitation Information	NASA	5-365100	Zupanski, D.			x				
Environmental Applications Research	NOAA	5-312500	Matsumoto		x	x	x	x		x

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
eTRaP Upgrade - Shear, Topography, Storm Rotation, and Rainfall Climatology & Persistence Model (R-CLIPER)	NOAA	5-311200	Kidder	x			x			
Fine-resolution CO2 Flux Estimates from AIRS and GOSAT CO2 Retrievals: Data Validation and Assimilation	NASA	5-319030	Baker	x	x	x				
Getting Ready for NOAA's Advanced Remote Sensing Programs A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal	NOAA	5-312540	Connell	x						
GOES-CARB: A Framework for Monitoring Carbon Concentrations and Fluxes	NASA	5-315270	Baker		x					
Guidance on Intensity Guidance	NOAA/ JHT	5-391050	Schumacher		x					
Impact Assessment and Data Assimilation of NOAA NPP/JPSS Sounding Products and Quality Control Parameters	NOAA	5-312830	Fletcher			x				
Impact Assessment of Cloud-affected AMSU-A Radiance Assimilation in TC Inner-core Region Using Hybrid Data Assimilation Approaches	UCAR/ NCAR	5-367930	Zhang			x				
Improvements in Statistical Tropical Cyclone Forecast Models (Competitive)	NOAA	5-312780	Brummer	x						
Improvements to Background Error Covariances and Moisture Representation in the Navy's Data Assimilation System	NRL	5-372380	Fletcher			x				

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
Improving CarbonTracker Flux Estimates for North America Using Carbonyl Sulfide (OCS)	NOAA	5-389740	Baker, Ian		x					
Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models (Competitive)	NOAA	5-312940	Maloney				x			
LAPS and WRF Model Setup and Evaluation for Applications to Toyota Racing	Toyota Racing Div	5-389760	Matsumoto							x
Legacy Atmospheric Sounding Data Set Project	NOAA	5-312750	Johnson					x		x
Modeling of Snow Drift and Mapping of Polar Bear Dens	NPI	5-367430	Liston				x			
NEAT Expanded	NOAA	5-311260	Miller	x						
NEAT: NESDIS Environmental Applications Team	NOAA	5-311080	Miller	x	x		x			
New Statistical Dynamical Intensity Forecast Models for the Indian Ocean and Southern Hemisphere	JTWC	5-324650	Schumacher	x						
North American Regional-scale Flux Estimation and Observing System Design for the NASA Carbon Monitoring System	NASA	5-365680	O'Dell			x				
Orbiting Carbon Observatory (OCO-2) Task	JPL	5-319950	O'Dell	x						
POES-GOES Blended Hydrometeorological Products	NOAA	5-311180	Kidder, Jones, Forsythe			x	x	x		

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
Quantifying the Source of Atmospheric Ice Nuclei from the Biomass Burning Aerosols (Competitive)	NOAA	5-312700	DeMott				x			
Quantitative Precipitation Estimation (QPE)	NOAA	5-312260	Chandra V.				x			
RAMMB Infrastructure for Product Development Demonstration and Operational Transition at CIRA/CSU	NOAA	5-312670	Connell	x						
Real-time Mexico-Central American & African Multi-satellite Precipitation Products and Distribution for Agricultural Use and Disease Mitigation Activities	BM Gates Foundation	5-378520	Jones	x				x		
Research Collaboration at the NWS Aviation Weather Center in Support of the Aviation Weather Testbed, Aviation Weather Research Program, and the NextGen Weather Program	NOAA	5-312800	Matsumoto		x	x		x		
Research to Advance Climate and Earth System Models Collaborative Research: A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models	NOAA	5-390150	Randall		x		x			
Research Collaboration with the Aviation Weather Testbed in Support of the NWS NextGen Weather Program	NOAA	5-311040	Matsumoto		x	x		x		
Satellite Meteorological Application Research, Development and Technical Support	NRL	5-372130	Miller	x						
Satellite Techniques for Improving the Accuracy of Solar Forecasting	NCAR (DoE)	5-325180	Miller	x						

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
Scientific Support to the GOES-R Algorithm Review Board	NOAA	5-312640	Vonder Haar	x						
SEMAP - Southeastern Modeling, Analysis, and Planning Project	GIT	5-347810	McClure					x		
Severe Weather/Aviation Impact from Hyperspace Assimilation	NOAA	5-312710	Matsumoto		x	x				
Snow Datasets for Arctic Terrestrial Applications	FWS	5-325820	Liston		x					
SSMI and SSMIS Fundamental Climate Data Record Sustainment and Maintenance	NOAA	5-370260	Kummerow, Berg, Alvarez					x		
Summer School on Atmospheric Modeling	NOAA	5-311100	Randall							x
Tasks Related to Technical Support of the WMO-GGMS Virtual Lab for Education and Training	WMO	5-365740	Connell	x						
The Role of the Vertical Distribution of Clouds in the Atmospheric Energetics	NASA	5-319310	Vonder Haar				x			
Towards Assimilation of Satellite, Aircraft, and Other Upper-air CO_2 Data into CarbonTracker	NOAA	5-377190	Baker, D.			x				
Tropical Cyclone Model Diagnostics and Product Development	NOAA/ NESDIS	5-322001	Schubert		x					
Upgrades to the Operational Monte Carlo Wind Speed Probability	NOAA/JHT	5-391060	Schumacher		x					
Use of the Ocean-Land-Atmosphere Model (OLAM) with Cloud System-resolving Refined Local Mesh to Study MJO Initiation	NOAA	5-388460	Maloney				x			

2013-2014 NOAA and Other Funding Project Theme Maxtrix

TITLE	Agency	Project #	PI	Satellite Algorithm Development, Training and Education	Regional to Global Scale Modeling Systems	Data Assimilation	Climate-Weather Processes	Data Distribution	Societal/Economic Impact Studies	Education and Outreach
Utility of GOES-R Instruments for Hurricane Data Assimilation and Forecasting (Competitive)	NOAA	5-311210	Zupanski, M, Zupanski, D., Grasso			x				
Variability in Snow Sublimation Across Basin Scale Systems	NOAA	5-311090	Doesken				x			
Weather Satellite Data and Analysis Equipment and Support for Research Activities	NOAA	5-312580	Kummerow					x		
Web-based Environmental Database Supporting Air Resource Management in National Park and Forest Service Lands	NPS	5-341970	Hand			x		x		
Wildland Fire Behavior and Risk Forecasting	NASA	5-325490	Schranz	x	x			x		

Other Agency Awards 2013/14
(Sorted by Awarding Agency)

PI	Title	Lead NOAA Collaborator	Awarding Agency	Total Funding Amount
Baker	A Global High-resolution Fossil Fuel CO_2 Inventory Built from Assimilation of in situ and Remotely-sensed Datasets to Advance Satellite Greenhouse Gas	No	Arizona State (NASA)	$37,268
Jones	Real-time Mexico-Central American & African Multi-satellite Precipitation Products and Distribution for Agricultural Use and Disease Mitigation Activities	No	BM Gates Foundation	$51,270
Lu	Downscaling NCEP Global Climate Forecast System (CFS) Seasonal Predictions for Hydrologic Applications Using Regional Atmospheric Modeling System (RAMS)	(NOAA-funded CPPA Program)	CU, CIRES	$116,644
Vonder Haar	Five Year Cooperative Agreement for Center for Geosciences/ Atmospheric Research	No (Mark DeMaria, RAMMB Co-advises a post doc on one project)	Department of Defense	$2,363,000
Fletcher	Improvements to Background Error Covariances and Moisture Representation in the Navy's Data Assimilation System	No	Department of Defense/ NRL	$200,000
Liston	Snow Datasets for Arctic Terrestrial Applications	No	FWS	$125,000
McClure	SEMAP-Southeastern Modeling, Analysis, and Planning Project	No	GIT	$53,900
Miller	CIRA Data Processing Center Support for the CloudSat Mission	No	JPL	$90,348
O'Dell	Orbiting Carbon Observatory (OCO-2) Task	No	JPL	$300,000
Schumacher	New Statistical Dynamical Intensity Forecast Models for the Indian Ocean and Southern Hemisphere	Mark DeMaria/ John Knaff, NOAA/NESDIS/STAR	JTWC	$97,920
Polonsky	CIRA Contributions in Formulating geoCARB	No	Lockheed Martin	$129,980

Other Agency Awards 2013/14
(Sorted by Awarding Agency)

Baker	Fine Resolution CO_2 Flux Estimates from AIRS and GOSAT CO_2 Retrievals: Data Validation and Assimilation	No	NASA	$194,778
Kidder, Forsythe, Jones	A Multisensor 4-D Blended Water Vapor Product for Weather Forecasting	Working with Sat Anal. Branch	NASA	$41,161
McClure	Enabling the Use of NASA and NAAPS Products in the Air Quality Decision-making Processes Involved in Daily Forecasting, Exceptional Event Analysis, and Development of Standards	No	NASA	$65,985
Miller	Application of 'A-Train' Satellite Observations to Support Decision Support Systems for Operational Aviation Weather Products	No	NASA	$75,000
O'Dell	North American Regional-scale Flux Estimation and Observing System Design for the NASA Carbon Monitoring System	No	NASA	$25,000
Schranz	Wildland Fire Behavior and Risk Forecasting	No	NASA	$163,022
Vonder Haar	The Role of the Vertical Distribution of Clouds in the Atmospheric Energetics	No	NASA	$32,713
Zupanski	Ensemble-based Assimilation and Downscaling of the GPM-like Satellite Precipitation Information	No	NASA	$91,989
Baker	GOES-CARB: A Framework for Monitoring Carbon Concentrations and Fluxes	No	NASA (via Pawson)	$220,000
Miller	Satellite Techniques for Improving the Accuracy of Solar Forecasting	No	NCAR (DoE)	$80,348
Liston	Modeling of Snow Drift and Mapping of Polar Bear Dens	No	NPI	$52,916
Hand	Assistance for Instrument Development to Measure the Relationship of Air Quality with Night Sky Visibility	No	NPS	$160,872

Other Agency Awards 2013/14
(Sorted by Awarding Agency)

Hand	Assistance for Night Sky Visibility Data Collection, Analysis and Presentation and Web-based Environmental Database Supporting Air Resource Management in National Park and Forest Service Lands	No	NPS	$339,999
Hand	Assistance for Visibility Data Analysis and Image Display Techniques	No	NPS	$814,101
Hand	Assistance for Visibility Data Analysis and Image Display Techniques	No	NPS	$972,903
Hand	Web-based Environmental Database Supporting Air Resource Management in National Park and Forest Service Lands	No	NPS	$90,000
McClure	Data Warehouse for Air Quality Modeling in the Oil and Gas Regions of Wyoming, Utah, and Colorado	No	NPS	$215,850
Miller	Satellite Meteorological Application Research, Development, and Technical Support	No	NRL	$223,000
Fletcher/ Jones	Analyzing the Impacts of Non-Gaussian Errors in Gaussian Data Assimilation Systems	No	NSF	$191,390
Liston	Collaborative Research: Linking Inuit Knowledge and Local-scale Environmental Modeling to Evaluate the Impacts of Changing Weather on Human Activities at Clyde River, Nunavut	No	NSF	$136,036
Liston, Hiemstra	Collaborative Research: AON A Snow Observing Network to Detect Arctic Climate Change-Snow Net II	No	NSF	$409,463
Lu	Collaborative Research: Sensitivity of Regional Climate Due to Land-cover Changes in the Eastern U.S. Since 1650	No	NSF	$390,639
Matsumoto	EAGER: Collaborative Research: Interoperability Testbed-Assessing a Layered Architecture for Integration of Existing Capabilities	No	NSF	$17,972

Other Agency Awards 2013/14
(Sorted by Awarding Agency)

Zupanski, Zupanski	Ensemble Data Assimilation for Nonlinear and Nondifferentiable Problems in Geosciences	No	NSF	$399,056
Matsumoto	LAPS and WRF Model Setup and Evaluation for Applications to Toyota Racing	No	Toyota Racing Division	$24,925
Jones, Fletcher	AFWA Coupled Assimilation and Prediction System Development at CIRA	No	UCAR/ NCAR	$49,630
Zhang	Impact Assessment of Cloud-affected AMSU-A Radiance Assimilation in TC Inner-core Region Using Hybrid Data Assimilation Approaches	No	UCAR/ NCAR	$11,502
Liston	Climate Science Connections to Vulnerability Assessments	No	USGS	$24,927
Connell	Tasks Related to Technical Support of the WMO-GGMS Virtual Lab for Education and Training	Mark DeMaria, NOAA/NESDIS/STAR	WMO	$38,462
Kummerow	A Collaborative Effort to Improve Geostationary Products of Hydrologic Variables	No	Yonsei University	$28,087

COMPETITIVE PROJECTS

1--CoCoRaHS: Capitalizing on Technological Advancements to Expand Environmental Literacy Through a Successful Citizen Science Network

2--Development of a Probabilistic Tropical Cyclone Prediction Scheme

3--Development of a Real-time Automated Tropical Cyclone Surface Wind Analysis

4—Guidance on Intensity Guidance

5--Improvements in Statistical Tropical Cyclone Forecast Models

6—Improving CarbonTracker Flux Estimates for North America Using Carbonyl Sulfide (OCS)

7--Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models

8--Quantifying the Source of Atmospheric Ice Nuclei from Biomass Burning Aerosols

9—Research to Advance Climate and Earth System Models Collaborative Research: A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models

10—Towards Assimilation of Satellite, Aircraft, and Other Upper-air CO_2 Data into CarbonTracker

11—Tropical Cyclone Model Diagnostics and Product Development

12—Upgrades to the Operational Monte Carlo Wind Speed Probability Program

13—Use of the Ocean-Land-Atmosphere Model (OLAM) with Cloud System-resolving Refined Local Mesh to Study MJO Initiation

14--Utility of GOES-R Instruments of Hurricane Data Assimilation and Forecasting

COMPETITIVE PROJECT TITLE: CoCoRaHS: Capitalizing on Technological Advancements to Expand Environmental Literacy Through a Successful Citizen Science Network (NA10SEC0080012)

The following is the report previously submitted to the Technical Sponsor.

NOAA Office of Education

Semi-Annual Project Progress Report

The following is a summary of the information that your semi-annual progress reports to NOAA's Office of Education should contain. Please contact your program officer (oed.grants@noaa.gov) if you have any questions.

- **OVERVIEW**
  - Award Number: NA10SEC0080012
  - Award Title: Capitalizing on Technological Advancements to Expand Environmental Literacy through a Successful citizen Science Network
  - Funded Institution: Colorado State University
    - Congressional District of Funded Institution: Colorado 2nd District
    - Total Annual Visitorship to Funded Institution (if applicable)_____NA_______visitors/year
    - Annual Visitorship to NOAA-funded Exhibit (if known): ____NA_______visitors/year
  - PI Name: Nolan Doesken

    Phone: 970-491-3690 or 970-491-8545

    Email: Nolan@atmos.colostate.edu
  - Project Website (if applicable): http://www.cocorahs.org
  - Award Period: From 10/1/2010 To 9/30/2013
  - Period Covered by this Report: From 4/1/2013 To 9/30/2013

- **PROGRESS**

    - Please provide a narrative description of activities undertaken and accomplishments achieved during the period covered by this progress report.

Lots went on during this period as the number of active volunteers in CoCoRaHS continued to grow. The weather provided ample opportunities for participants to measure, report, share data and learn. The "highlight" came September 9-16 in Colorado, New Mexico and Wyoming when heavy rains poured down on the region of the country with some of the highest concentration of long-time volunteers. Over 1150 volunteers sent in rainfall reports in Colorado during and after the storm, with nearly 500 reports from New Mexico. This allowed rapid and accurate mapping of one of the heaviest late-summer/early autumn rains in Colorado history and will provide storm documentation supporting meteorological and hydrologic research and input for design, construction, planning (and probably litigation, too) for many years to come. We are already planning a collaborative effort with the Denver Museum of Nature and Science to support their efforts to develop dome visualizations for their planetarium for this unusual storm. In so many ways this is a living example of why we continue to be motivated and passionate about CoCoRaHS.

We continued to make progress on nearly all aspects of the project – but we still lag behind on some of the cyberinfrastructure enhancements that we've long envisioned. We did submit a request for a no-cost extension for the project and this was granted. We are very pleased to have this extra time to complete more of the original proposed work, add more new volunteers and training resources and to complete a comprehensive summative evaluation.

The CoCoRaHS project team was recently notified by the president of the American Meteorological Society that the project has been selected to receive the AMS 2014 "Special Award". This is indeed an honor for all of us including our NOAA sponsors.

Further description of our recent progress is presented in the following sections. Categories of activities are based on the "Citizen Science Toolkit" that provide a logical framework for tracking activities and accomplishments.

Refine Protocols

We are preparing to introduce an option for reporting and viewing precipitation in metric units. This is consistent with the needs of the scientific research community, international opportunities and education interests. It will introduce an additional challenge, however, and the opportunity for a new type of data entry error. Implementation has been slower than expected as it involves nearly every aspect of every page of the existing website.

We continued to work on the conversion of our "Significant Weather" reporting protocol to "Storm Reports" consistent with the current direction of the National Weather Service. Our formats should end up being interchangeable. We will continue to request more detailed hail, freezing rain and heavy precipitation documentation than the NWS online reporting system in order to support research opportunities and educational programs.

Implementation of protocol modifications, including changes to snow measurement terminology described in the previous report, is contingent on the launch of the new CoCoRaHS website. This continues to be a long and slow process.

We have attempted to engage the forestry community in providing guidance for an acceptable protocol for gathering and reporting freezing rain information. For now, this will continue as an informal protocol. A training animation was recently developed and will be posted on our CoCoRaHS YouTube channel soon.

Recruit Participants

Passive and active recruiting continued with a total of 2,944 new volunteers signed up during this 6-month period (April-Sept). Sixty-seven percent (1,965) of these new recruits have begun reporting precipitation data as of late October 2013, a small improvement over previous reporting periods. We have never been able to achieve a higher participation rate than 60-70% of those that sign up.   It would seem that once a candidate jumps the hurdle of the CoCoRaHS sign up and registration process that it would be easy from there on. The cost of the rain gauge and the effort to get it installed is still a significant barrier. Also, since nearly all the registration process is done online, some fraction of applicants never get our messages – possibly due to their SPAM filtering.)

We continue to utilize many approaches to recruiting. National Weather Service spring "Skywarn" training programs continue to yield results as do social media and traditional print media. We track from each new application how people learned about CoCoRaHS. About 2/3 of all applicants choose to fill out that optional field. We see many and varied answers, but "word of mouth" from existing volunteers is a growing sector. Also, a number of college and K-12 classes in various states have made CoCoRaHS participation a class project. That's fun to see, although it only results in short-term participation.

Noah Newman, Education Coordinator, has continued to pursue targeted recruiting in the areas of professional ballparks (specifically the gardens that the concession companies are highlighting at select ballparks), community based gardens in urban areas, and science centers/zoos/aquariums. Limited success has occurred, but promising outcomes at science centers could be in the future as these partnerships are nurtured. The Wyoming CoCoRaHS coordinator continued an aggressive statewide recruiting campaign and added dozens of new volunteers including some in very remote areas. Extreme weather also provides opportunities for recruiting. After the recent Colorado floods in September 2013 many new volunteers signed up. An urban garden initiative has begun to yield results including in New York City.

Train Participants

Training new recruits is an ongoing function. A few state, regional and county volunteer coordinators do local face-to-face group and individual training sessions for new volunteers. We recently re-enlisted a former volunteer coordinator for the Denver, Colorado area and he conducted 14 training sessions during this 6-month period. This paid off in September as dozens of new observers had been trained and ready when the big rains hit Colorado.

The vast majority of training is unmonitored and takes place utilizing our various on-line options. Based on the quality of data being reported, we are assuming that our training materials and optional approaches are working. This includes animations, videos, slide shows, webinars, and traditional written instructions. We do not require participants to document what type of training they choose and we get very little unsolicited feedback. We do not currently monitor how much time they spend in training, and how satisfied they are with the training materials and options provided. We may want to include this topic in our upcoming participant survey that will be part of our summative evaluation.

The CoCoRaHS staff has all come to greatly appreciate the efficient learning that seems to accompany our animated training modules. It takes less time and fewer words to accomplish training goals. We only introduced one new episode during the past 6 months providing instruction on how to measure and report extreme rainfall amounts. This animation was nearly complete when the Colorado floods occurred in September 2013. We fast-tracked the completion and posted it quickly on the CoCoRaHS YouTube channel.   http://www.youtube.com/cocorahs/ . The number of YouTube training animations "views" are modest – fewer than we wish; on the order of a few hundred views per month. But the quality of data provided by volunteers continues to be excellent, suggesting that volunteer training is working well – or at least well enough.

Noah Newman, Education Coordinator, conducted 24 separate events concerning training participants (or potential participants) on how to read the gauge and report data to CoCoRaHS. Of these 24 events, some were specific school visits where multiple presentations to multiple classes were conducted in the same day (counting as 1 event), while others were hosting booths showcasing CoCoRaHS or small tours of the CSU campus weather station. A total of 1,460 people were reached in this period.

Training is not limited to instructions on how to measure and report precipitation. We also provide topical learning opportunities through the “Message of the Day”, the monthly newsletter called “the Catch” and through our Wx-Talk Webinar educational series.

Here is the list of webinars from the past 6 months – each featuring a nationally known expert on the topic. In some cases, the expert presenter is also a CoCoRaHS volunteer. Of these topical webinars, the ones on tornadoes and rain water catchment had the highest attendance with over 200 in attendance for the live sessions and similar numbers viewing the videos later.

Webinar #17 - Thursday, April 18, 2013
Forecasting the Ferocious: The How, What, Where and Why of Tornadoes
Greg Carbin, NOAA/Storm Prediction Center, Norman, OK

Webinar # 18 - Thursday, May 9, 2013
At the Cutting Edge: Harry Wexler and the Emergence of Atmospheric Science
Jim Fleming, Colby College, Waterville, ME

Webinar #19 - Thursday, June 13, 2013
Monitoring the Earth's Climate
Deke Arndt, NOAA/National Climatic Data Center, Asheville, NC

Webinar #20 - Thursday, July 25, 2013
Rainwater Harvesting - Catching and Using It
Billy Kniffen, Vice President and Education Coordinator, American Rainwater Catchment Systems Association (ARCSA), Menard, TX

Webinar #21 - Thursday, August 15, 2013
Atlantic basin seasonal hurricane prediction and the forecast for the 2013 Atlantic hurricane season
Phil Klotzbach, Colorado State University, Fort Collins, CO

Webinar #22 - Thursday, September 12, 2013
The Hundred Hunt for the Red Sprite
Walt Lyons, FMA Research, Inc., Fort Collins, CO

Speakers are already lined up for the next 6 months with topics ranging from cloud seeding and atmospheric rivers to aviation weather and highlights of 2013. The content of each webinar so far has been exceptional. Others tell us that our webinar attendance is excellent for long sessions like these (often at least 75 minutes including Q&A, but we really wish we could attract larger audiences to take advantage of these fantastic programs. We will be strategizing how to do so in the coming months.

Our educational animation “The Water Cycle”, which targets an important aspect of climate literacy, continues to get hundreds of hits per day on YouTube and has had over 100,000 views. The success of these CoCoRaHS animations has resulted in our animator being hired to do educational animations for the University Corporation for Atmospheric Research (UCAR) and for the Colorado Water Institute.

Not nearly so visible, but every bit as important is the training that takes place at our CoCoRaHS help desk staffed by Zach Schwalbe and by our data quality specialist, Peter Goble. Together they handle hundreds of questions each week with personalized responses. It is wonderful to be able to provide this level of individual support for our large community of volunteers and hope we can continue this service.

Accept Data

CoCoRaHS is good at accepting data. Participation in data collection remains high. New records for the number of daily precipitation reports were set during the past 6 months with typically more than 11,000 reports received per day beginning in May and continuing all summer. For the first time, the 12,000 mark was reached on September 12. During the past 6 months a total of 17,933 reporting stations contributed a total of over 2 million daily precipitation observations, 1955 hail reports, 4032 significant weather reports, 492 drought impact reports and 15,340 daily evapotranspiration (ET) reports. The number of ET reports have been steadily increasing. The number of drought impact reports was much less this year compared to the same period last year, but the difference is consistent with the greater precipitation amounts (less drought) this year compared to last. The number of hail reports was 8% lower than the same time last year, but this may not have been a strict indication that less hail fell this year. There is some evidence that the diligence in hail reporting has diminished somewhat. Many report hail in the "comments" section of their regular daily precipitation report but do not fill out the specific hail report. We will be considering this as we move forward. It will be very interesting to see if our proposed new "Storm Report" protocol may encourage more reporting next year. CoCoRaHS hail data provide a unique and detailed assessment of hail storm characteristics not obtained from any other data set, and deserves attention and encouragement.

We continue to employ Peter Goble to assist with data quality assessment. While most precipitation reports are fine, we are always enrolling new volunteers and are always experiencing some number of erroneous data entries each day. Many of the types of errors are known and predictable (decimal errors, false zeros, etc.) but are hard to completely overcome. Summer is the easy season for data checking. Winter, with dark mornings, snow and cold, is a much more challenging time. Peter has enrolled in the Master's program in our department (Atmospheric Science) and some changes in our QC process may be required in the coming months. Many of our state and regional volunteer coordinators also help with data quality evaluation. We have a very active "QC Committee" that uses an e-mail listserv and periodic web meetings to continue to advance the practice of data quality control. Our volunteer coordinators in Illinois (Steve Hilberg) and Wyoming (Tony Bergantino) have donated countless hours to this cause. Preserving high quality data, even from such a diverse volunteer network, remains essential. It adds greatly to the scientific use and credibility of the CoCoRaHS precipitation data resource.

Upgrades to the CoCoRaHS cyber-infrastructure have continued over the last six months. The performance tests of cloud service providers were completed. The conclusion was, that based on CoCoRaHS' performance needs and resource limitations, that a dedicated hosting environment would most likely provide the optimum combination of performance, reliability, and affordability. To this end, the primary database, which had previously been moved from a shared environment to a dedicated virtual server, has been moved to a dedicated server. This has enabled the CoCoRaHS database and dependent web applications to handle continued growth and larger bulk export requests. It also enables full control of the system hardware and software to tune the system to support the various demands on the system. Those include daily spikes in demand as most observers use the site over the same six hour window each day, as well as the load generated from data users, like NOAA, who export millions of observations on a nightly basis and the entire archive weekly.

The total number of archived daily observations is now over 22 million, with the rate of growth steadily increasing. All of the web applications, with the exception of the primary web application (which is scheduled to be replaced by an internationalized version), have been moved to the dedicated hosting environment. The coming internationalized website has been demoed (demonstrated), and will feature support for smartphones and tablets, as well as improvements to the structure of the increasing amount of training and educational content. An early version of the Web API that will be used by mobile app developers has been put into production. Internal development of mobile applications for iOS, Android, and Windows Phone 7 has begun, and is using the same Web API.

Analyze Data

We did not add any significant data analysis tools or features during this reporting period. Instead, we just added more data and more participants (potential data analysts). However, there was one very important indirect accomplishment. The PRISM Climate Group at Oregon State University who developed the PRISM CoCoRaHS climate portal last year, just released a new precipitation mapping system presenting daily precipitation maps for the lower 48 states in a vivid color scheme. Some of the first examples of these daily maps came out in late summer. The systematic daily production process began in September 2013. While this is not a part of CoCoRaHS per se, we benefit greatly. We can take some credit since CoCoRaHS precipitation data is the largest single source for daily gauge measurements going into the mapping system. When we recently announced this mapping tool, several thousand of our volunteers clicked on the PRISM link to take a look. This satisfies a very strong need expressed both by our volunteer participants and users of CoCoRaHS data. We are very pleased, indeed, to partner with PRISM in this way.

Other ongoing data analysis activities include:

“Water Balance Charts” http://www/cocorahs.org/ViewData/StationWaterBalanceChart.aspx

2013 Water Year summaries covering the period October 1, 2012 – September 30, 2013 http://www.cocorahs.org/WaterYearSummary/ . This is now our 4th year of producing these comprehensive reports for all stations.

Continuing to improve database and website performance to enable many and varied data analysis queries such as total precipitation summary reports, station summaries, and various data “sorts” for longer periods and larger areas. The better our system performs, the more we are able to encourage “inquiry” by our volunteers.

CoCoRaHS is also contributing to data analysis on a much broader scale. Since CoCoRaHS data became accessible through NOAA’s National Climatic Data Center “Global Historical Climate Network” and through ACIS – the “Applied Climate Information System” now CoCoRaHS data can be integrated into nearly all precipitation data analysis and research activity utilizing NOAA data.

Disseminate Results

CoCoRaHS shares data, information and research results with our participants in a variety of ways. We also routinely share data, information and expertise with research and operational users plus a broader public of web users.

Our primary methods of dissemination to our community of participants continue to be our website, our “Message of the Day”, our Blog (thanks to our state coordinator from Illinois, Steve Hilberg) and our e-newsletter (“The Catch”). At long last, we migrated our mailing list to “MailChimp” to manage e-mail communication for our list of about 30,000 current participants and members. This transition now allows for more pleasing formatting of Nolan’s e-mail messages, encourages embedded graphics, makes it easier to use the table of contents to move through these large newsletters and makes it easy to document “Opens” and link “Clicks”. So far, the response to this upgrade has been very positive.

The CoCoRaHS Social Networking channels continue to grow. Our Facebook followers as of 30 September 2013 total 4,448. Twitter followers grew by 579 to 1994. The CoCoRaHS “Map of the Day” has become a popular regular social media feature where we point out parts of the country (down to a state or county level) that have experienced particularly interesting precipitation patterns. There is something to show and learn every day, and that reinforces the need for continuous and dedicated monitoring.

Our YouTube channel activity has been as follows:
WxTalk Webinars: 5 new webinars posted with 908 new views.
Animations: The ‘Water Cycle’ animation continues to be the top viewed video with over 100,000 views.
Snow Training Animations: 7 videos with a total of 11,981 views for all videos combined
Total CoCoRaHS YouTube channel subscribers 469

CoCoRaHS data export remains popular. NOAAs NWS Forecast Offices and River Forecast Centers, NOHRSC and NCDC are routine users of the CoCoRaHS data download capability on an hourly, daily or weekly basis. Other agencies, universities and some commercial businesses also routinely tap into the CoCoRaHS data stream. There are many one-time special purpose users. In September, many agencies exported CoCoRaHS precipitation data during the Colorado flood event. This contributed to many near-real time maps capturing the rainfall pattern for the event.

CoCoRaHS enjoys many valuable partnerships across the country.

NASA GPM (Global Precipitation Measurement) mission partnership continued to mature with a CoCoRaHS-hosted webinar featuring GPM scientists at the Iowa Field Campaign in June. 85 people attended the webinar with some attendees connecting from Japan! The webinar has been viewed an additional 65 times on YouTube.

UNC Chapel Hill and observers in Washington have connected via CoCoRaHS and are assisting Dr. Erika Wise on her newly funded NSF project on collecting rainfall samples for isotope analysis on tree ring data. http://college.unc.edu/2013/10/10/erikawise/

National Drought Mitigation Center, Lincoln, Nebraska – collaboration on a national Drought Impact Reporting system

University of Oklahoma – "Field Photo Weekend" pilot project.

National Phenology Network – encouraging broader participation in phenology tracking.

Here are the meetings and conferences we participated in with CoCoRaHS-specific oral presentations. It was a relatively quiet period for meetings and presentations.

May 2013 WERA 1012 Coordinating Committee (http://www.cocorahs.org/WERA-MAY13/Home.html) Annual Report: http://nimss.umd.edu/homepages/saes.cfm?trackID=12536#3

June 2013 Fort Collins, Colorado "ClimateWise" community event

July 2013 American Association of State Climatologist Annual Meeting, St. Louis, MO (opportunity to meet with many of our partners/CoCoRaHS volunteer leaders from all across the country)

We still don't have much to show for it, but progress has been made towards completing traditional publications. We have good intentions and high hopes for highlighting CoCoRaHS contributions to climate literacy and citizen science. Henry Reges has a first draft completed documenting successes and challenges in volunteer recruiting and retention. Noah Newman is scheduled to complete a paper this fall for the National Association of Geoscience Teachers. Zach Schwalbe is making some progress on a manuscript documenting CoCoRaHS data and comparing CoCoRaHS rain gauge results with other types of rain gauges. Julian is working with NSF's "DataOne" project on a publication regarding data management for citizen science projects. As always, operational demands try to take all of our time, but we realize the importance of documenting our accomplishments and impacts.

Measure Effects

We are moving now from the formative evaluation phases of the project to summative evaluation. We had planned a major participant survey during this 6-month period. However, since it would be more useful if more of our technical deliverables (such as iphone apps and a mobile friendly website format) were completed, we decided to delay several activities into our no-cost extension period. We have extended the subcontract with our evaluator, David Heil and Associates (DHA) in Portland, Oregon, to facilitate this schedule change. We are currently developing a plan and timeline for this and continue to gather many project metrics. In particular, we are honing in for a date and key content areas for our final and extensive "Participant Survey."

We recently (mid October 2013) learned that the lead evaluator for our project, Susan Burger, will be leaving DHA to take an irresistible job as Director of Education at the Bishop Museum in Honolulu. This leaves us, once again (for the 3rd time), in some degree of limbo moving to this critical completion stage of the project. We are in steady communication with David Heil regarding this unplanned (for both of us) transition.

Susan did complete a project summary and status report earlier this summer. A survey was completed that focused on a year-after evaluation of the several hundred new CoCoRaHS volunteers who signed up during the 2012 “March Madness” recruiting campaign. This was an attempt to quantify progress in climate literacy as well as a variety of CoCoRaHS participation metrics. Results for this relatively small sample of a few hundred were not especially informative and certainly not conclusive. More recently, a survey of teachers participating with their classes in CoCoRaHS has been underway.

Here is the most recent Evaluation Summary report provided by DHA.

CoCoRaHS Evaluation Report
DHA, Inc. Contributions
Prepared by Susan Burger, August 2013

Introduction

David Heil & Associates, Inc. (DHA) is conducting a comprehensive evaluation of their three-year project, now entering a fourth extension year. Services provided by DHA thus far include front-end and formative evaluation of CoCoRaHS program implementation and outputs. Summative evaluation of outputs and outcomes, including strategies for recruiting and retaining a diverse population of participants, the effectiveness of improved training materials, and the impact of the program on current and new audiences of participants will take place over the final year of the project.

Evaluation Activities

- Communication
  - Two members of the David Heil & Associates (DHA) CoCoRaHS evaluation team met with Principal Investigator, Nolan Doesken, in December of 2012 to discuss progress on project implementation and plans for summative evaluation. It was decided to postpone summative evaluation of the CoCoRaHS grant projects until the planned improvements to the CoCoRaHS cyberinfrastructure were completed and volunteers had the chance to experience the improvements to the website interface and data visualization systems.

  - DHA and CoCoRaHS staffs maintain contact and provide updates via email. In addition, phone meetings are scheduled on a regular basis over the next several months as summative evaluation gets underway. These meetings will provide opportunities to discuss next steps in the evaluation and to verify that the evaluation is meeting the needs of the project team.

- Data Collection and Analysis
  - Because of the delay in implementing summative evaluation, DHA has collected only a limited amount of data over the past year. However, DHA has designed a survey for teachers in the CoCoRaHS K-12 program. This survey will be conducted with teachers near the beginning of the 2013-14 school year, and again near the end of the school year.

  - DHA also designed a Follow-up Survey to the survey of the 2012 March Madness New Recruits, and it was posted in April, 2013. Two hundred and fifty nine volunteers responded to the survey. Like the 2012 survey, it captured data regarding volunteer interests and recruiting and retention factors. In addition, a quiz on climate literacy in regard to the water cycle provided data to compare to the baseline data collected in the 2012 survey.

Formative and Preliminary Summative Findings

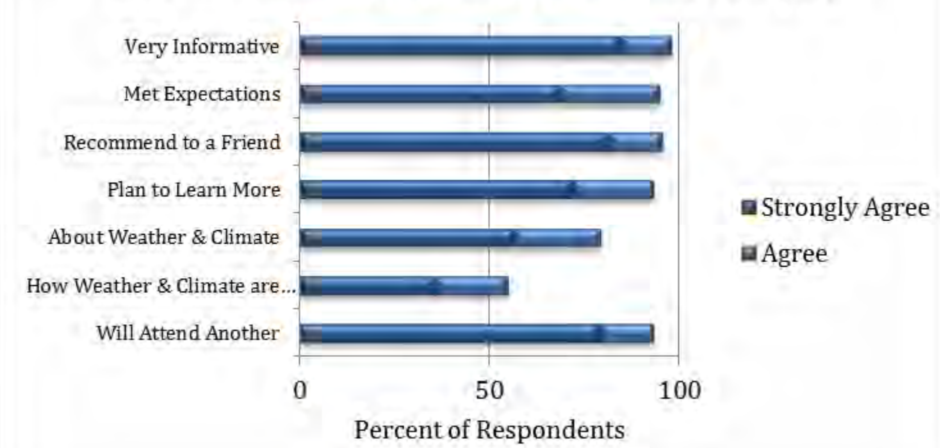
Informal Educational Impacts

WxTalk Webinars

CoCoRaHS began a monthly educational Webinar series in December 2011, called 'CoCoRaHS WxTalk' (wx is shorthand for weather). The one-hour interactive sessions feature experts in the fields of atmospheric science, climatology, and other relevant disciplines. The webinars are live, and are also archived on the CoCoRaHS website. Thus far 20 WxTalk Webinars have been conducted. Topics have included *snow, how weather satellites sense the Earth, who uses weather data and how they do it, clouds, flash floods, lightning, hurricane analysis and prediction, and wind and wildfire.*

CoCoRaHS incorporates a Pre-Webinar Quiz into most of the Webinars, which appears to be effective in getting participants thinking about the topic and also provides the presenter with information regarding pre-existing knowledge about the topic, so that they can tailor their presentation to the audience. CoCoRaHS also collects information from the participants following each Webinar, asking them to rate the Webinar along several dimensions. Participant evaluations from four of the webinars indicate that the participants find the webinars both enjoyable and informative, and they report learning something in the process. Figure I shows the results from the Webinar presented July 25, 2013.

Figure 1. Participant Ratings of the "Rainwater Harvesting - Catching and Using It" Webinar (n = 131)



It is clear that the response to the webinars continues to be overwhelmingly positive, with 93% or more of the survey respondents agreeing (4) or strongly agreeing (5) that they found the webinar to be very informative, that it met or exceeded their expectations, that they would recommend it to a friend, that they plan to learn more, and that they will attend another webinar. The response was not quite as positive for the two statements regarding what participants learned. Fifty-five percent agreed or strongly agreed that they had learned something new about how weather and climate are studied, while nearly 80% found they had learned something new about weather and climate. These figures are nevertheless encouraging, given that this particular webinar did not focus on how weather and climate are studied, and that the majority of CoCoRaHS volunteers are already well-informed regarding weather and climate.

Climate Literacy Data

Baseline and Follow-up Climate Literacy Quiz Data have been collected from the 2012 March Madness Recruits, and is currently being analyzed.

Formal Education Findings

Outputs K-12 Program

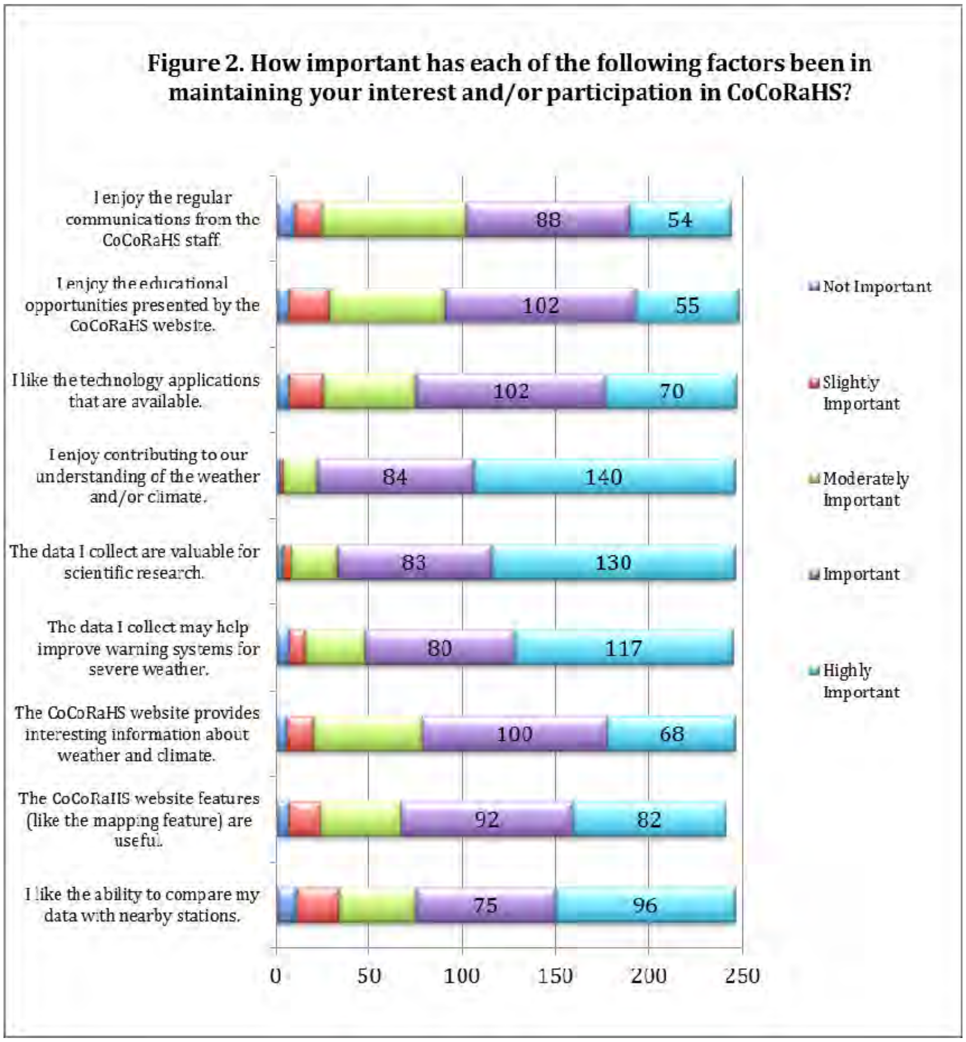
- Animated videos have been posted on the website as recruiting tools for younger audiences. The first is a two-minute video intended for general recruiting and a second is focused on recruiting schools for the K-12 program. Feedback from CoCoRaHS Coordinators has been very positive.
- The K-12 program is viewed as a vehicle for recruiting younger and underserved audiences. Approximately 500 teachers had been recruited to the program, as of August 2013. Teachers have been recruited though hosting teacher workshops and weather festivals. Teacher response has been very positive.
- During this report period the education coordinator visited 6 schools, 11 'water festivals', and hosted 6 professional development workshops for teachers to demonstrate how to measure precipitation and to show how the program is grounded in teaching standards. Approximately 1,350 students have been reached during school presentations and water festivals and 74 teachers were trained.
- The program is matched to education standards in the following areas: the water cycle, weather vs. climate, math, fractions, meniscus/surface tension, and how to accurately collect data.
- At this point in time the CoCoRaHS website provides educators with information on rain gauges and getting started, FAQs, training materials, and four lesson plans: 1) Equipment and Measurements; 2) Registration and Data Entry; 3) It's Not Easy Being Green (with accompanying slide show); and 4) Practice Reading the Rain Gauge. More lessons are being developed.

