Annual Report 2008-2009

CIRA

Cooperative Institute for Research in the Atmosphere

Colorado State University

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CIRA ANNUAL REPORT FY 08/09

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE

CIRA ADVISORY BOARD

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INTRODUCTION

This report describes research funded in collaboration with NOAA's Cooperative Agreement with Colorado State University for the Cooperative Institute for Research in the Atmosphere (CIRA) for the period July 1, 2008 through June 30, 2009.

In addition, we also included non-NOAA-funded research (i.e., DoD-funded Geosciences, NASA-funded CloudSat and National Park Service Air Quality Research Division activities) to allow the reader a more complete understanding of CIRA's research context. All of these research activities are synergistic to meet the objectives of the NOAA/CSU collaborations. The research infrastructure and intellectual talent are provided and used by both Federal and University sides of the funded activities.

We are pleased to report on a very productive year of research partnership with NOAA.

For further information on CIRA, please contact:

Our website: http://www.cira.colostate.edu/

Or

Professor Graeme L. Stephens, Director

stephens@cira.colostate.edu

CIRA MISSION

The mission of the Institute is to conduct research in the atmospheric sciences of mutual benefit to NOAA, the University, the State and the Nation. The Institute strives to provide a center for cooperation in specified research program areas by scientists, staff and students, and to enhance the training of atmospheric scientists. Special effort is directed toward the transition of research results into practical applications in the weather and climate areas. In addition, multidisciplinary research programs are emphasized, and all university and NOAA organizational elements are invited to participate in CIRA's atmospheric research programs.

The Institute's research is concentrated in several theme areas that include global and regional climate, local and mesoscale weather forecasting and evaluation, applied cloud physics, applications of satellite observations, air quality and visibility, and societal and economic impacts, along with cross-cutting research areas of numerical modeling and education, training and outreach. In addition to CIRA's relationship with NOAA, the National Park Service also has an ongoing cooperation in air quality and visibility research that involves scientists from numerous disciplines; and the Center for Geosciences/Atmospheric Research based at CIRA is a long-term program sponsored by the Department of Defense.

CIRA VISION

CIRA's Vision is to improve interdisciplinary research in the atmospheric sciences by entraining skills beyond the meteorological disciplines, exploiting cutting-edge advances in engineering and computer science, facilitating transitional activity between pure and applied research, and assisting the Nation through the application of our research.

The Cooperative Institute for Research in the Atmosphere

The Cooperative Institute for Research in the Atmosphere (CIRA) was established in 1980 at Colorado State University. CIRA serves as a mechanism to promote synergisms between University scientists and those in NOAA. The Institute facilitates collaborative research between NOAA Research, NOAA Satellites and Information Service, National Weather Service, as well as other federal agencies like NASA, the National Park Service, the U.S. Forest Service, and the Department of Defense.

The Institute's research is concentrated in six theme areas and two cross-cutting research areas: (1) Global and Regional Climate – Perform remote sensing in a continuation of ongoing climate monitoring projects with NOAA and study large-scale circulations and tropical air-ocean interactions; (2) Local and Mesoscale Weather Forecasting and Evaluation – Perform numerical simulation of mesoscale phenomena, develop and improve tropical cyclone diagnostic and forecast algorithms, etc; (3) Applied Cloud Physics – Study multi-phase cloud morphology, the development of deep convective clouds, ice nucleation materials, and aerosol and cloud interactions; (4) Applications of Satellite Observations – Develop and determine uses for satellite data sets and new climate and weather products based on combinations of satellite and non-satellite data; (5) Air Quality and Visibility – Investigate new technologies and approaches to measure and monitor atmospheric parameters that contribute to air quality and visibility and forecast air quality and other regional environmental problems requiring coupled models; (6) Societal and Economic Impacts - Document and better understand the impacts, uses, and values of NOAA products and services for the reduction of human impacts of natural disasters and for the economic benefit of the Nation; (7) Numerical Modeling – Identify processes that are important for the initiation of convection that leads to severe weather and to better understand the interactions of storms with their environments; and (8) Education, Training, and Outreach – Continue to instruct international collaborators in the use of operational forecast techniques to enhance and expand web- and geo browser-based visualization tools for classroom activities in support of the internationally-successful Global Learning and Observations to Benefit the Environment (GLOBE) program and to develop products that promote the understanding of atmospheric and related weather impacts on society.

Annually, CIRA scientists publish over 200 scientific publications, of which 30% appear in peer-reviewed publications. Some of the more important research being performed at CIRA is in support of NESDIS' new satellite programs including both GOES-R and NPOESS. These two multi-billion dollar weather satellite programs will support weather forecasting for the next 2-3 decades. They represent vastly improved sensors and have higher-frequency data collection. CIRA research is building prototype products, based on the new sensor technology, and determining how to best exploit these data even before the sensors are launched.

EDUCATION, TRAINING AND OUTREACH ACTIVITIES

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."

Training Module Created for Blended Total Precipitable Water Products

CIRA experimental blended total precipitable water (TPW) products from AMSU/SSM/I, GPS and GOES sounder continue to receive accolades from forecasters for predicting heavy precipitation events. The operational blended TPW monitoring website, http://www.osdpd.noaa.gov/bTPW/, presents animations of these products and products used routinely by a growing number of forecasters and even forecasters in other nations. An example is shown in Figure 1. John Forsythe, Stan Kidder and Andy Jones of CIRA, Sheldon Kusselson of NESDIS, Brian Motta and Ross Van Til of NWS and Kevin Fuell of the NASA Short-term Research and Prediction (SPoRT) center in Huntsville, AL prepared a training module on these products. In March of 2009, the blended TPW products were declared operational and are now being distributed nationwide via the NWS AWIPS system.

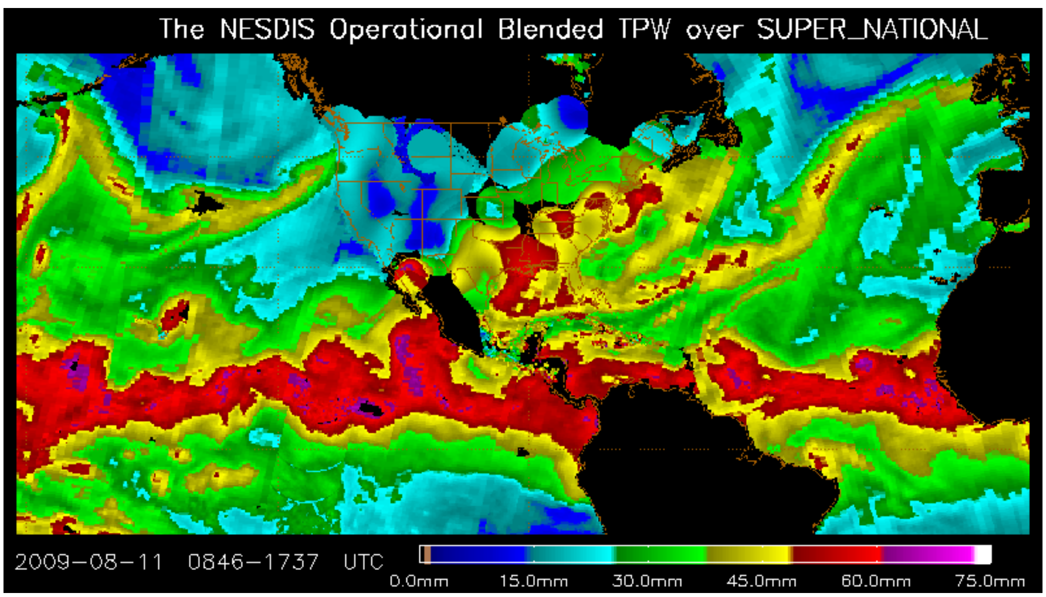


Figure 1. Example of the Now-operational Blended Total Precipitable Water Product from the NESDIS Web Site.

CIRA Personnel Visit India for CloudSat Education Network

The CloudSat Education Network (CEN) http://cloudsat.atmos.colostate.edu/education consists of students and teachers in 11 countries around the world. These countries are: Australia, Cameroon, Canada, Croatia, Dominican Republic, Estonia, Germany, India, New Zealand, Thailand, and United States. Schools and students participate in CEN by making cloud and weather observations at their school location on the date and time when CloudSat will be flying overhead and report this data to CEN through a unique login ID that identifies their geographic location.

The schools that participate in CEN are also schools that are involved with the GLOBE Program www.globe.gov . There are eight schools in Punjab, India that are actively involved with GLOBE / CEN since 2005(http://www.globe.gov/star/India_CloudSat?lang=de). Teachers at these schools have been trained in conducting these activities by Nan McClurg and the students from these schools have been consistently reporting ground observation data and have been communicating with Matt Rogers regarding the scientific validity and value of their data.

In April 2009, a team of CloudSat (CIRA / JPL) personnel consisting of Matt Rogers, Nan McClurg, and West Vane traveled to India to visit with the CEN teachers and students and to present the outcome of their data reporting (Figure 2). This team also accompanied students and teachers from five of the eight CEN schools to an Earth Day Youth Conference on Climate Change held at the Indian National Science Academy in New Delhi, India. The CEN student presentations at this conference were outstanding and the teachers accompanying these students as their mentors credited their leadership skills knowledge to being involved in CloudSat Education Network.

During the school visits, Matt Rogers gave several presentations on the CloudSat, the objectives of its mission, and the value of student collected data for research. The students were very impressed to have a CSU/CloudSat scientist at their school and were very pleased to have this opportunity to be able to personally interact with a young scientist like Matt Rogers. Each CEN school provided an opportunity for all students to participate in a dialogue with Matt through Q&A sessions at their classroom visits. West Vane was able to create a video of this successful model of education outreach, to be used by JPL. He was also able to interview some of the students and teachers to obtain feedback on the CEN activities and its relevance in their classroom curriculum.

In between the CEN school visits and the Youth Conference, Nan McClurg and Matt Rogers also attended a meeting of GLOBE country coordinators at their Asia-Pacific Regional meeting in Agra. In all, Matt gave ten separate talks between the schools and the various meetings and conferences, and was never anything less than amazed by the dedication and brilliance of the CEN students in India. The CEN outreach team from CIRA received great help and support from Mrs. Ravleen Singh and Dr. Anand Gupta of the Punjab State Council for Science and Technology, and owes much of the success of CEN in India to their tireless efforts.

Figure 2. Matt Rogers and Nan MClurg on Their Visit to India for the CloudSat Education Network.

Windsor Middle Schoolers Visit CIRA Months After Devastating Tornado

A group of 55 middle school teachers and students from Windsor, Colorado middle schools visited CIRA on September 30th to learn about atmospheric science. The CloudSat and GLOBE (Global Learning and Observations to Benefit the Environment) projects were discussed and prompted some great questions from the students. CIRA Deputy Director Steve Miller presented a video, satellite and radar analysis of the tornado which tore through Windsor on May 22, 2008. All of the students were touched by the tornado and their visit to CIRA gave them an understanding of how severe weather is monitored and forecast for public safety.

Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Has Observers in 46 States

The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) is headed up by the Colorado Climate Center at Colorado State University. CoCoRaHS is a large and growing collection of volunteers of all ages who help measure and report rain, hail and snow from their own homes (Figure 3). Data gathered by volunteers are collected via www.cocorahs.org/ and made available to the public, the National Weather Service, decision makers and to research scientists. Training and education is a key part of the CoCoRaHS network. All participants learn how to accurately measure and report all forms of precipitation. They also learn how and why these data are important in research, in commerce and in our daily lives. With the help of personalized e-mail messages, newsletters, and on-line web messages, participants are introduced to scientific terminology, activities and findings. CIRA has been a sponsor of CoCoRaHS since its inception in 1997. CoCoRaHS Maine will start on August 1, 2009, with Arizona and Delaware following on September 1st. CoCoRaHS will be approaching 20,000 observers by 2010.

Figure 3. CoCoRaHS Observers Use Inexpensive but Accurate Equipment to Measure Rain, Snow and Hail.

Colorado Climate Center Produces "Walking Through the Water Year" for K-12 and Public Education

"The Weather Brings Our Water" is the concept behind an educational series created by CIRA and the Colorado Climate Center with the Poudre School District. Colorado State Climatologist Nolan Doesken is coordinating this effort. Coloradoans are particularly attuned to the limitations of living in an arid climate. This educational effort is creating video modules shown on the local school district TV channel (and available to the public via local cable channels) and used for in-classroom lessons. There are a range of topics related to water and science at CIRA, for instance "How do we measure our water supplies?" By involving citizens in observing the precipitation in their own backyard or at their own school, a greater appreciation of our dry and variable climate can be gained.   The project will continue to encourage community participation in measurements via CoCoRaHS with the help of CIRA and others.

FX-NET For Fire Weather and Air Force One

Significant changes to the basic FX-Net system were made in the past year, including an upgrade to provide the latest version of the NOAAPort data and extended AWIPS data and file server functions. A new version of the FX-Net Client (v.5.2) includes the addition of significant new data analysis and display tools. Significant to the outreach tools are the added Google Earth Export Feature (see Figure 4). This feature allows NWS, US Forest Service and Bureau of Land Management agencies to provide enhanced briefing material and weather information to fire incident commanders, emergency managers and fire behavior analysts.

The FX-Net system has also become an important part of the forecasting and briefing systems the Air Force One forecasters at Andrews AFB use to provide timely weather information for pre-flight and in-flight briefings.

Enhancements to the Gridded FX-Net Forecaster Workstation included a new capability to the grid data codec to compress grid data sets with irregular boundaries, such as theta (potential temperature) fields. The newly designed algorithm and implemented encoding / decoding software provide good compression performance at the expense of minimum additional computation. FX-Net excels at displaying meteorological data in bandwidth-limited conditions, such as on the frontlines of fire weather forecasting.

Even though the ultimate all-hazards system is not a complete reality, the development team has been very successful in providing key elements to the users. Significant changes to the basic FX-Net system were made in the past year. The system was upgraded to provide the latest version of the NOAAPort data and extended AWIPS data and file server functions. The system delivered to the NWS's IMET program, the National Interagency Fire Center GACC (Geographic Area Coordination Center) offices, and NWS WSO users' was based onthe latest version of the AWIPS software, v. 8.3. The operating system was upgraded to RedHat Linux Enterprise v. 4.0. This makes the FX-Net servers completely up to date with the NWS WFO AWIPS systems.

The new version of the FX-Net Client (v.5.2) was released in March 2009. This version of the client includes the addition of significant new data analysis and display tools. Significant research effort was expended adding the high resolution topography maps. Multiple tools and processes were evaluated in order to provide these hi-res map backgrounds and ensure that the overlaid data sets were geophysically accurate.

The FX-Net team is working on AWIPS II thin client capability evaluations and standing up an AWIPS II Client. The evaluations will result in reports to the NWS AWIPS II program office regarding the AWIPS II existing thin client capability, the gaps in the architecture that need to be addressed to allow a fully functional AWIPS II thin client. The team is also working on transitioning the version control (Subversion) and client build systems (Install Shield) into an integrated system.

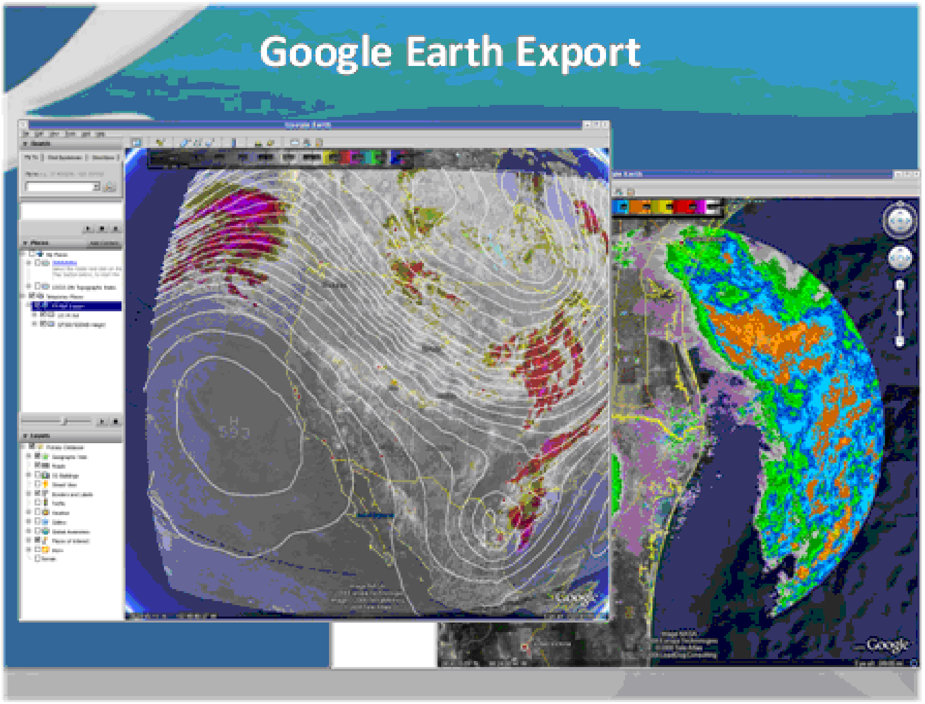


Figure 4. FX-Net Data Export to Google Earth

GLOBE

The GLOBE (Global Learning and Observations to Benefit the Environment – www.globe.gov) technology team comprised of 5 CIRA researchers continues to gather measurements from around the world. Announced in 1994, GLOBE began operations on Earth Day 1995. Today, the international GLOBE network has grown to include representatives from 110 participating countries and 129 U.S. partners coordinating GLOBE activities that are integrated into their local and regional communities. Due to their efforts, there are more than 50,000 GLOBE-trained teachers representing over 20,000 schools around the world. GLOBE students have contributed more than 19 million measurements to the GLOBE database for use in their inquiry-based science projects. GLOBE brings together students, teachers and scientists through the GLOBE Schools Network in support of student learning and research. Parents and other community members often work with teachers to help students obtain data on days when schools are not open.

The CIRA/GLOBE technology team provided support for the GLOBE Learning Expedition (GLE) and Annual Conference which took place 22-27 June 2008 in Cape Town, South Africa and brought together over 500 students, teachers, scientists, partners and guests from 51 countries. The GLE provided opportunities for students to present their research to an international audience, participate in field studies led by master teachers, and build networks for future collaborative activities. Automated web content uploading for various categories of pages (GLOBE Stars, News and Events, ESSP pages: Seasons and Biomes, Carbon Cycle, Watershed Dynamics, and From

Local to Extreme Environments) on the GLOBE web site was also implemented recently as part of the migration to a Content Management System.

During the last few months of 2008 and continuing through the beginning of 2009, the GLOBE Technology Team worked closely with one of the four NSF projects, FLEXE (From Local to Extreme Environments), to develop and deliver an online, collaborative application designed to encourage learning and facilitate teacher evaluation. The application included, among its many activities, a student report writer tool, along with a system that allows students to peer review each other's work, and finally revise their original report based on the reviews they received. The application provided ways for students to interact with scientists in learning more about the project-specific research topics.

GLOBE and CloudSat Collaborate for Local Elementary Outreach

On May 3, 2009, The GLOBE Program's Help Desk team, located at CIRA, collaborated with local CloudSat Scientist; Dr. Matt Rogers to bring a day of hands-on science activities to students at Red Feather Lakes Elementary School in Red Feather Lakes, Colorado.

After completing the science component of the CSAP tests, the students were treated to a fun set of hands-on activities designed to take them outside onto the school grounds for atmospheric data collection. After reviewing how the GPS technology works, the students were divided into small groups, and were handed a GPS unit per group. The groups were asked to spread around the school grounds and were assigned the task of obtaining coordinates for their locations using the GLOBE GPS units. After this activity, each group collected air temperature and dew point data, and calculated the relative humidity using sling psychrometers. Cloud and contrail observations were also collected. The event lasted for three hours and ended with the students presenting the three visitors with a banner and novelty size 'thank-you card'.

High School Students Gain Job Experience at CIRA through the Professional and Community Experience (PaCE) Program

CIRA continues to cooperate with the Poudre School District to allow high school students to work at CIRA via the PaCE program. Students earn school credit and learn about life in the workforce while also assisting with and being exposed to CIRA research. Typical duties include reading or backing up data, or helping write a web page.

CIRA Researchers at ESRL Improve Mapping and Web Tools

CIRA researchers have begun collaboration on the NNEW project to design and implement a suite of performance and latency tests for Open Geospatial Consortium (OGC) web services (Web Feature and Coverage services WFS and WCS) and associated database/web site. CIRA researchers also created web services for searching and retrieving ESRL GFS meteorological data, as well as an ESRL intranet web site for doing so (http://intranet.fsl.noaa.gov/data-locator/).

Interaction with World Meteorological Organization Regional Training Centers (International Training and Outreach)

CIRA collaborates with the World Meteorological (WMO) Regional Training Centers (RTC) in Costa Rica, Barbados, Argentina, and Brazil to promote satellite focused training activities. Activities with these RTCs over the past year have focused on providing support to monthly weather/satellite briefings carried out via the internet. Participation in monthly satellite weather briefings held by the WMO Focus Group of the Americas and the Caribbean via the Internet has become a relatively easy and inexpensive way to simultaneously connect people from as many as 24 different countries, view satellite imagery, and share information on global, regional, and local 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 Yahoo Messenger for voice over the Internet. http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp

CIRA also participated in the WMO sponsored Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV that was held for Spanish speaking countries in Argentina, 22 September – 3 October, 2008. The Argentina National Space Agency CONEA hosted the event at the Gulich Institute in the Space Center facility CETT in Cordoba Province. The World Meteorological Organization (WMO) was the primary sponsor; the local sponsors in Argentina were: el Servicio Meteorológico Nacional (SMN), la Comisión Nacional de Actividades Espaciales (CONAE), and la Universidad Nacional de Buenos Aires (UBA). Thirteen participants from various countries in Regions III and IV were sponsored by WMO: Argentina, Bolivia, Brazil, Chile, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panamá, Paraguay, Perú, and Uruguay. There were 12 other participants from SMN, UBA, and the Instituto Nacional de Agua (INA) in Argentina that were sponsored locally. CIRA prepared and delivered lectures focused on the status of GOES/POES, Introduction to Multispectral and Hyperspectral satellite data, and VISITview training.

Figures 5 through 7 highlight some of the material presented in the training session, some of the participants, and the communication tools used.

See http://rammb.cira.colostate.edu/training/rmtc/ for more information on various RTC and Regional Meteorological Training Centers of Excellence (RMTCoE) activities.

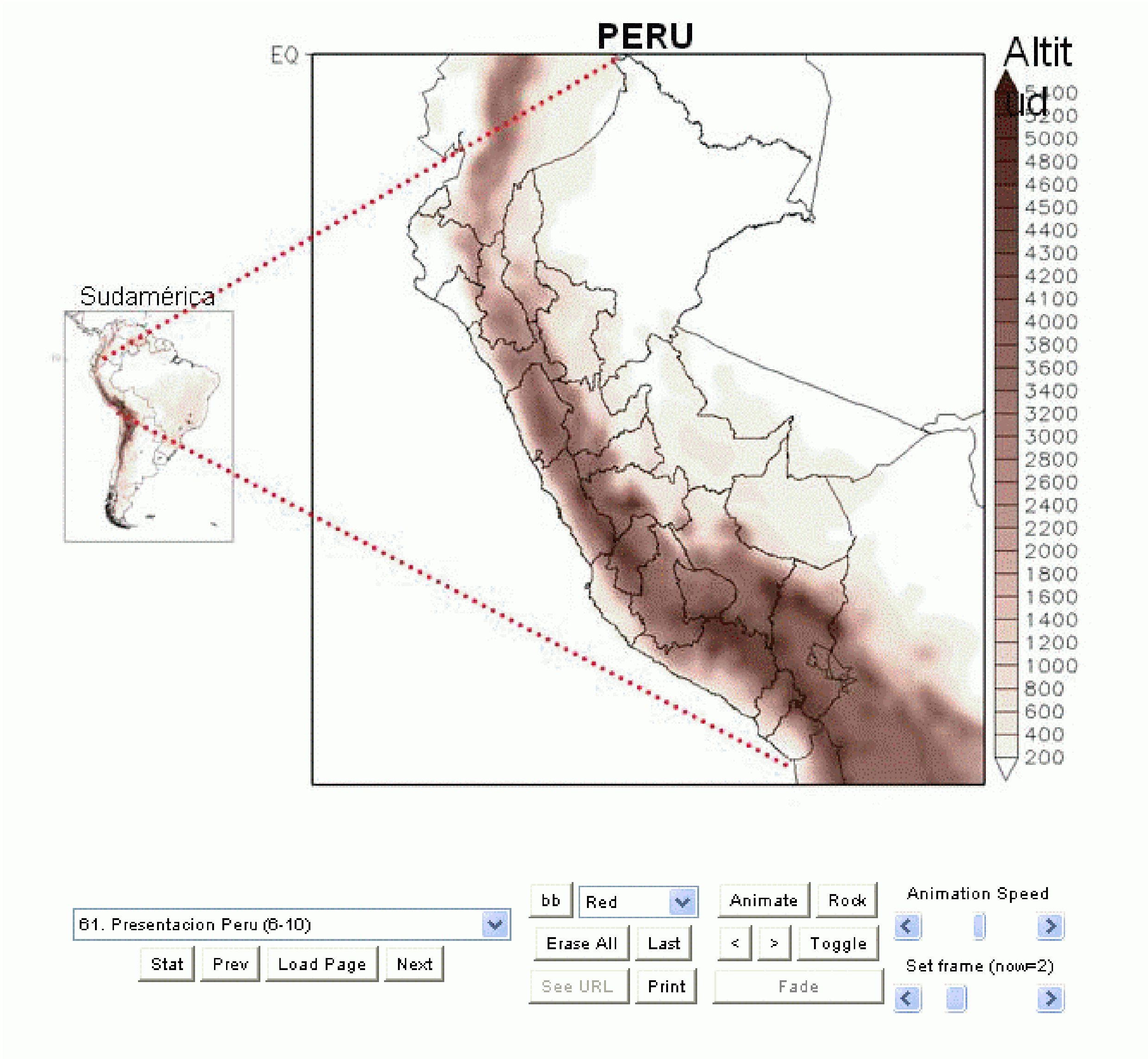


Figure 5. The VISITview Product Window.

Figure 6. Meteorologist Nelson Quispe Gutierrez (arrow) of the National Meteorological and Hydrological Service (SENAMHI) of Peru presented highlights from the Argentina training and a brief overview of SENAMHI during the October 2008 Focus Group Session. The Yahoo Messenger window used to communicate during a training is shown.

Figure 7. WMO Satellite Training in Spring (September 2008) at the Marie Gulich Institute in Argentina.

Next Generation Weather for Aviation Development Continues

As part of the NNEW (NextGen Network-Enabled Weather) project, CIRA developers implemented a THREDDS data server in order to serve up, in real time, several local weather modes to assist collaborating agencies within NNEW for input into their flight paths. THREDDS implements a web coverage service (WCS) as a mechanism for providing data to clients on request. CIRA researchers also developed a JMBL (Joint METOC Broker Language) prototype server to serve up MADIS datasets to a JMBL client. JMBL defines a web based interface for accessing meteorological and oceanographic data.

Advanced Linux Prototype System (ALPS) Visualization Enhancements

Faster processors and other technological advances have made it possible to routinely create forecast grid ensembles with a large number of members. CIRA researchers have been working with other GSD staff in exploring innovative ways to process and display ensemble data. As part of this activity, CIRA has developed software to store NCEP grids from the Short Range Ensemble Forecasts (SREF) and Global Ensemble Forecast System (GEFS) into the ALPS database and to implement creative approaches to interactively display this data on the ALPS workstation.

Advanced Display Systems Installed at NSW Southern Region Headquarters

Major changes have been made to the initial GTAS (Geo-Targeted Alerting System) prototype that was deployed to the FEMA offices in the Washington, D.C. area. The ability to display GIS (Geographic Information System) shapefiles has been enhanced significantly to allow the overlay of GIS data, labeling of shapes with specific attributes, disclosing more data as the user zooms in on a particular area, and shapefile layers being aware of shapes in other layers. An updated version of the HYSPLIT dispersion model has been installed and a new interface for the GTAS client defined that allows chemical information to be specified. The first prototype systems were installed at the NWS Southern Region Headquarter in Fort Worth, Texas and the adjacent weather forecast office and Emergency Operations Center.

The AutoNowcast (ANC) prototype is up and running at the FWD WFO and has been for several years now. This year, an updated package was delivered to the WFO to streamline the tools used by the forecasters to insert boundaries and polygons as well as support the new operational version of AWIPS (OB9.0). In addition, the software was installed on all workstations within the office so that any of the forecasters could use the ANC tools as opposed to just the short term forecaster. The complete ANC system also is now running on NWS' hardware at MDL rather than at NCAR.

Teamwork with USGS on Debris Flow Modeling in Southern California

Effort has begun to map a strategy for Debris Flow Support to provide precipitation gage data from the WFO Hydro Database, which has been specifically requested by USGS researchers. Suggestions have been made on adding Quantitative Precipitation Estimates (QPE) and Quantitative Precipitation Forecast (QPF) data sets to allow USGS Debris Flow models to develop a 'forecast' capability to their existing post-event analysis models. To support the USGS's ability in their analysis of storms which cause debris flows, a prototype application was developed to deliver near real-time data using data available from internet accessible databases. This was provided as a quick, partial implementation of the prototype to be installed at LOX (Oxnard) and SGX (San Diego) WFOs.

MADIS Data Now Operational

CIRA developers in collaboration with the GSD Information Systems Branch (ISB), worked on a major transition effort to transfer MADIS (Meteorological Assimilation Data Ingest System – http://madis.noaa.gov) to operations. MADIS is a system to ingest and distribute a variety of weather observations. This work involved porting over 15 years worth of code to the new hardware at NCEP, updating outdated software, setting up web access to the data, writing documentation as well as adding new data providers.

National Park Service Night Sky Program

The National Park Service Night Sky Program moved to CIRA in 2008. To compliment their research work measuring night sky quality, they advise parks on strategies to reduce light pollution and increase public understanding. This is critical for the public to understand the cause of light pollution, the degree of impact to the nighttime scenery, and what simple steps can be taken to improve night sky visibility. Training courses familiarize park rangers with the starry sky, telescope operation, night sky protection, and help them link their respective parks to the greater cosmos (Figure 8). Each of these rangers will in turn reach hundreds or thousands of park visitors each year. Further information about the program can be found at www.nature.nps.gov/air/lightscapes.

Figure 8. The summer Milky Way bisects the night sky over Tuolumne Meadows in Yosemite National Park, California, a location from which sky quality measurements indicate near-pristine conditions. The panoramic view of the entire sky is a mosaic of 45 individual images.

CloudSat's Role in Understanding Climate Highlighted at CSU Earth Day Booth

John Forsythe and Natalie Tourville manned a booth on the CSU Lory Student Center Plaza April 22 as part of the CSU Earth day festivities. The role of clouds in influencing global climate and how the CloudSat mission is increasing our understanding were discussed with dozens of visitors. Engineering students were particularly interested in the 1/10th scale model of CloudSat. The exhibit meshed nicely with other related demonstrations on water conservation and solar energy.

Emergency Management Response to the May 22, 2008 Weld County EF3 Tornado

On 22 May 2008, a strong tornado, rated 3 on the Enhanced Fujita scale, caused extensive damage along a 34-mile track through northern Colorado. CIRA researchers Dan Lindsey, Andrea Schumacher, Jeff Braun and Steve Miller teamed up with NCAR researchers to investigate the communication of warning information for this unusually intense and destructive storm. Sixteen school administrators, emergency managers, broadcasters and other related parties were interviewed. Further details were presented in June 2009 at the 23rd AMS Conference on Weather and Forecasting and a conference paper with the results is available at http://ams.confex.com/ams/pdfpapers/154329.pdf. The value of NOAA Weather Radio was evidenced by the fact that while other sources like the Internet were used early in the storm's life, the weather radio became a key source of information once telephone and power disruptions occurred. Emergency and school managers are using lessons learned from this storm to be more prepared in the future, such as conducting tornado drills with the lights out and purchasing more NOAA weather radios.

Science on a Sphere™ Installed at 16 New Public Venues, Including Internationally

Science on a Sphere™ (SOS) is a room sized, global display system that uses computers and video projectors to display planetary data onto a six foot diameter sphere, analogous to a giant animated globe. SOS is becoming a truly international venture, with installations appearing around the world and at special events such as the Paris Air Show. Initially driven with meteorological data, SOS now includes an increasing array of geophysical and planetary data.

SOS was installed at 16 new permanent public venues, including our first international sites in Korea, Taiwan, Mexico, and France (Figure 9). Real-time data distribution to existing SOS sites was enhanced with the addition of global model data, a global earthquake visualization, and a new view of the sun from NASA's stereo sun mission. A new remote presence capability called SphereCasting was developed, which allows a presenter to control multiple remote SOS systems across the Internet, with an accompanying video webcast.

Tests were conducted with the GME global atmospheric model running in Korea to see if it can be displayed using SOS. With our earthquake animation, locally gathered data from the Taiwan Central Weather Bureau has been integrated with the global database from USGS to give greater earthquake accuracy over Taiwan. A new animation of the "Blue Marble" image with nighttime lights was created. An animation showing the establishment of GLOBE schools around the world over the past 14 years was also made.

CIRA staff worked on setting up a quasi real-time animation from the NASA STEREO pair of satellites orbiting the sun to show more than half the solar disk in extreme ultraviolet light. This involves adapting our reprojection software so it can work with the spacecraft images provided by Goddard Space Flight Center. An algorithm was developed to use persistence imagery to fill in the part of the sun that has rotated out of view. Work is continuing on improving the reliability of the animation.

The map of Mercury was updated with improved use of older Mariner imagery along with improved navigation of the newer images from Messenger. The map of Saturn's moon Mimas was reworked with improved navigation information for the individual images. The Enceladus map now has color imagery more widely used, as well as improved navigation in the vicinity of the South Pole. Some new Cassini imagery was added to the Tethys map. The map of Saturn's satellite Rhea was updated with new imagery from a February Cassini flyby. Maps were updated for Titan and Iapetus using the latest available Cassini spacecraft imagery. The map of Iapetus is slated to be used in a paper in "Science" magazine.

Figure 9. Current Installations of Science on a Sphere™.

SHyMet: Satellite Meteorology and Hydrology Training Course

The Satellite Hydrology and Meteorology Training Course for Interns continued to be offered this past year. The Intern track of the Satellite Hydrology and Meteorology (SHyMet) Course covers Geostationary and Polar orbiting satellite basics (aerial coverage and image frequency), identification of atmospheric and surface phenomena, and provides examples of the integration of meteorological techniques with satellite observing capabilities. This course is administered through web-based instruction and is the equivalent of 16 hours of training. Initially the Intern Track was targeted for NWS interns. It is now open to anyone inside or outside of NOAA who wishes to review the "basics" of satellite meteorology.

This year also saw progress on the next course in the series: Satellite Hydrology and Meteorology for Forecasters. This course is expected to be released during Fall 2009 and will cover the following topics:

1. Introduction to Remote Sensing for Hydrology
2. Basic Satellite Principles
3. Satellite Applications for Tropical Cyclones: Dvorak Technique
4. Future Satellites
5. Regional Satellite Cloud Composites from GOES
6. Water Vapor Channels
7. Aviation Hazards
8. Volcanic Ash Hazards

Figure 10 shows an example of fire monitoring from a SHyMet module.

For a summary of this year's activity, see the project description for Getting Ready for NOAA's Advanced Remote Sensing Programs A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal. For additional information on this Intern course dedicated to operational satellite meteorology please visit the following website: http://rammb.cira.colostate.edu/training/shymet/intern_intro.asp

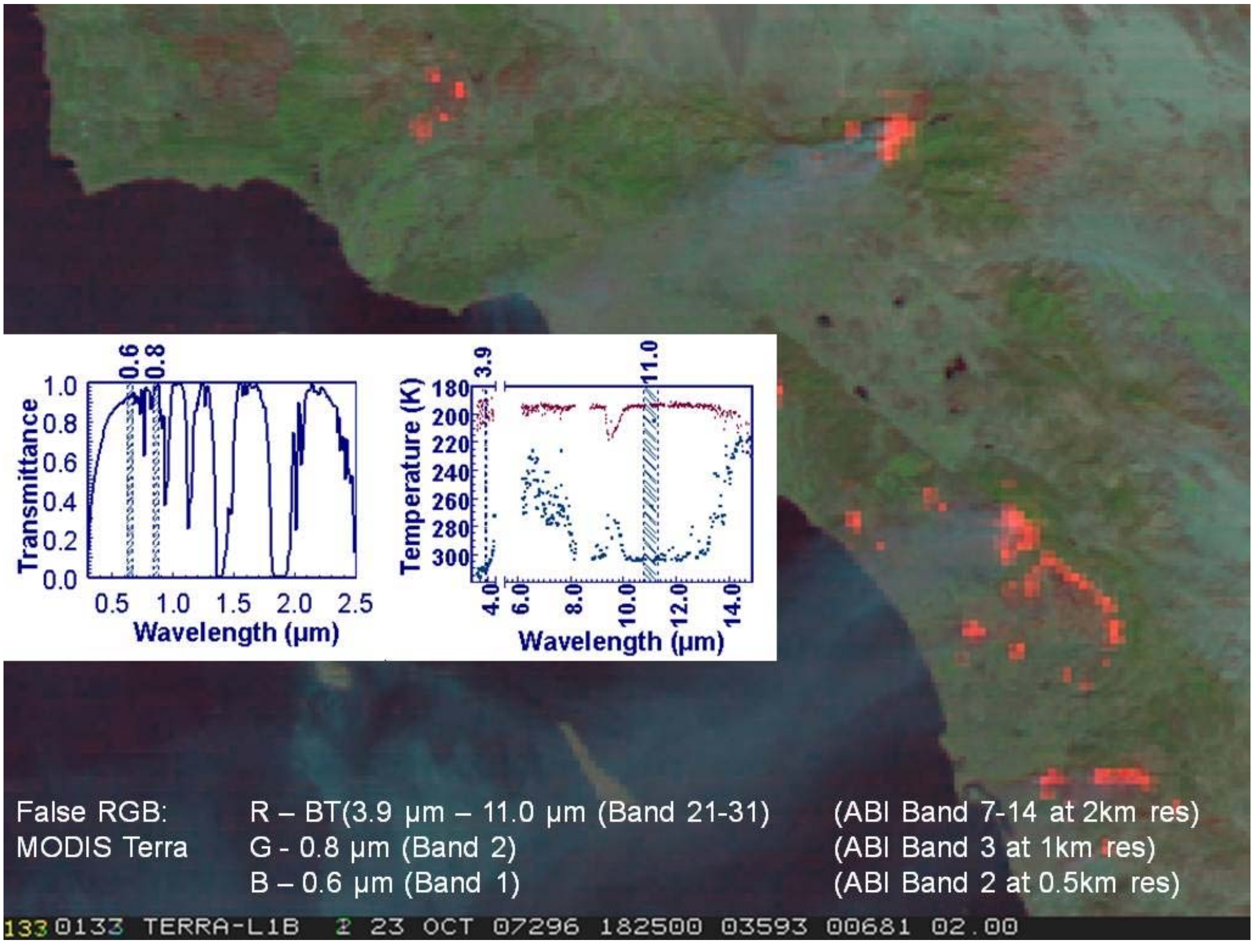


Figure 10. Example from module demonstrating a false Red/Green/Blue (RGB) product for fire and smoke detection using the brightness temperature difference product (BT 3.9µm – BT 11.0µm) to locate active hot fires and the 0.8 and 0.6 um channels to highlight green vegetation versus burned areas and regions of smoke. In the module, the graphic inserts showing channel locations can be removed to get a full view of the image.

Tropical Cyclone Forecast Support to NHC, JTWC and the international TC community

CIRA's Regional and Mesoscale Meteorology (RAMM) Branch continues to provide valuable satellite-based forecast and analysis products to the National Hurricane Center (NHC), the Joint Typhoon Warning Center (JTWC) and the international tropical cyclone community. RAMM Branch continues to update the Monte Carlo hurricane wind probability product that is used at NHC, and JTWC. This year experimental methods to objectively issue hurricane warnings and tropical cyclone conditions of readiness will be tested. This past Southern Hemisphere Hurricane Season saw the operational implementation of a pressure-wind relationship developed at CIRA and modified for use at the Australian Bureau of Meteorology at all three of the Australian Tropical Cyclone

Warning Centres. A training module on track models has been presented through CIRA's Virtual Institute for Satellite Integration Training (VISIT) program.

The RAMM Branch also maintains a real-time experimental tropical cyclone webpage at http://rammb.cira.colostate.edu/products/tc_realtime/, which contains real-time imagery and experimental products for all currently active tropical cyclones as well as an archive of past events. Examples of products include a satellite-based multi-platform tropical cyclone surface wind analysis, storm scale IR and visible imagery, synoptic-scale water vapor, total precipitation, and oceanic heat content imagery, AMSU-based vertical wind shear and deep-layer mean winds. These products are available to everyone.

Virtual Institute for Satellite Integration Training

The primary mission of the Virtual Institute for Satellite Integration Training (VISIT) is to accelerate the transfer of research results based on atmospheric remote sensing data into NWS operations.This transfer is accomplished through the education of NWS forecasters on the latest techniques to integrate remote sensing data, especially from satellite. The education approach is based primarily on the use of teletraining and recorded web-based training. Teletraining includes a live instructor utilizing the VISITview software and a conference call so there is interactivity between instructor and student (Figure 11). CIRA scientists Dan Bikos, Jeff Braun, Bernie Connell and Mark DeMaria contribute to VISIT training. The recorded web-based training modules are taken online anytime by listening to audio playback with video. For more information on VISIT see http://rammb.cira.colostate.edu/visit/visithome.asp

Figure 11. VISIT allows trainers and forecasters to interact in virtual teletraining and forecasters can also use recorded training to fit their dynamic schedules.

Increased Functionality for WRF Tools

CIRA researchers released WRF Portal to the modeling community and continued to extend and improve the software. The new version of WRF, 3.x, is supported and visualization was extended to support both NetCDF and GRIB (version 1 and 2) files. The portal was also generalized to provide support for running the FIM model and CIRA researchers ran complex Flow-following finite-volume Icosahedral Model (FIM) workflows at TACC (Texas Advanced Computing Center) in support of a GSD-led hurricane tracking experiment.

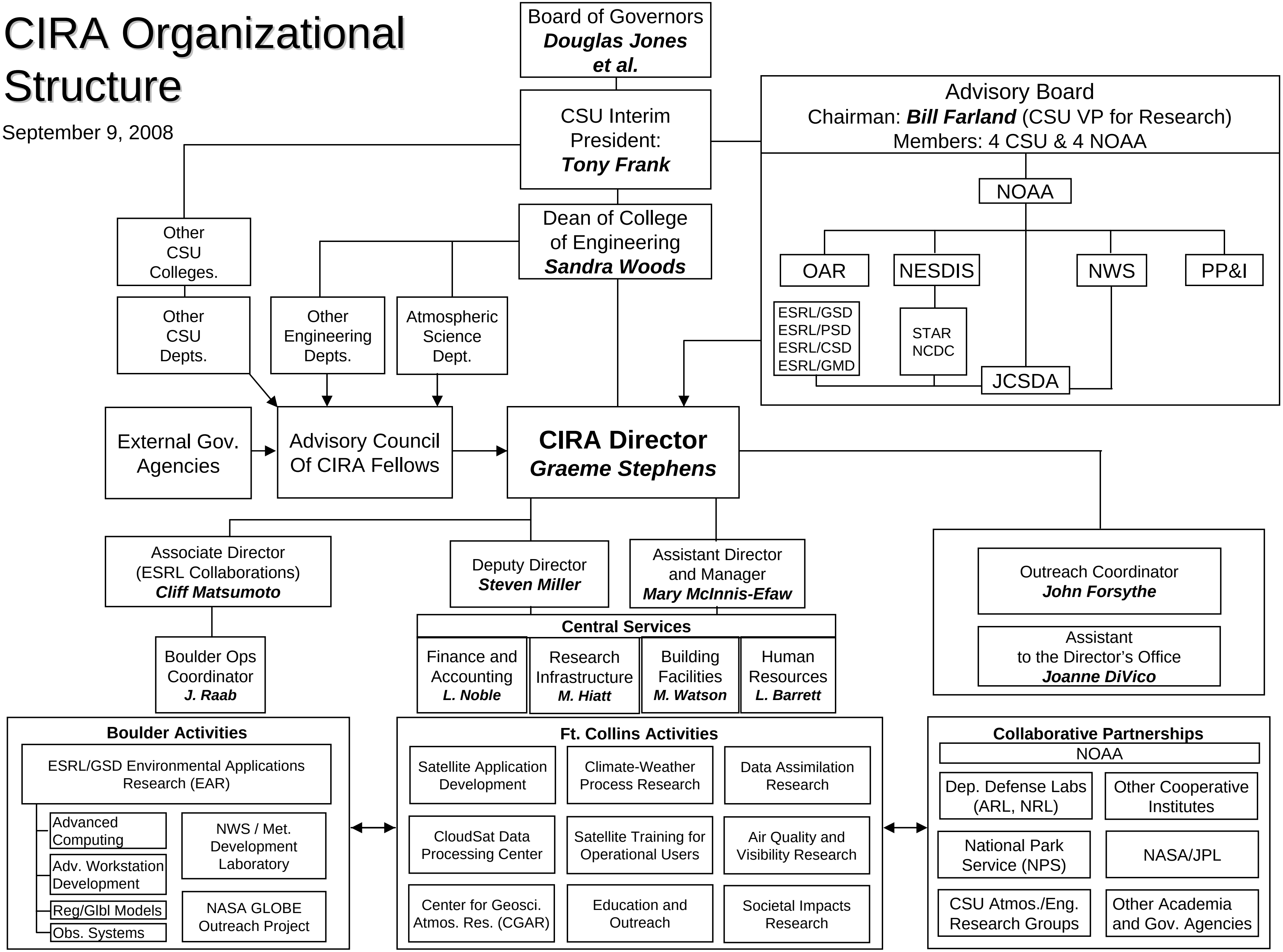
CIRA researchers adapted WRF Domain Wizard to support the latest features of WPS (WRF Preprocessing System) 3.0 and added a non-linear vertical grid stretcher. CIRA researchers also collaborated with LEAD (Linked Environments for Atmospheric Discovery) researchers to produce a version of WRF Domain Wizard for LEAD.

NOAA AWARD NUMBERS

Award Number	Identifier	Project Title	Principal Investigators-Project Directors
NA17RJ1228	Old Cooperative Agreement	COOPERATIVE INSTITUTE FOR RESEARCH FIVE YEAR COOPERATIVE AGREEMENT	Graeme Stephens (Lead), Steven Miller
NA06SEC4690004	awarded outside CA	CoCoRaHS: The Community Collaborative Rain, Hail and Snow Network - Enhancing Environmental Literacy through Participation in Climate Monitoring and Research	Nolan Doesken
NA07OAR4310263	awarded outside CA	Monsoon Flow and its Variability during NAME: Observations and Models	Richard H. Johnson
NA07OAR4310281	awarded outside CA	Simulation and analysis of the interaction between aerosols and clouds, precipitation and the radiation budget over the Gulf of Mexico and Houston	William Cotton
NA08OAR4320893	Shadow Award	The Cooperative Institute for Research in the Atmosphere	Graeme Stephens (Lead), Steven Miller
NA09OAR4320074	New Cooperative Agreement	A Cooperative Institute to Investigate Satellite Applications for Regional/Global-Scale Forecasts	Graeme Stephens (Lead), Steven Miller

CIRA Organizational Structure

September 9, 2008



CURRENT FELLOWS OF CIRA

Mahmood R. Azimi-Sadjadi, Electrical & Computer Engineering, CSU
Daniel Birkenheuer, NOAA/ESRL/GSD
V. Chandrasekar, Electrical & Computer Engineering, CSU
Harold Cochrane, Economics, CSU (Retired)
Jeffrey L. Collett, Jr., Atmospheric Science Department, CSU
William R. Cotton, Atmospheric Science Department, CSU
Mark DeMaria, NOAA/NESDIS/RAMMB
Scott Denning, Atmospheric Science Department, CSU
Graham Feingold, NOAA ESRL
Douglas Fox, Sr. Research Scientist Emeritus, CIRA, CSU, USDA (Retired)
Ingrid Guch, Director NESDIS Cooperative Research Program
Hariharan Iyer, Department of Statistics, CSU
Richard H. Johnson, Atmospheric Science Department, CSU
Pierre Y. Julien, Civil Engineering, CSU
Stanley Q. Kidder, Senior Research Scientist, CIRA, CSU
Steven E. Koch, NOAA/ESRL/GSD
Sonia Kreidenweis, Atmospheric Science Department, CSU
Christian Kummerow, Atmospheric Science Department, CSU
Alexander E. "Sandy" MacDonald, NOAA
Roger A. Pielke, Sr., Senior Research Scientist, CIRES, U of Colorado
James F.W. Purdom, Senior Research Scientist, CIRA, CSU
Steven A. Rutledge, Atmospheric Science Department, CSU
Graeme L. Stephens, Atmospheric Science Department, CSU
Thomas H. Vonder Haar, CIRA and Atmospheric Science Department, CSU

Meeting Dates

Combined Meeting CIRA Advisory Board/Advisory Council/Fellows	December 11, 2008
Combined Meeting CIRA Advisory Board/Advisory Council	May 27, 2009

CIRA RESEARCH HIGHLIGHTS

Global and Regional Climate Dynamics

--As part of an NSF-funded research collaboration entitled 'Norwegian-United States IPY Scientific Traverse: Climate Variability and Glaciology in East Antarctica', scientific investigations along two overland traverses in East Antarctica—one going from the Norwegian Troll Station (72º S, 2º E) to the United States South Pole Station (90º S, 0º E) in 2007-2008 and a return traverse starting at South Pole Station and ending at Troll Station by a different route in 2008-2009—were executed as scheduled. Analyses of the snow data collected during the traverse are in progress to understand snow accumulation and spatial variability across the East Antarctic Ice Sheet. The results of this investigation will add to understanding of climate variability in East Antarctica and its contribution to global sea level change.

--As part of an NSF-sponsored IPY collaborative research, a prototype international network for measuring Arctic winter precipitation and snow cover (Snow-Net) was initiated. Both snowfall and snow on the ground are changing, yet we are in a poor position to monitor this change partly because winter precipitation and snow on the ground are currently monitored by two separate systems. At 5 key Arctic sites we are augmenting existing meteorological and snow measuring instrumentation with solid-state snow pillows, heated plate precipitation sensors, snow fences (to capture the wind-blown flux), and eddy correlation towers for computation of sublimation. Several times a winter, ground surveys of snow cover depth, water equivalent, and other properties are conducted at these sites using tools that allow rapid collection of extensive data. These are augmented with aerial photography and airborne remote sensing from inexpensive platforms to visualize drift and deposition patterns. The combined suite of instruments and measurements is designed to allow us to close the winter water balance at each site, for the first time balancing the precipitation with measured accumulation. Field instruments were installed during 2007 and measurements were made during winter 2007-2008 and 2008-2009.

--Current information and knowledge related to snow tends to be compartmentalized by discipline, dispersed throughout the literature, and rarely inclusive. A synthesis is needed now more than ever because both the duration and the nature of the arctic snowpack are changing. We take a comprehensive approach to snow that will produce a better understanding of how changing snow conditions will affect the Arctic System. Our terrestrial snow work completes the suite of synthesis studies on the Arctic System undertaken in the first phase of the SASS Program by combining with an existing study of snow on sea ice, thereby producing a full system-wide assessment of snow impacts. The synthesis is organized into five tasks designed to provide answers to several pressing snow-related questions: 1) collect pan-Arctic datasets, 2) merge tools and models to simulate Arctic snow-related features, 3) produce spatially distributed time-evolving distributions of snow properties and characteristics for the terrestrial pan-Arctic System, 4) from these distributions develop a set of integrated indices and derived products that capture the essential snow-related impacts, and 5) use the impact indices to better understand the Arctic System.

--The long-term research objective of determining the regulatory mechanism for sub-seasonal precipitation variability in the east Pacific warm pool during Northern Hemisphere summer has been met. Predicting sub-seasonal precipitation variability in the east Pacific is crucial for predicting periods of enhanced tropical cyclone formation not only over the east Pacific, but also over the Gulf of Mexico and Caribbean Sea. Such basic understanding may also lead to improved parameterization in our climate models. It was shown that 1) bursts of Atlantic tropical cyclone activity are preceded by the propagation of MJO-induced Kelvin waves from the Pacific into the Atlantic; 2) Rossby wave propagation is the dominant means by which ENSO affects Atlantic hurricanes; 3) sub-seasonal SST variability in the east Pacific warm pool is much greater than once suspected, possibly playing an important role in forcing convection that affects the predictability of the North American monsoon region; 4) an ocean model with a dynamical mixed layer is necessary to capture realistic subseasonal SST variability in the east Pacific warm pool, and surface latent and shortwave radiation fluxes appear to be at the root of intra-seasonal SST variability in the east Pacific; and 5) several climate models exhibit a strong sensitivity of tropical intra-seasonal variability to wind-induced surface heat exchange, suggesting that surface flux forcing may be a key underlying mechanism of the MJO.

--As part of the effort to simulate and analyze the interaction between aerosols and clouds, precipitation and the radiation budget, the Town Energy Budget (TEB) urban model was coupled to the newest version of RAMS for a domain over the Gulf of Mexico and Houston. The Landsat Thematic Mapper ™ National Land Cover Data (NLCD) corresponding to 2001, along with two additional datasets (1992 and 2006) were processed and the NLCD land use categories were converted into the RAMS land use categories. These datasets were used for the initialization of the two finest grids of series the numerical simulations. We focused on a convective storm triggered by the sea-breeze circulation (Aug 24, 2001) and performed two series of sensitivity experiments with the different land use data sets and considering aerosol sources linked to the urban sub-grid urban fraction. [MUST PROVIDE A STATEMENT ON FINDINGS]

--Since 1983, CIRA has served as the International Satellite Cloud Climatology Project (ISCCP) processing center for GOES-West data. GOES data (currently GOES-11 data) are received from our ground station, converted into ISCCP B1 and B2 formats, and delivered to the Goddard Institute for Space Studies for processing into the ISCCP products and to the National Climatic Data Center (NCDC) for archiving. We also provide calibration sectors (small samples of GOES-11 and GOES-12 data) for comparison with observations from polar-orbiting satellites. Our current objective is to transition this ISCCP processing from a research setting (CIRA) into an operational setting (NCDC). Our processing code has been transferred to NCDC and we are working with NCDC personnel to implement the processing there and to quality check and compare the NCDC-produced files with the files produced at CIRA.

Mesoscale and Local Area Forecasting and Evaluation

--CIRA researchers supported the assessment of global icing forecasts created for the World Meteorological Organization's (WMO) World Area Forecast System (WAFS). Primarily intended for trans-oceanic operational flight planning, the global forecast grids provide information about potential icing at five flight levels. With very few observations of icing in the domains of interest to the operational planners, the CIRA team developed an icing diagnostic based on CloudSat cloud classification data and a global temperature analysis from the GFS model. The algorithm was developed and tuned in the CONUS domain, using the relatively rich icing observation data. Then, the global forecasts were verified in the areas of concern for operational planning.

--As the centerpiece of weather information in NextGen, the 4-D Data Cube will contain verification information about the forecasts utilized by the air traffic management algorithms. A new approach is necessary to create verification software sufficient for the NextGen operational setting, a complex, service-oriented architecture (SOA) comprised of weather and air traffic management components. In response to this need, CIRA researchers design and test configurations of the integration layer, a primary component supporting flexible, complex queries of the verification statistics. Building on an initial proof-of-concept from the previous year, the team expanded the Network-Enabled Verification Service (NEVS) capability to provide verification information about the FAA's experimental convective forecast, the Collaborative Storm Prediction Algorithm (CoSPA), during the 2009 convective season.

--One of the recent activities included an application of a theoretical approach recently published in Monthly Weather Review on model output from a complete system for numerical weather prediction (WRF-ARW model). The technique consists of first diagnosing the performance of the forecast ensemble which is based on explicit use of the analysis uncertainties, and then optimizing the ensemble forecast using results of the diagnosis. The technique includes explicit evaluation of probabilities which are associated with the Gaussian stochastic representation of both the analysis and forecast. It combines the technique for evaluating the analysis error covariance that was first presented in the Ensemble Transform data assimilation method developed by Bishop et al in 2001 and the standard Monte Carlo approach for computing samples from the known Gaussian distribution. Results from this study have been recently presented at the Weather Analysis and Forecasting conference in Omaha.

--As part of the Hydrometeorological Testbed (HMT) team, CIRA led an effort to test a newly developed observations-based forecast model verification tool by a group of PSD scientists for atmospheric rivers and their impacts on coastal orographic precipitation enhancement. The tool focuses on water vapor flux as a major determinant of orographic precipitation. The water vapor transport is estimated by using wind profilers and GPS-met (Integrated Water Vapor) IWV data.

--A web site for display of FIM model output was created and has currently has 24 products available for perusal with 3-hourly forecasts going out to 7 days (http://fim.noaa.gov/fimgfs). GFS model forecast plots are also available as are FIM-GFS difference plots, and plots from the two models can also be viewed side-by-side. Several different projections are also now available including: CONUS, Africa, the Arctic, West Atlantic, West Pacific, Europe, and the Southern Hemisphere. Additionally, the web site features the ability to loop any of these fields throughout the forecast periods. The Texas Advanced Computing Center (TACC) granted access to their 60,000 processor supercomputer for running the FIM at a higher resolution level, with grid points at about 15 km spacing. Separate web pages were created for FIM output from the TACC runs. Hurricane tracking software was used on the FIM output, providing FIM-produced forecasts of projected hurricane paths.

--In support of the Joint Hurricane Testbed, improvements to the Monte Carlo (MC) method for estimating the probability of occurrence of 34, 50 and 64 kt winds utilizing the uncertainty in the track, intensity and wind structure forecasts were implemented this past year. One effort involved the refinement of the MC wind probability estimates by making the underlying track error distributions a function of the forecast uncertainty. The current MC model uses basin-wide error statistics but recent research has shown that the spread of track forecasts from various models can provide information about the expected track error. A real-time tool to quantitatively estimate the track forecast uncertainty (the Goerss Predicted Consensus Error, GPCE) was incorporated into the MC model. Results showed that the GPCE version of the probability model improved the skill as measured by both a Brier Score and a threat score.

--For the Tropical Cyclone Forecast Product project, the NCEP/TPC operational SHIPS intensity model was updated prior to the 2008 hurricane season, where data from the 2007 season was added and the model coefficients re-derived. Methods have been developed to estimate the complex principal components (CPC) in a real-time manner to be used as potential predictors for the Rapid Intensification Index (RII) and SHIPS. Work continues with AOML and TPC on RII modifications and with operational transition issues. GOES predictors have been tested in the Atlantic and East Pacific versions of the RII. In both basins, the GOES predictors significantly improve the ability to anticipate rapid intensification events.

--For the Cloud and Microwave Emissivity Verification Tools for Use within the Common Radiative Transfer Model (CRTM) project, CIRA-developed software, including the CSU microwave land surface model documentation and codes, were delivered to JCSDA for integration into the CRTM. Our WRF-3DVAR use of the microwave emissivities has shown substantial improvement over the deserts of the Middle East, which represents a substantial bias improvement over the CRTM estimates.

--The Development of an Improved Climate Rainfall Dataset from SSM/I project involves the development of specific rainfall databases and procedures to produce rainfall products from TMI and AMSR-E. Significant progress has been made and we are on schedule to produce a complete climate rainfall dataset from SSM/I for the period from 1987 through the present using version 2008 of the GPROF retrieval algorithm by the end of the project. Initial results from the new retrieval algorithm indicate significant improvements in ocean rainfall estimates that will provide a much improved dataset for climate research applications.

--A study using the new CloudSat/CALIPSO dataset in the Arctic was conducted to examine the vertical structure of clouds and the generation of eddy available potential energy. The relationship between the vertical structure of clouds and radiation changes at the surface was quantified.

--A number of satellite networks (including dawn/dusk and other sun-synchronous orbits) were examined and the total flux constraint provided per satellite was found to not depend strongly on the orientation of a sun synchronous orbit (local time of ascending node) -- even dawn/dusk orbits provide much information, despite the high solar zenith angles and long atmospheric paths that affect their measurements. A fleet of four appropriately spaced sun-synchronous satellites with measurements similar to those planned for the Orbiting Carbon Observatory (OCO) could potentially improve surface CO_2 flux estimates by 50-60%

where our current understanding is worst. This work is of interest not only for understanding the functioning of the global carbon cycle (and its implication for predicting future levels of global warming), but also for use in monitoring compliance with international CO_2 emissions treaties.

--Surface observations over northwestern Mexico during NAME have been used to document the diurnal cycle of the surface flow during July and August 2004. Comparison of the observed flows with the special NAME North American Regional Reanalysis (NARR) reveals significant deficiencies in the NARR's ability to properly represent the sea and land breeze circulations. In another finding of this study, the diurnal cycle of convection over the Sierra Madre Occidental (SMO) in northern Mexico was determined to be unique in comparison to other mountainous regions of the tropics and subtropics. Early morning low clouds and insolation characteristics on the western slope of the SMO delay the development of upslope flow and deep convection there to the afternoon and evening.

Applications of Satellite Observations

--CloudSat launched on April 28th, 2006 and the CIRA CloudSat Data Processing Center (DPC) has been fully operational since the first CloudSat data were downlinked on May 20th 2006. Since that date, the CloudSat data downlink system has collected 99.9% of the available data, and the CIRA CloudSat Data Processing Center has processed 100% of the available input data to Level 2 products.

--Because of the success of the baseline 22-month CloudSat mission, NASA has extended the mission for an additional 3 years, including support of the CIRA CloudSat DPC. The CloudSat DPC is also responsible for maintaining an archive of the CloudSat data products and the distribution of products to the science community. As of December 31st, 2008, the data distribution system has provided data to over 712 users/groups in 50 different countries. The DPC was given a requirement to provide Level 0 and Level 1 products within 30 days of the receipt of data. We are currently generating both products, and displaying a geo-located browse image of the CPR science data within 2 minutes. This quick turnaround of data and the generation of the "quicklook images" was identified as one of two NASA "Firsts" for this mission. (The other being the accomplishment of formation flying.) A second mission requirement calls for CIRA to maintain 60 days of on-line raw data and data product storage. The DPC has maintained on-line data storage from the beginning of the mission with over 2 ½ years of data on-line as of the end of this past calendar year.

--CIRA participates in the GOES-R 'Satellite Proving Ground' where simulated GOES-R products for advanced instruments such as the Advanced Baseline Imagery (ABI) and the Geostationary Lightning Mapper (GLM) are demonstrated at NWS Weather Forecast Offices (WFOs) on their AWIPS display systems. This past year, the first prototype PG products were migrated into AWIPS at the WFO Boulder and WFO Cheyenne. One of the goals of the Proving Ground project is to leverage existing capabilities within CIRA to provide training and experience directly to NWS forecasters on the new capabilities of these instruments to maximize the utility of GOES-R.

--CIRA develops GOES-R proxy data for mesoscale weather and hazard events using a sophisticated cloud model and accurate radiative transfer modeling. Under the GOES-R Risk Reduction project, CIRA has developed the capability to produce radiance fields for GOES-R Advanced Baseline Imager (ABI) bands using the CSU RAMS Mesoscale forecast model output. The procedure has been successfully applied to develop synthetic imagery for different types of mesoscale weather events like lake effect snow, severe weather, and hurricanes. This past year, focus was on the creation of ABI radiances for different fire proxy datasets along with the model fields for "ground truth". The goal of these studies is to provide a variety of simulated fire hot spot scenarios along with synthetic GOES-R ABI imagery to support the development of ABI fire retrieval algorithms. The synthetic imagery is also being used for ABI fire detection uncertainty studies.

--CIRA-produced blended AMSU, SSM/I, and GPS Total Precipitable Water Vapor (TPW) product and the Percent of Normal TPW product are now being produced operationally at NESDIS (OSDPD) and to be part of AWIPS Operational Build 9, which means that the two products are available NWS-wide on AWIPS. NOAA 18, NOAA 19, and MetOp-A data are now also being added into the TPW products.

Air Quality and Visibility

--An initiative to improve WRF-Chem forecasts with data assimilation using the Gridpoint Statistical Interpolation (GSI, Purser et al., 2003a and b) is under way. Some results of this work are described in a journal paper on assimilation of surface observations of ozone and PM2.5 that has been accepted by the Quarterly Journal of the Royal Meteorological Society subject to revisions. The experiment demonstrated that assimilation of ozone and PM2.5 could lead to much improved forecasts of concentrations of these species in terms of standard statistical measures. A positive impact of assimilation is observed in forecasts at least out to 24 hours. The result for ozone is encouraging, especially since it is a volatile species dependent on the presence of precursors and sunlight. Improvement in the forecasting skill of PM2.5 concentrations with assimilation was expected. First, PM2.5 is much less reactive than ozone and the impact of assimilation should have longer-term effects. Second, PM2.5 forecasts generally show large errors in terms of basic statistics and their correction via assimilation should be substantial.

--One of the goals of a NASA sponsored project in support of the Clean Air Act and the National Ambient Air Quality Standards (NAAQS) is to improve air quality decision support system through the integration of satellite data with ground-based, modeled, and emissions data. CIRA is pursuing capabilities enhancement of the Visibility Information Exchange Web System (VIEWS) and its associated Technical Support System (TSS) through the integration of NASA satellite data products relevant to air quality and visibility with surface-based monitor data, air quality model output, and advanced analysis tools for intercomparing and interpreting the data. During the past year, a number of satellite data products for air quality, meteorology and land use/land cover were acquired in collaboration with the Joint Center for Earth Systems Technology for multiple years (2006-8) from OMI and MODIS Terra and MODIS Aqua, and loaded into VIEWS-TSS. A prototype visualization tool for satellite data products was implemented in VIEWS, along with many other improved tools for browsing existing data. Metadata were also added for satellite data and browsing of data catalogs was improved

--Recent work has focused on analyzing results from two large field campaigns comprising the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study conducted in spring and summer 2006 to characterize spatial and temporal patterns in nitrogen and sulfur species concentrations and to evaluate dominant pathways for nitrogen deposition within Rocky Mountain National Park (RMNP). Effort has also focused on developing new methods for improved measurements of ammonia and organic nitrogen. Measurements revealed that reactive nitrogen concentrations were much higher, on average, to the east of RMNP than to the west. This was true both for oxidized and reduced forms of nitrogen. Reduced nitrogen, in the form of ammonia plus particulate ammonium, was highest in NE Colorado. The discovery that organic nitrogen and ammonia are important contributors to total N deposition in RMNP is important, given that routine concentration and deposition network measurements do not include these species.

--Another project—an extension of previous efforts to characterize transport and deposition of airborne nitrogen and sulfur in Rocky Mountain National Park described above—includes objectives to study airborne concentrations and deposition throughout a full annual cycle in order to evaluate seasonal trends in pollutant concentrations, transport patterns and deposition fluxes as well as the addition of new methods for continuous measurement of trace oxidized nitrogen species in the gas phase. A field project in RMNP was begun in November 2008 and will run through fall 2009. Daily or higher time resolution measurements are being made of fine particle composition, particle size distributions, concentrations of key trace gases (esp. NH_3, HNO_3, NO_x, and NO_y), and wet deposition fluxes of inorganic ions, organic nitrogen and organic carbon.

--The Technical Support System (TSS) is an extended suite of analysis and planning tools designed to help planners develop long-term emissions control strategies for achieving natural visibility conditions in class I areas by 2064. The TSS is intended to provide state and tribal governments in the Western Regional Air Partnership's (WRAP) region with the emissions, modeling, and monitored air quality data and analysis tools necessary for the completion of their State and Tribal Implementation Plans. To achieve these objectives, the TSS consolidates the data resources of the Visibility Information Exchange Web System (VIEWS) and the WRAP's Emissions Data Management System (EDMS), Regional Modeling Center (RMC), and Fire Emissions Tracking System (FETS) into an online suite of data access, visualization, and analysis tools on the TSS website together with the technical information and guidance to apply these data and tools to state, local, and regional air quality planning. The TSS project team at CIRA currently collaborates with several other organizations to design and develop the technical infrastructure for the TSS. Launch of the first production version of the TSS website was completed, along with the integration of monitored, modeling, and emissions data for the baseline planning period of 2000-2004 and the integration of emissions modeling projections for 2018. Implementation of website usage and tracking system has also been completed.

Numerical Modeling

--Baseline calibration experiments UAS OSSE project have been performed for two 7-week periods using archived observations for six different data-denial types: RAOB, Aircraft, AMSU-A, AIRS, and GOES. Synthetic observations from the Nature Run are now available, and calibration data denial runs for the synthetic observations are now underway. A ‘Quick’-OSSE has begun in support of the hurricane UAS testbed. The purpose of the Quick-OSSE is to provide initial guidance for UAS flight paths and instrumentation by performing ad hoc, uncalibrated OSSE experiments using regional forecasting models. Code has been written and tested to generate synthetic UAS observations for dropsondes, in situ measurements, balloons, and SFMR using nested moving regional model output.

--CIRA researchers continue to play an integral part of the team that is preparing FIM for planned operational implementation. CIRA researchers have upgraded FIM to meet NEMS interoperability standards for "Phase I: Incorporation of the FIM into the NEMS D&T code" as specified in the NCEP-GSD LoA for transitioning FIM into operations.

--CIRA researchers organized, debugged, parallelized and optimized the NIM code. Optimizations included rewriting the matrix solving section which decreased the entire code serial runtime from 700 seconds to 108 seconds. Parallelizations were done with SMS. SMS was extensively refactored to simplify implementations and remove functionality that is no longer required. The new "SMS-LITE" has 55,000 fewer lines of source code and is even easier to port and maintain and yet contains all the new unstructured grid functionality.

--In collaboration with the ESRL Director and the GSD Project Manager, CIRA researchers investigated the feasibility of using Graphical Processing Units (GPUs) and the IBM cell processors for increasing the performance of weather codes, specifically the NIM code. Experiments on FIM subroutines have shown that, compared to the state-of-the-art CPUs, a 20X speedup is possible.

--Observed radiative fluxes from an airborne radiometer and fluxes simulated based on model output were compared to evaluate the ability of our model to represent the radiative effects of the aerosol-cloud system. A three-dimensional radiative transfer models was applied to our simulated cloud fields and compared to aircraft observations. Results show good statistical agreement between modeled and measured irradiance provided both cloud and aerosol are included in the calculations. A paper showing the importance of properly simulating both the aerosol, cloud, radiative fluxes has been published in *Geophysical Research Letters* (Schmidt et al., 2009).

--Simulations of aerosol-cloud interactions in trade cumuli (RICO) to assess the sensitivity of cloud macrophysical, dynamical, and radiative properties to aerosol changes at a range of model resolutions were also performed. This includes feedbacks among precipitation, entrainment and turbulent mixing. A paper describing the effect of aerosol on trade cumulus cloud morphology has been accepted for publication in the *Journal of Geophysical Research* (Jiang et al. 2009).

--A state-of-the-art, physically based, micrometeorological model (MicroMet) that can serve as an interface between the relatively coarse-resolution atmospheric models and fine-resolution hydrological and ecological models was developed. Several papers have been published summarizing its performance. This will lay the groundwork for substantial improvements to existing hydrologic and ecologic models. This need is particularly acute in the western mountain States where topographic variations lead to significant variations in winter snow precipitation, snow-depth distribution, spring snowmelt, and runoff rates (e.g., changes of over 500% across distances of a few 100 m for some variables). This, in turn, will lead to increased accuracy of operational weather, hydrologic, and water-resource forecasts.

--One of the primary goals of a collaboration with NASA and the University of California sponsored by the Global Precipitation Measurement Mission program is to develop an ensemble data assimilation system to downscale satellite precipitation observations and to produce high-resolution dynamic precipitation analysis for hydrological applications. During this past year, the MLEF algorithm was interfaced with the GSI forward operators and a capability for assimilation of precipitation sensitive satellite radiances was developed. Data assimilation experiments were performed with AMR-E and TMI radiances for a tropical cyclone case in fine spatial resolution (3 km grid distance in the inner nest). The experimental results indicated positive impact of data assimilation on the analysis and forecast of the cyclone intensity and location and the associated cloud microphysical variables and precipitation.

--In an effort to improve bulk microphysical parameterizations of non-convective precipitation processes by radar data assimilation, model performance was first evaluated relative to radar observations and model errors diagnosed to determine an optimal measure of distance from these observations to use in the data assimilation. The study was started with model verification on examples of IHOP (International H2O Project) cases because of readily available data archives of rich observational coverage and diversity of summer storm systems. The simulations were performed with Advanced Research WRF (ARW) community model with 4-km horizontal grid spacing and 51 vertical levels and three available microphysics options. The three different microphysical schemes used were Lin, WSM6 and Schultz. Model evaluation by global diagnostics such as reflectivity histograms, 3D contingency tables and standard skill scores in the radar reflectivity space as well as comparison of 2D cross-sections of the reflectivity fields between the model and LAPS analysis have been computed.