Outcomes K-12 Program

Outcomes from the K-12 education program will be assessed during the coming year.

Recruiting and Retention Factors

Figure 2 shows the importance of a variety of factors in retaining active volunteers. The top three motivators are related to making a contribution: to our understanding of weather and climate, to scientific research, and to improved warning systems for severe weather. At the same time, a majority of the respondents find the aspects that CoCoRaHS believes will attract younger audiences to be important as well. These include the educational opportunities, the



technology applications that are available, informational aspects of the website, new technological features like mapping, and being able to compare one's own data to that of others.

The improvements that have been made to the CoCoRaHS cyber-infrastructure will be the focus of the 2014 survey of CoCoRaHS volunteers, for the purpose of assessing their impact on recruiting and retention.

Summary of Findings

While CoCoRaHS has faced a number of challenges ranging from the rate of completion of cyberinfrastructure improvements to underserved audience engagement, it is clear that CoCoRaHS has made steady progress in all phases of the proposed work, including enhanced data mapping capabilities, data visualization, evapotranspiration data collection and analysis capability, instructional resources for teachers and for the public, substantial outreach to the K-12 community, and the production of high-quality information-rich webinars, with strong positive feedback from participants.

Next Steps for Evaluation

The DHA evaluation team will meet (via phone) in August, 2013 with the CoCoRaHS Team to review goals and measureable outcomes and lay out a plan and timeline for the summative evaluation that will take place over the next 12 months. Key components of the summative evaluation will include a survey of outcomes for participating teachers and students in the K-12 program, and a survey of all CoCoRaHS volunteers to assess educational and technological impacts on recruiting, motivation, engagement, and understanding of precipitation and the water cycle. In addition, focus groups will be conducted with K-12 educators and their students, as well as in-depth interviews with CoCoRaHS staff.

– Briefly describe any new partnerships that have been formed as part of, or as a result of, your project during the past six months. Please list each new partner by name. (You may add additional rows to the table as needed.)
Note: you do not need to list partners that were included in your original project narrative or listed in previous progress reports

Name of New Partner	**Role of New Partner in Project**
Dr. Erika Wise Univ. of North Carolina, Chapel Hill	We are collaborating, along with a school in Washington State, to help collect rainfall sample for isotope analysis to support her drought and tree ring research http://college.unc.edu/2013/10/10/erikawise/

-Indicate specific outputs produced during the period covered by this progress report (see definition of outputs below). Record your outputs in the table provided, selecting from the output type categories listed below the table. You may add additional rows to the table as needed. An example has been provided for you.

Note: the list of output types is still being refined. If you feel that one or more outputs from your project do not fit any of the suggested categories, please contact the NOAA Office of Education at oed.grants@noaa.gov or 202-482-0793

Outputs[1]: the immediate results of an action (e.g., services, events, and products) that document the extent of implementation of a particular activity. They are typically expressed numerically - e.g., the number of persons who visit a museum exhibit or listen to a radio program or the number who attend a series of professional development workshops, etc.

	Output type (see list)	**Number of outputs**	**Target Audience/ Participants**	**Number of users/ participants (total)**	**Average contact hours per participant (if applicable)**
Volunteer data collection	*Experiential activities – daily precipitation report, hail reports, significant weather reports, drought impact reports*	*1*	*CoCoRaHS trained volunteers*	*17,900 of which about 11,000 participate daily*	*2.5 hours per month per active volunteer for 6 months*
CoCoRaHS WxTalk Webinar Series	Web/Multidmedia (live and archived)	6	CoCoRaHS volunteer participants	897 live 936 later (one was not archived per presenters' request)	1
Attended American Association of State Climatologists annual meeting and hosted WERA 1012 Coordinating Committee and additional local meeting	Conference meetings	3	Professionals in meteorology/climatology	125	2.0
CoCoRaHS snow training animations	Web/multidmedia	6	CoCoRaHS volunteers and potential volunteers	2000 (based on YouTube hits)	0.1

PRISM daily precipitation maps	Visualization	1	Current participants in CoCoRaHS plus general national audience	2000 and growing	0.5 hours
CoCoRaHS heavy rain animation	Web/multimedia	1	CoCoRaHS volunteers and other rain gauge readers/heavy rain reporters	1000 (est)	0.1 hours
Blog updates	Web/multimedia		CoCoRaHS trained observers and general public	2000 (conservative Estimate)	0.1 hours per blog engagement
Water Year summary reports with 30-year climate normal for WY2013	Data access tool deployment	1	CoCoRaHS participants	4000 (est)	0.2 hours

Notes/Comments:

Output types:
--Experiential activity (activities, trips, programs, measurement protocols)
--Exhibit installation (spheres, domes, panels, kiosks, stations, etc.)
--Professional development (sessions, workshops, webinars)
--Conference/Meeting
--Curriculum/a (lesson plans, units, modules, frameworks, standards)
--Web/Multimedia (websites, web 2.0 features, videos, broadcasts, podcasts, games, apps)
--Educational/Opinion Research (reports)
--Exhibit/Education Space Upgrade (equipment upgrades, structural upgrades, layout upgrades)
--Visualization (data visualizations, spherical display modules, etc.)
--Data access tool development (hardware packages, software packages)
--Network development (networks, network members, new partnerships)

[1]Adapted from the *Framework for Evaluating Impacts of Informal Science Education Projects Report from a National Science Foundation Workshop (p.35,* http://insci.org/resources/Eval_Framework.pdf*)*

-Indicate specific outcomes achieved during the period covered by this progress report (see definition below[1]). Record your outcomes in the table provided, selecting from the outcome type categories listed below the table. You may add additional rows to the table as needed. An example has been provided for you. **Note that outcomes are often determined through independent evaluation, and projects in their early stages may not yet have outcomes to report.**

Note: the list of outcome types is still being refined. If you feel that one or more outcomes from your project do not fit any of the suggested categories, please contact the NOAA Office of Education at oed.grants@noaa.gov or 202-482-0793

Outcomes[2]: the changes that show movement toward achieving ultimate goals and objectives - e.g., the number of persons who, as a result of their participation in a project, demonstrate changes in: awareness and knowledge of specific concepts and/or issues; interest in and/or attitudes toward certain issues, careers, or courses of action; and behavior or skills.

Outcome description	**Outcome type (see list)**	**Activity/ Activities leading to the outcome**	**Target Audience/ Participants**	**How outcome was measured**
CoCoRaHS has been recognized for advancing Citizen Science	Capacity, Engagement	Practice, Preparation and Persistence	Professional informal science advocates	Referenced in various publications and citizens science reports. Recipient of national awards.
CoCoRaHS volunteer leadership are effective ambassadors over large geographic areas	Capacity, behavior	Long-term high levels of participation in recruiting, training and data QC	CoCoRaHS volunteer Coordinators	Very little turnover in volunteer leadership. Active involvement seen in many states measured by local recruiting and long-term participation.
CoCoRaHS volunteers are staying engaged in data collection over multi-year periods and are participating many days of the year. A sizable fraction of participants try to report precipitation nearly every day of the year.	Engagement	Volunteer training, data entry, data viewing, data analysis and impact from multiple outreach and engagements activities	CoCoRaHS active participants	"CoCoRaHS activity report" provides statistics on duration and level of activity of all recruits and participants Many, many volunteers are in this for the long haul.
CoCoRaHS protocols and participant training are effective	Skills	Online and group training resources	Participants and new recruits	Data quality is consistently high, and professionals trust using CoCoRaHS data
Topical "Webinars" are resulting in pursuit of knowledge by a significant number of volunteers	Awareness, knowledge, understanding	CoCoRaHS WxTalk Webinars	Current CoCoRaHS participants	Participant statistics from "GoToWebinar" and the results of exit surveys conducted after each event and outside evaluation report
Professional Organizations, including the National Weather Service, NCDC and the National Drought Mitigation Center, are routinely	Awareness, Knowledge and Understanding Capacity	Volunteer training, data quality control, and the large number of consistent measurements provided by		Based on sustained and growing list of data export subscribers

downloading and utilizing CoCoRaHS data for scientific applications		volunteers		
CoCoRaHS participants continue to be active in outreach and recruiting	Engagement	Volunteer recruiting	CoCoRaHS volunteers	Metadata are showing a large number of new CoCoRaHS recruits are being recruited by our current pool of volunteers. Many generational (parent-child-grandchild and sibling) volunteers now

Notes/Comments:

Interesting to see how it was originally easy to see outputs but difficult to identify outcomes, but with each passing year and the various metrics we are tracking it is getting easier and easier to document outcomes.

Outcome types:
--Awareness, knowledge, understanding
--Skills
--Engagement or interest
--Attitude
--Aspirations/Intention to act
--Behavior
--Societal or Environmental
--Capacity

[2]Adapted from the *Framework for Evaluating Impacts of Informal Science Education Projects Report from a National Science Foundation Workshop (p.35,* http://insci.org/resources/Eval_Framework.pdf*)*

-For this reporting period, provide a comparison of actual accomplishments and/or activities with those listed in the milestone chart from the approved project narrative in your application. (Please add additional rows to the milestone chart as needed)

Milestone Chart				
Task/Activity	**Expected completion date from approved project narrative timeline in your application**	**Expected completion date listed in previous progress report (if different from the date listed in your application)**	**Actual or current expected completion date**	**Explanation of any discrepancy**

Milestone Chart				
Task Activity	**Expected completion date from approved project narrative timeline**	**Expected completion date listed in previous progress report**	**Actual or current expected completion date**	**Explanation of any discrepancy**
Accept Data (CST) -Add support for Evapotranspiration	Sep 2011 - 2013		Completed	
Accept Data (CST) - QC System	Sep 2011 - 2014		This is ongoing. Our approved no-cost extension is enabling continued work on this and several other tasks in this table	There are endless opportunities for improving data quality control. This is important, but we have several other higher priorities that were defined as project deliverables.
Accept Data (CST) - Implement development SQL Azure cloud database and evaluate the feasibility of the cloud for the reporting database	Sep 2011 - 2013		Completed	We tested cloud computing on a variety of platforms and providers and have returned to the approach of having a dedicated server to support our data management
Accept Data (CST) - Transactional reporting database in production	Sep 2011 - 2013		May not be needed	The separate reporting database may not be needed due to the performance gains by upgrading the current database to a dedicated virtual environment. The

				system is pre-generating data analysis as needed for improved performance. If needed we will utilize a data warehouse, NoSQL data repository or Content Delivery Network (CDN) to generate or cache data analysis.
Recruit Participants (CST) -- improve registration process and provide registration to non-observers	Sept 2011	2012	Delayed into 2014	This was prototyped and demoed in late 2012 but will not be implemented until a total rebuild of the website is completed. This is ongoing.
Recruit Participants (CST) Support and expand local leadership teams -- acknowledge observer/coordinator contributions	Ongoing through Sept 2013	2014	Same	There is certainly room for improvement, but with e-mail updates and periodic group online meetings we are holding together the large team of 250+ state and regional volunteer coordinators. Without them, a national program would be impossible.
Refine Protocols (CST) Evapotranspiration	Sept 2011	Sept 2011	May 2012	Completed during late spring of 2012 and successfully implemented. Data collected during 2012 very effectively showed drought development and improvement through the combination of water ET and precipitation. Program working well in 2013 – but wish we could recruit greater participation.
Refine Protocols (CST) Adapt and Improve – document additions and improvements and justifications for changes	Ongoing through Sept 2013	Sept 2013	Now through Sept 2014	CoCoRaHS decided to retain the independent collection of both gauge catch and snow board snow water content as separate fields (this deviates from NWS procedures) but we feel we gather both

				scientifically and educationally valuable information that is missing from NWS data sets This will be tested in the upcoming 2013-14 winter
Train Participants (CST) Observer Training Short narrated modules Webinar training Training for Mobile Devices	2012 - 2013	2012-2013	Same -- now extended into 2014	With each passing year, we are more and more impressed with the ease and effectiveness of short animations to get key training concepts across to both new and experienced volunteers. But Webinar formats are an easy way to engage participants in interactive Q & A. At this point, training for Mobile Devices will be "on the fly" which is the expectation of that category of users
Train Participants (CST) Climate Education Webinar Series	Ongoing through 2013 but first webinar planned for spring 2011	Beginning spring 2011	Began fall 2011 and planned and scheduled throughout 2014	We are in "cruise" mode now with an entire season of webinars for the next year. This is running smoothly, has excellent content, and takes relatively little time to coordinate
Train Participants (CS)) Informal Education Through Training and support	Ongoing through 2013	Ongoing through 2013	Ongoing now through 2014	We are keeping up. This seems to be a strength of our current system as we are able to accommodate several thousand new recruits each year and give them a fairly personal and customized services.
Analyze Data (CST) Functional reporting database Services available on mobile devices	Start Later 2011 Complete in 2012 and 2013	2012-2013	Also now extending to 2014	This hasn't gone as originally planned, but we are getting higher performance out of our database, and are making all system modifications with mobile devices in mind. All CoCoRaHS interface development has

				occurred with the requirement of supporting mobile devices.
Analyze Data (CST) Mapping enhancements and connection to PRISM products	Start on PRISM products later in 2011, Other stuff comes later	Late 2011 and following	Launched fall of 2012	Done and working great!! Thanks you PRISM Climate Group. Now the PRISM group has added the capacity to map precipitation on a daily basis. We will be pushing our volunteers to this service as it represents a huge effort and accomplishment that there is no need for us to duplicate.
Analyze Data (CST) Climate Dashboard	Progression of deliverables beginning early 2011	2012	Unknown	We have not given this much attention. We are not sure if we will pursue this fully.
Analyze Data (CST) Water Year Summary reports	Start later 2011 and deliver in 2012	Fall 2010 and following	Staying on or ahead of schedule here	The comparison of station data with 30 year normal from PRISM into the interactive charts and Excel files are the latest improvement to the water year summary report. Now completed through WY2013 – excellent comprehensive analysis for participants and CoCoRaHS resource users.
Analyze Data (CST) Other activities – PRISM collaboration, Observer activity reports, charts and graphs, etc.	Not specified	On schedule	On schedule and expanding	As mentioned above, we are now able to utilize the PRISM daily precipitation maps. Plenty more opportunities here for improvement as time and resources allow.
Disseminate Results (CST) Social Networking – Blog, Facebook Twitter YouTube, etc	Fall 2010 and ongoing	Fall 2010 and ongoing	Will continue for the duration of the project and probably beyond	We continue to increase the number followers and participation on Facebook and Twitter. Thanks to the volunteer efforts of Illinois state coordinator Steve Hilberg, the Blog is spectacular. All social media are monitored

				continuously and updated regularly.
Disseminate Results (CST) "The Catch"	Fall 2010 and ongoing with specific technology deliverables summer-fall 2011	Fall 2010 and ongoing with specific tech deliverables summer-fall 2011	On schedule – Tech deliverable implemented summer 2013	We finally made the transition to sending out this routine newsletter in HTML using the MailChimp mailing system. Response has been very positive so far and we can now track how many people read this foundational CoCoRaHS educational and engagement tool
Disseminate Results (CST) Data Export enhancements	Series of deliverables beginning spring/summer 2011	Same	Staying pretty much on schedule, but takes more time than we hoped.	Much of the popularity of CoCoRaHS data has been a combination of data credibility, easy access and widespread usability. We provide personalize customer support as well. There is on ongoing cost to this investment, however, and that is less time to put towards our many other planned cyberinfrastructure enhancement. The benefit is that many data users have developed resources that we and our volunteers can use and enjoy, such as high resolution precipitation maps.
Measure Effects (CST) Project Evaluation	Series of deliverables beginning fall 2010	Same as first written	Delayed to 2014	Evaluation progress has slowed awaiting our completion of a few more cyberinfrastructure upgrades. The large participant survey will be scheduled soon and this will be the key tool to be used to construct the CoCoRaHS summative evaluation. This is now scheduled for 2014

-Describe reasons why established objectives were not met, if applicable.

So many things about the CoCoRaHS effort continue to run smoothly. Contributions to NOAA climate monitoring and climate literacy have been substantial. The partnerships that have been built and the impact that has been realized through the low common denominator of plastic rain gauges is really quite amazing. We have shown that citizen science can have a very important place at the table.

Still, our areas of struggle are clear and the reasons logical. Operational demands, ever-changing communications technology, unexpected new opportunities, short term interruptions (like a local flood) and a small staff, have kept us from reaching several of our cyberinfrastructure goals. Also, we have so many opportunities to publish and share our findings and experiences. While we have left only a modest trail of formal publications, somehow CoCoRaHS has become widely known for our contributions to Citizen Science, so we aren't failing. We're just not getting our names on many papers. Maybe that matters and maybe that doesn't, but it's still something we strive for.

It's also frustrating that we have to endure yet another bump in the evaluation road with Susan Burger leaving DHA at this stage of the project. This time, however, we have a pretty good handle on where we're going, and reasonable confidence that DHA will do what it takes to complete the job. But it is annoying and time consuming.

Now we're at an interesting stage of the project where we want to go full speed ahead completing the handful of unmet deliverables described in our original proposal. But with just a year left in this project (thanks to the no-cost extension) now we can't help but think beyond these immediate obligations and think and plan for a sustainable future. Knowing that NOAA's NWS is both a huge partner and a primary user of CoCoRaHS, we would love to see an ongoing partnership develop. But seeing federal funding challenges and NWS budget crises, this goal seems rather unachievable. NOAA's OED has been fantastic to work with. Reading from our last 6-month report -- I don't think I can say it any better, so I'll just repeat it.

"We have every intention of continuing CoCoRaHS as far into the future as we can. This grant and the previous NOAA OED grant were absolutely perfect in terms of timing and priority and have allowed us to develop and establish a wonderful nationwide community. Together we will figure out our way forward."

-We encourage you to submit a highlight from the work your project has accomplished over the past six months. Highlights help the Office of Education to publicly acknowledge and share the extraordinary work being done by our grantees. See the Highlights template that accompanies this document for further instructions.

Progress Report Prepared By: Nolan Doesken
Date: Nov. 4, 2013

COMPETITIVE PROJECT TITLE: Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme (NA11OAR4310208)

PRINCIPAL INVESTIGATOR: Andrea Schumacher

RESEARCH TEAM: N/A

NOAA TECHNICAL CONTACT: Jiann-Gwo Jiing (NOAA/NHC)

NOAA RESEARCH TEAM: Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

TC genesis represents an intensity forecasting challenge and is perhaps one of the more difficult stages of the tropical cyclone lifecycle to diagnose and predict. This project seeks to combine some of the strengths of both the NHC "in-house" genesis scheme and the NESDIS Tropical Cyclone Formation Probability (TCFP) product to develop a storm-centric scheme for objectively identifying the probability of TC genesis (within 48-hours and 120-hours) in the North Atlantic basin.

Tropical Cyclone (TC) forecasts affect risk mitigation activities of industry, public and governmental sectors and therefore supports directly NOAA's Weather and Water mission goals.

PROJECT ACCOMPLISHMENTS:

1--Real-time testing:

The real-time TCGI code that has been developed is currently running at CIRA and was tested and evaluated by the proposal team from July-September 2013. This evaluation period helped the team identify a few potential areas for TCGI improvement. TCGI utilizes both early and late cycle track guidance from the NOAA Global Forecast System (GFS) to determine positions for analyzed tropical disturbances. However, GFS forecast positions are not always available for weak disturbances (especially out to the 144 hours needed for TCGI runs) and therefore, a special Beta and Advection Model, Medium Layer (BAMM) was developed to support the TCGI project. This model, BAMG, required significant testing and evaluation by the proposal team in recent weeks and has resulted in its successful integration into the real-time TCGI scheme. BAMG is now a vital component of TCGI and allows the scheme to run even if GFS tracks are not available or other forecast model guidance is not run by NHC. One important aspect of integrating a new forecast tool such as TCGI into an operational environment is to maximize product transparency to potential users. The proposal team has incorporated predictor information into the TCGI real-time output that describes the specific contributions of each predictor for both the 0-48 and 0-120 hr forecast periods (Fig. 1). This information is designed to help the user more easily interpret the TCGI forecasts.

```
                    *          ATLANTIC TC GENESIS INDEX          *
                    *          AL972013 10/01/13 18 UTC           *

TIME (hr)           0     6    12    18    24    36    48    60    72    84    96   108   120
TCGI (%)                                               45.1                               65.0

HDIV (x10-7s-1)  -3.0  -4.0  -1.0  -3.0  -5.0   0.0  -6.0   1.0  -5.0   0.0  -4.0   0.0   0.0
VORT (x10-6s-1)   1.3   1.6   1.6   1.7   1.6   1.5   1.1   0.8   1.0   0.5   1.1   1.1   1.1
DV24 (x10-6s-1)   0.3   0.0  -0.1  -0.7  -0.5  -0.7  -0.1  -0.3   0.1   0.6   0.0  -0.1  -0.3
VSHD (kt)           5     9    11     9     9    17    19    19    19    26    24    28    27
MLRH (%)           67    67    64    63    67    64    68    62    64    52    54    52    54
PCCD (%)           42   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A
TNUM             1.00   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A

LAT  (deg N)     16.8  17.2  17.8  18.5  20.3  22.9  25.0  26.3  27.6  28.3  29.2  30.1  31.4
LON  (deg W)     83.0  83.5  84.4  85.1  85.8  87.0  87.4  87.5  86.8  86.5  85.5  84.4  82.9
DTL  (km)         169   172   217   259   132   154   382   358   270   188    56    -5  -140
TRACK SOURCE     AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO

Prob of Genesis (t= 48h) =  45.1 is  1.6 times the sample mean ( 27.9)
Prob of Genesis (t=120h) =  65.0 is  1.6 times the sample mean ( 40.3)

-----------------------------------------------------------------------------------------------
CONTRIBUTIONS OF CLIMATOLOGY AND INDIVIDUAL PREDICTORS TO TCGI PROBABILITY

               *******  48-HR ******    ******* 120-HR ******
                   AVG   FCST  %CONT          AVG   FCST  %CONT
CLIM (%)                        27.9                       40.3
HDIV (x10-7s-1)   -1.3   -3.1    9.1         -1.2   -2.2   15.9
DV24 (x10-6s-1)   -0.2   -0.3   -1.8         -0.2   -0.1    3.1
VSHD (kt)         16.8   12.3    4.8         19.0   18.5    0.7
MLRH (%)          64.9   66.0    0.1         61.3   60.8   -0.1
PCCD (%)          29.1   41.8    2.9         28.7   41.8    2.6
TNUM               0.9    1.0    2.1          0.9    1.0    2.4

%CONT = % contribution to TCGI probability

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PREDICTOR DEFINITIONS (Averaged Over 500 km Radius)

CLIM = Climatological Probability of Genesis (Source: NHC-TAFB Invest Database)
HDIV = 850-mb GFS Horizontal Divergence
DV24 = 24-hr Change in GFS 850-mb Vorticity (VORT)
VSHD = 850-200 mb GFS Vertical Shear
MLRH = 600-mb GFS Relative Humidity
PCCD = % GOES WV Pixels Colder Than -40C
TNUM = TAFB T-Number
```

Figure 1. Experimental TCGI output format.

2--Post-season reruns for 2011-2013 verification:

After the real-time evaluation period, the TCGI was run in real-time mode and TCGI forecasts were verified for tropical disturbances tracked during the 2011-2013 Atlantic hurricane season. Storm positions, genesis times and Dvorak T-numbers were determined using a combination of ATCF A- and F-Decks and resulted in a verification database that included 61 developing storms and 27non-developing tropical disturbances. Statistics generated from these 88 disturbances included 468 individual 48- and 475 120-hr TCGI forecasts and were compared to a homogenous dataset of NHC TWO forecasts. Note that the NHC 120-hr TWO did not become operational until 2013 and was not available for the full 3-yr analysis. Fig. 2 shows the reliability diagrams for the TCGI and NHC TWO 0-48 and 0-120-hr forecasts. Although there was some tendency for the TCGI to under-forecast at the lower (~0-40%) and upper (~70-100%) forecast probability bins, it was competitive with the NHC TWO statistics. Figure 3 shows the TCGI and NHC TWO 0-48 and 0-120-hr lead-times for the 2011-2013 verification dataset, while Fig. 4

present the Brier skill scores for these same forecasts. The latter analyses provide an alternative measure of the forecast skill that is provided by the reliability diagrams (Fig. 4).

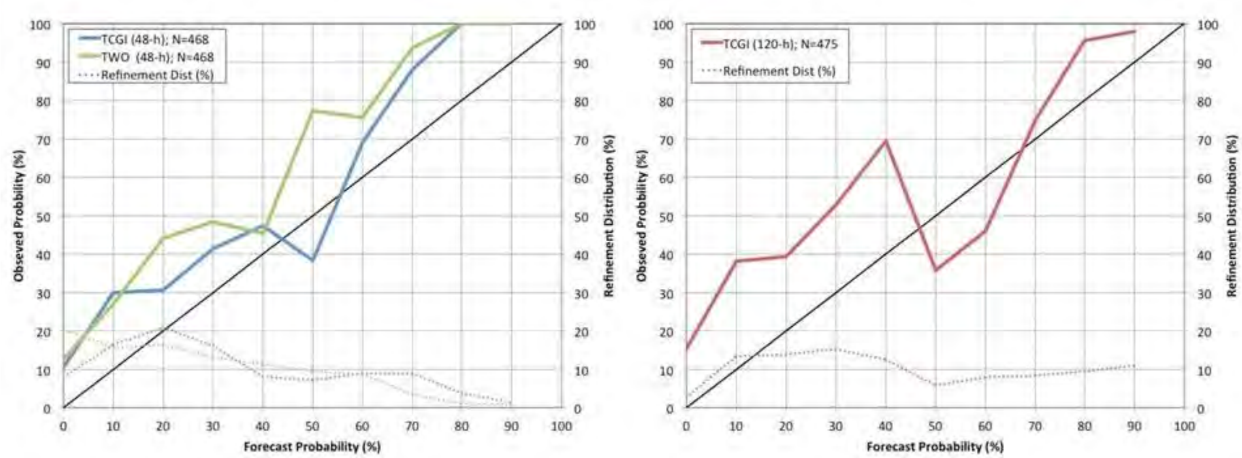

Figure 2. Reliability diagrams for TCGI and a homogeneous sample of NHC TWO Atlantic probabilistic TC genesis forecasts for the 2011-2013 North Atlantic hurricane seasons. The verification includes forecasts from 61 developing and 27 non-developing disturbances. The solid blue/green (red) lines indicate the relationship between the 48-hr (120-hr) forecast and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed lines indicate how the corresponding forecasts were distributed among the possible forecast values.

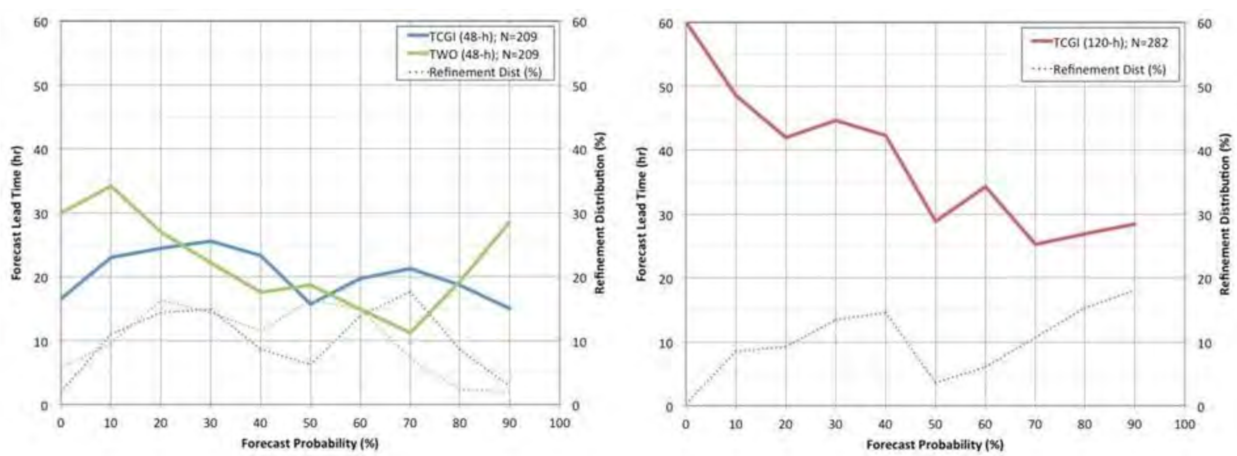

Figure 3. Forecast lead times (hours before genesis) for TCGI and NHC TWO Atlantic probabilistic TC genesis forecasts for the 2011-2013 North Atlantic hurricane seasons. The datasets include 209 48-hr and 282 120-hr forecasts from 61 developing disturbances. The solid blue/green (red) lines indicate the relationship between the 48-hr (120-hr) forecast probability and the forecast lead-time. The dashed lines indicate how the corresponding forecasts were distributed among the possible forecast values.

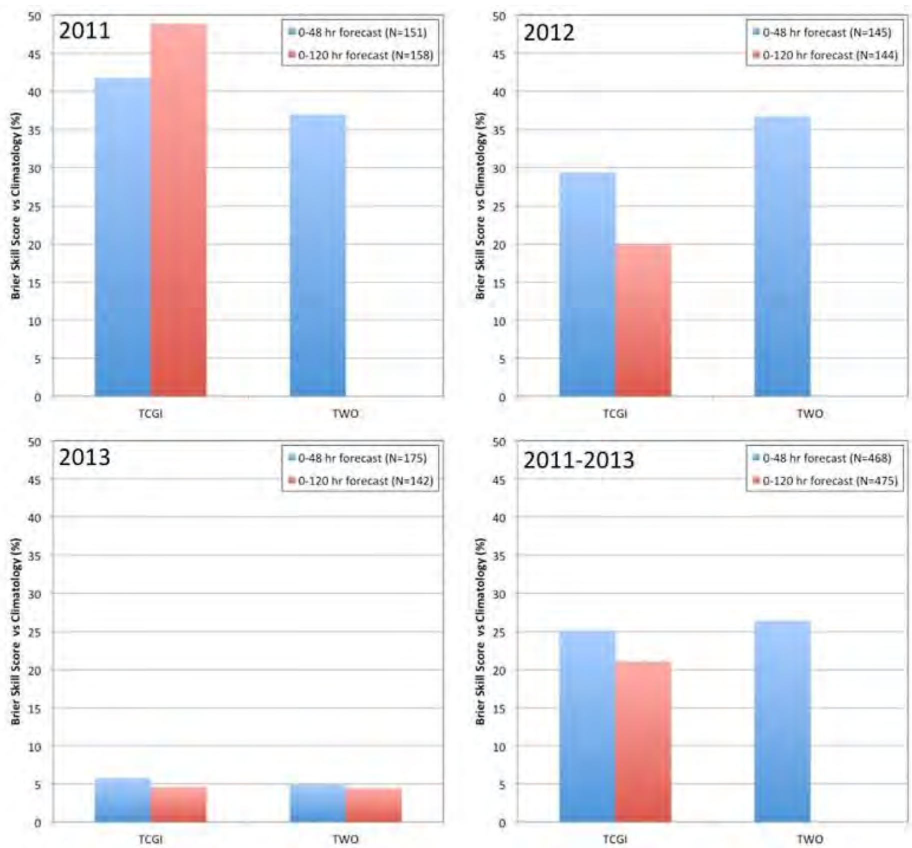

Figure 4. Brier Skill Scores for TCGI and a homogenous sample of NHC TWO Atlantic probabilistic TC genesis forecasts for the 2011-2013 North Atlantic hurricane seasons. Skill was measured against the climatological probability of tropical cyclogenesis determined from a 2001-2010 dataset of North Atlantic invests.

3--Make final code available for installation at NHC:

The proposal team has completed the TCGI project and turned over the real-time output (available on a CIRA web link) to the assigned NHC JHT points of contact on 11 September 2013. The proposal team has been and will continue to work closely with NHC forecasters as they evaluate TCGI for possible transition to operations. The TCGI code will be made available to NHC upon request.

The following is the report previously submitted to the Technical Sponsor.

NOAA Joint Hurricane Testbed (JHT)
Project Final Report

Date: February 28, 2014
Reporting Period: September 1, 2013 – February 28,September 2014
Project Title: Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme
Principal Investigator: Jason Dunion, University of Miami/CIMAS – NOAA/HRD
Co-PIs: John Kaplan, NOAA/HRD
Andrea Schumacher, CSU/CIRA
Co-Investigator: Joshua Cossuth, Florida State University
Award Period: August 1, 2011 – February 28, 2014

1. Long-term Objective and Specific Plans to Achieve Them:

The main goal of this project is to develop a disturbance-following tropical cyclone (TC) genesis index (TCGI) to provide forecasters with an objective tool for identifying the 0-48hr and 0-120hr probability of TC genesis in the North Atlantic basin. Predictors from a variety of sources were tested and potentially integrated into this new scheme and included Dvorak T-number / CI value estimates, environmental and convective parameters currently used in the NESDIS TC Formation Probability (TCFP) product (fixed grid scheme), environmental parameters from the Statistical Hurricane Intensity Prediction Scheme (SHIPS) that are relevant to TC genesis, and total precipitable water (TPW) retrievals from microwave satellites. Six robust TCGI predictors were identified and have been incorporated into an experimental real-time version of TCGI. The proposal team evaluated the performance of the scheme for several 2013 tropical disturbances in the Atlantic and made the TCGI code and output available to NHC forecasters on 11 September 2013. NHC forecasters are currently evaluating TCGI for possible transition to operations in the future.

2. Accomplishments:

a. Develop code for running real-time TCGI (0-48h and 0-120h)

The real-time code development phase of this project has been completed and required some re-evaluation of the TCGI predictors that were identified during the previous reporting period and resulted in a more robust scheme. These six predictors and their relative weights in TCGI for the 0-48 and 0-120 hr forecast periods are shown in Fig. 1. Figure 1 also depicts the TCGI genesis occurrence frequency relative to the range of binned discriminant function values that could be produced by TCGI during a given forecast cycle. Higher binned discriminant function values are associated with combinations of TCGI predictor values that favor higher TC genesis probabilities. The skill of the optimized TCGI relative to a climatological reference forecast derived from the developmental dataset (2001-2010) is shown in Fig. 2. These assessments indicate that TCGI has ~30 % and 39% skill relative to climatology for the 0-48 and 0-120 hr forecast periods respectively.

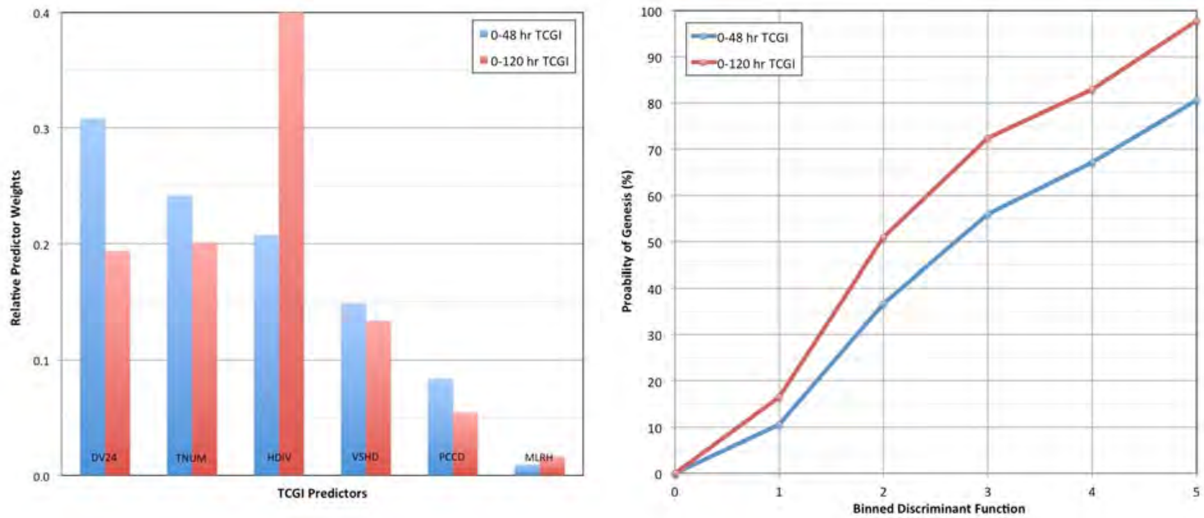

Fig. 1: The relative predictor weights (left) for the real-time TCGI and the corresponding genesis occurrence frequency (%) for the five quantiles that were utilized (see Kaplan et al. 2010 for more details). The predictors used in the TCGI are GFS 24-hr vortex tendency (DV24), 850-hPa divergence (HDIV), 850-200 hPa vertical shear (VSHD), Dvorak T-number (TNUM), GOES percent of cold cloud (<-40 C) pixel coverage (PCCD), and GFS 600-hPa relative humidity (MLRH). Note that DV24, HDIV, VSHD, PCCD, and MLRH are averaged over a radius of 500km and that all predictors are evaluated along the entire disturbance forecast track with the exception of two T=0 predictors (TNUM and PCCD).

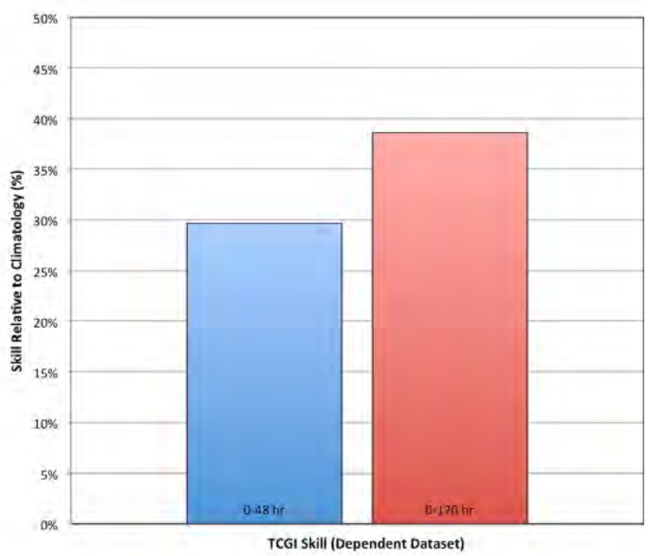

Fig. 2: TCGI skill (0-48 & 0-120-hr) relative to climatology (2001-2010 dependent TCGI dataset).

b. Perform real-time tests of TCGI (0-48h and 0-120h) either on NESDIS computers at CIRA with output being made available via an ftp site or on JHT computers

The real-time TCGI code that has been developed is currently running at CIRA and was tested and evaluated by the proposal team from July-September 2013. This evaluation period helped the team identify a few potential areas for TCGI improvement. TCGI utilizes both early and late cycle track guidance from the NOAA Global Forecast System (GFS) to determine positions for analyzed tropical disturbances. However, GFS forecast positions are not always available for weak disturbances (especially out to the 144 hours needed for TCGI runs) and therefore, a special Beta and Advection Model, Medium Layer (BAMM) was developed to support the TCGI project. This model, BAMG, required significant testing and evaluation by the proposal team in recent weeks and has resulted in its successful integration into the real-time TCGI scheme. BAMG is now a vital component of TCGI and allows the scheme to run even if GFS tracks are not available or other forecast model guidance is not run by NHC. One important aspect of integrating a new forecast tool such as TCGI into an operational environment is to maximize product transparency to potential users. The proposal team has incorporated predictor information into the TCGI real-time output that describes the specific contributions of each predictor for both the 0-48 and 0-120 hr forecast periods (Fig. 3). This information is designed to help the user more easily interpret the TCGI forecasts.