Education, Training, and Outreach

--CIRA/GLOBE technology team provided support for the GLOBE Learning Expedition (GLE) and Annual Conference which took place 22-27 June 2008 in Cape Town, South Africa and brought together over 500 students, teachers, scientists, partners and guests from 51 countries. The GLE provided opportunities for students to present their research to an international audience, participate in field studies led by master teachers, and build networks for future collaborative activities. Automated web content uploading for various categories of pages (GLOBE Stars, News and Events, ESSP pages: Seasons and Biomes, Carbon Cycle, Watershed Dynamics, and From Local to Extreme Environments) on the GLOBE website was also implemented recently as part of the migration to a Content Management System.

--During the last few months of 2008 and continuing through the beginning of 2009, the GLOBE Technology Team worked closely with one of the four NSF projects, FLEXE, to develop and deliver an online, collaborative application designed to encourage learning and facilitate teacher evaluation. The application included, among its many activities, a student report writer tool, along with a system that allows students to peer review each other’s work, and finally revise their original report based on the reviews they received. The application provided ways for students to interact with scientists in learning more about the project-specific research topics.

--CIRA researchers released WRF Portal to the modeling community and continued to extend and improve the software. The new version of WRF, 3.x, is supported and visualization was extended to support both NetCDF and GRIB (version 1 and 2) files. Workflow management was extended to support PBS, SGE, and LSF with both the internal and external workflow managers. The portal was also generalized to provide support for running the FIM model and CIRA researchers ran complex FIM workflows at TACC (Texas Advanced Computing Center) in support of a GSD-led hurricane tracking experiment.

--CIRA researchers adapted WRF Domain Wizard to support the latest features of WPS (WRF Preprocessing System) 3.0 and added a non-linear vertical grid stretcher. CIRA researchers also collaborated with LEAD (Linked Environments for Atmospheric Discovery) researchers to produce a version of WRF Domain Wizard for LEAD.

--CIRA researchers have begun collaboration on the NNEW project to design and implement a suite of performance and latency tests for OGC web services (WFS and WCS) and associated database/website. CIRA researchers also created web services for searching and retrieving ESRL GFS meteorological data, as well as an ESRL intranet website for doing so (http://intranet.fsl.noaa.gov/data-locator/).

--Tests were conducted with the GME global atmospheric model running in Korea to see if it can be displayed using SOS. With our earthquake animation, locally gathered data from the Taiwan CWB has been integrated with the global database from USGS to give greater earthquake accuracy over Taiwan. A new animation of the "Blue Marble" image with nighttime lights was created. An animation showing the establishment of GLOBE schools around the world over the past 14 years was also created.

--CIRA staff worked on setting up a quasi real-time animation from the STEREO pair of satellites orbiting the sun to show more than half the solar disk in extreme ultraviolet light. This involves adapting our reprojection software so it can work with the spacecraft images provided by Goddard Space Flight Center. An algorithm was developed to use persistence imagery to fill in the part of the sun that has rotated out of view. Work is continuing on improving the reliability of the animation.

--The map of Mercury was updated with improved use of older Mariner imagery along with improved navigation of the newer images from Messenger. The map of Saturn's moon Mimas was reworked with improved navigation information for the individual images. The Enceladus map now has color imagery more widely used, as well as improved navigation in the vicinity of the South Pole. Some new Cassini imagery was added to the Tethys map. The map of Saturn's satellite Rhea was updated with new imagery from a February Cassini flyby. Maps were updated for Titan and Iapetus using the latest available Cassini spacecraft imagery. The map of Iapetus is slated to be used in a paper in "Science" magazine.

--Even though the ultimate all-hazards system is not a complete reality, the development team has been very successful in providing key elements to the users. Significant changes to the basic FX-Net system were made in the past year. The system was upgraded to provide the latest version of the NOAAPort data and extended AWIPS data and file server functions. The system delivered to the NWS's IMET program, the National Interagency Fire Center GACC offices, and NWS WSO users' was based the latest version of the AWIPS software, v. 8.3. The operating system as upgraded to RedHat Linux Enterprise v. 4.0. This makes the FX-Net servers completely up to date with the NWS WFO AWIPS systems.

--The new version of the FX-Net Client (v.5.2) was released in March 2009. This version of the client includes the addition of significant new data analysis and display tools. Significant research effort was expended adding the high resolution topography maps. Multiple tools and processes were evaluated in order to provide these hi-res map backgrounds and ensure that the overlaid data sets were geophysically accurate.

--The FX-Net team is working on AWIPS II thin client capability evaluations and standing up an AWIPSII Client. The evaluations will result in reports to the NWS AWIPS II program office regarding the AWIPS II existing thin client capability, the gaps in the architecture that need to be addressed to allow a fully functional AWIPS II thin client. The team is also working on transitioning the version control (Subversion) and client build systems (Install Shield) into an integrated system.

--In order to take full advantage of the forecast grids available on the AWIPS II client systems in each GACC office, a tool was developed to allow users to extract a very specific set of surface grids. The Grid Extraction Tool, Web Interfaced (GETWI) allows users to export grids in various formats to enable the data to be used as input to fire potential algorithms and to create graphical fire potential products for the GACC web pages.

--SOS was installed at 16 new permanent public venues, including our first international sites in Korea, Taiwan, Mexico, and France. Our real-time data distribution to existing SOS sites was enhanced with the addition of global model data, a global earthquake visualization, and a new view of the sun from NASA's stereo sun mission. A new remote presence capability called SphereCasting was developed, which allows a presenter to control multiple remote SOS systems across the Internet, with an accompanying video webcast.

--As part of the NNEW project, CIRA developers implemented a THREDDS data server in order to serve up, in real time, several local weather modes to assist collaborating agencies within NNEW for input into their flight paths. THREDDS implements a web coverage service (WCS) as a mechanism for providing data to clients on request. CIRA researchers also developed a JMBL prototype server to serve up MADIS datasets to a JMBL client. The Joint METOC Broker Language (JMBL) defines a web based interface for accessing meteorological and oceanographic data.

--CIRA developers in collaboration with the GSD Information Systems Branch worked on a major transition effort to transfer MADIS to operations. This work involved porting over 15 years worth of code to the new hardware at NCEP, updating outdated software, setting up web access to the data, writing documentation as well as adding new data providers.

--Faster processors and other technological advances have made it possible to routinely create forecast grid ensembles with a large number of members. CIRA researchers have been working with other GSD staff in exploring innovative ways to process and display ensemble data. As part of this activity, CIRA has developed software to store NCEP grids from the Short Range Ensemble Forecasts (SREF) and Global Ensemble Forecast System (GEFS) into the ALPS database and to implement creative approaches to interactively display this data on the ALPS workstation.

--Major changes have been made to the initial GTAS prototype that was deployed to the FEMA offices in the Washington, D.C. area. The ability to display GIS (Geographic Information System) shapefiles has been enhanced significantly to allow the overlay of GIS data, labeling of shapes with specific attributes, disclosing more data as the user zooms in on a particular area, and shapefile layers being aware of shapes in other layers. An updated version of the HYSPLIT dispersion model has been installed and a new interface for the GTAS client defined that allows chemical information to be specified. The first prototype systems were installed at the NWS Southern Region Headquarter in Fort Worth, Texas and the adjacent weather forecast office and Emergency Operations Center.

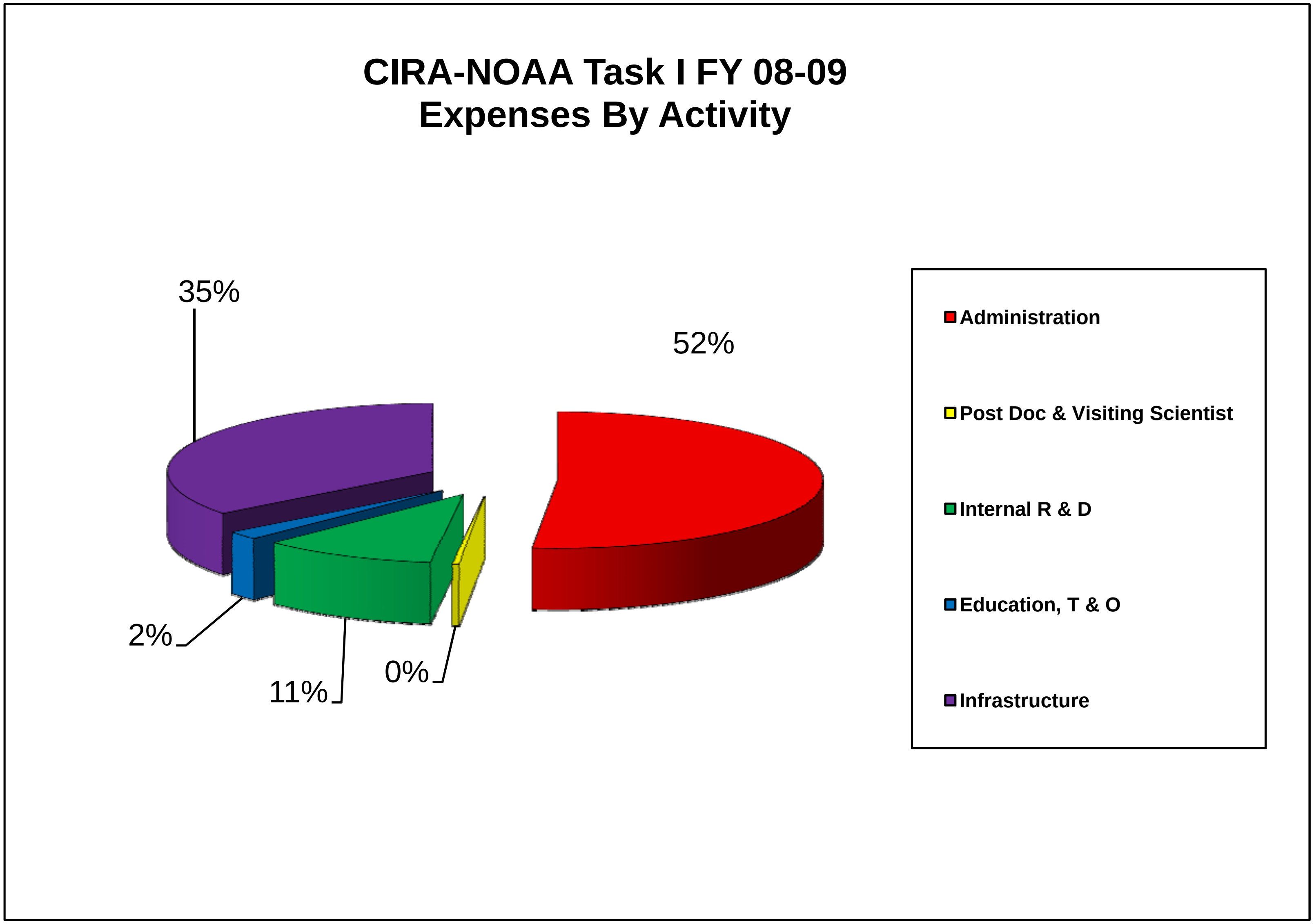
--The AutoNowcast (ANC) prototype is up and running at the FWD WFO and has been for several years now. This year, an updated packages was delivered to the WFO to streamline the tools used by the forecasters to insert boundaries and polygons as well as support the new operational version of AWIPS (OB9.0). In addition the software was installed on all workstations within the office so that any of the forecasters could use the ANC tools as opposed to just the short term forecaster. The complete ANC system also is now running on NWS' hardware at MDL rather than at NCAR.

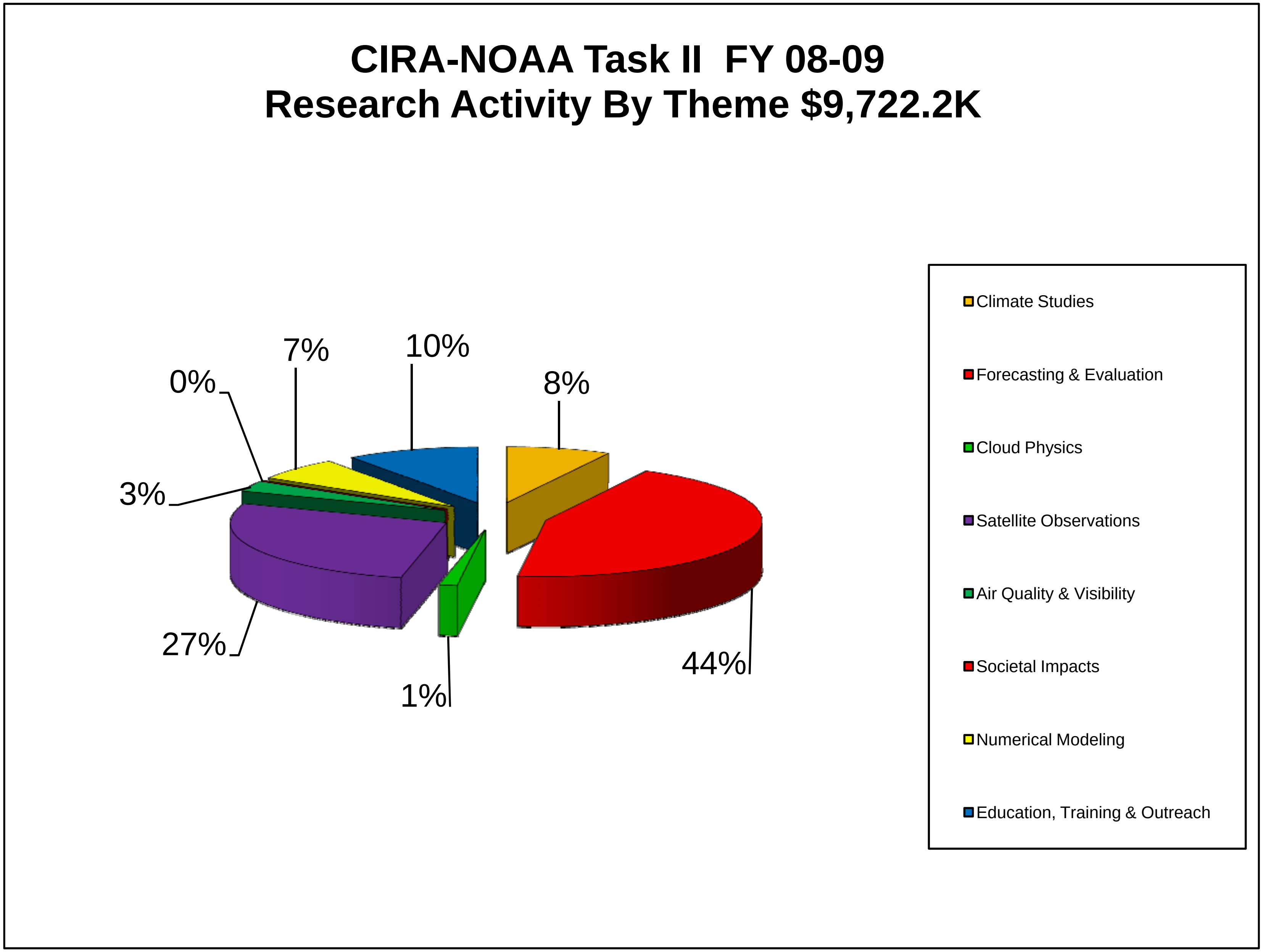
--Effort has begun to map a strategy for Debris Flow Support to provide precipitation gage data from the WFO Hydro Database, which has been specifically requested by USGS researchers. Suggestions have been made on adding Quantitative Precipitation Estimates (QPE) and Quantitative Precipitation Forecast (QPF) data sets to allow USGS Debris Flow models to develop a 'forecast' capability to their existing post-event analysis models. To support the USGS's ability in their analysis of storms which cause Debris Flows, a prototype application was developed to deliver near real-time data using data available from internet accessible databases. This was provided as a quick, partial implementation of the prototype to be installed at LOX (Oxnard) and SGX (San Diego) WFOs.

--CIRA participated in the WMO sponsored Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV that was held for Spanish speaking countries in Argentina, 22 September – 3 October, 2008. The Argentina National Space Agency CONEA hosted the event at the Gulich Institute in the Space Center facility CETT in Cordoba Province. CIRA prepared and delivered lectures focused on the status of GOES/POES, Introduction to Multispectral and Hyperspectral satellite data, VISITview training, and a demo on McIDAS software.

--The Satellite Hydrology and Meteorology (SHyMet) Intern course was offered online. It consisted of 9 modules, including introduction to GOES and POES satellite imagery and data, GOES sounder and high density wind products, and satellite application for severe weather and tropical cyclones. For NOAA individuals, the course was set up for tracking through the e-Learning Management System (LMS). For non-NOAA individuals, the course was offered through online modules and was tracked at CIRA. CIRA also produced 5 modules—Dvorak, cloud climatology, GOES-R, aviation hazards, and volcanic ash hazards—for the SHyMet Forecasters course.

--During the past year, the VISIT team at CIRA developed two new teletraining sessions on “An Overview of Tropical Cyclone Track Guidance Models used by NHC” and “An Overview of Tropical Cyclone Intensity Guidance Models used by NHC”. The VISIT team at CIRA also assisted in the development of two new audio / video playback version training modules covering “ASCAT Winds” and “AWIPS OB9 Blended TPW Products”.


CIRA-NOAA Task I FY 08-09
Expenses By Activity
35%
52%
2%
11%
0%
Administration
Post Doc & Visiting Scientist
Internal R & D
Education, T & O
Infrastructure


CIRA-NOAA Task II FY 08-09
Research Activity By Theme $9,722.2K
0%
7%
10%
8%
3%
27%
1%
44%
Climate Studies
Forecasting & Evaluation
Cloud Physics
Satellite Observations
Air Quality & Visibility
Societal Impacts
Numerical Modeling
Education, Training & Outreach

A GOES-R PROVING GROUND FOR NATIONAL WEATHER SERVICE FORECASTER READINESS

Principal Investigators: Steve Miller and Renate Brummer

NOAA Project Goal: Weather and Water

Key Words: GOES-R, Satellite Product Demonstration, Forecaster

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The next generation GOES environmental satellite systems, beginning with GOES-R, will contain a number of advanced instruments including the Advanced Baseline Imagery (ABI) and the Geostationary Lightning Mapper (GLM). National Weather Service (NWS) forecasters and other users must be introduced to and trained properly on these new capabilities in order to maximize the utility of GOES-R. The goal of our part of the Proving Ground project is to leverage existing capabilities within CIRA to provide this training and experience directly to NWS forecasters through the establishment of a 'Proving Ground' where simulated GOES-R products are demonstrated at NWS Weather Forecast Offices (WFOs) in their AWIPS display systems.

Under other funding sources and in coordination with the Regional and Mesoscale Modeling Branch (RAMMB) of NOAA/NESDIS, the Cooperative Institute for Research in the Atmosphere (CIRA) has set up a local AWIPS and the related Weather Events Simulator (WES), which are the primary data and product display systems utilized by the NWS. We have also established connections with many NWS Weather Forecast Offices (WFOs) and the National Centers for Environmental Prediction (NCEP) through the Virtual Institute for Satellite Integration Training (VISIT) and Satellite Hydrology and Meteorology (SHyMet) training programs, and through research interactions such as algorithm transfer through the Joint Hurricane Testbed (JHT). We also work closely with the NESDIS Satellite Analysis Branch (SAB) on numerous related tasks.

CIRA supports RAMMB in its GOES-R Risk Reduction (GOES-R3) and Algorithm Working Group (AWG) activities. Capabilities to produce GOES-R proxy data sets have been established under these programs. The proxy data are generated in two ways. Synthetic GOES-R data are generated by applying advanced radiative transfer code to numerical model output fields of temperature, moisture, and hydrometeor distributions. Proxy GOES-R data are also represented by existing satellite sensor technology (e.g., MODIS, MSG). In addition to these activities, the CIRA/RAMMB team develops a number of experimental GOES-R multi-sensor products for mesoscale applications including tropical cyclones, severe weather and hazard detection. These proxy data and experimental products will be part of the on-going Proving Ground demonstration material.

In cooperation with the Naval Research Laboratory (NRL) in Monterey, and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated

Program Office (IPO), CIRA participates in the development and near real-time demonstration to the operational community of value added satellite imagery products for the NexSat project (http://www.nrlmry.navy.mil/NEXSAT.html). NexSat applications are geared toward anticipating environmental imaging and detection capabilities of the Visible/Infrared Imager/Radiometer Suite (VIIRS). Some of the NexSat multi-spectral, blended-sensor, and satellite/model-fusion products bear direct relevance to future GOES-R ABI capabilities (via both stand-alone ABI applications and NPOESS/GOES-R blended applications) and, hence, may be leveraged for the Proving Ground demonstration activity.

We will leverage these resident capabilities and ongoing activities in cooperation with complementary work at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), located at the University of Wisconsin-Madison, to formalize the GOES-R Proving Grounds concept; providing demonstrations of GOES-R data and value-added products to the NWS and to other forecasters by way of proxy data sources such as MODIS, IASI, AIRS, MSG and ground-based lightning detection networks.

The NASA Short-term Prediction Research and Transition (SPoRT) Center located in Huntsville, Alabama has developed capabilities for demonstrating Earth Observing System (EOS) data at NWS WFOs. CIRA will coordinate with the SPoRT activities as well as with CIMSS, who have considerable experience in the use of MODIS data and demonstrating satellite products on NWS AWIPS workstations.

2. Research Accommplishments/Highlights:

CIRA established a working rapport and understanding of future cooperation with the NWS offices in Cheyenne, Wyoming and Boulder, Colorado. The CIRA/RAMMB Proving Ground Team (PIs, AWIPS experts) paid initial visits to both offices which allowed for detailed discussions about the Proving Ground mission goals, an initial PG product list, protocols for forecaster feedback and training, and the technical implementation of new products into existing AWIPS workstations. CIRA also had two PG experts participate in the WFO Boulder and WFO Cheyenne's "winter workshops," which gave us the opportunity to hold Proving Ground presentations to all forecasters at the two WFOs. Initial contacts were also established with the WFO Eureka and Monterey, CA. In addition one of CIRA's PIs visited the NCEP Tropical Prediction Center in Miami. Work also began on two new PG products in support of SPC's Proving Ground involvement.

CIRA developed a GOES-R PG web page. Initial developments were conducted on a CIRA-owned webserver. The webpage depicts a list of products with detailed product descriptions as well as a listing of all PG related site visits. The same PG web page structure can be found on the CIMSS-administered PG web site. First steps of combining the two web page products into one PG web page were successfully undertaken. The PG homepage can be viewed at http://cimss.ssec.wisc.edu/goes_r/proving-ground.html

A considerable amount of work was invested into the migration of first prototype PG products into AWIPS. AWIPS experts from NOAA/ESRL/GSD and from the CIMSS PG team shared their expertise with the CIRA/RAMMB team. The result of this support was that the CIRA/RAMMB team was successful with displaying initial PG products on the CIRA-owned AWIPS system and that we successfully installed our first PG product at the AWIPS systems of the WFO Boulder and WFO Cheyenne (Figure 1). Our technical team also attended presentations on the future AWIPS II system in order to be prepared for the upcoming changes.

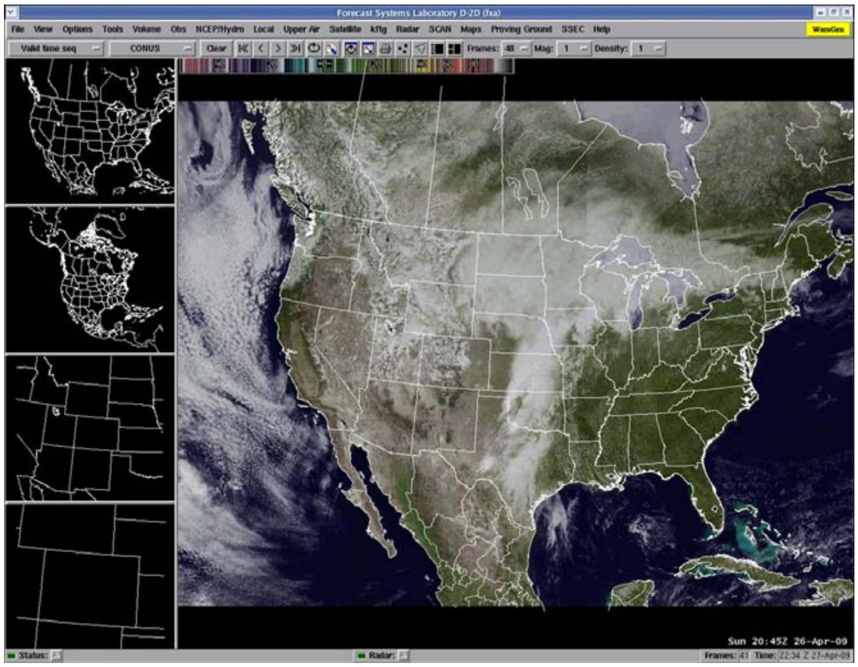


Figure 1. The GeoColor product displayed in AWIPS as part of the CIRA Proving Ground product list. The GeoColor technique blends VIS/IR satellite imagery with MODIS blue marble and OLS backgrounds, and allows for special color enhancement of certain type of clouds. AWIPS workstations at the WFO Boulder and Cheyenne have been modified to display this product.

The entire CIRA/RAMMB PG team participated in the regular GOES-R Proving Ground phone conferences and attended two Annual Meetings in Boulder. Detailed status presentations describing the progress of the CIRA PG tasks were prepared for each of these meetings. CIRA also sent one PG member to the Satellite Workshop held in Fairbanks, AK in July 2008. This workshop allowed for first PG contacts with the Alaska weather service.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

All primary objectives of this research have been accomplished.

4. Leveraging/Payoff:

What NOAA will recieve for resources invested is:

Demonstration of new satellite products to the user community to provide training on new capabilities in order to maximize the utility of GOES-R.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

NOAA/NESDIS, GOES-R Program Office, NWS, NOAA-HQ, CIMSS, SPoRT

6. Awards/Honors: None

7. Outreach:

(a) One undergraduate students is partially supported by this project (Greg DeMaria);
(e) Work on a web site continues to demonstate all Proving Ground products.

Conference proceedings

Gurka, J., A. Mostek, T.J. Schmit, S.D Miller, A. Bachmeier, M. DeMaria, 2009: GOES-R Proving Ground Program. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Miller, S.D.**,** M. DeMaria, D.A. Molenar, D.W. Hillger, E. Szokes, R.L. Brummer**,** A. Kuciauskas, F. Turk, H. Gosden, 2009: Contributions from CIRA to the GOES-R Satellite Proving Ground. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Mostek, A., M. DeMaria, J. Gurka, T.J. Schmit, 2009: NOAA Satellite Training. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Conference presentations

Brummer, R., 2008: CIRA's Plans for the GOES-R Proving Ground. Satellite Workshop in Alaska, Fairbanks, 30 July 2008

Connell, B. traveled to Miami, Florida to present a talk at NOAA's 2008 Satellite Direct Readout Conference (December 8-11). She gave a presentation on "Satellite Training Activities at CIRA." The conference was an excellent venue to find out more information on direct readout capabilities and to meet with international partners.

Knaff, J.A., D.W. Hillger, M. DeMaria, J. Gurka, 2009: Developing GOES-R Tropical Cyclone Products vis Proxies. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL.

Miller, S., 2009: Contributions from CIRA to the Satellite Proving Ground.
16th Conference on Satellite Meteorology and Oceanography, AMS Annual Meeting, Phoenix, January 2009.

Miller, S., 2009: CIRA – Update on GOES-R Proving Ground.
2nd Annual Proving Ground Meeting, Boulder, Colorado, 15 May 2009.

Szoke, E., 2009: An Overview Of The Goes-R Proving Ground: Current Forecaster Interactions And Future Plans. AMS 23rd Conference on Weather Analysis and Forecasting, Omaha, NE, 2-5 June 2009.

8. Publications: None. New Project

A HIGH-RESOLUTION METEOROLOGICAL DISTRIBUTION MODEL FOR ATMOSPHERIC, HYDROLOGIC, AND ECOLOGIC APPLICATIONS

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate - Understand climate variability and change to enhance society's ability to plan and respond

Key Words: Weather, Modeling, Spatial Distribution, Air Temperature, Precipitation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The overall objective of this proposal is to develop a state-of-the-art, physically based, micrometeorological model that can serve as an interface between the relatively coarse-resolution atmospheric models (e.g., 50- to 5-km grid increment) and fine-resolution (e.g., 1-km to 100-m grid increment) hydrological and ecological models. There are currently only limited physically-valid mechanisms (models) available to convert atmospheric forcing data to the sufficiently high spatial resolution required to drive terrestrial models operating at realistic spatial scales. This lack of available high-resolution atmospheric forcing data has hindered the development of spatially- and physically-realistic hydrologic and ecologic models. Evidence of this can be found by looking at the growth of intermediate-scale (e.g., 10-15 km grid increment) land-surface hydrology models over the last 10-15 years. These models have generally had to adopt the atmospheric modeling approach of "parameterizing" the subgrid-scale physics within the (hydrologic) system they are attempting to model.

We are developing a model that will be able to take the available, relatively coarse-resolution atmospheric datasets (observed [e.g., meteorological station observations, radar observations, satellite data], analyzed [e.g., LAPS, RUC, Eta], or modeled), and convert them, in physically realistic ways, to high-resolution forcing data (air temperature, relative humidity, wind speed and direction, incoming solar and longwave radiation, and orographic and convective precipitation). This will lay the groundwork for substantial improvements to existing hydrologic and ecologic models. This need is particularly acute in the western Mountain States where topographic variations lead to significant variations in winter snow precipitation, snow-depth distribution, spring snowmelt, and runoff rates (e.g., changes of over 500% across distances of a few 100 m for some variables). This, in turn, will lead to increased accuracy of operational weather, hydrologic, and water-resource forecasts.

2. Research Accomplishments/Highlights:

In order to meet these objectives we developed a state-of-the-art, physically based, micrometeorological model (MicroMet) that can serve as an interface between the relatively coarse-resolution atmospheric models and fine-resolution hydrological and ecological models. As part of this development we have published papers summarizing its performance.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Develop a state-of-the-art, physically based, micrometeorological model that can serve as an interface between the relatively coarse-resolution atmospheric models and fine-resolution hydrological and ecological models. “Complete.”

Develop a model designed to take the available, relatively coarse-resolution atmospheric datasets and convert them, in physically realistic ways, to high-resolution forcing data (air temperature, relative humidity, wind speed and direction, incoming solar and longwave radiation, and precipitation). “Complete.”

Use our high-resolution atmospheric forcing fields to drive the SnowModel terrestrial snow-evolution model over the west-central United States, Cold Land Processes Experiment (CLPX) and other study domains. “Complete.”

4. Leveraging/Payoff:

Our improved, high-resolution atmospheric modeling system is expected to lead to improved local weather and hydrologic forecasts, and improved understanding of, and the ability to simulate, the spatial variability of atmospheric and hydrologic processes and features.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

As part of our model development and testing, we have been collaborating with NOAA’s Forecast Systems Laboratory (FSL), Local Analysis and Prediction System (LAPS) personnel and the associated (LAPS) datasets.

6. Awards/Honors: None

7. Outreach:

<u>Conference and Meeting Presentations</u>

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Determining solid precipitation on Alaska's Arctic Slope. XXIV General Assembly of the International Union of Geodesy and Geophysics, 2 13 July, Perugia, Italy.

Hiemstra, C. A., and G. E. Liston, 2007: Using high-resolution atmospheric and snow modeling tools to define spatially-variable snow distributions. North American Mountain Hydroclimate Workshop, 17-19 October, Boulder, Colorado.

Liston, G. E., and C. A. Hiemstra, 2007: Using high-resolution atmospheric and snow modeling tools to define spatially-variable snow distributions. International Symposium on Snow Science, 3-7 September, Moscow, Russia.

Liston, G. E., C. A. Hiemstra, S. Berezovskaya, S. H. Mernild, and M. Sturm, 2007: Using high-resolution atmospheric and snow modeling tools to define pan-arctic spatial and temporal snow-related variations. Proceedings of the 16th Northern Research Basins International Symposium and Workshop, 27 August -2 September, Petrozavodsk, Russia.

8. Publications:

Liston, G. E., D. L. Birkenheuer, C. A. Hiemstra, D. W. Cline, and K. Elder, 2008: NASA Cold Land Processes Experiment (CLPX): Atmospheric analyses datasets. J. Hydrometeorology, 9, 952-956.

Liston, G. E., R. B. Haehnel, M. Sturm, C. A. Hiemstra, S. Berezovskaya, and R. D. Tabler, 2007: Simulating complex snow distributions in windy environments using SnowTran-3D. Journal of Glaciology, 53, 241-256.

Liston, G. E., and C. A. Hiemstra, 2008: A simple data assimilation system for complex snow distributions (SnowAssim). J. Hydrometeorology, 9, 989-1004.

Liston, G. E., C. A. Hiemstra, K. Elder, and D. W. Cline, 2008: Meso-cell study area (MSA) snow distributions for the Cold Land Processes Experiment (CLPX). J. Hydrometeorology, 9, 957-976.

ADVANCED ENVIRONMENTAL SATELLITE RESEARCH SUPPORT

Principal Investigator: Jim Purdom and Tom Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: Satellites, Global Observing System, Education and Outreach, International Cooperation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Five major objectives of this activity are:
1) Advancing more comprehensive utilization of satellite data;

2) Undertake portions of the research with this activity in a cooperative manner with national and international science groups;

3) Develop science requirements to help identify the role of satellites, both research and operational, within a Global Earth Observing System context;

4) Identify appropriate uses of satellite data for atmospheric and environmental applications based on four cornerstones of space-based remote sensing: resolution in the spatial, temporal, spectral and radiometric domains; and,

5) Research results will be applied to expand the use of environmental satellite data through training programs and lectures in national and international arenas.

2. Research Accomplishments/Highlights:

Leading WMO in addressing Integrated Observing Systems, including the role of satellites in the redesign and evolution of the Global Observing System.

WMO Integrated Observing Systems Planning and Implementation

Addressing merging of various WMO Observing Systems into a composite system (i.e., CBS, AREP, WyCOS, etc.)

CBS Management Group

Work plan and achievements within OPAG-IOS addressed; coordinated with other CBS MG leaders on future activities

WMO Global Satellite Optimization Workshop

Represented WMO OPAG IOS interest and chaired international teleconference for ½ day portion of NRC panel on NPOESS and GOES-R mitigation

As chair OPAG-IOS advised joint meeting of ET-SAT and ET-SUP, and ET-EGOS

World Meteorological Organization (WMO) Congress and Executive Council

Advisor to NOAA DAA and US Permanent representative to WMO

Advisor and US expert on WMO CBS Observing System Activity and WMO Integrated Observing System (WIGOS) developments

Advisor and US expert on Satellite Activities

NRC Panel on a National Mesoscale Observing Network

Advise as satellite observing system capabilities and utilization expert, as well as International Observing System capabilities expert to panel

NRC Panel mitigation of removal of climate sensors from NPOESS and GOES-R

Provide input from International perspective as well as expertise on geostationary hyperspectral data

THORPEX activity includes setting goals and objectives for both space-based and in-situ observing systems to support THORPEX

THORPEX International Core Steering Committee

Expert addressing satellite related activity as well as CGMS Rapporteur to ICSC

Co-chaired THORPEX Observing System Working Group

GOES-R Risk Reduction Technical Advisory Committee and GOES-R Technical Advisory Committee and GOES-IM Product Assurance Plan Technical Advisory Committee

Major focus is on uses of satellite data for atmospheric and environmental applications based on four cornerstones of space-based remote sensing: resolution in the spatial, temporal, spectral and radiometric domains.

Provided input on GOES-R requirements based on past experience, GOS needs, and user needs (workshop on spectral coverage, three GOES configuration strategy, HES spectral coverage options, synergy with hyperspectral polar sounders and GPS OS).

Helped to configure GOES R^3 and GOES-R AWG plans and participated in startup of both programs.

Virtual Laboratory for Satellite Data Utilization

Co-chaired five year assessment of activity within VL Management Group

Planning for future Virtual Lab activity

Planning for Earth Observing Partnership for the Americas (EOPA), renamed GEOSS Americas

Inaugural meeting on move of GOES to 60 West and planning meeting with CONAE

Planning for future Regional High Profile Training Event in the America's to assure full utilization through GEOSS Americas

Coordination Group for Meteorological Satellites (CGMS)

Virtual Lab Focus Group Report to CGMS

International Precipitation Working Group Report to CGMS

THORPEX Report to CGMS

Satellite Meteorology Subject matter Expert (SME) for Bulletin of American Meteorological Society

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

1) All activity in Sections 2, 5, 7 and 8 of this report focus on this objective.

2) See Section 5 below for the extensive activity in this area.

3) This is done within the OPAG-IOS activities.

4) Activity within the THORPEX program to optimize the use of observations for its field programs.

5) Activity within the Virtual Laboratory as well as numerous lectures at both National and International science meetings.

4. Leveraging/Payoff:

The research undertaken within this program is helping lead to the evolution of the global observing system (GOS), assuring an optimal mix of the surface and space based sub-systems of the GOS. Training and outreach activities are undertaken to assure high level utilization of space based earth observing data.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Chair, World Meteorological Organization (WMO) Open Program Area Group on the Integrated Observing System (OPAG IOS)

Co-Chair, WMO/CGMS Virtual Laboratory for Satellite Data Utilization and Training

Co-Chair, Joint Center for Satellite Data Utilization Advisory Board

Co-Chair, THORPEX Observation Systems Working Group

Rapporteur of the International Precipitation Working Group to the Coordination Group for Meteorological Satellites

Rapporteur of the CGMS to the THORPEX International Science Steering Committee

Advisor to General Kelly, U.S. Permanent representative WMO at WMO Executive Council

Advisor to Mr. John Jones, Deputy AA NWS, at WMO Commission on Basic Systems Extraordinary Session

Member WMO Commission on Basic Systems Management Group

Member GOES I/M Technical Advisory Committee

Member GOES R Risk Reduction Technical Advisory Committee

Member THORPEX Executive Board

Member NRC panel on Establishing a National Multipurpose Mesoscale Observations Network

Member NRC panel on NPOESS and GOES-R mitigation

Phase 1: Workshop to address decadal study

Phase 2: Recommendations from workshop

6. Awards/Honors: None

7. Outreach:

Presentations at Workshops and Conferences

EUMETSAT and AMS Joint Conference, Amsterdam, September, 24-28
Invited Presentation “Focus on training: The Global High Profile Training Event (HPTE)
Poster “Formation Flying: toward a robust polar orbiting satellite observing system”
Chair, Special Session honoring the achievements of Dr. W. P. Menzel

Chinese Meteorological Administration and National Satellite Meteorological Center, July 28 – August 9

Lectures and workshops provided to students on satellite data utilization

Detailed discussions on Chinese plans for future polar and geostationary satellite system capabilities and utilization

Presented four lectures to live audience that were recorded for future telecast, as well as a lecture on Severe Weather that was broadcast live to all CMA Offices across China (over 2000 CMA people);

Special lecture to all CMA and Administrators on Polar and Geostationary Satellite System Synergy … Relationship to GEOSS Spectral Bands and Their Applications Severe Weather and Heavy Rainfall Satellite Capabilities and Use of the Virtual Laboratory Polar and Geostationary Satellite System Synergy: Toward Optimum Utilization and Relationship to GEOSS

8. Publications:

Hinsman, D. and J. F.W. Purdom, 2007: Chapter 44 "The Space-Based Component of the World Weather Watch's Global Observing System (GOS)." *Measuring Precipitation from Space: EURAINSAT and the Future*, Levizzanni, Bauer and Turk, eds., Advances in Global Change Research 28, Springer, 2007, ISBN-13 978-I-4020-5834-9 (HB), 722 pp.

Purdom, J.F.W., 2007: Environmental Satellites. *Handbook on Weather, Climate, and water: Dynamics, Physical Meteorology, Weather Systems, and Measurements, 2nd, edition,* T.D. Potter and B. R. Colman, eds., Wiley Press.

Purdom, J.F.W. and D. Hinsman, 2007: Chapter 51 "The CGMS/WMO Virtual Laboratory for Education and Training in Satellite Matters." *Measuring Precipitation from Space: EURAINSAT and the Future*, Levizzanni, Bauer and Turk, eds., Advances in Global Change Research 28, Springer, 2007, ISBN-13 978-I-4020-5834-9 (HB), 722 pp.

ADVANCED VERIFICATION TECHNIQUES FOR THE HURRICANE WEATHER RESEARCH AND FORECAST (HWRF) MODEL

Principal Investigator: Wayne H. Schubert

NOAA Project Goal: Weather and Water

Key Words: Hurricanes, Numerical Models, Budget Studies

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The National Hurricane Center (NHC) in Miami performs an annual verification of their tropical cyclone track and intensity forecasts and those from the guidance models they utilize. The track metric is the great circle distance between the forecast storm position and the observed storm position out to 5 days. The intensity metric is the absolute difference between the forecast maximum sustained surface winds and the observed maximum wind. Although the NHC metrics are useful for monitoring trends in forecast improvements, they provide little insight into the reasons behind the errors. In this project three advanced verification techniques for the Hurricane Weather Research and Forecast (HWRF) model will be developed that will provide additional information on the underlying causes of the model intensity and track errors. These procedures include an analysis of the response of the model storm to environmental vertical wind shear relative to long-term statistical relationships, an evaluation of the tropical cyclone wind structure forecast using flight level aircraft reconnaissance data, and an evaluation of the model environment forecast by comparison with GOES water vapor imagery.

2. Research Accomplishments/Highlights:

Output from the operational HWRF model runs for Atlantic and east Pacific tropical cyclones were collected during the 2008 hurricane season. Code was written to routinely diagnose the forecasted vertical shear, sea surface temperature and land interaction. A statistical study was carried which revealed HWRF biases, and the close relationship between the track and intensity errors. Results also showed that the HWRF model tropical cyclones are more sensitive to vertical wind shear forcing than observed storms. The results also suggest that the relationship between thermodynamic factors and the maximum storm intensity in the HWRF model is somewhat different than observed relationships. This may be related to the model resolution and diffusion formulation.

Data were also collected during the 2008 season so that the model results can be compared to aircraft observations and satellite data. These verification tasks will continue.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The first of the three tasks in the project was accomplished during the 2008 hurricane center and results were presented at a workshop in Miami (see item 7b below). The data for the second two tasks were collected during the 2008 season, and new cases are being collected in 2009. The comparison of the model fields with the *in situ* and satellite data is on schedule.

4. Leveraging/Payoff:

This research has a direct connection to the public interest. The advanced verification and diagnostic techniques will provide hurricane model developers insight into the causes of forecast errors and guidance on methods for improvements. More accurate hurricane track and intensity errors will lead to more timely warnings which will assist with mitigation activities.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

This project is part of the much larger NOAA Hurricane Forecast Improvement Program (HFIP) to improve hurricane forecast models. This work is being coordinated with several other groups within NOAA, other universities and the Naval Research Laboratory through participation in scientific conferences and workshops, and frequent conference calls.

6. Awards/Honors: None

7. Outreach:

(a) Katherine Maclay (PhD candidate in the Department of Atmospheric Science) is contributing to this research; Gregory DeMaria (CSU undergraduate) is providing data processing and web page support.

(b) Results from this study were presented at the First Hurricane Diagnostics Workshop at the National Hurricane Center, Miami, Florida in May 2009 (see http://rammb.cira.colostate.edu/research/tropical_cyclones/hfip/workshop_2009)

8. Publications:

Maclay, K.S., M. DeMaria and T.H. Vonder Haar, 2008: Tropical cyclone inner core kinetic energy evolution. *Mon. Wea. Rev*., 136, 4882-4898.

AN IMPROVED WIND PROBABILITY ESTIMATION PROGRAM

Principal Investigator: Stanley Q. Kidder

NOAA Project Goal: Weather and Water

Key Words: Tropical Cyclones, Hurricanes, Typhoons, Wind Speed, Probabilities

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Under previous JHT support a new program for estimating the probability of occurrence of 34, 50 and 64 kt winds was developed. A Monte Carlo (MC) method was utilized to combine the uncertainty in the track, intensity and wind structure forecasts.

This year, three improvements to the existing MC model are proposed:

Topic1: The MC wind probability estimates will be refined by making the underlying track error distributions a function of the forecast uncertainty. The current MC model uses basin-wide error statistics but recent research has shown that the spread of track forecasts from various models can provide information about the expected track error. J. Goerss from NRL developed a real-time tool to quantitatively estimate the track forecast uncertainty (the Goerss Predicted Consensus Error, GPCE), which will be incorporated into the MC model.

Topic 2: The timeliness of the MC model will be improved by optimizing and modifying the code.

Topic 3: The code that calculates the track and intensity error distributions for the MC model will be generalized to also update the “stand-alone” intensity probability product utilized by NHC. This product is provided in real time as the “wind speed probability table” on the NHC web site, and was developed from data from 1988-1997. The current version of this product only extends to 72 h even though the NHC official forecasts were extended to 120 h in 2003.

2. Research Accommmplishments/Highlights:

Topic 2 was completed early in the project year. This improvement resulted in a speed-up by a factor of six of the MC model code.

The code that calculates the track and intensity error distributions for the MC model was generalized to also update the “stand-alone” intensity probability product utilized by NHC (Topic 3). After successful testing and evaluation, the final task was to provide NHC with a modified version of the code that returned all of the information for the wind speed probability table. This code was provided to C. Lauer from NHC prior to the start of the 2008 Hurricane Season, and was run for the entire 2008 season.

The remaining task was to make the track error distributions in the MC model a function of the forecast uncertainty through the GPCE parameter. A method to stratify the NHC track errors by the GPCE parameter was developed earlier on and it was confirmed that the distributions have a well-behaved dependence, with wider distributions for the larger GPCE values. This initial analysis was performed with the 2002-2006 sample used in the 2007 MC model. For the 2008 testing, the track error distributions for the 2003-2007 sample were stratified in a similar manner, with similar results.

Originally, it was proposed to run a parallel version of the MC model beginning in August of 2008. However, during a visit to NHC in July of 2008, it was determined that it was not feasible to modify the MC model processing during the hurricane season, so an alternate evaluation plan was developed in coordination with the NHC project focal points (Chris Lauer and Dan Brown). The new plan was to re-run all 2008 cases within 1000 km of land after the season so the probabilities from the operational and GPCE versions of the model can be compared.

This evaluation included both qualitative and quantitative components. For the qualitative comparison, a web site was developed to display the probabilities over a large domain, similar to that used in the graphical products on the NHC web page (see http://rammb.cira.colostate.edu/research/tropical_cyclones/tc_wind_prob/gpce.asp). This web page also lists the cases that were used in the evaluation (156 cases from 10 storms from the 2008 Atlantic season). To facilitate the comparison, the MC model was run on a 0.25 degree latitude/longitude grid, rather than the 0.5 degree grid used for the NHC products.

For the quantitative comparison of the operational and GPCE versions of the model, the 156 Atlantic cases were also run for the coastal breakpoints utilized used in the NHC operational text product. This allowed an evaluation for those cases most relevant to U.S. watches and warnings, and over a more focused region. Results showed that the GPCE version of the probability model improved the skill as measured by both a Brier Score and a threat score. The final step in this project is to perform some additional tests on eastern and western North Pacific cases.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

All proposed tasks are on schedule.

4. Leveraging/Payoff:

This project has a direct connection with the public interest. Coastal evacuations and other preparations for tropical cyclones are extremely expensive. The new GPCE-modified probability program will provide an improved quantitative measure of the risk of various wind thresholds in both graphical and tabular form. The increases in efficency will also enable more timely and accurate forecast information.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

This research is a joint effort between several groups within NOAA and the university community, including the NOAA/NESDIS Office of Research and Applications, the NOAA/NCEP TPC, and Colorado State University.

6. Awards/Honors: None

7. Outreach:

(a) Gregory DeMaria (CSU Undergraduate student) is partially supported by this project.

<u>Conference proceedings</u>

Santos, P., D. Sharp, M. DeMaria, S. Kiser, 2009: The Determination of Optimal Thresholds of Tropical Cyclone Incremental Wind Speed Probabilities to Support Expressions of Uncertainty in Text Forecasts. *AMS Symposium on Urban High Impact Weather,* 11-15 January, Phoenix, AZ.

<u>Conference presentations</u>

DeMaria, M., S. Kidder, C. Sampson, J.A. Knaff, C. Lauer, and C. Sisko, 2009: An Improved Wind Probability Program: A Year 2 Joint Hurricane Testbed Project Update. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL

Schumacher, A. gave a presentation entitled "Development of Probabilistic Forecast Guidance at CIRA" at a *Workshop on AWIPS Tools for Probabilistic Forecasting*. 22-24 October 2008, ESRL/Global Systems Divisions, Boulder, CO.

Schumacher, A. presented "An Overview of Research to Operations Activities at CIRA for 2008/2009" at the *National Hurricane Center Invited Seminar*. 10 October 2008, Miami, FL.

Schumacher, A.B., M. DeMaria, D. Brown, and E. Rappaport, 2009: Applications of the National Hurricane Center Tropical Cyclone Wind Speed Probability Product to Quantifying Potential Impacts of Hurricane Forecast Improvements. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL.

8. Publications: None

ANALYSIS OF CLOUDS, RADIATION AND AEROSOLS FROM SURFACE MEASUREMENTS AND MODELING STUDIES

Principal Investigator: Shelby Frisch

NOAA Project Goal: Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate observations and analysis (US. SEARCH Program—Studies of Environmental Arctic Change)

Key Words: Clouds, Radiation, Aerosols

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The effect of aerosols on cloud microphysical and radiative properties (the indirect effect") has the greatest uncertainty of all known climate forcing mechanisms. Increases in aerosol concentrations result in higher concentrations of cloud condensation nuclei (CCN), increased cloud droplet concentrations, and smaller droplet sizes. A possible secondary effect is the suppression of rainfall. Together, these effects generate more reflective clouds which, in theory, create a radiative forcing estimated on the global scale to range from 0.0 Wm-2 to -4.8 Wm-2.

While there is ample evidence that an increase in aerosol tends to decrease cloud drop size and increase cloud reflectance, many questions remain concerning the degree to which this occurs, the most important controlling parameters, and the measurement requirements for these parameters. For example, although the concept of the first indirect effect posed by Twomey (1974) clearly states that the comparison be made between clouds having the same liquid water content, many studies have ignored this requirement. Therefore, it is unclear whether drop sizes are smaller because of higher CCN concentrations or because of lower condensed water (Schwartz et al., 2002). Other important questions include the relative importance of cloud dynamics (particularly updraft velocity), aerosol composition, and aerosol size distribution (Feingold, 2003). Although it is clear that aerosol effects on clouds extend to cloud lifetime, precipitation (Warner, 1968; Albrecht, 1989), and cloud dynamics, an understanding of the magnitude of the first indirect effect is in and of itself a worthy goal.

References utilized:

Albrecht, B.A., 1989: Aerosols, cloud microphysics, and fractional cloudiness, *Science,* 245, 1227-1230.

Feingold, G. 2003: Modeling of the first indirect effect: Analysis of measurement requirements. *Geophys. Res. Letters, 30*, 1029-1033.

Ferrare, R., and 10 coauthors: Evaluation of daytime measurements of aerosols and water vapor made by an operational Raman lidar over the Southern Great Plains. In review, *J. Geophys. Res.*

Schwartz, S. E., Harshvardhan, and C. M. Benkovitz, 2002: Influence of anthropogenic aerosol on cloud optical properties and albedo shown by satellite measurements and chemical transport modeling. *Proceedings, Natl. Acad. Sci*., 99, 1784-1789, 2002.

Twomey, S., 1974: Pollution and the planetary albedo. *Atmos. Environ*., 8, 1251-1256.

Twomey, S., 1977: The influence of pollution on the short wave albedo of clouds. J. Atmos. Sci., 34, 1149-1152.

Warner, J., 1968: A reduction in rainfall associated with smoke from sugar-cane fires: An inadvertent weather modification? *J. Appl. Meteorol*., 7, 247-251.

2. Research Accomplishments/Highlights:

We have set up a synchronized data set of pertinent cloud and aerosol microphysical properties at a temporal resolution of 20s. Aerosol fields measured at coarser temporal resolution have been interpolated to 20s recognizing that aerosol temporal changes are much slower than cloud temporal changes. We demonstrate that although the various measures of aerosol effects on cloud microphysics are consistent, they are likely too low. This inference is based on theoretical analysis of cloud modeling (Feingold 2003). Radiative transfer modeling also demonstrates that uncertainties in these measures will translate to large uncertainties in radiative forcing estimates. This is a continuation of our study with the data from Pt. Reyes, CA.

In addition to a Department of Energy presentation on “Measures of aerosol-cloud interactions and their uncertainties: A case study from the AMF Pt. Reyes deployment” described in last year’s Annual Report, a JGR journal publication (see item 8) and a conference poster presented at a March 2009 DOE/ARM meeting (see Fig. 1) provide results from this study.

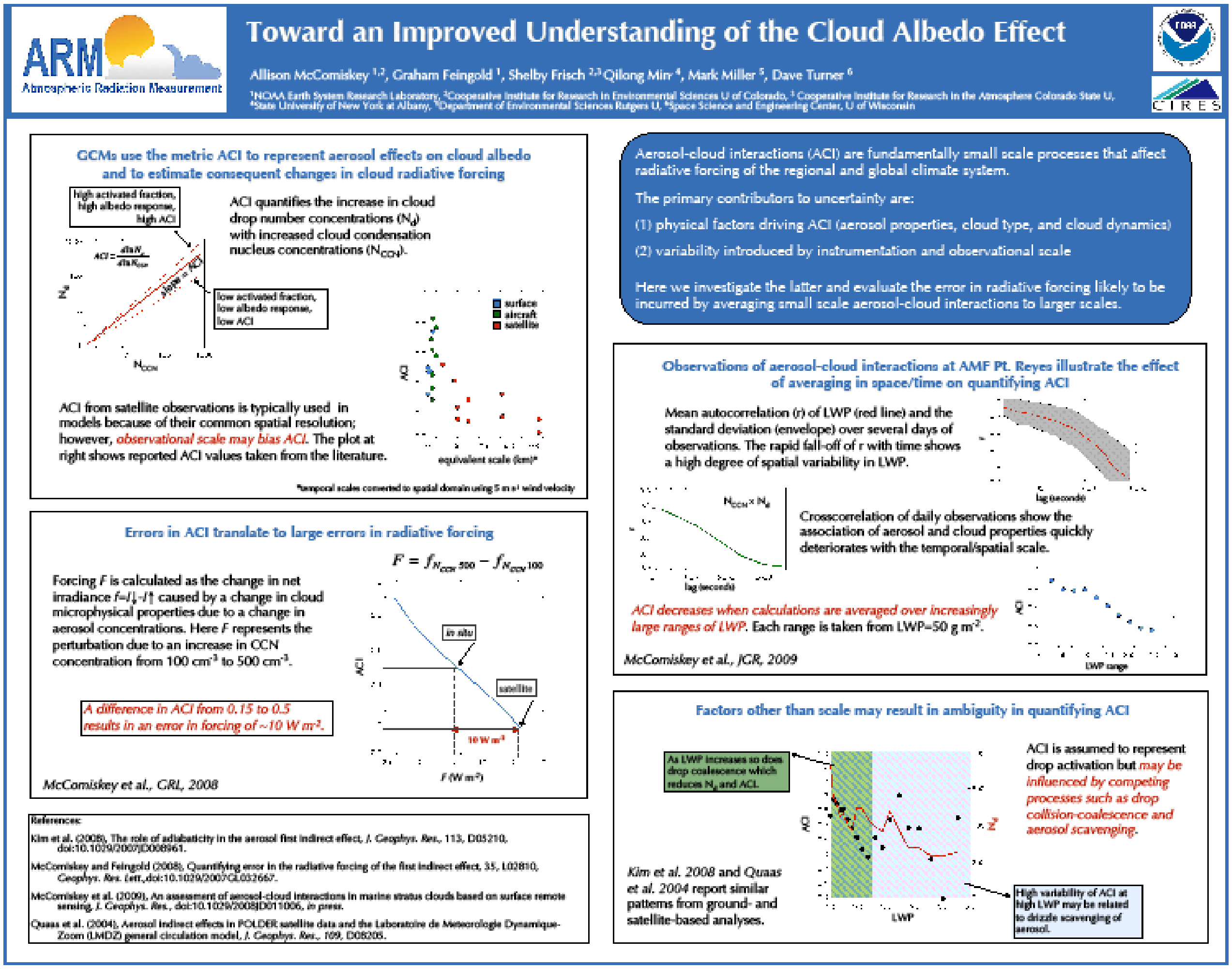


Fig. 1. DOE/ARM Conference Poster Presentation on an Improved Understanding of the Cloud Albedo Effect

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Completed. Funding for this project has ended.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

McComiskey, A.M., G. Feingold. A.S. Frisch, D.D. Turner, M.A. Miller, J.C. Chiu, Q. Min, and J. A. Ogren, 2009: An assessment of aerosol-cloud interactions in marine stratus clouds based on surface remote sensing. \it J. Geophys. Res., \bf 114, \rm D09203, doi:10.1029/2008JD011006.

ANALYSIS OF SIMULATED RADIANCE FIELDS FOR GOES-R ABI BANDS FOR MESOSCALE WEATHER AND HAZARD EVENTS

Principal Investigators: Manajit Sengupta and Lewis Grasso

NOAA Project Goal: Weather and Water

Key Words: AWG, GOES-R, Proxy Data, Algorithm Development

1. Long Term Research Objectives And Specific Plans To Achieve Them:

The goal of this project is the development of GOES-R proxy data for mesoscale weather and hazard events using a sophisticated cloud model and accurate radiative transfer modeling. ABI radiances are being provided for different case studies, along with the model fields for “ground truth”.

Under the GOES-R Risk Reduction Project, CIRA has developed the capability to produce radiance fields for GOES-R ABI bands using mesoscale model output. The procedure has been successfully applied to develop synthetic imagery for different types of mesoscale weather events like lake effect snow, severe weather, and hurricanes.

High quality simulations of satellite radiance provide one of the best ways of testing prototype algorithms for future sensors. These simulations have the advantage of providing ground truth that can be used to verify algorithm performance. It is therefore anticipated that the simulations will provide the necessary proxy data to the fire, wind and cloud algorithm groups for testing proposed algorithms. Therefore, the high-quality dataset provided by CIRA will lead to better algorithm selection, algorithm refinement as well as faster implementation after launch.

2. Research Accommmplishments/Highlights:

The GOES-R proxy data for mesoscale weather and hazard events were produced using the CSU RAMS mesoscale forecast model which has unique capabilities for producing cloud properties for various weather events. This past year we focused on the creation of Advanced Baseline Imager (ABI) radiances for different fire proxy datasets along with the model fields for “ground truth”. In addition to the binary forecast fields and radiance and brightness ASCII and NetCDF datasets, (McIDAS) AREA files, GIF imagery and GIF animation were created for visualization purposes.

GOES-R ABI fire proxy datasets were produced for a case of agricultural fires in Central America (April 2004) and for two Southern California wild fire days which occurred on the 23rd and 26th of October 2007. Information regarding the fire location and fire temperature was taken from a CIMSS dataset (ABBA retrieval based on GOES-11 images).

To create the synthetic fire proxy datasets, 6-hour RAMS forecast were produced at 400 m spatial resolution and at an interval of every 5 minutes. Forward radiative transfer calculations were used to produce model-based synthetic imagery. Then, ABI satellite footprints were created by applying an ABI wavelength-specific point spread function considering the actual ABI footprint for the area of Southern California. The resulting proxy datasets are simulating the ABI spatial (2 km in equatorial areas) and temporal (5 min) resolution. The same procedure was applied to also simulate current GOES imagery, which allows for comparison of the current and future (ABI) imager. An example of this comparison can be seen in Figure 1, which is based on our case study of the Southern California wildfires from 23 October 2007 at 18:50 UTC. On the left is a synthetically produced GOES-11 image for the 3.9 µm band. The right figure depicts the corresponding synthetic GOES-R ABI satellite image also at 3.9 µm.

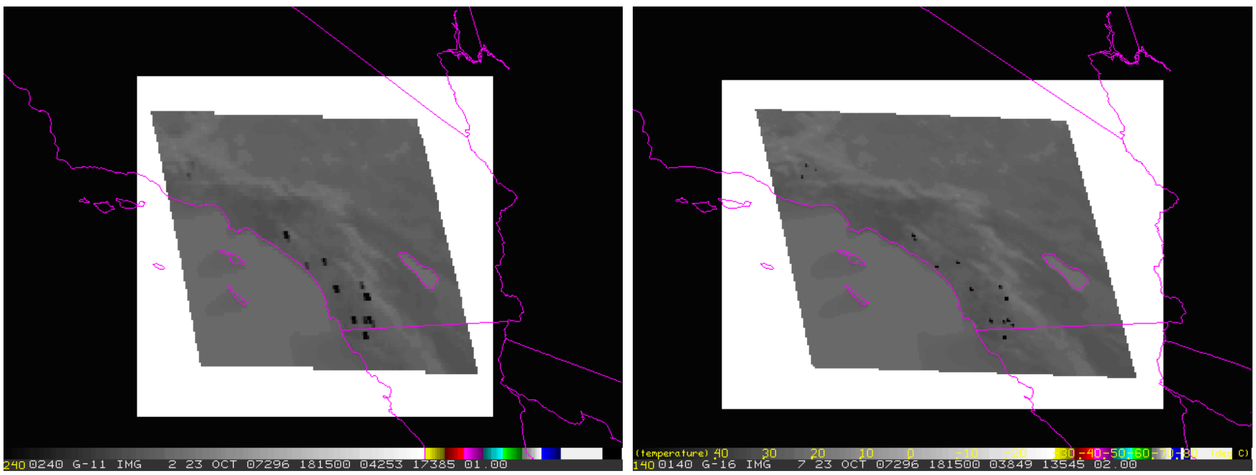


Figure 1. Fires in Southern California on 23 October 2005 at 18:50 UTC.
Left: GOES-11 (GOES-west) Imager band-2 (3.9 µm)
Right: GOES-R (at GOES-west location) ABI band-7 (3.9 µm)

Figure 1 emphasizes the advantage of the higher resolution of GOES-R ABI (depicted on the right) over the current GOES-11 imager (depicted on the left). The increase in spatial, temporal and spectral resolution should lead to improved fire retrieval algorithms (for retrieval of fire size and fire temperature).

All GOES-R ABI fire proxy datasets were produced for 6-hour time periods at 5 min time intervals for three different ABI wavelengths, 3.9 µm, 10.35 µm, and 11.2 µm. For the Southern California case, which occurred on 23rd of October 2007, we produced an additional proxy dataset for the band 2.25 µm. Synthetic datasets for current GOES imagers were produced at 3.9 µm and 10.7 µm. Many more technical details regarding the production of this synthetic imagery can be found in Grasso et al. 2008.

The goal of these studies is to provide a variety of simulated fire hot spot scenarios along with synthetic GOES-R ABI imagery to support the development of ABI fire retrieval algorithms. The synthetic imagery is also being used for ABI fire detection

uncertainty studies. GIF animations of CIRA's synthetic GOES-R ABI imagery, synthetic GOES-11/12 imagery, and satellite observational data can be viewed on the RAMMB GOES-R Case Study Database at:
http://rammb.cira.colostate.edu/research/goes-r_studies/administrative/GOESR_IPO_case_study_database.html

3. Comparison of Objectives Vs. Actual Accomplishments For Reporting Period:

All primary objectives of this research have been accomplished.

4. Leveraging/Payoff:

What NOAA will recieve for resources invested is:
Advanced algorithm development for mesoscale weather events and fires.
Extended operational use of the GOES-R satellite

5. Research Linkages/Partnerships/Collaborators, Communication And Networking:

NOAA/NESDIS, CIMSS, NASA/JPL

6. Awards/Honors: None

7. Outreach:

(a) Four undergraduate students are partially supported by this project (Daniel Coleman, Kashia Jekel, Greg DeMaria, Molly McClurg).
(b) see Section 8
(c) none
(d) Louie Grasso spoke about environmental satellites to a first grade class at Bauder Elementary.
(e) Work on a web site continues to illustrate the utlility of GOES-R proxy data.

Presentations

D. Lindsey gave a talk entitled "Wildfire-Induced Thunderstorms: Observations and Possible Climate Impacts" at both a CIRA Special Seminar, and at the University of Georgia's Geography Department the week of March 20, 2009.

Knaff, J.A., D.W. Hillger, M. DeMaria, J. Gurka, 2009: Developing GOES-R Tropical Cyclone Products vis Proxies. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL.

8. Publications:

Refereed Publications

Grasso, L. and D. Lindsey, 2009: An Example of the use of Synthetic 3.9 μm GOES-12 Imagery for Two-Moment Microphysical Evaluation. *International Journal of Remote Sensing*.

Grasso, L., M. Sengupta, and M. DeMaria, 2009: Comparison between Observed and Synthetic 6.5 and 10.7 μm GOES-12 Imagery of Thunderstorms." *International Journal of Remote Sensing.* In press.

Grasso, L.D., M. Sengupta, J. Dostalek, R.L. Brummer, and M. DeMaria, 2008: Synthetic Satellite Imagery for Current and Future Environmental Satellites. *International Journal of Remote Sensing*, 29, Issue 15, 4373-4384.

Zupanski D., M. Zupanski, L. Grasso, R. Brummer, I. Jankov, D. Lindsey, M. Sengupta and M. DeMaria, 2009: Assimilating synthetic GOES-R radiances in cloudy conditions using an ensemble-based method. Submitted to *International Journal of Remote Sensing*. Accepted.

Conference Proceedings

Brummer, R.L., M. Sengupta, L. Grasso, D. Hillger, D. Lindsey, R. DeMaria, and M. DeMaria: 2009: Synthetic satellite datasets for GOES-R ABI Bands. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Grasso, L.D., M. Sengupta, R.L. Brummer, R. DeMaria, and D.W. Hillger, 2009: Synthetic GOES-R imagery of fires at 3.9 μm. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Hillger, D.W., M. DeMaria, and R.L. Brummer, 2009: GOES-R ABI product development. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Sengupta, M., L.D. Grasso, R.L. Brummer, and D.W. Hillger, 2009: Improving fire detection: Current GOES to GOES-R. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Informal Publications

Grasso, L.D., M. Sengupta, D.W. Hillger, and R.L. Brummer, 2008**:** GOES-R Synthetic Imagery and Fire Detection, *CIRA Newsletter*, 30, Fall 2008, 1-3.

APPLICATIONS OF SATELLITE ALTIMETRY DATA TO STATISTICAL AND SIMPLIFIED DYNAMICAL TROPICAL CYCLONE INTENSITY FORECAST MODELS

Principal Investigator: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: Tropical Cyclones, Hurricanes, Intensity Forecasting, Satellite Altimetery, Ocean Heat Content, Sea Surface Height

1. Long-term Research Objectives And Specific Plans To Achieve Them:

CIRA's role in this project is to evaluate and improve the impact of satellite altimetry in statistical tropical cyclone intensity models and to assist with the validation of the satellite-based ocean heat content (OHC) estimates that are utilized by the statistical models.

In the FY06, CIRA worked with the Naval Research Laboratory in Monterey to assess the impact of the OHC input is the Statistical Typhoon Intensity Prediction Scheme (STIPS) that is run operationally for the Joint Typhoon Warning Center in Honolulu. To increase the sample size these forecasts were continued in FY07. In FY08, the impact of the OHC was evaluated on Atlantic tropical cyclone forecasts from the Statistical Hurricane Intensity Prediction Scheme (SHIPS). Results showed that the OHC had only a very minor impact for the typical storm but a larger influence for the strongest of the tropical cyclones. The final phase of this project was to evaluate the impact on SHIPS forecasts in the eastern North Pacific. These results are summarized in Section 2.

The physical mechanism behind the impact of the OHC is that in regions where it is large, a tropical cyclone is less likely to reduce the sea surface temperature through upwelling and mixing of cold water from beneath the surface. Another aspect of this research was to develop a more physical relationship between OHC and intensity change by investigating the ocean response to tropical cyclones. A large archive of forecast cases of the operational version of the Hurricane Weather Research and Forecast (HWRF) coupled ocean-atmosphere hurricane model was used for this purpose. A simple parameterization of SST cooling was developed. A simple method for estimating OHC from the monthly climatology and actual SST values was also developed so that the operational SHIPS forecasts can still be run when the satellite altimeter data is missing.

2. Research Accommmplishments/Highlights:

The final phase of this project was completed in FY09. An OHC archive for the eastern and central North Pacific was obtained from U. of Miami. This data was used to develop a version of SHIPS for these basins that includes OHC as a predictor. This model was implemented in NHC operations for the 2009 Hurricane Season. Preliminary tests showed that the impact is somewhat different than in the Atlantic. In the east Pacific, the sensitivity to OHC is observed for much lower values than in the Atlantic. It is hypothesized that the larger stability values in the east Pacific Ocean make it less succeptible to SST cooling, so lower values of OHC has the equivalent relationship with cooling than higher values in the Atlantic.

3. Comparison of Objectives Vs. Actual Accomplishments For Reporting Period:

All proposed tasks have been accomplished.

4. Leveraging/Payoff:

This research will help to improve the intensity forecasts for hurricanes that have the potential to rapidly weaken or intensify. Results show that OHC has the largest impact on very strong tropical cyclones, those that inflict the majority of the damage on coastal areas. This project has a direct connection with the public interest. Coastal evacuations and other preparations for tropical cyclones are extremely expensive, and hurricanes that undergo rapid intensity changes are the most problematic.

5. Research Linkages/Partnerships/Collaborators, Communication And Networking:

This research is a joint effort between several groups with NOAA, the university community, the Department of Defense. These including the NOAA/NESDIS Office of Research and Applications, the NOAA/NCEP TPC, NOAA/OAR/AOML, The Naval Research Laboratory, The Naval Research Laboratory in Monterey, The Joint Typhoon Warning Center, Colorado State University and the University of Miami.

6. Awards/Honors: None

7. Outreach:

(a) Katherine Maclay, PhD candidate, Colorado State University

Presentations

A. Schumacher presented "An Overview of Research to Operations Activities at CIRA for 2008/2009" at the *National Hurricane Center Invited Seminar*. 10 October 2008, Miami, FL.

Improvements to the SHIPS, LGEM and Rapid Intensity Index for the 2009 Hurricane Season. Informal briefing to the National Hurricane Center forecasters, May 2009.

8. Publications:

Refereed Journal Articles

Knaff, J.A., and C.R. Sampson, 2009: Southern Hemisphere Tropical Cyclone Intensity Forecast Methods Used at the Joint Typhoon Warning Center, Part I: Control Forecasts Based on Climatology and Persistence. *Australian Meteorological and Oceanographic Journal*, 58:1, 1-7. PDF

Knaff, J.A., and C.R. Sampson, 2009: Southern Hemisphere Tropical Cyclone Intensity Forecast Methods Used at the Joint Typhoon Warning Center, Part II: Statistical – Dynamical Forecasts. *Australian Meteorological and Oceanographic Journal*, 58:1, 9-18.

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BLENDED AMSU, SSM/I, AND GPS TOTAL PRECIPITABLE WATER PRODUCTS

Principal Investigator: Stanley Q. Kidder

NOAA Project Goal: Weather and Water; Climate. Programs: Local Forecasts and Warnings; Hydrology; Weather Water Science, Technology, and Infusion; Climate Observations and Analysis.

Key Words: AMSU, SSM/I, MetOp, GPS, NVAP, GOES Sounder, Total Precipitable Water (TPW), TPW Anomaly, Blended Product, McIDAS, DPEAS

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Make the Blended TPW and TPW anomaly products available to more users. The Blended GPS-AMSU-SSM/I TPW is available on a McIDAS server, but the anomaly product is not because software modifications are necessary to make it available. We propose to modify our software and place the TPW anomaly product on our McIDAS server in real time in McIDAS format, where it can be accessed by collaborators with McIDAS equipment. Also, we plan to collaborate with the Short-term Prediction and Research Transition (SPoRT) Center at NASA's Marshall Space Flight Center to convert the McIDAS-format products to AWIPS format and to supply them to forecasters in the NWS Southern Region for testing and evaluation.

Blend more data into the products. Currently we use data from the AMSU instruments on the NOAA 15, 16, and 17 satellites and from the SSM/I instruments on the DMSP F-13 and F-14 satellites. (DMSP F-15 SSM/I TPW data have recently been adversely affected by "RADCAL," and we no longer use them. DMSP F-16 has an SSM/IS instrument, but the data from it are not operational.) We want to add TPW data from the NOAA 18 and MetOp-A AMSU to our processing system.

Study the anomaly product. Currently, it is based on normals from the NASA Water Vapor Product (NVAP) data set (Randel et al. 1996). We don't know how representative the NVAP data are of "normal" for the Blended GPS-AMSU-SSM/I data, since the SSM/I TPW algorithms are different and NVAP from 1988 – 1999 did not have AMSU data available. We propose to study the possibility of producing a climatology of the Blended GPS-AMSU-SSM/I data to either replace or extend the NVAP normals.

2. Research Accomplishments/Highlights:

The most accomplishment is that all objectives have been achieved. Here are the highlights for each objective.

With funding from another grant ("POES-GOES Blended Hydrometeorological Products") we got the Blended TPW product and the Percent of Normal TPW product to be operational at OSDPD (http://www.osdpd.noaa.gov/bTPW) and to be part of AWIPS Operational Build 9, which means that the two products are available NWS-wide on AWIPS.

We indeed did add NOAA 18 and MetOp-A data into the TPW products. Now we have added NOAA 19 as well.