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TCGI (%)                                                45.1                              65.0

HDIV (x10-7s-1)   -3.0  -4.0  -1.0  -3.0  -5.0   0.0  -6.0   1.0  -5.0   0.0  -4.0   0.0   0.0
VORT (x10-6s-1)    1.3   1.6   1.6   1.7   1.6   1.5   1.1   0.8   1.0   0.5   1.1   1.1   1.1
DV24 (x10-6s-1)    0.3   0.0  -0.1  -0.7  -0.5  -0.7  -0.1  -0.3   0.1   0.6   0.0  -0.1  -0.3
VSHD (kt)            5     9    11     9     9    17    19    19    19    26    24    28    27
MLRH (%)            67    67    64    63    67    64    68    62    64    52    54    52    54
PCCD (%)            42   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A
TNUM              1.00   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A   N/A

LAT  (deg N)      16.8  17.2  17.8  18.5  20.3  22.9  25.0  26.3  27.6  28.3  29.2  30.1  31.4
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TRACK SOURCE      AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO  AVNO

Prob of Genesis (t= 48h) =  45.1 is  1.6 times the sample mean ( 27.9)
Prob of Genesis (t=120h) =  65.0 is  1.6 times the sample mean ( 40.3)

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CONTRIBUTIONS OF CLIMATOLOGY AND INDIVIDUAL PREDICTORS TO TCGI PROBABILITY

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%CONT = % contribution to TCGI probability

---------------------------------------------------------------------------------------------
PREDICTOR DEFINITIONS (Averaged Over 500 km Radius)

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MLRH = 600-mb GFS Relative Humidity
PCCD = % GOES WV Pixels Colder Than -40C
TNUM = TAFB T-Number
```

Fig. 3: Experimental TCGI output format.

c. 2011-2013 TCGI Verification

TCGI forecasts were verified for tropical disturbances tracked during the 2011-2013 Atlantic hurricane season. Storm positions, genesis times and Dvorak T-numbers were determined using a combination of ATCF A- and F-Decks and resulted in a verification database that included 61 developing storms and 27non-developing tropical disturbances. Statistics generated from these 88 disturbances included 468 individual 48- and 475 120-hr TCGI forecasts and were compared to a homogenous dataset of NHC TWO forecasts. Note that the NHC 120-hr TWO did not become operational until 2013 and was not available for the full 3-yr analysis. Fig. 4 shows the reliability diagrams for the TCGI and NHC TWO 0-48 and 0-120-hr forecasts. Although there was some tendency for the TCGI to under-forecast at the lower (~0-40%) and upper (~70-100%) forecast probability bins, it was competitive with the NHC TWO statistics. Figure 5 shows the TCGI and NHC TWO 0-48 and 0-120-hr lead-times for the 2011-2013 verification dataset, while Fig. 6 present the Brier skill scores for these same forecasts. The latter analyses provide an alternative measure of the forecast skill that is provided by the reliability diagrams (Fig. 4).

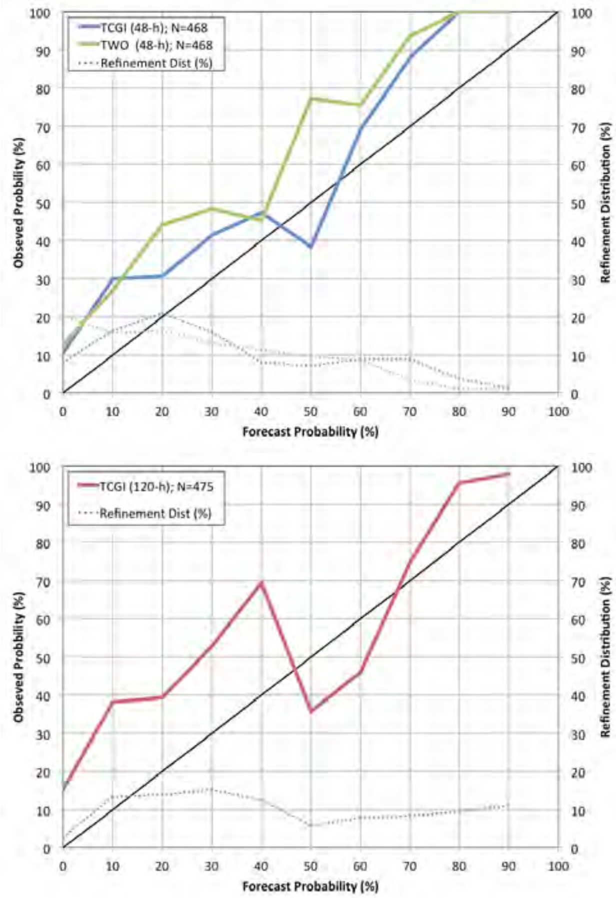

Fig. 4: Reliability diagrams for TCGI and a homogeneous sample of NHC TWO Atlantic probabilistic TC genesis forecasts for the 2011-2013 North Atlantic hurricane seasons. The verification includes forecasts from 61 developing and 27 non-developing disturbances. The solid blue/green (red) lines indicate the relationship between the 48-hr (120-hr) forecast and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed lines indicate how the corresponding forecasts were distributed among the possible forecast values.

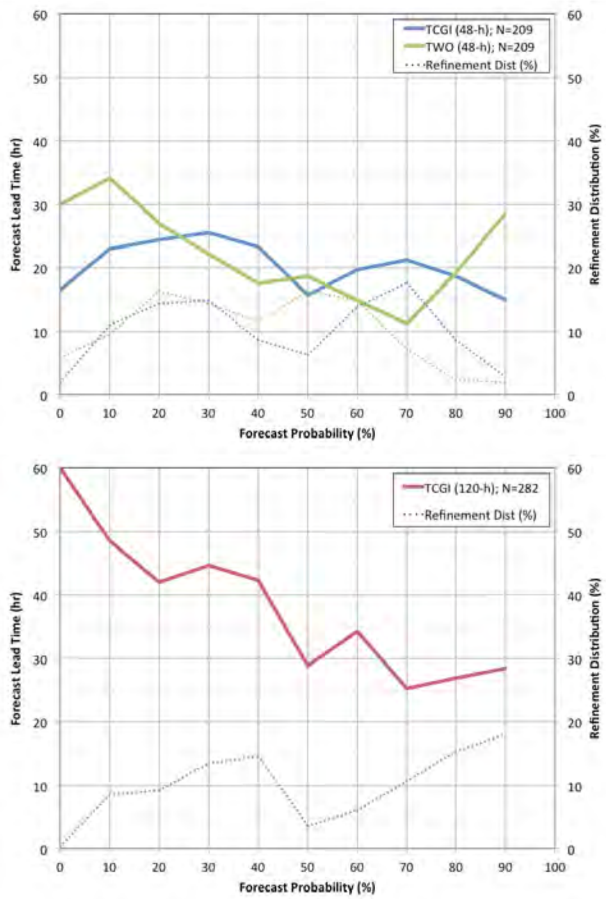

Fig. 6: Forecast lead times (hours before genesis) for TCGI and NHC TWO Atlantic probabilistic TC genesis forecasts for the 2011-2013 North Atlantic hurricane seasons. The datasets include 209 48-hr and 282 120-hr forecasts from 61 developing disturbances. The solid blue/green (red) lines indicate the relationship between the 48-hr (120-hr) forecast probability and the forecast lead-time. The dashed lines indicate how the corresponding forecasts were distributed among the possible forecast values.

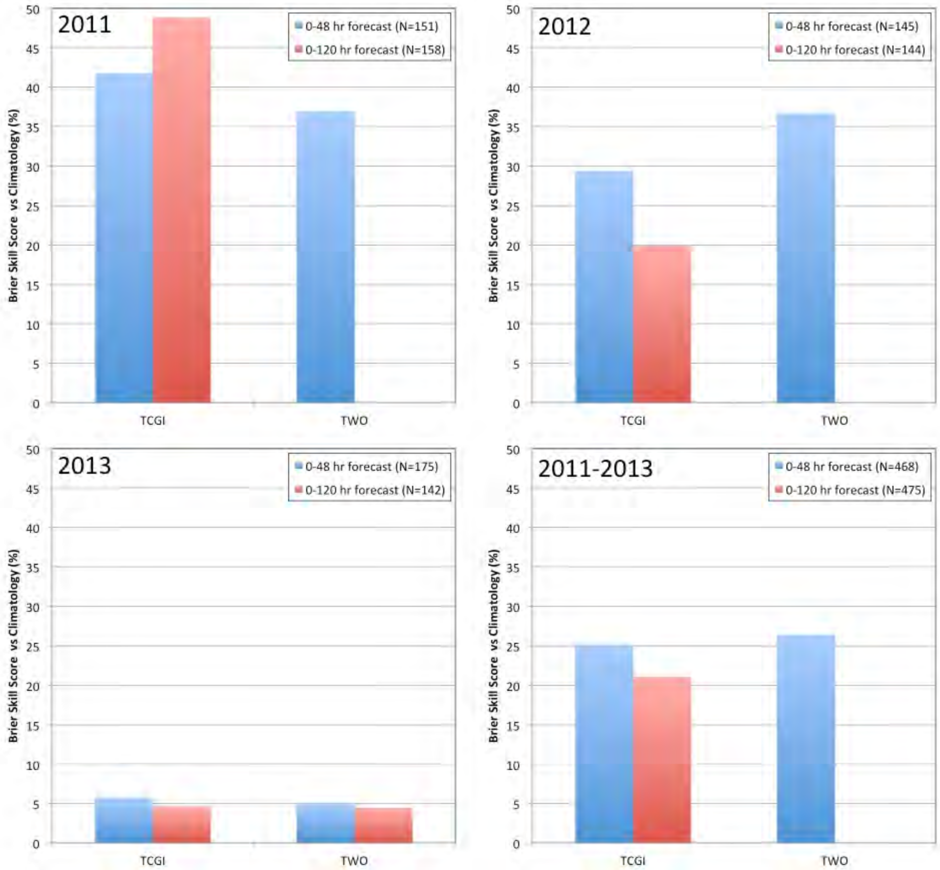

Fig. 7: Brier Skill Scores for TCGI and a homogenous sample of NHC TWO Atlantic probabilistic TC genesis forecasts for the 2011-2013 North Atlantic hurricane seasons. Skill was measured against the climatological probability of tropical cyclogenesis determined from a 2001-2010 dataset of North Atlantic invests.

3. Current / Future Efforts:

The proposal team has completed the TCGI project and turned over the real-time output (available on a CIRA web link) to the assigned NHC JHT points of contact on 11 September 2013. The proposal team has been and will continue to work closely with NHC forecasters as they evaluate TCGI for possible transition to operations. The TCGI code will be made available to NHC upon request.

COMPETITIVE PROJECT TITLE: Development of a Real-Time Automated Tropical Cyclone Surface Wind Analysis (NA11OAR4310204)

PRINCIPAL INVESTIGATOR: Renate Brummer

RESEARCH TEAM: Scott Longmore, Robert DeMaria

NOAA TECHNICAL CONTACT: Jiann-Gwo Jiing (NOAA/NHC)

NOAA RESEARCH TEAM: John Knaff and Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

Although surface and near surface wind observations and flight-level winds and their proxies exist in sufficient quantity to create high quality tropical cyclone surface wind analyses (cf., H*Wind analyses; Powell et al. 1998), a real-time and fully automated surface wind analysis system is not available at the National Hurricane Center (NHC). Such analyses could however be invaluable; providing useful information for a variety of current and future operational products.

In this project we created a real-time and fully automated surface wind analysis system at CIRA by combining accepted operational wind reduction procedures and a comparably simple variational data analysis methodology (Knaff et al. 2011). Results were then made available to NHC in real-time and in formats they requested. Specifically, this project made use of the Franklin et al (2003) flight-level to surface wind reduction findings along with current operational procedures and incorporated the analysis and quality control (QC) procedures used in the multi-platform tropical cyclone surface wind analyses (MTCSWA; Knaff et al. 2011). The real-time operationally-available aircraft reconnaissance wind data (i.e. HDOBS), and the MTCSWA satellite-based MTCSWA were used as input data. The MTCSWA serves as a first guess field with very low weighting and the aircraft-based data will be composited over a finite period (maximum of 9 hours@ three hours after synoptic time) and analyzed. The analyses are performed on a polar grid at a common 700-hPa level and then adjusted to the surface level (i.e. 10-meter). The polar grid resolution and domain size was specified by the JHT and is consistent with the resolution of the aircraft reconnaissance data and the needs of the forecasters.

If acceptable to operations, the wind analysis would run at NHC and make use of the local data stream and JHT servers. The resulting two-dimensional wind analysis would then produce 1-min sustained winds valid for 10 meter (m) marine exposure with sufficient resolution to properly capture the radii of maximum winds.

PROJECT ACCOMPLISHMENTS:

1-- Software Development

In August 2011 the project began with discussions with NHC about what data would be used to create surface wind analyses. The data used included the data available in the real-time HDOBS (flight-level winds, pressures, and SFMR surface wind speed estimates) and the operational satellite-based MTCSWA flight-level wind fields. Routines were developed to ingest the HDOBS and MTCSWA fields and store the information in a common data format. To provide estimates of real-time cyclone information, a track from a combination of operational best track positions, aircraft fixes and the OFCI forecast locations was created. In consultation with NHC hurricane specialists data weights for the flight-level and SFMR wind speed information that was a function of flight-level wind speed were implemented (Table 1). Another consideration requiring input from NHC was how the flight-level wind analysis would be reduced to the surface. Here we relied upon the information in Franklin et al. (2003) to provide the mean reduction factors (Fr) and other operational guidelines. Specifically we attempt to define a convective eyewall region and an outer region based on the radius of maximum wind (RMW) with azimuthal variation of 4% and 17%, respectively. Finally, the width of the eyewall region is at largest 20 nmi beyond the RMW.

Examples of Fr are shown in Figure 1. The input and track information were then used to create a series of motion relative analyses and those results were presented at the IHC in 2012.

Flight-Level Wind Speed (V[kt])	Flight-Level Zonal Weight	Flight-Level Meridional Weight	SFMR Wind Speed Weight
V ≥ 64	0.175	0.175	1.0
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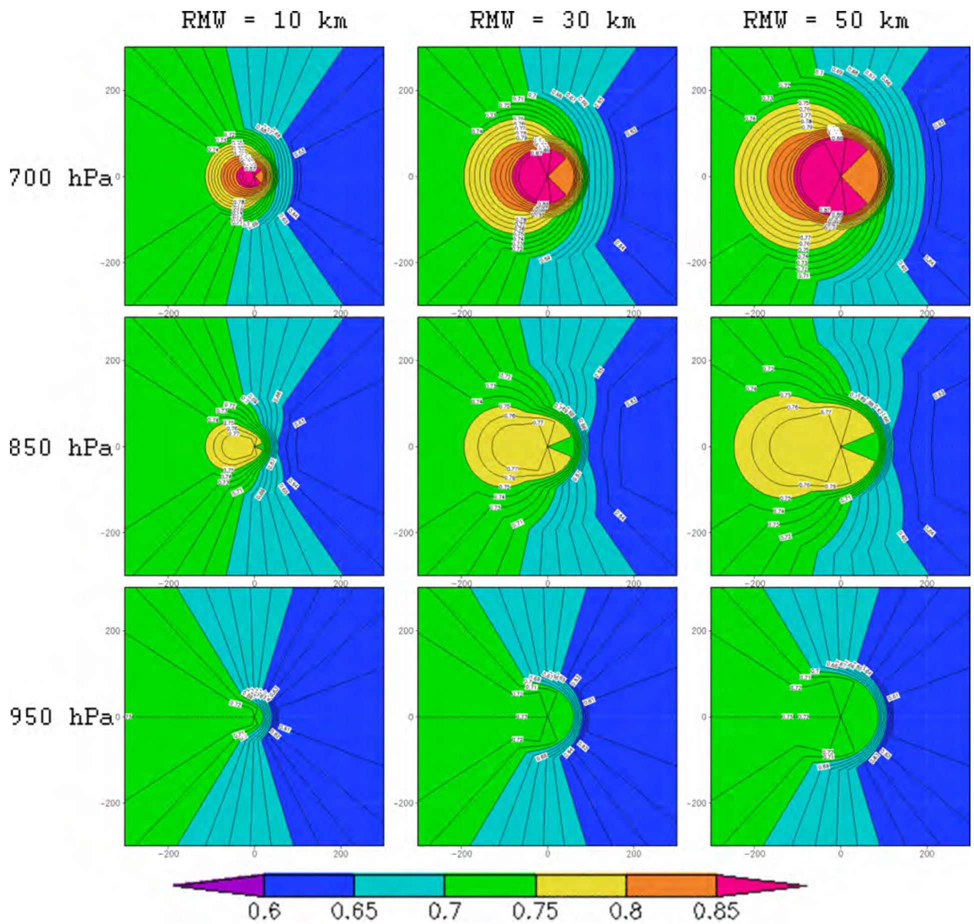

Figure 1. Examples of the flight-level to surface wind reduction factors (Fr) used for this application. These examples show the Fr values for a storm moving toward the top of the page for three values of RMW and three typical flight-level pressures.

Near the end of the first year of this project scripts were written to generate analyses in a real-time manner using operationally available data within the CIRA computer infrastructure. Runs were scheduled at the synoptic time minus 30 minutes, plus 30 minutes and plus 90 minutes We also reran the analyses for the 2010 and 2011 hurricane season to better refine the algorithm. The output of the real-time 2012 and post 2010/11 analyses were made available via ftp to forecasters and NHC's JHT representatives. We also attempted to move the scripts and other software to NHC, but abandoned that effort after finding out that the JHT servers were outside the firewall. It was also clear after the 2012 Hurricane season that some work was still needed on the existing scripts and software. We also were asked to improve methods of distribution of the analyses to better facilitate the use of these analyses in the NHC operational environment. Results were presented at the 2013 IHC. Since the IHC, several software features were corrected that were related to the errant negative weighting of the MTCSWA, too stringent gross error checking, and errors in the Fr estimation routine. Our script would also not run multiple aircraft cases at the same synoptic time.

During the 2013 Hurricane season real-time analyses were also created. Analyses were run one hour following the synoptic hour – a lesson learned from 2012. These analyses were then converted to GEMPAK format to better facilitate viewing by NHC forecasters (i.e. on N-AWIPS). The distribution was accomplished via ftp and naming conventions were coordinated with JHT operational representatives. Files were tested and they could be viewed in N-AWIPS, however the images were never imported in a real-time manner into NHC's operations. Thus, the operational utility of these analyses could not be evaluated.

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2—Example Cases

To examine some of these issues we present analyses associated with two 2011 hurricane cases, namely Hurricane Jova, 10 October 18 UTC and Hurricane Irene, 25 August 00 UTC. In the cases 2 and 61 input data were removed by the quality control, as part of the Jova and Irene analyses. Irene had several SFMR wind estimates that were in excess of 105 kt that were removed by the gross quality control operations – noting that the best track intensity estimate was 95 kt. Both cases also had a complete alpha flight pattern and thus similar amounts of flight-level observations.

Case 1: Hurricane Jova (2011), 10 October 18 UTC:
Best Track Intensity: 110 kt
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Best Track R50: 35, 40, 30, 30
Best Track R64: 25, 20, 20, 15

Some details of the automated analysis of Hurricane Jova are shown in Figure 2. The larger domain shows that region of analyzed gale-force winds is quite a bit larger than the best tracked R34 values. In addition the asymmetries appear shifted 90 degrees in the analysis with the strongest winds occurring in the SE and SW quadrants of the storm. R50 and R64 have similar values as the best track, but again the asymmetries seem rotated to the southern quadrants in the analysis. The maximum wind was estimated at 95 knots based on a maximum analyzed flight-level wind as 109 knots. The lower right panel of Figure 2 shows the flight-level wind speeds and SFMR equivalent flight-level wind speed inputs following quality control plotted as a function of latitude, along with a horizontal line representing the maximum wind found in the analysis at flight level (112 kt). It is clear that the analysis is under estimating the maximum found in the SFMR observations. However the analyzed maximum flight-level wind speed is slightly nudged toward those SFMR observations (i.e., the analyzed flight-level wind is larger than the observed maximum flight-level winds (109 kt) based on several SFMR observations that indicate higher surface winds than the flight-level winds would indicate). We note here that the 140 kt SFMR flight-level equivalent wind speeds that pass QC would supported by a 109 kt SFMR observation. The analysis on the other hand, produced a 95 kt maximum surface wind based on 112 kt at flight-level (Fr=.85). For the analysis as a whole, the fit to the wind speed data at flight level produced biases of -3.3 kt, mean absolute errors of 7.5 kt, and RMSE or 10.4 kt (n=1013). Tangential and radial wind RMSE's were 4.8 kt and 4.4 kt, respectively (n=455).

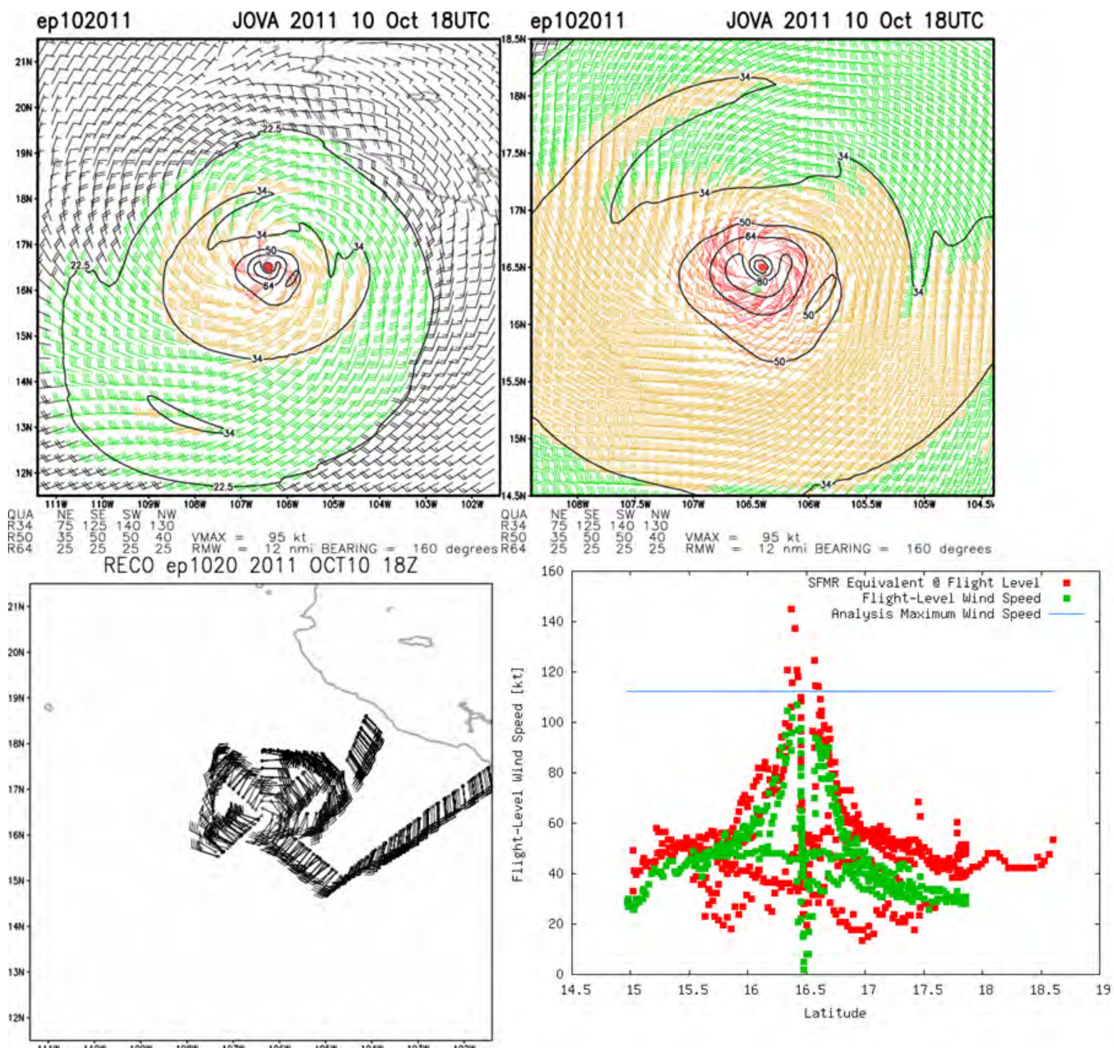


Figure 2. Some details of the surface and flight-level wind analysis associated with Hurricane Jova (2009) October 10 18UTC. (Top left) Large scale analysis showing the effective combination of MTCSWA and HDOBS data, (top right) small-scale view of the wind analysis showing the details of the wind asymmetries and inner core winds, (bottom left) a schematic showing the storm-motion-relative aircraft flight paths for this analysis, and (bottom left) plot of winds speeds as a function of latitude that have been

standardized to a 700-hPa flight-level and the maximum analyzed flight-level wind is indicated by the horizontal line.

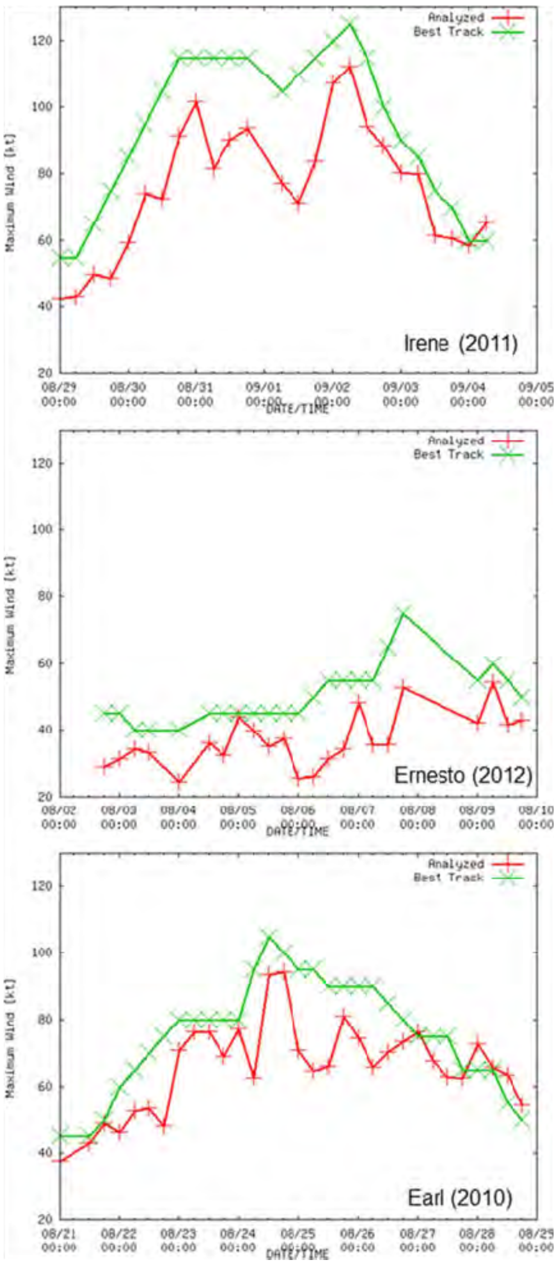
Case 2: Hurricane Irene (2011), 25 August 00 UTC:
Best Track Intensity: 95 kt
Best Track R34: 220, 180, 100, 150
Best Track R50: 100, 90, 50, 80
Best Track R64: 60, 60, 25, 50

Irene represented different challenges as it had a broad horizontal wind profile and the analysis produced poorer results in terms of maximum winds. The wind field in the NE quadrant was rather strong and constant. However, the azimuthally averaged radius of maximum wind was 18 nmi and the storm was moving to the northwest. The analyzed flight-level maximum wind was 101 kt and this was a little lower than the observations would suggest. The strongest flight-level winds were not close to the azimuthal mean radius of maximum wind so the estimated Fr for that point was ~ 0.7 (cf. Figure 1). As a result the maximum surface wind for Irene was estimated at 71 kt, which represents an underestimate of 25%. For the analysis as a whole, the fit to the wind speed data at flight level produced biases of -4.8 kt, mean absolute errors of 6.7 kt, and RMSE or 9.9 kt (n=1196). Tangential and radial wind RMSE's were 5.1 kt and 4.9 kt, respectively (n=557). The analysis based wind radii were also generally smaller than the best track values, especially the northeast quadrant, where the MTCSWA flight-level winds reduced to the surface were not indicating gale-force winds beyond 120 nmi, but Fr was order 0.63, which might be too small. While there seems to be a general low bias associated with the maximum surface wind estimates, these analyses do provide detailed information concerning both the 64- and 50-kt wind radii. In addition objective estimates of the radius of maximum wind and location are also provided. Objective guidance for these quantities does not currently exist. Furthermore, since the wind field is output other information could be ascertained from the digital wind field if that is desired in operations.

3-- Estimation of Maximum Winds

We examined a few cases when several days of consecutive aircraft sorties and analyses were performed to estimate the maximum wind speed estimates. Figure 3 shows three cases. Generally these are lower than the best track estimates. However, the analysis of flight-level maximum winds agrees quite well with the flight-level observations data as shown in Figures 2 and is true for most other cases. The mean Fr that would remove much of the bias in the maximum surface wind estimates is around 0.95. At this time it is unclear if there are problems with the Fr being used or if the underestimates are caused by undersampling the wind field (cf, Ehlhorn and Nolan 2012). As a result it is not clear how to rectify this shortcoming. However, both applying a bias correction to account for under sampling and modifying the Fr rules are relatively easy to implement within the software.

4-- Wind Structure
One of the potentially useful capabilities of these analyses is the monitoring of the wind structure over time. Figure 4 shows the azimuthally averaged profiles of wind speed, radial wind and tangential wind for Hurricane Earl. Analyses are separated by approximately one day. The evolution of the radius of maximum wind, radial convergence and steepness of the tangential wind can be compared between different analyses. These analyses could be particularly useful for detection of secondary wind maximum development, and initial eye formation. However, display methods would need to be developed to make such information easily accessible in operations.



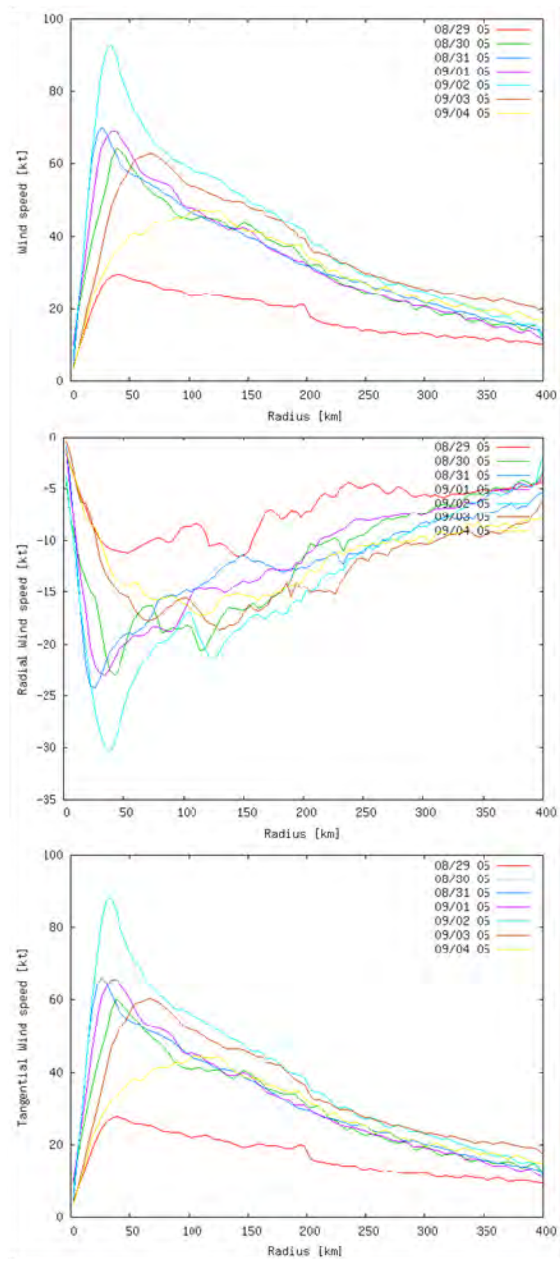


Figure 3. Left: Time series comparison of analyzed maximum winds and best track maximum wind estimates for three hurricane cases.

Figure 4. Right: Azimuthally averaged radial wind profiles from each day there were analyses for Hurricane Earl (2010). The total wind speed is shown at the top, radial wind in the middle and tangential winds in the bottom panels.

This project strived to create an automated tropical cyclone surface wind analysis that effectively analyzed the real-time data from aircraft reconnaissance using a satellite-based surface wind product as a first guess. The project was successful in this endeavor, but the work was never transitioned to pre-operations at NHC. The output analyses also tend to be low biased with respect to the maximum wind reported in the best track record. It is unclear if this low bias is due to the assumptions made to reduce the flight-level wind analysis to the surface or due to undersampling the wind field. Regardless of the exact cause, the method developed here could be easily modified to account for undersampling (bias correction) and/or modification of Fr. So with a little effort these methods could be tuned to alleviate many of the shortcomings of the current surface wind estimates. Furthermore, the application could easily be installed in NHCs operations and would provide an enhancement to operations by improved utilization of aircraft reconnaissance data.

The following is the report previously submitted to the Technical Sponsor.

NOAA Joint Hurricane Testbed (JHT)
Progress Report, Year 2

Date:	July 30, 2013
Project Title:	*Development of a Real-Time Automated Tropical Cyclone Surface Wind Analysis*
Principal Investigators:	Renate Brummer, Mark DeMaria (Co-I), John Knaff (Co-I)
Affiliations:	Brummer (CIRA/CSU), DeMaria and Knaff (NOAA/NESDIS)
Project Dates:	Aug.2011-Jul.2013

1. Long-Term Objectives and Specific Plans to Achieve Them

Although surface and near surface wind observations and flight-level winds and their proxies exist in sufficient quantity to create high quality tropical cyclone surface wind analyses (cf., H*Wind analyses; Powell et al. 1998), a real-time and fully automated surface wind analysis system is not available at the National Hurricane Center (NHC). Such analyses could however be invaluable; providing useful information for a variety of current and future operational products.

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2. Accomplishments

a. Software development

In August 2011 the project began with discussions with NHC about what data would be used to create surface wind analyses. The data used included the data available in the real-time HDOBS (flight-level winds, pressures, and SFMR surface wind speed estimates) and the operational satellite-based MTCSWA flight-level wind fields. Routines were developed to ingest the HDOBS and MTCSWA fields and store the information in a common data format. To provide estimates of real-time cyclone information, a track from a combination of operational best track positions, aircraft fixes and the OFCI forecast locations was created. In consultation with NHC hurricane specialists data weights for the flight-level and SFMR wind speed information that was a function of flight-level wind speed were implemented (Table 1). Another consideration requiring input from NHC was how the flight-level wind analysis would be reduced to the surface. Here we relied upon the information in Franklin et al. (2003) to provide the mean reduction factors (F_r) and other operational guidelines. Specifically we attempt to define a convective eyewall region and an outer region based on the radius of maximum wind (*RMW*) with azimuthal variation of 4% and 17%, respectively. Finally, the width of the eyewall region is at largest 20 nmi beyond the *RMW*. Examples of F_r are shown in Figure 1. The input and track information were then used to create a series of motion relative analyses and those results were presented at the IHC in 2012.

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Case 2: Hurricane Irene (2011), 25 August 00 UTC:

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3. Operational Transition Considerations

If the NHC desires to make this an operational capability there are a number of factors that need to be considered.

a. Software

The current software requires a FORTRAN 90 compiler, Python 6.4 or higher, Bash shell script, Gempak, and GrADS. The GrADS options can be easily removed from the scripts, but GrADS-based graphics may be useful for quick looks after the season.

A master script runs at 1 hour after synoptic time. It creates a production location and copies all the information and data it needs to that directory, and runs the executables in the proper order. Active storms are identified, and short-term tracks of each active storm are created that include the aircraft fix locations when available. HDOBs for the last couple of days are then copied to the processing location. Python code then reformats the aircraft information into a simple ASCII input file. The short-term tracks and reformatted HDOBS are then used as input the analysis executable. Each analysis takes less than 3 minutes on a five-year-old Linux workstation running RH5 32bit.

Scripts will likely have to be rewritten to operational standards, but the FORTRAN code follows NESDIS operational standards. Developers are willing to assist in any revisions.

b. Input data

Input data comes from three sources. The operational locations and aircraft fix information comes from the databases of the ATCF. In the CIRA implementation we have a mirror of NHCs a, b, f, and e decks in one directory location. When the analysis is run we copy a, b and f decks to a production area for each run. HDOBS are also mirrored at CIRA in one location from their locations on the NHC web server (http://www.nhc.noaa.gov/archive/recon/2013/AHONT1/ and http://www.nhc.noaa.gov/archive/recon/2013/AHOPN1/). Data from the last couple of days is typically used as input the analysis executable after being reformatted by a python routine. The final input are the flight-level MTCSWA files (*.WIN). The MTCSWA is also mirrored at CIRA from its location at the National Satellite Operations Facility (ftp://satepsanone.nesdis.noaa.gov/MTCSWA). The master script figures out what MTCSWA to use as a first guess/environmental field. The mirroring of HDOBS and MTCSWA is accomplished using wget (a gnu tool) scripts.

c. Output files

A number of files are archived from the surface wind analysis software   A list of files and a brief description of each is provided below. The master script can be modified to save fewer files if that is desired.

2011082500_2011al09_L_TCWA.AAV	Ascii, azimuthal mean radial profiles
2011082500_2011al09_L_TCWA.AIRC	Ascii, flight-level wind, location, weights
2011082500_2011al09_l_tcwa_airc.dat	Ascii, GEMPAK input flight-level wind
2011082500_2011al09_l_tcwa_airc.sfc	Binary, Gempak SFMR at flight-level
2011082500_2011al09_l_tcwa_airc.tbl	Ascii, Gempak locations for surface
2011082500_2011al09_L_TCWA.bin	data
2011082500_2011al09_L_TCWA.ctl	Binary, Grads binary grid
2011082500_2011al09_L_TCWA.DIA	Ascii, Grads control file
2011082500_2011al09_L_TCWA.fgue	Ascii, Diagnostic file
2011082500_2011al09_L_TCWA.FIX	Ascii, first guess from MTCSWA
2011082500_2011al09_L_TCWA.gif	Ascii, ATCF fix
2011082500_2011al09_L_TCWA.grd	Binary, large-scale surface wind plot
2011082500_2011al09_L_TCWA.gs	Binary, Gempak gridded analysis
2011082500_2011al09_L_TCWA_hr.gif	ASCII, grads script that makes the plot
2011082500_2011al09_L_TCWA.hrgs	Binary, small-scal surface wind plot
2011082500_2011al09_L_TCWA_hr.ps	Ascii, grads script that make the hr plot
2011082500_2011al09_L_TCWA.inp	Postscript file of small-scale plot
2011082500_2011al09_L_TCWA.log	Ascii, Short-term track file
2011082500_2011al09_L_TCWA.obs	Ascii, production log
2011082500_2011al09_L_TCWA.ps	Ascii, formatted HDOBS
2011082500_2011al09_L_TCWA_RECO.fld	Postscript file of large-scale plot
2011082500_2011al09_L_TCWA_RECO.gif	Ascii, all recon obs, locations, weights
2011082500_2011al09_L_TCWA_RECO.ksh	Plot of motion relative recon obs
2011082500_2011al09_L_TCWA_s.fil	Script that make the above plot
2011082500_2011al09_L_TCWA.SSFM	Ascii, Gempak input to grid wind speed
2011082500_2011al09_l_tcwa_ssfm.dat	Ascii, SFMR @ fl, locations and
2011082500_2011al09_l_tcwa_ssfm.sfc	weights
2011082500_2011al09_l_tcwa_ssfm.tbl	Ascii, Gempak input to make SFMR@fl
2011082500_2011al09_L_TCWA_u.fil	Binary, Gempak file SFMR@ fl
2011082500_2011al09_L_TCWA_v.fil	Ascii, Gempak locations for SFMR
	Ascii, Gempak input to grid u wind
	Ascii, Gempak input to grid v wind

4. Summary

This project strived to create an automated tropical cyclone surface wind analysis that effectively analyzed the real-time data from aircraft reconnaissance using a satellite-based surface wind product as a first guess.   The project was successful in this endeavor, but the work was never transitioned to pre-operations at NHC.   The output analyses (see locations below) also tend to be low biased with respect to the maximum wind reported in the best track record. It is unclear if this low bias is due to the assumptions made to reduce the flight-level wind analysis to the surface or due to undersampling the wind field. Regardless of the exact cause, the method developed here could be easily modified to account for undersampling (bias correction) and/or modification of F_r. So with a little effort these methods could be tuned to alleviate many of the shortcomings of the current surface wind estimates. Furthermore, the application could easily be installed in NHCs operations (details in Section 3) and would provide an enhancement to operations by improved utilization of aircraft reconnaissance data. We summarize what worked and what did not in bullets following the details on the output locations.

Output (gif image, by atcf number) 2010-2013 available at
ftp://rammftp.cira.colostate.edu/Knaff/JHT_TCSWA/
N-AWIPS files
ftp://rammftp.cira.colostate.edu/Knaff/JHT_TCSWA/nawips/
ATCF Fixes
ftp://rammftp.cira.colostate.edu/Knaff/JHT_TCSWA/atcf/

What worked?

- Software to grab the available HDOBS and analyze these data in a motion-relative composite manner
- Estimate wind structure from the analyses (R34, R50, R64, RMW)
- Create ATCF formatted fixes
- Create graphics and GEMPAK-formatted binaries
- Make real-time analysis information and binaries available via ftp

What did not work?

- We were unable to install any of the software in NHCs operational environment
- GEMPAK-formatted binaries were never imported into NHC's N-AWIPS
- Output was never viewed by specialists during their operational duties.
- Estimating Maximum winds from these analyses
- ATCF fixes were never imported to the operational ATCF.

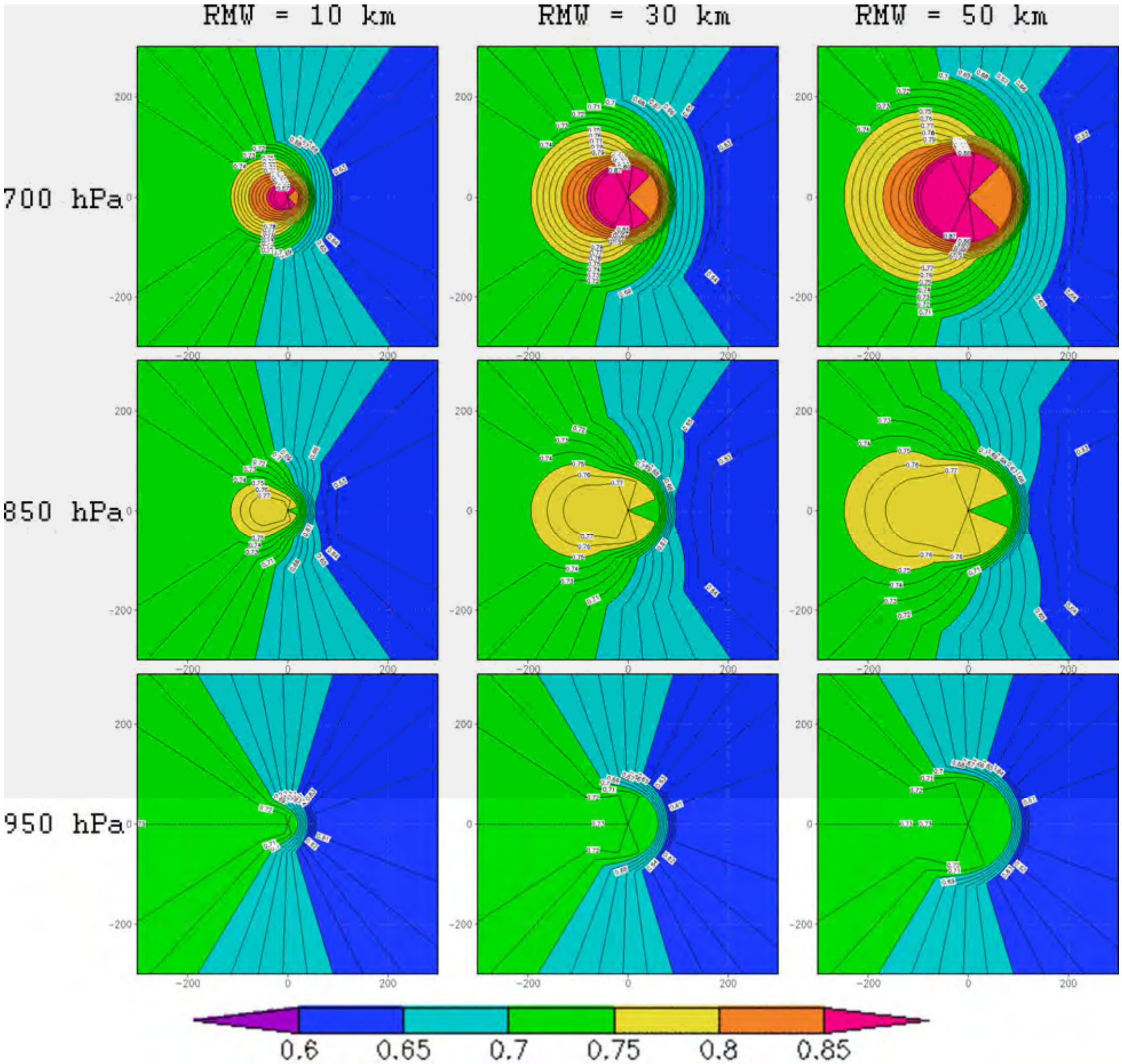

Figure 1: Examples of the flight-level to surface wind reduction factors (F_r) used for this application. These examples show the F_r values for a storm moving toward the top of the page for three values of RMW and three typical flight-level pressures.

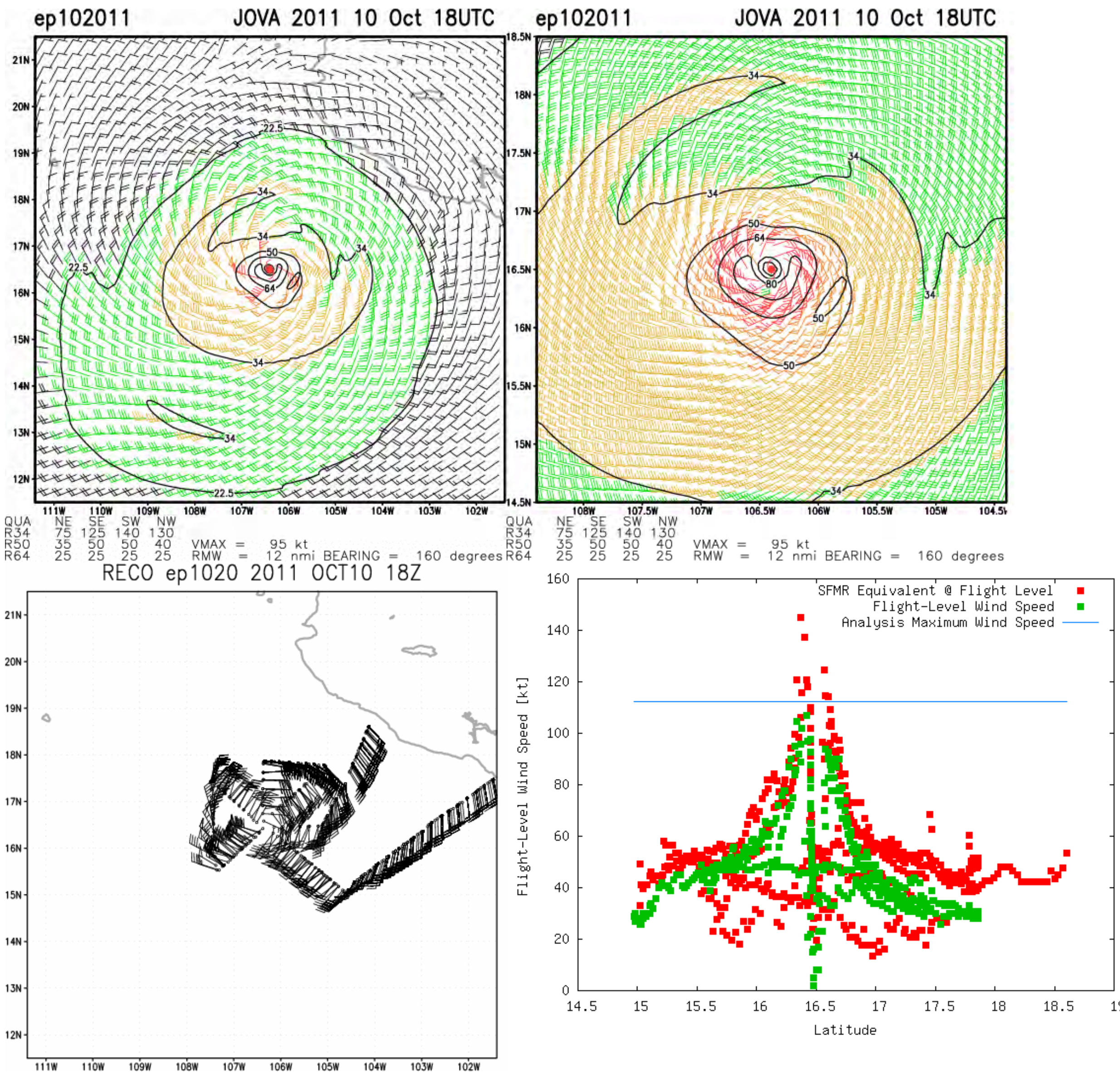

Figure 2: Some details of the surface and flight-level wind analysis associated with Hurricane Jova (2009) October 10 18UTC. (Top left) Large scale analysis showing the effective combination of MTCSWA and HDOBS data, (top right) small-scale view of the wind analysis showing the details of the wind asymmetries and inner core winds, (bottom left) a schematic showing the storm-motion-relative aircraft flight paths for this analysis, and (bottom left) plot of winds speeds as a function of latitude that have been standardized to a 700-hPa flight-level and the maximum analyzed flight-level wind is indicated by the horizontal line.

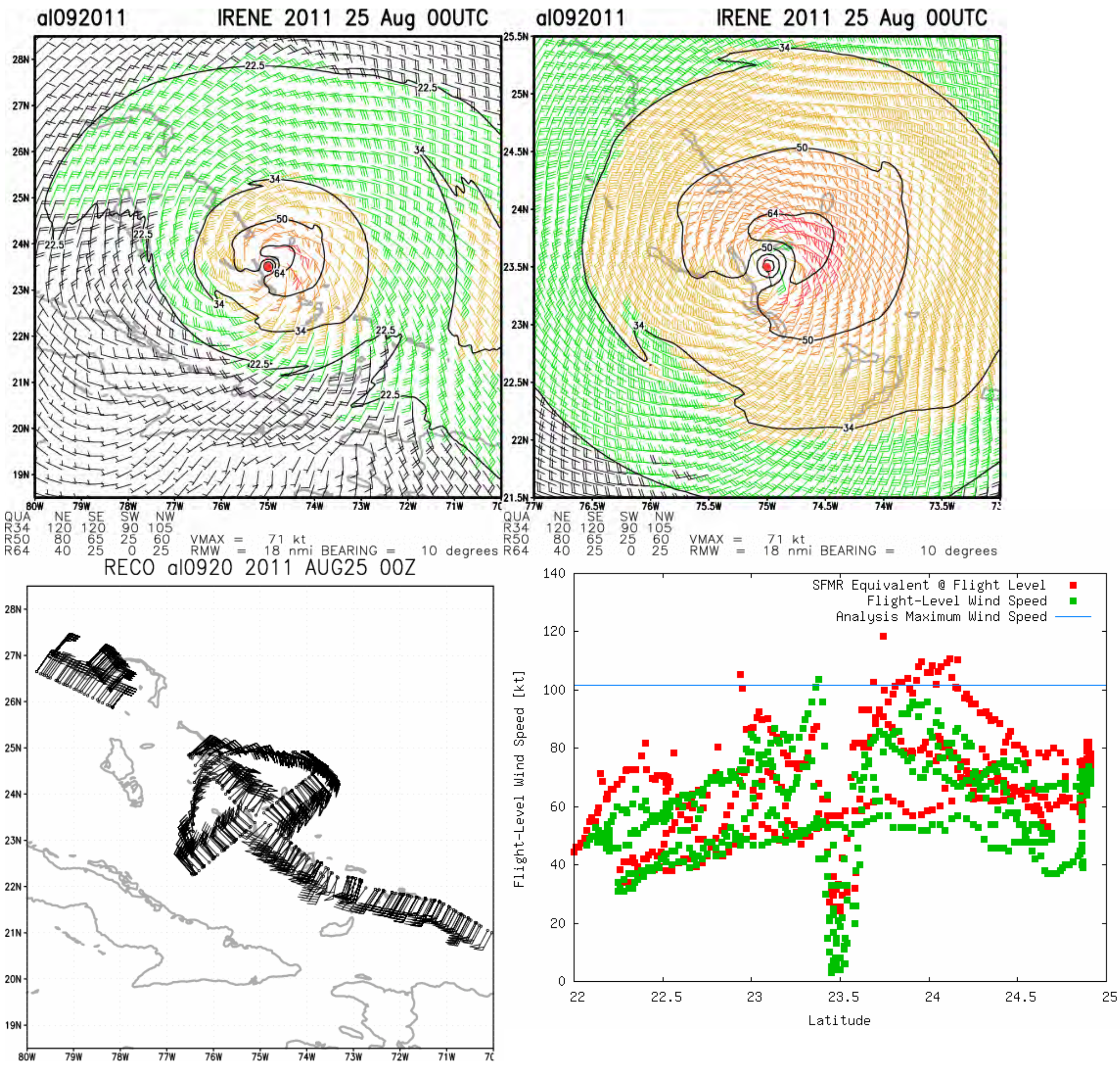

Figure 3: Same as Figure 2, except for Hurricane Irene (2011) on 25 August at 00 UTC.

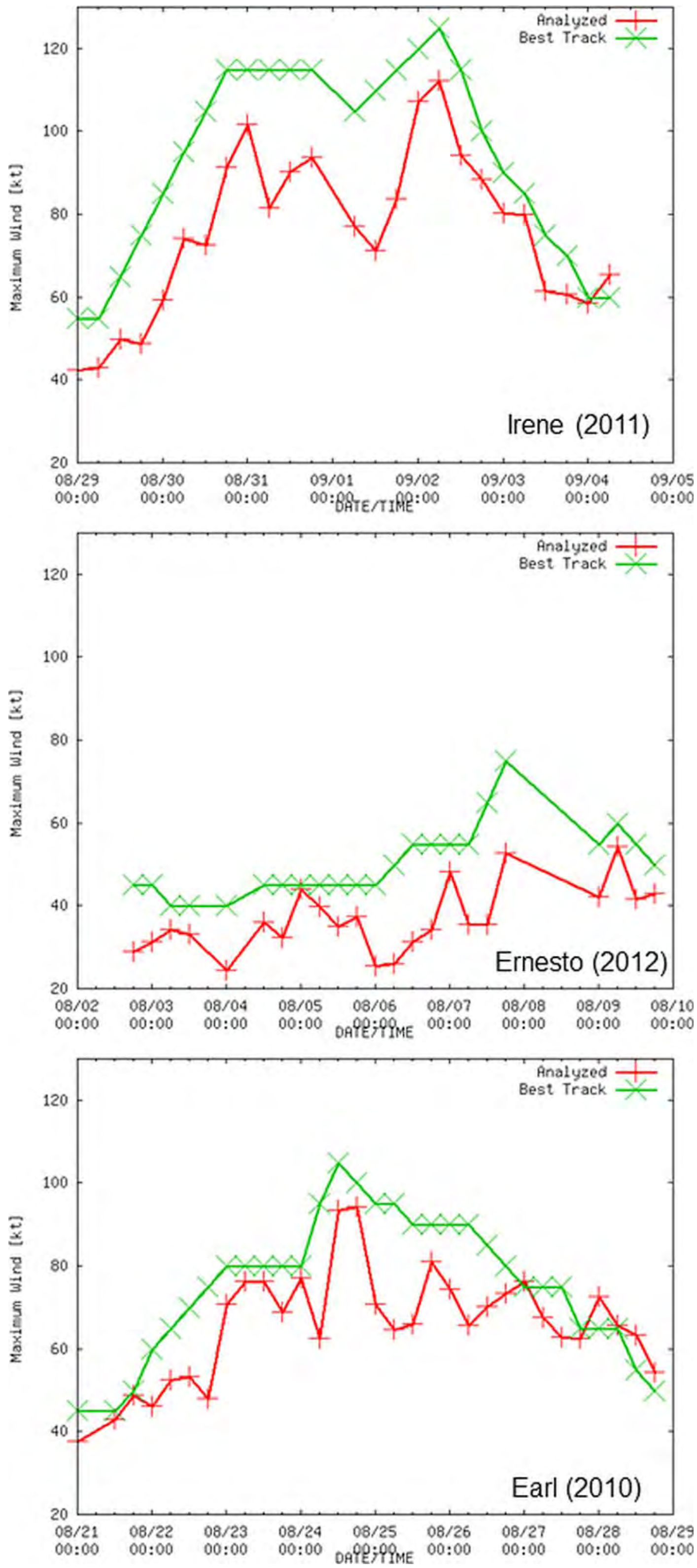

Figure 4: Time series comparison of analyzed maximum winds and best track maximum wind estimates for three hurricane cases.

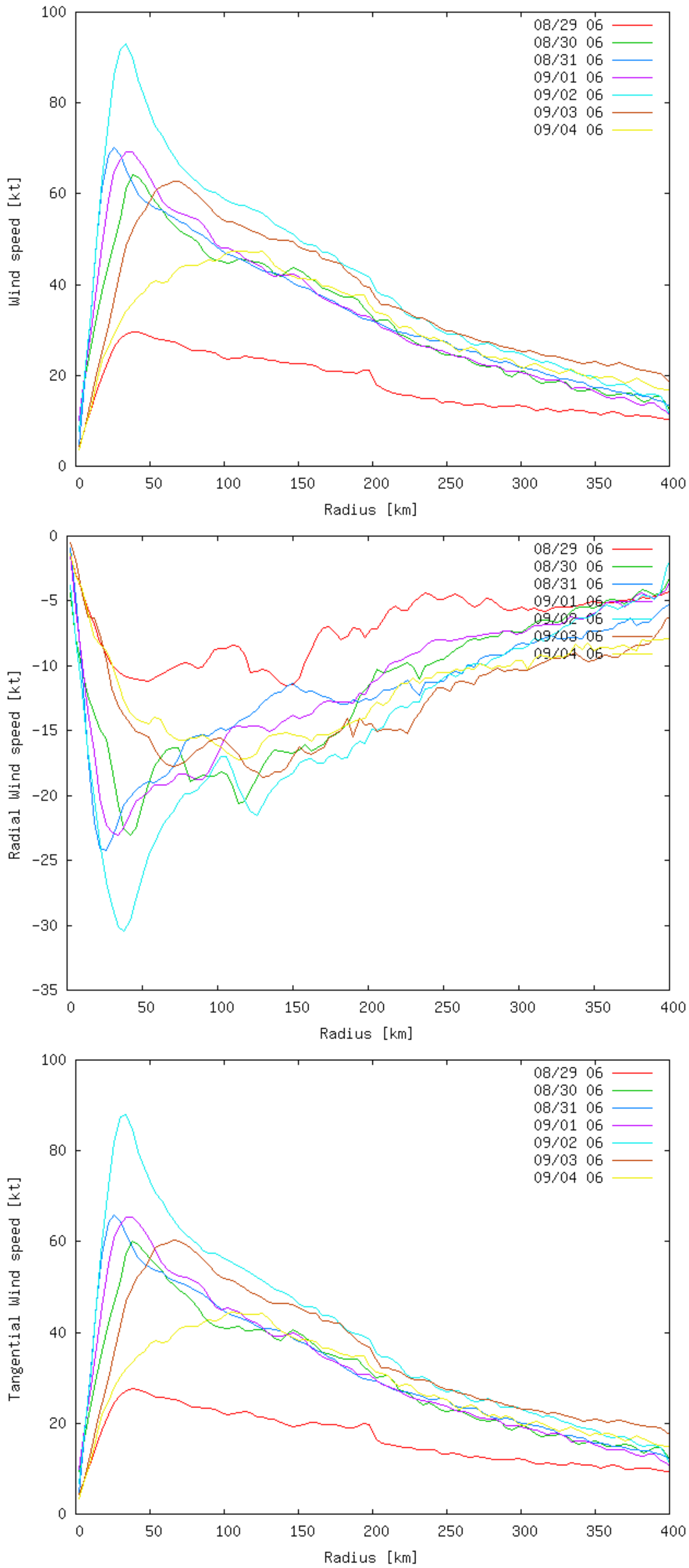

Figure 5: Azimuthally averaged radial wind profiles from each day there were analyses

for Hurricane Earl (2010). The total wind speed is shown at the top, radial wind in the middle and tangential winds in the bottom panels.

Appendix A: Original Milestones.

Year 1
Aug 2011 – Project begins
Aug 2011 – Discussions with NHC to determine desired analysis properties
Aug 2011 – Begin the development of local data ingest design
Aug 2011 – Develop routines to ingest aircraft flight-level, SFMR, and GPS sonde data
Sep 2011 – Develop scripts to combine aircraft center fixes, operational best tracks and OFCI
Nov 2011 – Combine the TC track and the analysis (CIRA and CIMAS)
Dec 2011 – Develop methods to standardize the data types based on NHC's preferences
Feb 2012 – Meet with NHC specialists to discuss options for data weights and smoothing constraints.
Mar 2012 – Present progress at the IHC (ALL)
Mar 2012 – Begin Development scripts to automate the local (CIRA) data ingest, quality control and analysis on a JHT workstation
Apr 2012 – Work with NHC to develop text and graphical output.
May 2012 – Begin testing of the automated analysis routines on past events (CIRA, FSU)
May 2012 – Evaluation of past events and their sensitivity to weight and smoothing, confer with NHC.
May 2012 – Start to test the automated routines in real-time at CIRA
July 2012 – Respond to feedback from NHC (ALL)

Year 2
Aug 2012 – Real-time testing continues
Dec 1012 – Evaluation of the analyses, gather feedback from NHC
Jan 2013 – Modify analysis parameters based on feedback and evaluation results
Feb 2013 – Rerun cases, if necessary
Mar 2013 – Present results at the IHC
May 2013 – Prepare the analysis for a full season of real time testing
July 2013 – Gather feedback and make appropriate changes to the analysis system
July 2013 – Project ends

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Franklin, J. L., M. L. Black, and K. Valde, 2003: GPS dropwindsonde wind profiles in hurricanes and their operational implications. *Wea. Forecasting*, **18**, 32–44.

Knaff, J.A., M. DeMaria, D.A. Molenar, C.R. Sampson and M.G. Seybold, 2011: An automated, objective, multi-satellite platform tropical cyclone surface wind analysis. *J. of App. Meteor.,* **50**, 2149-2166.

Powell, M. D., S. H. Houston, L. R. Amat, and N. Morisseau-Leroy, 1998: The HRD real-time hurricane wind analysis system. *J. Wind Eng. Ind. Aerodyn*., **77-78**, 53–64.

Uhlhorn, E.W., and D.S. Nolan, 2012. Observational undersampling in tropical cyclones and implications for estimated intensity. *Monthly Weather Review*, **140**(3) p.825-840.

COMPETITIVE PROJECT TITLE: Guidance on Intensity Guidance (NA13OAR4590187)

PRINCIPAL INVESTIGATORS: Andrea Schumacher

RESEARCH TEAM: Robert DeMaria, Dave Watson, and Renate Brummer

NOAA TECHNICAL CONTACT: Jiann-Gwo Jiing (NOAA/NHC)

NOAA RESEARCH TEAM: Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

An operational algorithm to estimate the confidence of the intensity forecasts from NHC's primary intensity models and their consensus will be developed. The models include the statistical-dynamical Decay-SHIPS (DSHP) and Logistic Growth Equation Model (LGEM) and the early versions of the GFDL and HWRF coupled ocean-atmosphere models (GHMI and HWFI). The technique builds on the results of Bhatia and Nolan who demonstrated that the errors and biases of DSHP, LGEM, and GFDL have significant systematic variability as a function of a number of storm environmental variables that are available in real time, including the magnitude of the vertical shear, the direction of the shear, the initial intensity, and the maximum potential intensity. The intensity model error will be estimated from a linear combination of these predictors, supplemented with other variables. These include additional synoptic parameters, inner core structure from infrared imagery and the eye diameter and radius of maximum wind parameters from the Automated Tropical Cyclone Forecast (ATCF) system, ocean input from the sea surface temperature and oceanic heat content, the spread of the individual intensity models forecasts, and the recent performance of each model from times before the forecast time. Versions will be developed for the Atlantic and the combined East/Central Pacific. This algorithm will be referred to as the Prediction of Intensity Model Error (PRIME) model. The PRIME model will be run at the end of the SHIPS model script. Assuming the model errors can be reliability estimated, the output from the PRIME model will be used to develop a corrected consensus forecast, which will be an unequally weighted combination of DSHP, LGEM, GHMI and HWFI forecasts. The error analysis will also be used to provide guidance for improvements to the DSHP and LGEM models.