We did study the anomaly product (also known as the Percent of Normal TPW product). We found the NVAP weekly normals are quite good and will be sufficient for now. Under separate funding (from NASA) the NVAP data set is being extended from its current 1988-1999 period to present. This work will be completed in 2011 and could then be used for the anomaly product. In addition, the Blended TPW product itself could serve as the climatological basis for the anomaly product. Now that the Blended TPW product is being produced operationally at NESDIS (OSDPD) in a few years a climatology of operationally produced Blended TPW could serve as the basis for the anomaly product.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

All Objectives complete.

4. Leveraging/Payoff:

The work done in this grant made possible a PSDI grant which made these products operational at OSDPD and distributed via AWIPS.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

We continue to collaborate with NASA's SPoRT (Short-term Prediction Research and Transition) Center (http://wwwghcc.msfc.nasa.gov/sport/). They acquire our Blended TPW and Percent of Normal TPW products and distribute them to the NWS Southern Region. They also have developed training modules in how to use the products.

6. Awards/Honors: None

7. Outreach:

Sheldon Kusselson has briefed the TPW products at the Storm Prediction Center and the NWS Tulsa Forecast office.

John Forsythe has briefed the product to the NWS Miami SOO and the NASA SPoRT (Short-term Prediction Research and Transition) Center.

8. Publications:

Forsythe, J. M., S. Q. Kidder, A. S. Jones, and S. J. Kusselson, 2008: CIRA's multisensor blended total precipitable water products serve forecaster needs. CIRA Magazine, Vol. 29 (Spring 2008), 8−11.

Kusselson, S. J. Kidder, S. Q., and J. M. Forsythe, 2007: A blended total water vapor product for the analysis and forecast of weather hazards. 22nd AMS Conference on Weather Analysis and Forecasting. Poster 2.42.

CIRA ACTIVITIES AND PARTICIPATION IN THE GOES I-M PRODUCT ASSURANCE PLAN (GIMPAP)

Principal Investigator: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: GOES, Imager, Sounder, Product Development

1. Long-term Research Objectives and Specific Plans to Achieve Them:

In April 1994, NOAA introduced a new geostationary satellite series with the launch of GOES-8: the new series is called GOES-I/M for GOES Improved/Multi-spectral. The fifth in this series, GOES-13 was launched in the spring of 2006. In response to the need to assure transition from GOES-7 to the new generation GOES products and beyond, CIRA has been involved in the NESDIS GOES-Improved Measurements and Product Assurance Plan, GIMPAP. The GIMPAP provides the means to assure the viability of GOES products, to improve products, to perform research to develop advanced products, and to ensure integration of the results into NESDIS and NWS operations.

The focus of CIRA's GIMPAP research is divided into five project areas including: I) Regional Cloud Climatologies, II) Severe Weather and Mesoscale Studies with GOES, III) National and International Training, IV) Tropical Cyclone Forecast Product, and V) Winter Weather Studies with GOES. Accomplishments of these projects are described in detail in Section 2.

2. Research Accommmplishments/Highlights:

<u>Project I: Regional Cloud Climatologies</u>

Progress was made with the Cheyenne Regional Cloud Climatology project. The wind regime products were converted into the required format, and products were successfully transferred to Cheyenne. Dissemination of the wind regime climatologies is utilizing the data transmission framework currently being implemented as part of the NESDIS/NWS Satellite Proving Ground. Once the climatologies have been used for a longer time period by the Cheyenne forecasters, we will plan a meeting to discuss the impact of this product on forecasting.

We also set-up new parameters for burn-off climatologies with Eureka. CIRA provided GeoTIFFs for a list of test cases selected by the Eureka office. Eureka has successfully entered the images into their GIS system and are testing their algorithm for determining marine stratus/clear line. Once the algorithm for determining the elevation of the marine depth layer is complete and tested, the rest of the 12Z images for the study period will be processed into GeoTIFFs, the GIS system will determine elevation for each morning, and with this information the burn-off climatologies will be built. A study will summarize the burn-off climatologies as soon as the results are available.

For the main archive, processing of the large sector U.S. climatologies continues. Products completed include monthly large sector composites for January through September 2008. In addition, processing of wind regime products continues. Monthly wind regime composites from both Channel 1 and Channel 4 for January through September 2008 have been completed. Also, combined monthly products have also been completed for January through September 2008. These include the products that will eventually be used in the Cheyenne office.

Project II: Severe Weather and Mesoscale Studies with GOES

As part of the “GOES and RUC Severe Weather Prediction” project, we collected RUC and severe weather report data from the summers of 2006 and 2007. Additional GOES data collection is currently in progress. Code is currently being written to read each dataset and perform the statistical analysis.

The second part of this project is the “Boundary Layer Moisture” Project. We collected RUC-13, Sounder, and Raob data from the summer of 2008. Initial statistical analysis shows that the use of the surface data along with the RUC analysis of low-level (particularly 925mb) water vapor improves the analysis over using the RUC alone. Including the sounder data degrades the analysis. The current plan incorporates this analysis technique into the GOES and RUC Severe Weather Prediction Project mentioned above.

The third part of our Severe Weather and Mesoscale Studies with GOES is the MCS Index project. This project is currently on hold but will resume at a later stage.

Project III: National and International Training

CIRA participated in the WMO-sponsored Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV that was held for Spanish speaking countries in Argentina, 22 September – 3 October 2008. The Argentina National Space Agency CONEA hosted the event at the Gulich Institute in the Space Center facility CETT in Cordoba Province. CIRA prepared and delivered lectures focused on the status of GOES/POES, Introduction to Multispectral and Hyperspectral satellite data, VISITview training, and a demo on McIDAS software. In addition, CIRA helped coordinate two sessions that linked up with the monthly weather briefings of the focus group of the Americas during the first week and two sessions that linked up with the GEOSS in the Americas Symposium being held in Panamá during the second week. The course took advantage of blended training by including remote presentations and sessions mentioned above as well as remote presentations from EUMETSAT, CPTEC, and UCR. Many contacts were made with participants, other lecturers, other personal at the Gulich Institute and CONAE.

Figure 1. WMO Satellite Training in Spring (Fall 2008) at the Mario Gulich Institute in Argentina.

The WMO Virtual Laboratory Task Team conducted 6 monthly English and Spanish weather briefings (for each month July through December 2008) through VISITview using GOES and POES satellite Imagery from CIRA (http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp) and voice via Yahoo Messenger. The September briefings were held in conjunction with the WMO Satellite Training in Argentina on September 23 and 25. There were participants from the U.S.: CIRA, COMET, SAB at NESDIS, the International Desk at NCEP, as well as outside the U.S.: Argentina, Antigua and Barbuda, Barbados, Bahamas, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Panamá, Peru, Paraguay, Uruguay, and Venezuela. The participants include researchers and students as well as forecasters. The discussions were well attended with a peak of 28 computer connections (average of 20) and multiple participants at many sites. Mike Davison at NCEP International Desk leads the sessions by providing an overall synoptic analysis. Throughout the sessions, participating countries offer comments on the features of interest for their local weather. Discussion topics varied by region and season, but some of the highlights included Hurricane Omar activity in the Caribbean and heavy rainfall in Brazil and Peru. *A new milestone for the focus group* was made when participants from the Argentina Training gave a 15-minute presentation at the beginning of the Spanish session during both October and November. Ing. Met. Nelson Quispe Gutiérrez of the National Meteorological and Hydrological Service (SENAMHI) of Peru presented highlights from the training and a brief overview of SENAMHI in October.

GOES-12 imagery for June through November 2008 were processed for the Regional Training Centers (RTCs) in Costa Rica and Barbados. The archives are being used to look at cloud frequency during the rainy and dry seasons and detect local variations from year to year. The archived imagery also provides access to examples for use in satellite-focused training efforts. The monthly cloud frequency composites for September through November 1997-2008 by 10.7 µm temperature threshold technique for Costa Rica are presented in the following figure

Project IV: Tropical Cyclone Forecast Product

The NCEP/TPC operational SHIPS intensity model was updated prior to the 2008 Hurricane Season, where data from the 2007 Season was added and the model coefficients re-derived. The GOES quality control was also adjusted to help screen bad GOES input. The SHIPS model ran smoothly for the 2008 Season, and the results will be evaluated as soon as the National Hurricane Center completes their final best tracks. Work is underway to test new modifications to the SHIPS model for the 2009 Season by extending the GOES archive back to the beginning of the developmental sample (1982). Currently, the GOES data only extends back to 1995 for the Atlantic and 1997 for the eastern Pacific. The new data will simplify the procedure because it may no longer be necessary to develop two sets of model coefficients (one with the 1982-present data without GOES and one with 1995-present with GOES data).
.
Methods have been developed to estimate the complex principal components in a real-time manner. Figure 2 demonstrates this capability by comparing the CPC-1, real and imagery components, with those created the next day for an active storm in the Southern Hemisphere. Plans are to 1) run such analyses every six hours in real-time at CIRA during the Hurricane Season and post the time series of the first five CPC on the RAMMB Tropical cyclone web page as a proof of concept, and 2) use the Tropical cyclone IR image archive to create similar time series for past cases as potential predictors for the Rapid Intensification Index (RII) and SHIPS.

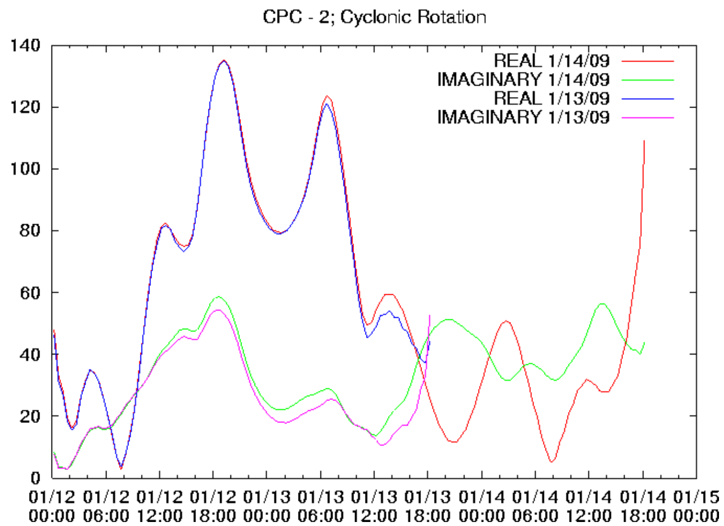

Figure 2. The Complex Principle Component #2 calculated in real-time and separated by 24-h. CPC-2 is associated with the rotation and orientation of cyclonically rotating convective elements in the period preceding rapid intensification. The time series match quite well considering that Fourier Series is used to create the Hilbert transforms.

We continue to work with AOML and TPC on RII modifications and with operational transition issues. The RII code was updated with GOES data from the 2007 Season for use in 2008, similar to that described for the SHIPS model described in Section 1 above. The extended GOES dataset (back to 1982) will also be evaluated for use in the version of the RII for the 2009 Hurricane Season.

GOES predictors have been tested in the Atlantic and East Pacific versions of the Rapid Intensification Index. In both basins the GOES predictors significantly improve the ability to anticipate rapid intensification events. This is especially the case in the East Pacific Basin where the GOES data is heavily weighted in the RII. This work has been prepared for publication.

No modification was found necessary to the Annular Hurricane Index (AHI). As a result the AHI has been successfully transitioned to NCEP/TCP where it is run every 6 hours as part of the SHIPS model processing, and the results appear in the SHIPS text file utilized by the NHC forecasters.

In addition, satellite datasets (GOES E, W, MeteoSat 9, 7, & MTSAT Water Vapor imagery) needed for the “Test Extended Range TC Formation Product” has been compiled and inventoried. In the next quarter, these data will be inter-calibrated and blended to form a tropical water vapor strip from which this product will be developed.

Project V: Winter Weather Studies with GOES.

The analysis of the *Henry's Rule* Project cases has been completed. Preparations are underway for the writing of a journal article. The findings will also be included in a new VISIT training session. A training dataset of fourteen cases of cyclones over the Eastern Pacific from November and December 2006 has been collected for the *Midlatitude Cyclones* Project. Standard EOFs have been computed and are currently being examined along with the principle component time series, all in relation to the time series of the central pressures of the surface lows. As part of the "*Warm sector of midlatitude cyclones over the United States"* Project, we studied twenty cases which have been placed into two categories. The first is the classic comma head shape, for which there is a continuous cloud shield covering both the comma head and the frontal zones. The brightness temperatures within the cloud shield over the comma head are roughly the same as those over the frontal zones. The second category is characterized by a comma head which is distinct (in a brightness temperature sense) from the frontal cloud band. In these cases, the brightness temperatures over the comma head indicate an average cloud-top temperature which is higher than those over the frontal zones. Initial results indicate a difference between the two categories in the snowfall patterns associated with the comma head. The classic cyclones produce a more diffuse swath of snow. The snowfall pattern associated with the second category tends to be narrower and better defined.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

All primary objectives of this research have been accomplished.

4. Leveraging/Payoff:

In response to the need to assure transition from GOES-7 to the new generation GOES products and beyond, CIRA has been involved in the NESDIS GOES-Improved Measurements and Product Assurance Plan, GIMPAP. The GIMPAP provides the means to assure the viability of GOES products, to improve initial products, to perform research to develop advanced products, and to ensure integration of the results into NESDIS and NWS operations. Examples of successful transitions include improved hurricane intensity forecast models provided to the NWS and fog and volcanic ash detection techniques provided to NESDIS operations. This research is continuing with an emphasis on applications of GOES to mesoscale weather analysis and forecasting.

5. Research Linkages/Partnerships/Collaborators, Communication And Networking:

This project involves considerable collaboration with NESDIS, the National Weather Service, NOAA/OAR and the World Meteorological Organization.

6. Awards/Honors: None

7. Outreach:

(a) One college undergraduate assisted in the project (Daniel Coleman).
(e) The CIRA/RAMMB web page depicts the results of our GIMPAP research activities.

Presentations

Connell, B**.** traveled to Cordoba, Argentina to present lectures at the WMO Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RAIII and IV September 22 – October 3, 2008. The lectures and laboratories focused on GOES/POES status, an Introduction to Multispectral and Hyperspectral satellite data, VISITview, and a demo on McIDAS.

Connell, B**.** traveled to Miami, Florida to present a talk at NOAA's 2008 Satellite Direct Readout Conference (December 8-11). She gave a presentation on "Satellite Training Activities at CIRA." The conference was an excellent venue to find out more information on direct readout capabilities and to meet with international partners.

Connell, B. gave a presentation on the GOES and the characteristics of its channels to a Remote Sensing class at the Metropolitan State College of Denver on November 10. Since the Remote Sensing class focuses mainly on earth resource topics, the students were presented with the perspective of how meteorologists view and use satellite imagery.

DeMaria, M. gave a guest lecture entitled "Applications of Satellite Data to Tropical Cyclone Forecasting" in Tom Vonder Haar's AT737 Satellite Meteorology class in the CSU Department of Atmospheric Science. Applications to tropical cyclone track, intensity and wind structure forecasting were summarized, include current and planned satellite missions. A class exercise on the Dvorak tropical cyclone classification method was also given.

DeMaria, M., J.A. Knaff, A.B. Schumacher, J. Kaplan, D. Brown, G. Gallina, J. Kossin, 2009: Improved GOES Utilization for Tropical Cyclone Forecasting. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL.

Knaff, J.A**.** 2009: Understanding and (possibly) rectifying historical and regional wind-pressure relationship differences. *International Best Track and Climate Stewardship Workshop (IBTrACS) Workshop*, 5-7 May, Ashville, NC.

Knaff, J.A**.**, D. Brown, J. Courtney, M. Gallina, 2009: An Evaluation of Biases and Errors Associated with the Subjective Dvorak Technique 1989-2007. *International Best Track and Climate Stewardship (IBTrACS) Workshop*, 5-7 May, Ashville, NC.

Schumacher, A. presented "An Overview of Research to Operations Activities at CIRA for 2008/2009" at the *National Hurricane Center Invited Seminar*. 10 October 2008, Miami, FL.

8. Publications:

Refereed Journal Articles

DeMaria, M., 2009: A Simplified Dynamical System for Tropical Cyclone Intensity Prediction. *Monthly Weather Review.* 137:1, 68–82.

Hillger, D.W., J.F. Schmit, 2009: The GOES-13 Science Test. A Synopsis. *Bulletin of the American Meteorological Society.* 6-11.

Knaff, J.A., 2009: Revisiting the Maximum Intensity of Recurving Tropical Cyclones. *Int. J. Climatology*. 29, 827-837.

Knaff, J.A. and R.M. Zehr, 2008: Reply. *Weather and Forecasting*, 23:1, 762-770.

Schumacher, A.B., M. DeMaria and J.A. Knaff, 2009: Objective Estimation of the 24-Hour Probability of Tropical Cyclone Formation, *Wea. Forecasting*, 24, 456-471.

Conference Proceedings

Connell, B.H., M. Davison, A. Mostek, V. Castro, and T. Whittaker, 2009: International satellite training activities. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Connell, B.H., and L.G. Guirola, 2009: Regional satellite climatologies for Central America from GOES. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Knaff, J.A., 2009: Propagating patterns in 6.7 µm imagery in re-intensifying tropical-to-extratropical cyclone transitions. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Lindsey, D.T., S.D. Miller, J. Braun, and D. Bikos, 2008: An analysis of the 22 May 2008 Windsor, Colorado, tornado. *24th Conference on Severe Local Storms*, 27-31 October, Savannah, GA.

CLOUD AND MICROWAVE EMISSIVITY VERIFICATION TOOLS FOR USE WITHIN THE CRTM

Principal Investigator: Andrew Jones

NOAA Project Goal: Weather and Water

Key Words: Local Forecasts and Warnings, Environmental Modeling, Weather Water Science, Technology, and Infusion Program

1. Long-term Research Objectives and Specific Plans to Achieve Them:

New quality control, standardized innovation vector analysis verification tools, and microwave emissivity analysis capabilities will be added to the Common Radiative Transfer Model (CRTM) for use within operational Joint Center for Satellite Data Assimilation (JCSDA) data assimilation systems. This work addresses three JCSDA priority areas: CRTM development, clouds and precipitation, and land surface data assimilation.

Approach: The observational emissivity method is a 1D variational (1DVAR) algorithm where the emissivities are grouped into retrieved "bands". Combinations of unique cloud data sets such as CloudSat with the microwave data will enable further quality control improvements.

The long-term project goals are as follows:

Use new CloudSat/CALIPSO cloud radar and lidar data sets as an important new cloud verification tool for the JCSDA.

Standardize key verification tools, such as satellite data innovation vector analysis and diagnostics to test the impact of data assimilation tests.

Add the CSU Microwave Land Surface Model (MWLSM) to the CRTM.

2. Research Accomplishments/Highlights:

Formal integration of the delivered software into the CRTM remains pending by the JCSDA. All CSU MWLSM documentation and codes were confirmed received by the JCSDA. An update was provided at a meeting with NOAA/NESDIS on Nov. 13, 2008.

Our WRF-3DVAR use of the microwave emissivities has shown substantial improvement over the deserts of the Middle East (see Figure 1) this represents a substantial bias improvement over the CRTM estimates.

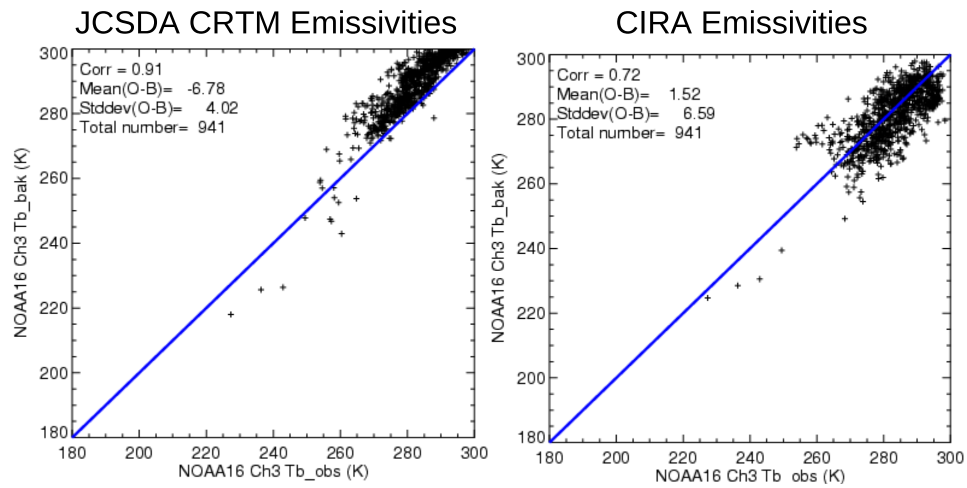

Figure 1. The NOAA-16 AMSU-A Channel 3 50.3 GHz WRF-3DVAR bias performance was improved from -6.78K to 1.52K using the improved CIRA microwave emissivity information as compared to the JCSDA CRTM results. The std. dev. increased slightly which is physically realistic due to the more realistic natural background variability.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

All Year 1 objectives were completed and delivered on schedule. Follow-on efforts as originally proposed in the multi-year proposal have not yet been funded due to JCSDA program reallocations.

4. Leveraging/Payoff:

The MWLSM was created under DoD funding and was provided at no cost.

A collaborative CSU/CIRA-NCAR/MMM WRF-Var work plan also leverages this work with ongoing WRF-Var development activities that involve use of the NOAA CRTM.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

This work is funded by the Joint Center for Satellite Data Assimilation (JCSDA). NOAA collaborators include: Drs. Fuzhong Weng (NESDIS/STAR) and Paul van Delst (CIMSS). Our NCAR collaborator is Dr. Zhiquan Liu.

On September 8-12, 2008 Dr. Jones was invited to NOAA-CREST (CUNY, New York, New York) for microwave emissivity and soil moisture data assimilation collaboration discussions.

On November 13, 2008 Dr. Jones visited NOAA/NESDIS (Camp Springs, MD) for the first NOAA soil moisture working group meeting.

6. Awards/Honors: None.

7. Outreach:

NOAA Soil Moisture Working Group interactions involved NOAA-CREST (CUNY) faculty members, Profs. Temimi and Lakhankar. Those soil moisture and emissivity science collaborations are on-going. Student visits from NOAA-CREST to CIRA are planned for Aug. 2009.

8. Publications: None.

COCORAHS: THE COMMUNITY COLLABORATIVE RAIN, HAIL AND SNOW NETWORK – ENHANCING ENVIRONMENTAL LITERACY THROUGH PARTICIPATION IN CLIMATE MONITORING AND RESEARCH

Principal Investigator: Nolan Doesken

NOAA Project Goal: Climate: Climate Observations and Analysis

Key Words: Rain, Hail, Snow, Measurements, Mesonet

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Objective 1: Help citizens across the United States become more aware and informed about weather and climate. Encourage "learning by doing" by engaging large numbers of volunteers in measuring and reporting precipitation (rain, hail and snow) from their own homes.

Objective 2: Help fill in the precipitation reporting gaps across the country with accurate observations from citizen volunteers.

Objective 3: Build and strengthen partnerships with NOAA offices including the NOAA Office of Education, National Weather Service Headquarters, regional headquarters and local forecast offices and the National Climatic Data Center

Objective 4: Provide important "now-time" data to the National Weather Service through "Hail Reports" and "Intense Precipitation Reports" from CoCoRaHS volunteers. This will support the forecast and warning mission of NOAA's National Weather Service.

Objective 5: Develop climatological information on precipitation patterns derived from CoCoRaHS data.

Objective 6: Develop a citizen-scientist outreach relationship between observers and scientists through collaborations and interactions with the general public that would not exist otherwise. This includes the development of education resources tailored for use by 4-H Programs across the country. This also includes resource materials developed for the growing national community of "Master Gardeners" and "Master Watershed Stewards"

Objective 7: Provide accurate precipitation data for potential research applications in the fields of hydrology, meteorology, climatology, environmental science, etc.

2. Research Accomplishments/Highlights:

We are now celebrating the 11th anniversary of the CoCoRaHS network. What began in 1998 as a local effort in Northern Colorado has now exploded (with the help of this NOAA Environmental Literacy grant) into almost every state and the District of

Columbia. By the end of 2009 we are on track to having every state involved. Over 7,500 volunteers now report precipitation daily and nearly 7,000 more have participated at least occasionally during the past year. This now makes CoCoRaHS the largest source of daily "ground truth" precipitation data in the U.S. All data collected by the large corps of volunteers are immediately available for use by NOAA, private businesses, utilities, research scientists, educators and the general public. CoCoRaHS is widely known in the professional hydrometeorological community as a credible and easily accessible data resource. CoCoRaHS is also known as a successful and practical citizen-science project. Participants are routinely exposed to other NOAA education resources and learning opportunities through a variety of integrated outreach tools – mostly via the CoCoRaHS website.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

From the time this project began, we have been on a fast track. Our original goal through this NOAA grant was to reach out to 30 states in 3 years. This was accomplished in less than 2 years. The popularity, simplicity, and the strong NOAA partnerships have helped CoCoRaHS exceed its original goals in terms of participation.

With so much energy going into expansion efforts, we have lagged a bit in some of our targeted educational outreach efforts. We have completed a packet of materials for 4-H leaders which includes simple lesson plans on a variety of weather topics. 14 lesson plans have been written and tested but have not yet been widely distributed or marketed. We are currently adding illustrations to the materials, thanks to a donation of time and talent from a professional illustrator who happens to also be a CoCoRaHS volunteer in New England. We made progress this year on CoCoRaHS resources for Master Gardeners but more work is still needed. A "Needs Assessment" has shown that Master Gardeners are particularly interested in detailed local climate descriptions and information on microclimates. This will be difficult to produce in a single educational resource for national dissemination, so we are continuing to assess alternatives.

We continued to work with our network of CoCoRaHS state and regional volunteer coordinators to offer group training programs across the country, some in conjunction with NWS's annual severe weather spotter training activities (SKYWARN). Some states conducted web-based group trainings using "Go To Meeting" software. Most volunteers continue to use slide show and video instructional materials on the CoCoRaHS website. Some of our coordinators have customized the general training materials to make them for "local friendly" so that CoCoRaHS has more of a local than a national "feel" for new participants.

The primary media for education is the approximately bi-weekly CoCoRaHS e-newsletter sent out by Nolan Doesken. Feedback is strong that this newsletter is very effective in keeping volunteers engaged and feeling that they belong. A comparably useful, although less personalized media, is the "Message of the Day" which appears on the screen each time a volunteer submits a data report. A steady stream of new and updated educational messages reaches the volunteers through these media.

More time has been invested in developing and testing an extensive “Survey” that will be posted online for all participants. September 2009 has been selected as “survey month”. The help of a professional evaluator was solicited to improve the survey. In addition, two PhD students from other universities who are involved in research on science education have also joined with CoCoRaHS staff to review and improve this evaluation tool.

During the past year, CoCoRaHS staff have attended meetings and met personally with NOAA staff and leadership at NWS Headquarters. We continue to enjoy excellent working relationships with National Weather Service field office personnel in many parts of the country and also with State Climatologists. CoCoRaHS is a “lowest common denominator” program that is both interesting and useful to a large sector of the weather and water profession. .

Some of the original proposed work such as the climate information for Master Gardeners and the CoCoRaHS evaluation survey will not be completed within the original proposed 3-year time period. A no-cost extension has been requested to help continue this work.

4. Leveraging/Payoff:

The measurement of precipitation by a large and diverse community of volunteers and the effective sharing and display of this information via the Internet is proving to be an incredibly cost-effective means for gathering high resolution “ground truth” precipitation data. At the same time, observing one element of our climate – precipitation – opens the door to appreciation and curiosity about other aspects of the earth’s climate system. The collection and sharing of precipitation data is a “lowest common denominator” that links the public, the private sector and also research and education. Listed below are several benefits that CoCoRaHS has already provided to NOAA.

Environmental and Science Education:
Precipitation is the source of our fresh water resources. Through a relatively simple measurement that most anyone across the country (and world) can take, we open the door to the entire hydrologic cycle and the climate system that drives it. The weather provides science lessons every day. Participation in CoCoRaHS provides a forum for learning and presents an opportunity to see the direct yet complex relationships that exist between the atmosphere and our existence on the surface of the earth. CoCoRaHS has the advantage that it engages participants over long periods of time (some volunteers have scarcely missed a day of reporting in 11 years). Persistent contact is a key factor in learning

Outreach and Partner Collaboration:
By its very nature, the CoCoRaHS project is collaboration. It is a partnership between a multitude of organizations, including governmental, academic, agricultural, and private interests. It has already fostered very strong working relationships between the National Weather Service and State Climate Offices, County Agricultural Extension Agencies, conservation programs, television stations, and local schools and universities. The

network provides a chance for all interested parties to work together to make a real and substantial contribution to enhancing our Nation's climate record and providing high quality data for research applications. The network is also a large outreach source for NWS offices. The format includes training of observers through an interactive training program with methods and practices adhering to standard co-op observation procedures. The network has resulted in good PR for the NWS in print, radio, and television media sources.

Warning Operations:
CoCoRaHS encourages volunteers to report occurrences of hail as well as snow and intense rainfall amounts. These reports include information on damage or flooding that is occurring along with the location and time. This information is available in real-time as an AWIPS text product called DENCCRAHS. This product is set up for all WFOs in participating states and is filtered to only alarm duty forecasters for reports over preset intensity thresholds from counties within each office's warning area. This provides a new source for storm reports that are extremely valuable for warning verification and for the issuing of new warnings. High density of snowfall observations can also provide support for winter weather product verification.

Climate Services:
CoCoRaHS enhances the climate record by providing an additional precipitation data set of excellent quality using the 4"-diameter high capacity rain gauge that has been showed to compare very favorably to NWS's official "Standard Rain Gauge". The data set of precipitation measurements is of unparalleled density in several parts of the country. It serves as a supplement to the already existing co-op network and allows rainfall patterns to be seen with a very high resolution. It can provide quality-control checks for questionable co-op observations. Long-term collection of data will allow for a better understanding of regional micro-climates within a forecast area. Through new software developed in partnership with the National Weather Service, CoCoRaHS data can now feed directly into "Local Climate Observations" used and disseminated by NWS forecast offices. Regional Climate Centers are now developing software to ingest CoCoRaHS data into their popular "Applied Climate Information System" (ACIS) which is a popular climate services tool used within NOAA.

Hydrologic Services:
CoCoRaHS provides tremendous benefit to NOAA hydrologic programs. The CoCoRaHS network provides additional data at a very high spatial density. Observations can supplement existing automated rainfall observations within the hydrologic network, as well as serve as quality control checks, and provide verification of automated gauge function. With extremely localized rainfall often providing the impetus for flash flooding and small stream rises, CoCoRaHS provides a tremendous help to the forecasting and verification of localized flooding events. In addition, the high density data can be ingested by River Forecast Centers for use in precipitation summary products and flood forecasting models. With an enhanced focus on drought, the high density CoCoRaHS network is a powerful tool for drought monitoring and forecasting activities.

Local Research:
CoCoRaHS provides a large and readily accessible data set documenting rainfall, hail and snow. The high concentration of observations provides for a better understanding of variability in the amounts of rainfall and snowfall across small areas and a truer picture of hail stone distribution. High density data fosters more effective studies of small scale climatology within a forecast area. Each year the number of research projects that incorporate CoCoRaHS data is growing. Agricultural, hydrologic, atmospheric, structural engineering (hail) and even entomological research projects have incorporated CoCoRaHS data within the past year.

Co-op Network:
CoCoRaHS is not a substitute or replacement to NOAA's long-standing Cooperative Observing network (COOP). It is, rather, a supplement – providing a low-cost alternative to fill in the gaps in the national network of stations currently 20-25 miles apart. In addition to supplementing and enhancing the COOP network, the CoCoRaHS network also provides a pool of highly motivated observers to draw from when openings in the existing COOP network appear.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

A remarkably large number of partnerships and collaborations have developed through CoCoRaHS. In fact, "Collaboration" is the word that best describes the nature of this project (and included in its name). Here is a list, although not exhaustive, of collaborators leveraging NOAA's funding for this project. A growing number of private companies are also getting involved.

National Oceanic and Atmospheric Administration, National Weather Service, U.S. Dept. of Agriculture, U.S. Bureau or Reclamation, California Dept. of Water Resources, , Utah State University, Mount Washington Observatory, Appalachian State University, Cornell University Cooperative Extension, Northeast Regional Climate Center, Museum of the Earth, University of Illinois Extension, Illinois State Water Survey, Purdue University, Indiana State Climate Office, Iowa State Climate Office, Iowa State University, Kansas State University, Maryland Department of Natural Resources, University of Missouri, Missouri Farm Service Agency, KY3,-- Springfield, Missouri, Western Regional Climate Center, Desert Research Institute, New Mexico Master Gardeners, New Mexico Floodplain Managers Association, New Mexico State University, University of Oklahoma, WeatherYourWay.com, AmbientWeather.com, Weatherwise Magazine, University of Texas, Texas Governor's office, WMGH-TV7 Denver, Penn State University, South Dakota State Climate Office, University of Tennessee, Wisconsin Department of Natural Resources, Michigan State University, Ohio State University, Marshall University (West Virginia), South Carolina Department of Natural Resources, University of Alabama at Huntsville, Desert Research Institute, University of Kentucky, University of Wisconsin, Wisconsin State Climatology Office, North Carolina State University, Florida State University, National Climatic Data Center, State Climate Office of North Carolina, NCAR, ARSC Aerospace Corporation/Kennedy Space Center, City of Aurora, U.S. Department of Interior, Bureau of Land Management, Wyoming Farm Service Agency, University of Wyoming, City of Golden, DayWeather, Inc., East Central Colorado Resource, Conservation and Development, Southeast Colorado Resource, Conservation and Development, Denver Water, Denver Cooperative Extension Office, University of Northern Colorado--Earth Sciences Department, City of Loveland Water and Power, Urban Drainage and Flood Control District, Northern Colorado Water Conservancy District, National Phenology Network, Mountain States Weather Services, City of Fort Collins Utilities--Water and Storm Water, Poudre School District, National Severe Storms Lab, WeatherYourWay. Ambient Weather, Salt River Project.

6. Awards/Honors:

Nolan Doesken, PI, was a recipient of the NOAA 2007 Environmental Hero award as a result of his leadership of the CoCoRaHS network.

7. Outreach:

(a) Several undergraduate students have worked as student employees through CoCoRaHS – both at Colorado State University and at other collaborating institutions. We have not made a point of tracking all of these students.

(b) CoCoRaHS presentations have been given to the public in various settings across the country and at the University level including departmental seminars at Colorado State University and New Mexico State University. Nolan Doesken gives several guest lectures and seminars each year and always makes a point of integrating CoCoRaHS findings and shamelessly inviting fellow scientists and students to join the CoCoRaHS observing network. An impressive part of the CoCoRaHS outreach effort at this time is conducted at the state and regional level by CoCoRaHS volunteer coordinators and facilitators.

(d) A sizeable number of CoCoRaHS volunteers are students and teachers. While most participation is independent, CoCoRaHS staff did visit several classrooms during the year, particularly in the local Poudre School District where all schools have been invited to become CoCoRaHS participants.

(e) Increasing public awareness regarding all aspects of daily weather and broader climate is an ongoing goal of CoCoRaHS and a regular target for the messages and training directed to our volunteers. We have teamed with NOAA to consistently deliver core messages regarding lightning safety, flood preparedness and safety, hurricane safety, winter storm readiness, drought and drought preparedness and other severe weather. We continue to meet and coordinate with NOAA Public Affairs and we continue to maintain a NOAA Resources website. In combination, we are striving for heightened public awareness of the hazards, challenges and opportunities that our variable, exciting and dangerous climate provides.

8. Publications:

Doesken, N., 2007: Let it Rain. *Weatherwise*, Vol. 60, 4, July/August, pp. 50-55.

Reges, H., R. Cifelli, N. Doesken, J. Turner: 2008: CoCoRAHS (The Community Collaborative Rain, Hail and Snow Network) – The Accidental Network: Evolving Collaborations. American Meteorological Society's 17th Symposium on Education, New Orleans, LA, Paper 1.3.

CONTINUATION OF THE CIRA RESEARCH COLLABORATION WITH THE NWS METEOROLOGICAL DEVELOPMENT LAB

Principal Researcher: Scott O'Donnell

NOAA Project Goal/Programs: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings and Hydrology

Key Words: Debris Flows, FFMP, AutoNowcaster, NWS, MDL, NCAR, AWIPS, USGS, GIS

During the past several years, this research effort has focused on bringing the NCAR AutoNowcast system into AWIPS. On successful completion of this task, I have been able to begin spending more of my time on assisting the Debris Flow forecasting project. As such, this has been a transition year for me—ratcheting down the time spent on the AutoNowcaster Program and beginning to map my strategy for Debris Flow Support to provide precipitation gage data from the WFO Hydro Database, which has been specifically requested by USGS researchers. I have suggested adding Quantitative Precipitation Estimates (QPE) and Quantitative Precipitation Forecast (QPF) data sets to allow USGS Debris Flow models to develop a 'forecast' capability to their existing post-event analysis models.

Prototype Debris Flow Monitor

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Flash Flood Monitoring Program (FFMP) attempts to fill the gap between the RFC-provided Flash Flood Guidance products issued several times each day and the operational forecaster needs during high-intensity, short duration rainfall events which are responsible for most of the flash floods occurring within the 0-3 hr time range.

Background:
FFMP alerts forecasters to those areas that have a high flash flood potential, often with a very quick response to intense rainfall. WFO forecasters have few real-time rainfall-runoff tools available to them, although they are responsible for issuing accurate flash flood forecasts in their area.

To support this capability, the CONUS has been discretized into 2-10 km^2 watersheds, provided to the WFO as sets of ESRI formatted 'Shapefiles'. This GIS data set contains most of the attributes necessary to aid the Service Hydrologist in doing their forecast duties, including an outline of each watershed, watershed area, contributing (inflow) and outflow watersheds, outlet location (pour point), etc. These watershed attributes are provided in a dBase-III database file, a “dbf” file. The local WFO Service Hydrologist maintains these shapefile data, adding or correcting details, expanding the provided database, and generally improving the contained data adding area specific details.

FFMP runs in the background, monitoring in real-time many input data sets. For each 2-10 km^2 watershed in the FFMP domain, it monitors precipitation accumulation from each input data type, such as radar estimates (QPE or MPE) and/or forecast rainfall (QPF) at several durations, while comparing each to the available excess rainfall guidance values. When a watershed's rainfall accumulation reaches a predefined threshold (defined by River Forecast Centers for each watershed) or when instantaneous rain rates reach prescribed limits, FFMP triggers a workstation alarm alerting the forecaster to the possible flash flood condition. The forecaster then evaluates the potential threat using the AWIPS D2D display, FFMP tables, and other available data to determine whether to issue a flash flood watch or warning for the affected area.

The National Weather Service's mission is to provide watches and warnings to the public for severe, weather-related events. The infrastructure to provide this service is well developed, with direct connections to local Emergency Managers and law enforcement officials.

The USGS and the NWS have agreed provide Debris Flow watches and warnings (as modified flash flood watches and warning). In the Debris Flow Experimental areas in Southern California (Oxnard (LOX) and San Diego (SGX) WFOs), FFMP has undergone a few modifications to support USGS Debris Flow forecast watersheds and to allow forecasters to add USGS Geological Hazards Team-provided Debris Flow Guidance to identify those areas most likely to experience a Debris Flow.

2. Research Accomplishments/Highlights:

To support the USGS's ability in their analysis of storms which cause Debris Flows, I developed a prototype application to deliver near real-time data using data available from internet accessible databases, such as, http://www.met.utah.edu/mesowest/. This was provided as a quick, partial implementation of the prototype to be installed at LOX and SGX WFOs. The incentive to doing that was to avoid needing to navigate the security layers within the NWS and explore the usefulness to the USGS of providing real-time rainfall data.

The benefit was almost immediately realized by eliminating the need to explicitly retrieve archive rainfall data, particularly after a debris flow event, and also to begin automated methods to populate (insert observations into) the project rainfall database. The prototype also exercised methods for managing the required USGS ftp data ingest facility to be used by the real-time application providing rainfall observations from the WFO's Hydro database.

The internet prototype application was expanded and extended to retrieve rainfall from the WFO's real-time Hydro database by directly querying this relational database, formatting the data to suit the USGS ingest methods, and delivering these data reports to the USGS automatically. The real-time relational database data retrievals will be completed before the onset of the next rainy season.

Plans for this coming year's Debris Flow project activities:
Additionally, a communication mechanism needs to be provided to send guidance data from the USGS models to the local WSFO (completing the feedback loop). These data will be automatically ingested, updating the FFMP data sets and displays.

In addition to the follow-on work in exchanging real-time data (gage and radar), I expect to begin collaborating with Western Region Scientific Services Division in the development of real-time, distributed hydrologic models which use (for rainfall input) new very high resolution QPE and QPF from experimental radar data sets such as the Smart-R and Q2. This work will supplement work being conducted at the USGS in support of the NWS's Debris flow forecasting experiment.

AWIPS Autonowcast Prototype Project

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The general project objectives are to deliver the NCAR 0- to 1-hour AN forecast products to AWIPS' short-term forecaster workstations and send forecaster user interactions to NCAR's AutoNowcaster. This effort provides the NWS forecasters with the ability to initialize, review, and modify the AutoNowcast forecast products on the AWIPS workstation using familiar AWIPS techniques to interact with these data.

To improve situational awareness of severe weather forecasts, NCAR has tested and installed an AutoNowcast display system (CIDD) at the Fort Worth-Dallas WFO. The NCAR CIDD is installed physically adjacent to the short-term forecaster workstation for convenient access and reference to the several types of AutoNowcast products (real-time and forecast) that are available within the AutoNowcast system.

The project requirements are to migrate the forecaster 'user roles' normally performed on the NCAR's stand-alone graphical display (CIDD) to AWIPS' D2D data display system. This interface provides simple point-and-click interfaces (menus, dialog and scroll boxes) allowing the forecaster to easily display and modify the AutoNowcast data sets within AWIPS.

2. Research Accomplishments/Highlights:

As the Technical Lead, I identified the following set of functional subtasks necessary to meet the project goals:

- --Data Management
- --Data Display
- --Forecaster Interaction (boundary and polygon editing)
- --Data Dissemination

Operational implementation has shown few modifications have been necessary to correct implementation errors. These previous accomplishments include:

--real-time decoding of NCAR-provided data;
--storage of NCAR-provided data in netCDF, AWIPS-ready format; and
--generating data display updates as data becomes available to AWIPS (the Data Management sub-task), AWIPS menu design, and extension interfaces.

This year, my effort has been to support the WFO's operations. I've also helped migrate NCAR provided software onto a full implementation of the Autonowcaster system at MDL. This has required analyzing code which was designed to operate using software not available to MDL and make the necessary corrections to make the software operate in a generic environment.

The migration of the Autonowcaster system to MDL anticipates the direct support of the Fort Worth prototype installation and also directly supporting the larger Melbourne NextGen installation of the Autonowcaster in 2010.

Autonowcaster projected activities:
New data sets and domains will be used in the Melbourne area and system modifications are expected to be necessary to enable the new area to move forward.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

The NWS Modernization Development Laboratory, Decision Assistance Branch (MDL, DAB, Steve Smith, Branch Chief) is the sponsor of this project providing support and direction.

The AutoNowcast Interface Project is a collaboration with the NCAR AutoNowcast (AN) development team (Rita Roberts, NCAR Project Lead).

The FFMP Project is sponsored by NWS/MDL/DAB. Tom Filiaggi is the FFMP (NWS) Project Lead.

The Debris Flow Project is a collaboration with the USGS Geological Hazards Team (GHT), headed by Sue Cannon, USGS Debris Flow Team Lead.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

DATA FUSION TO DETERMINE NORTH AMERICAN SOURCES AND SINKS OF CARBON DIOXIDE AT HIGH SPATIAL AND TEMPORAL RESOLUTION

Co-Principal Investigators: A. Scott Denning, (CSU) and Kenneth J. Davis, Klaus Keller, Natasha R. Miles, Scott J. Richardson (The Pennsylvania State University)
NOAA Project Goal: Climate

Key Words: Carbon Cycle, Greenhouse Gases, Terrestrial CO_2 Sinks

There is strong evidence that North America terrestrial ecosystems are currently a substantial sink of carbon dioxide. The magnitude of the sink has a large range of uncertainty, we have a limited understanding of how it has varied over time, and the processes responsible for this sink are not entirely clear. Our limited understanding is linked to methodological limits, as well as limited continental data. Quantifying spatial patterns and temporal variability of carbon dioxide sources and sinks at continental to regional scales remains a challenging problem.

In response to this challenge a rapid expansion of the N. American carbon cycle observational network is underway. This expansion includes a network (AmeriFlux) of continuous, eddy-covariance based CO_2 flux measurements and a network of continuous, continental CO_2 mixing ratio observations of comparable precision and accuracy to the marine flask network. Inverse studies of the N. American carbon budget have only begun to utilize these emerging data sources directly (i.e. tower fluxes and continuous continental mixing ratio observations), and how to best utilize these data together is a topic of great uncertainty and intensive research. This is the focus area of our research.

We are conducting a program of research that will turn the emerging wealth of data in N. America to our advantage. This will be accomplished by a continued collaboration between research groups at the forefronts of terrestrial boundary layer CO_2 flux and mixing ratio observations, and high resolution, land-atmosphere carbon cycle modeling. This collaboration has resulted in substantial progress towards fusion of flux and mixing ratio observations in a coupled land-atmosphere data assimilation framework. This project will further develop methods for fusion of CO_2 flux and mixing ratio observations via inverse modeling incorporating the N. American CO_2 mixing ratio observational network, forwards modeling built upon the N. American flux network, and cross-evaluation of these two approaches. Further, we will apply the methods already developed via this collaborative effort to examine interannual variability of N. American carbon fluxes from 2004 to 2008.

Hypotheses:

1. Flux and mixing ratio observations can be merged into a consistent analysis at synoptic, seasonal, and interannual time scales;

2. The N. American CO_2 budget will be well constrained by our data analysis system;

3. The 2004-2008 record of N. American net annual terrestrial CO_2 fluxes will show a persistent net sink of carbon of location and magnitude consistent with previous estimates based on ecological inventory methods, and;

4. The same flux record will yield detectable, spatially-resolved, climate-driven interannual variability.

Expected products include:

a. growing database of flux-tower based, continuous CO_2 mixing ratio observations suitable for application to continental inversions;

b. omprehensive analysis system for estimation of monthly CO_2 exchange across N. America at high spatial resolution;

c. significant reduction in the uncertainty in the annual net N. American CO_2 flux and its interannual variations, and;

d. spatially and temporally resolved terrestrial CO_2 fluxes and uncertainty estimates for 2004 through 2008 encompassing all of N. America.

Ultimately, our results will support the development of dynamic predictions of the future carbon cycle by providing a regionally and temporally resolved multi-year record of whole continent terrestrial carbon fluxes needed to evaluate continental-scale models.

2. Research Accomplishments/Highlights:

Figures 1 through 6 from the technical report are shown below and illustrate highlights of the ongoing research.

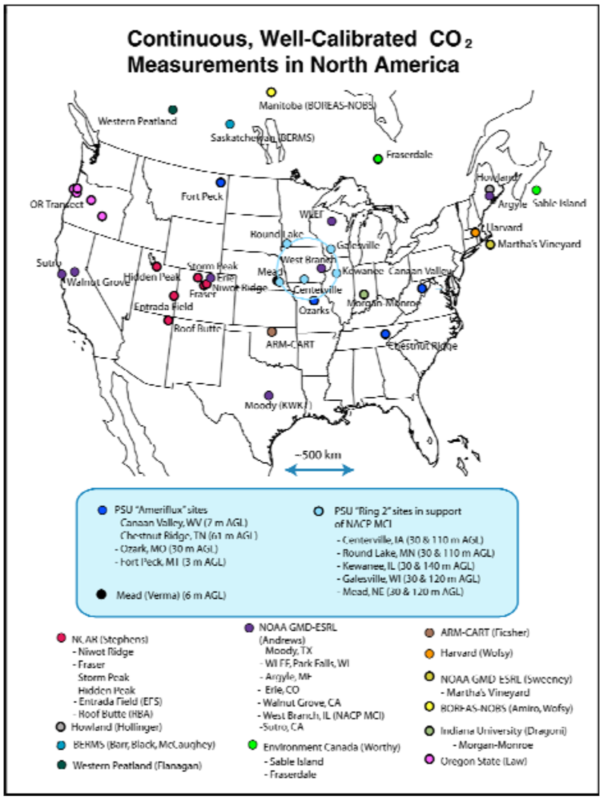

Figure 1. Locations of Continuous CO_2 Measurement Sites in North America. Sites supported under this project are indicated in dark blue.

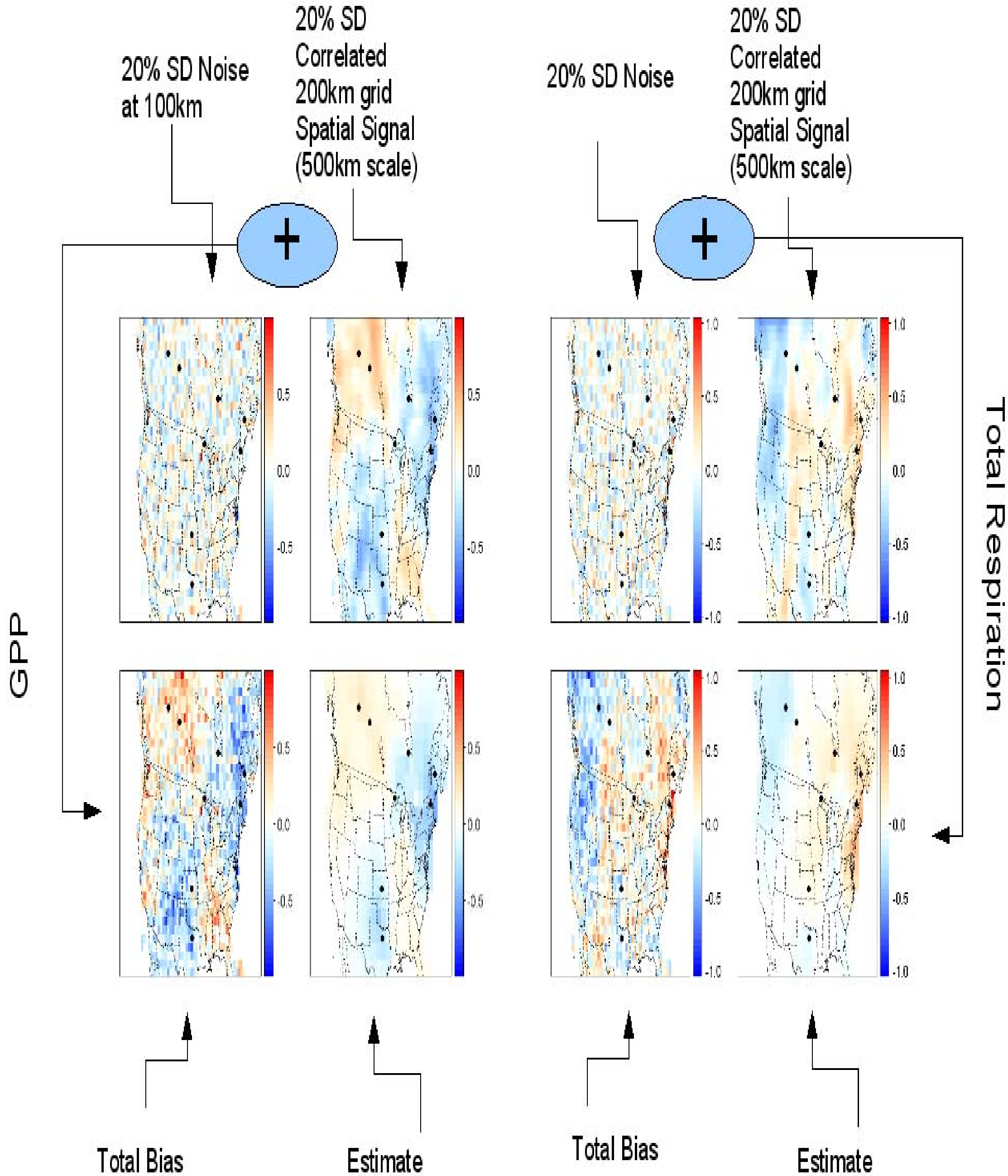

Figure.2. Example correction of GPP and total respiration signal. 4 Panel Plots: Upper left: small spatial scale bias applied over model domain, upper right: large scale bias over model domain which we would like to recover, lower left: total signal (sum of small and large), lower right: posterior estimate of mean bias. The eight CO_2 observing towers are shown as black dots on the images. Since biases are plotted as deviations from the prior (as in Eq. 2), the mean a priori fluxes can be visualized as solid white plots with all grid cells equal to zero.

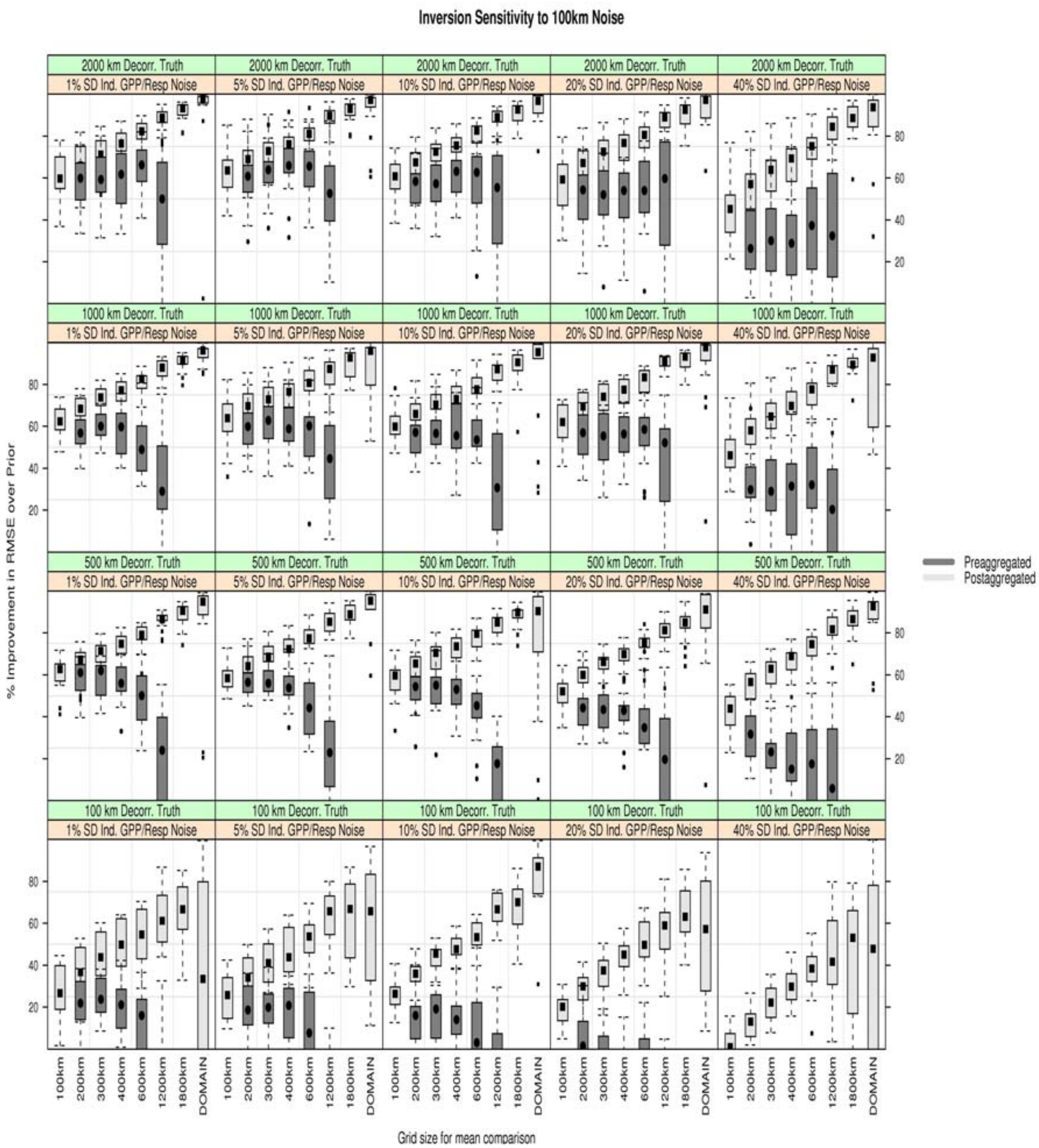

Figure 3. Improvement of posterior with respect to prior, for pre-aggregated (light) and post-aggregated (dark) inversion grid, factored over noise level and decorrelation length scale of true pattern used. Pre-aggregated (light) inversions are only performed for grid sizes between 200 km and 1200 km.

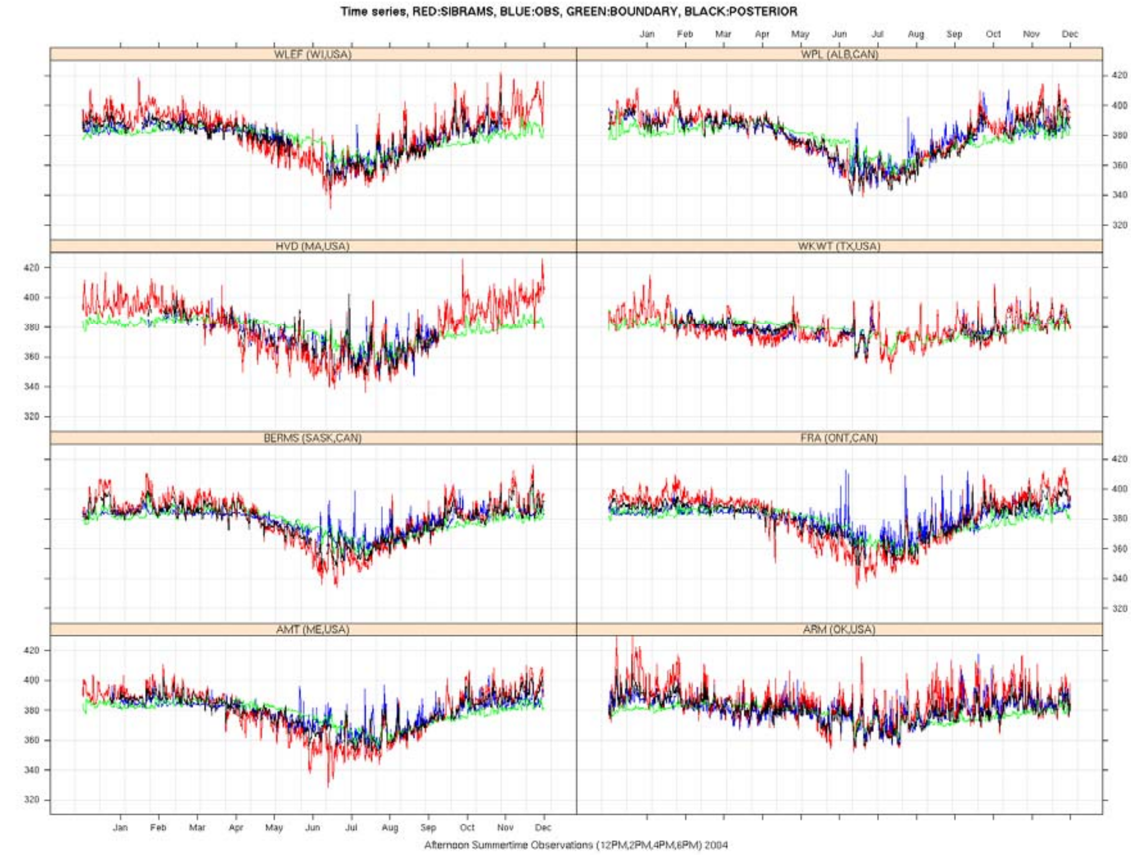

Figure 4. Simulated and Observed Afternoon CO_2 Mixing Ratios at the Eight Towers

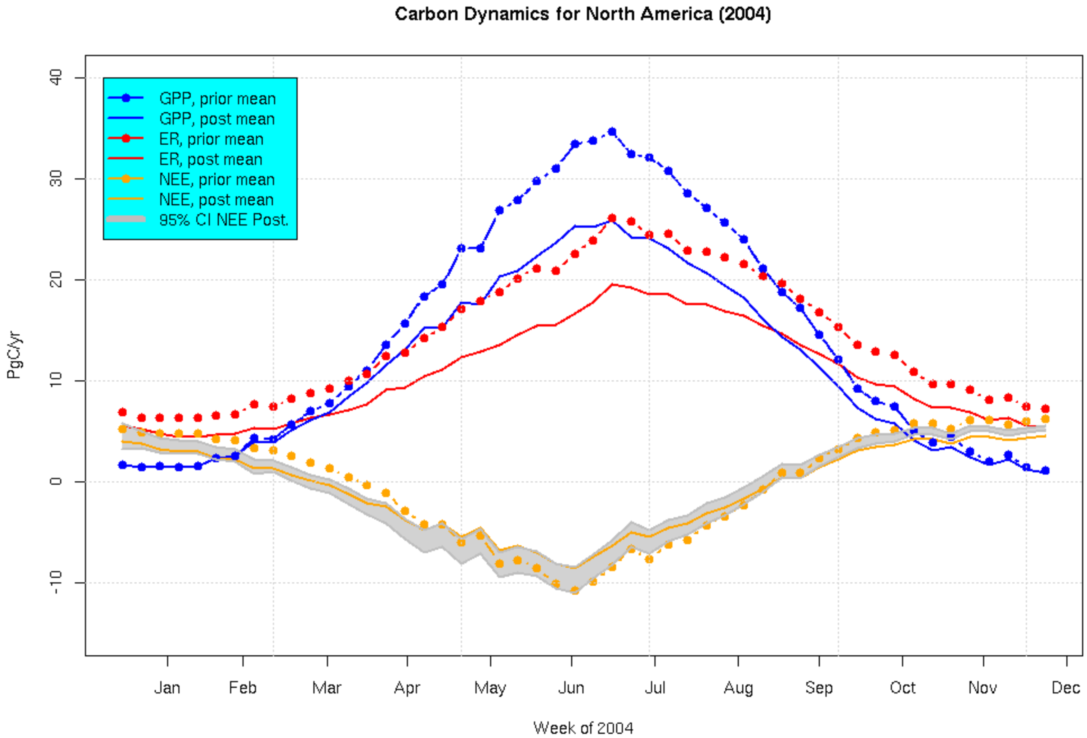

Figure 5. Prior and Posterior Estimates for GPP, ER, and NEE. Results are shown for a single inversion while the confidence intervals are derived from an ensemble of 100 inversions.

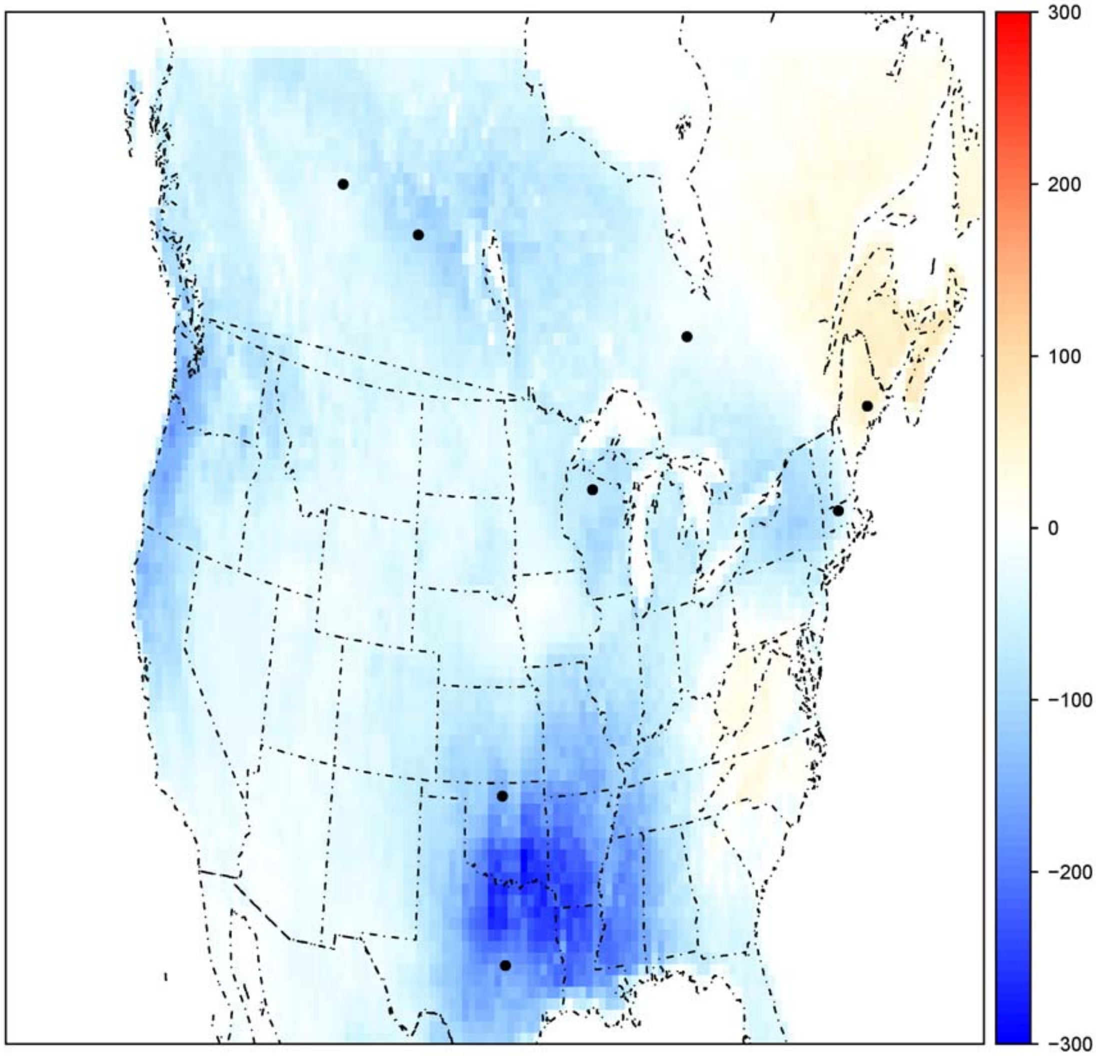

Figure 6. Estimated Annual Net Ecosystem Exchange of CO_2 for 2004

3. Comparison of Objectives Vs. Actual Accomplishments:

Information concerning instrumentation and sites collecting data can be found at http://www.amerifluxco2.psu.edu and http://ring2.psu.edu.
Results of our regional inversion have been submitted to the North American Carbon Program regional interim synthesis activity for inclusion in that comparison project.

4. Leveraging/Payoff:

The fate of anthropogenic CO_2 introduced into the atmosphere by the combustion of fossil fuels is one of the leading sources of uncertainty in projections of future climate. Coupled carbon-climate models simulate positive feedback (warming promotes additional CO_2 release to the atmosphere), but a recent comparison of 11 such models found a range of nearly 200 ppm in CO_2 and 1.5 K of warming in 2100 (Friedlingstein et al, 2006). Research leading to improved quantification and understanding of carbon sources and sinks has therefore been identified as a major priority for the US Carbon Cycle Science Program, with special focus on North America in the near term. The North American Carbon Program (NACP, Wofsy and Harris, 2002; Denning et al, 2005) involves process studies, an expanded flux measurement network, remote sensing and modeling, and inversions using new atmospheric mixing ratio observations. Cross-evaluation of models and data sources and hypothesis testing at a variety of spatial and temporal scales is envisioned within a new framework of model-data fusion.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Strong linkages to other related projects at CSU funded by NASA and DOE
Collaboration with Randall Kawa and James Collatz at NASA GSFC
Links to Peter Thornton at NCAR
The North American Carbon Program (NACP: an integargency collaboration sponsored by 9 federal agencies):
NACP Science Steering Group
Midcontinent Intensive Task Force
MCI Task Force, Data Systems Task Force, and Synthesis Task Force

6. Awards/Honors: None

7. Outreach:

<u>Presentations</u>
Schuh, A., A.S. Denning, M. Uliasz, N.R. Miles, K.J. Davis, and S.J. Richardson, Regional-scale atmospheric measurements of CO2 sources and sinks. Plenary talk, Air and Waste Management Association First International Greenhouse Gas Measurement Symposium, 23-25 March, 2009, San Francisco, CA.

Participation in the 2nd North American Carbon Program All-Investigators Meeting. 17-20 February, 2009, San Diego, CA, including a project-related presentations:
Co-convener of session on Integrated Studies of Regional Carbon Exchange at the Fall Meeting of the American Geophysical Union, December, 2008, San Francisco, CA.

Student Degrees Supported
Ph.D. dissertation:
Schuh, Andrew. Primary support from this project.

8. Publications:

Schuh, A. E., A. S. Denning, M. Uliasz, K. D. Corbin, 2009. Seeing the Forest through the Trees: Recovering large scale carbon flux biases in the midst of small scale variability. Jour. Geophys. Res., doi:10.1029/2008JG000842.

Conference Proceedings

Denning, A. S., K. D. Corbin, I. T. Baker, E. Lokupitiya, E. McGrath-Spangler, R. Stockli, A. Schuh, K. R. Gurney, N. Parazoo, D. Zupanski, M. Uliasz, N. Miles, K. Davis, and S. Richardson. The North American Carbon Cycle as Seen In Models and Observations. Presented at the American Geophysical Union Fall 2008 Meeting, San Francisco CA, USA.

Denning, A. S., N. Parazoo, A. Schuh, and M. Uliasz. Gulf Coast Atmospheric Inflow: A Key Element of the North American CO2 Budget. Presented at the American Geophysical Union Fall 2008 Meeting, San Francisco CA, USA.

DEVELOPMENT AND EVALUATION OF GOES AND POES PRODUCTS FOR TROPICAL CYCLONE AND PRECIPITATION ANALYSIS (PSDI)

Principal Investigators: L.D. Grasso

NOAA Project Goal: Weather and Water

Key Words: Tropical cyclone, Hurricane, Precipitation, Rainfall, Tropical Cyclone Intensity, Tropical Cyclone Formation, GOES-O Science Test, Mesoscale Convective System.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project encompases the following developments and improvements: (1) the development and operational implementation of an Advanced Microwave Sounding Unit (AMSU) –based global tropical cyclone intensity algorithm, (2) the development and evaluation of GOES and POES products for tropical cyclone and precipitation analysis, (3) the development of a GOES-based multi-platform tropical cyclone surface wind product (4) the GOES-O Science Test, and (5) the GOES MCS Index project.

The long-term goals of these five projects are as follows:

Project (1) the first project is intended to increase the utility of operationally available Advanced Microwave Sounding Units (AMSUs) aboard the recently launched Met-OP and NOAA-19 satellites and the NASA Aqua Satellite. Specifically this project will use the data from these platforms to estimate tropical cyclone intensity and wind structure using an already operational algorithm that is run at the National Centers for Environmental Prediction and currently makes use of AMSU data from NOAA-15, -16, and -18 Satellites. This will allow for 1) improved observations of tropical cyclones (increase observation frequency) that will lead to 2) improved operational estimates of tropical cyclone intensity and structure.

Project (2) Using a combination of model analyses, GOES water vapor imagery, and historical tropical cyclone formation datasets an algorithm to predict the probablity of tropical cyclone formation will be developed. Development involves statistical screening of the data and discriminant analysis to produce the probablity of formation in 5 degree latitude/longitude areas. An experimental version of this product for the Atlantic and eastern N. Pacific will be produced in real-time at CIRA. Following a period of evaluation by personnel at the National Hurricane Center, and working with personnel at NOAA/NESDIS/IPB the product will be transitioned to an operational platform. The final product will be displayed on the NESDIS Satellite Analysis Branch (SAB) website. Finally, the product will be extended to the central and western N. Pacific.

Project (3) This project has plans to transition an algorithm to create a multi-platform tropical cyclone surface wind analysis (MTC-SWA) from satellite-based resources. This algorithm, which is driven by operational tropical cyclone locations, combines information from four satellite-based data sources (Scatterometry from ASCT and QuikSCAT, Geostationary cloud feature winds, the Advanced Microwave Sounding Unit, and Infrared-based flight-level proxy winds) to create a flight-level (near 700 hPa) wind analysis using a variational data fitting approach. The resulting low-level winds are then adjusted to the 10-m elevation applying a very simple single column approach with differing treatment of land and ocean exposures.

The resulting surface wind analysis is used to create real-time two-dimensional wind fields from which graphics are created and displayed via the World Wide Web. In addition the surface wind fields are used to estimate operational tropical cyclone structure metrics (maximum extent of maximum, 34, 50 and 64 kt winds) and a dynamical estimate of minimum sea level pressure (i.e., a fix). These simple storm diagnostics are then supplied to various tropical cyclone warning agencies in a real-time manner and in a format conforming to their operational tools.

The ultimate goal it to transition this algorithm to operations at the National Satellite Operation Facility in Suitland, MD so that it can be operational maintained and supply tropical cyclone structure information to the community.

Project (4) GOES data are a major part NOAA's satellite activities, and the quality of GOES data relate directly to numerous satellite products and services provided by NOAA. The checkout of each GOES provides an opportunity to assess the quality of the GOES data being provided, and pre-operational generation of GOES products determines whether they meet specifications and are ready for use. In addition, past Science Tests have discovered problems with the GOES data or data flow, and have provided appropriate feedback to Satellite Operations to solve these problems.

The Science Test data for this project are received and archived, for both direct testing and post analysis that may be necessary. Science Test data include both operational scenarios and unique datasets that are not allowed during normal satellite operations. Some of the specialized data are designed to relate to future GOES-R capabilities.