Tropical Cyclone (TC) forecasts affect risk mitigation activities of industry, public and governmental sectors and therefore supports directly NOAA's Weather and Water mission goals.

PROJECT ACCOMPLISHMENTS:

1--Begin development of PRIME model with combined predictor set:

Year 1 activities consisted of the analysis of the developmental data to identify predictors that are best correlated with intensity errors. Co-PI D. Nolan and Co-I K. Bhatia from the University of Miami have been leading these efforts with input from A. Schumacher and M. DeMaria. Preliminary predictors for input to the PRIME model have been determined and results were presented at the 68th Interdepartmental Hurricane Conference (Bhatia et al., listed below). CIRA and UM researchers will begin work on the development of the PRIME model for the Atlantic in Year 2.

COMPETITIVE PROJECT TITLE: Improvements in Statistical Tropical Cyclone Forecast Models (NA11OAR4310203)

PRINCIPAL INVESTIGATOR**:** Renate Brummer

RESEARCH TEAM: Andrea Schumacher, Robert DeMaria,

NOAA TECHNICAL CONTACT: Jiann-Gwo Jiing (NOAA/NHC)

NOAA RESEARCH TEAM: Mark DeMaria and John Knaff (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

Although considerable effort is being made to improve dynamical tropical cyclone forecast models, statistical-dynamical models have generally provided the most accurate intensity predictions over the last few years. Four improvements to statistical-dynamical tropical cyclone forecast models were proposed. These included: (1) Improving the method to estimate the intensity growth rate in LGEM so the forecasts can be extended to seven days; (2) Developing special versions of SHIPS and LGEM for the Gulf of Mexico region; (3) Improving the databases used to develop SHIPS and LGEM through the use of the NCEP's new Climate Forecast System Reanalysis (CFSR); and (4) Developing an extended range climatology and persistence (CLIPER) model for track and intensity. This project supports the following NOAA mission goals: Weather and Water.

RESEARCH CONDUCTED:

The accomplishments on the four main topics are summarized in Section 2a, including suggestions from the developers on which of the new capabilities might be transitioned to operations.

1-- Seven Day LGEM

The persistence component was separated from the LGEM formulation so the model could be fitted to the full life cycle of each storm with a much smaller number of coefficients (separate coefficients are not needed for each forecast internal). Because the coefficients are not time dependent, the model can then be run to any length. Atlantic and East Pacific versions were developed from 2000-2011 data and then run out to 7 days on independent cases from 2012-2013 using operational input. The new version of the model is referred to as LGEM7. As shown below in Section b, the results were somewhat mixed. The model was generally well behaved and had skill relative to the new extended range baseline model at most forecast times out to 7 days in the east Pacific. In the Atlantic, LGEM7 only had skill at 7 days. The 2012-2013 sample sizes were fairly small at the extended ranges and the Atlantic sample was somewhat atypical, with most the intensification occurring at higher latitudes.

Because of the complexity of the new fitting technique for LGEM7, the test model only included the top 5 of the 20 LGEM predictors. The predictors related to baroclinic interactions, such product of product of shear with latitude, and the vortex in the GFS model were not included, which may explain the more negative results for the Atlantic version. Also, for days 1-5, LGEM7 had larger errors than LGEM, especially in the Atlantic.

2-- The Gulf-specific version of LGEM

The Gulf-specific version of LGEM uses the same formulation as LGEM7, but was developed from cases that were initially in the Gulf of Mexico region. The coefficients for the Gulf of Mexico version were different than those from the Atlantic basin version. In particular, the Oceanic Heat Content predictor was more important for the Gulf of Mexico. The Gulf of Mexico version was included in the LGEM7 runs for the 2012-2013 independent tests, but the sample of Gulf cases was too small to make a meaningful comparison.

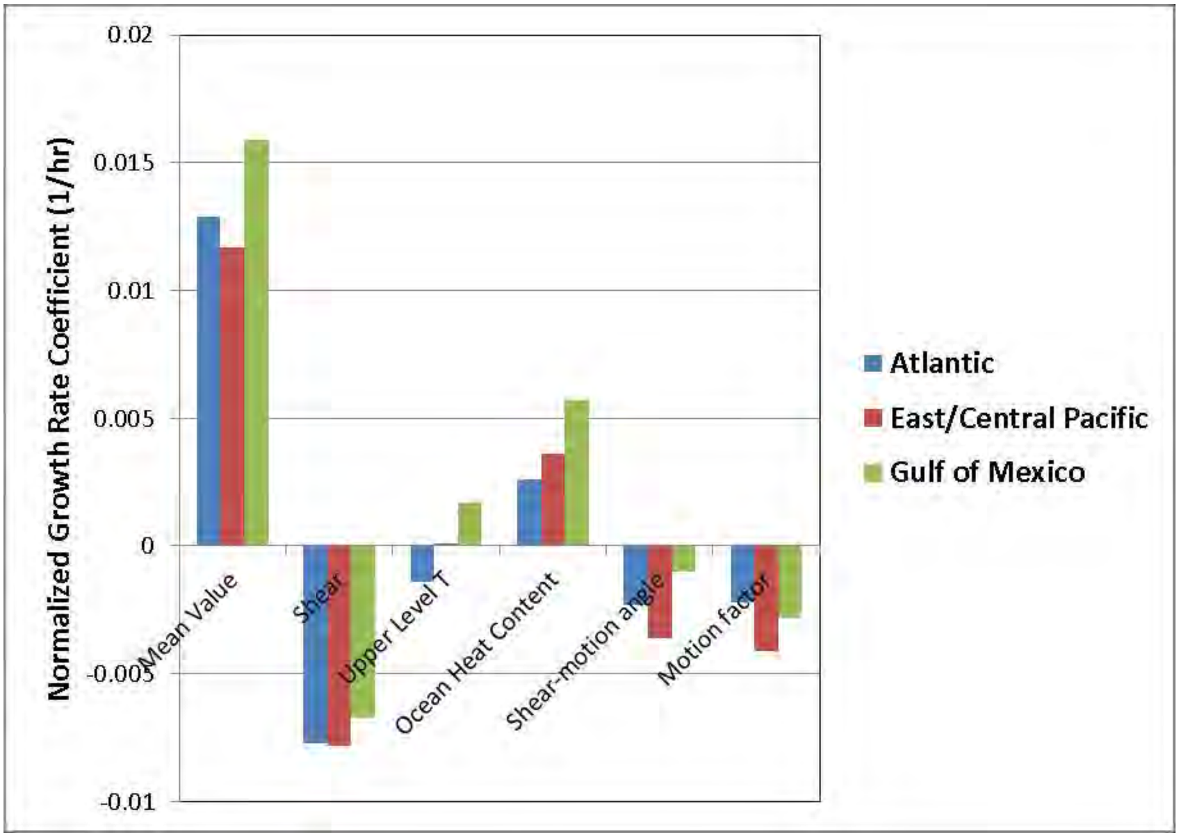

Figure 1. Normalized coefficients for the LGEM7 growth rate for the three versions of the model.

3-- SHIPS and LGEM from the new Climate Forecast System Reanalysis

The new CFSR fields from 1979 to 2009 were obtained from NOAA/ESRL and combined with operational GFS analysis fields from 2010-2012. Versions of the Atlantic SHIPS and LGEM models were developed from a 1 deg version of the CFSR fields for comparison with the 2013 operational model that was developed from the old SHIPS database (2 deg operational GFS analysis fields from 2000-2012 and 2.5 deg NCEP reanalysis fields from 1982-1999). The results with the dependent data showed a considerable improvement in the variance of the intensity changes explained by the model. The CFSR versions of SHIPS and LGEM were then tested with real time input for cases from 2008-2012. Unfortunately, the tests with the operational input showed a statistically significant degradation for the both SHIPS and LGEM for the runs with the coefficients developed from the CFSR data.

4-- Extended Range Baseline Models

Extended range baseline models were developed in the first year of the project and run operationally in 2012 and 2013 as part of the SHIPS model processing. The new baseline model uses a trajectory approach for track and intensity so it is referred to as Trajectory CLIPER (TCLP). Retrospective runs were also performed for a 10 year sample. For the 10 year sample, the mean track and intensity errors were within a few percent of those from the current baseline model OCD5 out to five days. Also, the TCLP errors provided just as good of a measure of annual forecast difficulty as OCD5, as indicated by correlations with the NHC Official track and intensity errors. The similarity of OCD5 and TCLP was confirmed in the real time runs during 2012 and 2013. The advantage of TCLP is that it can be run to any forecast length. The real time runs extend to 10 days.

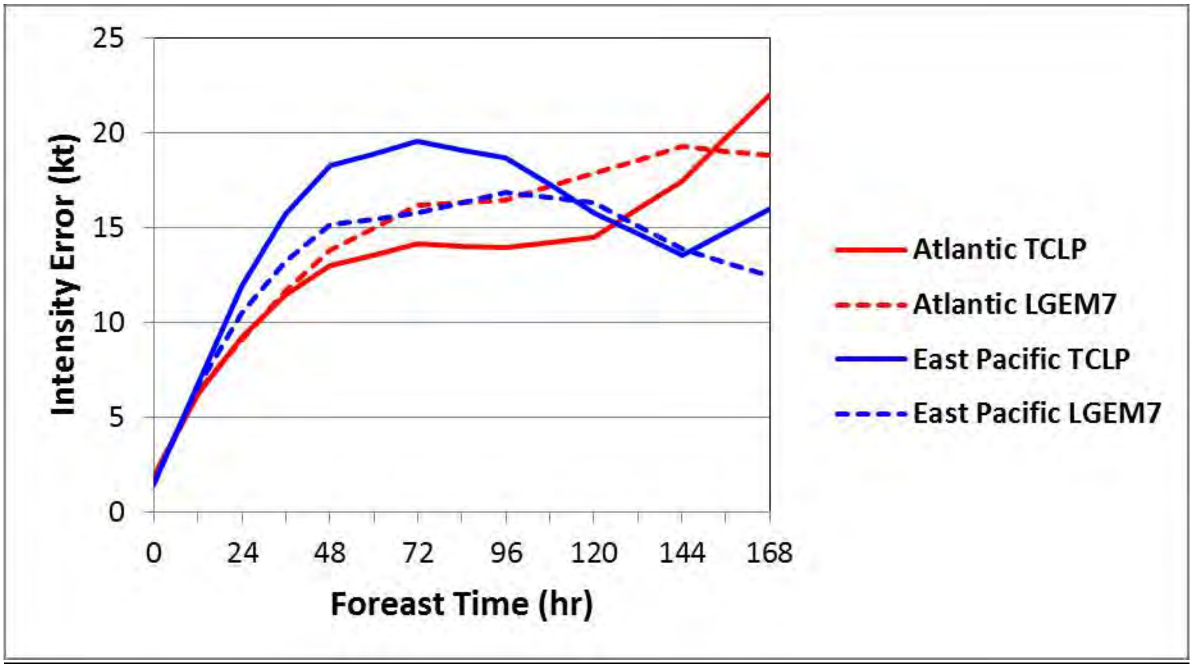

Figure 2. The average intensity errors from the extended range LGEM7 model and the trajectory CLIPER model (TCLP) for the 2012-2013 Atlantic and East Pacific cases. The Atlantic (East Pacific) sample includes 561 (555) cases with a 12 h verification and 85 (24) cases with a 168 h verification.

The following is the report previously submitted to the Technical Sponsor.

NOAA Joint Hurricane Testbed (JHT)
Final Report

Date: January 6, 2014
Project title: *Improvements in Statistical Tropical Cyclone Forecast Models*
Principal Investigators: Renate Brummer, Mark DeMaria
Affiliation: Brummer (CIRA/CSU), DeMaria (NOAA/NESDIS)
Progress report dates: Aug 2011-Dec.2013

1. Long-Term Objectives and Specific Plans to Achieve Them

Although considerable effort is being made to improve dynamical tropical cyclone forecast models, statistical-dynamical models have generally provided the most accurate intensity predictions over the last few years. Four improvements to statistical-dynamical tropical cyclone forecast models were proposed. These included: (1) Improving the method to estimate the intensity growth rate in LGEM so the forecasts can be extended to seven days; (2) Developing special versions of SHIPS and LGEM for the Gulf of Mexico region; (3) Improving the databases used to develop SHIPS and LGEM through the use of the NCEP's new Climate Forecast System Reanalysis (CFSR); and (4) Developing an extended range climatology and persistence (CLIPER) model for track and intensity.

2. ACCOMPLISHMENTS

The accomplishments on the four main topics are summarized in Section 2a, including suggestions from the developers on which of the new capabilities might be transitioned to operations. Supporting details are provided in Section 2b.

a. Summary and Recommendations

(1) 7-Day LGEM

The persistence component was separated from the LGEM formulation so the model could be fitted to the full life cycle of each storm with a much smaller number of coefficients (separate coefficients are not needed for each forecast internal). Because the coefficients are not time dependent, the model can then be run to any length. Atlantic and East Pacific versions were developed from 2000-2011 data and then run out to 7 days on independent cases from 2012-2013 using operational input. The new version of the model is referred to as LGEM7. As shown below in Section b, the results were somewhat mixed. The model was generally well behaved and had skill relative to the new extended range baseline model at most forecast times out to 7 days in the east Pacific. In the Atlantic, LGEM7 only had skill at 7 days. The 2012-2013 sample sizes were fairly small at the extended ranges and the Atlantic sample was somewhat atypical, with most the intensification occurring at higher latitudes.

Because of the complexity of the new fitting technique for LGEM7, the test model only included the top 5 of the 20 LGEM predictors. The predictors related to baroclinic interactions, such product of product of shear with latitude, and the vortex in the GFS model were not included, which may explain the more negative results for the Atlantic version. Also, for days 1-5, LGEM7 had larger errors than LGEM, especially in the Atlantic.

Developer Suggestion: Defer transition decision. Redevelop LGEM7 with the 2012-2013 cases added, and test again during the 2014 season. Add some of the predictors from LGEM that were not included in the initial LGEM7 tests.

(2) The Gulf-specific version of LGEM.

The Gulf-specific version of LGEM uses the same formulation as LGEM7, but was developed from cases that were initially in the Gulf of Mexico region. The coefficients for the Gulf of Mexico version were different than those from the Atlantic basin version. In particular, the Oceanic Heat Content predictor was more important for the Gulf of Mexico. The Gulf of Mexico version was included in the LGEM7 runs for the 2012-2013 independent tests, but the sample of Gulf cases was too small to make a meaningful comparison.

Developer Suggestion: Defer transition decision. Redevelop the Gulf of Mexico version along with LGEM7 and test again in 2014. It should also be tested on the retrospective runs that are usually performed prior to the new SHIPS model upgrades. Those runs include cases from the previous 5 seasons, which would provide a more representative sample for evaluation.

(3) SHIPS and LGEM from the new Climate Forecast System Reanalysis

The new CFSR fields from 1979 to 2009 were obtained from NOAA/ESRL and combined with operational GFS analysis fields from 2010-2012. Versions of the Atlantic SHIPS and LGEM models were developed from a 1 deg version of the CFSR fields for comparison with the 2013 operational model that was developed from the old SHIPS database (2 deg operational GFS analysis fields from 2000-2012 and 2.5 deg NCEP reanalysis fields from 1982-1999). The results with the dependent data showed a considerable improvement in the variance of the intensity changes explained by the model. The CFSR versions of SHIPS and LGEM were then tested with real time input for cases from 2008-2012. Unfortunately, the tests with the operational input showed a statistically significant degradation for the both SHIPS and LGEM for the runs with the coefficients developed from the CFSR data.

Developer Suggestion: Do not implement SHIPS and LGEM developed from the CFSR data set. The CFSR data can be used to fill some holes in the SHIPS development data set.

(4) Extended range baseline models

Extended range baseline models were developed in the first year of the project and run operationally in 2012 and 2013 as part of the SHIPS model processing. The new baseline model uses a trajectory approach for track and intensity so it is referred to as Trajectory CLIPER (TCLP). Retrospective runs were also performed for a 10 year sample. For the 10 year sample, the mean track and intensity errors were within a few percent of those from the current baseline model OCD5 out to five days. Also, the TCLP errors provided just as good of a measure of annual forecast difficulty as OCD5, as indicated by correlations with the NHC Official track and intensity errors. The similarity of OCD5 and TCLP was confirmed in the real time runs during 2012 and 2013. The advantage of TCLP is that it can be run to any forecast length. The real time runs extend to 10 days.

Developer Suggestion: Accept TCLP as a new operational model. No additional action would be required since TCLP is already part of the operational SHIPS model.

b. Supporting Details

(1) 7-Day LGEM

The 7-Day LGEM was developed following the method outlined in the proposal. The primary unknown in LGEM is the growth rate. In the operational version, the growth rate at each 6 hr forecast time from 0 to 120 h is fitted using a least squares procedure. Some predictors are time dependent, such as those that come from the GFS forecast fields, and some are only available at the initial time, such as the GOES predictors and the growth rate during the12 hr before the initialization time. The 2013 operational LGEM model has 19 predictors, and the coefficients are different at each 6 hr time interval. Thus, there are 21*19 = 399 prediction coefficients. The length of the model run is limited by the maximum time period that the coefficients are available (currently 5 days). If the model was extended beyond 5 days using this same method, the sample sizes would be become very small at the longer ranges, since they would only include tropical cyclones that lasted that long.

An alternate version was developed for the extended range forecasts, where the growth rate is assumed to be a linear function of various predictors, but the coefficients are not time dependent. The coefficients are determined by minimizing the error between the forecasted and observed intensity over the full life cycle of each cyclone in the developmental data set. Once these coefficients are determined, the model can be run to any forecast time. Fitting the coefficients to minimize the prediction errors over the entire life cycle of each cyclone is more involved because the error measure is a nonlinear function of the coefficients. However, this problem can be solved using the method outlined in DeMaria (2009), MWR, which is also utilized in some data assimilation procedures. Basically, the model equations are appended to the error function as constraints with Lagrange multipliers. The integration of the adjoint of the LGEM model provides the gradient of the error function with respect to the prediction coefficients. Then, a steepest descent method can be used to find the coefficients that minimize the prediction error. This is an iterative procedure where the model equation are integrated forward in time to update the error function, the adjoint equations are integrated backwards to update the gradient, and then the coefficients are adjusted using the gradient descent. The iteration is repeated until convergence. Typically, about 2000 iterations were needed for convergence.

Because the minimization procedure is more involved than a simple least-squares method, only five predictors were included in the new LGEM model. These were chosen based on the analysis of the gradient from the adjoint model, which provides an estimate of the importance of the predictors on the forecasts. These included the vertical shear, the average of the 200 and 250 hPa temperature, the oceanic heat content, the difference between the translational motion direction and the shear direction, and a Gaussian function of the storm speed that enhances the sensitivity to very slow storm motion. The shear-motion angle difference is a simplification of the shear direction predictor in the operational LGEM and SHIPS models. Also, because the new CFSR fields were not found to be useful for the operational version of LGEM, only the operational analyses were used for the fitting. These were available back to 2000. However, because only 5 coefficients are determined instead of 399, it was not necessary to include as large of a development sample as the operational LGEM, which uses data back to 1982. The fitting was performed separately for the Atlantic and combined East/Central Pacific data using data from 2000-2011, leaving 2012 and 2013 available for independent testing.

Once the coefficients are determined, persistence is included through a separate minimization procedure, where the final growth rate is a weighted average of the growth rate from the 12 h period up to the initialization time, and the value from the fit to the full life cycle of each storm. The weight on the persistence growth rate decays exponentially with the forecast time, where the e-folding time was chosen to minimize the forecast error. The e-folding time was found to be 12 h for the Atlantic and 14 h for the east/central Pacific. The new version of LGEM is referred to as LGEM7.

Figure 1 shows the normalized LGEM7 growth rate coefficients for the Atlantic and East/Central Pacific sample. A negative value means that predictor reduces the growth rate as that predictor becomes larger. The shear is the dominant predictor, with the OHC, shear-motion angle and storm speed predictors of secondary importance. The upper level temperature has the least influence on the prediction.

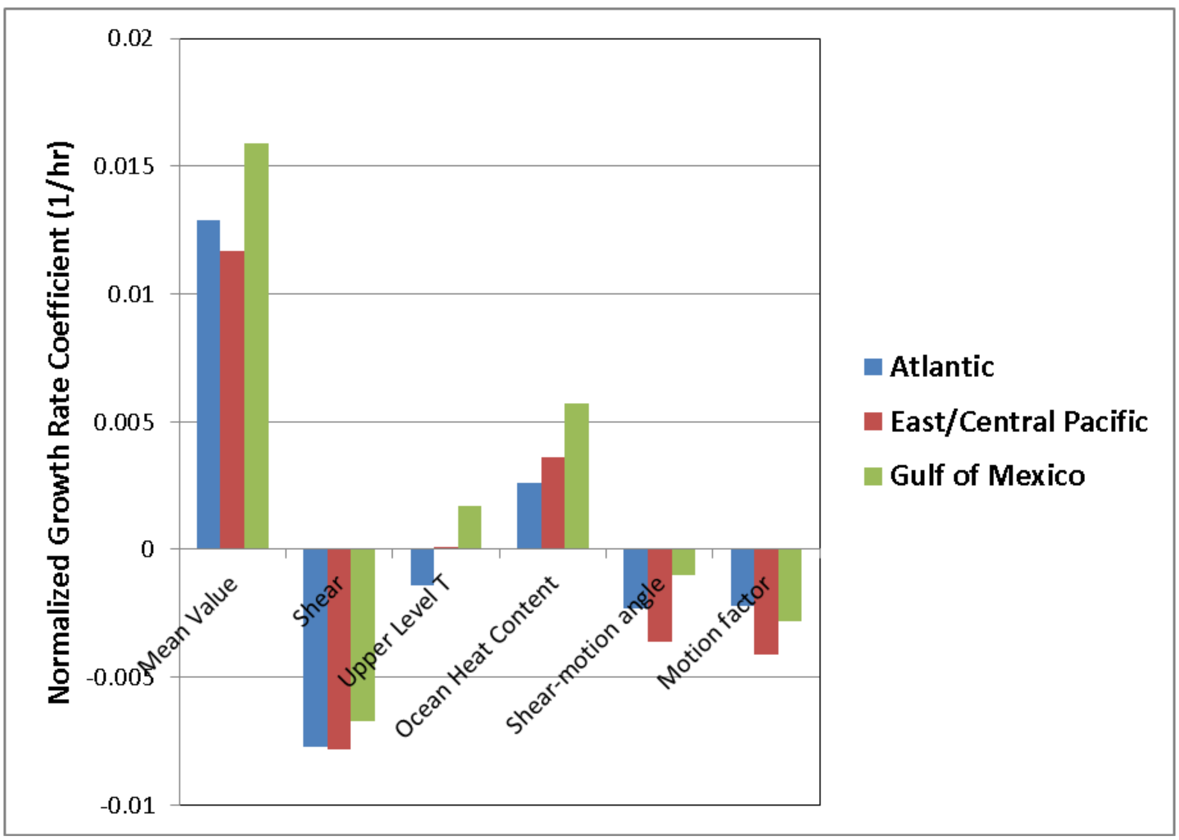

Figure 1. Normalized coefficients for the LGEM7 growth rate for the three versions of the model.

Although the LGEM7 was not ready in time for real time tests, it was re-run for all Atlantic and east Pacific cases from 2012 and 2013 using only information that was available in real time. The track forecasts are from the NHC experimental 7 day predictions. This represents a fully independent test since operational data was used as input and the developmental sample only included 2000-2011.

Figure 2 shows the errors of LGEM7 and the TCLP model and Fig. 3 shows the percent improvement of LGEM7 over TCLP (skill). LGEM7 had smaller errors than TCLP in both basins at 7 days (positive skill), although the number of cases with a 7 day verification was fairly small (85 in for the Atlantic and 24 for the east Pacific). However, in the Atlantic, the LGEM7 errors were larger than those of TCLP at most other forecast times. In the East Pacific, the LGEM7 errors were smaller than TCLP at most forecast times. These results suggest that LGEM7 potentially has some long range forecast skill, but the sample sizes were too small to make a firm conclusion. Additional testing on independent cases is needed to resolve this issue.

The LGEM7 errors were also compared to the LGEM errors out to 5 days as shown in Fig. 4. For the east Pacific, the LGEM7 errors 8% or less larger than the LGEM errors. However, for the Atlantic, the LGEM7 errors were up to about 22% larger than those from LGEM at the longer ranges. This suggests that the 5 coefficient version of LGEM7 is not capturing all of the predictive information in the operational LGEM. Many of the factors that were not included were related to high latitude cyclones such as the shear times latitude and the average tangential wind from the GFS model forecast. That may explain why the degradation was worse for the Atlantic than the East Pacific. The number of predictors in LGEM7 was restricted to gain experience with the more complex fitting procedure. The results in Fig. 4 suggest that additional work should be done to add back some of the LGEM predictors not currently included in LGEM7.

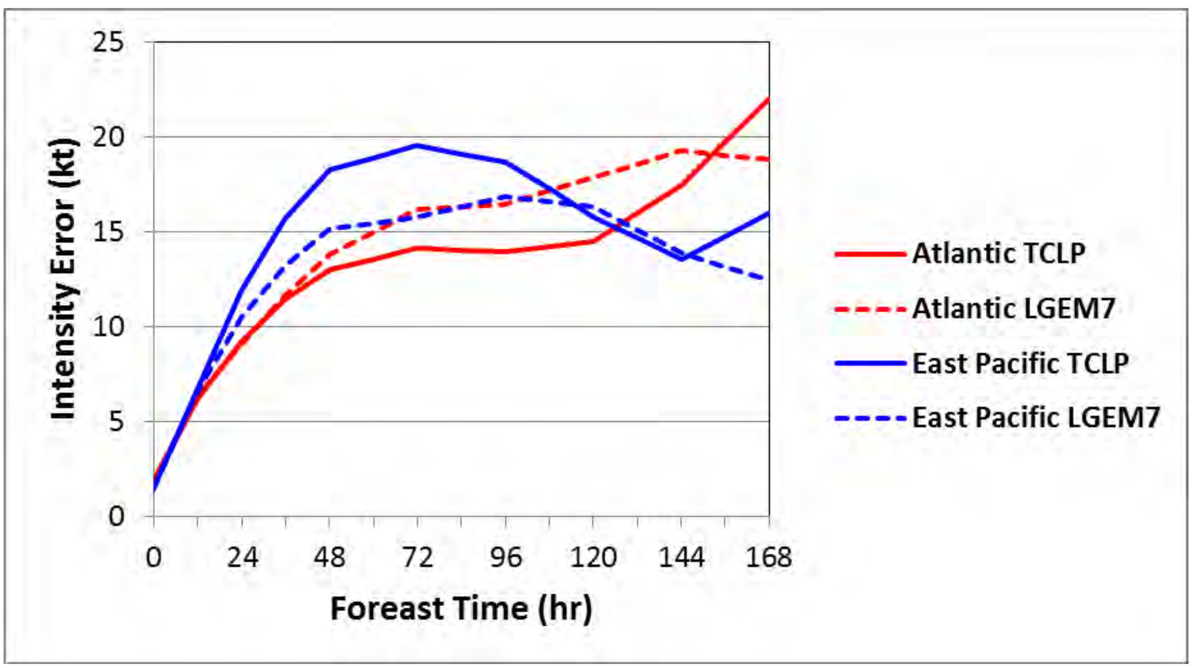

Figure 2. The average intensity errors from the extended range LGEM7 model and the trajectory CLIPER model (TCLP) for the 2012-2013 Atlantic and East Pacific cases. The

Atlantic (East Pacific) sample includes 561 (555) cases with a 12 h verification and 85 (24) cases with a 168 h verification.

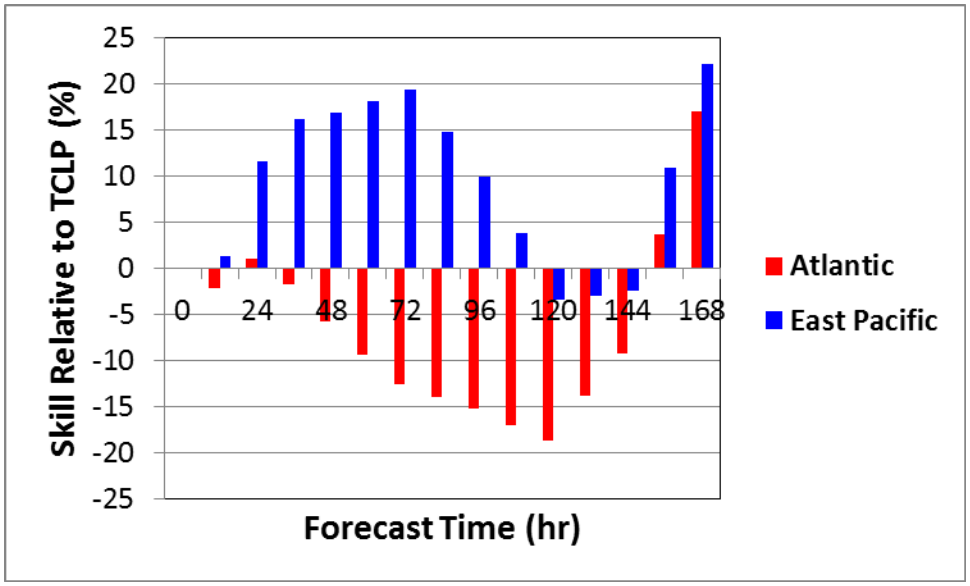

Figure 3. The skill of LGEM7 relative to TCLP.

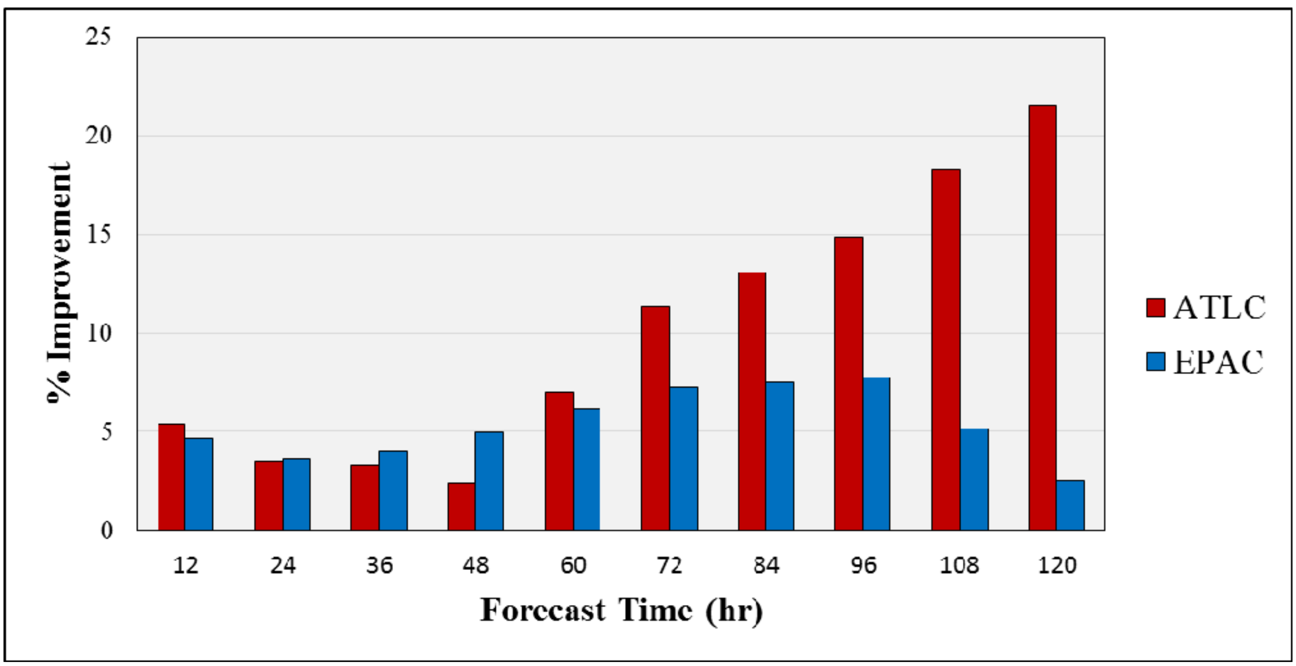

Figure 4. The improvement (percent error reduction) of the operational LGEM model compared with the experimental LGEM7 model for the 2012-2013 Atlantic and east Pacific forecasts. Positive improvement indicates that LGEM was better than LGEM7.

(2) The Gulf-specific version of LGEM.

As expected, the Gulf sample from 2000-2012 was significantly smaller than the total Atlantic sample. Because of the small sample size, especially at the longer ranges, the operational SHIPS and LGEM models were not fit to the Gulf data. Instead, the LGEM7 model was used, since it combines all forecast times together in the fit, and so can provide stable estimates of the coefficients with a smaller developmental data set. Figure 1 shows the LGEM7 coefficients for the Gulf model. The values are somewhat different than for the total Atlantic sample. In particular, the OHC coefficient is larger for the Gulf model.

The Gulf version of LGEM7 was run for all the Gulf TCs (defined as cases north of 17.5^{o}N and west of 81^{o}W) in the 2012-2013 independent data test. The mean errors from the Gulf version were within a few percent of those from the Atlantic basin version, and the sample size was not very large (only 22 cases with at least a 72 h verification). Also, the 2012-2013 cases, with mostly tropical storms and only two short-lived category one hurricanes, were not very representative of the longer term Gulf sample. Thus, a larger data sample will be needed to evaluate the Gulf version of LGEM7.

(3) SHIPS and LGEM from the new Climate Forecast System Reanalysis (CFSR)

The details of the evaluation of the SHIPS and LGEM models developed from the CFSR were described in the previous progress report for this project (available from http://www.nhc.noaa.gov/jht/current_projects.php). Basically, the dependent results showed significant improvements in the variance explained from the model fits with the CSFR data base compared to the operational model database. The model development uses the perfect prog approach, where best tracks and analysis fields are used for the fit. However, these results did not carry over when the models were run with operational input, which includes forecast tracks and model fields.

(4) Extended range baseline models

The new baseline models were developed using a trajectory approach as described in the original proposal. For track, the forecast is determined by integrating $dx/dt = c_x$ and $dy/dt = c_y$ where c_x and c_y come from the climatological storm motion fields modified by a beta-drift correction and persistence. For intensity, the prediction equation for LGEM is used where the growth rate and maximum potential intensity come from climatological values. The growth rate is modified to include a persistence factor. Because the model uses climatological and persistence input, it is referred to as the trajectory CLIPER model (TCLP). Because of the trajectory approach, TCLP can be run to any forecast length.

The primary purposes of the baseline models are to provide a measure of inter-annual variability in forecast difficulty and to use as method for evaluating forecast skill of more general models. A model should have errors smaller than those from the baseline to have skill. NHC currently uses the OCD5 model to evaluate forecast skill. OCD5 uses the traditional CLIPER model for track, and the decay version of the SHIFOR model, where track comes from the CLIPER forecast.

The TCLP model was run in real time in 2012 and 2013 as part of the operational SHIPS model on the NCEP super computer. Figure 5 shows the track and intensity errors for the NHC Official, OCD5 and TCLP forecasts. The track errors from OCD5 and TCLP are nearly identical out to 5 days. This provides confidence that the TCLP model can be used as a baseline beyond 5 days. The OCD5 and TCLP intensity errors show greater differences out to 5 days, although the errors are still less than about 10%. A comparison with a 10 year sample of retrospective runs (described below) showed that the intensity errors from TCLP ranged from 8% larger to 5% smaller than those from OCD5 at all forecast times out to 5 days.

The procedure for evaluating the utility of TCLP as a measure of forecast difficulty was described in detail in the presentation by DeMaria et al. at the 2013 Inter-Departmental Hurricane Conference (available from the http://www.ofcm.gov/ihc13/67IHC-Linking-File.htm). The 10 year sample of retrospective runs was used to correlate the annual TCLP errors with those from the NHC official forecasts. Results showed that TCLP-NHC Official error correlations were comparable to those from OCD5 for intensity and better than those of OCD5 for track.

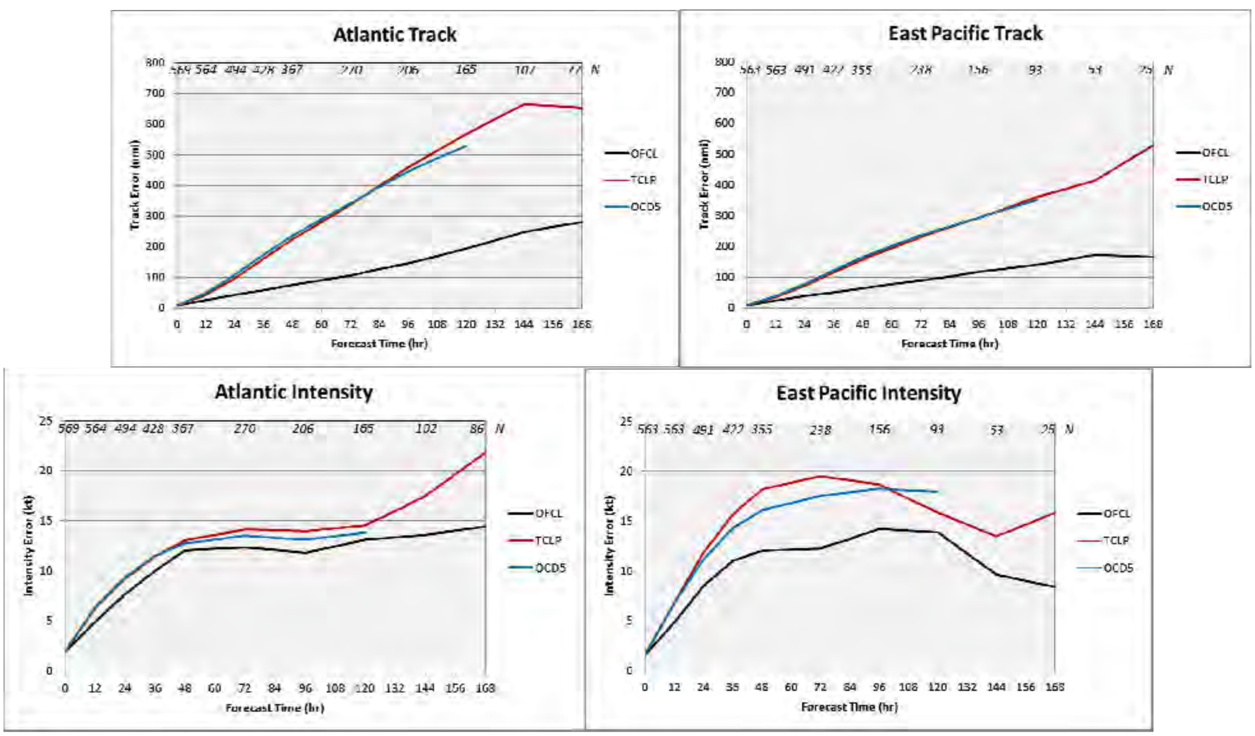

Figure 5. The average track and intensity errors for the 2012-2013 real time Atlantic and east Pacific NHC Official and baseline OCD5 and TCLP forecasts. The NHC and TCLP forecasts extend to 7 days. The sample sizes are shown along the top of each plot. All samples are homogeneous and use NHC’s usual verification rules.

3. FOLLOW UP PLANS

The LGEM7 model (Atlantic, East/Central Pacific, and Gulf of Mexico-specific versions) has already been added to a parallel version of the operational SHIPS processing script. The LGEM7 will be included in the operational runs during the 2014 season for additional testing. Depending on the NHC recommendation, the forecasts from this new model might be added to the ATCF, or could just be saved on the WCOSS system for later evaluation without making them available to the hurricane specialists. The new baseline TCLP forecasts have put into the ATCF in real time since 2012, so that will continue unless NHC decides not to implement that model. The small degradation in the TCLP intensity forecasts relative to OCD5 at some forecast times will be re-evaluated following the 2014 season. Some minor retuning of TCLP might be needed to address that issue.

COMPETITIVE PROJECT TITLE: Improving CarbonTracker Flux Estimates for North America Using Carbonyl Sulfide (OCS) (NA13OAR4310080)

PRINCIPAL INVESTIGATORE: Ian Baker

RESEARCH TEAM: Ian Baker

NOAA TECHNICAL CONTACT: Huilin Chen

NOAA RESEARCH TEAM: Andrew Jacobson

PROJECT OBJECTIVES:

1--Develop and test mechanistic representations of carbonyl sulfide (OCS) within landsurface models.
2--Evaluate and quantify relationships between OCS flux and CO2 biophysics.
3--Exploit results from 1 and 2 to constrain continental-scale CO2 flux in a data-assimilation framework.

PROJECT ACCOMPLISHMENTS:

This is a new project, and work has just started. I am working on objectives 1 and 2 currently, as well as preparing code for inclusion into a DA framework in anticipation of objective 3.

A baseline evaluation of model behavior is necessary prior to starting the project. We have produced global simulations of surface processes using the Simple Biosphere model (SiB3; Sellers et al., 1985, 1996, Baker et al. 2003, 2008) in ‘offline’ mode as a starting point. These simulations were forced by 1.25 x 1.0 degree Modern Era Retrospective Analysis for Research and Applications (MERRA) data, with precipitation scaled to Global Precipitation Climatology Project (GPCP; Adler et al., 2003) to minimize biases. Model phenology is determined using the Prognostic Growing Season Index (PGSI; Stockli et al., 2008, 2011) method. Mean annual Gross Primary Productivity (GPP) for years 2000-2012 is shown in Figure 1, and global uptake of carbon is estimated at around 119 GT year^{-1}. Actual global GPP is not observed directly, and simulated values can disagree by a factor of 2 or more (Huntzinger et al., 2012). However, some published estimates of global GPP based on eddy covariance flux tower observations (Jung et al., 2011) put global GPP at ~120 GT year^{-1}, which is very close to our value.

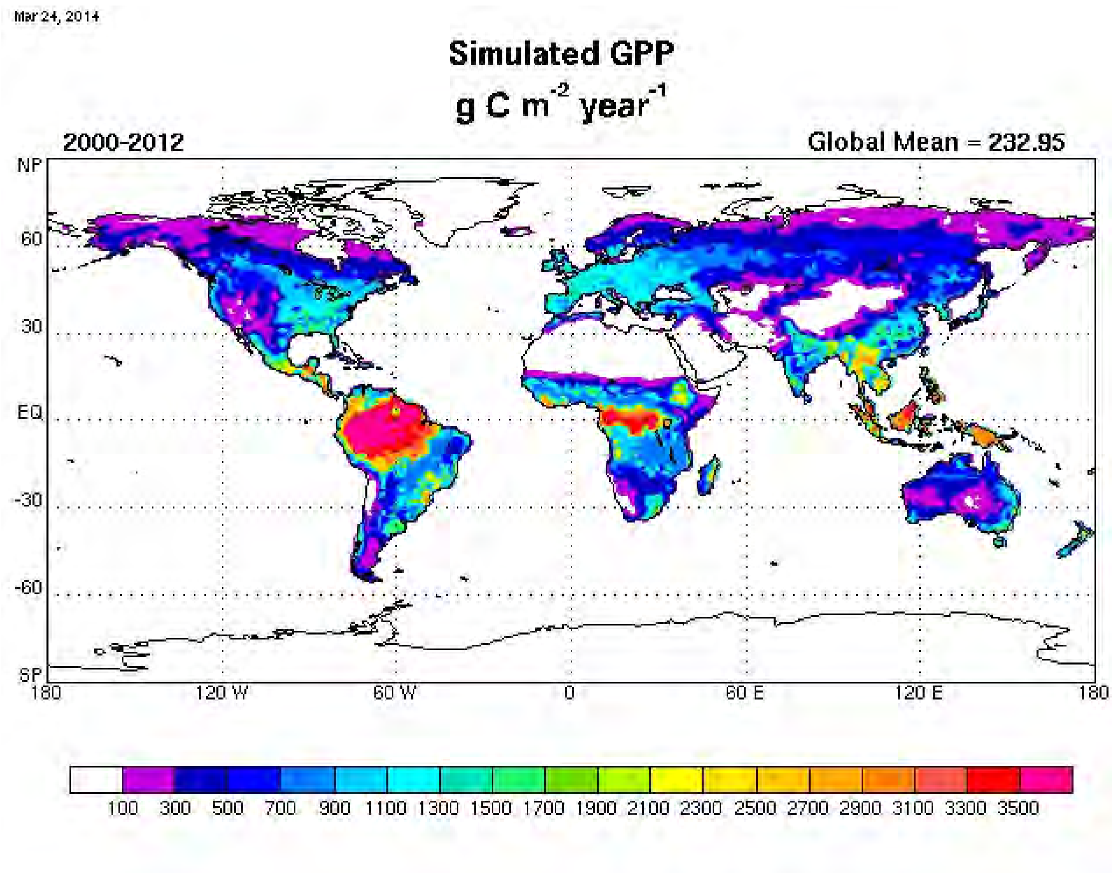

Figure 1. Mean annual GPP for years 2000-2012 in g C m^{-2} $year^{-1}$

We have demonstrated an ability to simulate ecosystem uptake of Carbonyl Sulfide (Berry et al., 2013). Carbonyl Sulfide (OCS) follows a pathway similar to CO_2 through stomates to the leaf interior, where it is consumed by Carbonic Anhydrase, an enzyme used to catalyze photosynthesis. Therefore, leaf uptake of OCS is demonstrates a global pattern similar to CO_2, as shown in Figure 2. However, it is worth noting that the magnitude of Sulfur uptake is by plants is several orders of magnitude less the uptake rate of CO_2.

OCS uptake by soil, while an order of magnitude less than uptake by plants, is an important process nonetheless. First, soil uptake occurs continuously, and is not-like plant uptake-occurring only during daylight hours when stomates are open. Secondly, ground uptake was previously considered a sink term only, but emerging research indicates that soil may be a source or sink term depending on temperature, moisture, and other soil characteristics. We are currently collaborating with multiple research teams to integrate their findings into our models.

Baseline simulations will provide a model ‘prior’ that can be used to constrain model parameters and physical processes within the North American data assimilation framework. Project collaborators at NOAA are assembling observational data and DA tools in these early stages of the project. We are ready to couple our models to theirs.

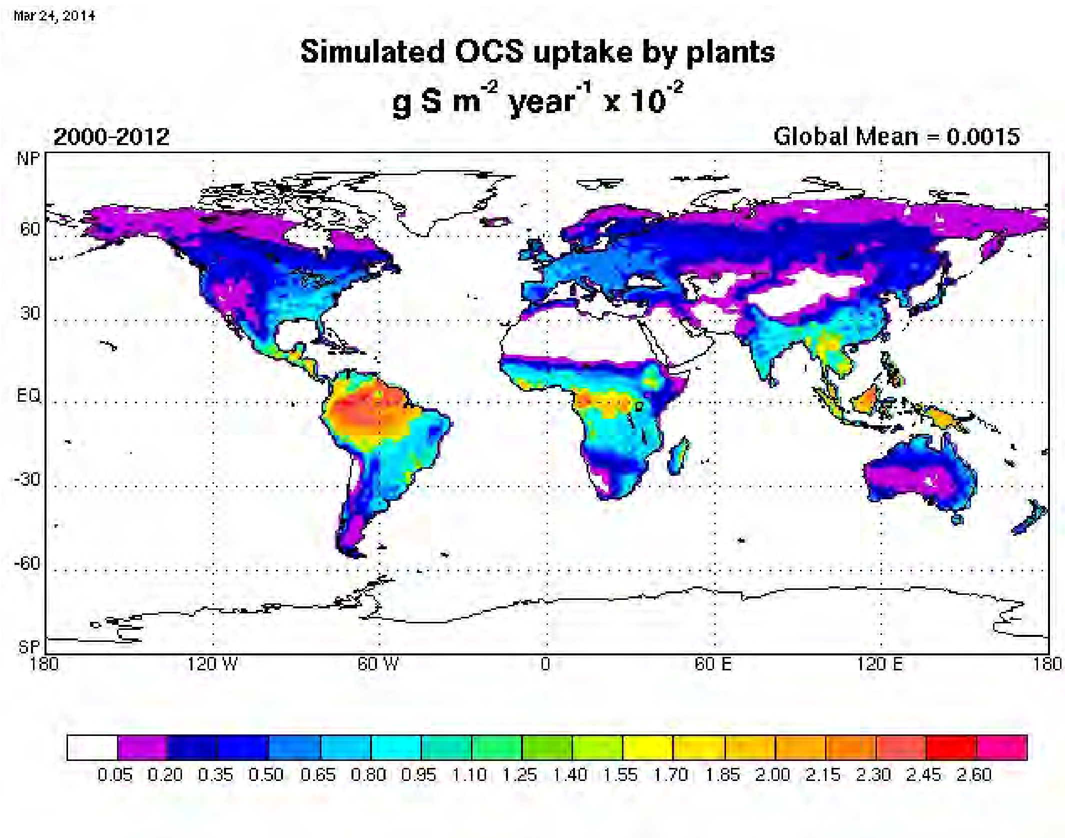

Figure 2. Global mean uptake of OCS by plants (g S m^{-2} $year^{-1}$).

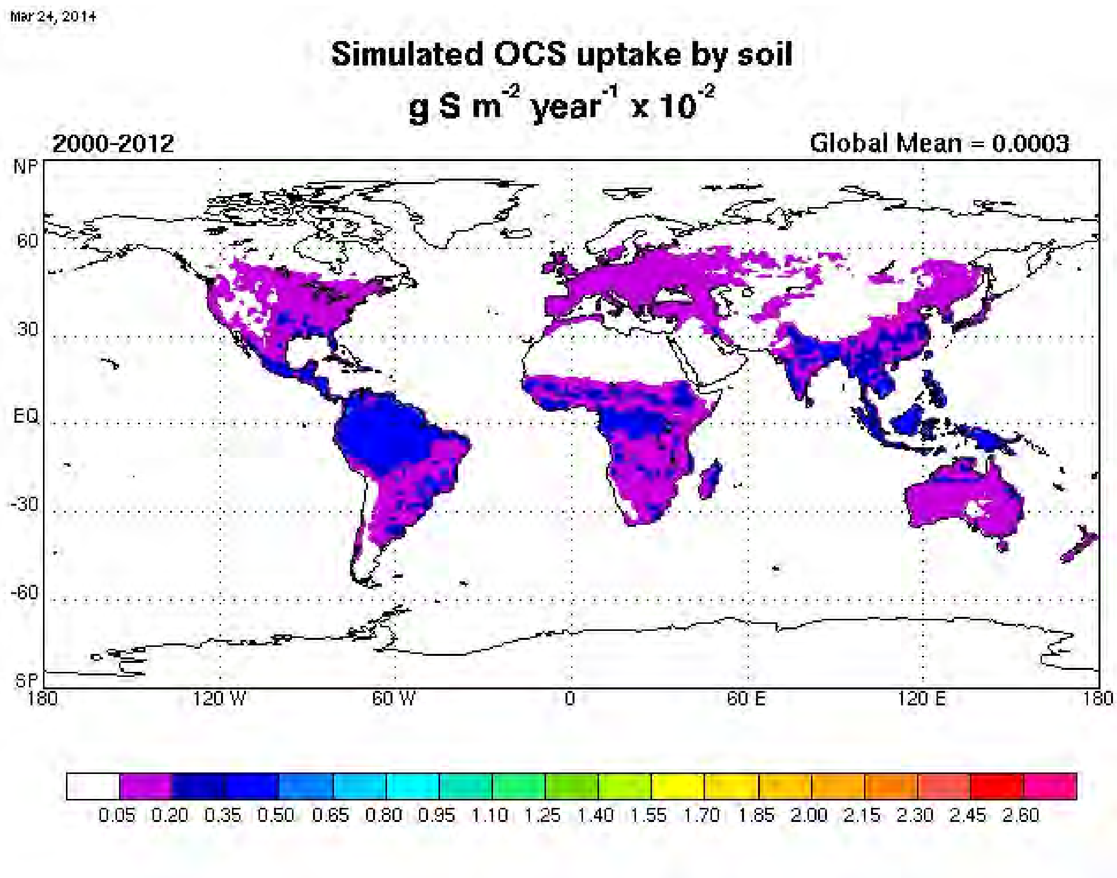

Figure 3. OCS uptake by soil (g S m^{-2} $year^{-1}$).

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COMPETITIVE PROJECT TITLE: Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models (NA12OAR4310077)

The following is the report previously submitted to the Technical Sponsor.

Project Title: Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models
Project Number: NA12OAR4310077
PIs: Eric D. Maloney (Colorado State University) and Shang-Ping Xie (Scripps Oceanographic Institute)
Report Type: Year 2 Report

Results and Accomplishments
The following sections list the primarily accomplishments for Year 2 by study, with the 20 publications accumulated for both Years 1 and 2 of the project listed in the publication list at the end of the document. Unfortunately, we cannot be comprehensive given space constraints for all publications, but please contact me for more details if you are interested in anything that was missed. Again, we will concentrate on the relatively new results from this year.

Simulations of the eastern north Pacific intraseasonal variability in CMIP5 GCMs (Jiang et al. 2014).

This paper was a contribution to the MAPP CMIP5 Task Force *Journal of Climate* special collection on CMIP5 model representation of North American climate. As a key component of tropical atmospheric variability, intraseasonal variability (ISV) over the eastern North Pacific Ocean (ENP) exerts pronounced influences on regional weather and climate. Since general circulation models (GCMs) are essential tools for prediction and projection of future climate, current model deficiencies in representing this important variability leave us greatly

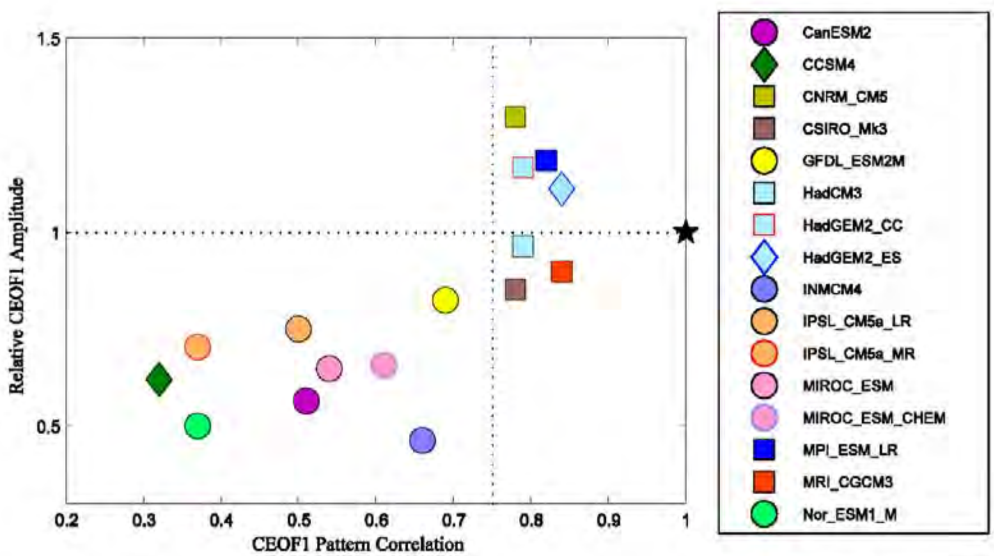

Figure 1. Pattern correlation coefficients of the CEOF1 mode between TRMM observations and CMIP5 GCM simulations. Y-axis: Relative amplitudes of CEOF1 in model simulations to the observed counterpart. Both pattern correlations and amplitudes are derived by averaging over the area of 5ºN-25ºN, 140ºW-80ºW where the active ISV is observed. The black "star" mark represents the TRMM observations. Models with "square" marks display westerly or weak easterly (<1.5 m s-1) summer mean wind at 850hPa, while strong easterly winds (> 4 m s-1) are noted in models with "circle" marks. Wind fields are not available in the data portal at the time of this analysis from the two GCMs with "diamond" marks.

disadvantaged in studies and prediction of climate change. In this study, the authors have assessed model fidelity in representing ENP ISV by analyzing 16 GCMs participating in phase 5 of the Coupled Model Intercomparison Project (CMIP5). Among the 16 CMIP5 GCMs examined in this study, only seven GCMs capture the spatial pattern of the leading ENP ISV mode relatively well, although even these GCMs exhibit biases in simulating ISV amplitude. **Figure 1** shows one particular metric that characterized this performance, where the success of the model in capturing the observed pattern and amplitude of observed variability is tested. Analyses indicate that model fidelity in representing ENP ISV is closely associated with the ability to simulate a realistic summer mean state. The presence of westerly or weak mean easterly winds over the ENP warm pool region could be conducive to more realistic simulations of the ISV. One hypothesis to explain this relationship is that a realistic mean state could produce the correct sign of surface flux anomalies relative to the ISV convection, which helps to destabilize local intraseasonal disturbances. The projected changes in characteristics of ENP ISV under the representative concentration pathway 8.5 (RCP8.5) projection scenario are also explored based on simulations from three CMIP5 GCMs. Results suggest that, in a future climate, the amplitude of ISV could be enhanced over the southern part of the ENP while reduced over the northern ENP off the coast of Mexico/Central America and the Caribbean.