Project (5) The long-term objective of the GOES Mesoscale Convective System (MCS) Index is to create a project which uses GOES Sounder data and numerical model output to predict whether upscale growth of convection into an MCS is likely. To achieve this, two summers of data (included observed MCSs from the GOES imager) will be used to generate the coefficients for the index, so that the index may be computed and plotted over the CONUS in real-time.

2. Research Accomplishments/Highlights:

Product (1): The statistical temperature retrievals for the Met-Op and Aqua satellites has been developed and integrated into the program that estimates tropical cyclone intensities and wind structures. BUFR Code is being developed to read the NASA Aqua AMSU antenna temperatures and BUFR code is being modified to read the AMSU antenna temperatures from the Met-Op and NOAA-19 satellites. Once the freeze has been lifted on the operational IBM supercomputer transition to operations will begin.

Product (2): Tropical Cyclone Formation Probability (TCFP) Product for the N. Atlantic and the eastern, central and western N. Pacific was delivered to The NESDIS in June 2008. However, final transition to operations was delayed due to compatibility issues with the new NESDIS AIX systems and a freeze placed on all NESDIS development and production machines during fall 2008. SAB currently maintains the operational product and website (http://www.ssd.noaa.gov/PS/TROP/TCFP/index.html) and CIRA maintains a backup website at http://rammb.cira.colostate.edu/projects/gparm/.

Product (3): The MTC-SWA analysis was run successfully during the 2008 Hurricane seasons and provided fixes for every active storm in the Automated Tropical Cyclone Forecast database during this time. The estimates were compared and validated against the operational estimates provided by the National Hurricane Center (NHC). The validation was conducted during all periods and only during those times when the storm was observed by aircraft reconnaissance. Results of this verification were provided to the NHC. Based on this evaluation the fixes (MSLP, wind radii) will be provided to the NHC during the 2009 hurricane season for further evaluation. An example of a surface wind analysis produced for Hurricane Paloma is shown in Figure 1 below. More examples can be found at http://rammb.cira.colostate.edu/products/tc_realtime/

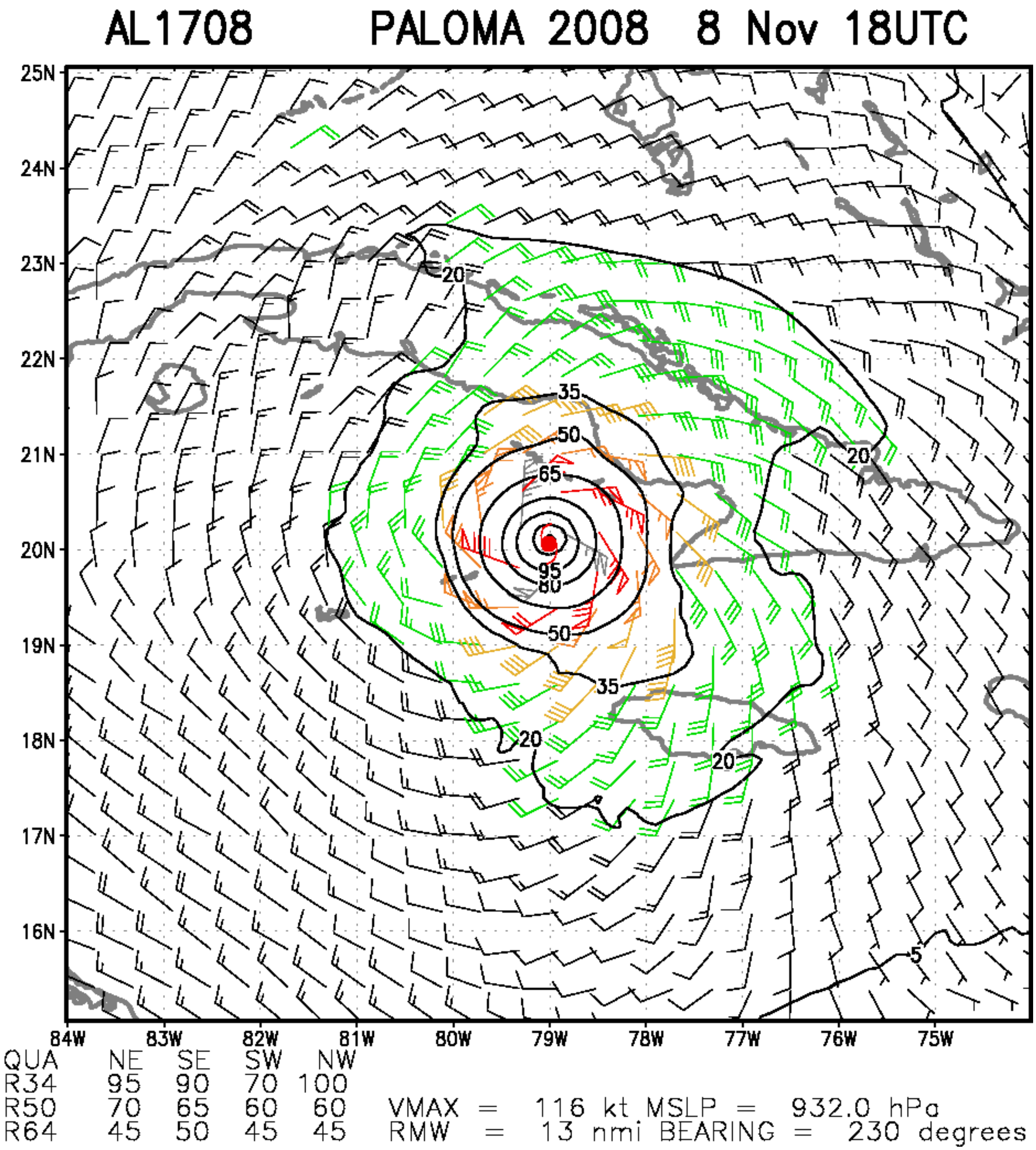

Figure 1: Surface Wind Analysis Produced for Hurricane Paloma.

The processing has undergone a critical design review at NSOF. The MTC-SWA algorithm and the required data ingest has also been ported to NSOF computers and will be run in parallel with the same process run at CIRA during 2009. Remaining tasks include web page development, archive agreements and monitoring scripts, which are being developed.

Product (4): A Science Test web page (http://rammb.cira.colostate.edu/projects/goes-o/) provides near-daily updates as the testing continues. A *NOAA/NESDIS Technical Report* is produced from each Science Test, outlining the test and conclusions about GOES data and products.

Product (5): An experimental version of the GOES MCS Index is running in real-time on a CIRA webpage: http://rammb.cira.colostate.edu/projects/mcsindex/mcsindex.asp. There are links on this page to real-time verification which updates daily.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Product (1) is about a year behind schedule due to increased NCEP security and the current freeze on the NCEP super computer. The BUFR Code development is in progress but behind schedule due to access to NCEP computing facilities. The operation transition of these improvements is in progress as well but has also been hampered by the development of the BUFR codes and the current moratorium on the NCEP supercomputer.

Product (2) has met our objectives for this reporting period.
Transfer of the new TCFP, including all FORTRAN code, scripts, and documentation, to the Satellite Services Division Satellite Analysis Branch was completed in June 2008. However, the TCFP product was delayed in its final transition to operations due to compatibility issues with the new NESDIS AIX systems and a freeze placed on all NESDIS development and production machines during fall 2008. The TCFP was declared operational in December 2008.

Project (3) is on schedule and the following tasks have been completed:

Develop GOES, AMSU, ASCAT, QuikScat data stream at CIRA/RAMMB
Start running the prototype analysis at CIRA
Begin website design
Run prototype analysis at CIRA post results to the web coordinate with JTWC/NHC/CPHC and WMO RMSCs.
Design review for the project
Develop local archive scheme and update archival requirements (if needed)
Develop data flow at NSOF (i.e., were will we get these data from in operations)
Validate/compare winds locally and at SAB (SAB's evaluation based on preliminary best tracks)
Review by users
Code revised and prepared for implementation, final SAB validation/comparison
Implement code at NSOF
Implement data ingest at NSOF

The following tasks are ongoing:

Code revised and web pages updated (if needed)
Begin monitoring codec development

Final Archive requirements identified
Operational and backup processing defined

Product (4): The launch of GOES-O has been delayed, so that the Science Test will occur during the coming fiscal year. Otherwise plans remain in place and testing will commence after launch, reaching maximum effort about 5 months after launch, just before the GOES-O will be placed in storage for future use.

Product (5): The GOES MCS Index was not able to be transferred to operations because year two funding was denied. This is because we determined that the algorithm performed better (statistically) by using the model input only, compared to both the GOES Sounder and the model data. Since the PSDI funding is for satellite-based products only, the funding was cut after FY08. This status is therefore *"determined to be inappropriate."*

4. Leveraging/Payoff:

Accurate and frequent information about tropical cyclones is not only important to operational forecasters, but affects almost all elements of business, homeland security and commerce.

Operational forecasters at the National Hurricane Center, Central Pacific Hurricane Center and Joint Typhoon Warning Center are required to forecast the likelihood of tropical cyclone formation in the next 24 hours. These forecasts are particularly important in coastal areas where storms may form, intensify, and then quickly move onshore, leaving little time for communities to prepare. Currently there is little objective guidance for tropical cyclone formation. The algorithm developed in this project offers a truly objective guidance method to aid in these forecasts.

The GOES-O Science Test is a key step before operational implementation.

The GOES MCS Index product can assist forecasters in determining whether MCS formation is likely. MCSs are very important because they provide 70% of the summertime precipitation to the central Plains, and are often responsible for flash flooding in that area.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

The tropical cyclone intensity and structure estimates that are created via this method are supplied to the National Hurricane Center, the Central Pacific Hurricane Center, the Department of Defense's Joint Typhoon Warning Center and several World Meteorological Regional Meteorological Specialized Centres around the globe.

Vertical wind profiles created via this algorithm are being tested as a potential supplier of a solely satellite-based vertical wind shear in the tropical rainfall potential product being developed at NESDIS.

We are in collaboration with Dr. Bob Kuligowski of NOAA/NESDIS, Michael Turk (NOAA/NESDIS), Antonio Irving (NOAA/NESDIS), Charles Sampson (NRL, Monterey), Edward Fukada (DOD/JTWC)and Ed Rappaport (NOAA/NHC).   The GOES-O project was a collaboration between RAMMB/CIRA, ASPB/CIMSS and STAR personnel in Washington DC, and the GOES MCS Index project was a collaboration between STAR, CIRA, and the Colorado State University Department of Atmospheric Science.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Refereed Publications

Schumacher, A.B., M. DeMaria, and J.A. Knaff, 2009: Objective Estimation of the 24-h Probability of Tropical Cyclone Formation. *Wea. Forecasting*, 24, 456–471.

Non-refereed Publications:

Hillger, D.W., and T.J. Schmit, 2009: The GOES-13 Science Test: A Synopsis. *Bull. Amer. Meteor. Soc.,* May, 6-11.

Conference Proceedings

Schumacher, A. presented "An Overview of Research to Operations Activities at CIRA for 2008/2009" at the *National Hurricane Center Invited Seminar*. 10 October 2008, Miami, FL.

Schumacher, A.S., 2008: Combining Model/Satellite Information for Cyclone Forecasts. *CoRP 5th Annual Science Symposium*, 11-14 August, CIOSS, Corvallis, OR.

DEVELOPMENT OF A POLAR SATELLITE PROCESSING SYSTEM FOR RESEARCH AND TRAINING

Principal Investigator: B.H. Connell

NOAA Project Goal: Weather and Water

Key Words: Local Forecasts and Warnings, Weather Water Science, Technology and Infusion

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Long term research goals include: The implementation of a polar satellite data processing and archive system for interaction with the StAR Regional and Mesoscale Meteorology Branch (RAMMB) located at CIRA to provide data to support: 1) real-time and case study analysis for the development/improvement of tropical cyclone and severe weather algorithms; 2) the development of simulated proxy datasets to provide analysis and training tools on the interpretation of polar data products; and 3) enhanced collaboration and data utilization with other CIRA projects ingesting additional polar data sets.

2. Research Accommmplishments/Highlights:

A data server and a 7 TB RAID storage system have been procured and configured, and initial research case study data sets from ASCAT, IASI, SSMI, MIRS and ATOVS have been obtained from the NESDIS DDS server. In addition, the project obtained and installed the NPOESS Product Validation Summary System (NPROVS), developed under contract to the Operational Products Development Branch (OPDB) of the StAR Satellite Meteorology and Climatology Division (SMCD). The NPROVS system also provided several case study data sets (Aqua-AIRS, IASI, MIRS, COSMIC, and IASI and ATOVS data from EUMETSAT). Utilization of the system will alleviate the need for a large analysis software development project.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The first year project goal was to procure and implement the polar data processing and archive system, and to begin data archival of a several data sets to support the RAMMB Cal/Val project. The project has met its initial objectives, and several additional accomplishments have also been completed. Utilization of the OPDB NPROVS system will significantly enhance both the analysis and case study data archive capabilities without additional cost to the project. The project has also coordinated with other CIRA researchers using polar data to determine the best methodology for making the data available for use with other projects.

4. Leveraging/Payoff:

Improved forecaster training with advanced satellite analysis techniques developed at RAMMB/CIRA will provide better forecasts and better utilization of NOAA satellite data.

5. Research Linkages/Partnerships/Collaborators, Communication And Networking:

This project supports some of the work being done in the RAMMB Cal/Val project, which will assess the quality of retrievals based on polar-orbiting satellite data, with radiosondes and dropsondes from the Gulfstream IV jet being used as validation datasets. The assessment will include not only statistics measuring the overall quality of the retrievals, but also the ability of the retrievals to capture significant meteorological features such as tropopause height, trade-wind inversion height, low-level moisture and CAPE. The project is also leveraging software and datasets developed by Stan Kidder and Andy Jones of CIRA to support their AMSU research.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

DEVELOPMENT OF AN IMPROVED CLIMATE RAINFALL DATASET FROM SSM/I

Principal Investigators: Christian Kummerow and Wesley Berg

NOAA Project Goals:

Key Words:

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Implement GPROF-2006 for SSM/I. This involves the development of specific rainfall databases and procedures, which are consistent with funded efforts to produce rainfall products form TMI and AMSR-E.

Investigate the sensitivity of the SSM/I rainfall products to Tb variability
Across DMSP platforms using F13 as the calibration standard
Across radiometer platforms using TMI as the calibration standard

Investigate the impact of changes in rainfall associated with the diurnal cycle over the tropics using TMI. Since TMI processes throughout the diurnal cycle, the 8+ years of available data can be used to determine the impact of diurnal variations on the different overpass times of the multiple sun-synchronous DMSP satellites within the tropics. Changes in the local observing times of the DMSP satellites due to orbit drift will also be addressed.

Produce and distribute daily and monthly gridded SSM/I rainfall products for the period of record. We will distribute the data via both ftp and from our current web site (http://rain.atmos.colostate.edu/RAINMAP), In addition, we will work with the community (i.e. GPCP, CPC, and other potential users) to develop a mechanism for long-term distribution of the data though NCDC and/or other data archive centers.

Create a composite monthly climate rainfall product from the available SSM/I data. We will apply the results from our investigation of diurnal cycle impacts on the sun-synchronous sampling of the DMSP sensors to account for sampling-related climate biases.

2. Research Accomplishments/Highlights:

Several aspects of the project have been ongoing over the past year. Significant progress has been made and we are on schedule to produce a complete climate rainfall dataset from SSM/I for the period from 1987 through the present using version 2008 of the GPROF retrieval algorithm by the end of the project. Initial results from the new retrieval algorithm indicate significant improvements in ocean rainfall estimates that will provide a much improved dataset for climate research applications. Details of specific activities undertaken over the past year include the following.

SSM/I TDR archive: A complete archive extending from the start of the SSM/I data record beginning with F8 in July of 1988 and extending through the present was delivered to NCDC. This archive was composited together from a variety of sources including CSU/CIRA, NOAA/ETL, Remote Sensing Systems and NOAA/NESDIS. In addition, software and associated expertise was provided to Hilawe Semunegus at NCDC to read both TDR and Wentz formatted antenna temperature data as well as do basic quality control of the data. As a result, NCDC is close to having the entire SSM/I antenna temperature archive converted to NetCDF format and available for public distribution through their CLASS system.

GPROF Version 2008: A beta version of the new ocean algorithm has been adapted for use with SSM/I F13, F14, and F15 observations and applied to the period from January through December 2005. Results from this initial year indicate excellent agreement between the sensors, which is a significant improvement over the ~15% mean differences between F13 and F15 from the previous Version 2004 algorithm. In addition to significantly better consistency between sensors, the new algorithm provides greatly improved sensitivity to light rain, especially at high latitudes. Testing and assessment of rainfall estimates from the beta version is currently ongoing.

Work to finalize the algorithm including integration with the land retrieval is currently being completed. Processing of the entire SSM/I data archive with the official version 2008 algorithm is expected to begin later this year and to be completed by early 2010.

Intersatellite Calibration of the SSM/I Brightness Temperatures: The initial calibration efforts have focused on the period of TRMM data availability, which extends from December of 1997 through the present. This approach uses TMI observations from TRMM, which crosses each of the SSM/I orbits multiple times each day, to provide a consistent reference standard. An optimal estimation (OE) approach is used to retrieval geophysical parameters from the TMI observations. These parameters are then used to computed estimated brightness temperatures from the SSM/I sensors, which are compared to the observed differences to determine calibration offsets for each channel. Comparisons with in-situ observations of marine wind speed from buoys and total precipitable water from radiosondes over ocean locations are being used to investigate the sensitivity of the calibration offsets to assumptions in the OE retrieval. We anticipate finalizing the details of the OE based on these sensitivity studies and processing the data to compute the calibration offsets for the TRMM period within the next several months. All of the software for computing simultaneous overpasses etc. has been completed so processing the data will be relatively straight forward once the OE is finalized. Analysis of the pre-TRMM intercalbration of the SSM/I sensors will involve use of the radiosonde and buoy observations to determine consistency between sensor pairs (i.e. F11 and F13) during overlapping periods. It is anticiplated that this part of the intercalibration effort should be completed by the end of 2009.

3. Comparison of Objectives Vs. Actual Accomplishments: None

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

None.

6. Awards/Honors: None.

7. Outreach: None

8. Publications: None.

ENVIRONMENTAL APPLICATIONS RESEARCH

Principal Investigator: C. Matsumoto

NOAA Project Goals: Various

Keywords: Various

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Various. See following reports.

2. Research Accomplishments/Highlights:

See following reports.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

See following reports.

4. Leveraging/Payoff: See following reports.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

See following reports.

6. Awards/Honors: See following reports.

7. Outreach: See following reports.

8. Publications: See following reports.

I. Research Collaborations with the ESRL/GSD Office of the Director

Project Title:The Use of Unmanned Aerial Systems for Atmospheric Observations

Principal Researcher: Nikki Privé

NOAA Project Goal / Program: Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate observations and analysis

Key Words: Unmanned Aircraft Systems (UAS), Climate, Observations, Arctic, Forecast

1. Long-term Research Objectives and Specific Plans to Achieve Them:

To develop a concept of operations for a global network of Unmanned Aerial Systems (UAS) for the purpose of improving atmospheric observations for climate and weather over data-poor regions. The observational goals and viability of such a network will be determined by using Observing System Simulation Experiments (OSSE) for contributions to operational weather forecasting, and through analysis of existing climate data for contributions to climate research. Numerical modeling and analysis of past data will be used to determine the optimal choices of UAS routing and instrumentation to improve numerical weather forecasts.

2. Research Accomplishments/Highlights:

Calibration of the global OSSE has been partially completed. Baseline calibration experiments have been performed for two 7-week periods using archived observations for six different data-denial types: RAOB, Aircraft, AMSU-A, AIRS, and GOES. Synthetic observations from the Nature Run are now available, and calibration data denial runs for the synthetic observations are now underway. Algorithms for the analysis of the calibration data have been written and tested on the baseline results.

A ‘Quick’-OSSE has begun in support of the hurricane UAS testbed. The purpose of the Quick-OSSE is to provide initial guidance for UAS flight paths and instrumentation by performing ad hoc, uncalibrated OSSE experiments using regional forecasting models. Code has been written and tested to generate synthetic UAS observations for dropsondes, in situ measurements, balloons, and SFMR using nested moving regional model output.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Objective: Running an observing system simulation of the effect of large numbers of UAS sondes on the medium range weather forecast.

Status: In progress. Code for the generation of synthetic UAS observations and diagnostic evaluation of the Nature Run have been completed. Baseline calibration data-denial experiments have been completed, and calibration of synthetic data sets is ongoing.

Objective: “Quick” OSSE for the hurricane testbed.

Status: In progress. Synthetic observing code for UAS observations has been written and tested for the Quick-OSSE Nature Run for dropsondes, balloons, and in-situ aircraft measurements. The Nature Run and forecast model are being set up for future experiments.

Objective: Observing System Experiments (OSE) for the hurricane testbed using existing UAS observations.

Status: The project moved more strongly in the direction of the Quick-OSSE to support the hurricane UAS testbed, and the OSE was not performed.

4. Leveraging/Payoff:

The proposed network of UAS observations, envisioned to be a key component of the NOAA-proposed GEOSS, would provide regular vertical profiles of atmospheric conditions across data-poor regions, with the goal of improving operational weather forecasting and providing quality data for climate change research. The current efforts to design and optimize the proposed UAS observational network help to ensure that the network would be viable and successful at reaching these goals.

5. Research Linkages/Partnerships/Collaborators: NCEP

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: Flow-following Finite-volume Icosahedral Model (FIM)

Participating CIRA Researcher: Brian Jamison

NOAA Project Goal/Program: Weather and Water—Serve society's needs for weather and water information / Environmental modeling; Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate predictions and projections

Key Words: Flow-following, Finite-volume Icosahedral Model

1. Long-Term Research Objectives and Specific Plans to Achieve Them:

The FIM model is a new global model that is being developed at GSD. It features an isentropic-sigma hybrid vertical coordinate system (successfully used in the Rapid Update Cycle (RUC) model) and an icosahedral horizontal grid (Fig. 1). Tasks for this project include: generating graphics of output fields, creation and management of web sites for display of those graphics, and creation and management of graphics for hallway public displays, including software for automatic real-time updates.

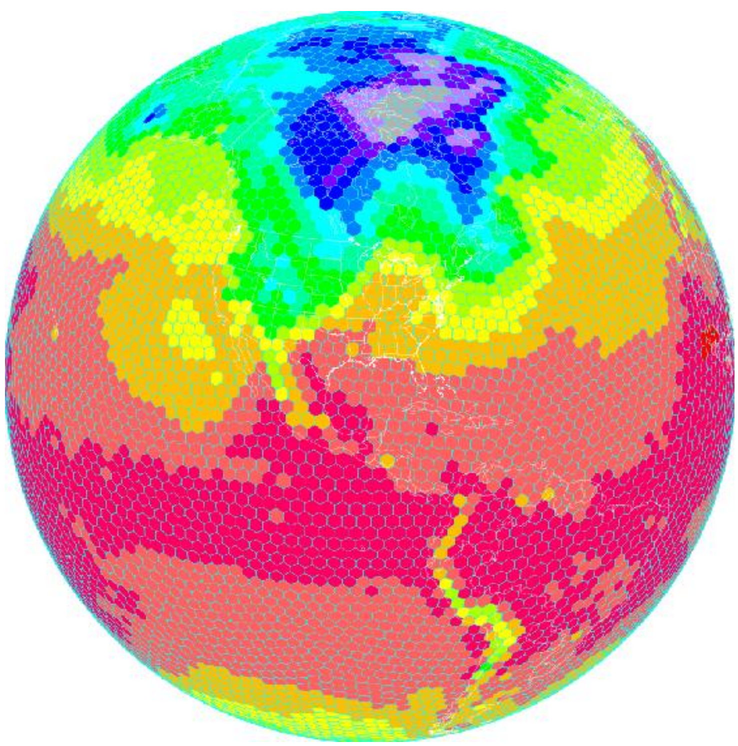

Fig. 1. An example of the icosahedral grid, with FIM model temperature plotted.

2. Research Accomplishments/Highlights:

Interpolation routines were developed that generate FIM output on a 0.5 degree latitude and longitude grid. These output fields can then be plotted using standard contouring packages. The NCAR Graphics Command Language (NCL) is the primary tool used for real-time graphics generation.

A web site for display of FIM model output was created and currently has 24 products available for perusal with 3-hourly forecasts going out to 7 days (http://fim.noaa.gov/fimgfs). GFS model forecast plots are also available as are FIM-GFS difference plots, and plots from the two models can also be viewed side-by-side. Several different projections are also now available including: CONUS, Africa, the Arctic, West Atlantic, West Pacific, Europe, and the Southern Hemisphere (Fig. 2). Additionally, the web site features the ability to loop any of these fields throughout the forecast periods.

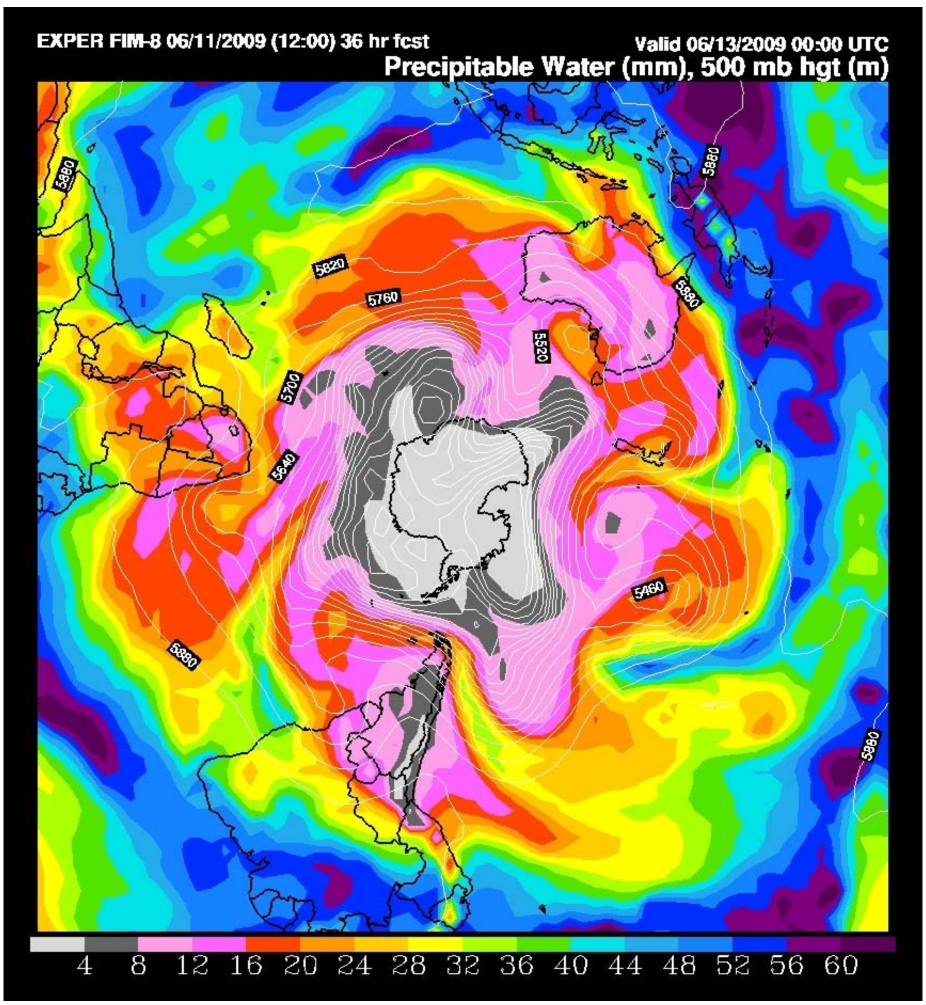

Fig. 2. A southern hemisphere view of FIM model output for a 36-hour forecast of precipitable water and 500 mb height.

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.

The Texas Advanced Computing Center (TACC) granted access to their 60,000 processor supercomputer for running the FIM at a higher resolution level, with grid points at about 15 km spacing. Separate web pages were created for FIM output from the TACC runs. Hurricane tracking software was used on the FIM output, providing FIM-produced forecasts of projected hurricane paths.

3. Comparison of Objectives Vs Actual Accomplishments for Reporting Period:

In progress; the accomplishments for this project during this fiscal year compare favorably with the goals outlined in the statement of work.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

II. Research Collaborations with the GSD Aviation Branch

A. High Performance Computing-Advanced Computing

Project Title: Advanced High-Performance Computing

Principal Researchers:Tom Henderson, Jacques Middlecoff, Jeff Smith, and Ning Wang

NOAA Project Goals/Programs:

In the area of High Performance Computing-Advanced Computing, CIRA proposed twelve research efforts. All twelve efforts support NOAA mission goals of (1) Weather and Water—Serve society's needs for weather and water information / Environmental modeling; (2) Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation / Aviation weather, Surface weather, and NOAA emergency response; and (3) Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond / Climate predictions and projections.

Key Words: Computational Grid, Gridpoint Statistical Interpolation, Model Parallelization, WRF portal, Domain Wizard, FIM

1. Long-term Research Objectives and Specific Plans to Achieve Them:

a) CIRA researchers will continue to support NOAA code interoperability, as well as ESRL needs, by supporting the NCEP Gridpoint Statistical Interpolation (GSI) code. The GSI is constantly changing, with a new version being released every few months. CIRA researchers will insure that the latest version of GSI is available and ported to ijet, ejet and wjet. CIRA researchers will assist in coding changes necessary to enhance and optimize the GSI to prepare it for regional- and global-scale modeling activities.

b) CIRA researchers will continue to develop and improve the WRF Portal (currently a beta release)—the graphical front end to the WRF NMM and ARW model. Specifically, they will extend support to the new 3.0 version of WRF, improve the visualization capabilities, and improve and broaden the workflow management to support a wider variety of WRF tasks on a wider variety of HPC systems. They will also adapt WRF Portal to support other models including FIM, GFS, and GSI, and will explore collaborations with the LEAD (Linked Environments for Atmospheric Discovery) researchers.

c) CIRA researchers will continue to develop and improve WRF Domain Wizard, a Java-based GUI front end to the WRF Preprocessing System (WPS). WRF Domain Wizard enables users to graphically select and localize a domain for WRF ARW and NMM, creates the namelist.wps and namelist.input files, runs WPS, and visualizes the output. CIRA researchers will adapt WRF Domain Wizard to support the latest features of WPS 3.0.

d) CIRA researchers will explore collaborations with other ESRL scientists on the FAA NNEW project and a new GSD probabilistic forecasting project. They will also assist in the research and development of web services for searching and retrieving meteorological data within GSD as well as visualizing that data using Google Earth.

e) CIRA researchers will continue to modify the Flow-following, Finite-volume Icosahedral Model (FIM) software to allow interoperability with NCEP's NEMS architecture implemented via the ESMF. This includes implementation of new coupling features and an ongoing effort to incorporate changes to NEMS and ESMF as they arise. In addition, system tests of FIM configured to use NEMS/ESMF will be added to the FIM automated test suite. Eventually, this task may be extended to include implementation and testing of a NIM ESMF (not necessarily NEMS) component.

f) CIRA researchers will 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.

g) CIRA researchers will continue to interact with the ESMF Core development team to specify requirements for features needed by FIM, NIM, and other NOAA codes.

h) CIRA researchers will continue to fine-tune software engineering processes (including source code revision control and automated testing) used during FIM development, ensuring that these processes remain suitable for a candidate production NWP code. Similar processes will be customized and implemented for NIM development as well. In addition, consulting support will continue to be provided to other GSD projects (GSI, etc.) as they improve their software development practices.

i) CIRA researchers will continue to assist with the computer science aspects of FIM. CIRA researchers will optimize the decomposition of the world into sub regions for parallelization and for cache optimization and incorporate new features such as the ongoing integration of WRF-CHEM into FIM.

j) CIRA researchers will do all the computer science research and development for the Non-hydrostatic Icosahedral Model (NIM) which is being developed by ESRL scientists. The goal is to run the NIM at sub 5km global resolution.

k) CIRA researchers will continue developing and enhancing software for the parallelization of atmospheric and oceanic weather and climate models. Collectively, this software suite is known as the Scalable Modeling System (SMS).

l) CIRA researchers will collaborate with ESRL scientists to support their codes and be available to provide design advice and expertise on a variety of software / web / database technologies for incorporation into the Lab’s various research endeavors.

2. Research Accomplishments/Highlights:

Objective A:
Dezso Devenyi has taken over most of the software engineering of GSI allowing CIRA researchers to assume the role of advisor and consultant on GSI. CIRA staff has provided extensive consulting support to help the GSI project set up a more easily accessible source code repository and have assisted local GSI developers with extensive software merge-updates.

Objective B:
CIRA researchers released WRF Portal to the modeling community and continued to extend and improve the software. The new version of WRF, 3.x, is supported and visualization was extended to support both NetCDF and GRIB (version 1 and 2) files. Workflow management was extended to support PBS, SGE, and LSF with both the internal and external workflow managers. The portal was also generalized to provide support for running the FIM model and CIRA researchers ran complex FIM workflows at TACC (Texas Advanced Computing Center) in support of a GSD-led hurricane tracking experiment.

Objective C:
CIRA researchers adapted WRF Domain Wizard to support the latest features of WPS (WRF Preprocessing System) 3.0, added a graphical namelist.input editor complete with error checking, added a non-linear vertical grid stretcher, and made numerous small improvements to the software. CIRA researchers also collaborated with LEAD (Linked Environments for Atmospheric Discovery) researchers to produce a version of WRF Domain Wizard for LEAD.

Objective D:
CIRA researchers have begun collaboration on the NNEW project to design and implement a suite of performance and latency tests for OGC web services (WFS and WCS) and associated database/web site. There was no collaboration on the GSD probabilistic forecasting project (no money was budgeted for our participation). CIRA researchers did create web services for searching and retrieving ESRL GFS meteorological data, as well as a ESRL intranet web site for doing so (http://intranet.fsl.noaa.gov/data-locator/).

Objective E:
CIRA researchers continue to play an integral part of the team that is preparing FIM for planned operational implementation. CIRA researchers have upgraded FIM to meet NEMS interoperability standards for "Phase I: Incorporation of the FIM into the NEMS D&T code" as specified in the NCEP-GSD LoA for transitioning FIM into operations.

Objective F:
CIRA researchers continued to contribute to the evolution of NCEP's NEMS architecture, collaborating with Tom Black and Mark Iredell as needed. Several suggestions made by CIRA staff have been or are being implemented within NEMS by NCEP developers. In addition, CIRA staff have been actively participating in discussions of a Common Modeling Architecture within the planned National Unified

Operational Prediction Capability (NUOPC). These discussions include representatives from operational centers in NOAA, Navy, and Air Force as well as researchers at NASA and NCAR. If successful, CMA will replace NEMS.

Objective G:
CIRA researchers have met with ESMF core team members to discuss new ESMF features and plans. CIRA staff reviewed several new features.

Objective H:
CIRA researchers improved FIM build and run automation, upgrading both to work robustly regardless of user environment and module settings. CIRA researchers continued to support and upgrade the FIM automated test suite, adding new tests as needed to ensure that new FIM features continue to work properly for serial and parallel configurations with a variety of compilers and libraries.

Objective I:
CIRA researchers constructed automatic, parallelized domain decomposition software that is part of the FIM code and that creates customized domains specifically tailored for the number of processors. This software can also be used to create sub-domains for cache blocking. Experiments with cache blocking did not show much speedup but did illuminate the fact that FIM is a streaming code. CIRA researchers have continued to support efforts of GSD scientists to incorporate elements of WRF-CHEM and WRF-ARW physics packages into FIM.

Objective J:
CIRA researchers organized, debugged, parallelized and optimized the NIM code. Optimizations included rewriting the matrix solving section which decreased the entire code serial runtime from 700 seconds to 108 seconds. Parallelizations were done with SMS.

Objective K:
CIRA researchers continue to improve SMS and to assist SMS users with SMS. SMS was extensively refactored to simplify implementations and remove functionality that is no longer required. The new "SMS-LITE" has 55,000 fewer lines of source code and is even easier to port and maintain and yet contains all the new unstructured grid functionality. The SMS regression test was revised to incorporate the changed functionality of “SMS-LITE” as well as the new unstructured grid functionality.

Objective L:
In collaboration with Sandy MacDonald and Jin Lee, CIRA researchers investigated the feasibility of using Graphical Processing Units (GPUs) and the IBM cell processors for increasing the performance of weather codes, specifically the NIM code. Experiments on FIM subroutines have shown that, compared to the state-of-the-art CPUs, a 20X speedup is possible. CIRA researchers continue to provide advice and assistance to ESRL scientists in all aspects of computer software.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

All Objectives A through L are progressing successfully.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors: Jeff Smith received the 2008 CIRA Research Initiative Award. Jacques Middlecoff and Tom Henderson received a certificate of appreciation from the ESRL director for work leading to the successful demonstration to Mary Glackin of FIM displayed on Science on a Sphere. Tom Henderson was recognized as GSD "Team Member of the Month" for February 2009.

7. Outreach:

8. Publications:

B. Aviation Systems—Development and Deployment

Project Title: FXC NNEW Demonstration

Principal Researcher: Jim Frimel

NOAA Project Goals/Programs: Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation/ Aviation weather

Key Words: Aviation Weather, Software Tools, Data Products

1. Long-term Research Objectives and Specific Plans to Achieve Them:

As a very broad description of this project, the Next Generation (NextGen) air transportation system is the FAA's plan to modernize the National Airspace System (NAS). The concept includes increase capacity and efficiency, improve safety, reduce environmental impacts, and improve user accessibility to information. The NextGen Network Enable Weather (NNEW), a component of NextGen, concepts include:

--A nationally consistent weather picture for all data (obs, analysis, and forecast).
--A Single Authoritative Source and a virtual repository of data (no single physical database, computer or location).
--A conceptually unified data source distribution among multiple physical locations and providers.
--Integration of weather information into the operational decision making processes.

2. Research Accomplishments/Highlights: (July 2008 – June 2009)

Over the past year, ASDAD's role was mainly to demonstrate a use case and data access to web service-provided Metar data and CIWS data. Additionally, they developed some baseline performance metrics for accessing web service data. This was accomplished by using AWIPS and FXC.

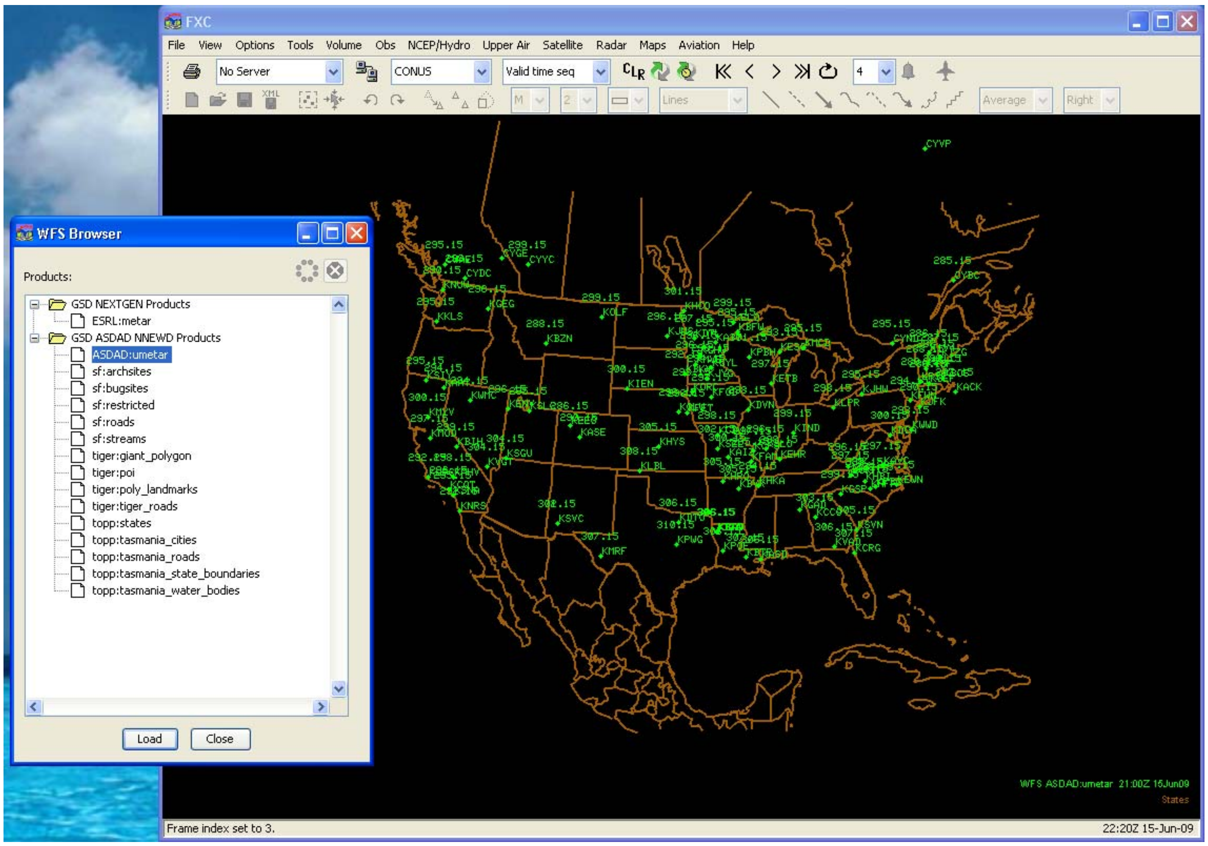

Fig. 1. View of the FXC WFS Browser and metar display.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

The actual accomplishments did meet the project's research objectives for the year.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: <u>Federal Avaiation Administration (FAA) Prototyping and Aviation Collaboration (PACE) Effort—Traffic Management Unit (TMU) Project</u>

Principal Researcher: Jim Frimel

NOAA Project Goals/Programs: Weather and Water—Serving society's needs for weather and water information / Local forecasts and warnings; Commerce and Transportation—Support the Nation's commerce with safe, efficient, and environmentally sound transportation / Aviation weather

Key Words: Aviation Weather, Software Tools, Data Products

1. Long-term Research Objectives and Specific Plans to Achieve Them:

PACE is an operational test area located within the Fort Worth Air Route Traffic Control Center's 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 Traffic Management Unit (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".

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 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, 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 suite 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.

Images 1 and 2 show current impact with no Forecaster Edits. ZFW TRACON departure gates are displaying green (no impact) and yellow (partial impact).

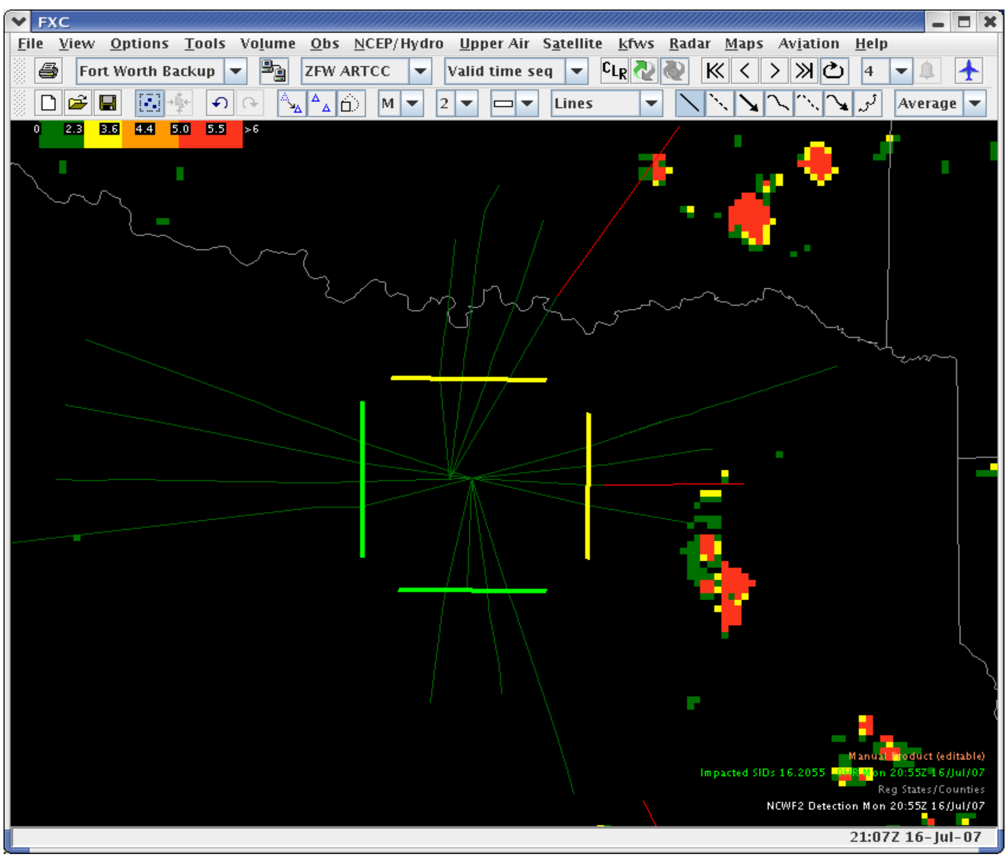

Fig. 2. Forecaster FXC tool showing current ZFW TRACON Departure Gate impacts with NCWF2.

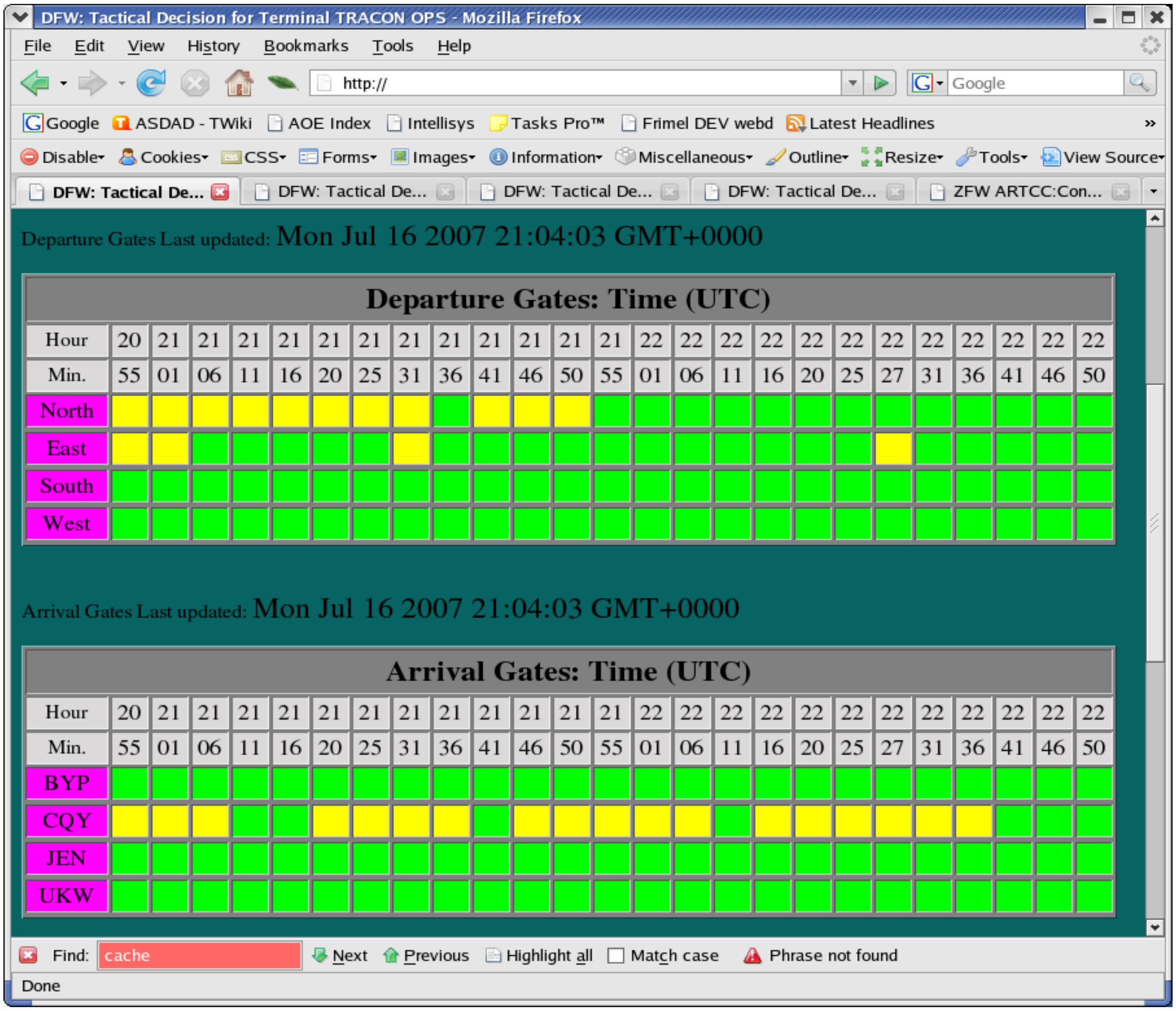

Fig. 3. Traffic Manager (WIDA) Web Display showing concurrent Red-light/Green-light Departure Gate Impact information.

2. Research Accomplishments/Highlights:

At the end of June 2007, the TMU Project team was notified of a budget and funding shortfall. As a result, priorities shifted to mothballing the TMU Project to a functional/stable release and all systems were migrated to a minimum environment topology for continued operational support. Additionally, this framework provided a minimally functional development and support environment based on the projected demands and resources. The decision to keep the project afloat was based on the high value and the potential for resurrecting this project in the future.

A core server and client system are still in use with software maintenance and system support being provided throughout the year. The TMU system is being used at the

Forth Worth Center Weather Service Unit (CWSU) for the daily weather briefings to the Traffic Managers and for the creation of web content graphics on the National Weather Service Southern Region Headquarters website for ZFW (http://www.srh.noaa.gov/zfw).

Due to a lack of continued funding, we are currently in discussions with NWS Headquarters to possibly sunset this project and associated systems in July 2009. We are also being asked to look into cost estimates for continued support, development and system upgrades to RedHat Enterprise 5 and a later AWIPS Operational Build. Additionally, we are looking into costing for continued support and for working on requirements driven from the TMU Project being available in an AWIPS II thin client.

The NWS has submitted a proposal for review by the FAA that would downsize the 20 CONUS CWSUs into 2. This June 3, 2009 NWS response proposal to the FAA for CWSU services does not include plans to use any of the technologies developed under the TMU Project. It is important to note that the TMU Project research was instrumental in driving requirements that had been included. It appears the weather service is also looking at "Plan B" scenarios in case the proposal is not accepted.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

The TMU research is highly dynamic, customer driven and relies heavily on customer feedback. As such, requirements, plans, schedules and goals are subject to change. Although constrained by these dynamics, the actual accomplishments did meet the project's research objectives for the year.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: FAA AWC, NWS CWSU

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: <u>FXC AI (Aviation Initiative) Demonstration</u>

Principal Researcher: Jim Frimel

NOAA Project Goals/Programs: Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation/Aviation weather

Key Words: Aviation Weather, Collaborative Software Tool

1. Long-term Research Objectives and Specific Plans to Achieve Them:

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 FXC Aviation Demonstration 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 National Weather Service (NWS) proposal for transforming the agency's aviation weather service program to meet the Federal Aviation Administration (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 Center Weather Service Unit (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 Center Weather Service Unit (CWSU) and the Weather Forecast Office (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 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 above. The FX-Collaborate (FXC) software, developed at NOAA's Earth System Research Lab, 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.

2. Research Accomplishments/Highlights:

Over the past year, no new research or development was directly applied to any AI Project work. There were no deliverables made to AI this year. However, it is important to mention that a core server and client systems are still in use and was supported throughout the year. The AI system continues to be used at the Leesburg, Virginia Center Weather Service Unit (CWSU) for its daily weather briefings to the Traffic Managers.

Due to a lack of continued funding, we are currently in discussions with NWS Headquarters to possibly sunset this project and associated systems in July 2009. We are also being asked to look into cost estimates for continued support, development and system upgrades to RedHat Enterprise 5 and a later AWIPS Operational Build. Additionally, we are looking into costing for continued support and for working on requirements driven from the AI Demonstration being available in an AWIPS II thin client.

The NWS has submitted a proposal for review by the FAA that would downsize the 20 CONUS CWSUs into 2. This June 3, 2009 NWS response proposal to the FAA for CWSU services does not include plans to use any of the technologies developed under the AI Demonstration. It is important to note that the AI Project demonstration was instrumental in driving requirements that had been included. It appears the weather service is also looking at “Plan B” scenarios in case the proposal is not accepted.

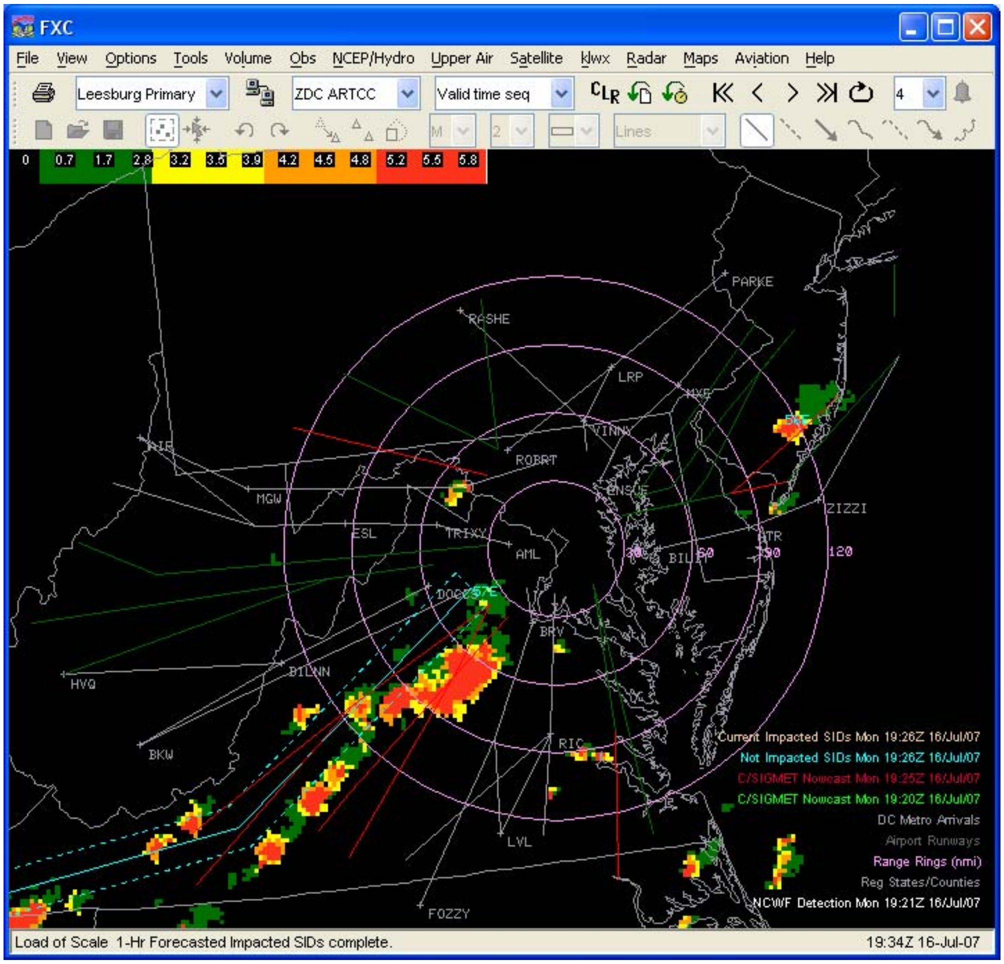

Fig. 4. View of the FXC AI BriefEE display with map enhancements and impacted DC Metro departure routes.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

The nature of the AI demonstration was short-fused, highly dynamic, and customer driven. With the demonstration time frame set to end in September 2006, requirements, plans, and goals were subject to adjustment in order to meet the time line without interfering with the overall objectives. The demonstration was completed and the objectives were met.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: <u>FXC VACT (Volcanic Ash Coordination Tool) Project</u>

Principal Researcher: Jim Frimel

NOAA Project Goals/Programs: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings; Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation / Aviation weather

Key Words: Volcanic Ash Advisories, Data Ingest and Display System, Collaborative Tool

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The FXC 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 FXC 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 FXC 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 FXC 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 FXC 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.

2. Research Accomplishments/Highlights:

At the end of June 2007, the FXC VACT Project team was notified of a budget and funding shortfall. As a result, priorities shifted to mothballing the FXC VACT Project to a functional/stable release and all systems were migrated to a minimum environment topology for continued operational support. Additionally, this framework provided a minimally functional development and support environment based on the projected demands and resources. The decision to keep the project afloat was based on the high value and the potential for resurrecting this project in the future.

A core server and client system are still in use with software maintenance and system support being provided throughout the year.

Due to a lack of continued funding, we are currently in discussions with NWS Headquarters to possibly sunset this project and associated systems in July 2009. We are also being asked to look in to cost estimates for continued support, development and system upgrades to RedHat Enterprise 5 and a later AWIPS Operational Build. Additionally, we are looking in to costing for continued support and for working on requirements driven from the FXC VACT Project being available in an AWIPS II thin client.

The NWS has submitted a proposal for review by the FAA that would downsize the 20 CONUS CWSUs into 2. The June 3, 2009 NWS response proposal to the FAA for CWSU services addresses the CONUS with mention of maintaining CWSU-Anchorage as-is; there appears to be no intent of continuing funding for Alaska.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

The VACT research is highly dynamic, customer driven and relies heavily on customer feedback. As such, requirements, plans, schedules and goals are subject to change. Although constrained by these dynamics, the actual accomplishments did meet the project's research objectives for the year.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators:

Alaska Volcano Observatory, FAA Alaska Center Weather Unit, FAA Anchorage Weather Service Unit.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

C. Forecast Verification

Project Title: Collaboration With ESRL/GSD/AB's Forecast Verification Section

Principal Researcher: Sean Madine
CIRA Team Members: Melissa Petty and Daniel Schaffer

NOAA Goal/Program: Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation/Aviation Weather

Key Words: Forecast Verification, Aviation Weather

Background on Forecast Verification Effort: According to the Federal Aviation Administration (FAA), the current air traffic system, a very important part of the national economy, will not scale to accommodate future demand in the national airspace. The FAA, in concert with other U.S. government organizations, has moved to transform the current management approach into the Next Generation Air Transportation System (NextGen), with planned realization in 2025. Air traffic management, when performed by either a human or a computer algorithm, requires accurate and timely forecast information about meteorological variables that impact aviation, namely convection, icing, turbulence, and visibility conditions. Verification provides information about an aviation forecast product's suitability for operations and its performance within the operational setting. CIRA researchers are working to build concepts and systems to meet the NextGen requirements for forecast verification data.

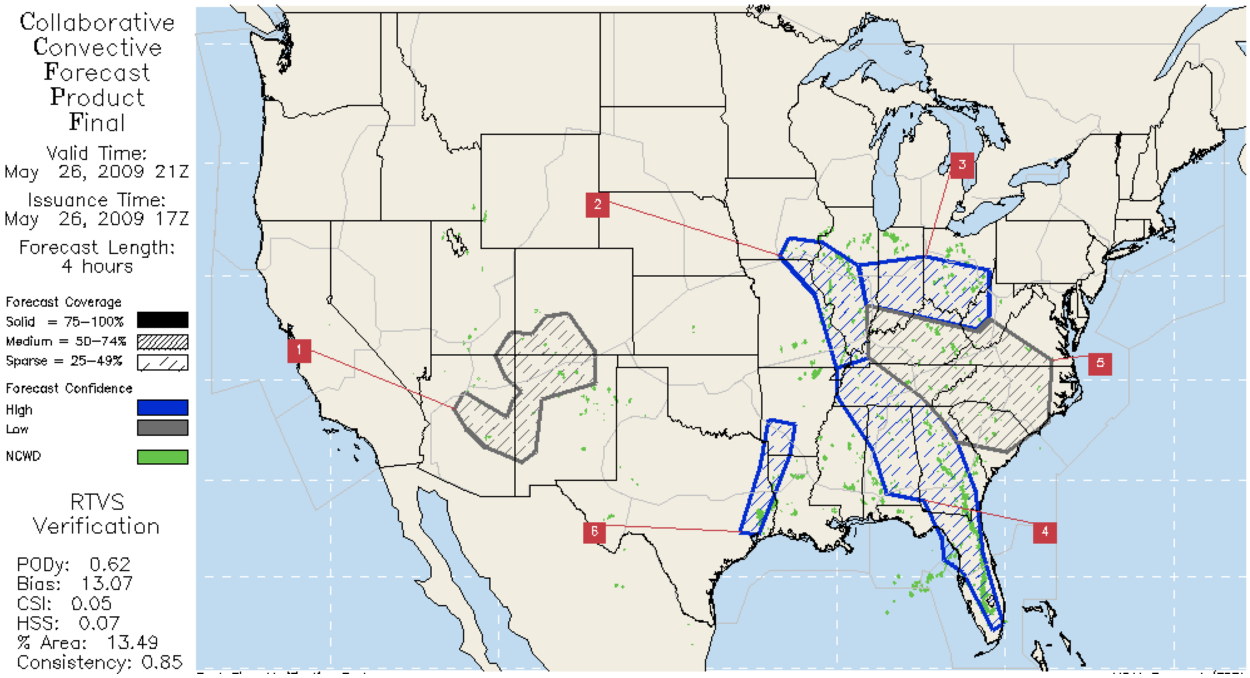

Fig. 1. Example of FVS verification of the Collaborative Convective Forecast Product (CCFP), a human-generated forecast issued by the NWS/AWC. This is just one of many forecast and analysis products evaluated by the FVS researchers.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The CIRA team will continue to collaborate with ESRL/GSD's Aviation Branch in the following areas, which are geared primarily to supporting NextGen, the nation's next generation air traffic management system.

The FVS objectives are to provide:

--Independent assessments of quality and skill for aviation weather forecast products transitioning to NextGen operations,
--Automated real time verification of the single authoritative weather source (SAS) and products in the 4-D weather cube
--A single authoritative source for verification
--Forecast selection for the single authoritative weather source
--Verification and assessment information for decision support tools

The research problems facing the FVS to achieve the stated goals include:

--Effectively integrating verification data with operational aviation weather decision criteria so that forecast evaluations and verification information directly reflect weather concerns of FAA operations,
--Developing verification capabilities for high resolution and global aviation forecasts through the use of new observation datasets,
--Developing appropriate verification techniques and metrics that measure the forecast quality with respect to critical FAA operational weather decision criteria (e.g., aviation business rules),
--Constructing relevant verification and assessment information that would add value to real-time automated aviation decisions, and
--Developing the engineering capabilities that are needed to support a real-time network enabled verification service (NEVS) of integrated (across all weather elements) quality assessment information for automated decision tools and end users and to support scientific evaluations for the FAA Research to Operations (RTO) process.

The Network-Enabled Verification Service (NEVS), a critical part of the NextGen weather component, will integrate scientific quality assessment concepts with the effective distribution of the quality assessment information to air traffice users. NEVS will provide an automated real-time network-enabled service that utilizes advanced integrated verification techniques and metrics for evaluating forecast quality, accuracy, timeliness, and reliability with respect to key operational aviation weather decisions. The purpose for the NEVS development is to provide:

--an automated network-enabled web-based verification capability that is compatible with the SWIM infrastructure and the NNEW architectures and NextGen information delivery mechanisms found within the 4-D Weather Data Cube,
--automated aviation forecast performance scoring in real time,
--the ability to join relevant air traffic information with meteorological verification information to provide critical aviation-specific scoring for air traffic impact assessments, and
--effectively communicate forecast error and uncertainty information directly to automated decision support tools.

Areas of Collaboration between CIRA and FVS:

--RTO Evaluations: Quality assessments for turbulence, ceiling and visibility, convective,volcanic ash, and flight level winds will be the primary focus. Task areas will include: developing the variable-specific quality assessment concepts and techniques and implementing those techniques within Real-Time Verification System (RTVS) and NEVS.
--Verification in NextGen Operations: Development of a sophisticated automated verification capability using the Network-Enabled Verification Service (NEVS) for selecting convective weather information for the SAS that is based on critical aviation operational decisions and verification of the SAS forecasts. This work will include R&D in two specific areas and focus mainly on convective weather:

1) verification concept development: effectively integrating verification data with non-meteorological operational aviation weather decision criteria so that forecast evaluations and verification information directly reflect weather concerns of FAA operations, new evaluation techniques and metrics for probabilistic forecasts, sector-based and high impact weather-event scoring, and graphical verification information bringing together verification metrics and operational traffic impact information such output from the Weather Impact Traffic Index (WITI), Airspace Flow Programs (AFP), ground stops and ground delay information. Extend quality assessment concepts developed for convection and adapt to forecasts of turbulence.

2) engineering concept development: data integration concepts using non-meteorological and meteorological data through a relational database management system, utilization of OGC-specific data formats, network-enabled data access, storage, and distribution concepts, and effective web-based access to quality assessment and forecast skill information.

2. Research Accomplishments/Highlights:

a. Study of Convective Forecasts in Air Traffic Flow Model

Air traffic managers have learned to effectively utilize current operational forecasts of convection to make strategic plans for air traffic flow in the NAS, despite the fact that the forecasts poorly represent the actual convection in many respects. Most notably, the majority of forecasts significantly overestimate the (spatial) amount of convection with an intensity considered hazardous to aviation. When the forecasts were interpreted at face value as input to initial NFM runs in the 2008 collaborative study, the flow model was unable to generate any meaningful results because the forecast capacity of the sectors in the NAS differed dramatically from the actual capacity. In an effort to make the current operational forecasts of convection useful as input, the NOAA/ESRL team worked to calibrate – or, more specifically, bias-correct – the weather products for the study. The effort consisted of two phases: the first to explore calibration options, the second to implement the most promising approach and provide calibrated forecasts for the NFM runs.

During Phase 2, the NOAA team implemented schemes to calibrate each of the experimental forecasts included in the study. The approach successfully rescaled the convective forecasts, making them useful as input to the NFM for the study. Examples are included below.

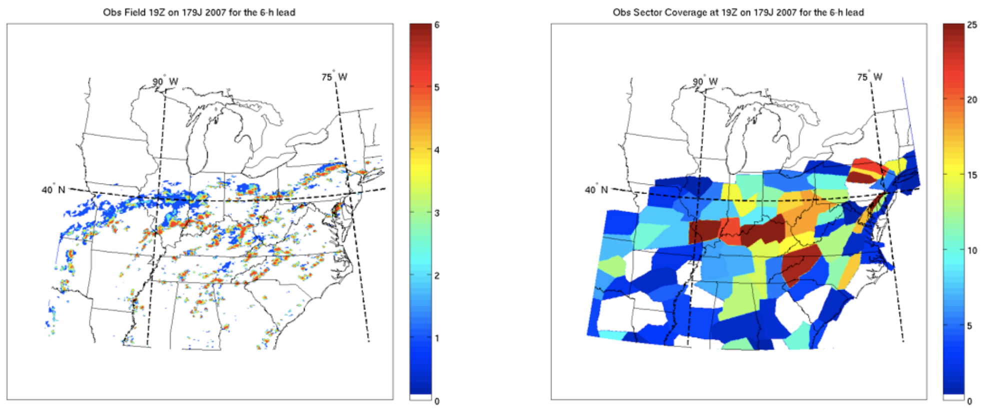

Fig. 2. Depictions of the actual convective weather at 19Z on 28 June 2007, a day of high weather impact in the NAS. The left image shows the convective weather on the native NCWD grid, with intensities ranging from 0 to 6. The right image depicts the coverage of hazardous convection (intensity 3 or higher) in the high-altitude sectors, with a scale from 0 to 25%.

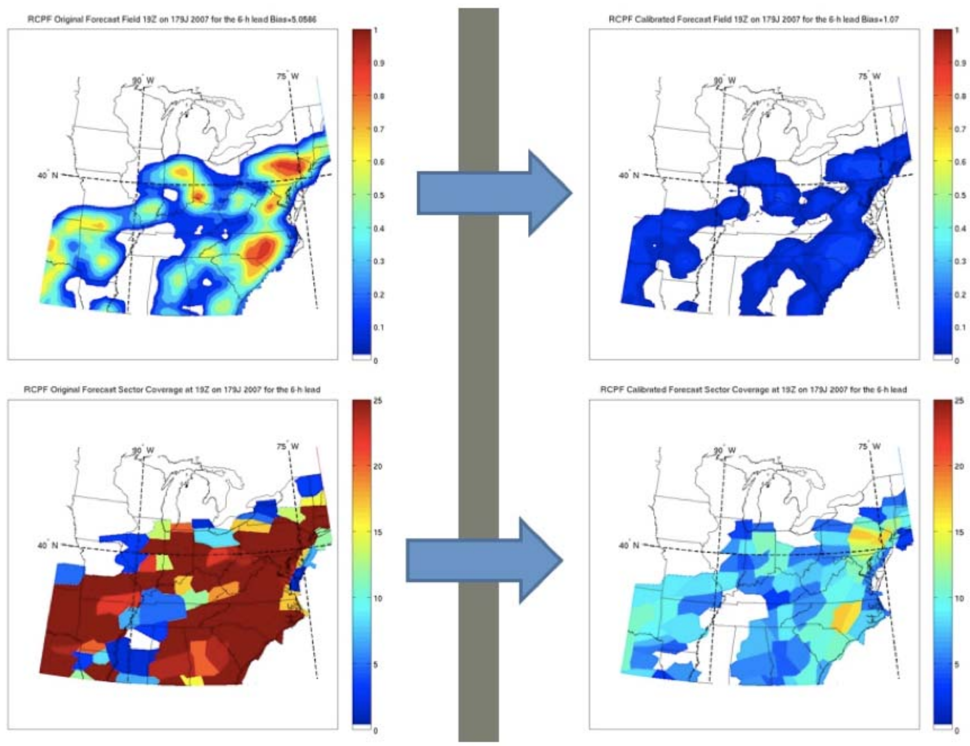

Fig. 3. Depictions of the RCPF forecast of convection for 19Z on 28 June 2007. The upper left image shows the uncalibrated forecast on the RCPF grid, with probabilities ranging from 0 to 1. The lower left image depicts the coverage of hazardous convection in the high-altitude sectors, with a scale from 0 to 25%. In this case, the NFM would interpret virtually no capacity over the whole of the east coast. The upper right image shows the calibrated forecast on the RCPF grid, with probabilities ranging from 0 to 1. The lower right image depicts the calibrated RCPF forecast coverage of hazardous convection in the high-altitude sectors, with a scale from 0 to 25%. After adjustment of the forecast, the NFM would interpret significant impact, but some capacity for air traffic over much of the airspace.

b. Assessment of Global Icing Forecast for Use in Aviation

CIRA researchers supported the assessment of global icing forecasts created for the World Meteorological Organization's (WMO) World Area Forecast System (WAFS). Primarily intended for trans-oceanic operational flight planning, the global forecast grids provide information about potential icing at five flight levels. With very few observations of icing in the domains of interest to the operational planners, the CIRA team developed an icing diagnostic based on CloudSat cloud classification data and a global temperature analysis from the GFS model. The algorithm was developed and tuned in the CONUS domain, using the relatively rich icing observation data. Then, the global forecasts were verified in the areas of concern for operational planning.