North American climate in CMIP5 experiments: Assessment of 21st Century projections. (Maloney et al. 2014a)

This is the third of a three part series of review papers led by the NOAA MAPP CMIP5 Task Force on CMIP5 models and North American climate. In Part 3 of this three-part study on North American climate in Coupled Model Intercomparison project (CMIP5) models, we examine projections of 21st century climate in the RCP8.5 emission experiments. This paper summarizes and synthesizes results from several coordinated studies by the authors. Aspects of North American climate change that are examined include changes in continental-scale temperature and the hydrologic cycle, extremes events, and storm tracks, as well as regional manifestations of these climate variables. We also examine changes in eastern north Pacific and north Atlantic tropical cyclone activity and North American intraseasonal to decadal variability, including changes in teleconnections to other regions of the globe.

Projected changes are generally consistent with those previously published for CMIP3, although CMIP5 model projections differ importantly from those of CMIP3 in some aspects, including CMIP5 model agreement on increased central California precipitation. The paper also highlights uncertainties and limitations based on current results as priorities for further research. Although many projected changes in North American climate are consistent across CMIP5 models, substantial intermodel disagreement exists in other aspects. Areas of disagreement include projections of changes in snow water equivalent on a regional basis, summer Arctic sea ice extent, the magnitude and sign of regional precipitation changes, extreme heat events across the Northern U.S., and Atlantic and east Pacific tropical cyclone activity.

The first and second parts of the three part series of papers described at the top of this section are Sheffield et al. (2013 a, b), which provide an assessment of the ability of CMIP5 models to simulate current North American climate and related processes.

Gross moist stability and MJO simulation skill in three full-physics GCMs (Benedict et al. 2014).

This paper describes development of a process-oriented model diagnostic that attempts to explain why some models produce a good MJO simulation, and why others do not. Previous studies have demonstrated a link between gross moist stability (GMS) and intraseasonal variability in theoretical and reduced-complexity models. GMS essentially gives a measure of how efficiently convection discharges moisture from the column. In such simplified models, moisture modes—convectively coupled tropical disturbances that are hypothesized to be dynamical relatives of the MJO and whose formation and dynamics are closely linked to moisture perturbations—develop only when GMS is either negative or “effectively” negative when considering additional sources of moist entropy. In most cases, these simplified models use a prescribed GMS value or otherwise assume it is a temporally independent property of the simulation. Limited work has been done to assess the GMS and its connection to intraseasonal variability in full-physics general circulation models (GCMs).

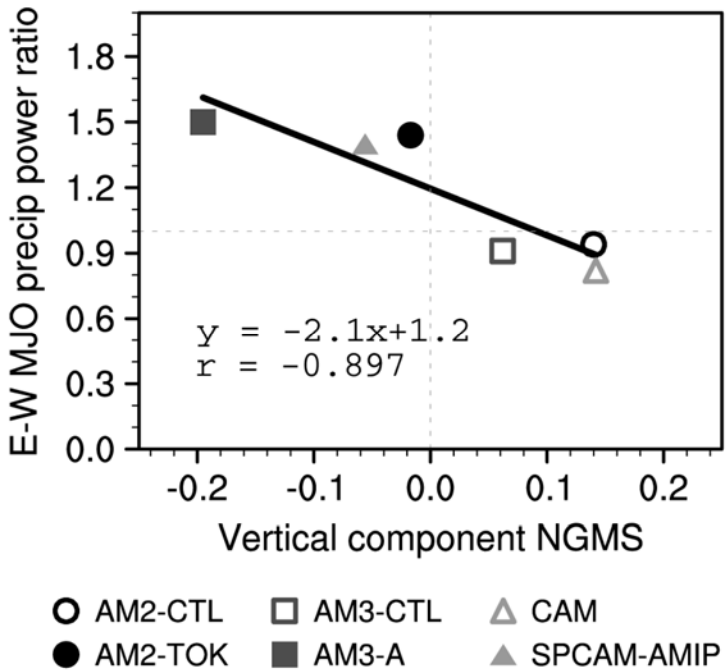

Figure 2. The relationship between October-April mean vertical component of gross moist stability and one metric of the robustness of MJO eastward propagation. The MJO metric is the ratio of eastward to westward tropical rainfall power within the MJO spectral region [periods 30-96 days, zonal wavenumbers +1 to +3 (eastward) or –1 to –3 (westward)]. Also shown are the best-fit line equation and correlation coefficient *r*.

The time-mean and intraseasonal behavior of GMS and its normalized version (NGMS) are examined in three pairs of GCMs to elucidate the possible importance of NGMS for MJO simulation. In each GCM pair, one member produces weak intraseasonal variability while the other produces stronger intraseasonal variability and robust MJO disturbances due to a change in the treatment of deep convection. A highly correlated linear relationship between time-mean NGMS and MJO simulation skill is observed, such that GCMs with less positive NGMS produce more robust MJO eastward propagation. The reduction in time-mean NGMS is primarily due to a sharp drop to negative values in the component of NGMS related to vertical advection (**Figure 2**), while the component related to horizontal advection has a less clear relationship with MJO simulation. Intraseasonal fluctuations of anomalous NGMS modulate the magnitude of background NGMS but, for the most part, do not change the sign of background NGMS. NGMS is reduced ahead of peak MJO rainfall and is increased during and after the heaviest precipitation. Total NGMS fluctuates during MJO passage but remains positive, suggesting that other sources of moist entropy are required to generate an effectively negative NGMS.

Process-oriented MJO simulation diagnostic: Moisture sensitivity of simulated convection. (Kim et al. 2014)

This paper describes further efforts to develop process-oriented diagnostics for Madden-Julian oscillation (MJO) simulations to facilitate improvements in the representation of the MJO in weather and climate models. These process-oriented diagnostics are expected to provide insights into how parameterizations of physical processes in climate models should be improved for a better MJO simulation. In this paper, we propose one such process-oriented diagnostic, which is designed to represent sensitivity of simulated convection to environmental moisture: composites of the relative humidity (RH) profile for precipitation percentiles.

The ability of the RH composite diagnostic to represent the diversity of MJO simulation skill is demonstrated using a group of climate model simulations participating in the Coupled Model

Intercomparison Project Phase 3 (CMIP3) and CMIP5. A set of scalar process metrics that capture the key physical attributes of the RH diagnostic is derived and their statistical relationship with indices that quantify the fidelity of the MJO simulation is tested. We found that a process metric that represents the amount of lower-tropospheric humidity increase required for a transition from weak to strong rain regimes has a robust statistical relationship with MJO simulation skill. Our results suggest that moisture sensitivity of convection is closely related to a GCM's ability to simulate the MJO.

Process-oriented diagnosis of east Pacific warm pool intraseasonal variability (Maloney et al. 2014b).

June-October east Pacific warm pool intraseasonal variability is assessed in eight atmospheric general circulation simulations. Complex empirical orthogonal function analysis is used to document the leading mode of 30-90 day precipitation variability in the models and Tropical Rainfall Measuring Mission observations. The models exhibit a large spread in amplitude of the leading mode about the observed amplitude. Little relationship is demonstrated between amplitude of the leading mode and ability to simulate the observed propagation characteristics.

Several process-oriented diagnostics are explored that attempt to distinguish why some models produce a better representation of intraseasonal variability than others. A diagnostic based on the difference in 500-850 hPa averaged relative humidity between the top 5% and the top 10% of precipitation events exhibits a significant correlation with leading mode amplitude (**Figure 3**). Diagnostics based on the vertically-integrated moist static energy budget also demonstrate success at discriminating models with strong and weak variability. In particular, the vertical component of gross moist stability (GMS) exhibits a correlation with amplitude of -0.9, suggesting that models in which convection and associated divergent circulations are less efficient at discharging moisture from the column are more able to sustain strong intraseasonal variability. The horizontal component of GMS exhibits a significant positive correlation with amplitude. Consequences of these successful diagnostics for the dynamics of east Pacific intraseasonal variability are discussed.

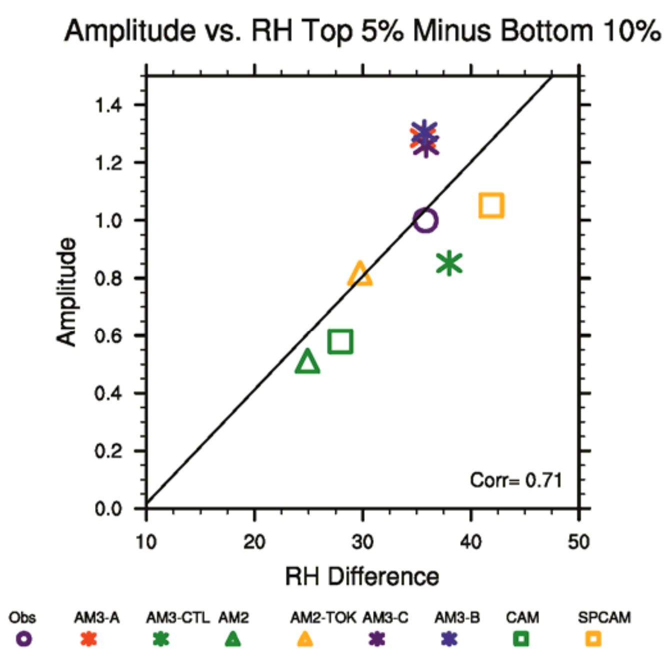

Figure 3. Amplitude of the leading CEOF mode versus the di erence in June-October average 500-850 hPa mass weighted relative humidity between the top 5% and bottom 10% of daily averaged precipitation events. Amplitude is averaged over the domain 5N-20N, 120W-90W, and relative humidity and precipitation are considered on a point-by-point basis in the same domain. Amplitude is normalized by the

TRMM amplitude. The correlation is shown in the bottom right, and the least squares regression line is also shown.

Several other diagnostics were tested including the warm pool mean surface zonal wind, the strength of surface flux feedbacks, and 500-850 hPa averaged relative humidity for the top 1% of rainfall events, but these diagnostics showed no significant relationship to leading mode amplitude. Vertical zonal wind shear does not appear to be a good predictor of model success at simulating the observed northward propagation pattern. Introduction of ocean coupling to one model with strong intraseasonal variability also did not improve the pattern of propagation.

Cause of the pause of global temperature rise (Kosaka and Xie 2013)
Despite the continued increase in atmospheric greenhouse gas concentrations, the annual-mean global temperature has not risen in the twenty-first century, challenging the prevailing view that anthropogenic forcing causes climate warming. Various mechanisms have been proposed for this hiatus in global warming, but their relative importance has not been quantified, hampering observational estimates of climate sensitivity. Here we show that accounting for recent cooling in the eastern equatorial Pacific reconciles climate simulations and observations. We present a novel method of uncovering mechanisms for global temperature change by prescribing, in addition to radiative forcing, the observed history of sea surface temperature over the central to eastern tropical Pacific in a climate model. Although the surface temperature prescription is limited to only 8.2% of the global surface, our model reproduces the annual-mean global temperature remarkably well with correlation coefficient $r = 0.97$ for 1970–2012 (which includes the current hiatus and a period of accelerated global warming). Moreover, our simulation captures major seasonal and regional characteristics of the hiatus, including the intensified Walker circulation, the winter cooling in northwestern North America and the prolonged drought in the southern USA.

Climate model evaluation (Li and Xie 2014)
Errors of coupled general circulation models (CGCMs) limit their utility for climate prediction and projection. Origins of and feedback for tropical biases are investigated in the historical climate simulations from the Coupled Model Intercomparison Project phase 5 (CMIP5), together with the available Atmospheric Model Intercomparison Project (AMIP) simulations. The excessive equatorial Pacific cold tongue and double intertropical convergence zone (ITCZ) stand out as the most prominent errors of the current generation of CGCMs. The comparison of CMIP-AMIP pairs enables us to identify whether a given type of errors originates from atmospheric models. The equatorial Pacific cold tongue bias is associated with deficient precipitation and surface easterly wind bias in the western half of the basin in CGCMs, but these errors are absent in atmosphere-only models, indicating that the errors arise from the interaction with the ocean via Bjerknes feedback. For the double ITCZ problem, excessive precipitation south of the equator correlates well with excessive downward solar radiation in the Southern Hemisphere midlatitudes, an error traced back to atmospheric model simulations of cloud during austral spring and summer. This extratropical forcing of the ITCZ displacements is mediated by tropical ocean-atmosphere interaction, and is consistent with recent studies of ocean-atmospheric energy transport balance.

NOAA MAPP CMIP5 Task Force
Eric Maloney is a co-chair, and Shang-Ping Xie is a member, of the NOAA MAPP CMIP5 Task Force. Accomplishments have included generation of a *Journal of Climate* special collection on North American Climate in CMIP5 Models, which includes the three overview assessment papers discussed in the report on Maloney et al. (2014a) above. Recent task force activities include thrusts related to 1) use of CMIP5 models to inform climate applications and 2) process-oriented model diagnostics to inform model development and applications. Regarding point #2, we have explicitly engaged modeling centers at NCAR and GFDL with plans to incorporate some of the process-oriented model diagnostics developed as a task force into standard model diagnostics packages used by these two modeling centers. The NOAA CMIP5 task force will end its activities this coming fall.

Highlights of Accomplishments

- We strongly contributed to a *Journal of Climate* special collection on North American climate in CMIP5 models, including a lead-author comprehensive paper by the PI (Maloney) examining CMIP5 projections of North American climate.
- We did a focused assessment of the ability of CMIP5 models to realistically simulate intraseasonal variability in the IAS region, and demonstrated a wide range of current capabilities. Intraseasonal variability is expected to increase in amplitude in a warming climate.
- We developed several successful process-oriented model diagnostics that can distinguish between models with good and poor intraseasonal variability, and applied these diagnostics to several versions of the GFDL AM2 and AM3, and the NCAR CAM and SP-CAM. This analysis extended to the tropical Americas. These metrics should help inform model development.
- We have attributed the recent global warming hiatus to recent processes related to east Pacific cooling.
- We have diagnosed reasons for CMIP5 model bias in the ITCZ and cold tongue regions of the Pacific, helping to inform model development
- We have contributed to the NOAA MAPP CMIP5 Task Force process-oriented model diagnostics effort, successful engaging NCAR and GFDL and making plans for incorporating our diagnostics into their standard model diagnostics packages.

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COMPETITIVE PROJECT TITLE: Quantifying the Source of Atmospheric Ice Nuclei from Biomass Burning Aerosols (NA10OAR4310103)

The following is the report previously submitted to the Technical Sponsor.

Annual Report for NOAA Award NA10OAR4310103

Quantifying the Source of Atmospheric Ice Nuclei from Biomass Burning Aerosols

Period Covered: 1 May 2013 – 30 April 2014

Submitted by:

Principal Investigator: Paul J. DeMott

Co-Principal Investigators: Anthony J. Prenni, Amy P. Sullivan

Date Submitted: February 18, 2014

Overview of Activities

The goals and objectives for this work were focused around identifying the contributions of biomass burning of forests, grasslands and other biomass combustion as sources for atmospheric ice nuclei (IN), to discern the nature of these IN, their association to other aerosol properties, their temporal transformations, and to quantify these results for use in numerical models:

Objective 1: Perform sampling of IN from controlled burns of Western and Southeastern U.S. forest and grassland fuels.

Objective 2: Perform sampling of IN within wildfire smoke plumes of opportunity.

Objective 3: Explore the impact of atmospheric processing on biomass smokes

Objective 4: Explore relations between IN number concentrations and other aerosol properties

Objective 5: Parameterize ice nucleation results for use in numerical modeling studies.

This annual report updates previous reports, as a living document of the project.

Review of Year 1 and Year 2 Activities and Results

The first and second annual reports summarized the following activities, methods, and results in detail. A brief synopsis is given here for framing progress made during Year 3. During Year 1, significant progress was made on Objectives 1, 2, and 4, plans were made for additional field deployments during year 2, conference presentations were made, a first publication draft was begun, and retention of new personnel was undertaken.

Experimental protocols and logistics for measurements of biomass burning aerosols in the ambient atmosphere were established in Year 1. Measurements were conducted using the CSU air quality laboratory, a custom designed panel truck vehicle, along with portable generators for locating downwind of the parked vehicle during sampling. Measurements of IN number concentrations were made using the Colorado State University (CSU) continuous flow diffusion chamber (CFDC) (*Rogers et al.* 2001, *Eidhammer et al*. 2010). Simultaneous measurements included condensation nuclei (CN), particle size distributions, PM2.5 mass, and PM2.5 chemical composition. Attempt was made to associate similar measurements in both background and smoke-affected air in every case. Measurements were made from seven fires in Colorado and Wyoming, and one case of intense smoke from long range transport. The first annual report includes a map of fire locations and a table of fire characteristics. While prescribed burn sampling was proposed to dominate Year 1 activities, weather conditions limited such sampling, so opportunities were sought to sample smoke from wildland fires, in advance of such a planned focus during Year 3.

Results from Year 1 were:

1) *New evidence was obtained for biomass burning particles as a source for ice nuclei*. Airborne measurements during projects supported under other agency funding and with different foci provided special sampling opportunities confirming the production of ice nuclei during burning of sage-dominated biomass in Wyoming and slash pile biomass in the Sierra's. Some of these results were incorporated into the draft of our first study publication (*Prenni et al.* 2012).
2) *Ice nucleation efficiency of biomass burning particles from prescribed burns was quantified.* Prescribed burns in coordination with the U.S. Forest Service in Colorado allowed for quantifying IN production from such fires and relation to other aerosol properties (*Prenni et al.* 2012). The number of IN clearly increase in the presence of smoke near prescribed fire sources, although the fraction of total particles (CN) which nucleate ice is usually less than found in background air. Also, the ice nucleating fractions of all particles were lower than estimated as needed for fires to have a large impact on regional IN budgets [*Petters et al.*, 2009], suggesting primarily local influence. Firming this conclusion will require more careful consideration of fire size, duration, and dispersion characteristics. Relations to other aerosol properties, such as concentrations of large aerosol particles (*DeMott et al.* 2010) were clearly noted and will be applied toward parameterizing IN from biomass burning for use in numerical model simulations.
3) *Larger, more intense wildfires were found to exhibit regional impacts on ice nuclei populations*. Sampling of four wildfires sized small to very large, at distances of several to nearly 1000 miles indicated IN number concentrations exceeding the background atmosphere and IN fractions of total aerosol at least equivalent to the background atmosphere, implying high occurrence of regional impacts on IN feeding clouds.
4) *Smoldering wildfires were observed to be associated with lower IN production efficiency*. For the same fire and IN activation conditions (T, RH), primarily smoldering fire conditions were associated with lowered efficiency of generating ice nuclei in comparison to flaming conditions as determined by visual and bulk chemical analyses (*Prenni et al.* 2010).
5) *Chemical marker studies added to growing database of such fire data from the laboratory and the atmosphere.*
6) *Student and postdoctoral recruiting and training were advanced, conference presentations were made*. Three different postdoctoral scientists assisted with measurements at times, and a new M.S. student (Christina McCluskey) was targeted for Summer 2011 acceptance.
7) *Presentations and publications*: Dr. Prenni presented results at the International Aerosol Conference in Helsinki in August 2010. A short abstract was published.

New research during Year 2 centered on objectives 1, 4 and 5. Following the proposed research plan, prescribed burn sampling was planned and executed at the Joseph W. Jones Ecological Research Center (http://www.jonesctr.org/) near Newton, GA during March 2011. Equipment was transported using the CSU Air Quality mobile laboratory to the site. Four large burns were sampled and one day was devoted to background sampling only. Fuels included wiregrass, pine needles, small shrubs, and longleaf pine trees typical of the large regions burned in the SE United States in springtime. Measurements included ice nuclei number concentration over a broad temperature range, ice nuclei chemical composition measurements (via post-analysis of TEM grid collections of IN), aerosol size distribution, total aerosol chemistry (as described in the Year 1 report), and total aerosol mass measurements (new TEOM device purchased to supplement existing EBAMS). Total chemistry and mass measurements were collected at near-fire and background sites on every day of the study. The entire suite of measurements became a standard suite for all subsequent sampling periods. We made additional measurements at the CO prescribed burning site (Sheep Creek) during summer 2011, which included IN data and additional bulk chemical data for comparison to earlier measurements.

The primary foci for measurements during Year 2 was determination of IN temperature spectra, and identification of the source physical and chemical characteristics of ice nuclei found in biomass burning plumes. Besides TEM analyses and correlations of IN to bulk smoke chemistry, additional exploratory measurements were made to identify the organic and biological contributions to ice nuclei in the smoke plumes. This was done in collaboration with University of Wyoming colleagues Thomas Hill and Gary

Franc who participate with us on the NSF-funded study “Collaborative Research: Laboratory and Ground-Based Studies Addressing Unresolved Aspects of Atmospheric Ice Nucleation.” That project has a special focus on methods to identify biological ice nuclei. Additional filters were collected in Georgia for rinsing and then testing the freezing of small volume suspensions as a function of temperature, followed by application of the methods of *Vali* (1971) to determine atmospheric number concentrations of IN. Heat treatments are then applied to liquid droplet populations to determine the proportion of IN that are inorganic versus organic, and separate untreated volumes are put through quantitative polymerase chain reaction (qPCR) analyses using special primers to quantify number concentrations of known biological ice nucleating bacteria (*Garcia et al.* 2012).

Some selected results that came from Year 2 studies included:

1) *A large and diverse data set was obtained for targeted analyses of IN sources from the Longleaf Pine ecosystem of the SE United States.* This data set will serve as the focus for Christina McCluskey’s Master’s thesis and the basis for up to two additional publications. Data underwent initial processing and quality control, including the ice nuclei number concentrations, IN TEM grid analyses of elemental compositions and morphology, bulk aerosol compositions, size distributions, and mass concentrations. The diversity of temporal sampling conditions during the prescribed burns is evident in Figure 1. Such images were collected throughout the sampling periods and will assist in further categorization of the smoke and fire character at different times. Additional information graciously provided by the Jones Center scientists included meteorological data, total burn area, total fuel mass per area, and GIS data on both soil and biomass types in each of the burn areas that were an average 500 acres in size.
2) *IN temperature spectra were obtained for aerosols lofted by prescribed fires for the first time.* An example of ice nuclei temperature spectra on one burn day are shown in Figure 2. While variability is evident even for 10 minute sample intervals, clear elevation of local IN concentrations was observed in the vicinity of the fires by up to 100 times above the background conditions for this region and time of year. While these measurements were performed at relatively close ranges of a few hundred meters to a few kilometers distance, elevation of concentrated plumes were observed on many occasions, clearly reaching to cloud levels. There is widespread use of prescribed burning in this region of the United States during springtime, so the possibility for regional impacts on the ice phase properties of clouds is an issue that can be explored using our data.
3) *The ice nucleating efficiencies of biomass burning aerosols of the basic type investigated (prescribed fires of the Longleaf Pine ecosystem substory) are grossly over-predicted by a recent generalized relation between global atmospheric IN number concentrations, cloud temperature, and aerosol concentrations larger than 0.5 m. DeMott et al.* (2010) used observational data from a variety of field campaigns to recommend such a relationship for use in predicting IN number concentrations active in mixed-phase clouds within global climate models. This relation provided an explicit link to aerosol variability while greatly reducing the uncertainty in predicting IN concentrations versus temperature, but it was hypothesized that specific dependence of ice nuclei on source chemical composition might be responsible for unexplained remaining variations in space and time. Data shown in Figure 3 demonstrate nearly an order of magnitude lowered efficiency of IN in the particles released from the burn on March 11 compared to values predicted for the background global atmosphere under similar perturbations to aerosol concentrations larger than 0.5 m. Nevertheless, inference could be made that for this particular burn and for the temperature regime isolated in this plot, specific relation of the ice nuclei concentrations to an aerosol parameter such as the concentrations larger than a certain size could be used to parameterize some amount of the variation noted. Remaining variations in this case may reflect actual variations in fire conditions and their impact on the particle chemical and surface properties as they affect ice nucleation. Thus, basic source functions for IN from fires should be possible, but there remain complexities to be explored.
4) *IN chemical speciation during burns reveals a diversity of sources from soil particles, unknown organic species with varied origins, and soot, the proportions of which appear to depend on combustion conditions.* A first example of such results is shown from segments of one burn day in Figure 4. First categorization of the ice nuclei on the basis of elemental compositions and morphology indicated the dominance of carbonaceous types during burns in general. These C-dominated types varied from highly organic types with inorganic inclusions attributed by *Stith et al.* (2011) to a biomass combustion source, to a range of unknown and apparently solid organics, some showing the morphology of plant fragments, to soot particle agglomerates. This is the first confirmation that soot

particles acting as ice nuclei are produced from biomass combustion. While this type has not been found to be abundant among atmospheric ice nuclei on the basis of general collections of this type in the free troposphere, it will be important to document its frequency of occurrence in the broader data set and the conditions under which it is favored for formation. In this regard, it was surprising on March 11 to find that soot IN were not associated with close flaming combustion, but appeared during smoldering and aged-smoke phases of the fire. Finally, the appearance of mineral and soil IN was maximized during the nearby flaming phase, as might have been expected in correlation to soil surface perturbation.

5) *Drop freezing studies of collected aerosols (not shown) support the majority contribution of organic ice nuclei produced from these prescribed fires, especially at activation temperatures warmer than -20°C.* As the filter collections at Jones Center were done value added and on short notice, the filter media employed (nylon) was not the same as employed in NSF studies (polycarbonate nucleopore). A consequence was the apparent (visual) inefficiency of efforts to completely remove the carbonaceous material into DI water. We will therefore seek to further refine this method during future burns to improve confidence in directly comparing CFDC and drop freezing derived IN number concentration estimates. For the particles retrieved from these filters, there were high fractions of labile particles, which is atypical for non-biological or inorganic ice nuclei.

Education and training objectives were also forwarded during Year 2. Christina McCluskey began her M.S. studies under support of this project in Fall 2011 and is focusing her research on the data collected during the Georgia campaign. Dr. Sonia Kreidenweis serves as Ms. McCluskey's academic supervisor and Dr. DeMott is mentoring her research and will serve on her thesis committee. Despite a full first-year class load, Christina actively worked on analysis toward her thesis preparation and a second reviewed publication that she will lead. Three postdoctoral scientists worked on the project at times, including Dr. Ryan Sullivan, Dr. Gavin McMeeking, and Dr. Yutaka Tobo. Dr. Sullivan has accepted a faculty position at Carnegie Mellon University. Dr. McMeeking, who participated in instrument setup and data collection in Georgia, transitioned to a research scientist position. He took over a modest number of Dr. Prenni's responsibilities on this project during the last year of the study due to Dr. Prenni's transitioning to a position of responsibility for measurements on National Parks Service related research studies. Dr. Yury Desyaterik, a research scientist, assisted Dr. Amy Sullivan for aerosol chemistry measurements during prescribed burns.

Presentations were made, as listed in the Publications and Presentations section, and the first major publication of the study (Prenni et al. 2012) was submitted for review at the end of the second year.

Year 3 Activities and Results

Activities during Year 3 included work on Objectives 2 to 5. Analyses of prescribed burn data from Georgia and Colorado were further analyzed and are being harmonized for comparison in a new publication for submission in Spring 2013. Major wildfires that exploded to the west of the CSU Atmospheric Science Department were also sampled intensively from our laboratory in late Spring and early Summer 2012. A new opportunity to consolidate efforts with a newly-funded NASA study also permitted sampling of a variety of fuel types in a laboratory setting, and independent new support for the role of biomass burning produced refractory black carbon as ice nuclei. Results are summarized here:

1) *Large wildfires, at least from the ecosystem of the Colorado Front Range forests, produce more ice nuclei and more efficient ice nuclei than do prescribed fires.* Two large wildfires, the named Hewlett Gulch and High Park fires, were centered on an area 30 km to the NW of our CSU laboratory, but reached within 3 km by line of sight of our facilities (Figure 5). Together, the fires burned through nearly 100,000 acres of forest in the time between late May and late June 2012. Smoke from the fires was continuously monitored by a large suite of aerosol instruments to characterize mass, size distribution, refractory black carbon concentration, and CCN number concentrations. On the basis of noting highest smoke mass in the boundary layer overnight and in the early morning hours, IN sampling was primarily focused during these times, but with periods of other sampling throughout the month. This permitted comparison of IN number concentrations as a function of aerosol concentrations and temperature to those measured in the GA prescribed fires, as shown in Figures 6a and 6b. It is clear in Fig. 6a that the wildfires provide a fairly consistent data set, and that the IN were consistently higher than for the same aerosol concentrations achieved in prescribed burns. This implies the production of more efficient ice

nuclei or a rapid conversion of particles to more be more efficient in the relatively longer transit times to the sampling site. Electron microscopy samples of IN were collected and should help reveal which factor is more important based on the elemental compositions and morphology of the IN. It is possible that the elevated IN efficiency is due to the burning of hardwood or even more likely due to the co-lofting of soil materials. This should be evident in the IN chemistry we will complete assessment of during the next few months. Figure 6b places the prescribed burn and wildfire data in the context of the “global” IN parameterization of DeMott et al. (2010). As discussed previously, the prescribed burn data from Georgia show up as significantly less efficient (IN over-predicted by parameterization) than the global average IN. The wildfire smoke IN, however, are substantially under-predicted in number by the parameterization. If this result is robust, it could provide a means of separating out the potential role of these different styles of biomass burning emissions. Also shown in Fig. 6 are results from a laboratory study in which the primary fuel from the Georgia burns, wiregrass, was burned. The laboratory results are perfectly consistent with the prescribed fire data, supporting that the power of the wildfires led to emission of a quite different IN population.

2) *Final categories of IN types were defined for comparing prescribed and wildfire electron microscopy data for giving inference to the specific role of refractory and other types of carbonaceous particles as ice nuclei.* Modest revisions were made to the first categorization analysis presented in Fig. 4 were made on the basis of a consistent analysis of all collected IN samples performed by Christina McCluskey as part of her thesis research. The new categories are shown in Fig. 7. The primary difference is the consolidation of mineral and metal oxide particles in a single category and the inclusion of a new tarball category as a commonly recognizable particle type. The results of analysis are given in the lower part of Fig. 8. Carbonaceous IN averaged about 70% of all IN in 10 integrated samples collected during the fires, with more than 40% of these being characterized as soot ice nuclei. Exceptions were samples dominated by mixed-carbonaceous particles that occurred during the longest transport to the collection site (A6, A7) and a sample dominated by mineral particles from the single instance of intense burning for which ashfall was noted during collection (A10). These results appear to confirm the production of soot ice nuclei in a large majority of such biomass combustion events.
3) *A novel coupled-instrument technique was used in new laboratory biomass combustion studies to validate the specific involvement of refractory black carbon in ice nucleation by soot-containing smokes.* A single particle soot photometer instrument (SP-2; Droplet Measurement Technologies), purchased with NASA funding, was used in series with the CFDC instrument during laboratory biomass combustion studies at the U.S. Forest Service Fire Sciences Lab at Missoula, Montana, in Fall 2012 (termed the FLAME-4 experiment). In a synergy between the respective studies, some fuels were selected for specific comparison to work done under this NOAA grant. In particular, a SE U.S. wiregrass and Western Ponderosa pine needles and branches were burned. The novel methods employed situated the SP-2 instrument as a pre-processor of aerosols ahead of the CFDC. The concept is to incandesce refractory carbon while leaving mineral and other ice nuclei types unaffected. Separate proof-of-concept laboratory studies have been conducted to support the use of this technique, a method that avoids the need to apply imperfect separation of activated IN at the outlet of the CFDC when sending these to single particle composition instruments such as the SP-2 or a mass spectrometer. The results of use of this method for sampling the combustion smoke from wiregrass are shown in the upper part of Fig. 8 for comparison to the elemental analyses performed by TEM of the Georgia prescribed burns dominated by wiregrass combustion. The correspondence of the reduction in ice nuclei by 39 to 55% in the laboratory burns is in excellent agreement with the assessment of the involvement of ice nuclei dominated by refractory carbon IN in the field burns. This evidence targets the specific role of the rBC containing particles, or at least their support as a matrix for ice nucleating sites. Analyses continue of additional burns that included ponderosa pine fuels that may be related to prescribed and wildfire results from Colorado.

Ms. McCluskey progressed in her research during Year 3 to the point that she will defend her thesis within 2 years of arriving to CSU. She made her first conference presentation at the AAAR meeting in 2012, and has been invited as one of 23 promising young scientists under the age of 40 to attend the

ESF-funded workshop - Atmospheric Ice Nucleation: http://www.imc.tuwien.ac.at/esf-ws01/ organized within the research networking programme on the Micro-Dynamics of Ice: http://microdice.eu/. This workshop will be held at the Vienna University of Technology on the weekend 6-7 April 2013. The workshop precedes the week of the EGU General Assembly where Ms. McCluskey has been accepted for oral presentation within the session AS3.5 - Atmospheric Ice Particles. Dr. McMeeking, who has assisted this study and was co-lead on the NASA study departed CSU in January 2013 for a lead scientist position at Droplet Measurement Technologies in Boulder, CO.

The first study paper by Prenni et al. (2012) was accepted for publication. A draft of a major publication is in progress at the time of this writing. Additional conference presentations were made during 2012 and Dr. DeMott included material in this study in two additional invited presentations/seminars.

Year 4 (no-cost) Activities and Results

Activities during the 4th year under no-cost extension centered on objectives 1, 3, 4, and 5. All activities and objectives identified in the previous annual report were met. The major accomplishments were:

1) *Electron microscopy analyses completed on wildfire ice nuclei samples, and all prescribed burn and wildfire samples were inter-compared on a common basis:* This is the first ever data base of this type.
2) *Examination of processing of smoke emissions from NASA-funded laboratory burns was begun to address the impact of smoke aging on ice nucleating particles.*
3) *Ms. McCluskey completed her M.S. thesis:* The thesis, centered around this study, was titled "Characteristics of Atmospheric Ice Nucleating Particles Associated with Biomass Burning in the US: Prescribed Burns and Wildfires." Ms. McCluskey is continuing her education as a Ph.D. student.
4) *A final publication prepared and submitted with the same title as the thesis:* The paper presents the major results of this study that include,
    a. Soot particles were identified as an ice nuclei source from biomass combustion for the first time, particularly from combustion of Southeast US forest sub-story fuels such as wiregrass.
    b. Western US wildfires were distinctly identified as more productive for ice nuclei production than prescribed fires in either the Western or Southeastern US.
    c. While carbonaceous sources for ice nucleating particles dominate in most fire situations, wildfire production of ice nuclei is found to also involve an ice nuclei source from soil particle lofting.
    d. Disentangling the quantitative contribution of wildfires to atmospheric ice nuclei, and likely their impact on regional cloud systems, depends on the natural background in which they occur. Western US fires in late spring and early summer can often occur within elevated ice nucleating particle scenarios created by long range transport of mineral dust particles. This may occur in other major biomass burning regions globally. The high overall particle concentrations in fire plumes also may create feedbacks on the impact of added ice nuclei that will require numerical modeling studies for full elucidation.
5) *Parameterizations of ice nuclei number concentrations were developed for use in numerical modeling investigations:* We are collaborating with Prof. Susan van den Heever of Colorado State University on regional model simulations of summer 2012 wildfire impacts on convective cloud systems affected and monitored during the NSF-funded Deep Convective Clouds & Chemistry Experiment (DC3) research aircraft campaign.
6) *Plans were drafted and submitted for continued related studies:* New research studies were proposed to NOAA via a letter of intent for the FY14 call, but were not approved for full proposal. Some of these planned studies are the subject of an NSF postdoctoral research proposal currently under review. New aircraft studies of biomass burning particles from major global source regions, including assessment of ice nucleating particle numbers and compositions by our group, were partly motivated by the results of this study and were proposed as part of a multi-institute/investigator response to a call for NASA Earth Venture Class mission proposals.

Presentations and Publications

Research results from this study were presented in multiple scientific forums during the course of this study, where NOAA funding on this grant was acknowledged.

Conference and special meeting presentations

Prenni, A. J., P. J. DeMott, A. P. Sullivan, R. C. Sullivan and S. M. Kreidenweis, 2010: Quantifying the Sources of Atmospheric Ice Nuclei from Biomass Burning Aerosols, *International Aerosol Conference 2010*, Helsinki, FI, 29 August – 3 September (www.iac2010.fi/).

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Prenni, A. J., P. J. DeMott, A. P. Sullivan, R. C. Sullivan, S. M. Kreidenweis, and D. C. Rogers, 2012: Biomass burning as a potential source for atmospheric ice nuclei: Western wildfires and prescribed burns. *Geophys. Res. Lett.*, **39**, L11805, doi:10.1029/2012GL051915.

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Vali, G., 1971: Quantitative evaluation of experimental results on the heterogeneous freezing nucleation of supercooled liquids, *J. Atmos. Sci.*, 28(3), 402-409.

Figure 1. Near-vicinity flaming (March 11) versus later smoldering combustion (March 11) during prescribed burning in Longleaf Pine ecosystem of SW Georgia.

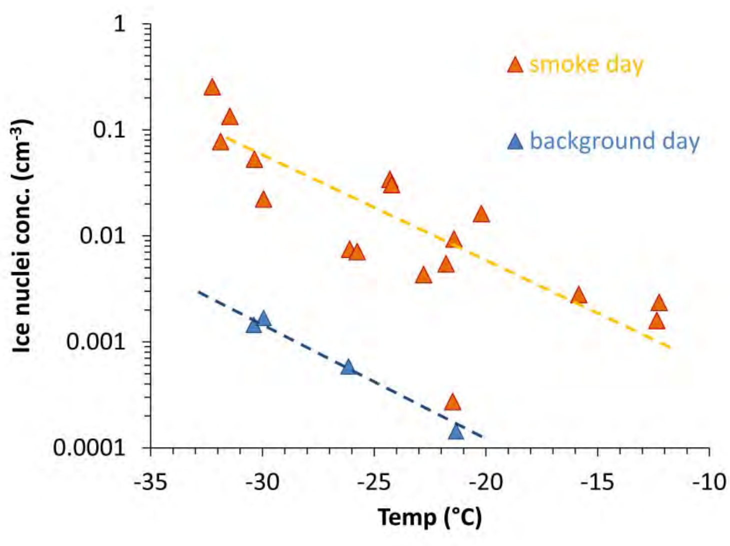


Figure 2. Period (5-15 minute) average ice nuclei concentrations measured on a fire day (3/15/11) versus a background sampling period (3/9/11) deemed to be characteristic of most background periods on the basis of bulk chemical composition data collected daily.

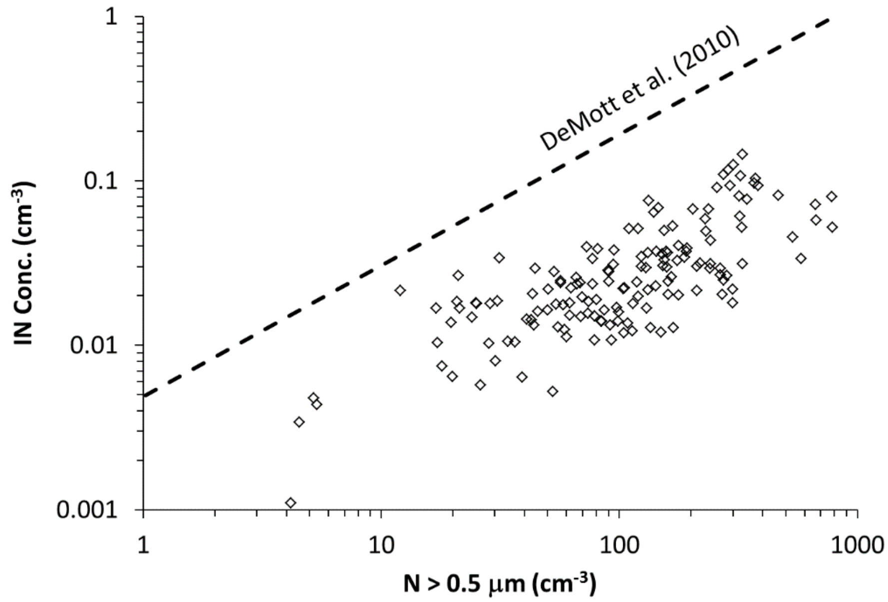


Figure 3. Relation between IN concentrations (all at -30°C) and aerosol concentrations larger than 0.5 m for 30 s intervals during smoke sampling on March 11, 2011. Comparison is made to global background IN predicted based on the observationally-based parameterization given in DeMott et al. (2010). These data demonstrate the relative inefficiency of the fire-produced IN from this ecosystem.

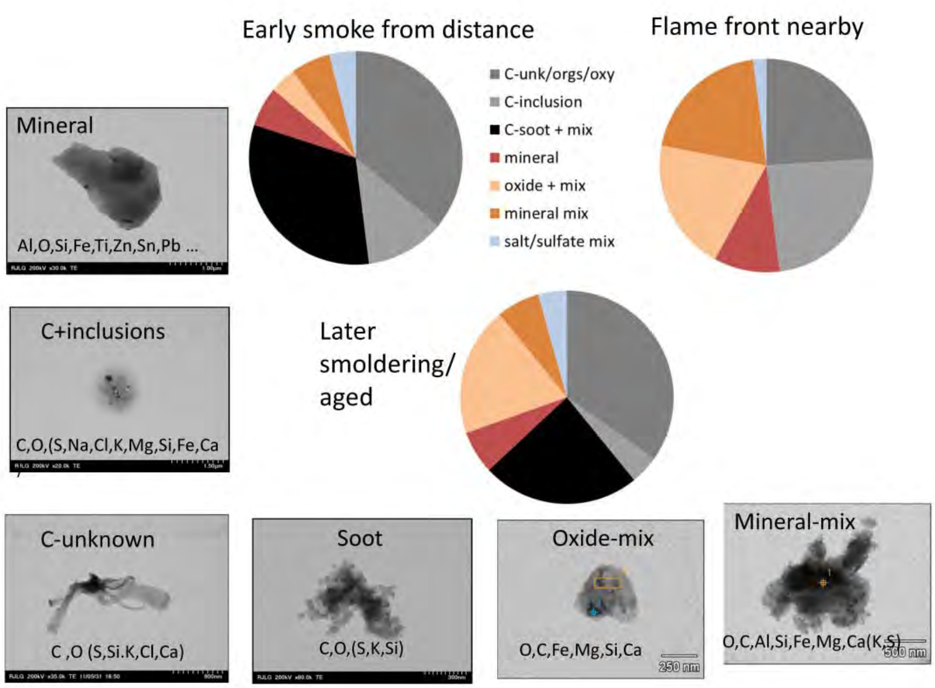


Figure 4. Ice nuclei particle types, with examples of their respective morphologies and elemental compositions observed during three subsequent hour-long periods on March 11, 2011. The flame front and later smoldering periods are shown in Figure 1.

Figure 5. Wildfires sampled at the CSU Atmospheric Science Department in late May and June 2012. The Hewlett Gulch fire looking NW on May 18, 2012 is on the left, and the High Park Fire looking W on June 11 is shown on the right. In both instances, overnight and early morning hours favored descent of the highest mass concentrations in plumes to the lower elevations around the laboratory.

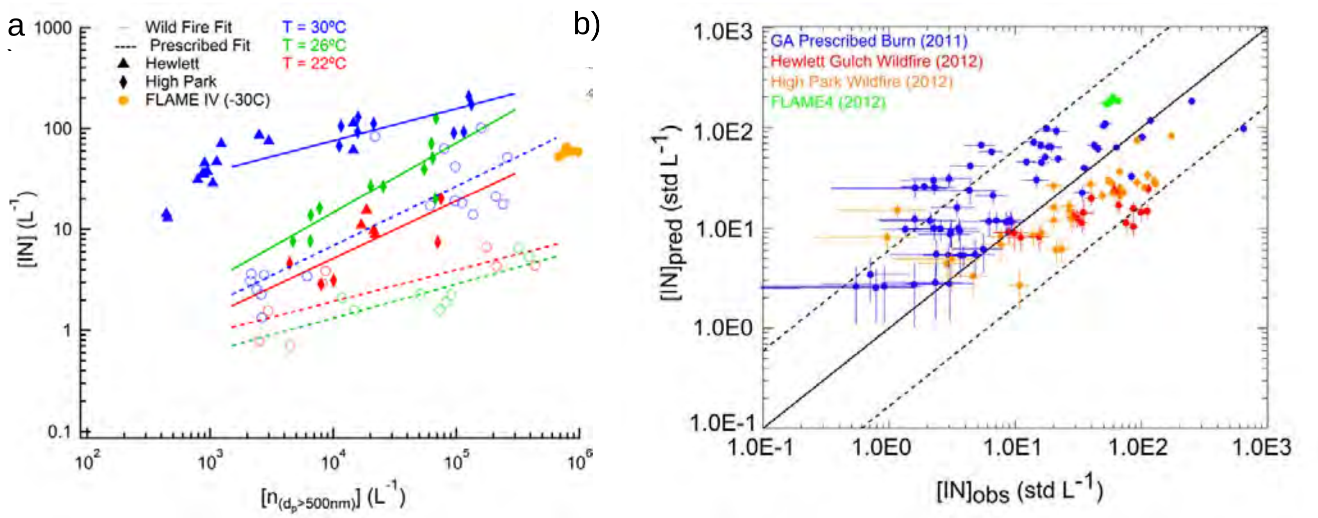


Figure 6. Comparison of prescribed and wildfire IN number concentrations at indicated temperatures with respect to aerosol particle concentrations larger than 500 nm diameter in a), and comparison of observed IN number concentrations to those predicted by the "global" IN parameterization of DeMott et al. (2010) that couples IN dependence on temperature and these aerosol particle concentrations. Also included are FLAME IV burn data for wiregrass, the main fuel in the prescribed burns in Georgia.

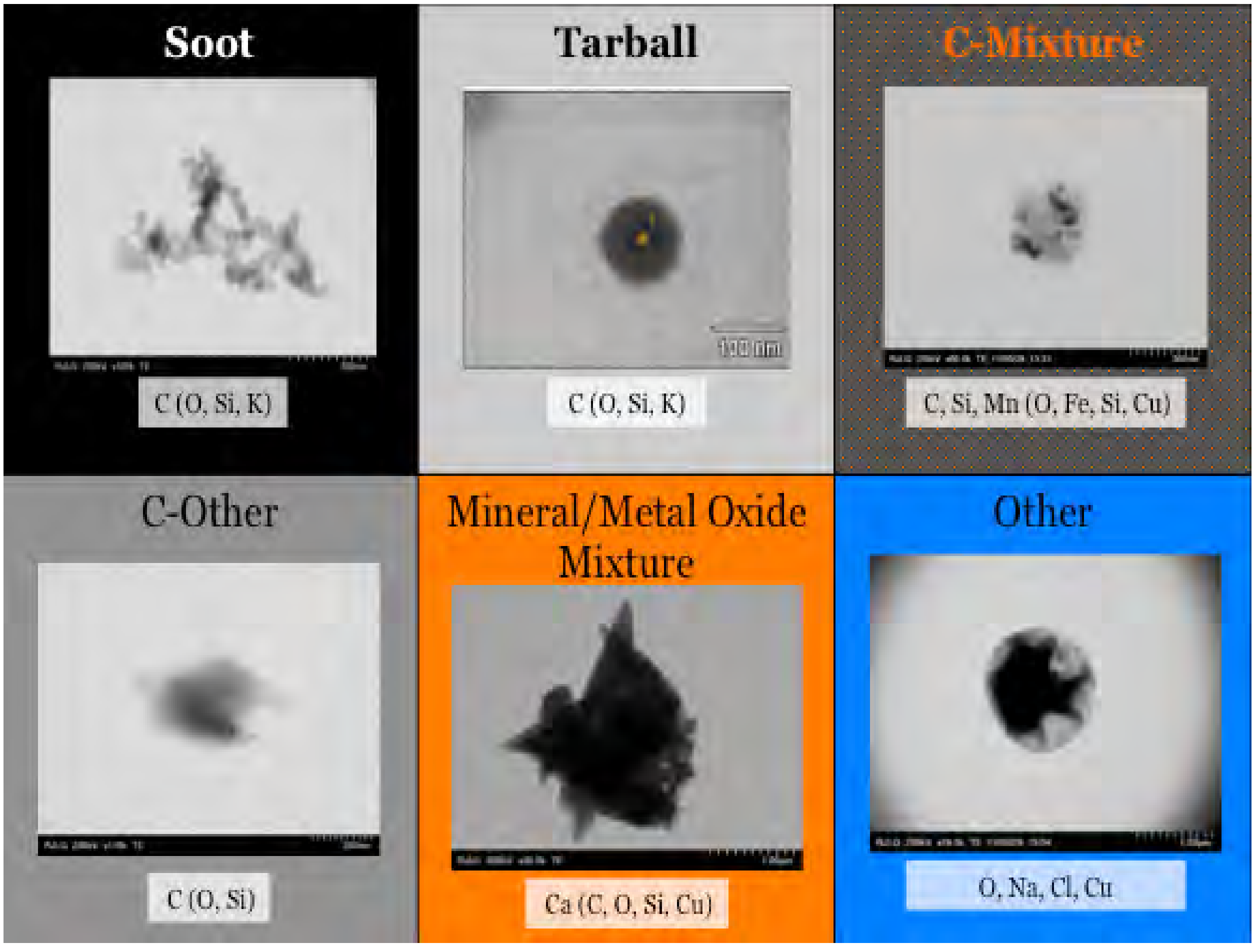


Figure 7. Final breakdown of compositional categories defined for the Georgia prescribed fire series.

Time	Sample	[IN]	$[n_{dp>500nm}]$	$\frac{OFF - ON}{OFF}$
10:54	room	122.0	488.2	
11:14	OFF	45.5	67.3	0.550
11:18	ON	20.5	30.1	0.390
11:21	OFF	33.6	59.6	0.460
11:25	ON	18.1	27.5	

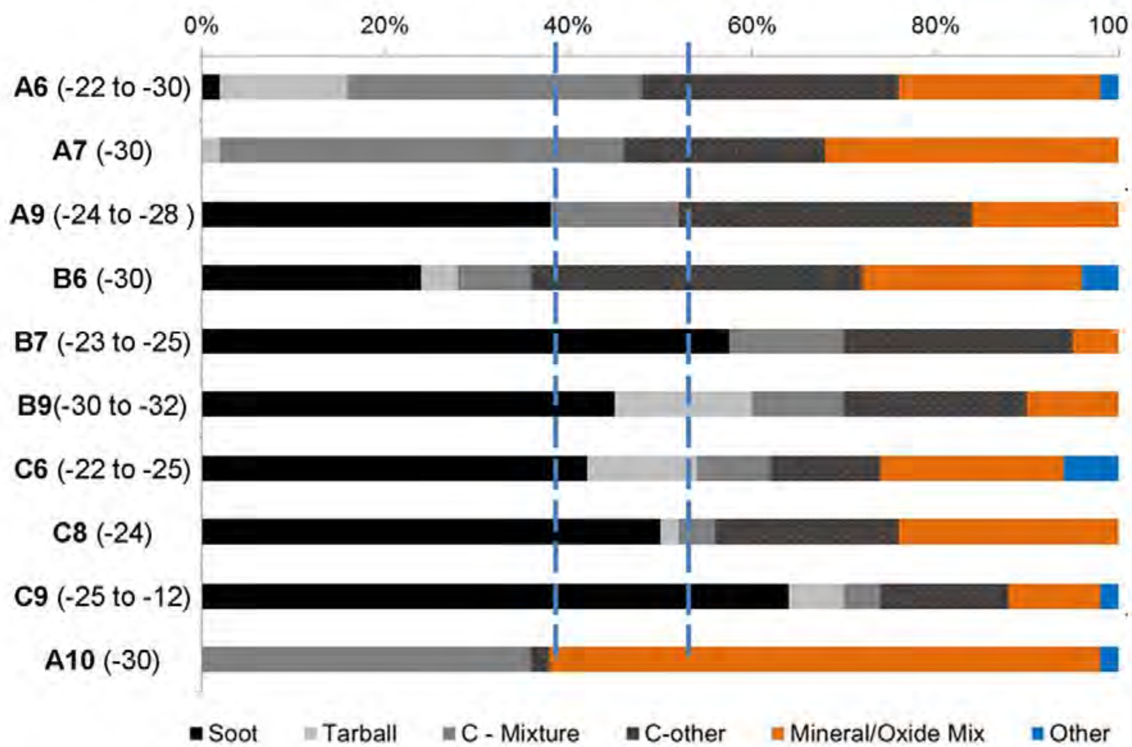


Figure 8. Fractional contributions of the compositional types of ice nuclei, color coded based on Figure 5, identified from analyses of all grids collected in the Georgia prescribed burns, in comparison to range of refractory black carbon IN found (blue dashed lines) using the SP2 instrument to pre-remove the carbonaceous particles after burning ~1kg of wiregrass in the USFS Fire Sciences Laboratory burn room (top table). In the SP2 studies, sample OFF and ON refer to the laser power for the SP2 used in advance of the CFDC instrument. Concentrations in the room decayed following the initial combustion, and decreased by about times in the SP2 due to the addition of dilution air used to focus the sample flow through the laser.

COMPETITIVE PROJECT TITLE: Research to Advance Climate and Earth System Models Collaborative Research: A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models (NA13OAR4310103)

PRINCIPAL INVESTIGATOR: David Randall

RESEARCH TEAM: (Casey Patrizio) full time, starting in summer 2014

NOAA TECHNICAL CONTACT: Daniel Barrie- OAR Climate Program Office

NOAA RESEARCH TEAM: Shrinivas Moorthi and Fanglin Yang, both at NCEP

PROJECT OBJECTIVE:

We will unify the representation of turbulence and SGS cloud processes in the GFS and CFS, and unify the representation of SGS precipitation due to deep convective precipitation and grid-scale clouds as the horizontal resolution decreases.

PROJECT ACCOMPLISHMENTS:

For the current fiscal year, CSU has received only $1000 of funding in support of this project. Most of the funding was used to support a visit by the P.I. David Randall to NCEP in December 2013. During the visit Randall discussed the project with NCEP scientists and also with collaborators from the University of Utah and the University of Colorado. In March 2014, Randall participated in interviews of two scientists for a postdoctoral position that will support the project.

COMPETITIVE PROJECT TITLE: Towards Assimilation of Satellite, Aircraft, and Other Upper-air CO_2 Data into CarbonTracker (NA130AR4310077)

PRINCIPAL INVESTIGATOR: David F. Baker

RESEARCH TEAM: Michael Trudeau, David F. Baker

NOAA TECHNICAL CONTACT: Pieter Tans, ESRL/Global Modeling Division

NOAA RESEARCH TEAM: Andrew Jacobson

PROJECT OBJECTIVES:

CarbonTracker-CO_2 (CT) is a data assimilation system that estimates sources and sinks of CO_2 from atmospheric measurements, using an atmospheric transport model to link CO_2 concentrations to surface fluxes. It solves for fluxes across continental biome-sized regions over land, and basin-sized regions over the ocean, using data from NOAA/GMD's global network of *in situ* CO_2 measurement sites (flasks, tall towers, and continuous sensors). Over the past 7 years, it has been the most-used CO_2 flux product in the world. As currently configured, however, the link between surface fluxes and the down-stream effect on CO_2 concentrations is truncated after only five weeks: this is too short a time for these fluxes to mix well into the middle to upper part of the atmospheric column. As a result, CT cannot estimate fluxes using data taken far away from the surface, such as aircraft profiles, and column-averaged CO_2 measurements from satellite and ground-based spectrometers. Given the current explosion of such data from satellites (GOSAT, OCO-2, *etc*.) and from the Total Column Carbon Observing Network (TCCON), we would like to modify CT to be able to use these data. In this project, we will experiment with lengthening the 5-week assimilation window currently used in the CT ensemble Kalman smoother (enKS), as well as adding an "outer-loop" inversion to optimize the prior used in the enKS at coarser scales, to minimize truncation errors from shorter window lengths in the enKS. We will also enhance CT to solve for the surface CO_2 fluxes at higher spatial resolution when using the new high-density data. Simulation experiments will be used to accurately assess the impact of the modifications.

PROJECT ACCOMPLISHMENTS:

We have modified CT to be able to sample column-integrated measurements and to use these to solve for surface fluxes. We have added a new atmospheric transport model (PCTM) and new meteorological drivers (GEOS5 MERRA) into CT, to allow CT to be run quickly at coarser resolution to facilitate the needed experiments.

No publications as yet. Details on CarbonTracker-CO_2 may be found at:
http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/

COMPETITIVE PROJECT TITLE: Tropical Cyclone Model Diagnostics and Product Development (NA13NWS48300233037)

PRINCIPAL INVESTIGATOR: Wayne Schubert

RESEARCH TEAM: Kate Musgrave, Scott Longmore, Andrea Schumacher, Louie Grasso, Robert DeMaria, Chris Slocum, Kathy Fryer

NOAA TECHNICAL CONTACT: Philip Hoffman (NOAA/OAR)

NOAA RESEARCH TEAM: John Knaff, Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

The National Oceanic and Atmospheric Administration (NOAA) initiated the Hurricane Forecast Improvement Project (HFIP) to reduce the errors in tropical cyclone track and intensity forecasts. This reduction will be accomplished through improved coupled ocean-atmosphere numerical hurricane models, better use of observations through advanced data assimilation techniques and ensemble forecasts. Model diagnostic techniques will also be developed to determine the sources of model errors and guide future improvements. The CIRA team performed six tasks that contribute to this HFIP effort. Details on these tasks are described in the next section.

The CIRA HFIP activities directly address NOAA's Weather and Water goal, which seeks to serve society's needs for weather and water information. This research falls within the NOAA-defined CIRA thematic area of Satellite Algorithm Development.

PROJECT ACCOMPLISHMENTS:

1—Retrospective forecasts using updated SPICE model

-- One of the main accomplishments of the CIRA HFIP project has been the development of improved statistical intensity forecast models. One of these is called the Statistical Prediction of Intensity with a Consensus Ensemble (SPICE) model. It uses input from a number of dynamical models with a variety of tracks as input to two statistical models to form a consensus. Each hurricane season, the HFIP program runs experimental models in real time for evaluation by the National Hurricane Center. To become eligible for the demonstration, the model must be run on retrospective cases from the past three hurricane seasons. SPICE was designated for the real-time demonstration period in 2013 after completing the retrospective testing process. The SPICE model is currently undergoing upgrades and retrospective testing on the 2011-2013 hurricane seasons in preparation for the 2014 season.

2—Real-time forecasts using updated SPICE model

-- The SPICE model was designated to run during the real-time demonstration period of the 2013 hurricane season due to its performance in the retrospective testing. SPICE was successfully run during that demonstration period from 1 August 2013 to 1 November 2013. Preliminary verification of the SPICE model for the 2013 hurricane season has been performed, with some of the results shown in Figure 1. SPICE had lower mean absolute errors in the Atlantic basin than either Decay-SHIPS or LGEM at longer forecast times.

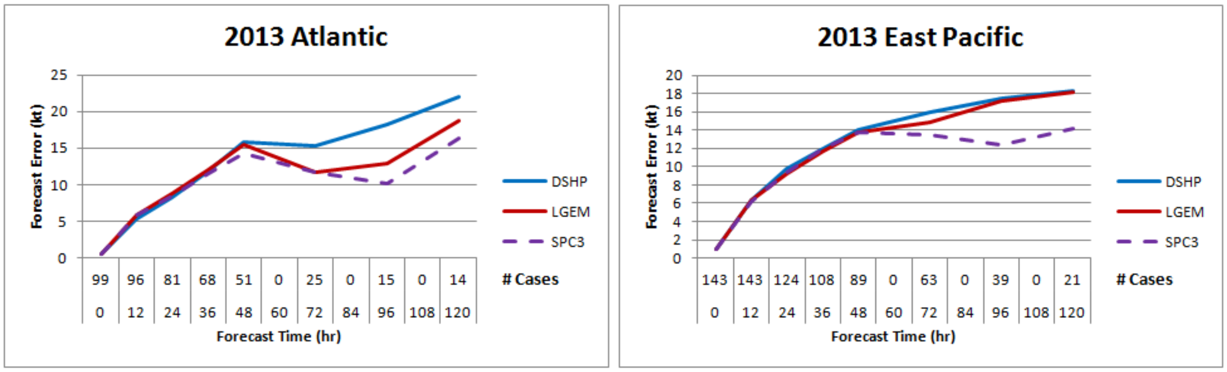


Figure 1. Mean absolute error (in kt) for forecast intensity for the 2013 Atlantic (left) and East Pacific (right) hurricane seasons for Decay-SHIPS (blue), LGEM (red), and SPICE (purple dashed).

3—Develop new hurricane forecast products: Environmental variable ensemble

-- A program to diagnose a number of variables from hurricane models was developed under HFIP and is being improved by adding new parameters. Variables thought to be important for intensity change, such as vertical shear, relative humidity, etc., are being diagnosed from several real-time global and regional models, and products that show their differences are being developed and displayed in real time. A multi-model comparison plot featuring the operational models GFS, HWRF, and GFDL was provided to the HFIP products website (http://www.hfip.org/products/) during the real-time demonstration from 1 August 2013 to 1 November 2013 (Figure 2).

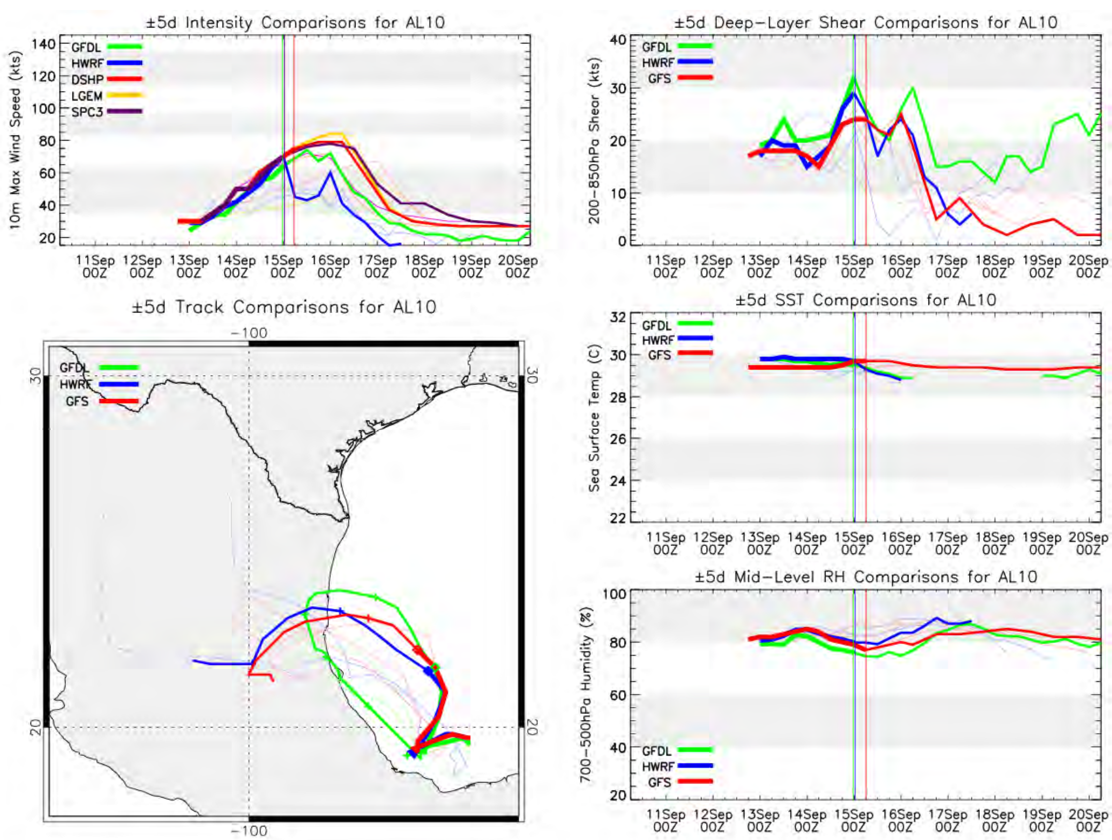


Figure 2. Multi-model comparison plot for Hurricane Ingrid, valid at 0600 UTC 15 September 2013. This plot compares forecasts of TC and environmental variables from the three operational models GFS,

HWRF, and GFDL. Clockwise from bottom-left: track (latitude and longitude of the center position), intensity (10 m maximum sustained winds), 850-200 mb vertical wind shear, sea surface temperature, and 700-500 mb relative humidity. Three additional models are included for the intensity forecasts: Decay-SHIPS, LGEM, and the HFIP experimental model SPICE.

4—Run experimental hybrid version of NHC's operational windspeed probability program in 2013. Provide experimental products for HFIP products web page. Perform verification in post-season.

-- An experimental version of NHC's operational tropical cyclone wind speed probability model was run for the 2013 hurricane season, with graphical output provided to the HFIP products website (http://www.hfip.org/products/). The experimental version uses track information from a set of dynamical model ensembles, instead of from randomly sampling from the tropical cyclone track forecast errors from the past five years, as is used in the operational version. The intensity and structure perturbations are determined in the same way (using random sampling of forecast errors) as the operational version. The experimental version can represent more complex scenarios such as clustering of tracks and bimodal distributions.

5—Create an experimental version of SHIPS and LGEM, based on the ECMWF forecast fields.

-- The operational versions of the statistical SHIPS and LGEM intensity models use input from the NCEP global forecast model. Work continues on adapting these models to use input from the ECMWF global forecast model, and the forecast errors will be compared with the operational version. The grib decoder routines used in the operational version of SHIPS and LGEM on NCEP's WCOSS system have been modified to use 1 degree ECMWF model output instead of the 1 degree GFS model output. A parallel version of the operational SHIPS/LGEM script was also created with a switch to run off the ECMWF fields instead of the GFS fields. A side benefit of this approach is that the operational Rapid Intensification Index (RII) will also be run off the ECMWF fields for comparison with the GFS version. Initial tests showed that the ECMWF grib files on WCOSS did not contain all the fields needed to run SHIPS and LGEM. When more complete ECMWF fields are provided, the development of the experimental SHIPS, LGEM and the RII will continue. The ECMWF versions of SHIPS and LGEM may be candidates for inclusion of future versions of the SPICE model.

6—Collect observed GOES data for 2013 storm cases. Provide data to other groups, and perform verification of HWRF synthetic imagery. Add satellite total precipitable water for evaluation of model moisture fields.

-- One of the difficulties of verifying hurricane models is the lack of observations near the storm, especially in the upper levels. Observations of the moisture fields are also very sparse near tropical cyclones. To aid in the evaluation and verification of the HFIP forecast models, synthetic GOES satellite data and total precipitable water (TPW) fields from the model output are being compared to the real GOES satellite imagery and a microwave-based satellite TPW product. This comparison will help to identify error sources in the models, and provide feedback to users on areas where the models can be improved. To facilitate this comparison observed GOES data and satellite precipitable water was collected for the 2013 hurricane season. Verification of HWRF synthetic imagery for the 2013 season has successfully been performed, with some of the results presented in Figure 3. The current operational HWRF shows reduced biases, particularly in the synthetic IR brightness temperatures, as compared to the previous version of HWRF. Satellite total precipitable water has been added, and Figure 4 shows a comparison of imagery generated from HWRF total-column precipitable water and blended satellite total precipitable water.

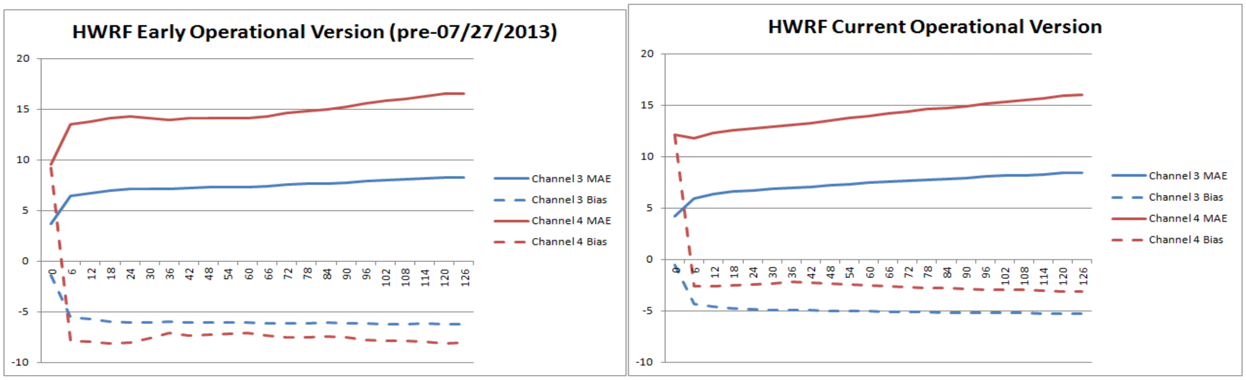


Figure 3. Mean absolute error (solid) and bias (dashed) for the HWRF synthetic Channel 3 (WV, blue) and Channel 4 (IR, red). The left panel highlights the period of the 2013 Atlantic hurricane season before the current operational version was implemented; the right panel shows the operational HWRF for the period from August 2013 through the end of the Atlantic hurricane season.

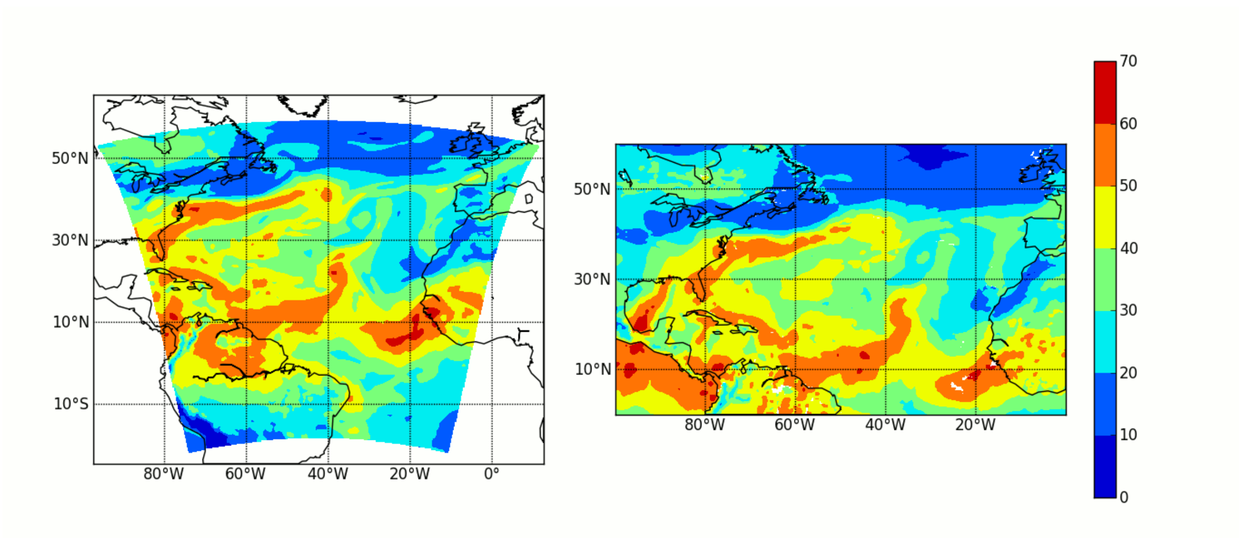


Figure 4. HWRF total-column precipitable water (left) and blended satellite total precipitable water (right) for Tropical Storm Erin, 12 UTC 18 August 2013.

The following is the report previously submitted to the Technical Sponsor.

Project Title: CIRA Support to Tropical Cyclone Model Diagnostics and Product Development [HFIP]

Project Reporting Period: 1 October – 31 December 2013

Principal Investigator (CIRA/CSU PI): Wayne H. Schubert

Research Team (CIRA/CSU Staff involved in the project listed in order of staffing time on project, contribution level, or other):

Kate Musgrave, Andrea Schumacher, Scott Longmore, Louie Grasso, Robert DeMaria, Jack Dostalek, Galina Chirakova, Chris Slocum, Dave Watson, Natalie Tourville, Kevin Micke, Renate Brummer, Kathy Fryer

Technical Contact Name/NOAA Office:
Mark DeMaria NOAA/NESDIS/STAR

NOAA Research Team (The equivalent of CIRA Research Team for NOAA Staff involved in the project and their affiliations):
Dr. Mark DeMaria, Dr. John Knaff
CIRA/Regional and Mesoscale Meteorology (RAMM) Branch

Project Objectives:
The National Oceanic and Atmospheric Administration (NOAA) initiated the Hurricane Forecast Improvement Project (HFIP) to reduce the errors in tropical cyclone track and intensity forecasts. This reduction will be accomplished through improved coupled ocean-atmosphere numerical hurricane models, better use of observations through advanced data assimilation techniques and ensemble forecasts. Model diagnostic techniques will also be developed to determine the sources of model errors and guide future improvements. The CIRA team is performing six tasks that contribute to this HFIP effort. Details on these tasks are described in the next section.

The CIRA HFIP activities directly address NOAA's Weather and Water goal, which seeks to serve society's needs for weather and water information. This research falls within the NOAA-defined CIRA thematic area of Satellite Algorithm Development.

Research Conducted (Accomplishments):

i) <u>Retrospective forecasts using updated SPICE model.</u>

One of the main accomplishments of the CIRA HFIP project has been the development of improved statistical intensity forecast models. One of these is called the Statistical Prediction of Intensity with a Consensus Ensemble (SPICE) model. It uses input from a number of dynamical models with a variety of tracks as input to two statistical models to form a consensus. Each hurricane season, the HFIP program runs experimental models in real time for evaluation by the National Hurricane Center. To become eligible for the demonstration, the model must be run on retrospective cases from the past three hurricane seasons. The SPICE model was upgraded to the 2013 version and run on retrospective cases covering the 2010-2012 hurricane seasons, and was designated to be run during the real-time demonstration in the 2013 hurricane season. The SPICE model will continue to be improved and run on the retrospective cases for the 2014 hurricane season. This quarter we were involved in a diagnostics workshop to assist in assessing retrospective model runs for the 2014 season, and next quarter will contain much of the retrospective runs for the SPICE model.

ii) <u>Real-time forecasts using the updated SPICE model.</u>

The SPICE model was designated to run during the real-time demonstration period of the 2013 hurricane season due to its performance in the retrospective testing. SPICE was successfully run during that demonstration period which ended on November 1. This quarter, preliminary verification of the SPICE model has been performed, with some results shown in Figure 1. SPICE had lower mean absolute error in the Atlantic basin than either Decay-SHIPS or LGEM at longer forecast times, as well as HWRF and GFDL.

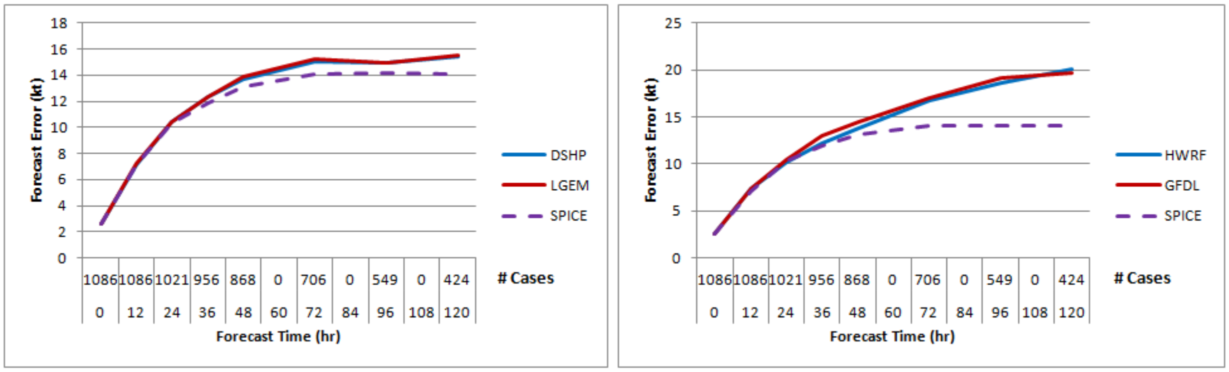


Figure 1. Mean absolute error (in kt) for forecast intensity for the retrospective runs of the 2010-2012 Atlantic hurricane seasons. The left panel features Decay-SHIPS (blue), LGEM (red), and SPICE (purple dashed), while the right panel festures HWRF (blue), GFDL (red), and SPICE (purple dashed).

iii) <u>Develop new hurricane forecast products: Environmental variable ensemble.</u>

A program to diagnose a number of variables from hurricane models was developed under HFIP and is being improved by adding new parameters. Variables thought to be important for intensity changes, such as vertical shear, relative humidity, etc., are being diagnosed from several real time global and regional models, and products that show their differences are being developed and displayed in real time. A multi-model comparison plot featuring the operational models GFS, HWRF, and GFDL was provided to the HFIP products website (http://www.hfip.org/products/) during the real-time demonstration, which ended on November 1.

iv) <u>Run experimental hybrid version of NHC's operational windspeed probability program in 2013. Provide experimental products for HFIP products web page. Perform verification in post-season.</u>

An experimental version of NHC's operational tropical cyclone wind speed probability model is being developed. The experimental version uses track information from a set of dynamical model ensembles, instead of from randomly sampling from the tropical cyclone track forecast errors from the past five years, as is used in the operational version. The intensity and structure perturbations are determined in the same way (using random sampling of forecast errors) as the operational version. The experimental version can represent more complex scenarios such as clustering of tracks and bimodal distributions. This quarter we completed running the hybrid model in real time for the 2013 hurricane season and providing graphical output to the HFIP products website. Results will be compared with the operational version post-season. Preliminary verification has been completed and the results will be presented next quarter.

v) <u>Create an experimental version of SHIPS and LGEM, based on the ECMWF forecast fields.</u>

Last quarter we reported that the operational versions of the statistical SHIPS and LGEM intensity models use input from the NCEP global forecast model. Work continues on adapting these models to use input from the ECMWF global forecast model, and the forecast errors will be compared with the operational version. This quarter the grib decoder routines used in the operational version of SHIPS and LGEM on NCEP's WCOSS system were modified to use 1 degree ECMWF model output instead of the 1 degree GFS model output. A parallel version of the operational SHIPS/LGEM script was also created with a switch to run off the ECMWF fields instead of the GFS fields. A side benefit of this approach is that the operational Rapid Intensification Index (RII) will also be run off the ECMWF fields for comparison with the GFS version. Initial tests showed that the ECMWF grib files on WCOSS did not contain all the fields needed to run SHIPS and LGEM. A meeting was held with NCEP NCO and they are going to provide the location on WCOSS of the more complete ECMWF grib files. The more complete ECMWF files have access restrictions, but since the parallel SHIPS script will run under the operational NHC account, it should be possible to gain access to those. When that information is provided, the development of the experimental SHIPS, LGEM and the RII will continue. The ECMWF versions of SHIPS and LGEM may be candidates for inclusion of future versions of the SPICE model.

vi) <u>Collect observed GOES data for 2013 storm cases. Provide data to other groups, and perform verification of HWRF synthetic imagery. Add satellite total precipitable water for evaluation of model moisture fields.</u>