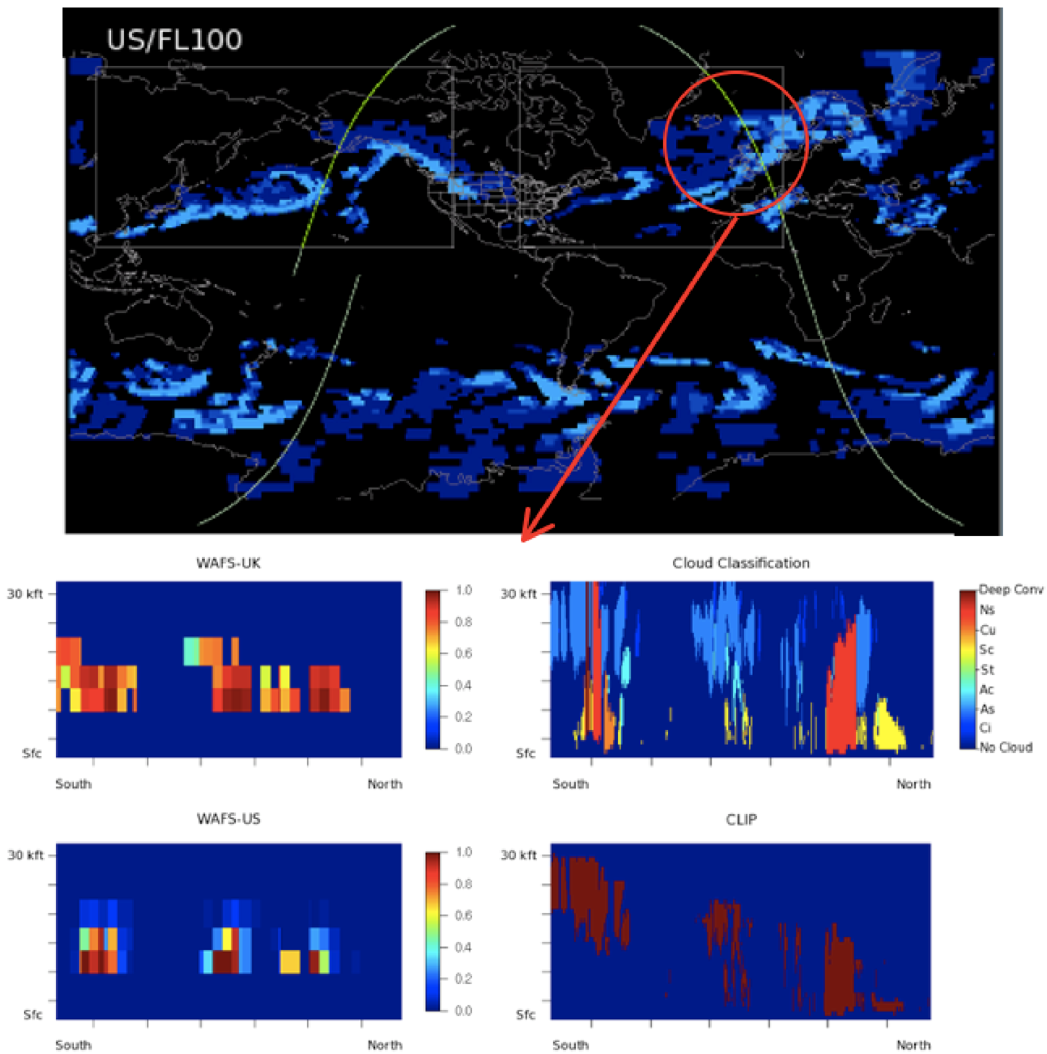

Fig. 4. The top image depicts an example of a global icing forecast, with the icing potential represented from dark blue (low potential) to light blue (high potential). The red circle on the image identifies part of a CloudSat swath through a region with significant icing potential. In the panels below, the upper left and lower left images show cross-sections of icing potential from two experimental forecasts. The upper right shows the CloudSat detection of clouds and their type, and the lower right plot show the areas of icing in red, from the CloudSat Icing Product (CLIP).

c. Research and Development of the Network-Enabled Verification Service

As the centerpiece of weather information in NextGen, the 4-D Data Cube will contain verification information about the forecasts utilized by the air traffic management algorithms. Traditional approaches to the development of verification software have yielded effective solutions for agile, focused analysis. However, a new approach is necessary to create verification software sufficient for the NextGen operational setting, a complex, service-oriented architecture (SOA) comprised of weather and air traffic management components. In response to this need, the CIRA researchers have collaborated with other groups at NOAA's Earth System Research Laboratory (NOAA/ESRL) to develop a proof-of-concept version of the Network-Enabled Verification Service (NEVS).

CIRA researchers continued to design and test configurations of the integration layer, a primary component supporting flexible, complex queries of the verification statistics. Building on an initial proof-of-concept from the previous year, the team expanded the NEVS capability to provide verification information about the FAA's experimental convective forecast, the Collaborative Storm Prediction Algorithm (CoSPA), during the 2009 convective season.

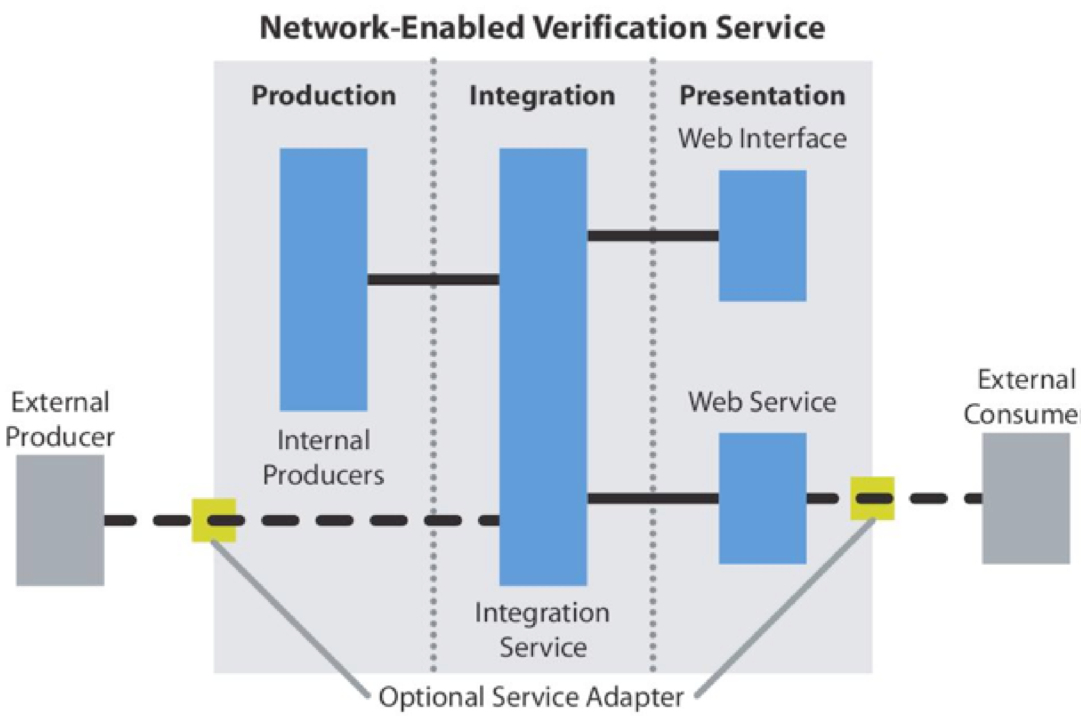

Fig. 5. A diagram of the NEVS architecture. The production layer contains the essence of verification, the combination of forecast and observation. The integration layer captures and organizes the typically large volume of production layer data, while the presentation layer provides request mechanisms for powerful access, creating plots and providing exported tabular data. The yellow interface points represent the NEVS interface into the NextGen Network Enabled Weather (NNEW) layer, a critical aspect of NextGen weather operations.

3. Comparison of Objectives Vs. Actual Accomplishments for the Report Period:

Objective: Develop concepts to support assessment of meteorological forecasts for aviation.

Status: Significant progress. The research team developed the following concepts and applied them to assessments of forecasts for operations in the following:
--Convective impact of air traffic sectors in the National Airspace System
--Calibration of probabilistic convective forecasts for use in automated air traffic management
--Analysis of forecast products used as supplemental in operational planning
--Development of global icing diagnostic, CloudSat Icing Product (CLIP)
--Diagnostic tools to understand the performance of high spatial and temporal convective forecasts

Objective: Research and support for an assessment of the FAA's National Ceiling and Visibility (NCV) product; and research and support for an assessment of the FAA's Graphical Turbulence Guidance (GTG3) product.

Status: On hold. The sponsor of this work, the FAA's AWRP, has postponed the evaluation of the products mentioned in the objective. Work will resume when the FAA initiates the research.

Objective: Engineering research for the Network-Enabled Verification Service (NEVS).

Status: Significant progress. CIRA researchers continued to design and test configurations of the integration layer, expanding the NEVS capability to provide verification information about the FAA's experimental convective forecast, the Collaborative Storm Prediction Algorithm (CoSPA), during the 2009 convective season.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborations:

CIRA researchers in the RTVS group collaborated and/or partnered with the following organizations during the 2007-2008 fiscal year:
--Federal Aviation Administration (FAA)
--National Weather Service (NWS)
--National Center for Atmospheric Research (NCAR)
--National Center for Environmental Prediction (NCEP)
--Boeing, Phantom Works (Research and Development)
--Cooperative Institute for Research in the Environmental Sciences (CIRES)

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

III. Research Collaborations with the GSD Information & Technology Services

Project Title: Data Systems Group (DSG) Research Activities

Principal Researcher: Christopher MacDermaid
CIRA Team Members: Leslie Ewy, Paul Hamer, Patrick Hildreth, Bob Lipschutz, Glen Pankow, Richard Ryan, MarySue Schultz, Amenda Stanley, and Jennifer Valdez

NOAA Project Goals/Programs: (1) Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings, Air quality, Environmental modeling; (2) Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation/ Aviation weather

Key Words: Data acquisition, Data Decoding, Data Formats, Observations, Transformation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

CIRA researchers in DSG collaborate with the NOAA Earth System Research Laboratory Global Systems Division (ESRL/GSD) scientists and developers to assemble and maintain a state-of-the-art meteorological data center. The results of this work facilitate the ability of fellow scientists to perform advanced research in the areas of numerical weather prediction (NWP), application development, and meteorological analysis and forecasting. Multiple computers operate in a distributed, event-driven environment known as the Object Data System (ODS) to acquire, process, store, and distribute conventional and advanced meteorological data. These services include data ingest, data transformation, data distribution, system and data monitoring, data saving, compute services, and on-line storage.

Design and development for new and modified data sets are ongoing activities. Use of ODS applications and methods will expand as legacy translators and product generation methods are replaced by new, more flexible techniques. Object Oriented (OO) software development for point data types will continue.

Design and development will continue toward creating an automated "archive search" system. This will facilitate the retrieval of data sets for use by researchers studying interesting weather events.

Development of new metadata handling techniques is ongoing. This facilitates the use of real-time and archived data sets.

2. Research Accomplishments/Highlights:

DSG's highlights of the past year include:

--Updated data transformation software for the following subsystems:
- --METAR
- --RAOB
- --AMDAR, for Japanese Aircraft data
- --Profile, for Dropsonde data
- --TAF, to support 30 hour TAF reports
- --NEXRAD, to handle a new data format

--Created tools to filter proprietary data from NCEP PREPBUFR files.

--Coordinated real-time system updates to implement FIM-to-SOS data transfers.

--Supported the Real-Time Verification System (RTVS) Transition to Operations project, including:
- --Implementing the TOC defined point-to-point data acquisition
- --Porting ODS GRIB decoder software to run on 64-bit platform
- --Developing new ODS AirSig and METAR decoder software

--Supported the GOES Ground Station, including:
- --Consulting with the vendor of GSD's GOES ground station receiver equipment, and writing up GSD's Equipment Fund request for replacement of end-of-life legacy systems

- --Supported the Meteorological Assimilation Data Ingest System (MADIS), including:
  - --Changing to a consultation role for the transition team for the transition of MADIS to NWS operations
  - --Assisting with questions from MADIS staff about decoders and accounts for external users
  - --Testing and implementing a push based method of managing user accounts
  - --Establishing a method to ingest one-minute ASOS surface data
  - --Adding new Mesonet data sets, including:
    - --Suwannee River Water Management District
    - --Colorado E-470 Public Highway Authority (new processing for new stations)
    - --Idaho Department of Transportation
- --Managed the GSD Web Servers, including:

  - --Developing a new web site for the Weather In-Situ Deployment Optimization Method (WISDOM); this site communicates to the general public, scientists, and government officials the scientific research that is being done using specialized balloons deployed during severe weather events
  - --Updating the Unmanned Aircraft Systems web site to better reflect the research being done to collect the information in the gap between the instruments on Earth's surface and the satellites above

--Developing interactive web sites for all staff to use for submitting ideas on how to improve the workplace; a team of non-management staff also utilize the site to track the progress of ideas from research to implementation
--Creating a plan for moving from the old URL structure to a new URL that better reflects GSD as being part of the Earth System Research Lab (ESRL)
--Participating in the selection of a new Web Application Firewall that will replace the legacy system; this will provide better security for our web sites including adding security for the new web technologies that are being used within GSD that were previously unprotected

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Objective: Acquisition of Meteorological Data
The ESRL GSD Central Facility (CF) data systems are responsible for acquiring, processing, storing, and distributing global meteorological data sets in support of GSD's various research and development projects. These systems deliver some 700 GB of data per day to GSD scientists and collaborators.

CIRA researchers within the GSD Information and Technology Services (ITS) group are now working to implement a more scalable and maintainable cluster architecture for the CF ingest and processing environment.

The current CF data systems comprise a number of High-Availability (HA) pairs for ingest and processing. In addition, various stand-alone machines are dedicated to specific ingest and distribution tasks, as well as to Facility Data Repository (FDR) processing that transfers real-time data sets to GSD's Mass Store System. The HA pairs are configured to automatically fail-over from the designated primary host to its backup in the event of a system failure. This feature also provides valuable continuity of data flow during required system maintenance or in the event of a hardware failure.

While the current HA pairs provide robust availability through their automated fail-over mechanism, a major drawback is the need for two machines to support a single processing configuration. Thus, system expansion or refreshment necessitates acquiring and supporting two new hosts at a time, adding to both the systems administration and power and cooling burden. Further, limited local disk space on the current systems often constrains processing of larger data sets, which has become problematic in particular for the FDR functions. In addition, at the application level, needing to individually configure each host's functionality is tedious, making support and maintenance relatively difficult.

The new DSG Cluster (DC) will address the present CF systems' limitations with these benefits:

--Scalability - processing capacity can be added one machine at a time, rather than two

--Availability – while comparable to HA in providing automatic resource fail-over, this will be a big improvement for the stand-alone hosts, which don't have any fail-over method and limited hardware support currently

--Throughput – cluster load balancing mechanisms will allow for much greater aggregate throughput than we achieve on the current hand-configured systems

--Utilization – cluster hosts are more effectively used than HA pairs in that half the hosts are not virtually idle; rather, the cluster load balancing methods will ensure that jobs are distributed sensibly across the hosts. In addition, the shared storage array provides space to all cluster applications, whereas in the current architecture, spare disk space on one host is unavailable to another host needing space

--Maintainability – cluster hosts will share a common system configuration, substantially simplifying ongoing system administration; host reboots and fail-overs for patching should also be easier than with the present arrangement. On the application side, multiple configurations will be replaced by a single, common set of configuration files; in addition to reducing the number of files to maintain, this will reduce the total number of configuration lines by eliminating the present duplication of many configuration items across hosts

--Supportability – application log files will reside on the networked storage, eliminating the need to know which specific host ran the job

--Energy efficiency – the cluster will perform data processing more efficiently in terms of energy consumption; higher efficiency in CPU utilization means less heat generation, lower cooling requirements and reduced energy requirements compared to the current computing infrastructure

The DC architecture, depicted in Fig. 1, comprises six basic components:

--RedHat Cluster Suite for managing cluster services
--Network Attached Storage (NAS) for local data processing
--Sun Grid Engine (SGE) for job queuing and load balancing
--Unidata's Local Data Manager (LDM) for data transport and event-driven job Triggering
-- fcron for cluster-wide scheduled job triggering
--DSG's Object Data System (ODS) software for radar, satellite, point, and gridded data

These components will collectively operate within the context of the Linux operating system running on each of the cluster's six 64-bit compute platforms. As shown in Fig. 2, data processing will be event- or time-driven, depending on the data type, and distributed among cluster nodes using SGE load balancing job activation services.

Status: Commissioning of the DSG Cluster for operations is expected to be in summer, 2009.

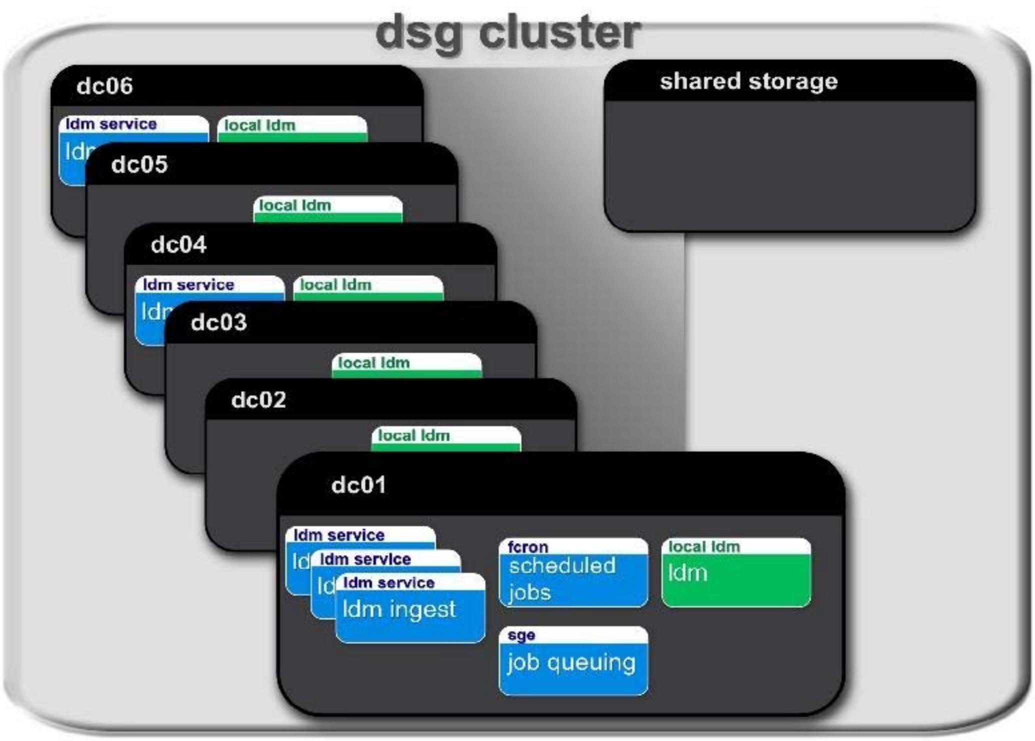

Fig. 1. Schematic of the DSG Cluster System.

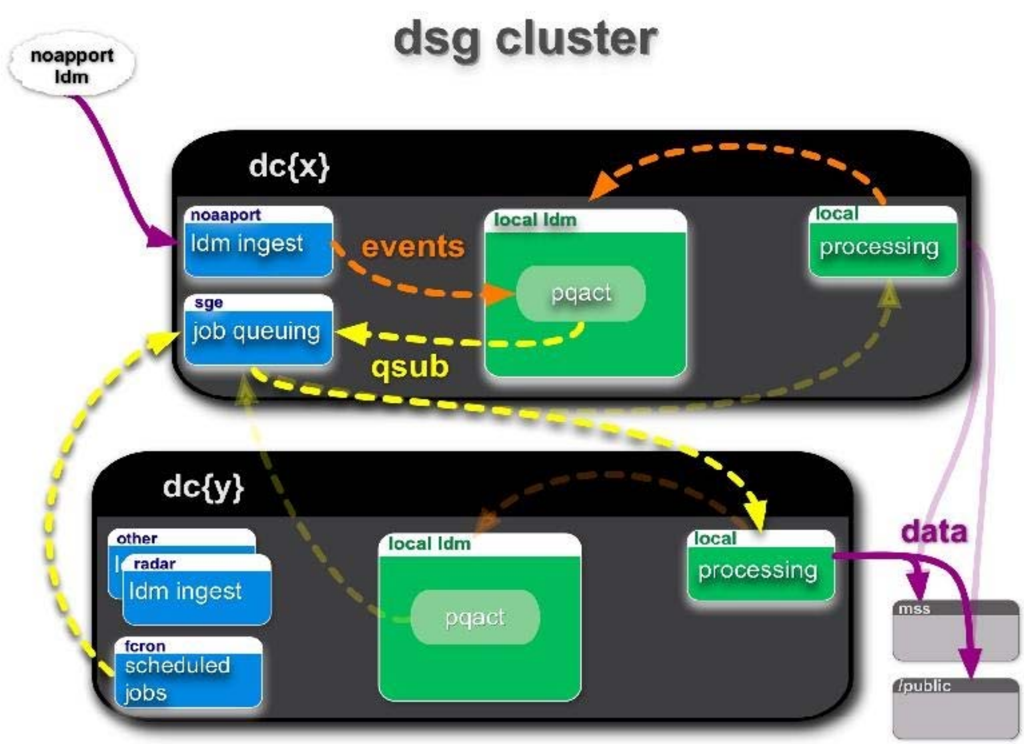

Fig. 2. Data and Control Flow Within the DSG Cluster System.

Objective: Data Processing
Scientifically analyze and process data into meteorological products in real-time, and make them available to CIRA and GSD researchers and systems developers for current and future research initiatives. The resulting meteorological products cover a broad range of complexity, from simple plots of surface observations to meteorological analysis and model prognoses generated by sophisticated mesoscale computer models.

Status: This work is in progress.

Objective: ODS Improvements/Upgrades
Design and development for new and modified data sets continue. Use of ODS applications and methods will expand as legacy translators and product generation methods are replaced by the new techniques including OO software development for point data.

Status: This work is in progress.

Objective: Metadata Handling
Metadata handling techniques for use with all data sets are planned for implementation for real-time data processing. An automated system for acquiring and incorporating metadata is part of this plan. Further work will continue on the interactive interface that allows for easy query and management of the metadata content. Program interfaces will be added to allow for secure, controlled data access. Retrospective data processing and metadata management are slated for incorporation.

Status: This work is in progress.

4. Leveraging/Payoff:

CIRA researchers in DSG collaborate with GSD scientists and developers to assemble and maintain a state-of-the-art meteorological data center. Data acquired, decoded and processed by DSG have been vital to the success of MADIS, RTVS, and GSD's X-window workstation (FX-Net). Some of the NOAA projects using this data center are listed below.

MADIS - MADIS is dedicated to making value-added meteorological observations available from GSD for the purpose of improving weather forecasting, by providing support for data assimilation, NWP, and other hydrometeorological applications.

RTVS - Verification is the key to providing reliable information for improving weather forecasts. As part of GSD's involvement with the Federal Aviation Administration (FAA) Aviation Weather Research Program (AWRP), the Forecast Verification Branch develops verification techniques, mainly focusing on aviation weather forecasts and tools that allow forecasters, researchers, developers, and program leaders to generate and display statistical information in near real time using the RTVS.

Developmental Testbed Center (DTC) - The WRF (Weather Research & Forecasting Model) DTC is a facility where the NWP Research and operational communities interact to accelerate testing and evaluation of new models and techniques for research applications and operational implementation, without interfering with current operations.

FX-Net - FX-Net is a meteorological PC workstation that provides access to the basic display capability of an AWIPS workstation via the Internet. The AWIPS workstation user interface is emulated very closely. Bandwidth limitations are addressed by using new data compression techniques along with multi-threaded client-side processing and communication.

RUC - RUC is a high-frequency weather forecast and data assimilation system that provides short-range numerical weather guidance for general public forecasting as well as for the special short-term needs of aviation and severe-weather forecasting.

Web - The scientific research being done by CIRA Researchers and GSD scientists needs to be available to a wide audience, which includes: the general public, collaborating scientists, and government officials. Researching effective ways to communicate to this audience is vital. When our web sites communicate well, we attract better awareness, better funding, and better interaction among researchers. The UAS (Unmanned Aircraft Systems <http://uas.noaa.gov>) project as well as the WISDOM (Weather In-Situ Deployment Optimization Method <http://wisdom.noaa.gov>) project are two examples of projects that received funding due in part to the story communicated on their web sites.

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors:

--Chris MacDermaid—GSD Team member of the month for May 2008
--Paul Hamer—2008 CIRA Research Initiative Award

7. Outreach: None

8. Publications: None

IV. Research Collaborations with the GSD Forecast Applications Branch

Project Title: Local Analysis and Prediction System (LAPS

NOAA Project Goals/Programs: Weather and Water—Serve society's needs for weather and water information
--Local Warnings and Forecasts
--Weather Water Science, Technology, and Infusion
--Environmental Modeling (for activities #A, B, C, E, F, G, H, I, and J)
--Coasts, Estuaries, and Oceans (for activity #J)
--Hydrology (for activities #C and I)

Key Words: Local analysis and prediction, high resolution modeling

A. LAPS/WRF Improvements

Participating CIRA Scientists: Steve Albers, Isidora Jankov

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Local Analysis and Prediction System (LAPS) integrates data from virtually every meteorological observation system into a very high-resolution gridded framework centered on a forecast office's domain of responsibility. Thus, the data from local mesonetworks of surface observing systems, Doppler radars, satellites, wind and temperature (RASS) profilers (404 and boundary-layer 915 MHz), radiometric profilers, as well as aircraft are incorporated every hour into a three-dimensional grid covering a 1040km by 1240km area. New analysis techniques such as STMAS are being developed within the LAPS umbrella. LAPS has analysis and prediction components. The prediction component is being configured using the RAMS, MM5, WRF, and ETA models. Any or all of these models, usually being initialized with LAPS analyses, are run to provide short-term forecasts. Ensemble forecasts using multiple models and initialization methods, with verification are also produced.

LAPS (increasingly including the new STMAS analysis package) is run in real-time at ESRL/GSD for a domain centered on the Denver, CO Weather Forecast Office. LAPS has also been ported to many locations (~150 worldwide), including universities such as Univ. of Oklahoma ("OLAPS"), and Univ. of North Dakota. LAPS is running on-site at each National Weather Service Forecast Office (WFO) as an integral part of AWIPS. LAPS software is also being implemented at various U.S. government agencies such as Federal Highways Administration (MDSS), Range Standardization and Automation (RSA) at the U.S. Space Centers, National Ocean Service, U.S. Forest Service, and for international government weather bureaus such as China, Italy, Taiwan, Thailand, and Korea.

Research objectives related to LAPS continues to be the improvement and enhancement of the system 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.

It is worth noting that LAPS and WRF improvements frequently have cross-cutting benefits that leverage towards many of the supported research projects (both within and external to NOAA) described later in this report. Funding has materialized for certain projects since the Statement of Work was formulated; LAPS improvements benefiting these projects are included in this section.

2. Research Accomplishments/Highlights:

Observational Data Sets

Improvements were made in LAPS to analyze observations from new types of instruments and new data formats, thus expanding the envelope of meteorological data environments that we can operate in with our ever growing set of users. These improvements are detailed below for surface and upper air observations.

Surface Observations

MADIS mesonet data is now the default source to be used for LAPS, instead of the legacy NIMBUS system. Updates were made allowing better QC flexibility for MADIS data in the LAPS surface observation ingest for testing various approaches to using surface data in STMAS (and traditional LAPS). The type of MADIS QC checks can now be controlled with a user supplied namelist parameter. This includes an option to test the MADIS dynamic blacklist feature. We now make use of more of the MADIS QC checks for wind and other variables.

ASOS/AWOS data from MADIS were added into the intermediate obs "LSO" file via the 'obs_driver' program. The new data can be turned on or off via namelist to help in sensitivity experiments. Surface obs ingest software now has an option to allow multiple reports from the same mesonet station within the time window. The surface observation waiting functionality was improved.

Upper Air Observations

Sounding access routines work more reliably with addition of observation time as well as improved QC. Removal of duplicate sounding levels was improved.

Dropsonde handling was improved in terms of station names, addition of significant wind level data, and more robust quality control. This should give us more wind data to try out with our hurricane cases. Sounding ingest now has a namelist flag 'l_fill_ht' to decide whether to write calculated heights from the hypsometric equation if they aren't reported in the raw sounding data. Heights for significant T levels are now computed even if we are above the highest mandatory level to help give more complete dropsonde output.

Station names were fixed so that they contain the observation counts for POES soundings. Software was upgraded to support the use of WISDOM balloon data with ingest and analysis routines.

Surface Analysis

We have a new ability to read surface pressure (and other variables) from dropsondes into the surface analyses. In a related change the fit of surface pressure to the obs can now be adjusted via namelist. More complete surface data can now be read in from various types of sounding.

We now utilize station pressure measurements if altimeter settings are absent for the reduced pressure analysis. A QC check was added when we read in the first-guess mean sea level pressure field. Improvements were made to a recently constructed routine that interpolates the 3-D balance package fields to make 2-D surface products.

Radar Processing

CIRA staff have worked towards more efficiency and other functional improvements for radar remapping and mosaicing. This is described in detail as follows. The automated radar list generated upon localization has been improved. Testing was conducted with a new version of the Archive II to NetCDF conversion software developed by ITS. Associated NCDC archived radar data access scripts were improved. A correction was made in the way hours are incremented to handle the end of day transition better for real time Archive-II to NetCDF conversion.

The radar remapping software was modified so it can better handle the new super resolution wideband data. The remapper also can automatically switch from the high-res data back to archive low-res as the latter needs the proper default values for scale and offset to be used when they are absent from the NetCDF file. Conversely the remapper was enhanced to read in the reflectivity and velocity scale/offset parameters. This is a relatively new addition to the NetCDF data and it will be important to use this for high-resolution data or if the scaling otherwise changes from the default values we've been using.

The wideband radar remapping was adjusted (in the vertical) to reduce the potential for ring shaped artifacts. This was done by increasing the allowable altitude of echo base (from 800m to 3000m AGL) for "low fill" extrapolation of reflectivities down to the ground. For artifacts we're seeing at GSD, please see the next section on Cloud/Precipitation Analyses.

The remapper can now optionally display input PPI tilts for testing and this can be enabled via namelist. Some recent changes for the radar remapper were cleaned up to allow better backwards compatibility. Some other streamlining was done and reliability was improved. The addition of some allocate statements means it can now remap with larger domains on the IBM platform.

The WSI NOWRAD radar remapping code is now more robust in its ability to run on 64-bit platforms such as JET. This cartesian reflectivity data ingest was optimized so it can run a bit faster for case reruns. In the LAPS radar reflectivity mosaicing program a 4-D radar array is now allocatable for better IBM memory utilization.

Software to utilize 3-D contingency tables was set up for forecast radar verification. See the "Mesoscale NWP Model Initialization and Evaluation" section below for more details on the radar verification.

Wind/Temperature Analysis

An option was added to use mean sea level pressure as the boundary condition for hydrostatic integration as this helps the height analysis for strong hurricane cases. Several quality control checks were added to the wind analysis. LAPS wind analysis QC thresholds are now adjustable via namelist (request from the PADS project). Observation counts from the pre-balanced wind and temperature analyses were included in the comment block of the NetCDF output files so they can be used downstream in the balance package.

Software is being developed to interpolate temperature observations in the vertical using pressure instead of height for more accurate placement in tropical cyclones.

Cloud/Precipitation Analyses

For global LAPS runs, we now set the present weather string to "UNKNOWN" for mesonet stations to help 'deriv.exe' run more accurately (for surface precipitation type diagnosis) as well as more efficiently on large domains.

A post-processing QC step was turned on to blank out radar echoes where significant clouds aren't analyzed. As a result, the cloud and 3-D radar analyses should now be more consistent with somewhat less false echo. The radar QC steps (minimum echo top thresholds) have been increased (as a function of time of day) in the cloud analysis to reject the increased ground clutter we see during the night. Further refinements were made to the echo top test for using radar in the cloud analysis to help suppress ground clutter.

Radar reflectivity is now set to a base value if less than "usable" value. Logging was improved in the cloud analysis to help in assessing how the analysis verifies against the input data (e.g. radar).

Partial changes were made to add a new field of precip melting level using a new parameter called 'twet_snow', with a default value of +1.3C. For cloud omega, a new namelist parameter called 'l_deep_vv' was added so the user can independently control whether we do the deep parabolic profiles in the cloud analysis and model hot start. We thus get the benefit of the change we made with Adan Teng (from CWB) to get deeper parabolic profiles in convective clouds even if their upper regions are more stable.

The precipitation analysis can potentially read in model precip fields as either the "raw" values or when they are normalized to the LAPS analysis cycle time. LAPS precip accumulation now reads radar distance as a quality indicator, and can apply a simple spatially varying gauge bias correction. Note that this software is intended to be fairly flexible so we can apply various precip analysis methods on a situation dependent basis, and possibly incorporate techniques that several of us in FAB are working on. The radar reflectivity analysis web product now has precip gauge and surface weather reports plotted for comparison.

General Software Improvements & Portability

LAPS documentation, logging, reliability, and error handling were improved. Obsolete software was removed. Quality control checks were improved. The LAPS product directory list was updated for the localization procedure. For example radar verification subdirectories are now created upon localization.

Scripts for processing radar data and managing web pages were updated. The humidity "what-got-in" script now includes GPS data. The LAPS scheduling script now better supports timing of analysis runs and handles the cycle time better. Script routines that manipulate and convert time were given more functionality. LAPS scripts were improved that access archived observational data files to rerun LAPS analyses, including the access of archived RUC and GFS data. Other scripts that save LAPS analysis runs to the Mass Store were set up.

Software portability was improved for different platforms. For example variables are now more thoroughly initialized so LAPS can run better on 64-bit platforms. LAPS source code was modified to be more portable for compiling with 'gfortran'. Support was added for configuring LAPS with the 'ifort' and 'icc' compilers. This is being tested both here on the JET machine and at a LAPS installation at the Mauna Kea Weather Center in Hawaii. Other configuration flags were cleaned up including FORTRAN flags for the IBM, and C debugging flags more generally. The top level Makefile was improved with a better sequence of building the libraries as well as an IBM specific target that does the build more efficiently. A map projection subroutine (GETOPS) was improved so that it no longer modifies the input lat/lon by a machine epsilon amount for polar stereo projections.

STMAS

Work continues with development and testing of a major new option in LAPS to produce analyses using new newly embedded Space-Time Multi-scale Analysis System (STMAS).

We helped with porting of STMAS 2D software to the Meteorological Development Lab (MDL). Towards this end the porting and running is now somewhat more automated along with better attendant documentation. We also started to port STMAS software to the NWS Southern Region Headquarters. Another STMAS port to MIT/LL is being discussed in the context of LAPS / STMAS improvements in using ASOS high frequency observations and TDWR Doppler radar data. ASOS data capability has been added and further tested so we can start to see how well these high frequency observations help the analysis as they become available over more areas in the United States.

We updated the surface analysis "lsx" NetCDF CDL to be compatible between LAPS and STMAS. LAPS scripts that help to run the STMAS analysis were improved, along with case data access scripts and web data plotting. STMAS surface only pre-generated web products were made more efficient. Observation plots were improved so that they work better in the STMAS environment.

Discussions were held within FAB on how to best analyze clouds in STMAS. Analysis techniques (such as heights and temperature) were discussed with STMAS developer Yuanfu Xie. We are also evaluating how STMAS runs compare with the traditional LAPS analyses.

A software module diagram was updated as we learn more about the STMAS 3-D analysis software. Quality control was discussed (including with the AMB/RUC group) and refined for STMAS. MADIS QC was improved so we can select a subset of QC checks that should work best for STMAS. Work continues on an STMAS paper that we are coauthoring.

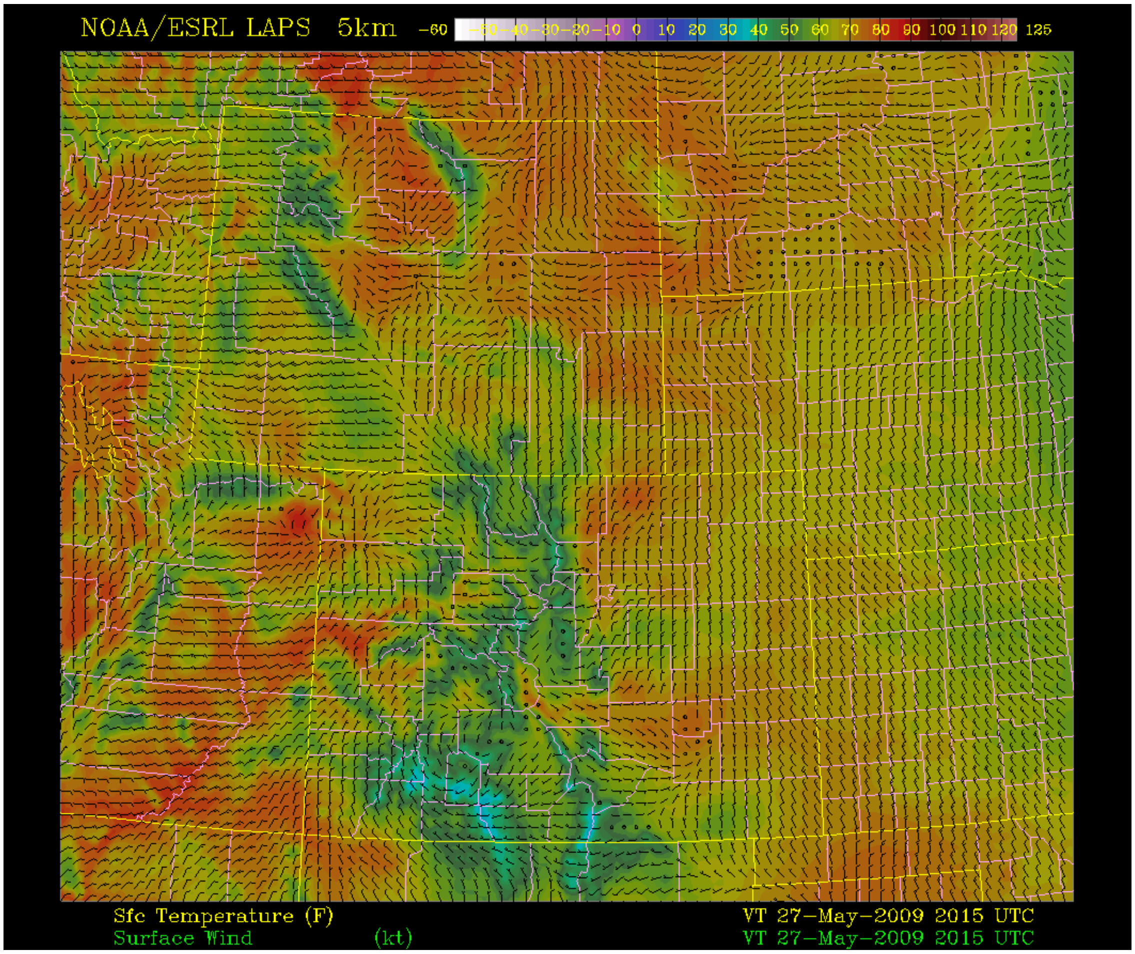

Fig 1. STMAS Surface Temperature and Wind on the 5-km Colorado Domain.

LAPS Implementation

We presented a summary detailing LAPS handling of Land-Surface and Soil Moisture at a mini-workshop held by the ESRL Physical Sciences Division. We maintain the LAPS software distribution and the associated web site. We are also continuing to run a global LAPS domain that feeds analyses to Science On A Sphere (SOS) as well as the internet.

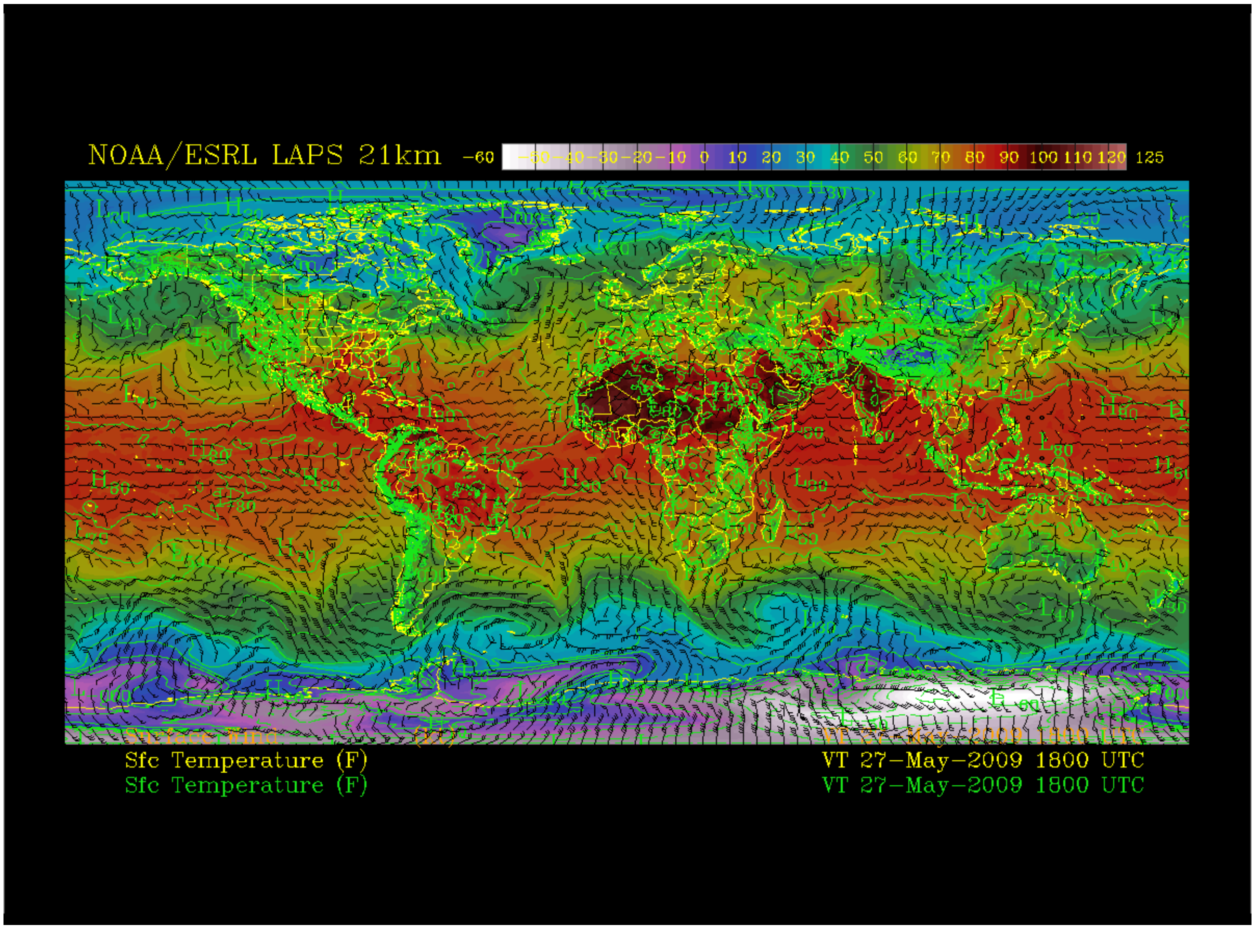

Fig 2. Analyzed Surface Temperature and Wind on the GLAPS 21-km Global Domain.

WWW LAPS Interface

Our web plotting software was improved to support surface wind speed difference plots, with some other minor bug fixes to the observation plots (helping the AOML Dennis case). METAR temperatures were added in the 3D temperature observation plots as a green color. The color range of background surface wind speed image plots was adjusted to match that of the analysis. Color tables and labels for SH and RH, as well as forecast U/V labels were improved. There is now an adjustable parameter for surface wind speed color table range. The color bar range for surface vorticity images was reduced slightly.

Soil moisture and surface vorticity plots are now done with the "raster" mode for better reliability. Elsewhere within the 'lapsplot' program, the station pressure field contour labeling was fixed and wind barbs can now be plotted up to 300kt (good for intense hurricanes). Plotting flexibility was improved to help domains running with radar data only.

Plotting software now handles forecasts that go beyond 99 hours, and allows display of balanced (particularly surface) fields. Units are now more consistent between background and analyzed winds. Integrated water vapor values were added to sounding plots to help with analysis assessment. Labeling routines were improved to be more flexible.

Pre-generated web analysis images now have a more general check for whether we should generate 2D or 3D web product sets, as well as a better generalization of image framing depending on the domain aspect ratio.

The "on-the-fly" page was updated with the latest available fields. The "on-the-fly" web page now has animation capability where the user can select the number of frames. LAPS plotting software including the "on-the-fly" page can now change dataroots in mid-stream so one can overlay (and difference) fields from multiple LAPS runs. We now allow height and precipitable water to have variable density contours with the "on-the-fly" page. Visibility images were added to the "on-the-fly" page with a newly updated color table in 'lapsplot'.

The "on-the-fly" page was improved in terms of surface wind plots, labels, observation plot color, zoomable precip type, and wet bulb zero images. Wind barb only plots can now be animated. Rain/snow concentration and vorticity cross-section images now work properly. "On-the-fly" plots of sounding animations, soil moisture observations, multiple domain comparisons, and various other fields were improved. A pause was added at the end of an "on-the-fly" page animation to improve viewability. Other "on-the-fly" page updates support projects such as STMAS hurricane work, the NSF project with radar reflectivitity, and CU Doctoral Student Brad Beechler's radar work. Updates for improving portability were made to the export version of the "on-the-fly" page. Documentation for this page is now available in the export version of LAPS.

Mesoscale NWP Model Initialization and Evaluation

The default model initialization (in lapsprep) now includes WPS output. A directory was created for the WRF WPS initialization file when LAPS is localized. Documentation was added about how to do the WRF/WPS initialization. The model initialization software can now use balanced surface analysis fields. Snow cover is now initialized better, particularly with respect to missing data values. Some PERL model preprocessing scripts/modules were added.

Improvements were made to model post processing and model file copying scripts. The 'sched_sys.pl' (and related) scripts are now more generalized for applications such as model precipitation post-processing. Associated scripts also now run better for both real time and case reruns. Omega fields were fixed with the proper units in the model post processing software. The model post processing (lfmpost) Makefile now works more smoothly on various platforms. LAPS model initialization output was optimized to save disk space. Support was added (in LAPS libraries and plotting software) for a forecast filename length that can extend beyond 99 hours.

Software is being developed that compares analyzed and model forecast radar reflectivity for the WRF numerical model. This software generates histograms and contingency tables for various thresholded values of forecast reflectivity so we can compare several ensemble forecast members with the "observed" analyses. The histograms have options for masking areas where both forecast and analysis have values exceeding a threshold. Contingency tables with some standard statistical scores showing hits and misses were calculated for several values of the thresholded reflectivity.

Radar verification software was improved to be more general allowing future addition of other data types. It also has functionality to generate statistics for designated sub-regions. Radar reflectivity histograms are now shown for each vertical level.

Radar quality information (2D vs 3D) is now being written out by the cloud analysis and used by the radar verification histogram program. Radar verification software was improved to apply the QC for 2D radar data, add contingency tables every 10dBZ as well as other streamlining. This software was used in the preparation of a presentation on the use of radar data to evaluate and adjust model microphysics at the AMS NWP conference in June, 2009 (see HMT section below where an associated NSF proposal is described).

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Our achievements for this project compare favorably with the goals projected in the statement of work.

B. <u>Range Standardization and Automation (RSA) Project</u>

Participating CIRA Scientists: Steve Albers and Isidora Jankov

1. Long-term Research Objectives and Specific Plans to Achieve Them:

In early 2000s, the Air Force initiated the RSA program to modernize and standardize the command and control infrastructure of the two US Space Launch facilities (ranges) located at Vandenberg AFB, California and Cape Canaveral Air Station, Florida. In cooperation with Lockheed Martin Mission Systems staff serving as system integrator, ESRL/GSD developed and installed an integrated local data assimilation and forecasting system at the Western and Eastern Ranges with capabilities to incorporate local meteorological sensor data. Upgrades, enhancements and maintenance to the system continue.

2. Research Accomplishments/Highlights:

Discussions were held with the new RSA contractor (ITT) about what update we could provide to the radar processing software at the ranges to keep up with changes in the WSR-88D data stream. A methodology was set up to generate a source code patch of the radar remapper so we can try and merge the new version of the radar code with the older LAPS release being used at the Ranges. LAPS builds and analysis runs have resumed on our in-house shadow server (atlas) to see how well the latest software performs.

Future work will involve an implementation of WRF model into the system with the purpose of replacing the existing MM5 model runs. Prior to the model switch an extensive evaluation of how the two models' performance compare to each other will be performed.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Given the limited funding, our achievements for this project compare favorably with the goals projected in the statement of work.

C. <u>Model Ensembles and Ensemble Post Processing</u>

Participating CIRA Scientists: Isidora Jankov and Steve Albers

1. Long-term Research Objectives and Specific Plans to Achieve Them:

(Refer to Activity I—Hydrometeorological Testbed)

2. Research Accomplishments/Highlights:

Ensemble forecast system testing and implementation continued in support of the Hydrometeorological Testbed and the project supported by California's Department of Water Resources. Prior to the past season's experiment, significant changes in ensemble forecasting system have been made. Primary changes were related to the model version. The model update involved notable effort in upgrading operational scripts. Also, during the last season the integration domain was enlarged to cover the entire state of California and a larger part of the Pacific Ocean. The forecast length was extended from 72 to 120 hours and the forecast cycle was decreased from 6 to 3 hours. The integration domain enlargement resulted in coarsening of horizontal resolution from 3 km to 9km. The ensemble design stayed the same as previous years (3 WRF-ARW runs with various microphysics and one WRF-NMM run). In addition, one higher resolution run (5 km) with an hourly cycle and 12 hr forecast length was run over the same domain. Output from the high resolution run was used as input to a moisture flux tool developed by colleagues from PSD. Testing of the system included using the ensemble output to drive stream-flow models that provide ensemble river stage forecasts as well as designing alternative domain configurations to accommodate a wider user base.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

D. <u>Wind PADS (Precision Airdrop)</u>

Participating CIRA Researcher: Steve Albers

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Since 1996, GSD has participated in the development of diagnostic algorithms to forecast turbulence using numerical model output for the FAA. Taking advantage of these algorithms and in a joint effort with GSD scientists, a modified turbulence algorithm was used to provide variance and mean of the winds along dropsonde trajectories to estimate a probabilistic envelope within which the dropsonde would hit the target. This algorithm was implemented in a program for the military to estimate the proper location of cargo dropping from aircraft in the battlefield. In support of this dropsonde effort, an overhaul of the wind analysis was embarked upon to fully utilize dropsonde data with high vertical resolution.

2. Research Accomplishments/Highlights:

Over the past 5+ years, CIRA researchers have collaborated with Planning Systems Incorporated on this project, including improvements to the adjustment of wind observations for the model background time trend along with design and implementation of observation time weighting in the 3-D wind, temperature, and surface analyses. The accomplishments of the project were recognized with the 2008 NOAA Technology Transfer Award.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA/CIRA funding was unavailable so only minimal work was done during this period. However, Steve Albers won a special CIRA award for our past efforts on the Precision Airdrop Support System that was recognized by NOAA. We are fielding some questions relating to the balance package, wind analysis, and software efficiency.

E. Taiwan Central Weather Bureau (CWB)

Participating CIRA Researcher: Steve Albers

1. Long-term Research Objectives and Specific Plans to Achieve Them:

A long-term scientific collaboration with the Taiwan Central Weather Bureau (CWB) has been on-going to implement and update the GSD-developed LAPS analyses and hot-start forecast techniques at the CWB. Over the years, GSD has hosted various visiting scientists from CWB in the areas of radar analyses and model initialization, improvements with the Kalman filter, balance packages, and model forecast verification.

2. Research Accomplishments/Highlights:

We continued to operate real-time LAPS and STMAS runs both at GSD and at the CWB. We consulted with the CWB to help get a version of our LAPS "on-the-fly" page working at CWB.

We worked to troubleshoot the processing of LAPS/STMAS radar data, as well as assess comparisons of STMAS vs LAPS running at the CWB. Discussions were held with the CWB about their public web displays of temperature fields.

We identified some issues with the tropical cyclone bogusing procedure involving anomalously low boundary layer temperatures that the CWB was able to resolve. We are currently investigating how to get the LAPS balance package to run properly on the new 64-bit machines the CWB is planning to acquire. Surface observation ingest is also being evaluated for possible improvements.

3. Comparison of Objectives Vs Actual Accomplishments for Report Period:

Our achievements for this project compare favorably with the goals projected in the statement of work, however GSI funding was dropped.

F. NWS Interaction

Participating CIRA Scientists: Ed Szoke, Steve Albers, Isidora Jankov

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. We continue to support and monitor a shadow run that helps us ensure that the LAPS software is ready for AWIPS releases. Discussions are being held about future plans to upgrade LAPS and introduce STMAS in both AWIPS and the new AWIPS-II workstations running in National Weather Service WFOs.

Recently a high resolution WRF-ARW model run has been set up for operational use by the local NWS office in Boulder. The new WRF model run replaced the old MM5 runs. In addition, Isidora Jankov was invited to discuss options for setting up a high resolution model for numerical prediction for convective weather forecasting at NWS in Omaha.

EFF Activities

We continued our interaction with the local National Weather Service (NWS) Weather Forecast Office (WFO) in Boulder, located within the David Skaggs Research Center. The interaction includes Ed Szoke working forecast shifts at the Boulder WFO. There are also occasional cooperative research projects, some resulting in co-authored conference papers. Additionally, one of the Boulder forecasters does periodic weather briefings as a part of the long-running Daily Weather Briefing program, which involves a 30-minute weather briefing held on every workday at 11:00 A.M in GSD. Several CIRA researchers also take part in presenting and producing weather briefings.

G. Regional Climate Studies

Participating CIRA scientist: Chris Anderson

1. Long-term Research Objectives and Specific Plans to Achieve Them:

A modeling system was developed based on WRF that can be used to perform seasonal to decadal regional simulations of climate. The research objective is to use the system to test the utility of downscaling seasonal forecasts from the NCEP Climate Forecast System for use in western water management decisions.

2. Research Accomplishments/Highlights:

Last year, Chris worked with the Western Water Assessment in NOAA/PSD to provide an educational seminar and initial analysis in support of Colorado front range water managers, who prepared a grant to assess sensitivity of decision tools to climate shifts.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA/CIRA funding was unavailable for work during this period.

H. LAPS III (Ensemble-based LAPS)

NOAA/CIRA funding was unavailable for work during this period.

I. Hydrometeorological Testbed (HMT) / California Department of Water Resources (DWR)

Participating CIRA Scientists: Isidora Jankov and Steve Albers

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Hydrometeorological testbed (HMT) is a well-funded, multi-year project (hmt.noaa.gov) designed to improve the use of research quality observations and modeling in operational forecasts of precipitation and streamflow. Three large field campaigns were held in December through March of the past four winter seasons in California. CIRA staff in the Forecast Applications Branch (FAB) are an integral part of ESRL/GSD's effort to provide high-resolution model analyses and forecasts, as well as forecast interpretation by meteorologists, in support of field operations and NWS operational forecasting. Starting in 2010, a second area in the Eastern U.S. will be the focus of the HMT experiment in which CIRA staff will be heavily involved.

2. Research Accomplishments/Highlights:

We set up LAPS analysis runs for the winter exercise period for the California domain with the DWR project. This is a similar region to what we did for HMT in the previous winter season. We ran 5km and 9km domains that are used to initialize the WRF. We also set up model initialization scripts and model post-processing scripts including web displays.

Discussions were held about the accuracy of the LAPS wind and cloud analyses over the California modeling domains. We collaborated to diagnose and fix some aspects of the analyses in response to verification studies against wind profilers and GPS water vapor measurements. The wind and cloud analyses are being evaluated for use in a water vapor flux calculation. A preliminary upslope component of the moisture flux routine is now in place. We also worked on testing the interpolation of WRF-NMM precipitation back onto the LAPS domain to see if bias effects can be reduced.

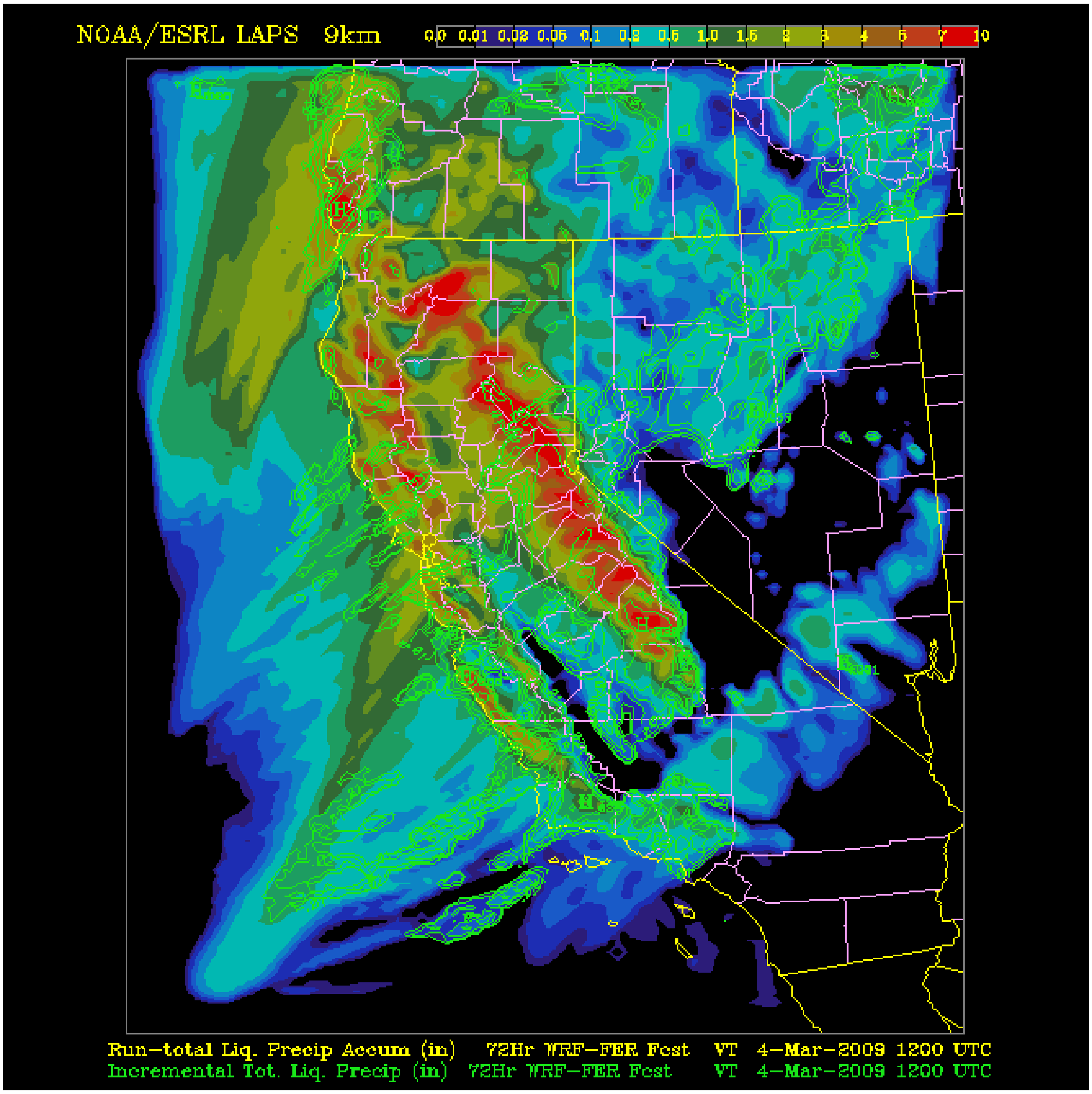

Fig 3a. 72-hr Forecast of Run-total Precipitation (image) and 1-hr Precipitation (contours) from WRF-ARW Run Using Ferrier Microphysics Valid at 1200 UTC March 4, 2009.

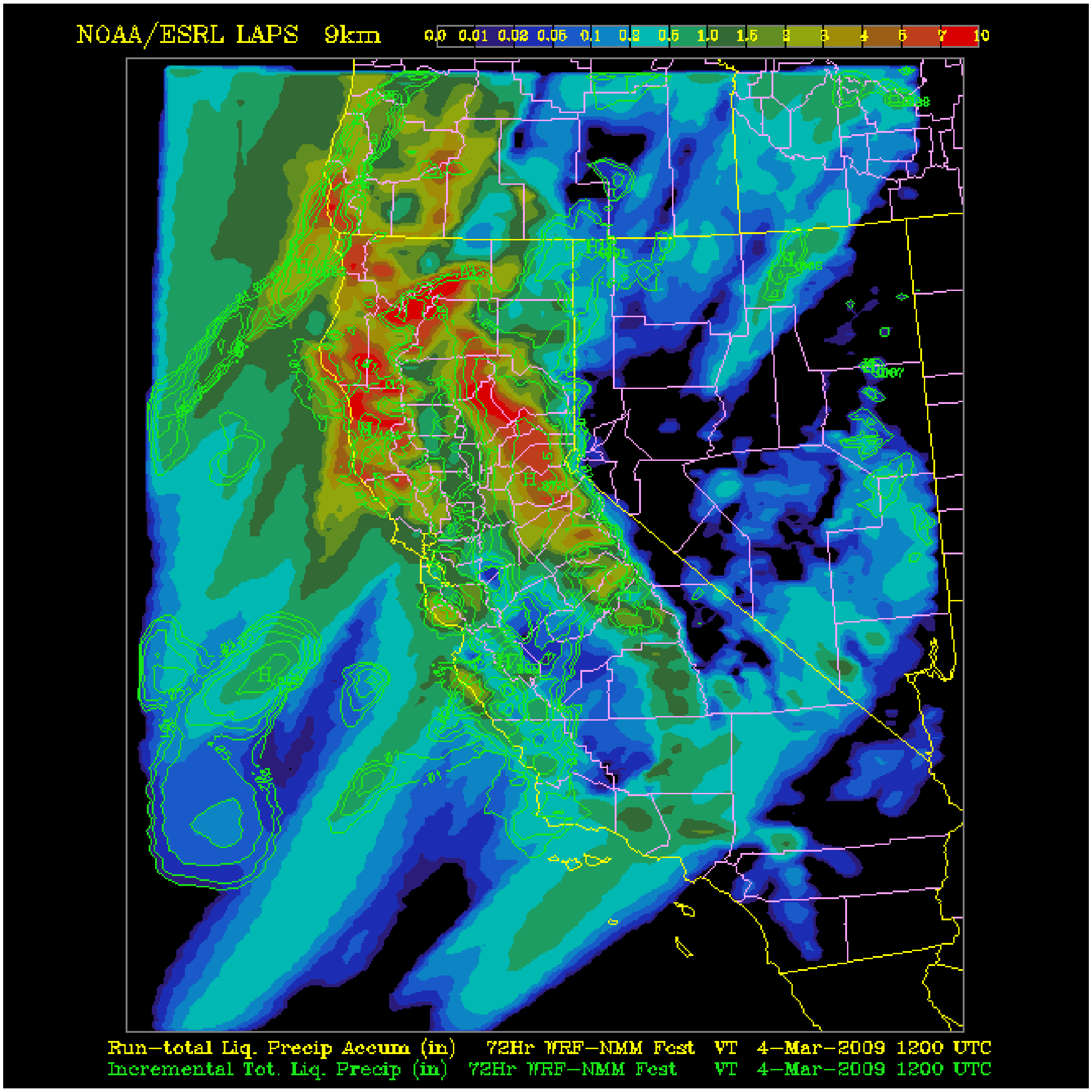

Fig 3b. As in Fig 3a Except for WRF-NMM Run.

We gave a presentation on the LAPS soil moisture analysis at a soil moisture workshop convened by ESRL/PSD. In another collaboration with PSD, some proposals were submitted to investigate the relationship between ensemble forecast spread and forecast error.

A study performed in collaboration with several scientists from NOAA/PSD (Jian-Wen Bao, Paul Neiman and Allen White) and CIRES (Huiling Yuan) focused on a detailed analysis of a high-resolution numerical model with various microphysics and its performance in cases of atmospheric river events has been accepted for publication in

Journal of Hydrometeorology. The evaluation consisted of comparisons of the flow and cloud structure against observations from experimental radars deployed for the HMT project. This study has revealed more details about performance of various microphysical schemes for this type of event with mountainous terrain and different precipitation regimes (Bright Band vs. Non-Bright Band). Even though various microphysics have demonstrated a large diversity in their solutions, it has been found that all model configurations had a tendency to overestimate simulated precipitation amounts possibly due to the model's tendency to overestimate the moisture content and the upslope wind component's duration and intensity.

An additional evaluation of the WRF-ARW model performance when using various microphysics was assessed by producing synthetic satellite imagery and using an objective measure of difference in various microphysics compared to observations. This research was performed in collaboration with a group of CIRA scientists. Current related activities involved preparation of a manuscript for submission to Journal of Hydrometeorology.

Steve Albers and Isidora Jankov continue to work in collaboration with CIRES scientist Tomislava Vukicevic and a PhD student Marcus van-Lier Walqui on a recently granted NSF proposal. The work focuses on improving nonconvective precipitation accuracy by objectively estimating the individual contributions of parameterized processes representing generation and depletion of the various hydrometeors. The objective method will include use of the Weather Research and Forecasting (WRF) model and its 4-dimensional variational (4DVAR) data assimilation system for radar reflectivity data assimilation. Preliminary results from this study have been recently presented at the Weather Analysis and Forecasting conference in Omaha.

One of the recent activities included an application of a theoretical approach developed in collaboration with CIRES scientist Tomislava Vukicevic and FAB scientist John McGinley, recently published in Monthly Weather Review, on model output from a complete system for numerical weather prediction (WRF-ARW model). The technique consists of first diagnosing the performance of the forecast ensemble which is based on explicit use of the analysis uncertainties, and then optimizing the ensemble forecast using results of the diagnosis. The technique includes explicit evaluation of probabilities which are associated with the Gaussian stochastic representation of both the analysis and forecast. It combines the technique for evaluating the analysis error covariance that was first presented in the Ensemble Transform data assimilation method developed by Bishop et al in 2001 and the standard Monte Carlo approach for computing samples from the known Gaussian distribution. Results from this study have been recently presented at the Weather Analysis and Forecasting conference in Omaha.

One additional HMT activity consisted of taking part in a team effort to test a newly developed observations-based forecast model verification tool by a group of PSD scientists for atmospheric rivers and their impacts on coastal orographic precipitation enhancement. The tool focuses on water vapor flux as a major determinant of orographic precipitation. The water vapor transport is estimated by using wind profilers and GPS-met (Integrated Water Vapor) IWV data.

We have finished the 2008-2009 field experiment over California. We look forward to conducting further analysis of the results and participating in future HMT field seasons that will cover several locations around the country, each having unique forecast challenges.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Our achievements for this project compare very favorably with the goals projected in the statement of work.

J. LAPS/WRF Modeling Activities

Participating CIRA Scientists: Steve Albers, Isidora Jankov

Fire Weather

The LAPS analysis runs at 500m resolution and utilizes a downscaled RUC background together with the latest observational data. The relocatable 500-m resolution forecast downscales the latest NAM run into the future. We also initialized some WRF-NMM 500m runs with the LAPS analysis.

Department of Homeland Security (DHS)

We set up and continued to monitor LAPS analysis runs to support the initial Dallas-Ft. Worth implementation of the Geo-Targeted Alert System (GTAS). Doppler radars from 5 sites near DFW were included. The LAPS analysis is then used to initialize the outer nest of a high resolution (4.5 km) WRF-NMM model run. The outer nest provides boundary condition for the inner nest with 1.5 km horizontal grid spacing. The model output is used as an input to the HYSPLIT dispersion model as well as for a display on AWIPS work stations.

ATMET/AFTAC

We are continuing with a reorganization of LAPS top level routines to support a single executable compilation and runtime option. Various makefiles were updated to help in consolidating ATMET related software changes (e.g. global parameter access) in the libraries. There are quite a few ATMET related changes providing compatibility for the wind, temperature, surface, and cloud analyses. This includes use of f90 memory modules for arrays, static files, and namelist parameters. System time is also read in from the top level surface driver. The wind, surface, temperature, and cloud analyses now make use of the parameter for controlling the writing of "little files" output.

Some further ATMET changes were made, largely to eliminate redundancy of various library routines that do similar things with global and program specific namelist parameters. Reduced pressure level is now a global parameter in the ATMET memory module. ATMET supplied us with a new module called 'mem_static.f90' that reads topography and other static data. Other changes relate to writing out temperature analysis files closer to the top level routine.

Finnish Meteorological Institute

We continued to work with the FMI on various LAPS topics including the use of radar data in the LAPS analyses. They sent us a real-time feed of several of their radars and these were tested in our global LAPS run. We helped prepare a presentation on LAPS being given at the FMI by our NOAA colleague Linda Wharton.

Atlantic Oceanographic and Meteorological Laboratory (AOML)
We participated in hurricane case studies where LAPS and WRF are run for hurricanes Dennis and Katrina. Results of these studies were discussed with AOML in several telecons and improvements to LAPS ingest and analyses were made as here described. Improvements with balance package weighting were tested. This was done in collaboration with Isidora Jankov, John McGinley and visiting PhD student Jin-Young Kim.

A VRC (2-dimensional radar ingest) program addition was made to read in AOML aircraft 2 dimensional radar reflectivities for use in the (improved) mosaicing program and downstream in the cloud analysis package. Upper air obs can now be thinned prior to plotting to help with the dense AOML radar data. Our new ability to read surface pressure (and other variables) from dropsondes into the surface analyses helps for hurricane analysis.

We gained greater experience with the use of observational data (e.g. radar and dropsonde) both near and inside of tropical cyclones. We also proposed a "data warehouse" to help various researchers run and compare results from case studies. LAPS archive data access scripts were made more efficient and more complete to help with hurricane case reruns. We started a real-time LAPS analysis run over the Caribbean that caught the tail end of the 2008 hurricane season.

Steve Albers and Isidora Jankov worked on presentations about LAPS data assimilation and associated WRF forecasting for Hurricanes Dennis and Katrina given at the annual AMS conference in Phoenix. AOML radar reflectivity ingest now allows special handling when AOML data goes beyond the 24 hour clock time.

We continued to participate in telecons with AOML and we did runs of LAPS / STMAS for a case study of Hurricane Rita. We are also doing some analysis runs in real-time for the 2009 hurricane season. Investigations with GSD/ISB into the decoding of dropsondes were started and several improvements were made. LAPS / STMAS dropsonde ingest was refined to be more complete and reliable. We are starting to work on ingest and assimilation of airborne radar velocity data for LAPS / STMAS.

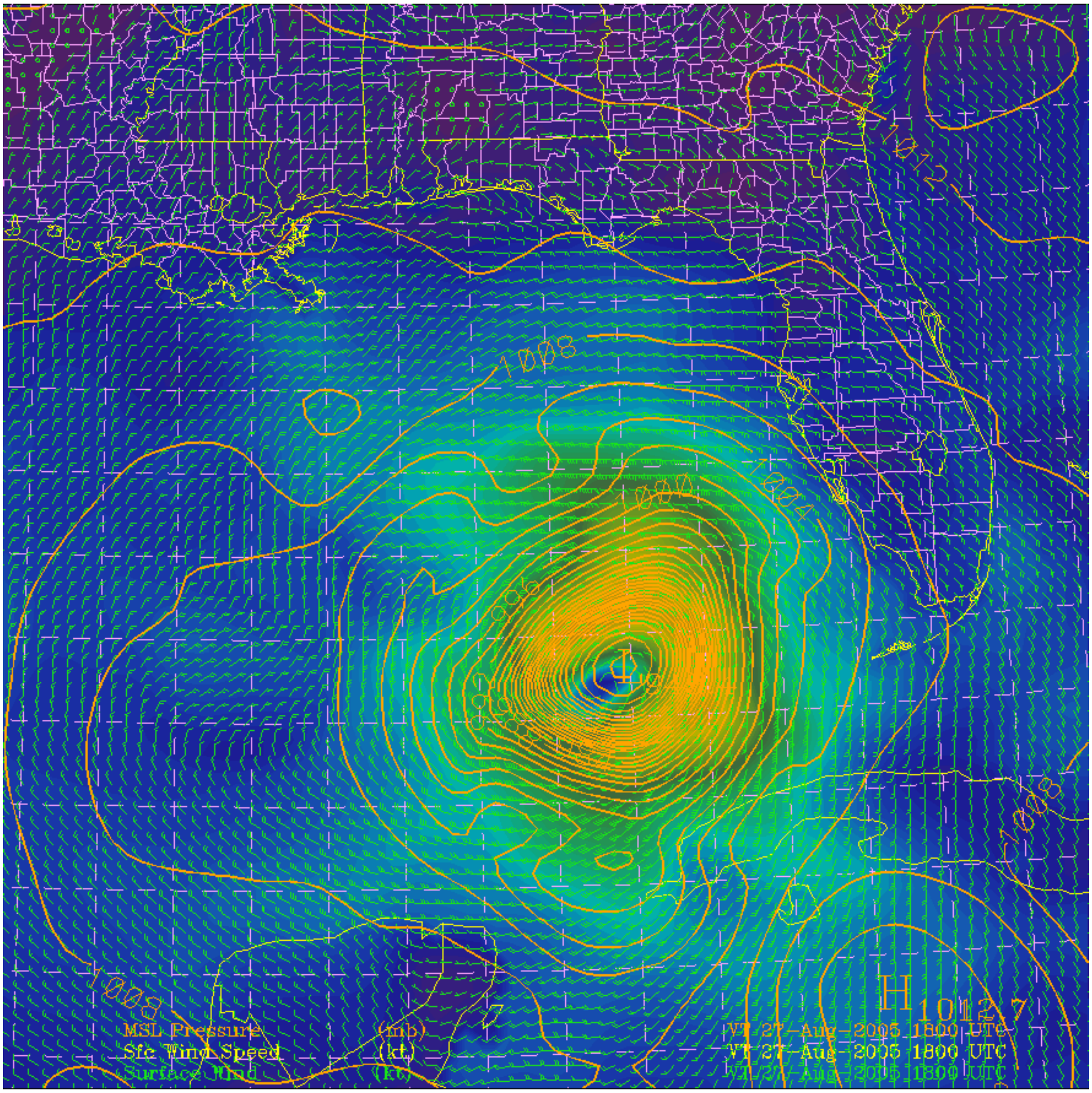

Fig 4. Hurricane Katrina Surface Pressure and Winds as Analyzed by LAPS Using Supplemental Dropsonde Observations.

WISDOM Balloon Project

We assisted Yuanfu Xie from GSD/FAB in setting up radar and other data ingest for the WISDOM domain STMAS run to help monitor balloon trajectories. In addition we have a larger domain over the Caribbean running the LAPS analysis that can help track long lived balloons.

During the WISDOM test field exercise from late September into November, we provided forecast support for the project, both to determine where the balloons might go as well as the forecast weather at the launch sites. The 2008 season was intended to be a trial operation to demonstrate the feasibility of launching the balloons, although a couple of storms were marginally sampled.

Our achievements in these other research areas meet or exceed the goals projected in the statement of work.

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 rerunning LAPS and STMAS, together with WRF forecasts. Several meetings were held and retrospective LAPS runs are being tested for this case study. A successful proposal was submitted to the GSD Director for a CIRA-managed special project dedicated to continued research on this topic.

K. Non-LAPS Activities

Science on a Sphere

Participating CIRA Researcher: Steve Albers (coordinating with Mike Biere)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Refer to the SOS development project under VI. Research Collaborations with the Technology Outreach Branch

2. Research Accomplishments/Highlights:

CIRA staff continued to monitor the reliability of various real-time animations, both on our operational and newer developmental machines. CIRA staff also attended SOS meetings.

Tests were conducted with the GME global atmospheric model running in Korea to see if it can be displayed using SOS. With our earthquake animation, locally gathered data from the Taiwan CWB has been integrated with the global database from USGS (Fig. 5) to give greater earthquake accuracy over Taiwan. A new animation of the "Blue Marble" image with nighttime lights was created.

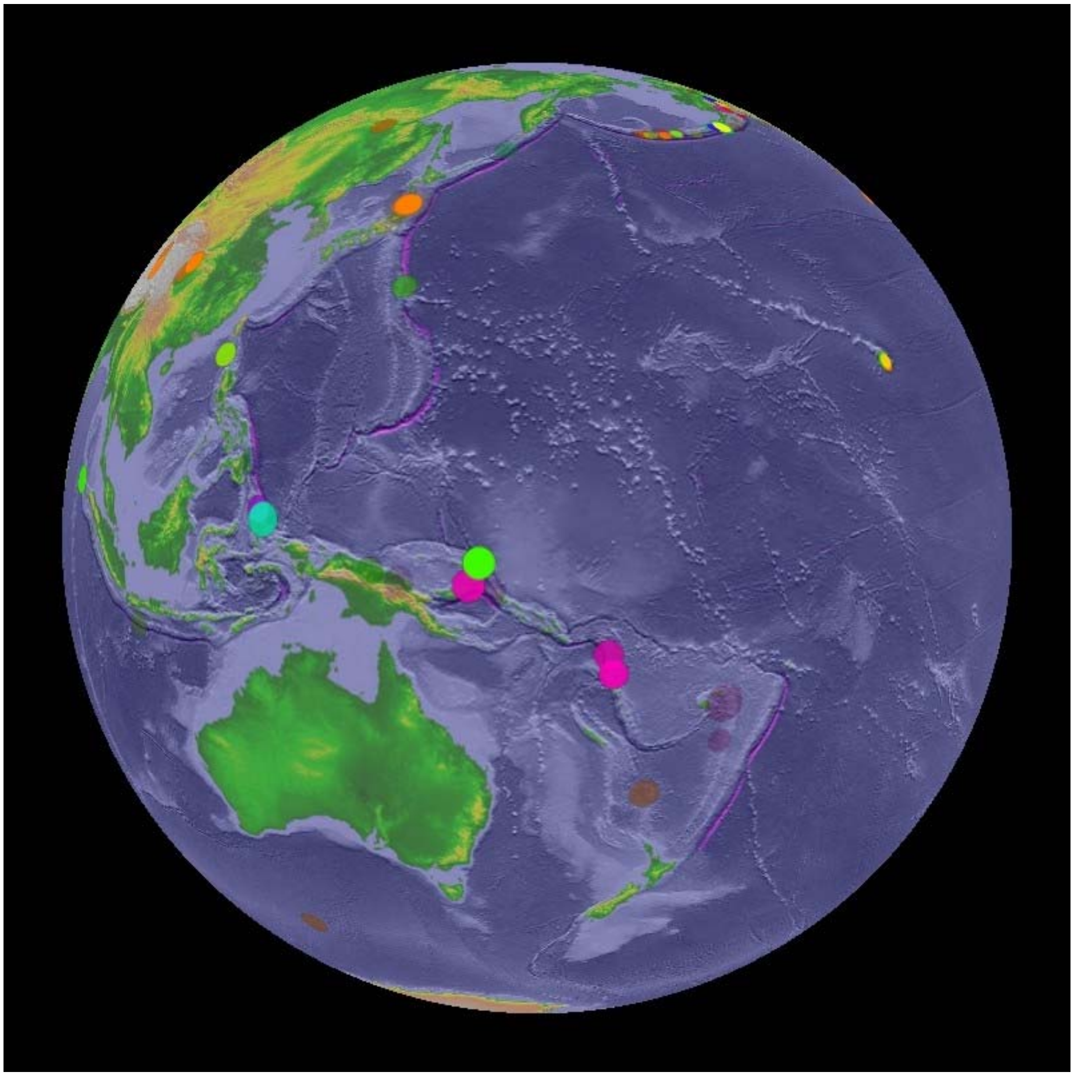

Fig 5. Earthquake Animation Frame as Seen on SOS. The 30-day animation is updated with the latest data every hour. Circle size represents the magnitude, color denotes earthquake depth, and transparency relates to the age of the quake as it fades over a 7 day period.

We made an animation showing the establishment of GLOBE schools around the world over the past 14 years.

CIRA staff worked on setting up a quasi real-time animation from the STEREO pair of satellites orbiting the sun to show more than half the solar disk in extreme ultraviolet light. This involves adapting our reprojection software so it can work with the spacecraft images provided by Goddard Space Flight Center. An algorithm was developed to use persistence imagery to fill in the part of the sun that has rotated out of view. Work is continuing on improving the reliability of the animation.

The map of Mercury was updated with improved use of older Mariner imagery along with improved navigation of the newer images from Messenger. The map of Saturn's moon Mimas was reworked with improved navigation information for the individual images. The Enceladus map now has color imagery more widely used, as well as improved navigation in the vicinity of the South Pole. Some new Cassini imagery was added to the Tethys map. The map of Saturn's satellite Rhea was updated with new imagery from a February Cassini flyby. Maps were updated for Titan and Iapetus using the latest available Cassini spacecraft imagery. The map of Iapetus is slated to be used in a paper in "Science" magazine.

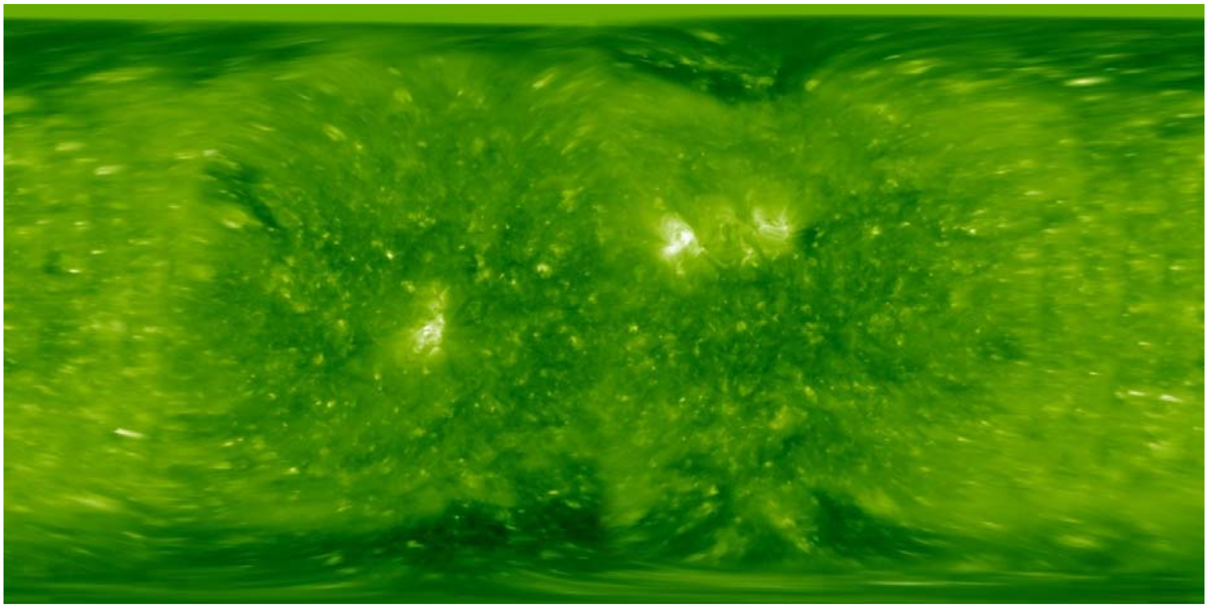

Fig 6. Cylindrical Map of the Sun in Extreme Ultra-violet Light as Mapped Using a Pair of Views About 90 Degrees Apart from NASA's STEREO Satellite. Note that more than half of the Sun's surface is visible in this view on May 17, 2009 at 2340UTC. The remaining portion of the sun is filled in with "persistence" information from when the far side had last rotated in view. These are displayed in near real-time with Science On A Sphere. Animations are shown using frames at 10-minute intervals and help to provide advance warning of solar storms.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

Data Link Dissemination (DLD) Project

Participating CIRA Researcher: Ed Szoke

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Refer to the TAMDAR project under V. Research Collaborations with the Assimilation and Modeling Branch.

2. Research Accomplishments/Highlights:

Even though the TAMDAR (Tropospheric AMDAR (Aircraft Meteorological Data Relay)) data from the Midwest that had been part of the TAMDAR Great Lakes Field Experiment continued to be available to forecasters and numerical models, funding levels were drastically reduced to ESRL in the last fiscal year. A small amount of monitoring and case study work continued with the limited funding over the past year.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

Flow-following Finite-volume Icosahedral Model (FIM)

Participating CIRA Researcher: Ed Szoke

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The FIM is a new global model that has been developed over the last couple of years at ESRL/GSD. It features an icosahedral grid with a grid spacing of 30 km, and in the vertical the hybrid isentropic-sigma coordinate used in the RUC. The homepage at http://fim.noaa.gov/ describes the model in detail and gives access to the forecasts, which are run twice daily out to 7 days.

2. Research Accomplishments/Highlights:

Our efforts have involved examining the model forecasts to determine their quality and comparison to forecasts from the GFS and ECMWF. This effort is important to establish how the FIM compares to other models, since one potential role for the FIM in the future may be as a member of the North American Ensemble Forecast System (NAEFS). A conference paper was submitted to the 23rd Weather Analysis and Forecasting/19th Conference on Numerical Weather Prediction, with the talk given in early June at the conference.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

GOES-R Proving Ground

Participating CIRA Researcher: Ed Szoke

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The GOES-R Proving Ground was established to help National Weather Service forecasters prepare for the transition to the GOES-R satellite era, with the first launch scheduled for 2015. The key to the effort is close two-way interaction with forecasters to determine the best potential products that can be developed from the myriad of possible products that will be available with the expanded number of channels on the GOES-R satellites. As outlined on the project homepage at http://cimss.ssec.wisc.edu/goes_r/proving-ground.html, three principal groups are involved: CIRA, CIMSS at the University of Wisconsin-Madison, and SPoRT, a NASA sponsored group co-located with the University of Alabama-Huntsville and the NWS Huntsville Weather Forecast Office (WFO).

2. Research Accomplishments/Highlights:

Our efforts are principally to be the main liaison with the Boulder and Cheyenne WFOs, where we have begun to introduce test GOES-R like products onto their AWIPS workstations. A conference paper was submitted to the 23rd Weather Analysis and Forecasting/19th Conference on Numerical Weather Prediction, with the talk given in early June at the conference.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

QC Procedures for Application to US Operational and Real-time Mesonetwork Precipitation Observations

Participating CIRA Researcher: Randy Collander

(Additional NOAA Mission Goal to Understand climate variability and change to enhance society's ability to plan and respond / Climate observations and analysis)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Precipitation observations from several thousand sites in the United States, in hourly and daily resolution, are received by the National Centers for Environmental Prediction (NCEP) in Washington, D.C. on a daily basis. Much of this data is manually inspected and quality controlled at the River Forecast Centers (RFC) and other locations before being disseminated to the National Weather Service (NWS) offices and other users. The Environmental Modeling Center (EMC) at NCEP desires to have an automated, objective system for performing a more consistent quality control on the hourly data, with the expectation that a cleaner data set would be of great value in evaluating current model predictions as well as input to current numerical weather prediction models. This quality control software was completed in late FY04, with refinements implemented in each subsequent fiscal year to address issues discovered through routine scrutiny of daily results and case studies.

2. Research Accomplishments/Highlights: None.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

NOAA funding unavailable for work during this period.

Balloon-borne Atmospheric Sampling

Participating CIRA Researcher: Randy Collander

(Additional NOAA Mission Goal to Understand climate variability and change to enhance society's ability to plan and respond / Climate observations and analysis)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Research activities drawing upon extensive experience with design and implementation of balloon vehicles and balloon-based instrument payloads advanced in FY08, including a third successful field experiment in October. The AirCore TM method for obtaining vertical atmospheric profiles of trace gases designed by scientists in the ESRL Global Modeling Division (GMD) was exercised in a high-altitude balloon flight. The AirCore TM consists of a 250 ft. thin-walled, stainless steel coil of tubing that is open and subsequently fills with air as the coil is parachuted to the ground. During the descent, a so-called "noodle of air" flows into the tube and maintains a record of gas concentrations at various altitudes. The AirCore TM weighs only 16 pounds and can be carried aloft with inexpensive meteorological balloons conducting up to 25 profiles with essentially expendable equipment for the price of one high-altitude aircraft sampling flight.

2. Research Accomplishments/Highlights:

In FY09, two successful stratospheric balloon flights of the AirCore TM atmospheric gas concentration profile sampler were conducted by a team of NOAA/ ESRL scientists from the Global Monitoring Division (GMD) and the Global Systems Division (GSD). A revised valve closure system designed to close the sampling valve at 30,000 ft was tested, and an additional instrument package that records temperature during the flight was also flown. These temperature readings are necessary for proper post-flight analysis of the collected air sample. The flights were conducted jointly by ESRL and the Edge of Space Science (EOSS) Balloon Group, a Colorado educational non-profit corporation for promoting science and education through amateur radio and high-altitude balloon flights. The balloons were launched (see Fig. 1 below) and cut down by radio command from the EOSS ground station at Windsor, CO. with the payload landing over 60 miles to the northeast near the Wyoming-Nebraska border. The AirCore TM samples were recovered and returned the same day for trace gas analyses at ESRL laboratories in Boulder. As with previous flights, the analyses showed that CO2 is not uniformly distributed through the atmosphere, as has generally been believed. The AirCoreTM could feasibly collect 1000 or more profiles inexpensively on a daily basis around the world, as it can be easily deployed on commercial and private aircraft, from Unmanned Aircraft System platforms, or carried aloft with small balloons.

Fig. 1. Balloon Launch Near Windsor, CO

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

In progress; our achievements for this project compare favorably with the goals projected in the statement of work.

Development of a Multi-Vehicle Atmospheric Trajectory Prediction System

Participating CIRA Researcher: Randy Collander

(Additional NOAA Mission Goal to Understand climate variability and change to enhance society's ability to plan and respond / Climate predictions and projections)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Based on extensive experience in the development and operation of advanced trajectory models related to the Global Air-ocean In-situ System (GAINS) project, CIRA proposed to participate with Global Solutions for Science and Learning (GSSL) in the continuing development of advanced multi-vehicle trajectory models in support of development and flight operations of a wide range of atmospheric vehicles including buoyant, heavier than air, aerodynamic decelerators, and hybrid vehicles. The models would combine atmospheric data and vehicle performance algorithms for the prediction and analyses of flight paths. The potential vehicles include zero-pressure and super-pressure balloons, airships in both powered and un-powered flight, airplanes, gliders, guided and unguided parachutes along with hybrid systems using a combination of vehicles.

Specifically:

a. Develop multi-vehicle trajectory models for use in vehicle development as well as operational scenarios. These models would combine atmospheric data (observations and numerical weather model output) and vehicle performance algorithms for prediction and analysis of flight paths.

b. Adapt numerical weather model output into vehicle-specific trajectory models capable of utilizing historic and real-time data. Data should be both spatially and temporally consistent.

2. Research Accomplishments/Highlights: None

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA funding unavailable for work during this period.

Ultra-Light Dropsonde Project

Participating CIRA Researcher: Randy Collander

(Additional NOAA Mission Goal to Understand climate variability and change to enhance society’s ability to plan and respond / Climate observations and analysis)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The ability to make accurate long-term predictions of hurricane trajectories is limited by the ability to make detailed measurements of associated atmospheric variables. The objective of this program is to develop and deliver a dropsonde system that has dramatically lower-cost and lighter-weight than anything currently available. The resulting system would facilitate deployment of dropsondes by unmanned aerial vehicles (UAVs) and permit much more extensive measurement surveys. Extensive testing of the design and instrumentation will be completed in three phases. First, testing in an environmental chamber will be performed to verify that performance specifications are met, including range, resolution and accuracy of pressure, relative humidity and temperature sensors. Next, the sonde will be dropped from a suitable tower to evaluate the accuracy of altitude and wind speed and direction sensors in addition to the chamber-tested sensors. The third phase involves deployment at moderate altitudes by dropping from a meteorological balloon. Pending successful completion of the experimental testing, development of UAV deployment capabilities will be addressed.

2. Research Accomplishments/Highlights:

Accomplishments were made in all three planned phases of testing in FY09. Phase One began in January, at which time a series of experiments were performed in the ESRL/GMD environmental chamber at the DSRC in Boulder (see Fig. 2 below) by NOAA and CIRA personnel in conjunction with the Applied Research Associates (ARA) personnel who designed and built the dropsonde.

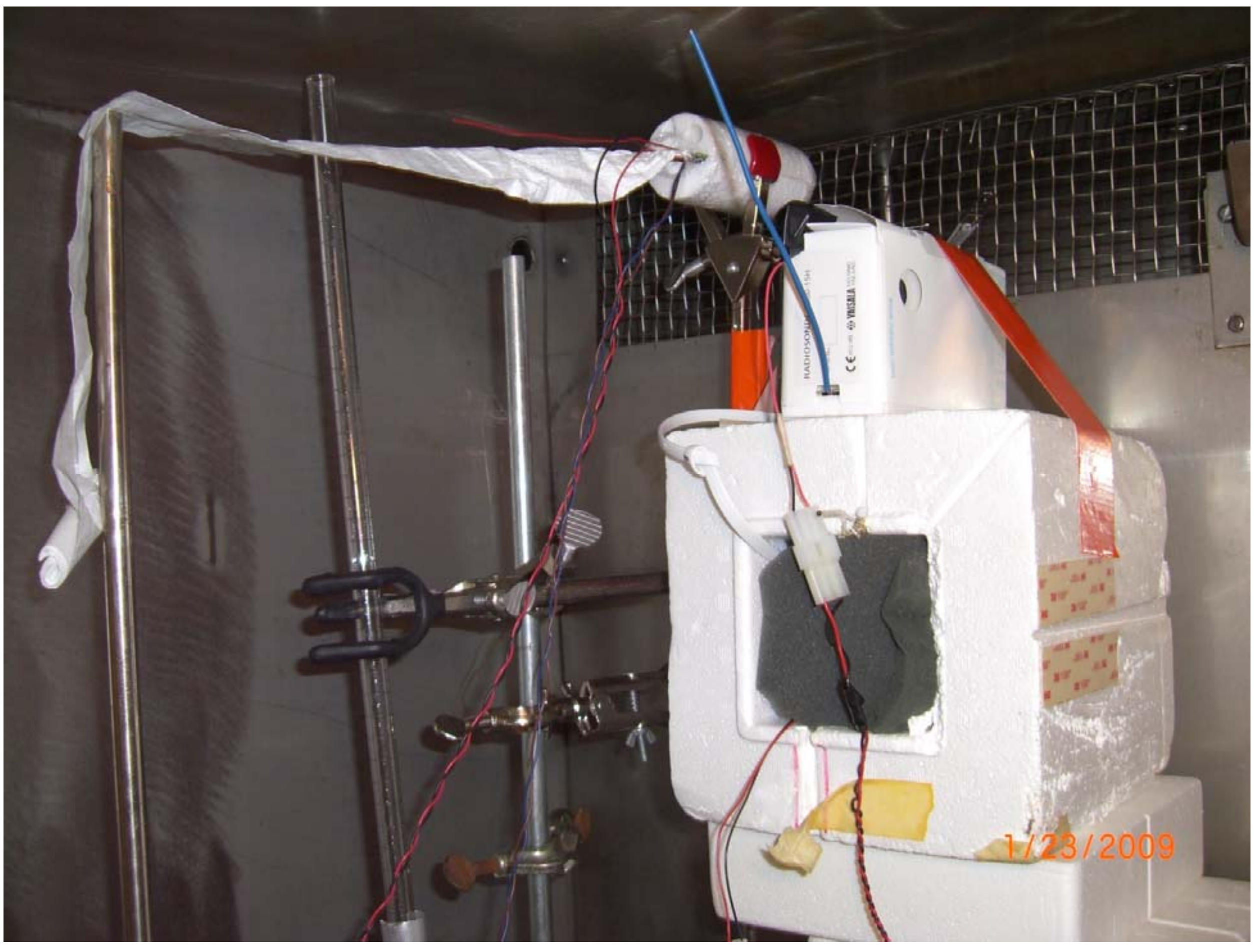

Fig. 2.   ESRL/Global Monitoring Division Environmental Chamber.

In each of three tests, the dropsonde was exposed to temperature and pressure conditions that simulated descent through the atmosphere from 70,000 ft to the surface. The temperature in the chamber was brought down to -60C and depressurized to 70 hPa, and the dropsonde was allowed to "soak" under these conditions for 10 minutes before gradually being returned to ambient surface conditions (+20C and 830 hPa) over a 40 minute period. Phase Two was conducted at the Boulder Atmospheric Observatory (BAO) Tower near Erie, Colorado.

Fig. 3.   Boulder Atmospheric Observatory (BAO) Tower Near Erie. CO.

One at a time, five ultra-light dropsondes were dropped from the top of the 300m tower and this was repeated twice. Data was recorded during each descent, testing the data transmit capabilities as well as GPS position and temperature and relative humidity measurements. Results compared favorably with those recorded during environmental chamber testing. In April, an ultra-light dropsonde was flown on an Edge of Space Sciences (EOSS) balloon launched from Windsor, Colorado on a flight that concurrently served as a test flight for the AirCore system discussed elsewhere in this summary. As a result of the various tests, design changes to the insulating material of the dropsonde, as well as positioning of sensors and battery requirements to improve the capabilities and measurement accuracy, have been noted and may be implemented in the future, pending additional support of the project.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

In progress; our achievements for this project compare favorably with the goals projected in the statement of work.

Trend Analysis

Participating CIRA Researcher: Randy Collander

(Additional NOAA Mission Goal to Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Quantifying current atmospheric temperature trends is key to identifying and understanding potential future global climate changes. Based upon extensive experience in the development and analyses of high-quality data sets, specifically for upper-air observations, CIRA proposes the following tasks in collaboration with Air Resources Laboratory (ARL) and GSD scientists to quantify past temperature trends:

a. Update site-specific upper-air observation data set with most recent data for North America

b. Perform statistical analysis of multi-year upper-air data set to support ongoing climate trend research

2. Research Accomplishments/Highlights: None

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA funding unavailable for work during this period.

ESRL Model Prediction Post Processor

Participating CIRA Researcher: Randy Collander

(Additional NOAA Mission Goal to Support the Nations Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The ESRL Model Prediction Post-Processor project is aimed at using all available global forecast model grids as input to algorithms that compute probabilities of key meteorological variables. Forecast products are provided to users via a web-based interface and formatted for input to sophisticated decision support software methods.

2. Research Accomplishments/Highlights: None

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA funding unavailable for work during this period.

FX-NET

Participating CIRA Researcher: Randy Collander

1. Long-term Research Objectives and Specific Plans to Achieve Them:

FX-Net is a meteorological PC workstation that provides access to the basic display capability of an AWIPS workstation via the Internet. The AWIPS workstation user interface is emulated very closely. FX-Net is a request-based, client-server system intended to be an extension of the AWIPS D2D capability over the Internet. The client runs as a Java application on a PC. After retrieving products via the Internet, it allows a user to locally interact with the information. CIRA proposes to enhance FX-Net through the introduction of additional meteorological products into its display capabilities.

2. Research Accomplishments/Highlights: None

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA funding unavailable for work during this period.

Web Site Development

Participating CIRA Researcher: Randy Collander

1. Long-term Research Objectives and Specific Plans to Achieve Them:

CIRA proposes to collaborate with GSD scientists on web site development. Effort will include developing and updating project-specific web pages for displaying technical documents, generating graphical images and providing a user-friendly interface to these images, along with tools and methods for display manipulation useful to project researchers. Existing web pages will additionally be modified and content refreshed as dictated by project progress. The following known and anticipated projects include:

a. Developmental Testbed Center (DTC) WRF Rapid Refresh Dynamic Core Testing

1) Develop software to generate meaningful graphical representations of meteorological parameters of interest to project collaborators;

2) Develop new tools or modify existing methods (primarily web-based) for displaying graphical representations of specific meteorological parameters.

b. Precipitation Data and Quality Control

Utilize recent automated precipitation QC project results to update the GSD Precipitation website using Perl and Java scripting to develop tools which enable users to interactively manipulate graphical displays to show/hide stations which failed the QC, in addition to displays of bar graphs and other statistical measures of station quality, and periodically update master stations lists.

2. Research Accomplishments/Highlights: None

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

NOAA funding unavailable for work during this period.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborations: None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Albers S., I. Jankov, J. Mcginley, Y. Xie, J.Y. Kim, S.G. Gopalakrishnan, J. Gamache, and S. Aberson, 2009: The use of LAPS as an assimilation and model initialization tool for tropical cyclones.13th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Phoenix, AZ, Amer. Meteor. Soc.

Jankov, I., J. W. Bao, P. J. Neimen, P. J. Schultz, and A. B. White, 2008: Evaluation of microphysical algorithms in WRF-ARW model simulations of atmospheric river events affecting the California coast. European Geosciences Union General Assembly 2008, Vienna, Austria, EGU.

Jankov, I., J. W. Bao, P. J. Neiman, P. J. Schultz, H. Yuan, and A. B. White, 2009: Evaluation and comparison of microphysical algorithms in WRF-ARW model simulations of atmospheric river events affecting the California coast. Accepted by J. Hydrometeor.

Kim, J.Y., I. Jankov, S. Albers, J. A. McGinley, J. H. Oh, S. G. Gopalakrishnan, and X. Zhang, 2008: Hurricane Dennis simulation by using various initial and boundary conditions with HRPS. AGU Fall Meeting, San Francisco, CA, Amer. Meteor. Soc.

Kim, J-Y., I. Jankov, S. Albers, J. H. Oh, J. A. McGinley, S. G. Gopalakrishnan, and X. Zhang, 2009: Hurricane Dennis simulations by using various initial conditions and WRF dynamic cores. 13th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Phoenix, AZ, Amer. Meteor. Soc.

Moninger, W. R., S. G. Benjamin, B. D. Jamison, T. W. Schlatter, T. L. Smith, and E. J. Szoke, 2009: TAMDAR jet fleets and their impact on Rapid Update Cycle (RUC) forecasts. 13th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Phoenix, AZ, AMS.

Schultz, P., S. C. Albers, C. J. Anderson, D. Birkenheuer, I. Jankov, and J. McGinley, 2009: A computationally efficient method for initializing numerical weather models with explicit representation of moist convection. Submitted to Wea. Forecasting.

Szoke, E., S. Benjamin, E. Dash, B. Jamison, W. Moninger, A. Moosakhanian, T. Schlatter, B. Schwartz, and T. Smith, 2008: Effect of meteorological observations from aircraft on NWP short-term forecasts of aviation-impact fields including precipitation, ceiling, and visibility. European Geosciences Union General Assembly 2008, Vienna, Austria, EGU.

Szoke, E. J., S. Benjamin, J. M. Brown, and M. Fiorino, 2009: An examination of FIM performance for a variety of weather scenarios. 23rd Conference on Weather Analysis and Forecasting and 19th Conference on Numerical Weather Prediction, Omaha, NE, AMS, 18A.1.

Szoke, E. J., S. Miller, M. DeMaria, S. Bachmeier, J. Gerth, R. Schneider, J. Gurka, S. Goodman, and K. Fuell, 2009: An overview of the GOES-R Proving Ground: Current forecaster interactions and future plans. 23rd Conference on Weather Analysis and Forecasting and 19th Conference on Numerical Weather Prediction, Omaha, NE, AMS, 12B.3.

Tollerud, E. I., F. Caracena, S. E. Koch, B. D. Jamison, R. M. Hardesty, B. J. McCarty, C. Kiemle, R. S. Collander, D. L. Bartels, S. Albers, B. Shaw, D. L. Birkenheuer, and W. A. Brewer, 2008: Mesoscale moisture transport by the low-level jet during the IHOP Field Experiment. Mon. Wea. Rev. 136, 3781-3795. pdf

Tollerud, E. I., J. A. McGinley, S. L. Mullen, T. Vukicevic, H. Yuan, C. Lu, and I. Jankov, 2009: Optimizing precipitation estimates using merged observations and model output: A case study in the California Sierra Nevada Mountains. AMS Annual Meeting (89th), Phoenix, AZ, AMS.

Vukicevic, T., I. Jankov, and J. McGinley, 2008: Diagnosis and optimization of ensemble forecasts. Mon. Wea. Rev., 136, pp. 1054-1074.

V. Research Collaborations with the GSD Assimilation and Modeling Branch

Project Title: Rapid Update Cycle (RUC)/WRF Model Development and Enhancement

Principal Researchers: Tracy Smith and Kevin Brundage

NOAA Project Goals/Programs: Weather and Water—Serve society's needs for weather and water information/Local forecasts and warnings; Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation / Aviation weather

Key Words: 4-D data assimilation and forecast system, rapidly updated analyses

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The primary focus of the GSD Assimilation and Modeling Branch is the refinement and enhancement of the Rapid Update Cycle (RUC) and development of the Weather Research and Forecast (WRF) model. The RUC is a national scale 4-D data assimilation and forecast systems specifically designed to run at a high temporal frequency (1-hour cycle), taking advantage of a variety of special observations such as ACARS, RASS, profiler, radar, GPS integrated precipitable water vapor, and GOES soundings. It is run operationally at the NOAA/NWS National Centers for Environmental Prediction, and in various experimental configurations at the ESRL Global Systems Division. In addition to refinement and enhancements of the RUC, CIRA researchers collaborate on the development of the Weather Research and Forecast (WRF) model used by CIRA and GSD researchers. Development and testing of WRF based components for the Rapid Refresh (RR) system, intended to replace the RUC hydrostatic forecast model now used at NCEP, are currently underway. Overall goals are to continue the development work on the Weather Research and Forecast (WRF) and Rapid Refresh models used by CIRA researchers and to improve the required visualization techniques for the RUC and RR fields. Additionally, CIRA researchers continue to work on applications of the RUC and RR to forecast problems, including investigations into the use of mesoscale model time-lagged ensembles to improve the accuracy of short-range forecasts, in particular QPF and wind energy, would also continue.

2. Research Accomplishments/Highlights:

During the past year, the RUC, RR, and wrfRR systems were converted to utilize the GSD-developed Workflow Manager software. This scheduling utility provides an XML-based interface to control the execution of the various components of the Mesoscale modeling systems. Utilizing this new utility provides significant improvements in the flexibility and efficiency of these model runs.

GSD's high performance computational (HPC) resources were upgraded in 2008, incorporating approximately 2000 Intel Harpertown processors (hjet). Benchmark codes and evaluation assistance were provided for this project. In anticipation of significant computational refresh scheduled for the spring of 2009, GSD's iject HPC system was decommissioned in December 2008. This necessitated the transition of all model runs and processing currently on ijet to be transitioned to the recently acquired wjet and hjet systems.

Assistance was provided for an important demonstration project predicting hurricane tracks utilizing the new FIM on the Texas Area Computing Center (TACC) supercomputer. During this demonstration, a G9 (~15km) real-time FIM run was executed twice daily on ~1700 processors at TACC to provide 10-day hurricane tracks for Gustav, Hanna, and Ike during fall 2008.

The RUC was also used extensively for data impact studies, most recently evaluating wind profilers, GPS, and TAMDAR, including moisture observations. The RUC is also being used as a platform for current and future simulated observation studies.
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3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Various RUC data impact studies are in progress. RUC/WRF transition to operational "Rapid Refresh" to replace the current RUC running at NCEP is in progress. Incorporation of the NCEP GSI analysis package for the Rapid Refresh is also in progress. Visualization techniques continue to evolve and improve.

4. Leveraging/Payoff:

The RUC is an important forecasting tool for both aviation and severe weather forecasts, which ultimately impact public safety.

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Benjamin, S., S. Weygandt,, J. M. Brown, T. Smirnova, D. Devenyi, K. Brundage, G. Grell, S. Peckham, W. R. Moninger, T. W. Schlatter, T. L. Smith, and G. Manikin, 2008: Implementation of the radar-enhanced RUC. 13th Conf. on Aviation, Range, and Aerospace Meteorology, New Orleans, LA, Amer. Meteor. Soc., CD-ROM, 6.2.

Moninger, W., S. G. Benjamin, B. D. Jamison, T. W. Schlatter, T. L. Smith, and E. J. Szoke, 2008: New TAMDAR fleets and their impact on Rapid Update Cycle (RUC) forecasts. 13th Conf. on Aviation, Range, and Aerospace Meteorology, New Orleans, LA, Amer. Meteor. Soc., CD-ROM, P2.20.

Smith, T. L., S. G. Benjamin, J. M. Brown, S. S. Weygandt, T. Smirnova and B. E. Schwartz, 2008: Convection forecasts from the hourly updated, 3-km High Resolution Rapid Refresh (HRRR) model. 24th Conference on Severe Local Storms, Savannah, GA, Amer. Meteor. Soc., CD-ROM, 11.1.

Szoke, E. J., S. Benjamin, R. S. Collander, B. D. Jamison, W. R. Moninger, T. W. Schlatter, B. Schwartz, and T. Smith, 2008: Effect of TAMDAR data on RUC short-term forecasts of aviation-impact fields for ceiling, visibility, reflectivity, and precipitation. 13th Conf. on Aviation, Range, and Aerospace Meteorology, New Orleans, LA, Amer. Meteor. Soc., CD-ROM, 6.4.

Project Title: <u>TAMDAR (Tropospheric Airborne Meteorological Date Reporting) Project</u>

Participating CIRA Researchers: Brian Jamison, Randy Collander, Tracy Smith, and Ed Szoke

NOAA Project Goals/Programs: Weather and Water—Serve society's needs for wather and water information / Environmental modeling and local forecasts and warnings; Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation / Aviation weather

Key Words: TAMDAR, Airborne weather sensors, aircraft data impact on model forecasts

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The TAMDAR project is an evaluation of a new observing system using sensors placed on a number of regional aircraft. The sensors report temperature, pressure, humidity, winds, eddy dissipation rate, and icing. Tasks primarily involve examining the data for quality, and investigating the impact of the data on weather model forecasts. For these tasks, retrospective runs of the Rapid Update Cycle (RUC) 20 km model were performed.

Retrospective runs of the RUC for the period of August 15-25, 2007 were necessary in order to determine the effect of adjustments to the model and/or the input data. This time period was selected primarily due to its substantial convective activity. Runs for this period previously completed during fiscal year 2007-2008 include:

a) baseline run using all data with no alterations in parameters, for which successive runs will be compared to determine impacts.

b) run with all TAMDAR data removed.

c) run with all aircraft (AMDAR) data removed.

d) run with all profiler data removed.

e) run with all VAD data removed.

f) run with all RAOB data removed.

g) run with GPS integrated precipitable water removed.

h) run with all surface data removed.

2. Research Accomplishments/Highlights:

Continuing into the 2008-2009 fiscal year, runs include:

i) run with all mesonet data removed.

j) run using the RRTM radiation package.

k) run using a more appropriate aircraft reject list.

l) run without the TAMDAR winds.

m) run with 240 Digital Filter Initialization (DFI) steps.

n) run with 320 DFI steps.

o) run with the cloud analysis sequence changed.

Analyzing the retrospective run results has greatly increased our knowledge of the relative value of each of the contributing data sets, and gives a good perspective of the relative impact of the TAMDAR data. Feedback to AirDat (the designers of the TAMDAR sensors) has proven very worthwhile.

3. Comparison of Objectives Vs Actual Accomplishments for Reporting Period:

The accomplishments for this project during this fiscal year compare favorably with the goals outlined in the statement of work.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Benjamin, S., B. D. Jamison, W. R. Moninger, B. Schwartz, and T. W. Schlatter, 2008: Relative forecast impact from aircraft, profiler, rawinsonde, VAD, GPS-PW, METAR and mesonet observations for hourly assimilation in the RUC. 12th Conference on Integrated Observing and Assimilation Systems for Atmosphere Oceans, and Land Surface (IOAS-AOLS), 20-24 January 2008, New Orleans LA, AMS.

Benjamin, S. G., W. R. Moninger, B. D. Jamison, and S. R. Sahm, 2009: Relative short-range forecast impact in summer and winter from aircraft profiler, rawinsonde, VAD, GPS-PW, METAR, and mesonet observations for hourly assimilation into the RUC. 13th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Phoenix, AZ, AMS.

Brown, J.M., T.G. Smirnova, S.G. Benjamin, B. Jamison, and S.S. Weygandt, 2008: Rapid-refresh testing: examples of forecast performance. 13th Conference on Aviation, Range, and Aerospace Meteorology, 20-24 January 2008, New Orleans, LA, AMS.

Koch, S. E., C. Flamant, J. W. Wilson, B. M. Gentry, and B. D. Jamison, 2008: An atmospheric soliton observed with Doppler radar differential absorption lidar, and molecular Doppler lidar. J. Atmos. Oceanic Tech (accepted).

Moninger, W., S. G. Benjamin, B. D. Jamison, T. W. Schlatter, T. L. Smith, and E. J. Szoke, 2009: TAMDAR jet fleets and their impact on Rapid Update Cycle (RUC) forecasts. 13th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Phoenix, AZ, AMS.

Szoke, E. J., S. Benjamin, R. S. Collander, B. D. Jamison, W. R. Moninger, T. W. Schlatter, B. Schwartz, and T. Smith, 2008: Effect of TAMDAR data on RUC short-term forecasts of aviation-impact fields for ceiling, visibility, reflectivity, and precipitation. 13th Conference on Aviation, Range, and Aerospace Meteorology, 20-24 January 2008, New Orleans, LA, AMS.

Szoke, E., S. Benjamin, E. Dash, B. Jamison, W. Moninger, A. Moosakhanian, T. Schlatter, B. Schwartz, and T. Smith, 2008: Effect of meteorological observations from aircraft on NWP short-term forecasts of aviation-impact fields including precipitation, ceiling, and visibility. European Geosciences Union General Assembly 2008, Vienna, Austria, EGU.

Tollerud, E. I., F. Caracena, S. E. Koch, B. D. Jamison, R. M. Hardesty, B. J. McCarty, C. Kiemle, R. S. Collander, D. L. Bartels, S. Albers, B. Shaw, D. L. Birkenheuer, and W. A. Brewer, 2008: Mesoscale moisture transport by the low-level jet during the IHOP Field Experiment. Mon. Wea. Rev. (accepted).

Yuan, H., C. Lu, J.A. McGinley, P. J. Schultz, B.D. Jamison, L. Wharton, and C. J. Anderson, 2009: Evaluation of short-range quantitative precipitation forecasts from a time-lagged multi-model ensemble. Wea. Forecasting, 24, 18-38.

Project Title: <u>HRRR (High-Resolution Rapid Refresh Model) Project</u>

Participating CIRA Researcher: Brian Jamison

NOAA Project Goal/Program: Weather and Water—Serve society's needs for weather and water information/Local forecasts and warnings; Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation/Aviation weather

Key Words: HRRR, Ultra High-resolution, Rapidly Updated Analyses

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The High-Resolution Rapid Refresh (HRRR) model is an adaptation of the Rapid Update Cyclemodel developed at GSD. The primary difference is that the HRRR model uses a sub-CONUS domain at 3 km resolution, and radar reflectivity is used as an input variable. The initial HRRR domain extended from northern Minnesota to northern Oklahoma, and included most of the northern East Coast. The domain has now been expanded to include most of the CONUS east of the Rocky Mountains. Tasks for this project include: generating graphics of output fields, creation and management of web sites for display of those graphics, and creation and management of graphics for hallway public displays, including software for automatic real-time updates.

2. Research Accomplishments/Highlights:

In the previous year, routines to generate the graphics were written as well as scripts to run these routines hourly to coincide with the hourly output of the model. A web site was also created for display of these images (http://rapidrefresh.noaa.gov/hrrr3). This web site also offers the option to display an alternate version of the HRRR which is initialized with the Rapid Refresh (RR) model (an upgrade to the RUC model that includes assimilation of radar reflectivity, TAMDAR observations, enhanced convection and enhanced land-surface radiation). Many refinements have been incorporated since. The most pronounced of these is the expansion of the HRRR domain, currently dubbed the HRRR-Large. This domain encompasses a good portion of the plains and eastern states of the CONUS, at the same 3 km resolution. Several new products aimed at severe weather forecasting are now available for the HRRR-Large, as are links for zoomed in quadrants with more detail (Fig. 1).

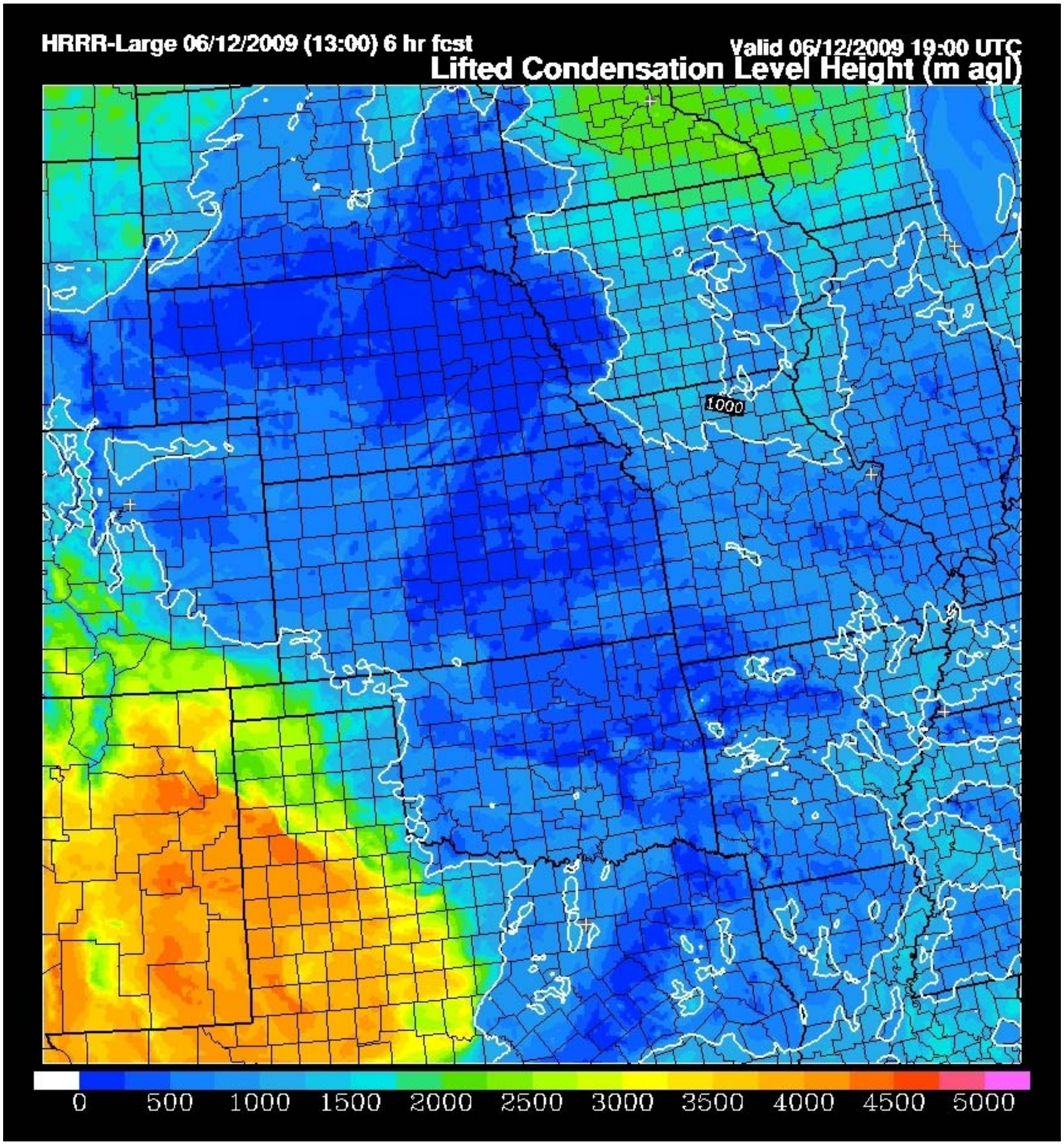

Fig. 1. A 6-hr Forecast of Lifted Condensation Level (LCL) Height From the Southwest Quadrant of the HRRR-Large Model.

A similar graphics web site for the RR model (http://rapidrefresh.noaa.gov/RR13_1hcyc) was updated. The RR is coarser than the HRRR at 13 km resolution; however, the domain covers all of North America rather than just the continental US. Similar to the HRRR-Large, zoomed in quadrants for the CONUS sub-domain are now available (Fig. 2).

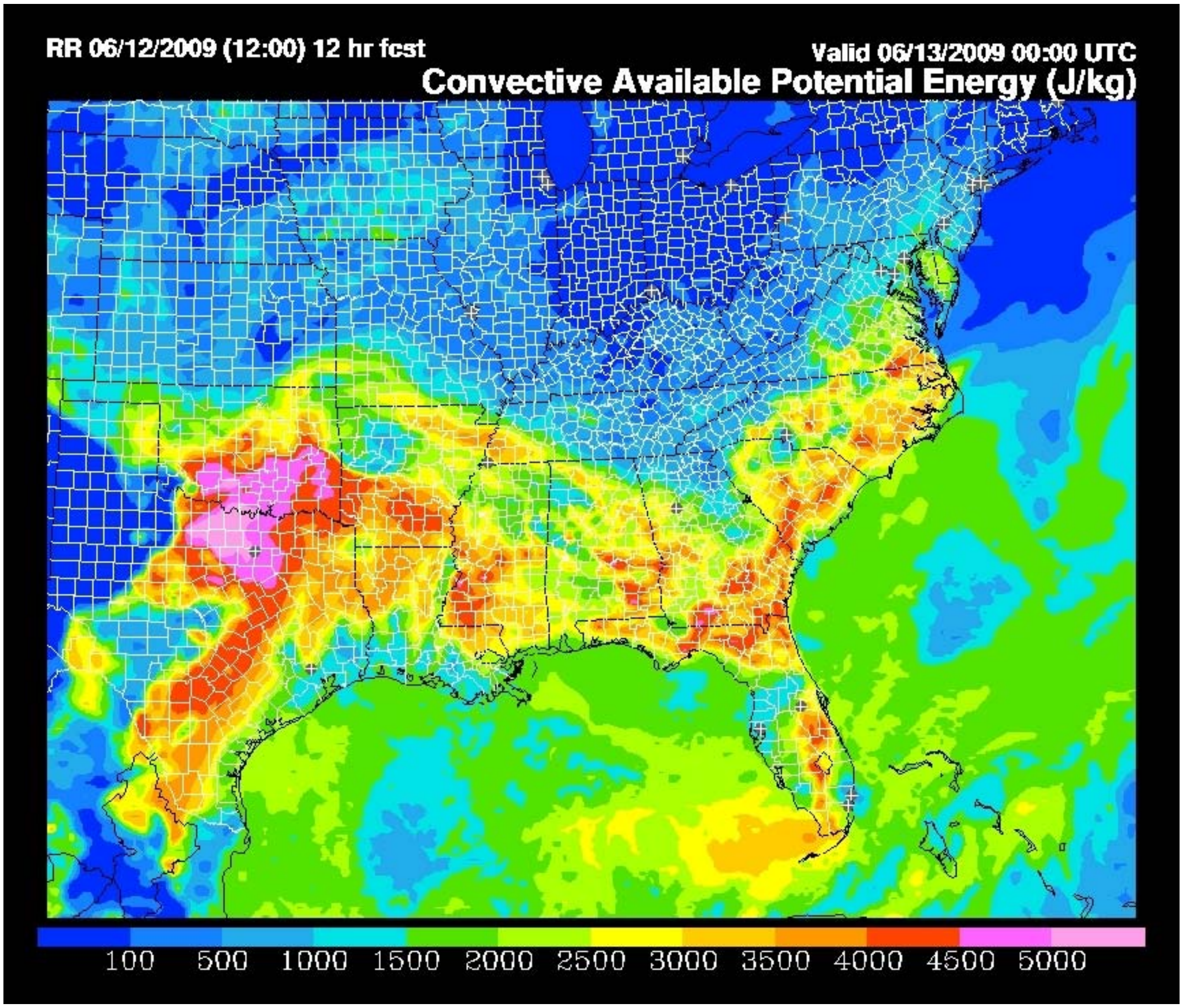

Fig. 2. A Southeast CONUS Regional Zoomed Plot of Convective Available Potential Energy (CAPE) From the Rapid Refresh Model.

RR products for the Alaska region and the continental US (CONUS) were also updated and are linked from the web site.

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

3. Comparison of Objectives Vs Actual Accomplishments for Reporting Period:

In progress; the achievements for this project during this fiscal year compare favorably with the goals outlined in the statement of work.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: <u>Hydrometeorology, QPE and QPF, and Data Assimilation and Ensemble Forecasting</u>

Principal Investigator: Chungu Lu

NOAA Project Goal/Program: Weather and Water/Weather water science, technology, and infusion

Key Words: Quantitative Precipitation Forecast (QPF), and Probabilistic QPF (PQPF), and Quantitative Precipitation Estimate (QPE), Data Assimilation and Ensemble Forecasting

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project is supported by the NOAA Office of Atmospheric and Oceanic Research (OAR). The long-term research objectives and scientific plans are to provide understandings on weather and water related scientific issues, and to provide service for the nation's needs for weather, environmental, and hydrological predictions. To achieve these goals, our approach is to develop and utilize hi-resolution numerical models, efficient data assimilation systems, and various ensemble and probabilistic forecasts.

2. Research Accomplishments/Highlights:

Over the last few years, we have developed time-lagged, multi-model ensemble systems and ensemble-based data assimilation systems, and applied these systems to various projects and experiments. We also conducted various QPF, PQPF, and QPE studies. These studies have helped NOAA provide better service to the nation in regard to weather, environmental, and hydrological predictions. During the reporting period, we have developed a method to construct mesoscale background error covariance for a data assimilation system. We also conducted global precipitation verification studies using various satellite data and a global atmospheric forecast model (GFS). In addition, we participated in WMO THORPEX related research activities and collaborated with NOAA NCEP for providing basic and applied research to the NOAA operational departments.

Based upon NOAA's support, we have developed several NSF, DoD, and NASA proposals. We anticipate some of this funding will foster and enforce our research into next the several years. Last year, we hosted two postdoctoral fellows. One was funded by National Research Council, and the other one was jointly supported by CIRA, Colorado State University and NOAA/GSD. We also promoted strong international cooperation. We trained a Ph.D. student from Korea whose dissertation involved the ensemble-based data assimilation method. This research was funded by the Korean Research Foundation and Pukyong National University. We hosted meteorological delegations from China, Korea, and Taiwan. The PI was invited by China Meteorological Administration (CMA) to serve in the China-US atmospheric science advisory committee. We collaborated with Chinese scientists on several scientific projects. The PI was also invited to Korea for discussions on the future collaboration with Korean scientists.

In the coming year, we will continue work on hydrometeorology, data assimilation, ensemble forecasting, and probabilistic forecasting under NOAA's general requirements, as well as specific projects. In addition, with some possible external funding, some additional research will be carried out to support NOAA's general goals. We will continue the collaboration with Chinese and Korean scientists. We are going to host two new Ph.D. students to complete their dissertations with us. One of these students will be supported by the Korean Research Foundation, and the other will be supported by the Chinese Higher Education Committee.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators:

Korean Research Foundation, China Meteorological Administration, Korea's Pukyong National University.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Kim, O., C. Lu, J. McGinley, and J. Oh, 2008: Recovery of Mesoscale background error covariance using time-lagged ensembles. In review, Wea. Forecasting.

Kim, O., C. Lu, J. McGinley, and J. Oh, 2008: Data assimilation with background error covariance using time-phased ensembles. The Asia Oceanic Geosciences Society (AOGS), Busan, Korea.

Lu, C., Kim, O., J. McGinley, and J. Oh, 2008: Recovery of mesoscale covariance using time-phased ensembles. The 1st China-US international Symposium on mesoscale meteorology and data assimilation, Norman, OK.

Xu, X., C. Lu, X. Shi, and S. Gao, 2008: The world water tower: An atmospheric perspective. Geophys. Res. Lett., 35, L20815, doi:10.1029/2008GL035867.

Project Title: Study of Gravity Waves and Turbulence Interaction in the Upper Troposphere

Principal Investigator: Chungu Lu

NOAA Project Goal/Program: Commerce and transportation / Aviation weather

Key Words: Aviation Safety, Upper-level Jet, Gravity Waves, Turbulence, Atmospheric Model Simulation.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project is supported by the NOAA Office of Atmospheric and Oceanic Research (OAR). The long-term research objectives and scientific plans are to gain physical understandings of mesoscale gravity-wave dynamics and turbulence generation in the upper troposphere, and to provide public aviation safety advisory based on the obtained scientific understandings. The research may also provide insight into initiation and intensification of severe weather, because gravity wave and turbulence may trigger convections, and transfer and deposit energy into weather systems. Propagation and dissipation of gravity waves also play important roles in global general circulation and serve as a forcing for upper atmospheric dynamics. Therefore, an understanding of interaction of gravity waves and turbulence may also be relevant to global climate studies.

2. Research Accomplishments/Highlights:

Since the start of the project, we have conducted data analyses, model simulations, and theoretical investigations. We have transferred an algorithm for unbalanced flow diagnostics in the upper troposphere to U.S. Federal Aviation Administration two years ago. A series of papers have been published on world-class journals in atmospheric science and geophysics, such as the Journal of Atmospheric Science and Journal of Geophysical Research. During the report period, we conducted analysis using spectral, multi-order structure functions, and multi-fractal methods. We also conducted a series of WRF model simulations of gravity wave generation, propagation, and dissipation in a baroclinic atmospheric condition. These analyses further revealed scale interactions and energy cascade between mesoscale gravity waves and turbulence.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

All research is still in progress, and the on-going research effort will be carried over to the next few years.

4. Leveraging/Payoff:

In leveraging current NOAA/OAR's support for this project, we are now developing an NSF proposal for the basic understanding of gravity waves and turbulence and their connection to global weather and climate. During the past year, a Ph.D. student from Texas A&M University was trained in our group. We supervised the student on using the WRF model for simulating gravity waves and their dissipation. We also collaborated with the Institute of Atmospheric Physics, Chinese Academy of Sciences for a series of research projects (the PI was invited for a short visit to Beijing, China). Professor Ulrich Achatz from the University of Frankfurt in Germany paid a visit to our group in Boulder, Colorado. We also discussed future collaboration in this area. It has also been proposed that a postdoctoral fellow from China Ocean University will conduct research on gravity waves next year. This research collaboration is supported by Chinese National Nature Science Foundation.

5. Research Linkages/Partnerships/Collaborators:

Collaboration with NOAA/ESRL/GSD is planned to continue along this line in the coming years. In particular, we will work on mesoscale gravity wave climatological studies using GSD's MADIS or STMAS data assimilation system with high-resolution observational and model data. We will continue to work on several planned publications on interaction of gravity waves and turbulence.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Lu, C. and J. Boyd, 2008: Rossby wave ray tracing in a divergent barotropic atmosphere J. Atmos. Sci. 65, 1679-1691.

Lu, C., and S. Koch, 2008: Gravity waves and turbulence in spectral, structure functional, and multi-fractal spaces. First US-China Symposium in mesoscale meteorology, Norman, OK.

Lu, C. and S. Koch, 2008: Interaction of upper-tropospheric turbulence and gravity waves as observed from spectral and structure function analysis. J. Atmos. Sci., 65, 2676-2690.

Wang, N. and C. Lu, 2008: A two-dimensional continuous wavelet algorithm and its application to meteorological data analysis. J. Atmos. Ocean. Tech., in review.

Project Title: Global Icing Verification Studies Using CloudSat

Co-Principal Investigators: Chungu Lu and Sean Madine

NOAA Project Goal / Programs: Commerce and transportation / Aviation weather

Key Words: Aviation Safety, Clouds, Icing, CloudSat Data.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project is supported by the NOAA Office of Atmospheric and Oceanic Research (OAR). The long-term research objectives and scientific plans are to gain physical understanding of clouds and cloud icing conditions that may affect aviation operations and to provide public aviation safety advisory based on the obtained scientific understandings.

2. Research Accomplishments/Highlights:

We have completed the initial phase of verification of the world area forecast system for global icing conditions.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The project is still in progress, and continued funding is expected.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Kay, M.P., C. Lu, S. Madine, J. Luppens Mahoney, and P. Li, 2009: Detecting cloud icing conditions using CloudSat datasets. Preprints, 23rd Conference on Weather Analysis and Forecasting, 1-5 June 2009, Omaha, NE, Amer. Met. Soc.

Kay, M.P., S. Madine, C. Lu, and J. Luppens Mahoney, 2009: A novel approach for evaluating world area forecast system global icing forecasts using CloudSat data. International Conference on Nowcasting and Short-range Forecasting, British Columbia, Canada.

Madine S. and C. Lu, 2009: CloudSat data and verification of global icing forecasts for aviation. NOAA/NESDIS Cooperative Institute Directors' and Administrators' meeting, CIRA, Colorado State University, Fort Collins, CO.

Project Title: <u>Multi-regional Climate Model Ensemble Downscaling of Multi-GCM Seasonal Forecasts (MRED)</u>

Co-Principal Investigators: Chungu Lu and Sean Madine

NOAA Project Goal/Program: Climate/CPPA

Key Words: Climate Change, Regional Climate, Ensemble Downscaling

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project is supported by the NOAA Climate Program Office. The long-term research objectives and scientific plans are to gain physical understanding of global and regional climate change, and to provide tools for predicting future climate.

2. Research Accomplishments/Highlights:

Conducted an initial test run of WRF-NMM model for the period of 1 November 2005 – 1 May 2006, using NCEP/DOE AMIP-II Reanalysis dataset. The preliminary results for a winter seasonal study showed a reasonable simulation, with total precipitation from WRF-NMM 6 month integration being comparable to NCEP-GFS total precipitation amount for the same periods.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The project is still in progress, and continued NOAA/CPPA support is expected.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Anderson, C. J., C. Lu, and J. A. McGinley, 2009: Initial tests of WRF-NMM for use as a regional seasonal forecast model. NOAA Climate Program Office, PI's meeting. Silver Spring, MD.

Project: <u>Fire Weather Prediction System</u>

Co-Principal Investigator: Chungu Lu

NOAA Project Goal/Program: Weather and Water/Local Forecast and Warning

Key Words: Public Safety, Numerical Weather Prediction, Fire Weather Modeling.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project is supported by the NOAA Office of Atmospheric and Oceanic Research (OAR). The long-term research objectives and scientific plans are to gain physical understanding of interaction of weather conditions and wild fire environment, and to provide NOAA a potential prediction tool for wild fire situation.

2. Research Accomplishments/Highlights:

We configured and set up a WRF-NMM based high-resolution modeling system, which can be coupled with fire behavior model.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The project is still in progress, and continued NOAA/OAR fund for this work is expected.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: Chemical Data Assimilation

Principal Scientist: Mariusz Pagowski

NOAA Project Goal/Program: Weather and Water—Serve society's needs for weather and Water information/Environmental modeling, Air quality

Key Words: Atmospheric Modeling, Air Chemistry, Data Assimilation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project involves assimilation of chemical species into WRF-Chem to improve forecasting concentrations of atmospheric constituents. Of particular importance are tropospheric ozone and fine aerosols (i.e., aerosol with diameter smaller than 2.5 μm, further referred to as particulate matter 2.5 or PM2.5) which are the key components of smog and are especially harmful to human health. Currently, a 3DVAR system (Gridpoint Statistical Interpolation, GSI) is being developed. Also, investigation of assimilation with Ensemble Kalman Filter is ongoing. Plans are made and funding being sought for the development of adjoints and a 4DVAR system.

2. Research Accomplishments/Highlights:

Data assimilation is an essential part of weather forecasting in all major meteorological centers. Until now, however, few attempts have been made to assimilate chemical species for air quality forecasting. Usually, air quality forecasts are initialized using concentrations of species obtained from the previous day's forecasts with no regard to the observations. This approach generally leads to better forecasts compared to those initialized with the climatological values of concentrations of the species.

This "state-of-the art" in air quality modeling is both a result of the complexity of the problem (the number of chemical species varies in the model from tens to hundreds and is the multiple of the number of atmospheric state variables) and the scarcity of observations compared to meteorology (especially with respect to vertical profiles). This is likely to change in the near future with the availability of satellites and unmanned aerial vehicles.

An initiative to improve WRF-Chem forecasts with data assimilation using the Gridpoint Statistical Interpolation (GSI, Purser et al., 2003a and b) is under way. Some results of this work are described in a journal paper on assimilation of surface observations of ozone and PM2.5 that has been accepted by the Quarterly Journal of the Royal Meteorological Society subject to revisions. Summary of this paper is presented below.

The modeling domain is shown in Fig. 1.

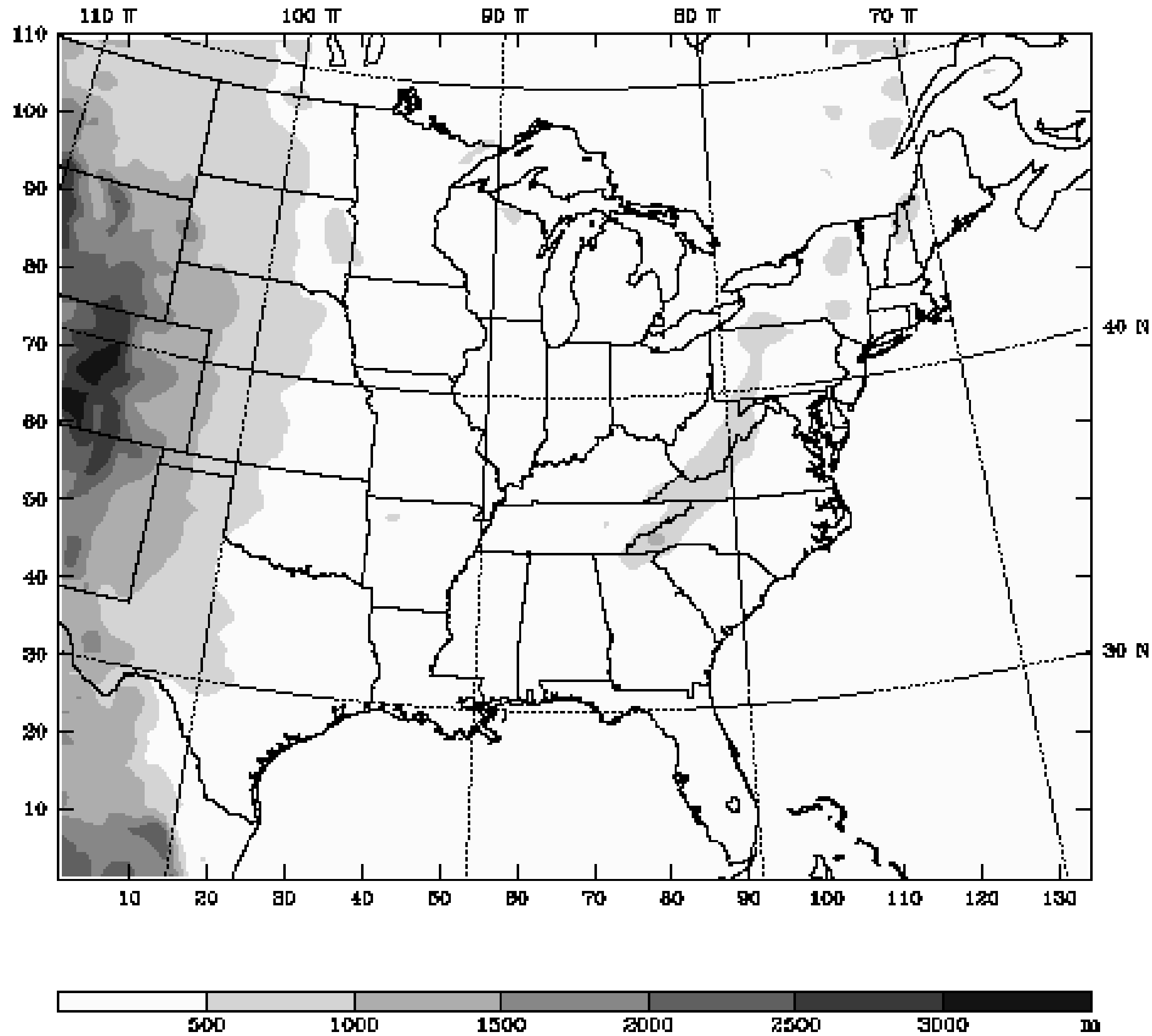

Fig. 1. Modeling Domain.

In GSI, specification of background error matrix covariance requires determination of correlation error length scales and variances. To calculate background error correlations and the characteristic length scales, we used NMC method (Parish and Derber, 1992) using WRF Chem ozone forecasts from August 2004 at 27 km resolution. Background error covariances for ozone and PM 2.5 were calculated from the differences between the 48h and 24h forecasts and were used to calculate correlation length scales for different model levels by fitting Gaussian curves. The horizontal and vertical length scales and standard error deviations are shown in Fig. 2.

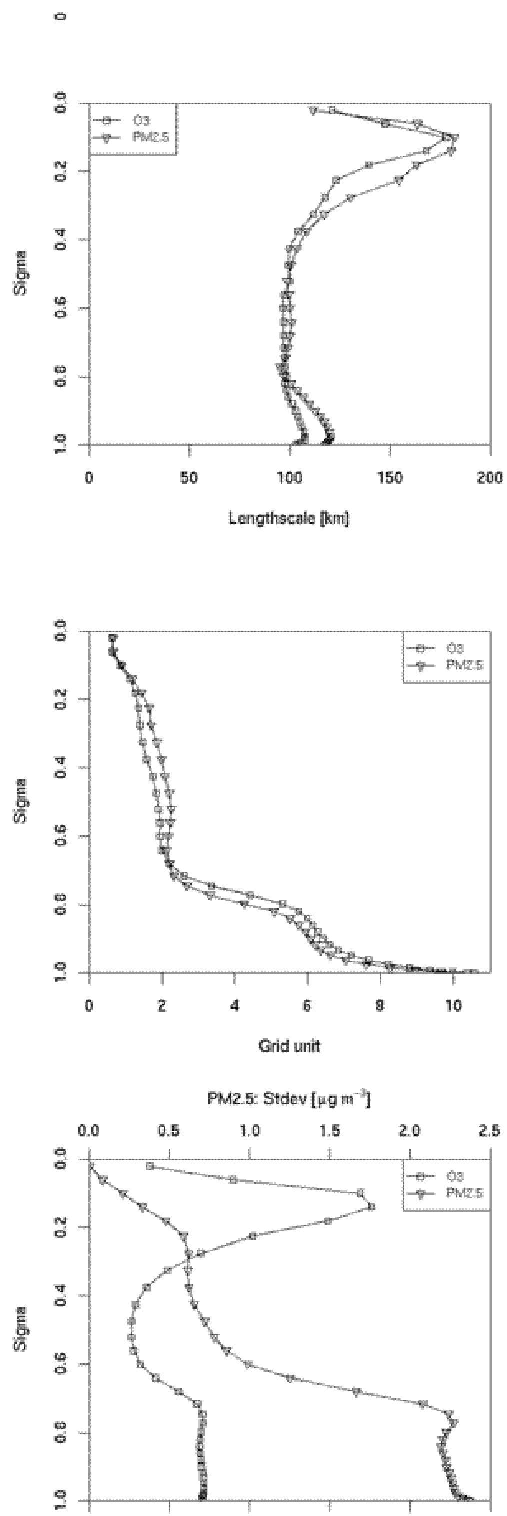

Fig. .2. Variability of the horizontal and vertical correlation length scales and standard error deviations at different model levels for ozone and PM2.5.

Map with measurement network of surface ozone concentrations that was used in the data assimilation experiment is given in Fig. 3.

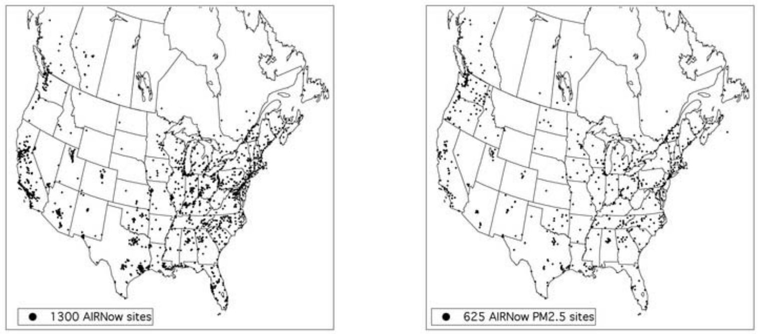

Fig. 3. Map of Real-time Ozone and PM2.5 Measurement Stations That Constitutes the AIRNow Network.

Performances metrics (bias, root-mean square errors, and correlation) for the data assimilation experiment in August 2006 with cycle implemented at 24-hour intervals at 0000 UTC and non-assimilated forecasts are shown in Figs. 4 and 5 for ozone and PM2.5 concentrations.

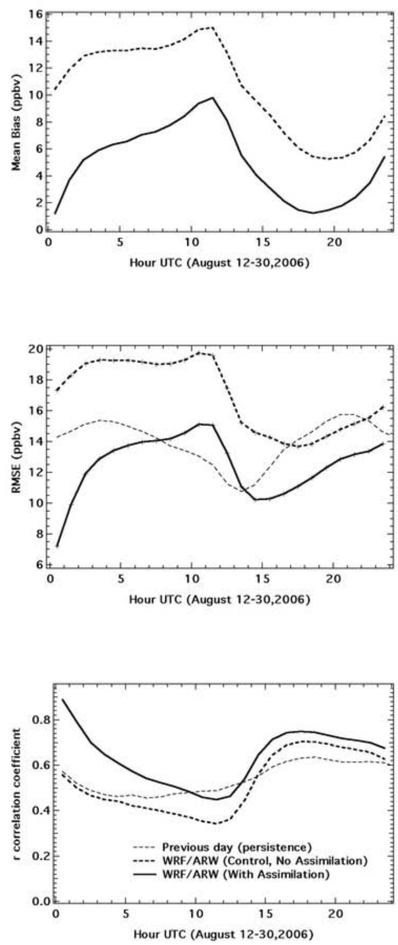

Fig. 4. Bias, RMSE, and Correlation for Data Assimilation Experiment and Non- assimilated Forecasts for Ozone.

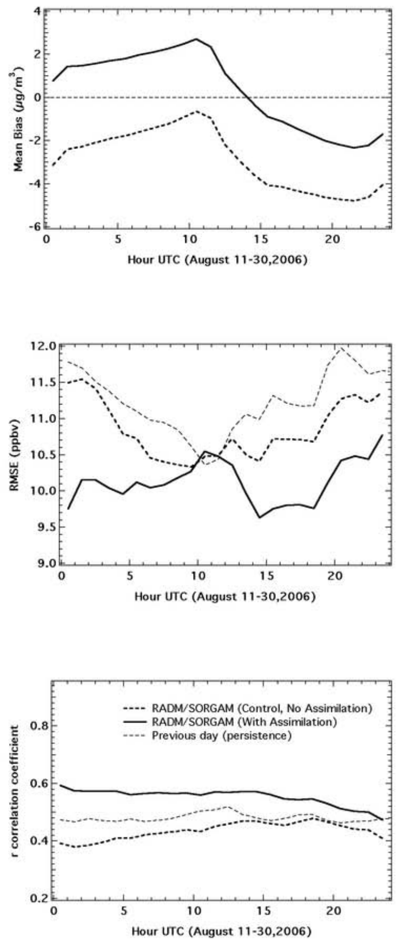

Fig. 5. Bias, RMSE, and Correlation for Data Assimilation Experiment and Non-assimilated Forecasts for PM2.5.

Equitable threat score and bias ratio for the next-day 8-hour average maximum ozone concentration for non-assimilated and assimilated forecasts are shown in Fig. 6. Corresponding plots for the 24-hour average of PM2.5 are shown in Fig 7.

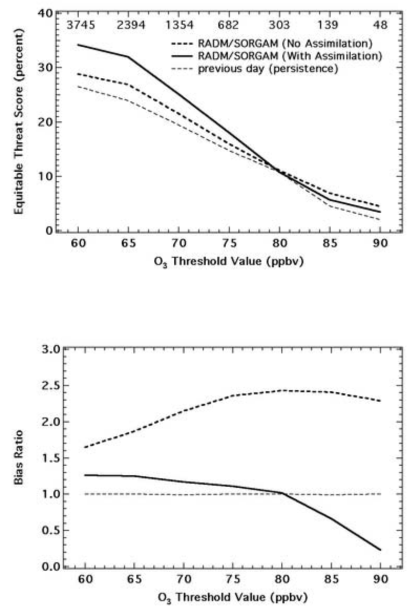

Fig. 6. Equitable Threat Score and Bias Ratio for Different Thresholds of the Next-day 8-hour Average Maximum Ozone Concentration for Non-assimilated and Assimilated Forecasts.