As mentioned previously, one of the difficulties of verifying hurricane models is the lack of observations near the storm, especially in the upper levels. Observations of the moisture fields are also very sparse near tropical cyclones. To aid in the evaluation and verification of the HFIP forecast models, synthetic GOES satellite data and total precipitable water (TPW) fields from the model output is being compared to the real GOES satellite imagery, and a microwave-based satellite TPW product. This comparison will help to identify error sources in the models, and provide feedback to users on areas where the models can be improved. To facilitate this comparison observed GOES data and satellite precipitable water was collected for the 2013 hurricane season, completed this quarter. Verification of HWRF synthetic imagery for the 2013 season has successfully been performed, with some of the results presented in Figure 2. The current operational HWRF shows reduced biases, particularly in the synthetic IR brightness temperatures, as compared to the previous version of HWRF. Satellite total precipitable water has been added, and Figure 3 shows a comparison of imagery generated from HWRF total-column precipitable water and blended satellite total precipitable water.

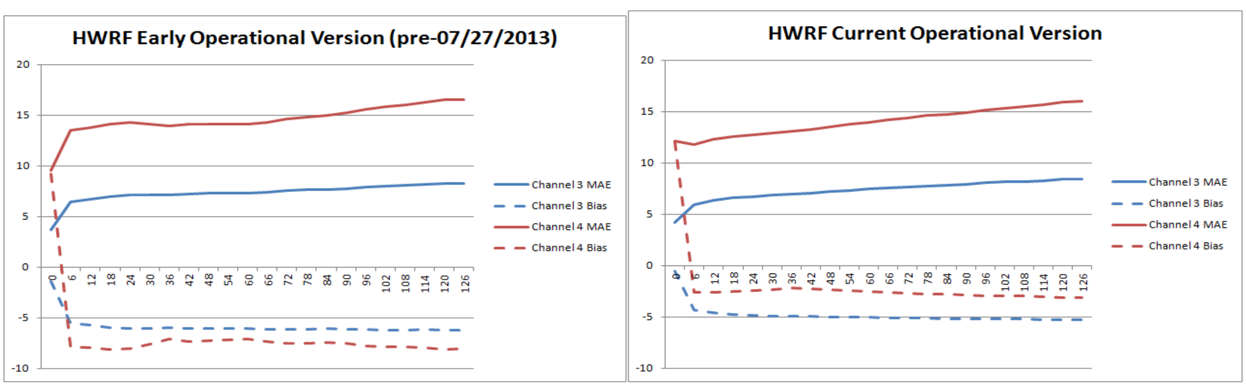


Figure 2. Mean absolute error (solid) and bias (dashed) for the HWRF synthetic Channel 3 (WV, blue) and Channel 4 (IR, red). The left panel highlights the period of the 2013 Atlantic hurricane season before the current operational version was implemented; the right panel shows the operational HWRF for the period from August 2013 through the end of the Atlantic hurricane season.

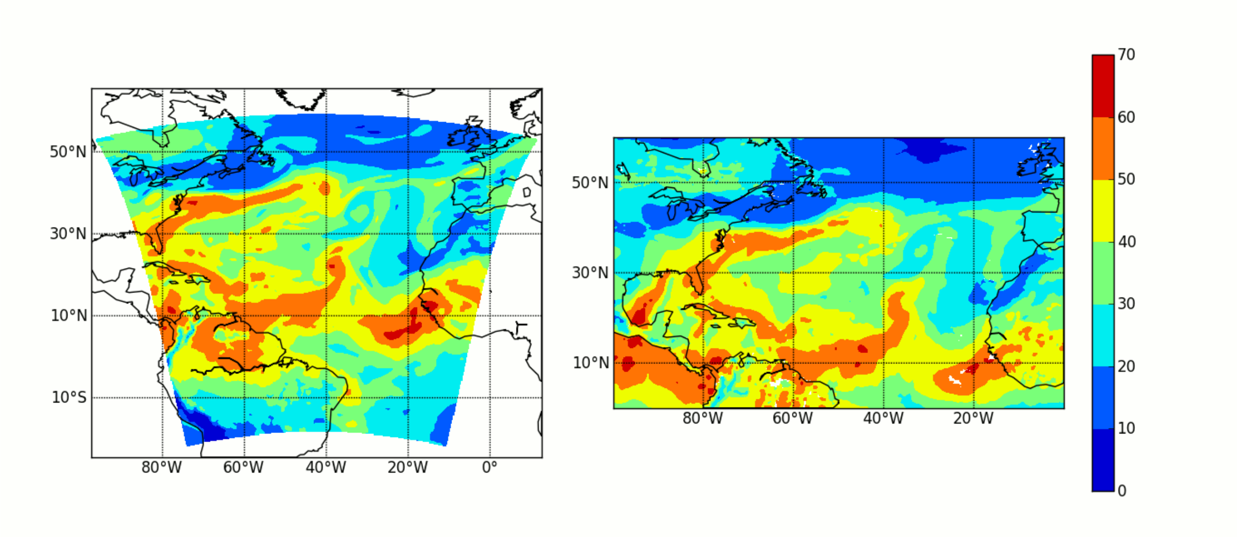


Figure 3. HWRF total-column precipitable water (left) and blended satellite total precipitable water (right) for Tropical Storm Erin, 12 UTC 18 August 2013.

Project Publications/Presentations:

<u>Refereed:</u>

DeMaria, M., C.R. Sampson, J.A. Knaff, and K.D. Musgrave, 2013: Is tropical cyclone intensity guidance improving? *Bull. Amer. Meteor. Soc.*, accepted.

Knaff, J.A., M. DeMaria, C.R. Sampson, J.E. Peak, J. Cummings and W.H. Schubert, 2013: Upper oceanic energy response to tropical cyclone passage. *J. Climate*, **26**, 2631-2650.

Knapp, K.R., J.A. Knaff, C. Sampson, G. Riggio, A.D. Schnapp, 2013: A pressure-based analysis of the historical western North Pacific tropical cyclone intensity record, *Mon. Wea. Rev.*, **141**, 2611-2631.

<u>Presentations:</u>

DeMaria, M., J. Knaff, K. Musgrave, A. Schumacher, R. DeMaria, L. Grasso, S. Longmore, and C. Slocum, 2013: 2013 NESDIS HFIP activities. *HFIP conference call*, October 23.

DeMaria, M., K. Musgrave, A. Schumacher, L. Grasso, J. Knaff, and D. Lindsey, 2013: NESDIS/CIRA Diagnostics - 2013. *2013 HFIP Diagnostics Workshop*, November 22, College Park, MD.

COMPETITIVE PROJECT TITLE: Upgrades to the Operational Monte Carlo Wind Speed Probability Program (NA13OAR4590190)

PRINCIPAL INVESTIGATORS: Andrea Schumacher

RESEARCH TEAM: Robert DeMaria, Dave Watson

NOAA TECHNICAL CONTACT: Jiann-Gwo Jiing (NOAA/NHC)

NOAA RESEARCH TEAM: Mark DeMaria (NOAA/NESDIS/STAR)

PROJECT OBJECTIVES:

This project seeks to complete a number of upgrades to the current Monte Carlo wind speed probability model (hereafter MC model), many of which are based on NHC feedback over the past few hurricane seasons. Specific plans to improve the MC model include replacing the linear forecast interpolation scheme with a more precise spline fit scheme, applying a bias correction to the model track error statistics to provide consistency between NHC's uncertainty products, and applying a bias correction to the radii-CLIPER used by the MC model to improve the accuracy of the wind speed probabilities for exceptionally small or large (e.g. 2012's Hurricane Sandy) tropical cyclones. Additionally, several additions to the MC model will be completed such as estimates of the arrival and departure times of 34/50/64 kt winds, an integrated Goerss Predicted Consensus Error (GPCE) parameter, and wind speed probabilities beyond 5 days (proposed to 7 days). Finally, the error statistic generation code will be consolidated into a single streamlined version that will reduce the time needed to update the MC model statistics each year.

Tropical Cyclone (TC) forecasts affect risk mitigation activities of industry, public and governmental sectors and therefore supports directly NOAA's Weather and Water mission goals.

PROJECT ACCOMPLISHMENTS:

1--Replaced linear forecast interpolation scheme with spline fit scheme

The starting point for the MC model is the NHC official track and intensity forecasts, which are available at 12 h intervals to 48 h and 24 h intervals from 48 to 120 h. A linear interpolation is used to obtain track and intensity between the forecast times. Verification statistics (DeMaria et al. 2009) show that the errors are larger for the times between the NHC forecast points, and an eastward bias is introduced for re-curving cyclones. This is especially problematic for storms close to the U.S. east coast, but just offshore, because it leads to an underestimate of the probabilities at the coast.

To correct this problem, the linear interpolation scheme was replaced with a spline fit. Figure 1 shows the Brier scores and threat scores (averaged over all probability thresholds) calculated for all 2013 Atlantic tropical cyclones. Overall, replacing the linear time interpolation scheme with a spline fit has very little impact on the basin verification statistics. The impact this fix has on wind speed probabilities can best be seen by examining the special case of a tropical cyclone forecast to recurve. Figure 2 shows the difference between the forecast track and corresponding wind speed probabilities using linear interpolation (left) and the spline fit (right) for Hurricane Earl when it was forecast to recurve along the U.S. east coast. The spline fit methodology corrects the eastward bias in this case, providing a more realistic interpolated track forecast after 48 hours. The corresponding 34-kt wind speed probabilities along the North Carolina coast increase from 50-60% with the linear interpolation scheme to 70-80%.

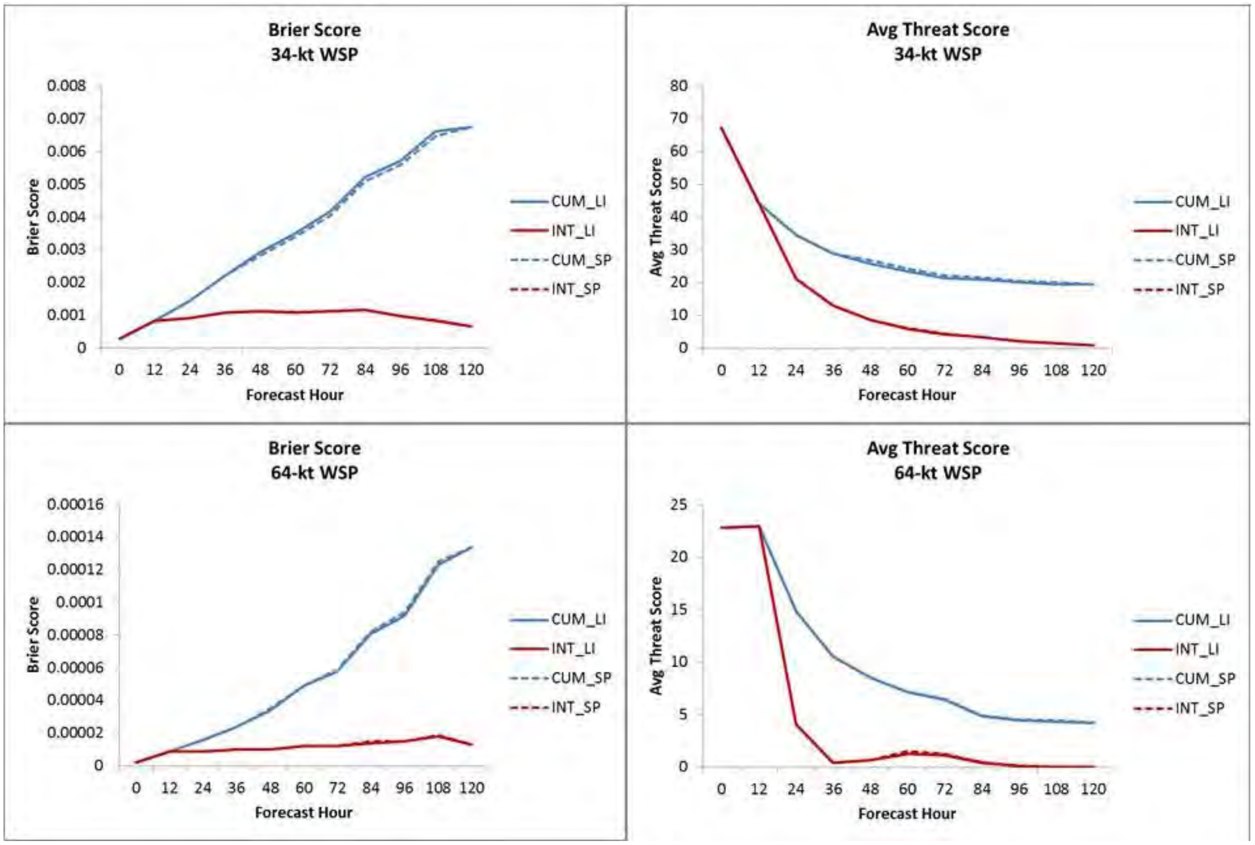


Figure 1. Brier scores for the 34-kt (left, top) and 64-kt (left, bottom) wind speed probabilities and threat scores average over all probabilities thresholds for the 34-kt (right, top) and 64-kt (right, bottom) wind speed probabilities for 2008-2012 Atlantic tropical cyclones. Verification metrics for cumulative (integrated) wind speed probabilities are shown in blue (red). Solid lines represent values using the linear interpolation scheme and dashed lines represent values using a spline fit scheme.

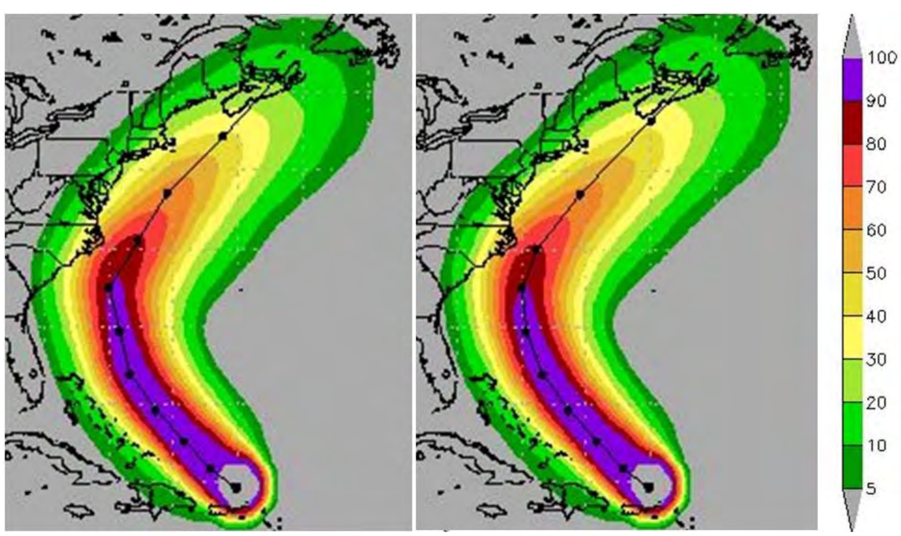


Figure 2. 34-kt wind speed probabilities using linear interpolation (left) and spline fit (right) for Hurricane Earl on 31 Aug 2010 0000 UTC.

2--Development of integrated GPCE parameter:

It has been shown that past NHC track forecast errors can be separated into terciles based on their corresponding GPCE value, and that track forecast errors in the low (high) terciles tend to correspond to less (more) spread in forecast errors (DeMaria et al. 2013). This finding motivated the use of a GPCE parameter in the MC model. At present, this GPCE parameter determines the track error statistics used by the MC model to estimate wind speed probabilities, but the GPCE categories (low, medium, high) are not output directly.

It was proposed that a time integrated GPCE parameter be developed from the GPCE information used by the MC model. This information could be relayed to users through the NHC discussion product, and could potentially be used to modify the cone of uncertainty. A preliminary time integrated GPCE parameter has been developed using the following methodology; 1) GPCE values at each forecast time from 12h to 120h is normalized by their standard deviation and 2) 12h to 120h normalized GPCE values are averaged. This methodology provides a single GPCE parameter for each 120h track forecast that characterizes the overall uncertainty of that forecast. The same methodology was applied to NHC track forecast errors from 2008-2012. The time integrated forecast errors corresponding to the three time integrated GPCE terciles are shown in Figure 3. Similar to the findings for GPCE values at each forecast time, the low (high) integrated GPCE tercile tends to correspond to less (more) spread in integrated forecast errors. Testing continues to determine the optimal weighting scheme for providing the most separation in integrated forecast errors.

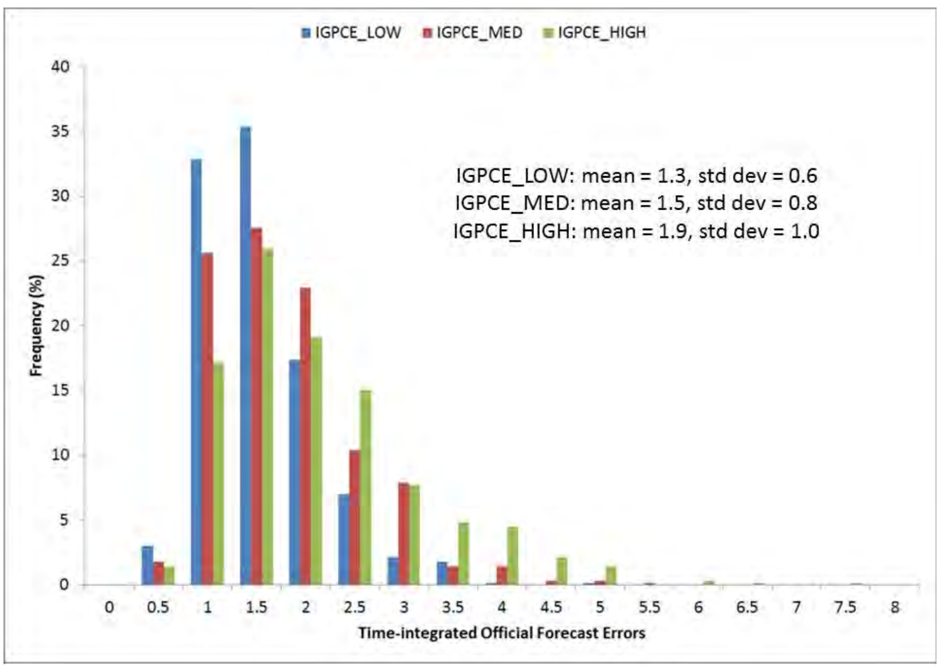


Figure 3. Integrated forecast error distributions corresponding to the low, medium, and high integrated GPCE parameter terciles for all 2008-2012 NHC Atlantic tropical cyclone forecasts.

3--Work begun on bias corrections:

Two bias correction tasks were proposed in Year 1. The first task involves bias-correcting the model track error statistics to provide consistency between NHC uncertainty products. Work has begun on standardizing the MC model error statistics for 2008-2012 with those used to create the NHC cone of uncertainty. Once this is complete, a correction will be applied to account for the bias introduced by the serial correlation of errors. The second task involves using NHC forecast 34, 50, and 64-kt wind radii forecasts to bias correct the radii-CLIPER model to reduce wind speed probability biases in tropical cyclones that are significantly smaller or larger than climatology. NHC radii forecast data has been collected and preliminary work has begun to determine the best methodology for using radii forecasts to bias correct radii CLIPER. Both of these tasks are expected to be completed in the next 2-3 months.

The following is the report previously submitted to the Technical Sponsor.

NOAA Joint Hurricane Testbed (JHT)
Mid-Year Project Progress Report, Year 1

Date:	March 3, 2014
Reporting Period:	September 3, 2013 – February 28, 2014
Project Title:	Upgrades to the Operational Monte Carlo Wind Speed Probability Program
Principal Investigator:	Andrea Schumacher, CIRA / Colorado State University
Award Period:	September 3, 2013 – August 31, 2015

1. Long-term Objectives and Specific Plans to Achieve Them:

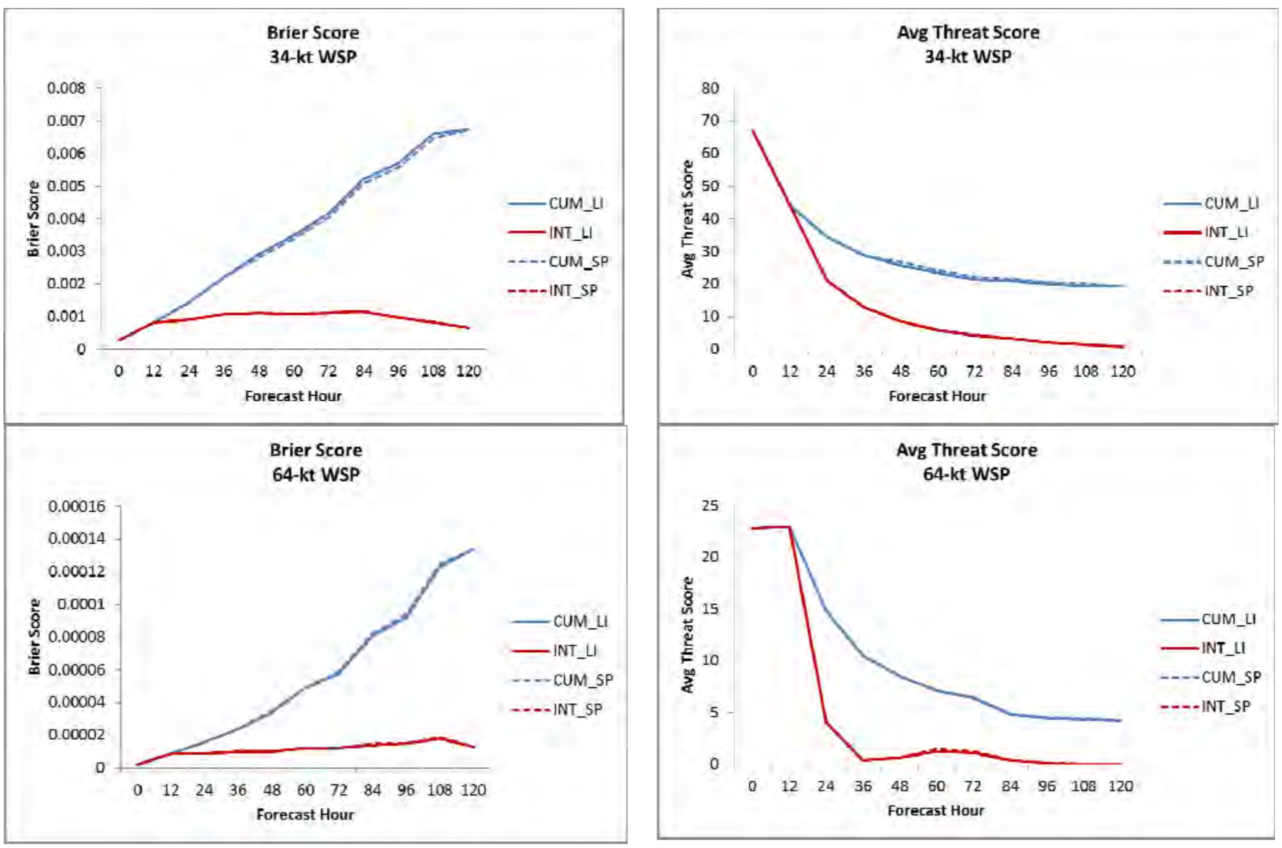
This project seeks to complete a number of upgrades to the current Monte Carlo wind speed probability model (hereafter MC model), many of which are based on NHC feedback over the past few hurricane seasons. Specific plans to improve the MC model include replacing the linear forecast interpolation scheme with a more precise spline fit scheme, applying a bias correction to the model track error statistics to provide consistency between NHC's uncertainty products, and applying a bias correction to the radii-CLIPER used by the MC model to improve the accuracy of the wind speed probabilities for exceptionally small or large (e.g. 2012's Hurricane Sandy) tropical cyclones. Additionally, several additions to the MC model will be completed such as estimates of the arrival and departure times of 34/50/64 kt winds, an integrated GPCE parameter, and wind speed probabilities beyond 5 days (proposed to 7 days). Finally, the error statistic generation code will be consolidated into a single streamlined version that will reduce the time needed to update the MC model statistics each year.

2. Mid-year Accomplishments:

a. Replaced linear forecast interpolation scheme with spline fit scheme

The starting point for the MC model is the NHC official track and intensity forecasts, which are available at 12 h intervals to 48 h and 24 h intervals from 48 to 120 h. A linear interpolation is used to obtain track and intensity between the forecast times. Verification statistics (DeMaria et al. 2009) show that the errors are larger for the times between the NHC forecast points, and an eastward bias is introduced for re-curving cyclones. This is especially problematic for storms close to the U.S. east coast, but just offshore, because it leads to an underestimate of the probabilities at the coast.

To correct this problem, the linear interpolation scheme was replaced with a spline fit. Figure 1 shows the Brier scores and threat scores (averaged over all probability thresholds) calculated for all 2013 Atlantic tropical cyclones. Overall, replacing the linear time interpolation scheme with a spline fit has very little impact on the basin verification statistics. The impact this fix has on wind speed probabilities can best be seen by examining the case of a tropical cyclone forecast to recurve. Figure 2 shows the difference between the forecast track and corresponding wind speed probabilities using linear interpolation (left) and the spline fit (right) for Hurricane Earl when it was forecast to recurve along the U.S. east coast. The spline fit methodology appears to be correcting the eastward bias in this case, providing a more realistic interpolated track forecast after 48 hours. The corresponding 34-kt wind speed probabilities along the North Carolina coast increase from 50-60% with the linear interpolation scheme to 70-80%.



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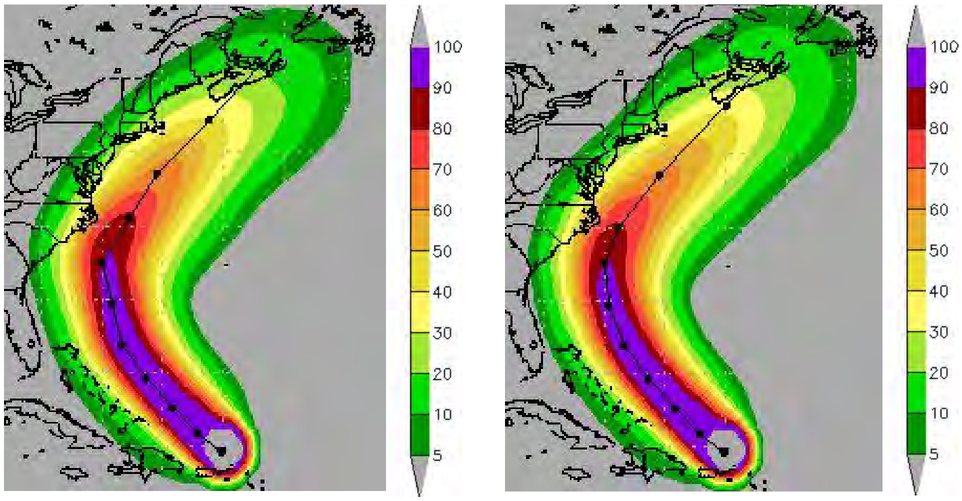

Figure 2. 34-kt wind speed probabilities using linear interpolation (left) and spline fit (right) for Hurricane Earl on 31 Aug 2010 0000 UTC.

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It was proposed that a time integrated GPCE parameter be developed from the GPCE information used by the MC model. This information could be relayed to users through the NHC discussion product, and could potentially be used to modify the cone of uncertainty. A preliminary time integrated GPCE parameter has been developed using the following methodology; 1) GPCE values at each forecast time from 12h to 120h is normalized by their standard deviation and 2) 12h to 120h normalized GPCE values are averaged. This methodology provides a single GPCE parameter for each 120h track forecast that characterizes the overall uncertainty of that forecast. The same methodology was applied to NHC track forecast errors from 2008-2012. The time integrated forecast errors corresponding to the three time integrated GPCE terciles are shown in Figure 3. Similar to the findings for GPCE values at each forecast time, the low (high) integrated GPCE tercile tends to correspond to less (more) spread in integrated forecast errors. Testing continues to determine the optimal weighting scheme for providing the most separation in integrated forecast errors.

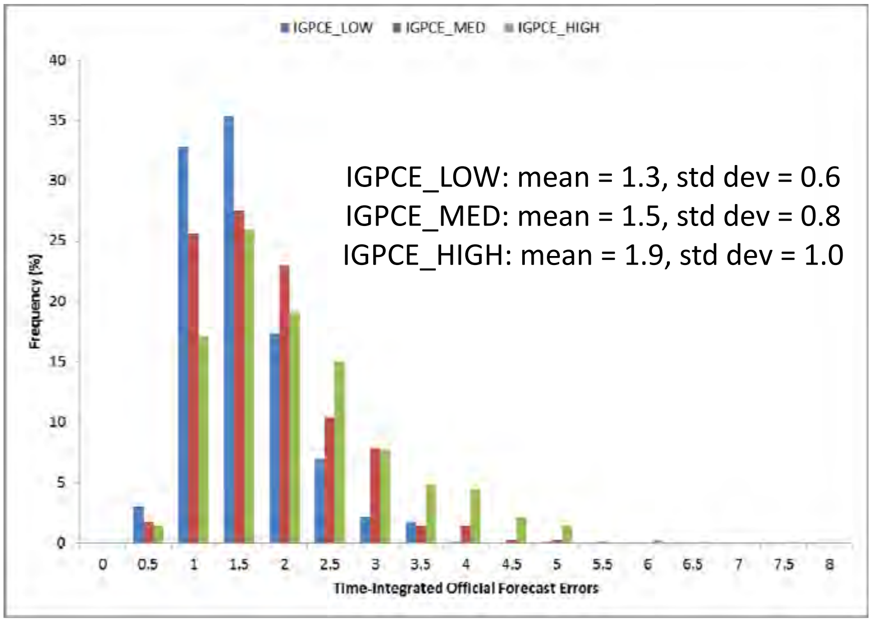

Figure 3. Integrated forecast error distributions corresponding to the low, medium, and high integrated GPCE parameter terciles for all 2008-2012 NHC Atlantic tropical cyclone forecasts.

c. Work begun on bias corrections

Two bias correction tasks were proposed in Year 1. The first task involves bias-correcting the model track error statistics to provide consistency between NHC uncertainty products. Work has begun on standardizing the MC model error statistics for 2008-2012 with those used to create the NHC cone of uncertainty. Once this is complete, a correction will be applied to account for the bias introduced by the serial correlation of errors. The second task involves using NHC forecast 34, 50, and 64-kt wind radii forecasts to bias correct the radii-CLIPER model to reduce wind speed probability biases in tropical cyclones that are significantly smaller or larger than climatology. NHC radii forecast data has been collected and preliminary work has begun to determine the best methodology for using radii forecasts to bias correct radii CLIPER. Both of these tasks are expected to be completed in the next 2-3 months.

3. Current & Future Year 1 Efforts:

Apr 2014 -	Complete development of bias correction for radii-CLIPER
May 2014 -	Complete development of bias-correction for MC model error statistics so that 67% cones are consistent
May 2014 -	Prepare final updated version of MC code for parallel runs during the 2014 season (to include new interpolation scheme, wind speed probabilities out to 7 days, and GPCE parameter output).
Jun 2014 -	Coordinate with JHT and TSB staff to implement experimental MC model code on IBM or JHT workstation or implement code at CIRA.

COMPETITIVE PROJECT TITLE: Use of the Ocean-Land-Atmosphere Model (OLAM) with Cloud System-resolving Refined Local Mesh to Study MJO Initiation (NA13OAR4310163)

The following is the report previously submitted to the Technical Sponsor.

Project Title: Use of the Ocean-Land-Atmosphere Model (OLAM) with Cloud System-Resolving Refined Local Mesh to Study MJO Initiation
Project Number: NA13OAR4310163
PIs: Eric D. Maloney and William Cotton (Colorado State University) and Robert Walko (University of Miami)
Report Type: Year 1 Report

Results and Accomplishments
The following sections list the primarily accomplishments for Year 1. We note that we are only 5 months into the project, and so the results thus far are somewhat preliminary. However, these will be discussed in detail to the extent possible.

The Moist Static Energy Budget in NCAR CAM5 Hindcasts during DYNAMO (Hannah and Maloney 2014a)
This paper describes part of our multimodel assessment of DYNAMO hindcast ability as outlined in our NOAA proposal. The Dynamics of the MJO (DYNAMO) field campaign took place in the Indian Ocean during boreal fall and winter of 2011-2012 to collect observations of Madden-Julian Oscillation (MJO) initiation. Hindcast experiments are conducted with an atmospheric general circulation model with varying values of a dilute CAPE entrainment rate parameter for the first two MJO events of DYNAMO from 01 October – 15 December 2011. Higher entrainment rates better reproduce the gross features of MJO precipitation and zonal wind, with MJO hindcast skill up to 20 days (**Figure 1**). Simulations with lower entrainment rapidly diverge from observations such that no coherent MJO convective signal is present after five days, and the model has no MJO predictive skill beyond 12 days.

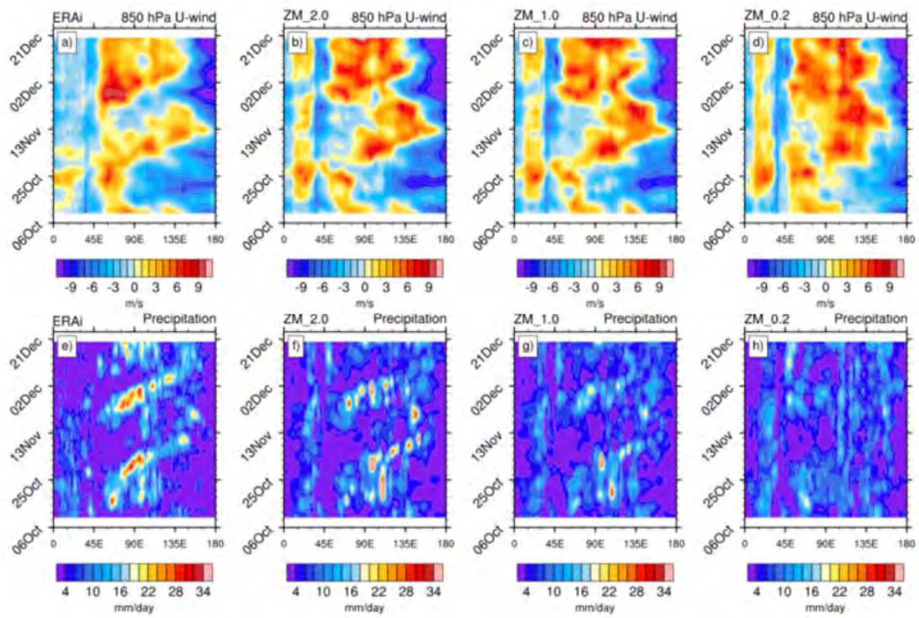

Figure 1. Hovmöller diagram of equatorial 850 hPa wind (a-d) and precipitation (e-h) averaged from 5ºS-5ºN for 05-09 day lead times for ERA-I (left) and high through low entrainment models (left to right).

Analysis of the tropical Indian Ocean column moist static energy (MSE) budget reveals that the simulations with superior MJO performance exhibit positive mean vertical MSE advection, inconsistent with reanalysis that indicates a weak drying tendency on average from vertical advection. All simulations have a weaker MSE tendency due to the net MSE source, and weaker cloud-radiative feedbacks. The gross moist stability (GMS) is used to interpret these MSE budget results in a normalized framework relevant to moisture mode theory. Simulations with larger entrainment rate are characterized by negative effective GMS (**Figure 2c**), indicating a favorable condition to destabilize a moisture mode in which convection and associated divergent circulations have a net moistening effect on the column. However, this is achieved by excessively strong moistening by vertical MSE advection (**Figure 2b**) that compensates for surface flux and cloud radiative feedbacks that are too weak.

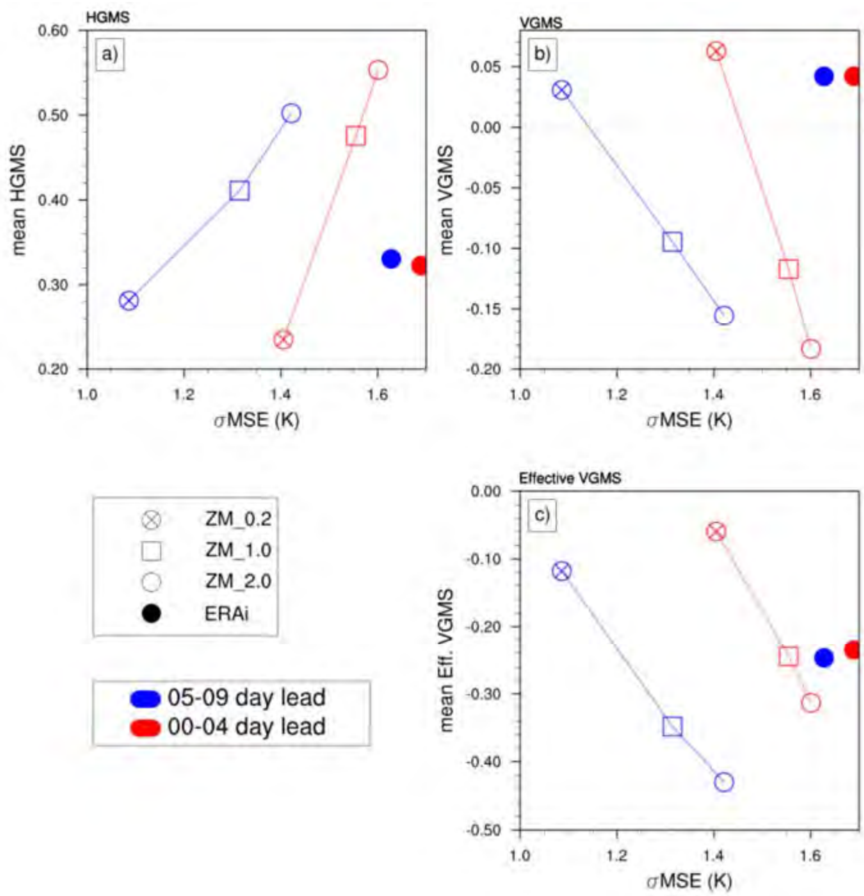

Figure 2. Average horizontal component of GMS (a), vertical component of GMS (b) and effective VGMS (c) plotted against the standard deviation of column MSE, which gives a crude estimate of the MJO variability. Datasets are specified by marker style and lead times are by color. ZM_0.2 is the low entrainment models, and ZM_2.0 is the high entrainment model.

DYNAMO Hindcast Experiments in SP-CAM (Hannah and Maloney 2014b)

In this paper, SP-CAM hindcast simulations of the first two MJO events during the DYNAMO field campaign are characterized and compared to hindcasts with the conventional CAM5 (ZM_1.0) and ERAi reanalysis data. SP-CAM produces a better mean precipitation pattern and a more robust MJO convective signal than ZM_1.0 at both 0-4 and 5-9 day lead times (**Figure 3**). In spite of these results, RMM skill scores suggest that SP-CAM has less skill than ZM_1.0 at reproducing the observed RMM amplitude. Closer inspection shows that a systematic model drift in SP-CAM wind and outgoing longwave radiation heavily influence RMM skill scores. This RMM bias in SP-CAM is most heavily influenced by the drift of 850 hPa zonal wind, but the drift of 200 hPa zonal wind and outgoing longwave radiation fields also have an impact on RMM skill scores. Analysis of the column MSE budget of the equatorial Indian Ocean shows that SP-CAM has stronger cloud-radiative feedbacks than ZM_1.0 at 0-4 day leads, but shares the problem of overly efficient MSE import by vertical advection that was discussed in Hannah and

Maloney (2014a). MSE export by meridional advection in SP-CAM is larger than ERAi and becomes even larger at later lead times, associated with enhanced off-equatorial synoptic eddy activity.

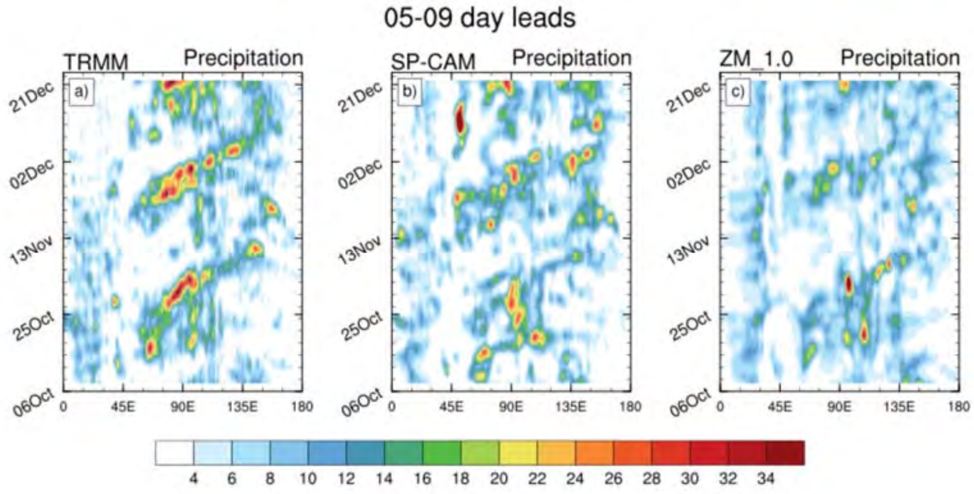

Figure 3. Hovmöller diagram of equatorial precipitation (e-h) averaged from 5°S-5°N for 5-9 day lead times.

The vertical component of gross moist stability (VGMS) describes the export of column MSE due to convection and divergent circulations per unit convective activity. VGMS in SP-CAM is significantly negative, similar to ZM_1.0. Both models strongly disagree with ERAi, which has a weak positive VGMS. This difference is quantifiably attributed to more bottom-heavy omega and diabatic heating profiles in SP-CAM. VGMS can be modified to obtain an effective VGMS, which is thought to be more relevant to the observed MJO, by including the influence of column MSE source terms. Negative effective VGMS implies a positive feedback between the column MSE anomaly and the combined effects of convection, divergent circulations and MSE sources. This positive feedback is necessary for building up column moisture on a large scale, which can destabilize a moisture mode such as the MJO.

Robert Walko Visit to CSU and OLAM tutorial

Co-PI Bob Walko visited CSU in October of 2013 not only to attend a two-day collaborative meeting related to the project, but also to provide an OLAM tutorial to CSU students, staff, and faculty. The visit was extremely productive, and lead to a concrete plan with how to proceed with the OLAM simulations to be conducted as the project proceeds. The initial plan is to provide some baseline assessments of MJO skill based on a low resolution version of the OLAM model, before proceeding with mesh refinements over the Indian Ocean DYNAMO domain.

Highlights of Accomplishments

- We showed the MJO hindcasts during the DYNAMO period could be improved through increasing convective entrainment.
- We showed that with increased entrainment, the NCAR CAM5 appears to produce a good MJO for the wrong reasons, with enhanced vertical advection compensating for too weak of cloud-radiative feedbacks.
- The SP-CAM produces an improved representation of the MJO relative to the NCAR CAM during the DYNAMO period, although the SP-CAM exhibits a poorer MJO skill score based on RMSE since SP-CAM mean state drift projects strongly onto the MJO indices used to assess skill.
- The SP-CAM produces too strong of a simulation of vertical MSE advection relative to ERA-I that helps to destabilize the MJO, associated with too bottom-heavy of a diabatic heating profile.
- Co-PI Bob Walko visited CSU and provided a tutorial on the OLAM model to the department.

Publications From the Project

Hannah, W. M., and E. D. Maloney, 2014a: The Moist Static Energy Budget in NCAR CAM5 Hindcasts during DYNAMO. *J. Adv. Modeling Earth Sys*., accepted pending major revisions.

Hannah, W. M., and E. D. Maloney, 2014b: DYNAMO Hindcast Experiments in SP-CAM. *J. Adv. Modeling Earth Sys*., to be submitted.

PIs Contact Information

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Miami, FL 33149-1031.
Phone: (305) 421-4621

COMPETITIVE PROJECT TITLE: Utility of GOES-R Instruments for Hurricane Data Assimilation and Forecasting (NA10NES4400012)

The following is the report previously submitted to the Technical Sponsor.

Project Progress Report

Award Number: NA10NES4400012

Program Officer:	Heather Hay, 301-763-8282, heather.hay@noaa.gov
Program Office:	National Environmental Satellite Data and Information Service Program Office (NESDISPO)
Award Period:	06/01/2010 – 05/31/2014
Project Title:	UTILITY OF GOES-R INSTRUMENTS FOR HURRICANE DATA ASSIMILATION AND FORECASTING
Recipient Name:	Colorado State University
PI:	Milija Zupanski
Reporting Period:	12/01/2012 – 11/30/2013

Progress Report

1. Personnel and Collaboration

This is a collaborative research with PI Jun Li from CIMSS, University of Wisconsin, Madison. We also collaborate with Min-Jeong Kim from CIRA/NCEP/JCSDA (current affiliation NASA/GMAO) on including all-sky radiances in assimilation. John Knaff of NESDIS/STAR/RAMMB provided MSG SEVIRI data and will continue to contribute for lightning data and hurricane analysis. On the CIRA side, this research includes support of two research scientists/postdocs, Dr. Man Zhang (current affiliation NOAA/ESRL/GSD) and Dr. Karina Apodaca.

2. Summary of Accomplishments and Findings

This report covers the second half of the third year and the beginning of the fourth year of the project. In Year 2 we have combined all components into a single system and conduct benchmark experiments. In Year 3 we assimilated lightning observations and prepared for simultaneous assimilation of lightning and IR cloudy radiances. Since we obtained a one-year no-cost extension, we decided to spend some time on upgrading the HWRF modeling system and the lightning observation operator. Major tasks and accomplishments covered in this report are:

1) Include lightning data in the MLEF-HWRF system.

Status: Completed.

This task has been completed and the results are submitted for publication in Quarterly Journal of Royal Meteorological Society (Apodaca et al. 2014). In summary, we extend the utility of lightning data assimilation from cloud-resolving scales to mesoscales and synoptic scales at a coarse resolution in which convection cannot be explicitly resolved. By taking this approach we examine the impact of lightning observations on storm environment with potential applications to general multivariate/multisensory data assimilation, reanalysis and climate. Our results suggest that lightning can be beneficial even without explicit convection, due to correlations between forecast errors of model variables, generally represented in the ensemble forecast error covariance. Since lightning observations are fundamentally associated with a storm, characterized by convection and vertical updraft, it is also associated with the storm environment and the related changes in wind field, temperature, moisture, and pressure. One can think of the total information of a single lightning observation to have two major contributions: (a) from the cloud-resolving scales, that typically include cloud microphysics and convection, and (b) from the mesoscales that characterize storm environment. In coarse resolution data assimilation, without explicit cloud microphysics, lightning data assimilation effectively utilizes the mesoscale component of lightning observations. Our results suggest that the mesoscale component (b) is non-negligible and can also have a positive impact on the forecast of lightning.

As a brief review of the impact of lightning data assimilation we include Fig.1, which shows the data assimilation increments of wind and absolute vorticity. The figure suggests that additional vorticity has been advected into the region of high CAPE, and presumably strengthens the convection.

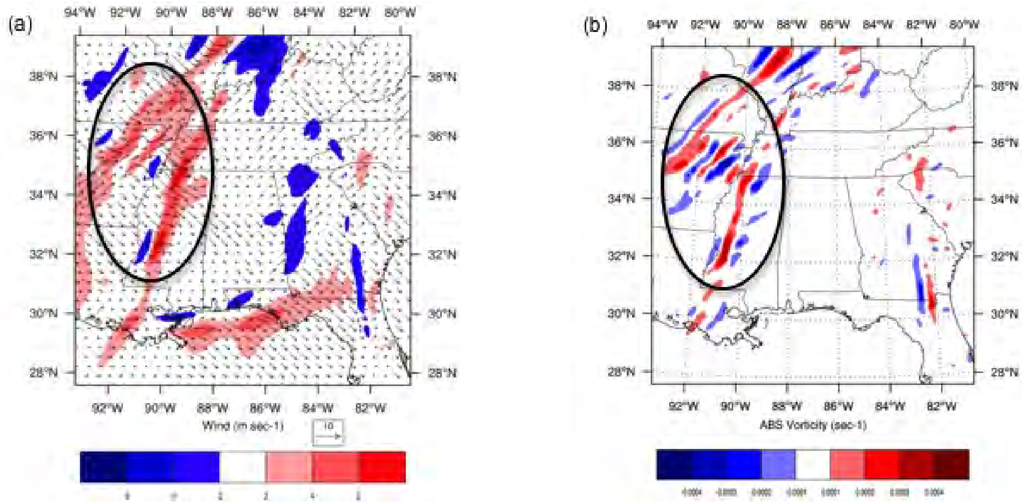

Figure 1. Analysis increments at 850 hPa of (a) winds and (b) absolute vorticity at 0000 UTC 28 April 2011. Regions of positive increments are found in the upper left-hand side in both plots indicated by the ellipses. Winds are being advected to the region of strong CAPE seen in the ellipse of Figure 9(a).

2) Include advanced IR sounding product in cloudy region, evaluate the impact of full spatial resolution cloudy soundings.

Status: Completed.

We have presented the related results in the previous year report. This component of the project has been performed in collaboration with Dr. Jun Li of CIMSS, Univ. Wisconsin-Madison. Since they did not ask for a project extension, this item has been closed.

However, we have extended this task into assimilation of all-sky IR radiances in TC core area, instead of using an IR sounding product. Note that this is more difficult due to using all-sky radiative transfer equation and the implied increased nonlinearity of observation operator. In Fig.2 we show the impact of assimilating all-sky SEVIRI IR10.8 radiances on cloud water in control data assimilation experiment (clear-sky radiances only) and the MLEF experiment (all-sky radiance assimilation) for hurricane Fred (2009). The results indicate that all-sky IR radiance assimilation can capture details of cloud target in TC analysis and consequently increase the skill of quantitative cloud forecast.

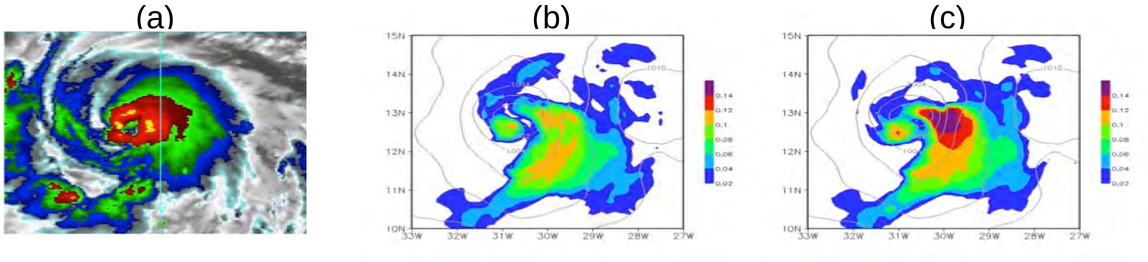

Figure 2. Assimilation of MSG SEVIRI IR10.8 radiances for hurricane Fred (2009) on 0200 UTC 9 Sep 2009: (a) verification, (b) clear-sky IR radiance assimilation (CTL), and (c) all-sky IR radiance assimilation (ANL).

3) Conduct a thorough evaluation of the value-added impact of lightning data in TC data assimilation applications.

Status: Ongoing.

This task has been partially addressed in the task (1) above. However, due to the approved one-year extension of the project, we decided to upgrade the HWRF modeling system and the lightning observation operator before proceeding with experiments. Currently interfaced HWRF model is the 2011 operational version, with only two domains. By upgrading the system with the current operational version we will have an improved resolution and also have results that are more relevant for NOAA operations. Similarly, the currently interfaced lightning observation operator is based on vertical updraft only, without taking into account cloud properties that are likely important. Therefore, we upgraded the lightning observation operator based on the McCaul et al (2009) algorithm commonly used in GOES-R GLM development. With this improvement, lightning now depends directly on vertical updraft as before, but also on cloud properties such as cloud ice and vertical graupel flux. The upgrades listed above will be also beneficial to the new NOAA-funded project at CIRA that explores impact of moisture and precipitation observations on hurricane structure and intensity.

References:
McCaul, E.W., S. J. Goodman, K. M. LaCasse, and D. J. Cecil, 2009: Forecasting lightning threat using cloud resolving model simulations. *Wea. Forecasting*, **24**, 709–729.

4) Present results at a conferences/workshops and publish results in peer-reviewed journal.

Status: Completed.

Results are resented in three peer-reviewed papers at five conferences/workshops: Apodaca et al. (2013, 2014), Zhang et al. (2013a, b), Zupanski et al. (2013), and Zupanski (2013a, b, c). For details, please see the publication list at the end of this report.

5) Prepare technical report documenting the utility of GOES-R data.

Status: Ongoing.

We have begun preparing a technical document on the utility of GOES-R data. However, the complete final report will be available only after the end of the project. e.g., after all results are compiled and evaluated.

3. Peer-reviewed publications

Apodaca, K., M. Zupanski, M. DeMaria, J. A. Knaff, and L. D. Grasso, 2014: Hybrid variational-ensemble assimilation of lightning observations in a mesoscale model. *Q. J. Roy. Meteorol. Soc*., submitted.

Zhang, M., M. Zupanski, M. Kim, and J. Knaff, 2013a: Assimilating AMSU-A Radiances in TC Core Area with NOAA Operational HWRF (2011) and a Hybrid Data Assimilation System: Danielle (2010). *Mon. Wea. Rev*., **141**, 3889-3907.

Zupanski M., 2013a: All-sky satellite radiance data assimilation: Methodology and Challenges. *Data Assimilation for Atmospheric, Oceanic, and Hydrologic Applications* (*Vol. II*). S.-K. Park and L. Xu, Eds, Springer Heidelberg New York Dordrecht London, 465-488.

4. Conferences/Workshops:

Apodaca, K., M. Zupanski, M. DeMaria, J. A. Knaff, and L. D. Grasso, 2013: Assessing the impact of lightning observations in a hybrid data assimilation system. *The Sixth WMO Symposium on Data Assimilation*, October 7-11, 2013, College Park, MD.

Zhang, M., M. Zupanski, and J. A. Knaff, 2013b: Direct assimilation of al-sky SEVIRI IR10.8 radiances in TC core area using an ensemble-based data assimilation method. *The Sixth WMO Symposium on Data Assimilation*, October 7-11, 2013, College Park, MD.

Zupanski, M., K. Apodaca, and M. Zhang, 2013: Utility of GOES-R Geostationary Lightning Mapper (GLM) using hybrid variational-ensemble data assimilation in regional applications. *Warn-on-Forecast and High-Impact Weather Workshop*, Feb 6-7, 2013, National Weather Center, Norman, OK.

Zupanski, M., 2013b: Extracting maximum information from GOES-R ABI and GLM instruments in regional data assimilation applications to high-impact weather. *Joint Centers for Satellite Data Assimilation Seminar*, June 4, 2013, NCWCP, College Park, MD.

Zupanski, M., 2013c: Utility of GOES-R ABI and GLM instruments in regional data assimilation for high-impact weather. *JCSDA Science Workshop on Satellite Data Assimilation*, June 5-7, 2013, NCWCP, College Park, MD.