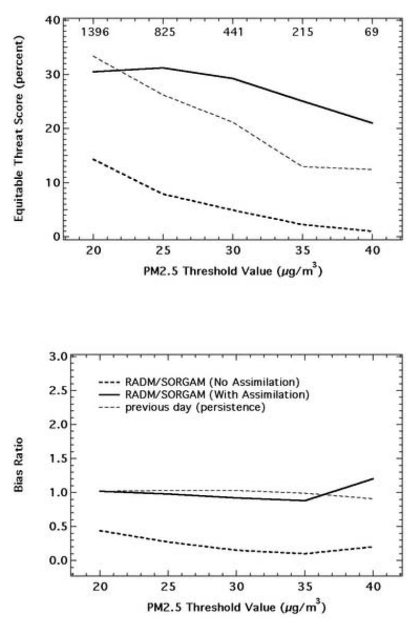

Fig. 7. Equitable Threat Score and Bias Ratio for Different Thresholds of the 24-hour Average PM2.5 Concentration for Non-assimilated and Assimilated Forecasts.

The experiment demonstrated that assimilation of ozone and PM2.5 could lead to much improved forecasts of concentrations of these species in terms of standard statistical measures. A positive impact of assimilation is observed in forecasts at least out to 24 hours. That result for ozone is encouraging, especially since it is a volatile species dependent on the presence of precursors and sunlight. Measurements of concentrations of precursors were not available for this evaluation period so we could not determine if assimilation of ozone had any positive impact on their predicted concentrations. Currently, modeled concentrations of the precursors are only affected implicitly by assimilation of ozone. In the near future, we plan to influence concentrations of the precursors through adjoints and to minimize adjustment of their concentrations after the assimilation.

Improvement in the forecasting skill of PM2.5 concentrations with assimilation was expected. First, PM2.5 is much less reactive than ozone and the impact of assimilation should have longer-term effects. Second, PM2.5 forecasts generally show large errors in terms of basic statistics and their correction via assimilation should be substantial.

Extensions to the work presented here include an investigation of forecast performance at different assimilation times and with higher frequency of the assimilation cycle, and the use of GSI to assimilate measurements from aircraft and ozone sondes.

Horizontal and vertical length scales and background error variances will receive further tuning since the current data are derived from a monthly series of 48-hour forecasts that are issued continuously without data assimilation. The tuning will be accomplished on a seasonal basis when the assimilation cycle is implemented in real time. With an increased sample size and greater statistical confidence, zonal dependence of background error scales will be introduced.

References Used:

References:

Pagowski, M., G.A. Grell, S.A. McKeen, S.E. Peckham, D. Devenyi, Three-dimensional variational data assimilation of ozone and fine particulate matter observations. Some results using the Weather Research and Forecasting – Chemistry model and Gridpoint Statistical Interpolation, pending revisions.

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

Purser R.J., W.-S. Wu, A.F. Parrish, and N.M. Roberts, 2003a: Numerical aspects of the application of recursive filters to variational statistical analysis. Part I: Spatially homogeneous Gaussian covariances. Mon. Wea. Rev., 131, 1524-1535.

Purser R.J., W.-S. Wu, A.F. Parrish, and N.M. Roberts, 2003b: Numerical aspects of the application of recursive filters to variational statistical analysis. Part II: Spatially inhomogeneous and anisotropic general covariances. Mon. Wea. Rev., 131,1536-1549.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators: None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Delle Monache, L., J. Wilczak, S. McKeen, G. Grell, M. Pagowski, S. Peckham, R. Stull, J. McHenry, and J. McQueen, 2008: Kalman-filter bias correction method applied to deterministic, ensemble averaged, and probabilistic forecasts of surface ozone, Tellus, in press.

Koch, S.E., W. Feltz, F. Fabry, M. Pagowski, B. Geerts, K.M. Bedka, D.O. Miller, and J.W. Wilson, 2008: Turbulent mixing processes in atmospheric bores and solitary waves deduced from profiling systems and numerical simulation. Mon. Wea. Rev., 136, 1373-1400.

Project Title: <u>FX-Net Forecaster Workstation Project</u>

Principal Researcher: Sher Schranz
CIRA Team Members: Jebb Stewart, Evan Polster, and Ning Wang

NOAA Project Goal/Programs: Weather and Water—Serve Society's need for weather and water information / Local forecasts and warnings, Air quality, Environmental modeling, and Weather and water science, technology, and infusion (STI). FX-Net is a cross-cutting solution provided to all these program elements.

Key Words: PC workstation, Fire Weather, Air Quality, Compression Algorithm

FX-Net for Fire Weather/All Hazards

Fire Weather Mission Goal: NOAA's National Fire Weather Program seeks to eliminate weather-related wild land fire fatalities and injuries, and to reduce fire suppression and land management costs by providing more timely and accurate weather information. NWS forecasters at Weather Forecast Offices and the Storm Prediction Center utilize the latest model and observation data to produce national outlooks identifying critical fire weather patterns. The NOAA mission is to provide tools to support the forecasters producing these long- and short-range forecasts in support of fire-management decision makers.

When a wild land fire does erupt, the NOAA mission to provide services in support of public safety becomes critical. Forecasters must produce very short-range, ‘now’ casts of weather hazards that will directly affect fire-fighting activities. Forecasters become dependent on the tools they can carry with them to the fire. Their ability to function effectively as a part of the fire fighting coordination team is dependent on these tools.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The long-term goals of the NWS FX-Net fire weather research project are: 1) to provide the most comprehensive real-time atmospheric data set possible to tactically deployed weather forecasters; 2) to provide the tactically-deployed all-hazards user access to additional earth information such as emergent dispersion, GIS, oceanic, and hydrologic data; and 3) provide an integrated data manipulation, analysis, and display system for this wide range of earth information.

A new long-term goal added for FY06-07 was to begin preliminary research into the transition of the FX-Net Thin Client capabilities to the AWIPS II architecture. The AWIPS II system was scheduled to begin operational testing in FY09. The AWIPS II Thin Client capability was not ready for operational testing in FY09. Planning activities and a new Statement of Work with the NWS AWIPS Program Office resulted in a revised evaluation and transition schedule. The AWIPS II software suite and some portions of the architecture were changed in FY09. The FX-Net team continues to provide performance parameters and thin client requirements to the NWS transition program (OSIP) to provide a baseline for expected AWIPS II performance. It is anticipated that the FX-Net team will continue to research and develop data analysis and display tools for operational all-hazards and fire weather forecasters.

Accomplishing these goals requires the development of a system capable of delivering GEOSS and IOOS data over small-band width Internet communications links. The ultimate goal is to provide a comprehensive system for an all-hazards Incident Support Specialist (ISS) deployed anywhere on or offshore. The ultimate system would include inter-system collaboration, dispersion modeling capability, data interrogation and editing capability and a database-independent data retrieval system. These goals are reflected in the future research planning to add these capabilities to the AWIPS II platform.

Research for this project has concentrated on compressing the data as much as possible while retaining data precision, providing extended and newly created data sets and developing tools needed in a field situation. To meet these goals with a very small development team is a major challenge. In order to meet this challenge the development group employs a number of research and development strategies. All members of the group conduct extensive research in tool development, leveraging existing and newly developed code. Code developed for the AWIPS program is used extensively in the FX-Net system. Java code and techniques required for the FX-Net client are developed and leveraged with some help from the Open Geospatial Consortium (OGC), XML development support web sites, Java web groups, external training and interaction with local web developers at UCAR and ESRL.

Future research will include evaluating new data distribution, data basing and display technologies to meet the goals of the ultimate system. In addition to UCAR's IDV system and Slovakia's IBL system, new technologies to be evaluated include distributed data base systems utilizing Service Oriented Architecture (SOA) including JMBL, OGC and WXXM servers. Research is continuing to focus on the many open source programs, such as Eclipse, to develop an SOA system that provides the same capability and performance as the current FX-Net thin client while adding developmental and operational flexibility.

The Wavelet Compression (see project 2.0 Gridded FX-Net in this document) research for the FX-Net project continues to concentrate on code optimization, improved compression ratios for image data, and extended precision control capabilities. The newer version of the compression code will be entirely free of proprietary code to allow university and government users complete flexibility in utilizing the code in their experimental and governmental systems.

2. Research Accomplishments/Highlights and Current Status:

Even though the ultimate all-hazards system is not a complete reality, the development team has been very successful in providing key elements to the users. Significant changes to the basic FX-Net system were made in the past year. The system was upgraded to provide the latest version of the NOAAPort data and extended AWIPS data and file server functions. The system delivered to the NWS's IMET program, the National Interagency Fire Center GACC offices, and NWS WSO users' was based on the latest version of the AWIPS software, v. 8.3. The operating system was upgraded to RedHat Linux Enterprise v. 4.0. This makes the FX-Net servers completely up to date with the NWS WFO AWIPS systems.

The new version of the FX-Net Client (v.5.2) (see Fig. 1) was released in March 2009. This version of the client includes the addition of significant new data analysis and display tools. Significant research effort was expended adding the high resolution topography maps. Multiple tools and processes were evaluated in order to provide these hi-res map backgrounds and ensure that the overlaid data sets were geophysically accurate.

Added features of the 5.2 FX-Net Java Client included the following:

--Added high resolution topography maps to every regional scale (Fig. 2)
--Added new AWIPS Cylindrical Equidistant projection. This allows the Atlantic Mercator scale to work for lat/lon sampling. (Fig. 3)
--Added the ability to export FX-Net display to Google Earth. (Fig. 4).

The FX-Net team is working on AWIPS II thin client capability evaluations and standing up an AWIPSII Client. The evaluations will result in reports to the NWS AWIPSII program office regarding the AWIPSII existing thin client capability, the gaps in the architecture that need to be addressed to allow a fully functional AWIPS II thin client. The team is also working on transitioning the version control (Subversion) and client build systems (Install Shield) into an integrated system.

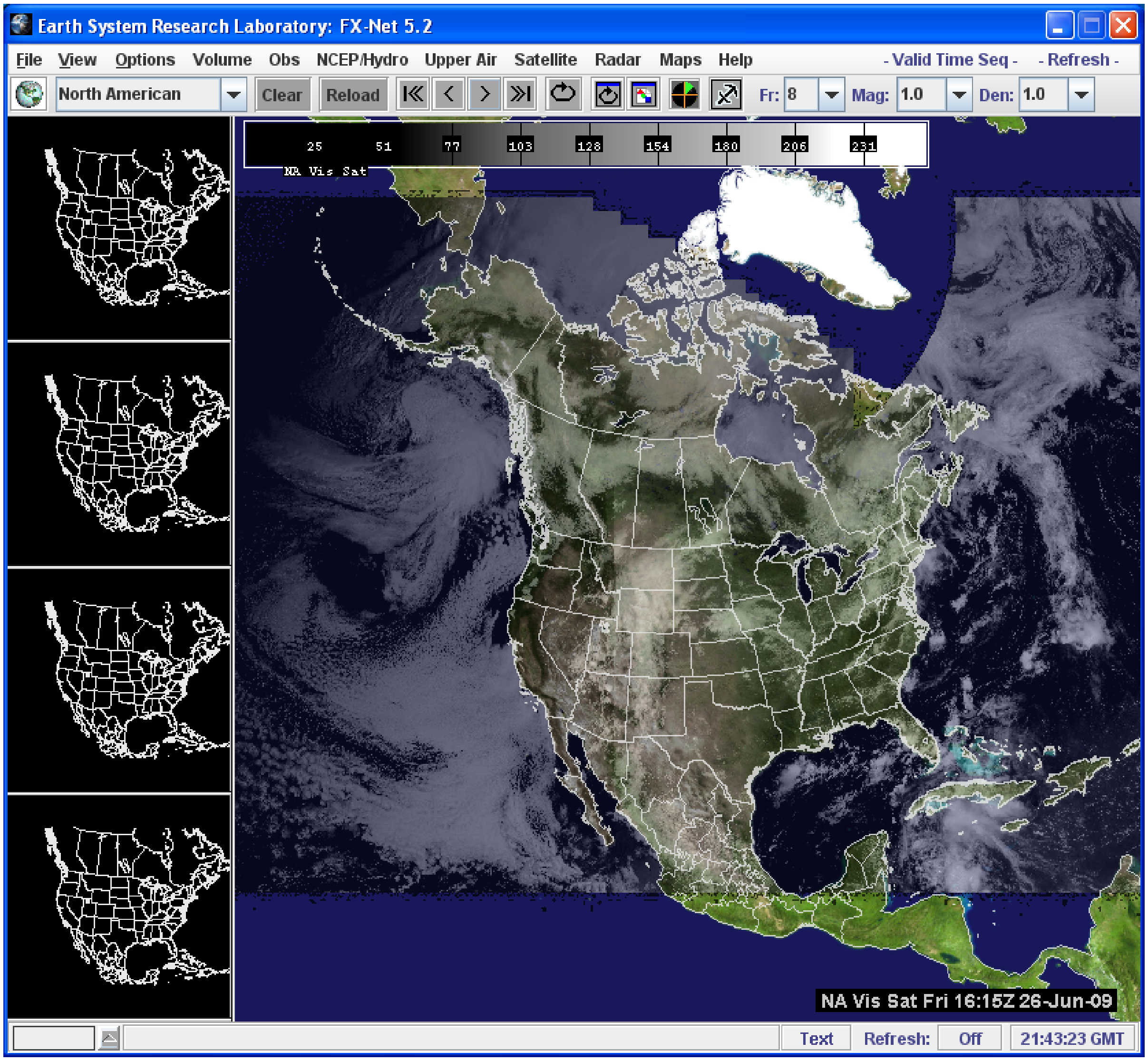

Fig. 1. FX-Net v. 5.2 Thin Client. This is the National Version used by the National Interagency Fire Center (NIFC) Geographical Area Coordination Centers, State of Colorado Weather Modification scientists and the Air Force One Forecasters at Andrews AFB.

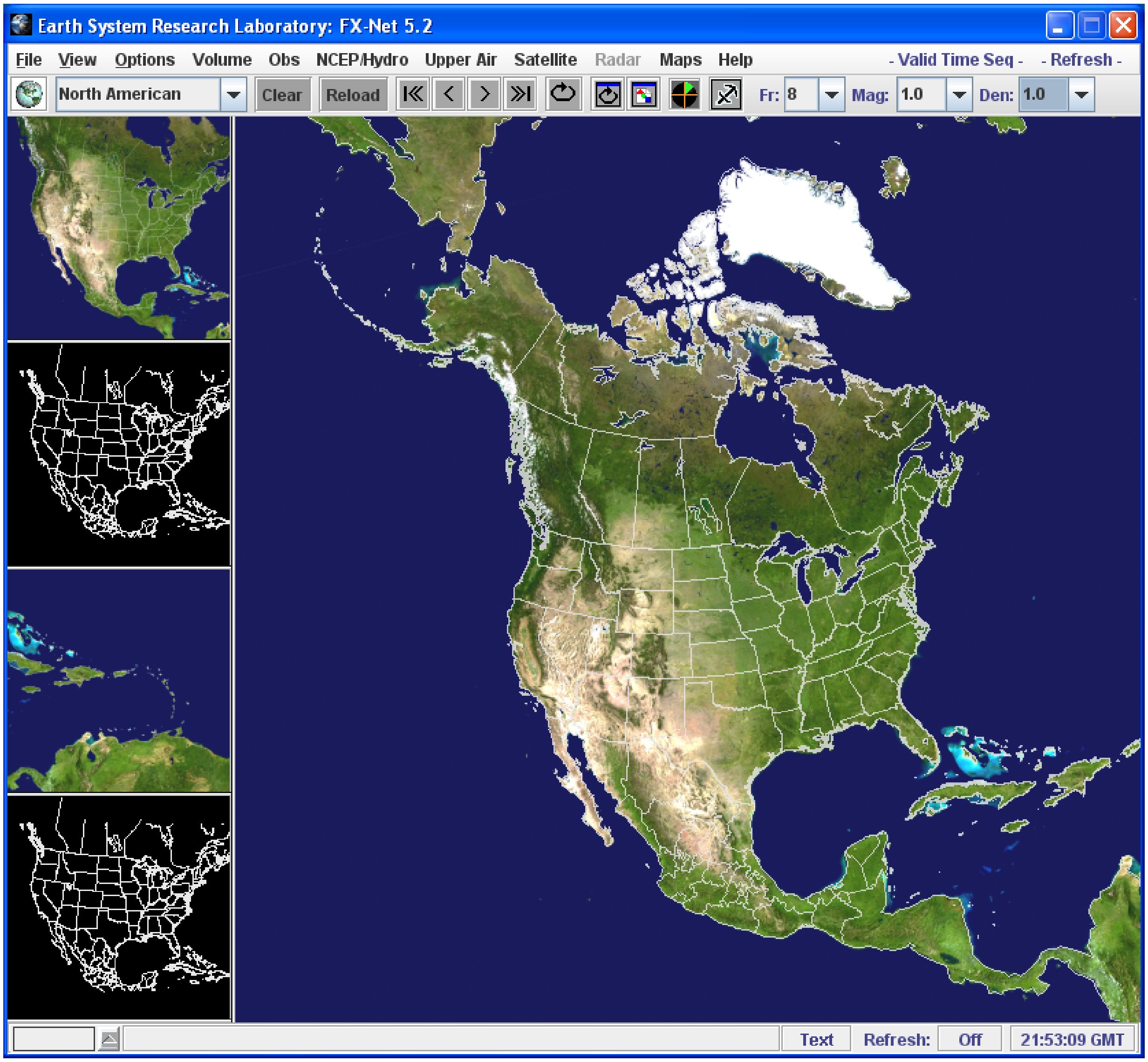

Fig. 2. High Resolution, 'Blue Marble' Background Maps. Any data set can be overlaid on this background image. When another image is overlaid, the 'Image Combination' control menu is made available to adjust the brightness of the background map and the overlaid image.

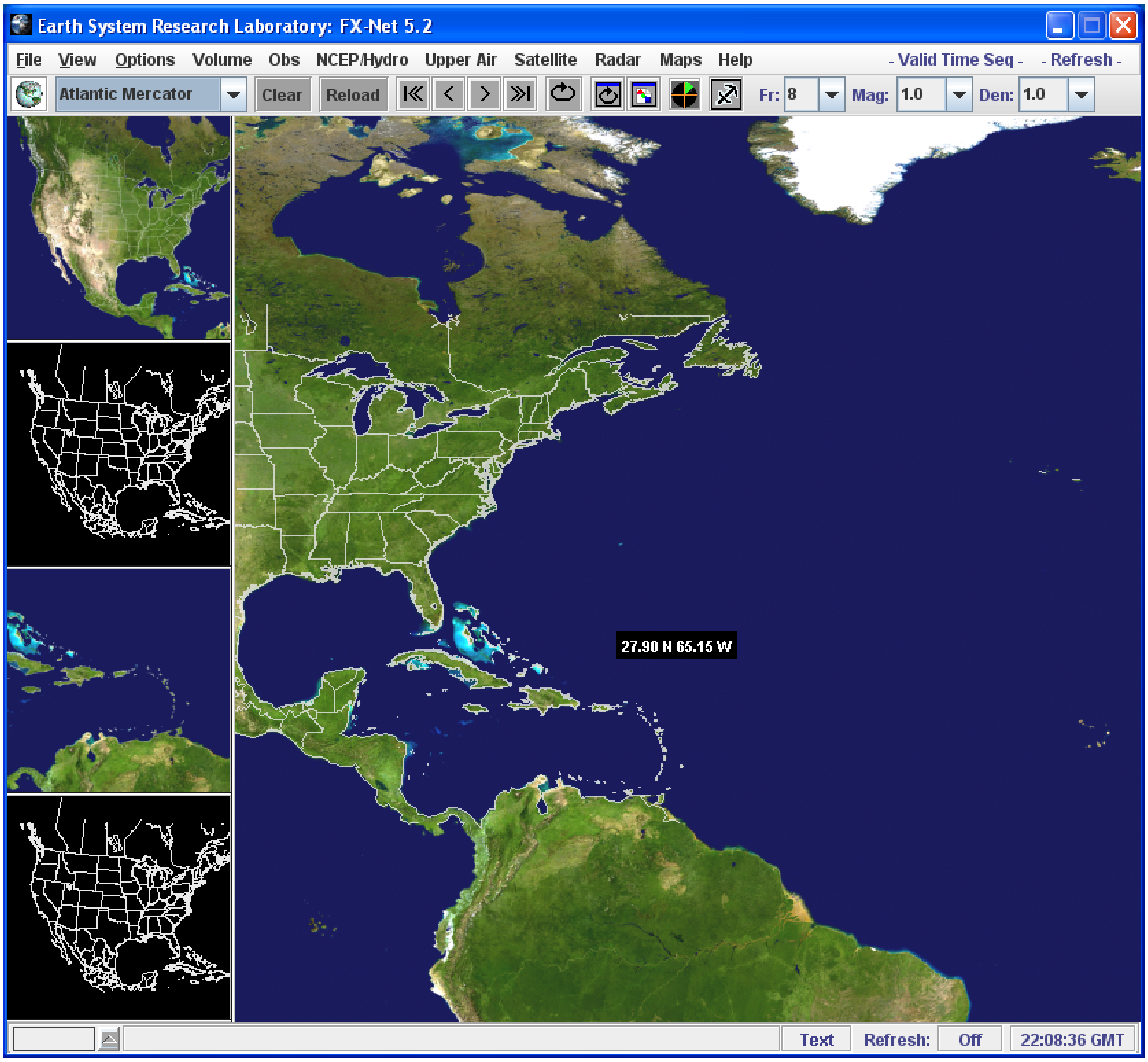

Fig. 3. Atlantic Mercator Scale with Lat/Lon Sampling Activated.

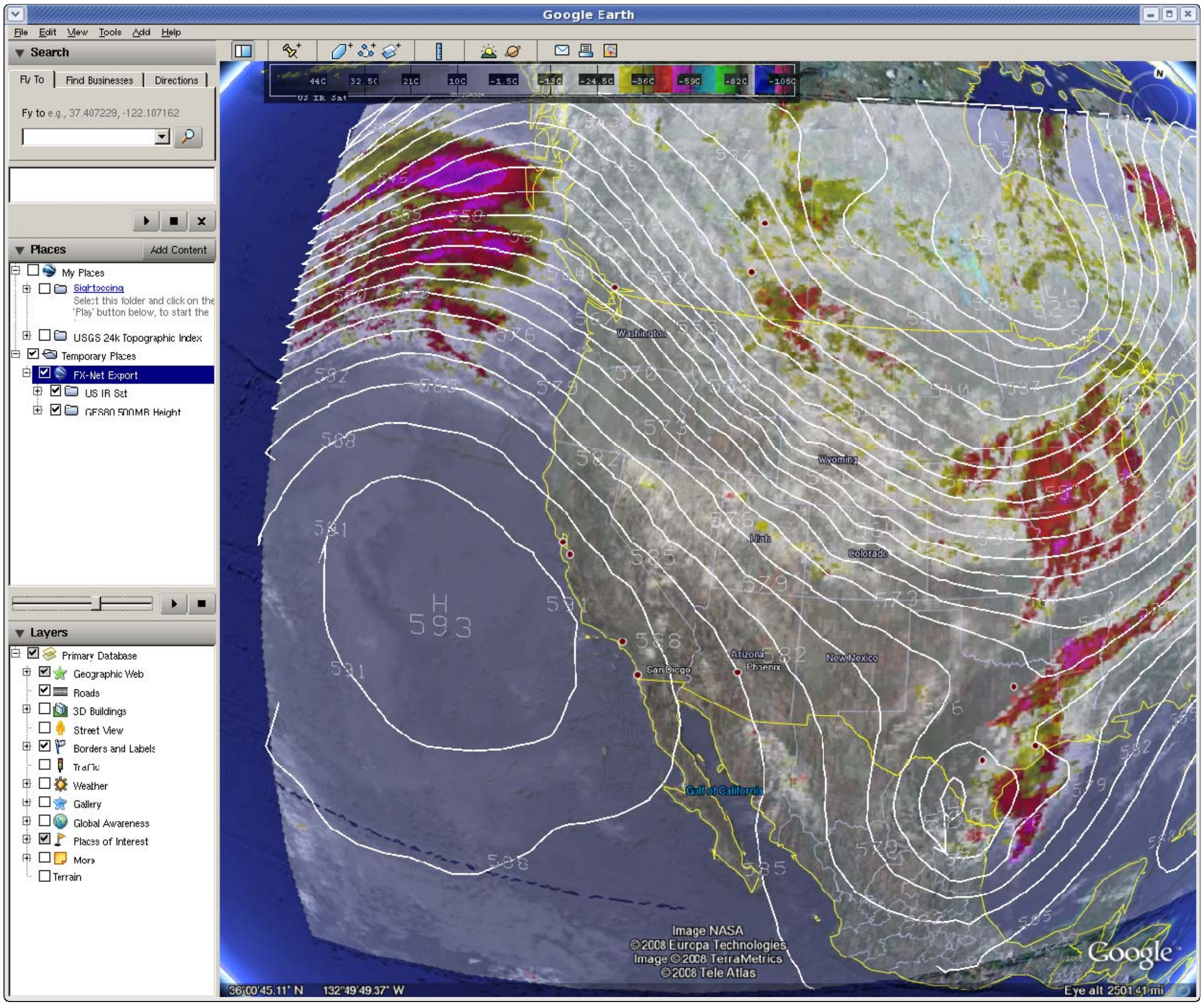

Fig. 4. A Google Earth Screen Shot: An Example of an FX-Net Display Exported to Google Earth.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress. For the upcoming year, plans are to:

a. Deliver a new version of the FX-Net thin client to the NWS and NIFC.
b. Deliver analysis documents and requirements analysis information to the AWIPS II program office in support of the AWIPS II Extended Thin Client project and the NWS Operations and Services Improvement Process (OSIP) process.
c. Evaluate and prototype thin clients using new technology.

4. Leveraging/Payoff:

The FX-Net system is highly leveraged in terms of program funding and technology. The project is funded by the National Weather Service, the US Forest Service and the Bureau of Land Management. It is a solid example of cross-agency, non-redundant systems research, development and support.

The National Weather Service supports control center teams overseeing natural hazards incidents with on-site, interactive weather forecasts. NWS provides members of their forecasting team, who are specially trained in all-hazards situations, with an FX-Net system as they are deployed to the hazard site. The Incident Meteorologists (IMETs) are deployed to wild fires as part of a fire-fighting team, as part of the security services at national political conventions, or a HazMat team in the aftermath of a massive natural disaster, such as hurricane Katrina or an oil spill recovery operation. The team is tasked with protecting lives and property. In order to support the team, the IMET must have timely, high-resolution, operational data to keep the fire control managers up to date on the latest weather conditions.

When forecasting the weather in the WFO, IMETs use the operational NWS forecasting system, AWIPS, as their daily forecasting system. When deployed to the field for fires and floods, the IMETs previously had to rely on the Internet for all their real-time atmospheric data. Limitations in bandwidth and the need to have many Internet windows open at once caused resource and time restrictions, and in many cases the data were not refreshed frequently enough to support their mission. To alleviate these restrictions, the NWS implemented an All Hazards Onsite Meteorological Support System to support the IMETs at remote locations. The core component of the system is the FX-NET workstation. FX-NET provides AWIPS like displays on a laptop remote from the data server. The use of Wavelet Compression technology allows the transmission of high-resolution observations, models, satellite, and radar data over bandwidth-restricted communication links. The system can be used over a link as slow as 56 kbps.

5. Research Linkages/Partnerships/Collaborations:

a. FX-Net at the National Interagency Fire Center (NIFC)

Via a technology transfer Memorandum of Agreement which began in 2002, the latest version of the FX-Net Client was installed at the Bureau of Land Management's (BLM's) Federal Test Center in Lakewood, Colorado. The system passed the rigorous network and security tests administered at the Test Center, and was certified for use by the 11 Geographical Area Coordination Centers (GACCs), the NIFC, the National Forest Service and the Ag Outlook Board. The FX-Net servers and clients are distributed and maintained by the FX-Net Project team.

In FY08-09, Predictive Services forecasters used FX-Net to view long-range forecasts to aid their fire potential forecasts and utilized real-time data to support NIFC fire suppression resource managers.

BLM users at the above locations provide long-range fire predictions, daily fire indexes, and drought outlook products for various BLM web sites and for operational use by fire weather forecasters and local land management agencies. Specialized maps were added to the FX-Net system to accommodate end user needs.

b. State of Colorado Water Resources Board: Weather Modification Winter Experiment. Private sector and State of Colorado scientists used the FX-Net system for their weather prediction needs during the 08/09 winter season snow enhancement experiments. The system was primarily used by private sector forecasters under contract with the Water Resources Board to predict optimum conditions for weather modification cloud seeding experiments.

c. Other FX-Net Users:

Researchers from the U.S. Air Force Weather Agency (AFWA), lead forecasters for Air Force One, Boeing, NASA and the Weather Modification community have also used the system for model verification, field studies and experimental weather forecasting.

The National Weather Service training facility in Kansas City, MO uses FX-Net to develop training packages for AWIPS I and AWIPS II.

Forecasters for Air Force One continue to use FX-Net to view high resolution cross sections along the aircrafts' flight path to forecast turbulence and icing conditions.

d. FX-Net and the Public Sector

The FX-Net team continued to support the transition of FX-Net to ENSCO, Inc's MetWiseNet product.

6. Outreach/Education:

--Seminars, etc.: Presentations and demonstrations of FX-Net were given to visitors from Australia, Argentina, Israel, and several private sector companies.

--FX-Net was demonstrated to NOAA/OAR Administrator, Dr. Rick Spinrad and other visitors to the exhibits at the Annual AMS Conference and Exhibit in Phoenix, AZ January 2009.

- -A 'World' version of FX-Net was developed for the 2009 International Wildfire Conference in Sydney, Australia, June, 2009. (Fig. 5)

--FX-Net training was held at the Annual Incident Meteorologist's (IMETS) training meeting in March 2009 in Boise, Idaho.

- -K-12 outreach, public awareness: Several members of the FX-Net team gave FX-Net demonstrations to the public during outreach activities at the NOAA-Boulder facility.

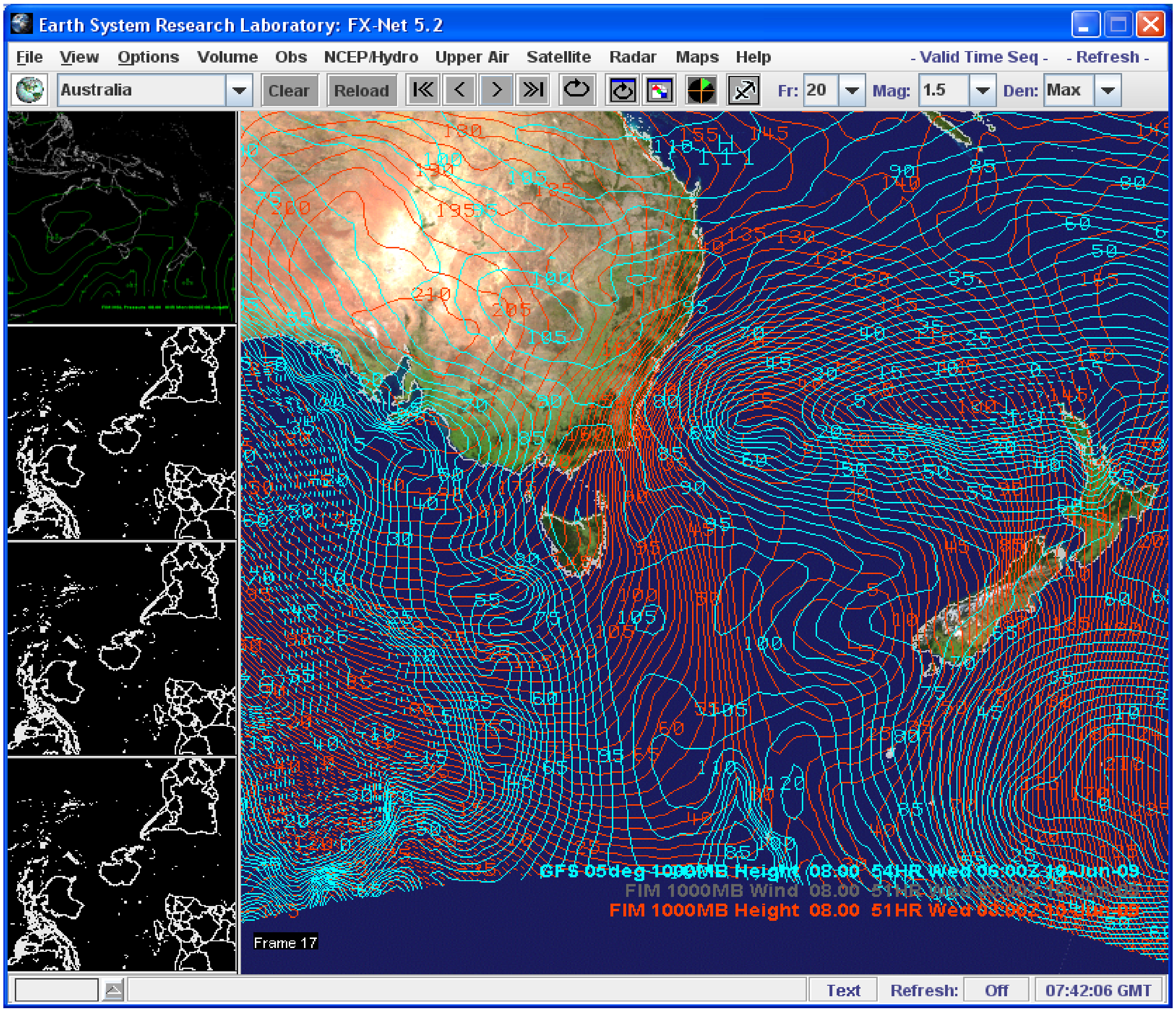

Fig. 5. FX-Net ‘World’ howing GFS 0.5 Degree Model Forecast Fields Over Southern Australia and New Zealand.

Project Title: Gridded FX-Net Forecaster Workstation Project

Principal Researcher: Sher Schranz
CIRA Team Members: Jebb Stewart, Evan Polster, and Ning Wang

NOAA Project Goal/Programs: Weather and Water—Serve society's need for weather and water information/Local forecasts and warnings, Air quality, Environmental modeling, and Weather and water science, technology, and infusion (STI). Gridded FX-Net is a cross-cutting solution provided to all these program elements.

Key Words: Distributed Data Thick Client Workstation, Fire Weather Services Improvement, Incident Meteorologist, All-Hazards system, Air Quality Services, Compression Algorithms

Gridded FX-Net for Fire Weather

Fire Weather Mission Goal: NOAA's National Fire Weather Program seeks to eliminate weather-related wild land fire fatalities and injuries, and to reduce fire suppression and land management costs by providing more timely and accurate weather information. NWS forecasters and collaborative forecasters at the National Interagency Fire Center (NIFC) and at the 11 Geographical Area Control Centers (GACCs) utilize the latest model and observation data to produce national outlooks identifying critical fire weather patterns. The NOAA mission is to provide tools to support the NWS and NIFC forecasters producing these long and short-range forecasts in support of fire-management decision makers.

Forecasters become dependent on the tools they can carry with them to the fire. Their ability to function effectively as a part of the fire fighting coordination team is dependent on these tools.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Gridded FX-Net is a highly-leveraged, technology transfer research project being developed in collaboration with the National Interagency Fire Center Predictive Services group and the FX-Net development team.

As a technology transfer program, the NIFC Gridded FX-Net system aims to improve the GACC forecaster's capabilities to provide long-term fire behavior and fire potential products. An essential part of producing these products are the numerical prediction models delivered via the NOAAPort to the AWIPS data servers. The research for this project centers on combining the enabling technologies from the FX-Net and AWIPS systems. The goal is to deliver gridded model output data, bit-mapped satellite and radar imagery, as well as all the observational data available via NOAAPort to multiple AWIPS D2D (Display-2D) clients.

The FY08-09 Gridded FX-Net project goals were to upgrade and maintain the GFX-Net servers and distributed clients, and to develop a grid extraction tool.

2. Research Accomplishments/Highlights:

Server software: Updated AWIPS software to version OB8.3. Updated the server OS to Redhat Linux Enterprise v. 4.

Client systems: Some client systems were upgraded to Redhat Linux Enterprise v. 4.0 and AWIPS version OB8.3. Each GACC office is responsible for sending their systems back to the Gridded FX-Net development team to have their systems upgraded. We anticipate more of these systems to be sent for upgrade in FY09-10.

Gridded Extraction Tool: In order to take full advantage of the forecast grids available on the AWIPS II client systems in each GACC office, a tool was developed to allow users to extract a very specific set of surface grids. The Grid Extraction Tool, Web Interfaced (GETWI) allows users to export grids in various formats to enable the data to be used as input to fire potential algorithms and to create graphical fire potential products for the GACC web pages. See Fig. 6 for the GETWI interface.

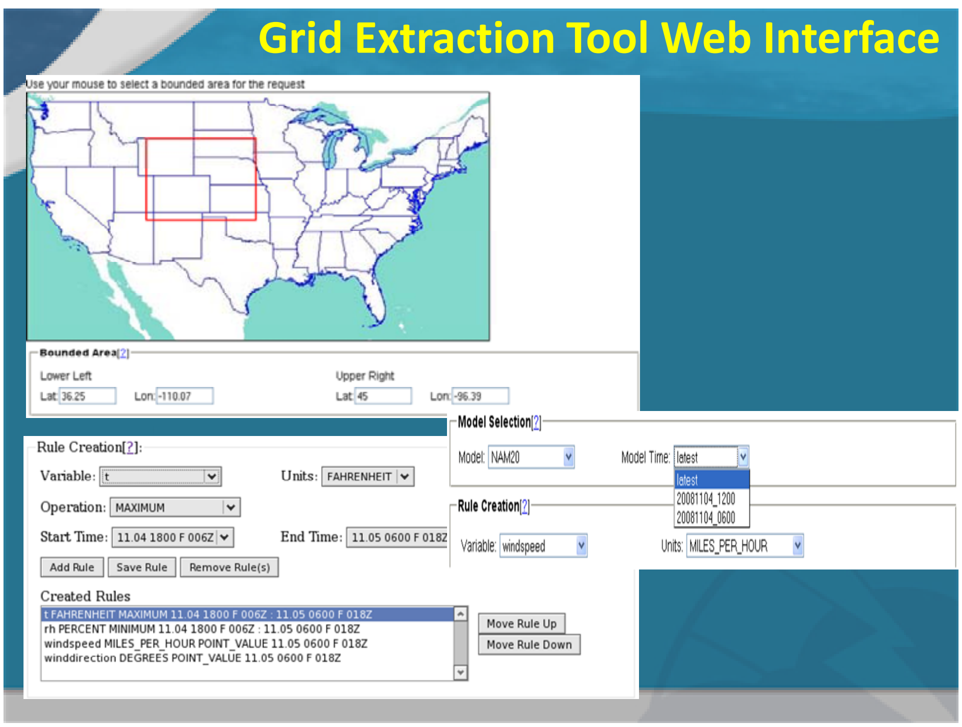

Fig. 6. Grid Extraction Tool, Web Interface (GETWI). Grids can be extracted and combined in various user-defined ways, then exported in several formats to allow users the flexibility to use them in fire potential algorithms, fire prediction products and GIS application displays, such as ARCMap.

Wavelet Compression:
--Implemented Data Masking for enhanced compression performance. This allows inconsistencies in gridded fields to be filled with averaged data to smooth the overall grid. This improvement enhances the speed and performance of the compression codec.

--Added 2 dimensional error tolerance controls to the wavelet compression to provide more flexibility in choosing file size for imagery.

--Have completed a preliminary version of the wavelet compression with no external, proprietary algorithms. This new version of the codec is undergoing extensive testing.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress. Plans for the upcoming year include:

a. Grid Extraction Tool: One major area of future development is to enhance the GETWI to provide more complex operations for data extraction allowing greater control over data. This will include the capability to use multiple variables in operations allowing users to implement or develop their own algorithms within the GET to improve their forecasts or decision support.

b. Compression: Wavelet compression will continue to evolve as new quantization and compression algorithms are investigated and improved to continue providing high fidelity data over low bandwidth lines without requiring significant resources for encoding and decoding. A final version of the single-author wavelet compression will be completed.

4. Leveraging/Payoff:

The Gridded FX-Net system, by providing BLM, NIFC and GACC offices with gridded model output data, will allow timelier, more accurate delivery of fire behavior and fire danger products to the public.   Algorithms currently unavailable to the GACC offices, due to the lack of gridded data, will become available to forecasters to run with local data and the benefit of local expertise. As a result these localized products become more accurate and local emergency managers, fire weather analysts and the general Public can have access to more accurate products.

5. Research Linkages/Partnerships/Collaborations:

Technology transfer components include the AWIPS system, the LDM network, Wavelet Compression and FX-Net development expertise.

Based on the prototyped technologies developed for the Gridded FX-Net system, the NWS regional headquarters offices in the Alaska and Pacific regions are developing new operational concepts for their remote Weather Service Offices that do not currently have AWIPS systems.

6. Awards/Honors: None

7. Outreach: Numerous demonstrations of this system have been given to public agencies and the private sector.

8. Publications: None

Project Title: New Programs

Principal Researcher: Sher Schranz

NextGen: NextGen is a new project in ESRL/GSD. This is a broad development effort requiring participation by every branch in the division. This project is funded by the NWS and by the FAA. GSD's role is to 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 decision support systems. The GSD director has 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 in the FY09/10 federal fiscal year.

Fire Weather Modeling and Research: NOAA has provided funding for fire weather modeling for FY09 and FY10. Sher Schranz is the ESRL/GSD Program Manager. Research papers and conference presentations will be delivered to the NWS and NOAA/OAR as deliverables for this program. An experimental 3km WRF/Smoke model will be delivered to the NWS fire weather forecasters for the FY09 fire season.

Project Title: Science on a Sphere (SOS) Development

Principal Researcher: Michael Biere
CIRA Team Members: Steve Albers

NOAA Project Goal: The Science on a Sphere™ Development project addresses NOAA's cross-cutting priority of promoting environmental literacy.

Key Words: Dataset Display and Animation, Spherical Visualization

1. Long-term Research Objectives and Specific Plans to Achieve Them:

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.

2. Research Accomplishments/Highlights:

--SOS was installed at 16 new permanent public venues, including our first international sites in Korea, Taiwan, Mexico, and France.

--Our real-time data distribution to existing SOS sites was enhanced with the addition of global model data, a global earthquake visualization, and a new view of the sun from NASA's stereo sun mission.

--A new remote presence capability called SphereCasting was developed, which allows a presenter to control multiple remote SOS systems across the Internet, with an accompanying video webcast.

--An easy way for users to update their data sets was developed. Now, any playlist can be updated to the latest versions available on our Internet server, via a simple graphic user interface request.

--A new software release, version 3.2.7, was released to our users with the above new capabilities and numerous bug-fixes and performance enhancements.

Status of Specific Objectives:

Objective: CIRA proposed to continue the development of new capabilities and data sets for the Science On a Sphere (SOS) global visualization system. The SOS installed base continues to expand, with over 20 museums and science centers currently housing an SOS exhibit at the start of FY 2009.

Status: As of June 2009, there were a total of 36 sites where SOS is in operational use. This year has seen our first international sites in Asia, Mexico, and Europe.

Objective: CIRA staff will continue to develop and enhance near real-time global data sets for SOS museum sites. Our collection of planetary imagery will continue to be enhanced as higher resolution data becomes available from ongoing NASA missions. New displays of numerical forecast models will be developed as well; the FIM model is of particular interest within ESRL.

Status: FIM, GFS, and GLAPS global model forecast displays are now part of our real-time data feed available to our SOS systems installed around the world. A real-time display of global earthquakes was also developed and included in the real-time distribution (see Fig. 1 below), as well as data from NASA's mission providing a stereoscopic view of the sun from two space probes.

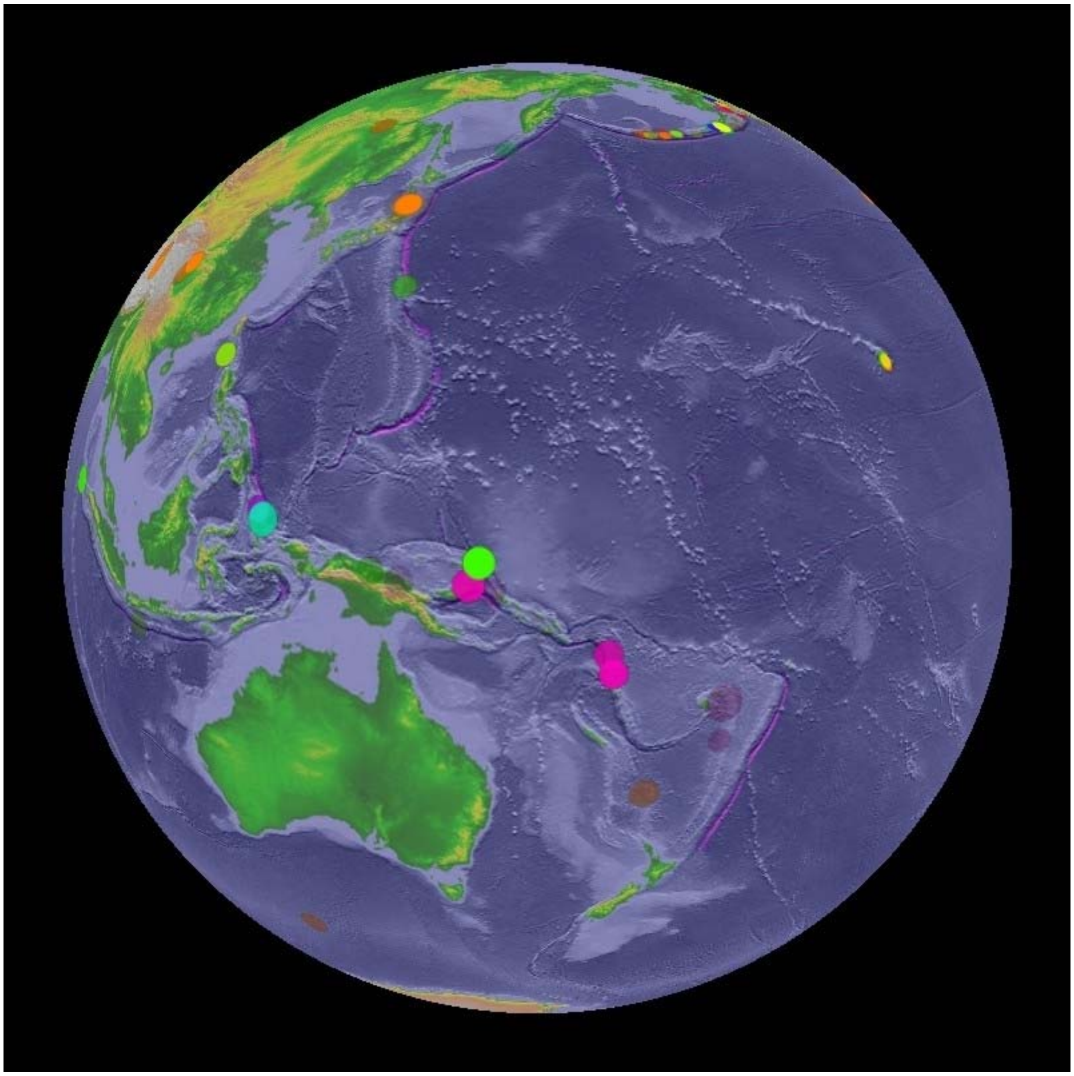

Fig 1. Earthquake Animation Frame as Seen on SOS™. The 30-day animation is updated with the latest data every hour. Circle size represents the magnitude, color denotes earthquake depth, and transparency relates to the age of the quake as it fades over a 7 day period.

Objective: Additional SOS sites are expected to be awarded by the NOAA Environmental Literacy Grant program in FY 2009. CIRA researchers will be providing technical support for SOS installation at any additional new sites that may arise, either within or outside this program. FY 2009 will also see the first foreign installations of SOS in Taipei and Seoul.

Status: In FY2009, the NOAA Environmental Literacy Grant program provided a few SOS systems to institutions, but these were just a fraction of the total systems installed this year, including a number of foreign museum installations. Our new sites this year were:

--National Museum of Natural Science, Taichung, Taiwan, R.O.C
--Gwacheon National Science Museum, Gwacheon, Republic of Korea
--National Renewable Energy Lab, Golden, CO
--Smithsonian National Museum of Natural History, Washington, D.C.
--International Museum of Art & Science, McAllen, TX
--Microsoft Visitor Center, Redmond, WA
--Ted Stevens Marine Research Institute (NMFS), Juneau, AK
--NASA Visitor Center, Wallops Island, VA
--National Museum of Surveying, Springfield, IL
--Boonshoft Museum of Discovery, Dayton, OH
--Climate Institute, Puebla, Mexico
--Harsco Science Center, Harrisburg, PA
--North Carolina Aquarium, Manteo, NC
--National Zoo, Washington, D.C.
--Alaska State Museum, Juneau, AK
--Stennis Space Center, MS
--The Wildlife Experience, Parker, CO
--Cite des Sciences et de l'Industrie, Paris, France

We also assisted the French Space Agency, CNES, in installing their SOS exhibit at the Paris Air Show at Le Bourget, France.

Objective: CIRA plans to continue support of the SOS museum sites via our on-line Web Forum, as well as ongoing telephone and email support.

Status: The on-line Web discussion group for SOS user sites and others interested in SOS operational issues continues to be an important resource for our users. Administration of the group has been a relatively easy task since the level of activity on the group has been low to date. No further enhancement of this resource is anticipated. Other personnel on the project provide the primary interface to our client sites for telephone support, with occasional issues being elevated to involve CIRA staff.

Objective: A major new software addition to SOS is planned for this year, which we are calling SphereCasting. This capability will allow a presenter at one SOS site to simultaneously lead a presentation at many remote sites around the country. As the presenter manipulates the sphere at his local site, the remote sites will be updated in sync. A remote sphere pointer capability will allow the presenter to point out features of interest to his audience, similar to how one might use a laser pointer locally. An audio-visual netcast of the presenter will accompany his presentation as part of the Spherecast.

Status: SphereCasting was developed and added to the SOS system this year. The system works as two separate components. An audio-visual netcast component was implemented using Apple QuickTime streaming technology. A remote-control sphere component was developed using Jabber "chat room" software for the Internet connectivity and control of the remote SOS systems.

A prototype Spherecast was made to the 2008 SOS users group, led in Boulder at ESRL by Dr. Alexander MacDonald, to remote viewers at the Bishop Museum in Honolulu. The maiden public spherecast to a few SOS sites was done on April 1, 2009, led by Dr. Steven Schneider from the SOS system at the Lawrence Hall of Science at Berkely, CA.

Objective: Once the basic Spherecast capability has been successfully demonstrated, we expect to enhance the system with additional features providing enhanced ease of use, such as an automated data distribution mechanism. The use of KML within our system will be investigated to see if there are aspects of Google Earth where we might be able to provide compatible functionality.

Status: An easy way for users to automatically update their data sets was developed. From the graphical user interface, all the data sets in the current playlist can be updated with one menu click on "Update Playlist Data." All the clips in the current playlist are then updated to the latest version available from our SOS FTP servers.

Some use of KLM within the SOS data library has started, but not as part of the core SOS software functionality.

We released a new software update of the SOS software, version 3.2.7, to our client sites. This version included SphereCasting, an easy-to-use data update mechanism, and a number of additional bug fixes and performance enhancements.

VII. Research Collaborations with the GSD Information Systems Branch

Project Title: NEXTGEN Project – Data Distribution

Participating CIRA Researchers: Joanne Edwards, Tom Kent

NOAA Project Goal/Program: Weather and water—Serve society's needs for weather and water information / Local forecasts and warnings

Key Words: Web Services, Web Technologies, WCS, JMBL, THREDDS

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The focus of the Data Distribution portion of the NextGen project is the exploration of different technologies that will support a more standardized approach to distributing data to clients via a smart push/pull capability. There are two projects examining this capability, namely the NWS NextGen project, and the FAA's NextGen Network Enabled Weather project (NNEW). CIRA, in collaboration with the Information Systems Branch of the Global Systems Division (GSD), is responsible for investigating emerging web technologies and standards for accessing global geospatial data, and for developing prototype software to evaluate these technologies for use by NWS and NOAA forecasters and research scientists. NOAA and the NWS have both stated an interest in a more global approach to research and forecasting. CIRA researchers will provide information and guidance to these organizations for the development of systems that will facilitate the access of global datasets.

2. Research Accomplishments/Highlights:

a. Implementation of a THREDDS (Thematic Real-time Data Distribution System) to deliver gridded data via a Web Coverage Service (WCS) to clients.

As part of the NNEW project, CIRA developers implemented a THREDDS data server in order to serve up, in real time, several local weather modes to assist collaborating agencies within NNEW for input into their flight paths. THREDDS implements a web coverage service (WCS) as a mechanism for providing data to clients on request.

b. Development of prototype web service using the Joint METOC Broker Language (JMBL) for delivering MADIS observations to JMBL users upon request.

CIRA researchers developed a JMBL prototype server to serve up MADIS datasets to a JMBL client. The Joint METOC Broker Language (JMBL) defines a web based interface for accessing meteorological and oceanographic data. JMBL utilizes an XML specification for exchanging data between clients and server. JMBL users request data from the JMBL server using the XML-based schema. The JMBL server accepts the request via an XML/Simple Object Access Protocol (SOAP)-based interface. The server decodes the request using the known schema, extracts the data from the database, formats the data into XML and returns the data to the client in a SOAP envelope. The work completed during the past reporting period included development of the JMBL server, written in Java, to read a JMBL request, decode it, retrieve the MADIS data using existing MADIS access code, and generate the response. This implementation made use of the existing MADIS system and required very little code changes on the MADIS side.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Objective: Implement a smart push capability for delivering data to clients using web services.

Status: In progress.

4. Leveraging / Payoff: The second phase of the AWIPS Technology Infusion, formerly known as AWIPS Evolution, is the extension of AWIPS II to all phases of the NWS enterprise. AWIPS II Extended includes projects that provide major enhancements to the infrastructure and include a Data Delivery system for a smart push/pull capability. The Data Delivery system can leverage some of the experience gained and work done by prototyping THREDDS and JMBL servers.

5. Research Linkages/Partnerships/Collaborators:

CIRA, GSD (ISB and ITS), FAA, NWS

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: <u>AWIPS I and AWIPS II</u>

Principal Researcher: Joanne Edwards

CIRA Team Members: Leigh Cheatwood-Harris, Tom Kent, Jim Fluke,
Herb Grote, Jim Ramer

NOAA Project Goal/Program: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings

Key Words: Independent Validation and Verification, ADE/SDK, SOA

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Advanced Weather Information Processing System, or AWIPS as it is known, is an interactive computer system that integrates meteorological and hydrological data, and satellite and radar data. The AWIPS project is sponsored by the National Weather Service (NWS). The project's objective is to improve the accuracy and timeliness of the forecasts and warnings disseminated to the public by modernizing the technology used by Weather Forecast Offices (WFOs) in the conterminous United States, Alaska, Hawaii, Puerto Rico and Guam.

In order to continue to make AWIPS a viable tool for the timely dissemination of critical weather information, the NWS has embarked on a very ambitious goal to fully restructure AWIPS so that it is able to meet the ever-increasing demands of more and larger datasets, and to incorporate new science. The new project, called AWIPS II, is being developed by the NWS contractor, Raytheon. CIRA, in cooperation with the Information Systems Branch, is responsible for the validation and verification of the AWIPS II system. The goal is to ensure that the system can handle the capabilities that are being placed upon it. This will enable CIRA researchers to learn about new capabilities such as Service Oriented Architecture (SOA), Enterprise Service Bus (ESB), Mule, Spring, Java, Camel, Eclipse, and plug-ins. By gaining this critical knowledge, CIRA researchers will be prepared to assist Raytheon in adding new functionality to the AWIPS II system.

2. Research Accomplishments/Highlights:

In support of AWIPS and AWIPS II, the following efforts and activities occurred during the past year:

a. Evaluated AWIPS II Task Orders 8, 9 and 10

b. Continued training on SOA technology

c. Developed new plug-ins for AWIPS II

d. Continued support of AWIPS I

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

Objective: Continue evaluation of AWIPS II. The objective is to provide an independent verification and validation of the proposed next version of AWIPS, which is built upon a Services Oriented Architecture (SOA) paradigm. Another part of the objective is to gain a good understanding of the AWIPS II architecture in order to add functionality.

Status: Both parts of the objective are still in progress. Since AWIPS II is being developed in stages, the Independent Validation and Verification activities continue. There is also a need to continue delving into the software to better understand what the system is doing. This process is continuous.

AWIPS II is being developed in stages, called Task Orders (TOs). The system being evaluated is called the AWIPS Development Environment/Software Development Toolkit or ADE/SDK. CIRA researchers have continued to be leaders in the evaluation of the ADE/SDK. In 2008, we completed the Independent Validation and Verification of

Task Orders 8, 9 and 10. CIRA researchers provided valuable feedback to the NWS, who passed on the information to Raytheon. The evaluation of the ADE/SDK has also enabled CIRA researchers to begin to explore the fundamentals of a SOA system.

Since GSD was instrumental in developing the current AWIPS, GSD was tasked to provide valuable input to the evaluation of AWIPS II capabilities via what became known as the Master Deliverables Matrix. CIRA researchers and developers compared AWIPS II capabilities with those of AWIPS I and provided this valuable information to the NWS. This matrix showed not only the tasks that were not complete but also the percentage completion. This document provided vital information to the NWS to help gauge the completeness of AWIPS II.

Objective: Begin developing an in-depth knowledge of AWIPS II for future enhancements to AWIPS II.

Status: This objective is in progress. It will be used in extending AWIPS II infrastructure capabilities to include a Data Delivery System to provide a smart push/pull capability, as well as for Collaboration between forecast offices, and an AWIPS II Thin Client. These projects are part of the AWIPS II Extended project and will begin in FY ’09.

The training was begun late in 2007 and for all intents and purposes was completed on December 31, 2008. As many developers were working on other projects, the training was not completed. Training will resume in preparation for these projects.

As a result of the training, CIRA staff was successful in writing a plug-in in order to extend the AWIPS II capabilities. This plug-in ingests a MADIS dataset and stores it in the PostGres database. CIRA staff was also able to read the data from the database and display it using a web interface.

Objective: Continue support of AWIPS I development to support on-going weather forecast field operations.

Status: This objective is in progress. CIRA researchers completed the ingest and display of two highly anticipated radar products: the Dual Polarization products and the FAA ASR-11/ARSR-4 radars (Airport Surveillance Radar – model 11 and Air Route Surveillance Radar – Model 4). The ingest and display of dual polarization data began in 2007 and continued in 2008. The work done in 2008 was considered an upgrade to the previous work. The upgrades included a “Hot Key Toggle” which enables the forecaster to flip back and forth on one display as there could potentially be eight products on a single display featuring a 4-panel display with single overlays. This functionality was well received by the field offices.

CIRA developers successfully implemented the capability to ingest and display products from the FAA surveillance radars. These radars provide lower coverage and a wider range than the WSR-88D radars. CIRA developers also participated in requirements and design reviews with personnel from forecast and regional offices, with Raytheon and NWS development organizations. This capability was implemented as part of the AWIPS Operational Build 9 system.

4. Leveraging/Payoff:

The knowledge gained from the SOA and AWIPS II training can be used as leverage for other development activities within GSD such as development of a Services Delivery Proving Ground, an Earth Information System, and a capability to provide probabilistic forecasting functionality to forecasters. Some of the potential benefits of the addition of the FAA radars to AWIPS are listed below:

- As backup during WSR-88D radar outages
- Low-altitude information at longer ranges than the WSR-88D radars
- Data in areas of incomplete WSR-88D coverage
- Different viewing perspectives in storms to better sample radial velocity maxima and storm morphology

5. Research Linkages/Partnerships/Collaborators:

CIRA, ISB, NWS and Raytheon collaborated on the research required for the evaluation of AWIPS II.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Project Title: <u>Meteorological Assimilation Data Ingest System (MADIS)</u>

Principal Researcher: Joanne Edwards
CIRA Team Members: Tom Kent, Leigh Cheatwood-Harris

NOAA Project Goal/Program: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings

Key Words: Transition, WISDOM, NEPP, HCN, CRN

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Meteorological Assimilation Data Ingest System (MADIS) is dedicated toward making value added data available from GSD for the purpose of improving weather forecasting, by providing support for data assimilation, numerical weather prediction, and other hydro-meteorological operations. The objectives for MADIS are two-fold:

a. To transition the system to NWS real-time operations at the National Centers
b. To continue to provide MADIS subscribers with new observation datasets

2. Research Accomplishments/Highlights:

Objective: To transition MADIS to NWS operations

Status: In progress; CIRA developers in collaboration with the Information Systems Branch (ISB), worked on a major transition effort to transfer MADIS to operations. This work involved porting over 15 years worth of code to the new hardware at NCEP, updating outdated software, setting up web access to the data, writing documentation as well as adding new data providers.

Objective: To continue to provide subscribers with new datasets

Status: In progress; During the past reporting period, CIRA researchers and developers successfully added a number of new datasets to MADIS. These datasets include data collected from WISDOM balloons, precipitation and temperature data from three new sources – the New England Pilot Project network (NEPP), the Climate Reference Network (CRN), and the Historical Climate Network (HCN). The WISDOM (Weather In-Situ Deployment Optimization Method) project has a goal of improving the 3 to 7 day predictions of hurricane track and intensity. It is an interagency project between NOAA and DHS (Dept. of Homeland Security) to test the concept during the 2008 hurricane season. CIRA developers designed and wrote software that would automatically collect and decode data from the balloons and make the data available through MADIS. Developers wrote communications software using remote procedure calls to collect the information. Data were collected every minute, decoded into a CSV format and sent to MADIS via the LDM, and then served on a web page for scientists to view the data.

Other important datasets that were added to the MADIS data stream were precipitation and temperature data from three networks – NEPP, HCN and CRN. The former NERON (NOAA Environmental Real-time Observation Network) was split into two networks – the New England Pilot Project (NEPP) network, and the Modernized Historical Climate Network (HCN-M). The NWS Eastern Region, which manages the NEPP, and the NWS Office of Science and Technology asked GSD to help with data ingest, processing and distribution of the datasets. The NCDC also asked GSD to help with ingest, processing and distribution of datasets from the CRN. These datasets consist of temperature and precipitation from three gauges, which required the use of algorithms, and in the case of precipitation a complex algorithm, to produce the final result. CIRA developers wrote PERL scripts to process these three datasets. The processing involved:

--writing code to ingest the raw datasets
--converting the data to a CSV format
--applying the algorithms to the datasets

--generating the results
--inserting the results back into the CSV dataset

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

In progress.

4. Leveraging/Payoff:

With MADIS transitioned to NWS operations, this will provide 24x7 maintenance support and offsite system backup. This transition also leverages NOAA's extensive data management infrastructure.

5. Research Linkages/Partnerships/Collaborators:

GSD must collaborate with NCEP, NOAA, DHS, NCDC, NESDIS, NWS OS&T, NWS ER, Raytheon.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

VIII. Research Collaborations with the GSD Information Systems Branch (ISB)/ Information Presentation Section

Project Title: Exploratory Workstation Development

Principal Researchers: U. Herb Grote, Jim Ramer

NOAA Project Goal/Program: Weather and Water - Serve society's needs for weather and water information / Local forecasts and warnings

Key Words: ALPS, GTAS, FXC, Forecaster Collaboration, Graphical Product Generation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The objective is to develop advanced interactive display capabilities that improve the operational forecaster's ability to create forecast products and enhances his/her ability to collaborate with other forecasters. New data sets, such as forecast ensembles, will be processed and displayed to convey the information in the most informative way. This activity will also allow forecasters/users at different locations to collaborate in real-time on a forecast for a particular weather or weather-dependent event.

Collaboration is of particular importance in certain applications. In order to prepare a consistent forecast, such as a prediction of a severe weather event or dispersion of a toxic chemical, all participants must have a common situational awareness. All participants must have access to the identical data sets and be able to display the data in the same manner. This facilitates the exchange of ideas and allows forecasters and users to get a similar understanding of the weather event. The display system must be able to display a diverse set of real-time meteorological data, allow users to graphically annotate the display, provide a text chat capability, and post and retrieve information from web servers. The system also needs to be able to run dispersion models to help predict movement of volcanic ash, smoke, or toxic chemicals, and must have an alert capability that can interface with available dissemination technologies.

A. Advanced Linux Prototype (ALPS)

Background and Research Objectives: The ALPS system is an enhanced version of the existing AWIPS system that is used by operational forecasters. The software includes the current operational baseline plus many advanced and exploratory features. ALPS has been proven to be a valuable testbed for evaluating new data sets and forecast tools. It is hoped that many of the ALPS developments will be transferred into the new AWIPS II environment.

2. Research Accomplishments/Highlights:

Faster processors and other technological advances have made it possible to routinely create forecast grid ensembles with a large number of members. CIRA researchers have been working with other GSD staff in exploring innovative ways to process and display ensemble data. As part of this activity, CIRA has developed software to store NCEP grids from the Short Range Ensemble Forecasts (SREF) and Global Ensemble Forecast System (GEFS) into the ALPS database and to implement creative approaches to interactively display this data on the ALPS workstation. Some of the display techniques are: basic display of all ensemble members for a particular variable ("spaghetti" plot), multi-load 10%-50%-90% (also known as 10/median/90) display, histogram function overlay, and different strategies for grouping members. Other display features include dynamic readout and selective display by "toggling" on/off various members. An example is shown in Fig. 1.

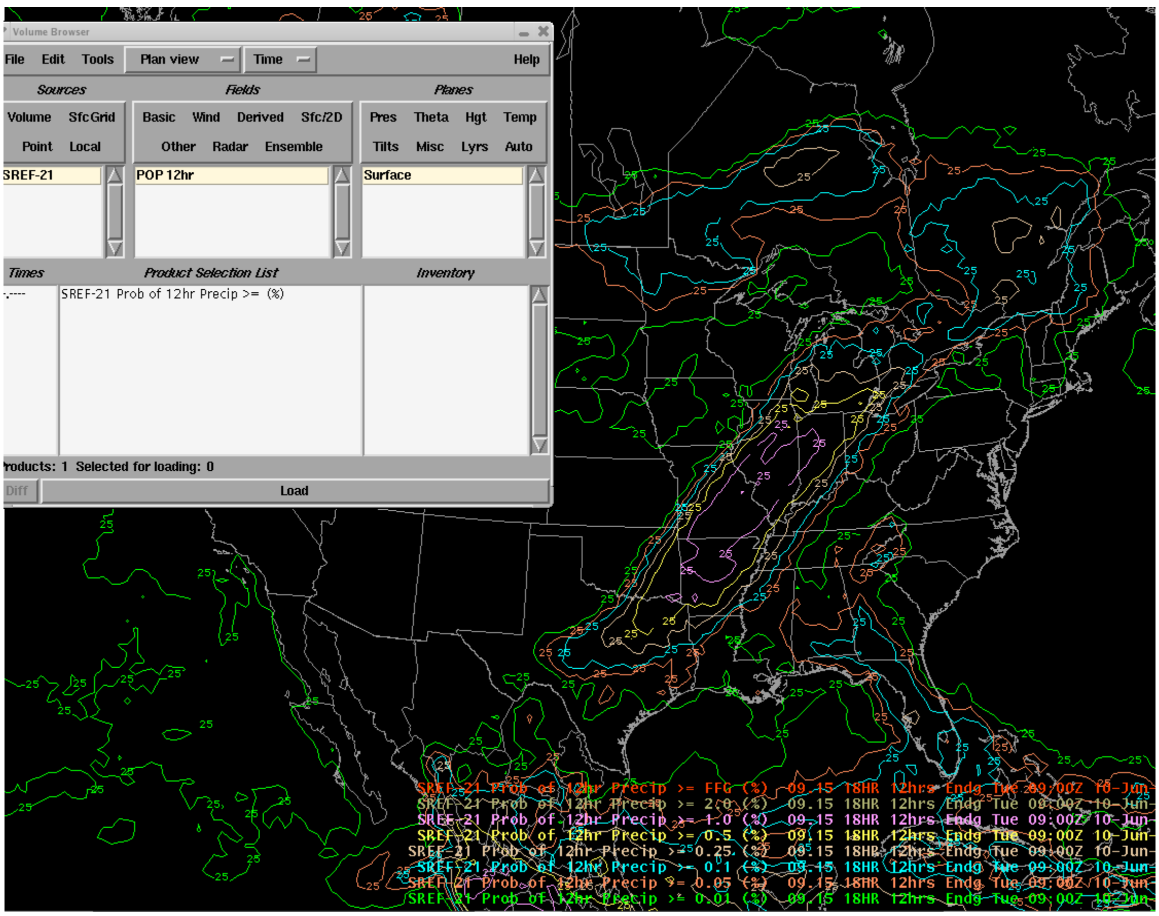

Fig.1 The SREF Probability of Precipitation Threshold Graphics for Several Accumulations. The set of thresholds is readily configurable. Here, we specified contours at 25 percent.

The increasing interest in climate warming and other phenomena by scientist and the general public prompted an investigation into displaying climate data on the ALPS workstation. The first step in the investigation consisted of finding a suitable archive of climate data. A few sample data sets were downloaded and converted into a data format readable by the ALPS system. The ALPS system has a large number of display and processing features that were apropos for climate data. Some of the display capabilities (e.g. animation and time series) had to be modified to accommodate the much larger time frame needed for climate data.

3. Comparison of Objectives Vs. Actual Accomplishments for the Report Period:

The goal to acquire and display ensemble data was met. Considerably more work is needed to find the most effective way to display ensemble data and to explore the use of probabilistic forecasts. Special workshops are being planned by GSD to discuss issues associated with ensembles and probabilistic forecasts.

4. Leveraging/Payoff:

Many commercial and private users could benefit from probabilistic forecasts. This would let the user decide whether to proceed with a specific activity based on the likelihood of an event occurring. The acceptable threshold may vary from one activity to another.

The ALPS system has a wealth of features for displaying atmospheric and other types of data. The NWS has invested a large amount of resources to provide this capability. The use of ALPS to display climate data could provide climatologists a powerful display capability with relatively small additional investment.

5. Research Linkages/Partnerships/Collaborators:

The ensemble work is being coordinated with several NWS operational forecasters and other NOAA scientists. The work to display climate data on ALPS involved staff from ESRL/GMD (Global Monitoring Division).

6. Awards/Honors: None

7. Outreach:

ALPS is being used by a few selected NWS installations in support of weather forecasting experiments, e.g. Hydro-Meteorological Testbed (HMT). Also, the Central Weather Bureau in Taiwan has expressed interest in using the ALPS system operationally.

8. Publications: None

B. Geo-Targeted Alerting System (GTAS)

Background and Research Objectives: The objective of the GTAS project is to develop a prototype public notification system to be used by the NWS and FEMA offices in the event of a biological, chemical or radiological release in major U.S. metropolitan areas.

The key system components of the GTAS system are FX-Collaborate (FXC), the HYSPLIT dispersion model developed by ARL, and the WRF forecast model. A prototype system is scheduled to be installed in each of the NWS regions in the contiguous U.S. starting with the NWS Southern Region. The prototype system must be able to display weather data, run a dispersion model for various chemicals, and provide a means of alerting the public using available technologies. An important consideration in this activity is the ability for the NWS and FEMA to collaborate on the extent and motion of a dispersion plume.

2. Research Accomplishments/Highlights:

Major changes have been made to the initial GTAS prototype that was deployed to the FEMA offices in the Washington, D.C. area. The ability to display GIS (Geographic Information System) shapefiles has been enhanced significantly to allow the overlay of GIS data, labeling of shapes with specific attributes, disclosing more data as the user zooms in on a particular area, and shapefile layers being aware of shapes in other layers. An updated version of the HYSPLIT dispersion model has been installed and a new interface for the GTAS client defined that allows chemical information to be specified. The first prototype systems were installed at the NWS Southern Region Headquarter in Fort Worth, Texas and the adjacent weather forecast office and Emergency Operations Center. In order to comply with international standards for distributing emergency information, the GTAS system now also can generate CAP (Common Alert Protocol) messages.

3. Comparison of Objectives Vs. Actual Accomplishments for the Report Period:

The plan to deploy GTAS to additional locations has been achieved. The system also has been enhanced based on its anticipated use at various installations.

4. Leveraging/Payoff:

GTAS development leverages the development done by ARL on dispersion models, and by GSD on FXC and AWIPS. The dispersion model uses the NAM12 forecast model and is scheduled to take advantage of the WRF model development.

5. Research Linkages:

The integration of the dispersion model into GTAS is done in collaboration with NOAA/ARL. CIRA and GSD staff is working with the developers of the HYSPLIT model to assure that the model will work as designed in the GTAS environment. The development of the GTAS system is performed in coordination and with the support of other ISB staff and contractors

6. Awards/Honors: None

7. Outreach:

GTAS has a web site (http://fxc.noaa.gov/GTAS/) available to the public that describes the GTAS project. The site includes some documentation and the current state of the project.

8. Publications: None

C. Exploratory Display and Collaboration (FXC)

Background and Research Objectives: The FXC activity was conceived as a means to test new workstation concepts and technology, and address special user requirements. Some of the features tested with FXC are real-time user collaboration, OGC services, GIS displays, remote briefings, and dissemination techniques. FXC also has a comprehensive graphic annotation capability for creating meteorological products that is being used by a number of different customers, including the USAF, NASA, the Central Weather Bureau in Taiwan, private companies, and a large number of NWS forecast offices (e.g. http://www.srh.noaa.gov/oun/enhanced.php). These graphical products are posted to the web for public use, included in presentations, and used in briefings to various end users. One of the objectives of this activity is to work with government and private companies to improve the utility of FXC for communicating weather information to the public and specific groups of users.

2. Research Accomplishments/Highlights:

In addition to the many changes made for GTAS and for the Aviation NNEW project (GSD/AB), the software was also enhanced for a commercial company and NWS forecasters. The graphic metafile and processing software was changed to provide much higher spatial resolution (in Cartesian and earth coordinates) for graphics. Projects, such as GTAS, required very precise mapping of graphics. Users also needed to be able to save graphics generated on FXC in various XML formats. The capability to create KML (KMZ) files, which are compatible with GoogleEarthTM, and custom XML formats were added. A number of minor enhancements such as varying the animation delay in GIF images and rotating icon images in graphics were also added.

3. Comparison of Objectives Vs Actual Accomplishments for the Report Period:

The research objectives for this report period were met. In addition to the work performed for a commercial contractor, technical support was also provided to FAA activities at GSD.

4. Leveraging /Payoff:

The FXC development leverages the large amount of development invested in AWIPS. The AWIPS system is the primary source of real-time data and preprocessed graphics for FXC. Other groups are leveraging the investments in FXC to develop their custom systems, e.g. FAA/VACT, CWB, and GTAS.

5. Research Linkages/Partnerships/Collaborators:

Most of the research and development is done within GSD. However, significant feedback on the system performance and capabilities is being provided by its many users.

6. Awards/Honors: None

7. Outreach:

FXC has a web site (http://fxc.noaa.gov) available to the public that describes FXC and some of its applications. The site includes a collection of graphical images generated by forecasters, documentation, and links to sites using FXC.

8. Publications: None

EVALUATION OF HURRICANE MITIGATION HYPOTHESES THROUGH AN INTERACTIVE PROGRAM OF OBSERVATIONAL ANALYSES AND NUMERICAL SIMULATION

Principal Investigator: William Cotton (CSU) with William Woodley, Daniel Rosenfeld, Joseph Golden, Alexander Khain and Isaac Ginis

NOAA Project Goal: Weather and Water

Key Words: Tropical Cyclones, Hurricanes, Typhoons

Because of the threat they pose to national security, natural disasters such as earthquakes, floods, fires and severe storms, including descructive hail, tornadoes and hurricanes come under the purview of the Department of Homeland Security.

The proposed research is designed to establish a strong theoretical foundation to develop methods for hurricane modification by hygroscopic seeding and/or black arbon seeding.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

--Implement a sea-spray source model into the hurricane simulations
--Develop algorithms for targeting seeding beneath outer spiral rainbands
--Preliminary testing of targeted vs. broadcast hyugroscopic seeding effectiveness

2. Research Accommplishments/Highlights:

The research on this project commenced in February 2009 and, thus, has nothing to report at this time.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Work done so far:

--Identified plumes of sulfer emitted from Kilauea volcano on the Big Island of Hawaii, interacting with the trade wind cumulus. Analysis is being undertaken to obtain the cloud icrostructure from satellite and precipitation from ground-based NEXRAD network and space-borne radars

--Identified a weak troical cyclone that interacted with smoke from forest fires over northern Florida and anlyzing this case with similar instruments

--Performed a series of idealized simulations (with horizontally homogeneous initialization and cyclical boundary conditions) including the new tendency equations for each sea-salt mode applied at first model level above the sear.

--Added separate routines to consider the scavenging of sea-salt particles by rain and drizzle drops.

--Added new routines that are expected to compute the scavenging of the different sea-salt modes more accurately.

--Performed a series of simulations including the new tendency equations for each sea-salt mode applied at first model level above the sea to choose the relaxation value.

--Added a routine to consider the microphysical sinks for the added variables

Specific progress is itemized in the monthly reports to the Department of Homeland Security.

4. Leveraging/Payoff: National security

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Department of Homeland Security

6. Awards/Honors: None

7. Outreach:

Presentations

W. Cotton presented a talk at the HAMP Kick-off meeting, November 2008.

W. Khain (invited lecture), 2-d Summitt in Hurricanes and Climate, Greece, May 31-June 5.

Students
M.S. Steven Herbener (unsupported but working on project)

8. Publications: None

EXPANSION OF CIRA RESEARCH COLLABORATION WITH THE NWS METEOROLOGICAL DEVELOPMENT LAB

Principal Investigator: Scott O'Donnell

NOAA Project Goal/Programs: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings and Hydrology

Key Words: Debris Flows, FFMP, AutoNowcaster, NWS, MDL, NCAR, AWIPS, USGS, GIS

1. Long-term Research Objectives and Specific Plans to Achieve Them**:**

A. AutoNowcast Interface Project

The general project objectives are to deliver the NCAR 0- to 1-hour AN forecast products to AWIPS' short-term forecaster workstations and send forecaster user interactions to NCAR's AutoNowcaster. This effort provides the NWS forecasters with the ability to initialize, review, and modify the AutoNowcast forecast products on the AWIPS workstation using familiar AWIPS techniques to interact with these data.

To improve situational awareness of severe weather forecasts, NCAR has tested and installed an AutoNowcast display system (CIDD) at the Fort Worth-Dallas WFO. The NCAR CIDD is installed physically adjacent to the short-term forecaster workstation for convenient access and reference to the several types of AutoNowcast products (real-time and forecast) that are available within the AutoNowcast system.

The project requirements are to migrate the forecaster 'user roles' normally performed on the NCAR's stand-alone graphical display (CIDD) to AWIPS' D2D data display system. This interface provides simple point-and-click interfaces (menus, dialog and scroll boxes) allowing the forecaster to easily display and modify the AutoNowcast data sets within AWIPS.

B. FFMP and Debris Flow Projects

The Flash Flood Monitoring Program (FFMP) attempts to fill the gap between the RFC-provided Flash Flood Guidance products issued several times each day and the operational forecaster needs during high-intensity, short duration rainfall events, which are responsible for most of the flash floods occurring within the 0-3 hr time range.

FFMP alerts forecasters to those areas that have a high flash flood potential, often with a very quick response to intense rainfall. WFO forecasters have few real-time rainfall-runoff tools available to them, although they are responsible for issuing accurate flash flood forecasts in their area.

To support this capability, the CONUS has been discretized into 2-10 km^2 watersheds, provided to the WFO as sets of ESRI formatted 'Shapefiles'. This GIS data set contains most of the attributes necessary to aid the Service Hydrologist in doing their forecast duties, including an outline of each watershed, watershed area, contributing (inflow) and outflow watersheds, outlet location (pour point), etc. These watershed attributes are provided in a dBase-III database file, a “dbf” file. The local WFO Service Hydrologist maintains these shapefile data, adding or correcting details, expanding the provided database, and generally improving the contained data adding area specific details.

FFMP runs in the background, monitoring in real-time many input data sets. For each 2-10 km^2 watershed in the FFMP domain, it monitors precipitation accumulation from each input data type, such as radar estimates (QPE or MPE) and/or forecast rainfall (QPF) at several durations, while comparing each to the available excess rainfall guidance values. When a watershed's rainfall accumulation reaches a predefined threshold (defined by River Forecast Centers for each watershed) or when instantaneous rain rates reach prescribed limits, FFMP triggers a workstation alarm alerting the forecaster to the possible flash flood condition. The forecaster then evaluates the potential threat using the AWIPS D2D display, FFMP tables, and other available data to determine whether to issue a flash flood watch or warning for the affected area.

The National Weather Service's mission is to provide watches and warnings to the public for severe, weather-related events. The infrastructure to provide this service is well developed, with direct connections to local Emergency Managers and law enforcement officials.

The USGS and the NWS have agreed provide Debris Flow watches and warnings (as modified flash flood watches and warning). In the Debris Flow Experimental areas in Southern California (Oxnard (LOX) and San Diego (SGX) WFOs), FFMP has undergone a few modifications to support USGS Debris Flow forecast watersheds and to allow forecasters to add USGS Geological Hazards Team-provided Debris Flow Guidance to identify those areas most likely to experience a Debris Flow.

2. Research Accomplishments/Highlights:

A. AutoNowcast Interface Project

New data sets and domains will be used in the Melbourne area and system modifications are expected to be necessary to enable the new area to move forward.

As the Technical Lead, the following set of functional subtasks was identified as necessary to meet the project goals:

- --Data Management
- --Data Display
- --Forecaster Interaction (boundary and polygon editing)
- --Data Dissemination

Operational implementation has shown few modifications have been necessary to correct implementation errors. These previous accomplishments include:

--real-time decoding of NCAR-provided data;
--storage of NCAR-provided data in netCDF, AWIPS-ready format; and
--generating data display updates as data becomes available to AWIPS (the Data Management sub-task), AWIPS menu design, and extension interfaces.

This year, much effort has been toward supporting the WFO's operations. Assistance have been provided to migrate NCAR provided software onto a full implementation of the Autonowcaster system at MDL. This has required analyzing code which was designed to operate using software not available to MDL and make the necessary corrections to make the software operate in a generic environment.

The migration of the Autonowcaster system to MDL anticipates the direct support of the Fort Worth prototype installation and also directly supporting the larger Melbourne NextGen installation of the Autonowcaster in 2010.

B. FFMP and Debris Flow Project

During the past several years, the overall collaborative research effort with MDL has focused on bringing the NCAR AutoNowcast system into AWIPS. On successful completion of this task, it has become possible to begin spending more time on assisting the Debris Flow forecasting project. As such, this has been a transition year—ratcheting down the time spent on the AutoNowcaster Program and beginning to map a strategy for Debris Flow Support to provide precipitation gage data from the WFO Hydro Database, which has been specifically requested by USGS researchers. Suggestions have been made on adding Quantitative Precipitation Estimates (QPE) and Quantitative Precipitation Forecast (QPF) data sets to allow USGS Debris Flow models to develop a 'forecast' capability to their existing post-event analysis models.

To support the USGS's ability in their analysis of storms which cause Debris Flows, a prototype application was developed to deliver near real-time data using data available from internet accessible databases, such as, http://www.met.utah.edu/mesowest/. This was provided as a quick, partial implementation of the prototype to be installed at LOX and SGX WFOs. The incentive to doing that was to avoid needing to navigate the security layers within the NWS and explore the usefulness to the USGS of providing real-time rainfall data.

The benefit was almost immediately realized by eliminating the need to explicitly retrieve archive rainfall data, particularly after a debris flow event, and also to begin automated methods to populate (insert observations into) the project rainfall database. The prototype also exercised methods for managing the required USGS ftp data ingest facility to be used by the real-time application providing rainfall observations from the WFO's Hydro database.

The internet prototype application was expanded and extended to retrieve rainfall from the WFO's real-time Hydro database by directly querying this relational database, formatting the data to suit the USGS ingest methods, and delivering these data reports to the USGS automatically. The real-time relational database data retrievals will be completed before the onset of the next rainy season.

Additionally, a communication mechanism needs to be provided to send guidance data from the USGS models to the local WSFO (completing the feedback loop). These data will be automatically ingested, updating the FFMP data sets and displays.

In addition to the follow-on work in exchanging real-time data (gage and radar), collaboration with Western Region Scientific Services Division in the development of real-time, distributed hydrologic models which use (for rainfall input) new very high resolution QPE and QPF from experimental radar data sets such as the Smart-R and Q2 is expected to begin. This work will supplement work being conducted at the USGS in support of the NWS's Debris flow forecasting experiment.

3. Comparison of Objectives Vs Actual Accomplishments for Reporting Period:

A. In progress.

B. In progress.

4. Leveraging/Payoff: None

5. Research Partnerships/Collaborators:

The NWS Modernization Development Laboratory, Decision Assistance Branch (MDL, DAB, Steve Smith, Branch Chief) is the sponsor of this project providing support and direction.

The AutoNowcast Interface Project is a collaboration with the NCAR AutoNowcast (AN) development team (Rita Roberts, NCAR Project Lead).

The FFMP Project is sponsored by NWS/MDL/DAB. Tom Filiaggi is the FFMP (NWS) Project Lead.

The Debris Flow Project is collaboration between the USGS Geological Hazards Team (GHT), headed by Sue Cannon, USGS Debris Flow Team Lead.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

FUNDS FOR THE COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE, TASK 1

Principal Investigator: Graeme L. Stephens

NOAA Project Goals: Various

Key Words:

1. Long-term Research Objectives and Specific Plans to Achieve Them:

2. Research Accomplishments/Highlights:

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

6. Awards/Honors:

7. Outreach:

CIRA conducted various tours for corporations and local public and private schools

Seminars

August 8, 2008, Y.N. Takayabu (Univ. of Tokyo). Dynamical and Thermodynamical Controls on Tropical and Subtropical Convective Activity Inferred from Three Dimensional Latent Heating Distributions with TRMM SLH Beta-Version data.

August 8, 2008, S. Shige (Osaka Prefecture Univ., Japan). Spectral Retrieval of Latent Heating Profiles from TRMM PR Data: Comparisons of Lookup Tables from Two and Three Dimensional Simulations.

August 21, 2008, S. Vannitsem (Institut Royal Meteorologique de Belgique, Belgium). Dynamical Properties of Model Output Statistics (MOS): The Impact of Initial Condition and Model Errors.

August 21, 2008, A. Carrassi (Institut Royal Meteorologique de Belgique, Belgium). Model Error and Sequential Data Assimilation: A Deterministic Formulation.

August 28, 2008, T. Karl (NCAR). Volatile and Semivolatile Organic Compounds in the Atmosphere.

September 4, 2008, A. White (NOAA/ESRL/PSD). Improving Observations of Coastal Storms.

September 11, 2008, S. Birkel (Univ. of Maine). Climatic Implications of the Mechanical Collapse of the Laurentide Ice Sheet.

September 17, 2008, J. Edwards, L. Cheatwood, B. Motta (CIRA & NOAA/ESRL/GSD). AWIPS II (Version T08).

September 18, 2008, D. Noone (CIRES). Water Vapor Pathways and Cycling Rates Deduced from Global Water Isotope Measurements.

September 18, 2008, G. Liston (CIRA). From Coast to Pole: A Research Expedition Traversing Antarctica.

September 25, 2008, A. Robinson (Carnegie Mellon Univ.). Source Appointment of Organic Aerosols: The Molecular Marker Approach.

October 2, 2008, S. Solomon (NOAA/ESRL/CSD). Linkages Between Ozone Depletion and Climate Change: Evolution of the Science and Connections to Public Policy.

October 3, 2008, T. Matsui (GEST UMBC & NASA GSFC). On the Development of Multi-Scale Cumulus Ensemble Models with Satellite Radiance Observations and Multi-Sensor Satellite Simulators.

October 9, 2008, G. McKinley (Univ. of WI – Madison). The Changing North Atlantic Carbon Cycle: 1992-2006.

October 16, 2008, C. Thorncroft (SUNY). A Multiscale Analysis of the West African Monsoon.

October 16, 2008, D. Nolan (Univ. of Miami). Environmental Controls of Tropical Cyclone Formation as Seen in High Resolution Simulations.

October 23, 2008, C. Deser (NCAR). Atmospheric Circulation Trends, 1950-2000: The Relative Roles of Sea Surface Temperature Forcing and Direct Atmospheric Radiative Forcing.

October 30, 2008, W. Cotton (CSU). Weather and Climate Engineering.

November 4, 2008, R. Levy (NASA/GSFC). Retrieving Global Aerosol Properties from MODIS: The Challenge of the Climate Data Record.

November 6, 2008, G. Kiladis (NOAA). Multiscale Organization of Equatorial Waves.

November 13, 2008, S. Denning (CSU). Earth's "Carbon Cycle" is Key to NASA's Earth Science Program.

November 19, 2008, D. Birkenheuer (NOAA/ESRL/GSD). Use of GPS Data at ESRL GSD to Further the Advance of GOES Radiometric Quality and Utility.

November 19, 2008, D. Thompson (CSU). The Ozone Hole and Climate Change.

November 20, 2008, M. Hernandez (CU). Characterization of Bioaerosols from Non-Point Sources.

November 21, 2008, K. Lapina (MTU). Assessing the Impact of Boreal Wildfires on 03 and 03 Precursors Using Observations at the Pico Mountain Observatory.

December 4, 2008, L. Dilling (CIRES). Communicating About Climate Changes: Moving Beyond the Myths toward More Effective Strategies for Societal Engagement.

December 11, 2008, A. Heymsfield (NCAR). Microphysics of Maritime Tropical Convective Updrafts at Temperatures from -20 to -60C and the Role of Dust.

January 22, 2009, J. Flemming (Colby College). Fixing the Sky: Does Geo-Engineering Have a History?

January 29, 2009, D. de Haan (Univ. of San Diego). Irreversible Aerosol-Forming Reactions of Volatile Dicarbonyl and Amine Compounds.

January 30, 2009, D. Schecter (NRA, WA). Hurricane Formation in Diabatic Turbulence.

February 5, 2009, J. Overpeck (Univ. of AZ). A Paleoclimatic Perspective on Future Sea Level Rise and Drought: It Could Get Worse Than We Think.

February 12, 2009, T. Bertram (Univ. of WA). Constraints on Tropospheric Ozone Production: From Aircraft Observations to in situ Heterogeneous Kinetics

February 19, 2009, A. Eldering (JPL). Insights into Tropospheric Chemistry: New Results Utilizing EOS TES.

February 26, 2009, W. Washington (NCAR). 20th and 21st Century Climate Change: Computer Modeling, Societal Impacts and Environmental Justice.

March 5, 2009, G. Vallis (Princeton). Meridional Energy Transport in the Coupled Atmosphere-Ocean System.

March 12, 2009, M. Holland (NCAR). Perennial Arctic Sea Ice: Here Today, Gone Tomorrow?

March 18, 2009, D. Lindsey (NOAA/NESDIS/RAMMB). Wildfire-induced Thunderstorms: Observations and Possible Climate Impacts.

March 25, 2009, J. Marsham (NCAR). Recent Observations from CSIP and IHOP of Cold Pool Outflows, Bores and Waves from Deep Convection and Subsequent Initiation.

March 26, 2009, T. Birner (CSU). Stratospheric Severe Weather: The Dynamics of Sudden Stratospheric Warmings.

March 30, 2009, M. Evans (Leeds Univ.). Two Short Stories about the Marine Boundary Layer.

April 2, 2009, D. Waliser (JPL/Cal Tech). Cloud Ice: A Climate Model Challenge with Signs and Expectations of Progress.

April 9, 2009, B. Randel (NCAR). The Asian Monsoon Anticyclone, Pollution Near the Tropopause and Transport to the Stratosphere.

April 16, 2009, J. Shaman (OSU). The ENSO-North African-Asian Jet Teleconnection: Dynamics and Implications.

April 23, 2009, B. Kahn (JPL). A-train Studies of Temperature and Water Vapor Variance Scaling and Upper Tropospheric Relative Humidity Distributions.

April 30, 2009, A. Gettelman (NCAR). Simulating the Past, Present and Future of the Tropical Tropopause Layer.

Post Doctoral Program

David Baker – CIRA Post Doc

Project Title: Carbon Cycle Data Assimilation

Principle Investigator: David Baker

NOAA Project Goals: Climate and Mission Support (Satellite sub-goal)

Key Words: Carbon Cycle, OSSE, Data Assimilation, CO_2 Flux, Remote Sensing

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Work aims at obtaining new information on the functioning of the global carbon cycle using trace gas measurements from satellites. I use atmospheric transport models to relate atmospheric trace gas concentrations to surface fluxes, then estimate the fluxes from the concentration measurements using a variational data assimilation method. This method is highly-efficient, computationally, and allows me to solve for the fluxes at fine spatial and temporal scales, at which the driving physical processes are more apparent than at the coarse scales resolved up to now.

2. Research Accomplishments/Highlights:

In the past year, I published the results of previous work that used my variational data assimilation system to perform observing system simulation experiments (OSSEs) for the Orbiting Carbon Observatory (OCO) in Baker, et al., 2008. The measurement uncertainties used were taken from a linear error analysis of OCO concentration retrievals done by Dr. Hartmut Bösch using the `full-physics' retrieval algorithm for OCO (surface properties, aerosol effects, and viewing geometry were considered). In addition to quantifying the impact of random measurement errors, the effects of a variety of systematic error sources also were examined. My study was the most detailed analysis of its kind up to that time.

The assimilation software used for this OSSE study assumed climatological conditions for most quantities. Over the past year, I have been modifying this software so that it can be used to produce a CO_2 flux product from operational satellite data with a lag time of only days to weeks after the data are observed (with a goal of supporting the OCO mission). This process involved replacing the climatological quantities assumed before with actual values appropriate for the time period in question (taken either from measurements or models, as appropriate). These quantities include analyzed meteorology products to drive the atmospheric transport model, and a priori estimates of the surface fluxes (including those from the land biosphere, oceans, fossil fuel burning, and biomass burning/wildfires).

At a September 2008 meeting of the Pawson carbon cycle assimilation team in Greenbelt, Maryland, arrangements were made to obtain land biospheric fluxes from two sources for use in processing OCO data: SiB3 fluxes from Scott Denning and Nick Parazoo (CSU), and CASA/GFED fluxes from Jim Collatz and Randy Kawa (NASA/Goddard), including fluxes from wildfires. Also at this meeting, arrangements were made with Michelle Reinecker and Steven Pawson (NASA/Goddard) to obtain GEOS5 analyzed meteorological products at 0.5°x0.66° resolution; these are to be used both to drive the PCTM atmospheric transport model during the assimilation, as well as to provide needed parameters for generating the SiB3 a priori fluxes in near-real-time (precipitation, temperature, radiation, etc). Working with Nick Parazoo (CSU), I set up an automatic interface to move these fields onto local CSU computers within a day of their generation. Later, I discussed obtaining suitable ocean fluxes from Scott Doney and Ivan Lima (Woods Hole Oceanographic Institute), and an improved global fossil fuel product with Kevin Gurney (Purdue Univ.).

To model the OCO concentrations as well as possible, one would like to run the transport model and estimate fluxes at as fine a spatial resolution as possible. Running a full assimilation at the 0.5°x0.66° resolution provided by the GEOS5 analysis products is expected to be prohibitively expensive with the computational resources available, however. To get around this, I have developed a grid-refinement approach for executing the assimilation efficiently: the coarser-scale flux features are converged fully first by running the assimilation at a coarser resolution (7.5°x10.0°, then 4.5°x6.0°), then the finer-scale details are resolved (at 1.5°x2.0° and 0.5°x0.66°) with a more-limited number of additional iterations of the method. Besides being computationally tractable, this approach has two added advantages:

--the lower-magnitude ocean fluxes, which require many iterations of the optimization method to converge, are fully converged; and

--since the resolution of the satellite data is not fine enough to constrain fluxes for all the grid boxes at the finer resolutions, only those areas closest to the measurements are updated during the later iterations.

I am currently testing the assimilation system at these GEOS5-based resolutions and evaluating the performance of this grid refinement approach. I am also currently using my assimilation system to perform OSSEs for theoretical constellations of OCO-like satellites, to determine what sort of satellite network might be needed to estimate CO_2 fluxes at scales as fine as 1°x1° (see the write-up for the " Monitoring Future Carbon Controls" project).

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

I had hoped to be using my CO_2 flux data assimilation system to process real OCO data by this point. With the demise of the OCO satellite in February 2008, I have shifted my focus towards interpreting the data from the Greenhouse-gases Observing Satellite (GOSAT), as well as performing OSSEs for other trace gas satellite missions in the planning stages.

4. Leveraging/Payoff:

My assimilation research and software development aimed at processing OCO data should be equally applicable to other trace-gas-measuring satellites, such as GOSAT or ASCENDS. On a broader level, the information such satellites will shed on the working of the global carbon cycle should be crucial for refining our predictions of global warming, and may be useful in monitoring compliance with global greenhouse-gas emission treaties.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As noted above, I have worked with researchers from NASA's Goddard Space Flight Center and Jet Propulsion Laboratory, the Woods Hole Oceanographic Institute, the University of Leicester, Purdue University, Colorado State University, and the National Center for Atmospheric Research in this research. Dr. Fu-Lung Chen of the National Institute of Aerospace also contributed his MODIS cloud database to my effort.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Baker, D. F., H. Bösch, S. C. Doney, and D. S. Schimel, Carbon source/sink information provided by column CO_2 measurements from the Orbiting Carbon Observatory, Atmos. Chem. Phys. Discuss., 8, 20051-20112, 2008.

Armin Soorooshian – CIRA Post Doc

Project Title: Aerosol Effects on Cloud Microphysics and Precipitation

Principal Investigator: Armin Sorooshian

NOAA Project Goal: Climate Goal

Key Words: Aerosol, Precipitation, Clouds, Ocean, Ecosystem, Satellite, A-Train, Models

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Use a multi-platform approach to study interactions between aerosol, clouds, and precipitation. Currently there is significant uncertainty as to how aerosol may modify cloud microphysics and precipitation rates. Using in-situ measurements, satellite observations, and models of varying complexity these issues are addressed in this project in an unprecedented way.

2. Research Accomplishments/Highlights:

Novel findings related to ocean-aerosol-cloud-precipitation interactions have been reported in two peer-reviewed manuscripts that were accepted for publication this year.

The first paper relies on a combination of airborne in-situ, surface- and satellite remote sensing data to shed light on the question of whether ocean biota emissions influence aerosol and cloud microphysics in the marine boundary layer. A clear link is shown between ocean chlorophyll and aerosol, but there is no obvious effect on cloud microphysics – probably because meteorological factors dominate.

The second paper addresses a new idea which attempts to apply new metrics to assess the impact of aerosol on precipitation. Using a combination of simple cloud models, output from large eddy simulations, and satellite data this work has identified regions in the world that are most likely to be susceptible to precipitation changes.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

"Complete" : The goal this year was to study the links between aerosol, cloud microphysics, and precipitation and this was fully fulfilled and resulted in two peer-reviewed publications.

4. Leveraging/Payoff:

The results of the project related to aerosol effects on precipitation should be of great interest to the public and policy makers as we have shown for the first time that certain regions of the globe may be more vulnerable to precipitation suppression simply as a result of the characteristic pollution in their regions. The climatic and societal issues associated with pressure on water resources warrants vigorous pursuit of this line of research.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As part of my postdoctoral research, I have collaborated closely with CSU and CIRA scientists (i.e. Matt Lebsock and Graeme Stephens), NOAA/ESRL scientists (i.e. Graham Feingold, Hongli Jiang, and Allison McComiskey), and also scientists at various academic institutions (i.e.. Naval Postgraduate School, California Institute of Technology, and Georgia Institute of Technology).

6. Awards/Honors:

Outstanding Poster Presentation (Boulder Laboratories Postdoctoral Poster Symposium, 2009)

Invited ACCESS participant (Atmospheric Chemistry Colloquium for Emerging Senior Scientists; 2009)

7. Outreach:

Seminars

NOAA (Chemical Sciences Division, 2009)
Colorado State University (Dept. of Atmospheric Sciences, 2009)

Conference Oral Presentations

A. Sorooshian and G. Feingold (2009), Precipitation in warm clouds and its susceptibility to aerosol perturbations, Goldschimdt Conference, Davos, Switzerland.

Conference Poster Presentations:

Sorooshian, A., G. Feingold, M. D. Lebsock, H. Jiang, and G. Stephens (2009), Where in the world will aerosol reduce precipitation? International GEWEX/ILEAPS Meeting, Melbourne, Australia.

Sorooshian, A., G. Feingold, M. D. Lebsock, H. Jiang, and G. Stephens (2009), Where in the world will aerosol reduce precipitation? Gordon Research Conference – Radiation and Climate, Colby Sawyer College, New Hampshire.

Sorooshian, A., L. T. Padró, A. Nenes, G. Feingold, A. McComiskey, S. P. Hersey, H. Gates, H. H. Jonsson, S. D. Miller, G. L. Stephens, R. C. Flagan, J. H. Seinfeld (2008), On the Link Between Ocean Biota Emissions, Aerosol, and Maritime Clouds: Airborne, Ground, and Satellite Measurements off the Coast of California, American Geophysical Union (AGU), Annual Meeting, San Francisco, California.

8. Publications:

Sorooshian, A., L. T. Padró, A. Nenes, G. Feingold, A. McComiskey, S. P. Hersey, H. Gates, H. H. Jonsson, S. D. Miller, G. L. Stephens, R. C. Flagan, J. H. Seinfeld (2009), On the link between ocean biota emissions, aerosol, and maritime clouds: airborne, ground, and satellite measurements off the coast of California, Global Biogeochem. Cycles, doi:10.1029/2009GB003464, in press.

Sorooshian, A., G. Feingold, M. D. Lebsock, H. Jiang, and G. Stephens (2009). On the precipitation susceptibility of clouds to aerosol perturbations. Geophys. Res. Lett., 36, L13803, doi:10.1029/2009GL038993.

8. Funds for CIRA General Publications:

Stephens, G.L. and Vonder Haar, T.H., 2009. Annual Report on the Cooperative Institute for Research in the Atmosphere 01 July 2008 – 30 June 2009, Cooperative Institute for Research in the Atmosphere, Colorado State University, Ft. Collins, CO.

FURTHER EXPANSION OF CIRA RESEARCH COLLABORATION WITH THE NWS METEOROLOGICAL DEVELOPMENT LAB

Principal Researcher: Ken Sperow

NOAA Project Goal/Programs: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings; Hydrology

Key Words: NWS, MDL, NCAR, AWIPS, AWIPS II, AWIPS Migration, AutoNowcast (ANC), Four-dimensional Stormcell Investigator (FSI), TDWR, AWIPS Data Visualization and Monitoring System for Observational Records (ADVISOR), CWSU, SOA

This past year, I have contributed to four research projects: AutoNowcast (ANC); Four-dimensional Stormcell Investigator (FSI); AWIPS Data Visualization and Monitoring System for Observational Records (ADVISOR); and NWS' Advanced Weather Interactive Processing System (AWIPS) Evolution, referred to as AWIPS Migration (previously AWIPS II).

<u>The AutoNowcast (ANC) Prototype Project</u>

1. Long-term Research Objectives and Specific Plans to Achieve Them:

ANC is a suite of automated applications developed by NCAR Research Applications Laboratory (RAL) that produce 0- to 1-hour predictor fields of storm initiation, growth, and decay. The long-term objective of this project is to transfer the ANC software into NWS operations with the goals of providing short-term forecast guidance, area weather updates, and use of the ANC generated forecasts by meteorologists at the Center Weather Service Units (CWSUs).

The first phase of the project is a proof of concept at the Dallas-Fort Worth (FWD) WFO. The main objective is to provide the ANC products and interactive tools within AWIPS Two-Dimensional Display (D-2D). This effort provides the NWS forecasters with ANC forecast products, while using familiar AWIPS techniques to display and interact with the data.

The second phase of the project, to run concurrently with the first, is to run the complete ANC system at MDL. The objectives of this phase are to better understand the configuration, architecture, and customization of the system with the intention of streamlining the system for operational use.

2. Research Accomplishments/Highlights:

The ANC prototype is up and running at the FWD WFO and has been for several years now. This year we delivered updated packages to the WFO to streamline the tools used by the forecasters to insert boundaries and polygons as well as support the new operational version of AWIPS (OB9.0). In addition the software was installed on all workstations within the office so that any of the forecasters could use the ANC tools as opposed to just the short term forecaster. The NWS sent me to the FWD WFO twice this past year; in the fall to attend a yearly project review and then this past spring to assist in the training of the WFO staff, observe the use of ANC by the forecaster, and continue to build relations with the WFO staff and NCAR ANC personnel on site.

We made great progress this year with the second phase of the ANC project, running the complete ANC system on NWS' hardware at MDL. This task required coordinating with NCAR, UCAR, the University of West Texas, and GSD to purchase the correct hardware, acquire datasets in the correct formats for ingest, and install the ANC package from source code and configuration files. It was determined by NCAR that seven servers were needed to run the system. MDL had four older servers and ordered 3 additional servers last year. Last summer I setup the new servers and had a fully functioning version of ANC running at MDL by the fall. We had expected to get everything running a bit sooner but ran into issues since the Terascan formatted Satellite data NCAR used was not available to MDL. NCAR updated their software to run with the GINI formatted data.

Part of the second phase of the ANC project was to evaluate how the system ran at MDL through performance monitoring. It turned out that with minimal changes to the software I was able to run the entire ANC system on a single server as opposed to 7 servers. This change has had a positive impact on the project since the cost to run ANC from a hardware perspective has been significantly reduced. As a result of this change I designed and implemented changes to the topology of the network to establish a development, test and in the future production systems. We have ordered two additional servers that will be used to run ANC for FWD in a "production" configuration. The production system includes redundant hardware with fail-over capabilities. Goals for the next year include feeding the FWD WFO with ANC data from MDL rather than NCAR and start setting up additional instances of ANC for a separate experiment planned for the Melbourne, Florida WFO. As preparation for the MLB experiment I used my understanding gained from the FWD system and met with NCAR ANC team members to document the steps required to setup a new system. The final product of this effort was a comprehensive Microsoft Project plan that included LOE and dependencies.

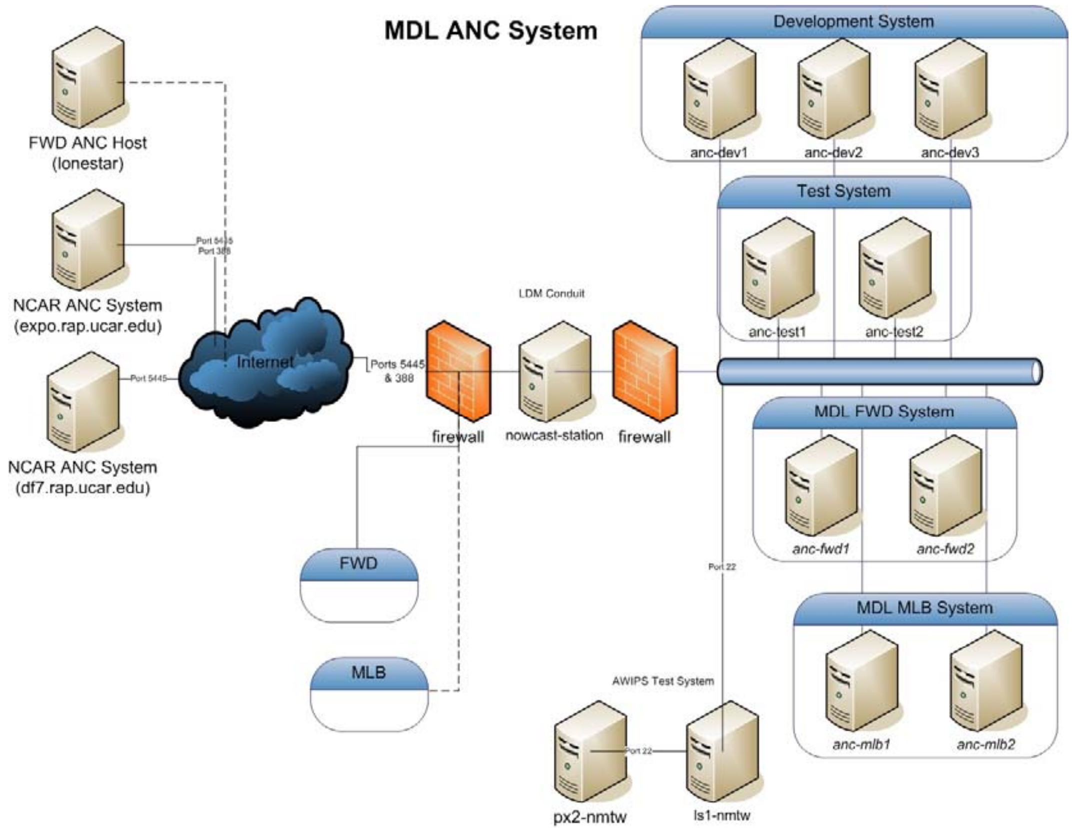

Fig. 1. Diagram showing the ANC cluster at MDL illustrating the development, test, and planned production systems.

3. Comparison of Objectives Vs Actual Accomplishments for the Reporting Period:

All planned objectives for this past year were met. The forecast office reported that the tools within AWIPS are "intuitive and easy to use."

The objective for MDL to run ANC on NWS' hardware are on schedule as planned.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

The NWS' Meteorological Development Laboratory, Decision Assistance Branch is the sponsor of this project providing support and direction. The AutoNowcast Interface Project is a collaboration with the NCAR AutoNowcast (ANC) development team and the NWS/DAB.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

AWIPS Migration

1. Long-term Research Objectives and Specific Plans to Achieve Them:

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.

MDL is not directly responsible for the migration of its applications from AWIPS to AWIPS Migration; this is the responsibility of Raytheon, the prime contractor. However, 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 Migration uses many technologies (JAVA, Mule, Hibernate, JavaScript, JMS, JMX, etc.) which are new to MDL and the NWS. In order for MDL to be in a position to add value, they need people that have a working understanding of these technologies.

2. Research Accomplishments/Highlights:

I am a member of the AWIPS Migration Independent Validation and Verification (IV&V) group. As such I have been leading MDL's efforts to organize MDL staff in testing MDL applications as Raytheon migrates them to the new infrastructure. Additionally, I have installed each release of AWIPS Migration on my laptop and provided feedback on the process. Using the new framework I developed a prototype meteogram tool that will allow forecasters to display time-series of any gridded or image data within CAVE. In June I went back to NWS headquarters and provided training on how to setup, develop, and test AWIPS Migration software within Eclipse to over 20 developers from OH, SEC, MDL, and ASM. Additionally, I have helped MDL staff to get their AWIPS II development environments running, so that they are in a position to better understand the environment as well as start modifying the code.

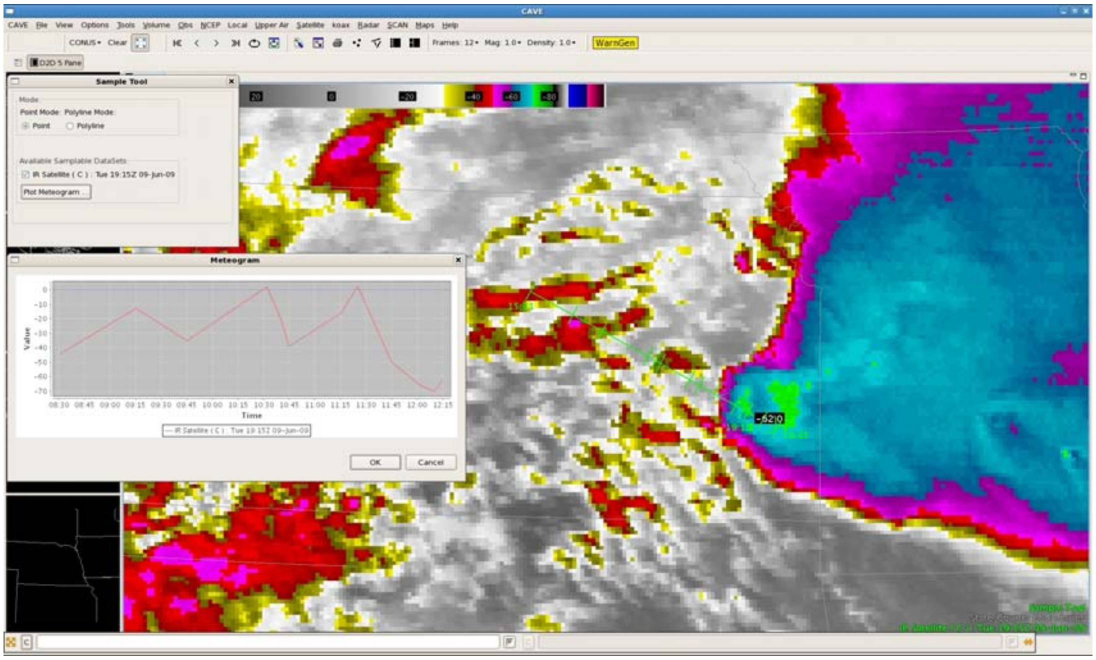

Fig. 2. Screen Shot of New Meteogram Tool Developed Within the AWIPS Migration Infrastructure.

3. Comparison of Objectives Vs Actual Accomplishments for the Reporting Period:

Objectives for the past year were successfully met.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

The NWS' Meteorological Development Laboratory, Decision Assistance Branch is the MDL sponsor of this project. The NWS' Systems Engineering Center (SEC) is leading the AWIPS Evolution project.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

Four-dimensional Stormcell Investigator (FSI)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The "FSI" is defined as the National Severe Storms Laboratory (NSSL) Warning Decision Support System – Integrated Information (WDSSII) display graphical user interface (GUI) that has been designed for specific NWS warning operations. It is a separate application that is launched from the D2D. The FSI gives severe weather warning decision meteorologists advanced WSR-88D radar analysis capabilities. The user can create and manipulate dynamic cross-sections (both vertical and at constant altitude), such that one can "slice and dice" storms and view the data in three-dimensions and across time. The objective of this project is to make this tool available to forecasters and, in doing so, increase warning skill and lead time, thus improving public service.

2. Research Accomplishments/Highlights:

The FSI was integrated into AWIPS in build OB8.2, prior to my involvement with the project. Last summer I successfully implemented a project to make Terminal Doppler Weather Radar (TDWR) data available within the FSI. I conducted both requirement and design approach reviews and as well as made the coding changes required so that the TDWR data are available in build OB9 of AWIPS.

3. Comparison of Objectives Vs Actual Accomplishments for the Reporting Period:

Objectives for the past year were successfully met.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

The NWS's Meteorological Development Laboratory, Decision Assistance Branch is the sponsor of this project providing support and direction. Greg Stumpf, Tom Filiaggi, and Michael Churma from MDL are providing consultative support for this task.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

AWIPS Data Visualization and Monitoring System for Observational Records (ADVISOR)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

ADVISOR will be an AWIPS monitoring and display tool designed to aid forecasters in decision-making. It will be comprised of two main components: a monitoring process, which will receive and evaluate incoming data (station reports - METARS, buoys, ships, MAROB, 3-hour synoptic, aircraft/ACARS and Mesonet sites; gridded data – forecasts and numerical model; radar; and satellite), and a configurable table in which the forecaster will be able to interrogate the data. ADVISOR will be a highly configurable application, which will allow sites to display and or monitor most parameters available within AWIPS. In addition, sites will be able to create new parameters to display and or monitor from any combination of existing parameters (e.g. Wind Chill which depends on temperature and wind speed).

2. Research Accomplishments/Highlights:

The ADVISOR task is still in its formative stages. The ADVISOR team is working to get the project through gate 1 of the OSIP process. In the past year we developed use cases and prototype user interfaces. This project will be prototyped in the new AWIPS Migration framework with the intention of bringing the application into operations after AWIPS Migration has been deployed to the field.

3. Comparison of Objectives Vs Actual Accomplishments for the Reporting Period:

Objectives for the past year were successfully met.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

The NWS's Meteorological Development Laboratory, Decision Assistance Branch is the sponsor of this project providing support and direction. Cece Mitchell, Mike Churma, and Tom Filiaggi are all part of the ADVISOR team responsible for defining and developing this application.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

GETTING READY FOR NOAA'S ADVANCED REMOTE SENSING PROGRAMS A SATELLITE HYDRO-METEOROLOGY (SHYMET) TRAINING AND EDUCATION PROPOSAL

Principal Investigator: B.H. Connell

NOAA Project Goal: Weather and Water; Programs: Local Forecasts and Warnings, Hydrology

Key Words: Training, Outreach, National and International Cooperation and Collaboration

1. Long-term Research Objectives And Specific Plans To Achieve Them:

The overall objective of the SHyMet program is to develop and deliver a comprehensive distance-learning course on satellite hydrology and meteorology. This is being done in close collaboration with experts from CIRA, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison, the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, the National Weather Service (NWS) Training Center (NWSTC) in Kansas City, Missouri, and the NWS Warning Decision Training Branch (WDTB) in Norman, Oklahoma. 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 providing new training on the these tools to be used operationally.

The (SHyMet) Course will cover the necessary basics of remote sensing, satellite instrumentation, orbits, calibration, and navigation, and will heavily focus on identification of atmospheric and surface phenomena, and the integration of meteorological analysis with satellite observations and products into the weather forecasting and warning process.

During the initial years of activities of this proposal, CIRA and CIMSS prepared an outline of the Satellite Hydro-Meteorology (SHyMet) training course (see Training Topics: http://rammb.cira.colostate.edu/training/shymet/).

The specific objectives for this past year of the project included:

a. Maintain and make small incremental changes to the SHyMet Intern Course http://rammb.cira.colostate.edu/training/shymet/intern_intro.asp .

b. Identifying the resources and course content for the following topics:

- --Dvorak Method
- --Future Satellites
- --Cloud Climatology
- --Aviation Hazards
- --Hazard Detection

c. Update the CIRA SHyMet web page to reflect new/revised course offerings.

d. Advertise and make SHyMet course materials available nationally and internationally to individuals outside NOAA/NWS.

e. Attend meteorological and educational conferences and symposiums as the opportunities arise to present materials related to SHyMet and to actively solicit training needs from the community.

2. Research Accommmplishments/Highlights:

The SHyMet Intern course was offered online. It consisted of 9 modules (http://rammb.cira.colostate.edu/training/shymet/intern_topics.asp). For NOAA individuals, the course was set up for tracking through the e-Learning Management System (LMS). For non-NOAA individuals, the course was offered through online modules and was tracked at CIRA.

Statistics for January - December 2008 (compared to entire period April 2006 – December 2008). Note: the metrics for the SHyMet course are tracked through the expertise of the VISIT program.

--37 new NOAA/NWS employees/participants have registered at CIRA (170 total for period April 2006 – December 2008)

--20 of the new NOAA/NWS individuals have completed SHyMet Intern Course (80 total for period April 2006 – December 2008)

--3 non-NOAA participants have registered at CIRA ((NESDIS/SAB contractor, Comoros, and Pakistan) (22 total for period April 2006 – December 2008)

--1 non-NOAA individual has completed the SHyMet Intern Course. (10 total for period April 2006 – December 2008)

--Registrations through LMS tracking indicate that an additional 46 individuals not registered at CIRA have taken various SHyMet modules this year.

Table 1. Number of students registered via the LMS for SHyMet training sessions (only web based) for the last year and for the total period July 1, 2006 to December 31, 2008.

SHyMet training session	Registrations/Completions 2008	Total Registrations
Orientation	83/68	317
GOES Imaging and Sounding Area Coverage	66/65	279
GOES Channel Selection	85/74	296
Introduction to POES	57/52	262
GOES Sounder Data and Products	64/56	205
GOES High Density Winds	60/52	204
Cyclogenesis	68/50	212
Introduction to Satellite Severe Weather	75/57	236
Tropical Cyclones	57/49	295
Totals	615/523	2306

SHyMet teletraining session (April-June 2006)	Registrations
GOES Sounder Data and Products	53
GOES High Density Winds	48
Cyclogenesis	54
Introduction to Satellite Interpretation for Severe Weather	52

NWS Central Region has made the SHyMet intern course mandatory for all interns.

To be linked with the needs of the NWS customer, a member of the SHyMet team from CIRA is participating in the NWS Satellite Requirements and Solutions Steering Team (SRSST) monthly teleconference meetings as a subject matter expert.

From the SHyMet and VISIT meeting at CIMSS in Madison, WI in November 2007, The following topics were selected for the SHyMet for Forecasters course. The organizations responsible for the topics are listed in parenthesis.

--Hydrology – introductory session on what remote sensing is available for hydrology. (NWS Hydrologist, Boulder)
--Feature Identification from satellite imagery (CIMSS)
--Dvorak method (RAMMB/CIRA)
--Future Satellites (CIRA)
--Cloud climatology (CIRA)
--Water vapor channels (CIMSS)
--Aviation hazards (CIRA)
--Hazard detection (Fog, fire, volcanic ash, dust, aerosols) (CIRA)

Of the 5 modules that CIRA was responsible for this past year, 2 modules were directly produced under SHyMet funding: the Dvorak and Cloud Climatology modules. SHyMet leveraged with GOES – R funding to produce a future satellites module on GOES-R (#4), and it leveraged with VISIT funding to produce the Aviation hazards (#7), and Volcanic Ash hazards (#8) modules. Although item 8 as listed above was to include multiple topics for hazard detection, a decision was made to focus solely on volcanic ash. This was due to the very limited training content that is currently available for volcanic ash and recent major eruptions of 3 different volcanoes in Alaska during the summer of 2008 and early 2009 that affected aviation, as well as ground transportation and health.

In order to be aware of other training activities, a SHyMet team member participated in the NPOESS/GOES-R Training Resources Development Workshop held at COMET in May 2008 and 2009. CIRA also participates in the COMET NPOESS/GOES-R training monthly conference calls.

Expertise on the use of the VISITview browser was provided to the monthly virtual sessions of the WMO Regional Focus Group of the Americas and the Caribbean.

3. Comparison of Objectives Vs. Actual Accomplishments for theReporting Period:

All of the obejctives have been met. Due to the nature of the project, many of the objectives will be continued in the next year.

4. Leveraging/Payoff:

The training materials being developed will help the user (the weather forecaster, the hazard analyst, other teachers/trainers) better utilize current satellite products that are available. This will in turn lead to better weather/hazard forecasts for the public.

5. Research Linkages/Partnerships/Collaborators, Communication And Networking:

Other groups within NOAA, in particular the Satellite Applications Branch of NESDIS, has expressed a strong interest in the proposed training. The Department of Defense (DOD) has had considerable interest also.

NOAA is a member of the World Meteorological Organization's Coordination Group for Meteorological Satellites (CGMS). CGMS supports an International Virtual Laboratory for Training in Satellite Meteorology. In paper 17, which was prepared for the CGMS-XXXII congress in 2004, Appendix B lists the expectations for international "Centres of Excellence", Satellite Operators (ie NOAA), and WMO/CGMS. CIRA actively interacts with theRegional Meteorological Training Centers of Excellence in Costa Rica, Barbados, Brazil, and Argentina. The VISITview tool, which is heavily used by SHyMet, has been adopted as an online training tool by CGMS. As such, CIRA, in cooperation with SHyMet and VISIT, has promoted VISITview and shared their expertise in training through:

1) monthly international weather briefings (visitview site http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp ,

2) presentations on VISITview and national and international training efforts where appropriate

See http://rammb.cira.colostate.edu/training/rmtc/ for more information on the international training activities.

The national and international interest outside NWS indicates that the training research and development activities at CIRA have wide-ranging applications.

6. Awards/Honors: None

7. Outreach:

CIRA has participated in monthly VISITview weather briefings using GOES satellite imagery (http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp) and voice via Yahoo messenger between the US and WMO designated RA III and RA IV countries. Each month there is and English/Spanish bilingual session and a Spanish only session. Participants are forecasters, researchers, and graduate and undergraduate students. The sessions last 60-90 minutes. VISIT sessions are proving to be a very powerful training tool. People learn how to use new products in real time situations with appropriate guidance.

Professional Meetings

A poster was presented at the AMS 16th Conference on Satellite Meteorology and Oceanography in Phoenix, AZ in January 2009: "International Satellite Training Activities" by B. Connell, M. Davison, A. Mostek, V. Castro, and T. Whittaker

Presentations

Braun, J**.** was asked to "talk about the weather" on two separate occasions to students of Rocky Mountain High School who attend the *Introduction to Chemistry, Physics, and Earth Sciences* (ICPE) classes - November 13 and December 9, 2008.

Connell, B. gave a presentation on the GOES and the characteristics of its channels to a Remote Sensing class at the Metropolitan State College of Denver in the Fall 2008.

Connell, B**.** traveled to Miami, Florida to present a talk at NOAA's 2008 Satellite Direct Readout Conference (December 8-11). She gave a presentation on "Satellite Training Activities at CIRA." The conference was an excellent venue to find out more information on direct readout capabilities and to meet with international partners.

Connell, B. gave a presentation on the GOES and the characteristics of its channels to a Remote Sensing class at the Metropolitan State College of Denver on November 10, 2008. Since the Remote Sensing class focuses mainly on earth resource topics, the students were presented with the perspective of how meteorologists view and use satellite imagery.

8. Publications:

Conference Proceedings

Connell, B.H**.,** M. Davison, A. Mostek, V. Castro, and T. Whittaker, 2009: International satellite training activities. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Guch, I**.,** S.Q. Kidder, P. Menzel, R. Ferraro, S. Ackerman, D. Khanbilvardi, T. Strub, B. Vant Hull, R. Hudson, and M. DeMaria, 2009: Collaborative training efforts at the NESDIS Cooperative Institutes. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Mostek, A**.,** M. DeMaria, J. Gurka, T.J. Schmit, 2009: NOAA Satellite Training. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

INVESTIGATION OF AEROSOL-CLOUD-RADIATION AND SURFACE FLUX INTERACTIONS USING LARGE EDDY SIMULATIONS

Principal Investigator: Hongli Jiang

NOAA Project Goal / Program: Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate forcing*.*

Key Words: Climate, Aerosol, Radiation, Surface Fluxes

1. Long-term Research Objectives and Specific Plans to Achieve Them:

To perform comparisons of observed radiative fluxes from an airborne radiometer flying above and below fields of clouds and fluxes simulated based on our model output in collaboration with Peter Pilewskie and Sebastian Schmidt (University of Colorado).

To examine and explore the robustness of the scale dependency of microphysical responses to aerosol perturbations to a field of cumulus clouds by studying the impact of improved resolution of cloud dynamics, entrainment, and turbulent mixing at progressively higher model resolutions.

2. Research Accomplishments/Highlights:

We compared observed radiative fluxes from an airborne radiometer and fluxes simulated based on our model output to evaluate the ability of our model to represent the radiative effects of the aerosol-cloud system. A three-dimensional radiative transfer models was applied to our simulated cloud fields and compared to aircraft observations. Results show good statistical agreement between modeled and measured irradiance provided both cloud and aerosol are included in the calculations.

We have performed simulations of aerosol-cloud interactions in trade cumuli (RICO) to assess the sensitivity of cloud macrophysical, dynamical, and radiative properties to aerosol changes at a range of model resolutions. This includes feedbacks among precipitation, entrainment and turbulent mixing.

The region between clouds comprising hydrated aerosol and small cloud fragments has been shown to be of importance for radiative forcing. A study examining the effect of aerosol on the morphology of the inter-cloud region was performed using model simulations of trade cumulus.

3. Comparison of Objectives Vs Actual Accomplishments for Reporting Period:

A paper showing the importance of properly simulating both the aerosol, cloud, radiative fluxes has been published in *Geophysical Research Letters* (Schmidt et al., 2009).

A paper describing the effect of aerosol on trade cumulus cloud morphology has been accepted for publication in the *Journal of Geophysical Research* (Jiang et al. 2009).

A paper describing the effect of aerosol on the morphology of the inter-cloud region has been submitted to *Geophysical Research Letters* (Koren et al. 2009) for publication.

4. Leveraging/Payoff:

We have demonstrated that when viewed in a statistical sense, the large-eddy simulations reproduce the observed populations of non-precipitating warm boundary layer cumulus clouds over land reasonably well (Jiang et al. 2008). The comparisons of the radiative fluxes between measurement and modeling have shown that the measurements below clouds or cloud gaps can only be reproduced by the model calculations when including the aerosol radiative effects (Schmidt et al. 2009). These two studies provide strong indication that the cloud-aerosol system is correctly represented by the LES. In the study of scale dependency of effect of aerosol on trade cumulus clouds, we made important contributions to our physical understanding of aerosol-cloud interactions, particularly (i) that the frequency of convection may be modified by aerosol, and (ii) that the small clouds make very important contributions to the number of clouds, cloud fraction, and even cloud reflectance (Jiang et al. 2009).

5. Research Linkages/Partnerships/Collaborators, Communications, and Networking:

Research was conducted in collaboration with:
Feingold, G: NOAA/ESRL
Schmidt, S. and Pilewskie, P: University of Colorado, Boulder, CO
Koren, I: Weizmann Institute, Israel.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Jiang, H., G. Feingold, H. Jonsson, M-L Lu, P. Y. Chuang, R. C. Flagan, and J. H. Seinfeld, 2008: Statistical comparison of properties of simulated and observed cumulus clouds in the vicinity of Houston during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS). *J. Geophysical Res. 113, D13205, doi:10.1029/2007JD009304*

Jiang, H., G. Feingold, and I. Koren, 2009: Effect of aerosol on trade cumulus cloud morphology. *J. Geophysical Res., in press,* doi:10.1029/2009JD011750.

Koren, I., G. Feingold, H. Jiang, and O. Altaratzi, 2009: Aerosol effects on the inter-cloud region of a small cumulus cloud field. *Geophys. Res. Lett. Submitted*.

Schmidt, K. S., G., Feingold, P., Pilewskie, H. Jiang, O., Coddington, and M., Wendisch, 2009: Irradiance in polluted cumulus fields: Measured and modeled cloud-aerosol effects. *Geophys. Res. Lett.* VOL. 36, L07804, doi:10.1029/2008GL036848.

IPCC STUDIES FOR CLIMATE OBSERVATIONS

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Climate

Key Words: Scientific Data Stewardship (SDS), Microwave Remote Sensing, SSM/T-2, Total Precipitable Water, Data Rescue, Climate Data Records (CDRs)

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The objective of this research is to study the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (FAR) from Working Group 1 and make recommendations on priorities for Scientific Data Stewardship of Climate Data Records (CDR's). Involvement of young scientists in this report is also an objective, which has been achieved.

2. Research Accomplishments/Highlights:

A major early result of this study was the rescue of 15 months of SSM/T-2 data from 1993-1994 to add to NCDC's archive. SSM/T-2 is a passive microwave moisture sounding instrument. The first data exists from late 1991 onwards, but NCDC's archive began in July 1994. CIRA had some old 8mm tapes which were successfully read to extend the archive back to April 1993. This data will be delivered to NCDC for archival (points of contact: Hilawe Semanegus and Axel Graumann). Sources for pre-1993 data are still being sought, personnel of The Aerospace Corp may have some leads at AFWA.

Aaron Schwartz defended his M.S. Thesis entitled "Clouds, Energetics, and Climate in the Arctic from CloudSat" in May 2008. The study used the new CloudSat/CALIPSO dataset in the Arctic to examine the vertical structure of clouds and the generation of eddy available potential energy. The relationship between the vertical structure of clouds and radiation changes at the surface was quantified.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Complete: SSM/T-2 data rescue.

Complete: M.S. Thesis of Aaron Schwartz.

In Progress: Report on priorities for SDS and CDR's of water vapor.

4. Leveraging/Payoff:

The M.S. Thesis of Aaron Schwartz uses new datasets over the Arctic, the region of Earth experiencing the most rapid climate change. Sea ice extent was at a record low in 2007. This will provide a valuable benchmark of clouds and radiation during this time.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

The rescued SSM/T-2 data will be delivered to NCDC and be publicly available for all scientists. SSM/T-2 is the earliest satellite sensor to carry the 183 GHz channels which are sensitive to upper tropospheric moisture. Understanding the change in atmospheric moisture with time is a key component of current global change research.

6. Awards/Honors: None.

7. Outreach:

Aaron Schwartz, M.S. thesis defended May 2008.

Invited talk “Observing Atmospheric Water Vapor for Weather and Climate Applications” at NOAA CoRP Science Symposium, College Park, MD, June 2007.

8. Publications: None.

MONSOON FLOW AND ITS VARIABILITY DURING NAME: OBSERVATIONS AND MODELS

Principal Investigator: Richard H. Johnson

NOAA Project Goal: CL Climate – Understand climate variability and changes to enhance society's ability to plan and respond.

Key Words: North American Monsoon, Modeling

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The goal of this research is to improve understanding of the North American Monsoon and its variability on multiple spatial and temporal scales. Data from the 2004 North American Monsoon Experiment (NAME) will be used to accomplish this goal.

2. Research Accomplishments/Highlights:

--Surface observations over northwestern Mexico during NAME have been used to document the diurnal cycle of the surface flow during July and August 2004. Comparison of the observed flows with the special NAME North American Regional Reanalysis (NARR) reveals significant deficiencies in the NARR's ability to properly represent the sea and land breeze circulations.

--A prominent atmospheric undular bore that occurred during NAME on 31 July has been described using wind profiler data and modeled using the Weather Research and Forecasting (WRF) model. The bore developed as a result of convective outflows colliding with a sea breeze and moved across the Gulf of California where is dissipated over Baja California. Conditions in the Gulf are conducive to the frequent occurrence of internal bores, which serve to transport moisture rapidly along the Gulf.

--The diurnal cycle of convection over the SMO is unique in comparison to other mountainous regions of the tropics and subtropics. Early morning low clouds and insolation characteristics on the western slope of the SMO delay the development of upslope flow and deep convection there to the afternoon and evening

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

--A study has been completed of the diurnal variability of the surface flow over the North American Monsoon region (Ciesielski and Johnson 2008).

--A second study, the NAME gridded sounding data set has been used to determine the latent heating and moistening over northwestern Mexico and the surrounding region.

--Further work is in progress by Andy Newman (Ph.D. student) to understand the diurnal cycle in this complex region using the NCAR WRF model. Work is continuing by Zach

Finch (M.S. student) to study upper-level troughs that affect precipitation in the NAME region using the CSU gridded data set.

--We completed a paper on the correction of the humidity biases in the Vaisala RS-80H sondes that were used in NAME (Ciesielski et al. 2009).

--A paper was published in 2008 on an observational and modeling study of an atmospheric undular bore that occurred during NAME (Martin and Johnson 2008).

4. Leveraging/Payoff:

Research on monsoon surges carried out by Peter Rogers, who joined the NWS Phoenix office after completing the M.S. degree at CSU, was used by the Tucson and Phoenix NWS offices for forecasting monsoon surges and associated rainfall. Peter has since joined the Grand Forks NWS office.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

This work supported by NOAA on NAME is being used by our group and other investigators in NASA studies of precipitation measured from space (TRMM-related research). In addition, the NAME sounding data have been placed on our group web site for public access (http://tornado.atmos.colostate.edu/name/).

6. Awards/Honors:

Richard Johnson was appointed Chair of the Expert Team on Severe Monsoon Weather, of the WMO/CAS Working Group on Tropical Meteorology. Richard Johnson was also appointed a member of the NOAA CPPA Science Panel.

7. Outreach:

Peter Rogers (M.S. 2005), currently employed with the National Weather Service in Grand Forks, ND

Elinor Martin (M.S. 2007), currently pursuing Ph.D. degree at Texas A&M University
Zachary Finch (M.S., in progress)

8. Publications:

Ciesielski, P. E., and R. H. Johnson, 2008: Diurnal cycle of surface flows during 2004 NAME and comparison to model reanalysis. *J. Climate*, 21, 3890-3913.

Ciesielski, P. E., R. H., Johnson, and J. Wang, 2009: Correction of humidity biases in Vaisala RS80-H sondes during NAME. *J. Atmos. Ocean. Tech.* (in press)

Johnson, R. H., P. E. Ciesielski, B. D. McNoldy, P. J. Rogers, and R. K. Taft, 2007: Multiscale variability of the flow during the North American Monsoon Experiment. *J. Climate,* 20, 1628-1648.

Martin, E. R., and R. H. Johnson, 2008: An observational and modeling study of an atmospheric internal bore during NAME 2004. *Mon. Wea. Rev*., 136, 4150-4167.

Rogers, P. J., and R. H. Johnson, 2007: Analysis of the 13-14 July gulf surge event during the 2004 North American Monsoon Experiment. *Mon. Wea. Rev*., 135, 3098-3117.

NESDIS POSTDOCTORAL PROGRAM

Principal Investigators: Various (see below)

NOAA Project Goal: Various (see below)

NESDIS Post Doc - 2008-2009 CIRA Annual Research Report

<u>Yong Chen – NESDIS Post Doc</u>

Project Title: Develop and evaluate Community Radiative Transfer Model (CRTM) for uses in numerical weather prediction models.

Principal Investigator: Steve Miller

NOAA Project Goal: Weather & Water: Serve Society's Needs for Weather and Water Information

Key Words: Community Radiative Transfer Model (CRTM), Satellite Data Assimilation, Impacts

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Develop and validate the CRTM for visible, infrared, and microwave under various atmospheric (clear, aerosol, and cloudy sky) and surface conditions. Integrate new radiative transfer components into CRTM.

Tests of CRTM in satellite data assimilation system GSI (Grid Statistical Interpolation).

2. Research Accomplishments/Highlights:

Land surface emissivity comparisons for IASI window channels have been carried out in the NCEP GSI. The land surface emissivity for IASI is computed using the IR emissivity data base in Community Radiative Transfer Model (CRTM) and the Naval Research Laboratory (NRL) index emissivity model. However, for IASI window channels, the observations under clear conditions can be also used to retrieve the surface emissivity directly since the needed correction for atmospheric absorption is minimal and can be done fairly accurate using the atmospheric profiles from the National Centers for Environmental Prediction (NCEP) global data assimilation (GDAS) and forecast system (GFS). This retrieval is used as "truth". The studies characterize the root mean square errors and standard deviation errors from two methods according to surface types in GFS land surface model. It is found that larger emissivity differences are found over desert for 8.3-9.2µm. Also, the simulated brightness temperatures are shown the larger uncertainty from the two emissivity methods. The hyper-spectral IR land surface emissivity need more investigation, especially over desert area due to the complication of decoupling the emissivity and land surface temperature signals. This work was presented at the 2008 American Geophysical Union Fall Meeting, on 15-19 December 2008, in San Francisco, California.

Assess and improve IASI water vapor channels used in GSI. It is too much vertical structure from IASI water vapor which did not match NWP relatively smooth structure that could cause the negative impacts. Carefully select water vapor channels based on their Jacobians to make sure those channels spreading even according to their peak heights to avoid the too much vertical structure.

Develop the prototype new transmittance model (with Yong Han) which includes the trace gases for hyper-spectral infrared sensor such as CrIS, IASI.

Support Paul Van Delst of NCEP/EMC for the implementation of multiple transmittance model algorithms (ODCAPS) into CRTM.

Update the Sensor Response Function (SRF) software so that the same code works for both infrared and microwave instruments.

Generate the transmittance coefficients for FengYun-3 microwave sensors mwhs_fy3a, mwri_fy3a, and mwts_fy3a in OPTRAN.

Prepare the development of CRTM for NPP-CrIS transmittance coefficients. Programs are written to process the following steps in order to obtain the channel transmittance: Fourier transform transmittance spectra (results from LBLRTM) in to the interferometric domain, apodizing the resultant interferogram with an interferometer instrument response function, and then Fourier transform the result back into the spectral domain (channel base). The coefficients are in two formats, one is for Compact OPTRAN (ODAS), and the other is for new transmittance model (ODPS) which additionally include trace gases coefficients.

The new transmittance model ODPS (Optical Depth in Pressure Space) has been implemented into CRTM (with Yong Han).

ODPS transmittance coefficients (TauCoeff file) for all sensors currently supported by CRTM trained with LBLRTM v11.3 have been finished.

CRTM is ready for new satellite sensors, such as SSMIS on DMSP 17-20, AVHRR3, HIRS4, AMSUA, and MHS on NOAA-19.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Update software work for both new transmittance model (ODPS) and Compact-OPTRAN (ODAS) in LBLRTM calculations. The new transmittance model has increased gas variables and effect transmittances to calculate. The input profiles for LBLRTM are different for ODPS and ODAS, we have to write program more flexible to handle different situations and accordingly to calculate the effect transmittances. Produce the ODPS coefficients for all satellite sensors which are available for ODAS. (Compete) CRTM is ready for CrIS/ATMS-NPP. (Complete)

Implement the multiple transmittance model algorithms into CRTM and use in GSI, Assess the ODPS transmittance model in GSI system, and compare with ODAS in terms of accuracy, speed and impacts. (in progress)

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking: None.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

Prasanjit Dash – NESDIS Post Doc

Project Title: An Improved SST Product from AVHRR/3 Sensor flown OnBoard MetOp-A

Principal Investigator: Steve Miller
Technical Advisor: Alexander Ignatov

NOAA Project Goal: Climate; Environmental Data Record (EDR), primarily Sea Surface Temperature (SST), is derived, archived, and will be used for climatic studies, with a near real-time (NRT) QC/QA and monitoring of the products.

Key Words:

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Establish a robust NRT SST Quality Monitor for satellite SST products from multiple platforms and systems for cross-platform and timeseries stability analyses.

2. Research Accomplishments/Highlights: See below.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

A. A web-based NRT SST Quality Monitor (SQUAM) is established at NESDIS (initial version “complete”; further improvements will be made over time):

Prototype system: This is the SST Quality Monitor (SQUAM) to operationally monitor the SST products of NOAA NESDIS. The interface is web-based and provides information in near real-time time (NRT) for heritage MUT and newer ACSPO..

--Currently, SQUAM continuously monitors AVHRR SST products from five platforms (NOAA16, 17, 18, 19, & MetOp-A) and for two different processing systems: the NESDIS heritage Main Unit Task (MUT) and the newer Advanced Clear-Sky Processor for Oceans (ACSPO).

--SQUAM performs a series of statistical checks and quality control procedures, to monitor the SST products for stability and cross-platform consistency. The diagnostics are posted in near real-time (NRT) on a dedicated web-site at: http://www.star.nesdis.noaa.gov/sod/sst/squam/

--SQUAM compares satellite SSTs with eight other reference SSTs.

--SQUAM compares performances of the MUT system and the ACSPO system.

--From implementation viewpoint, SQUAM has 2 major running subsystems: (1) IDL codes to analyze global SST products and generate comprehensive statistics and diagnostics (2) cron and scripts to run IDL in NRT and web publish. The web-pages were designed with HTML and Javascript and we continuously make it as user-friendlier as is possible.

--SQUAM is fully implemented for AVHRR products and was also tested on selected data for MSG SEVIRI. The SQUAM is designed flexibly to include other newer/future satellite products, e.g., MetOp-B, NPOESS.

--The results of the SQUAM were presented in AMS and GHRSST-2009 meetings.

B. An SST Calibration system at NESDIS has been redesigned and an initial web facility is being set-up to provide access to scientists and users

--The CALVAL system had many elements from heritage (state-of-the-art) but required a comprehensive re-establishment, with newer functionalities.

--The CALVAL system routinely calculates SST coefficients for four platforms (NOAA16, 17, 18, & MetOp-A), from two different processing systems: MUT and ACSPO. The MUT calibration is fully functional and we are currently monitoring the performance of ACSPO coefficients, which will be improved and incorporated into the ACSPO system some time in the future.

--Similar to the SQUAM, the CALVAL has 2 major running subsystems: (1) IDL codes to analyze global SST products and generate comprehensive statistics and diagnostics (2) cron and scripts to run IDL in NRT and web publish.

--Calibration results are posted at: http://www.star.nesdis.noaa.gov/sod/sst/calval/. Currently it is password protected, until in-depth analyses of the results (access can be provided upon request).

--The CALVAL system identifies and handles outliers and their effect on the SST coefficients.

Implemented, in addition to conventional least squares fitting approach, a robust regression approach (new element and yet to be established in the community).

The initial Cal Val system is set-up but needs further research (goal for next year).

4. Leveraging/Payoff:

To understand the global temperature patterns, predict changes in the pattern and quantify its effects, conserve and manage marine resources by providing proper input to global and local models. Provide users and scientific community an easy access to view the performance of SST products that they obtain from NESDIS.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

AMS, GHRSST. The work was reported in GHRSST (www.ghrsst-pp.org) and is expected to be a part of GHRSST at some point of time. Also, will be used a valuable tool for inter-comparison of several SST products, under the IC Technical Advisory Group (IC-TAG) of the GHRSST.

6. Awards/Honors: None.

7. Outreach:

AMS Jan 2009, Arizona
GHRSST May-June 2009, California

8. Publications:

Conference Extended Abstract:

Dash et al., 2009. Web-based global quality control and monitoring of NESDIS AVHRR SST products for long term stability and cross-platform consistency in near real-time. American Meteorological Society (AMS) 89th Annual Meeting & 16th 16th Conference on Satellite Meteorology and Oceanography, Jan 11-15, 2009, Phoenix, AZ, USA. [http://ams.confex.com/ams/pdfpapers/144238.pdf]

Further SQUAM related publications will be listed at:
http://www.star.nesdis.noaa.gov/sod/sst/squam/references.htm

Min-Jeong Kim – NESDIS Post Doc

Project I Title: GOES–R AWG Proxy and Cal/Val Data Developments

Principal Investigator: Dr. Fuzhong Weng

NOAA Project Goal: Supporting NOAA's Mission (programs: geostationary satellite acquisition

Key Words: GOES-R, Radiative Transfer, CRTM, OSSE, Global Forecasting System, Data Assimilation, GSI

Project II Title: The inclusion of cloudy radiance assimilation in NCEP GDAS

Principal Investigator: Dr. Fuzhong Weng

NOAA Project Goal: Supporting NOAA NCEP Weather Forecast Model Improvements

Key Words: GOES-R, Radiative Transfer, CRTM, OSSE, Global Forecasting System, Data Assimilation, GSI

1. Long-term Research Objectives and Specific Plans to Achieve Them:

--Continue to run the GOES-R proxy data management systems
--Develop the cloudy radiance data assimilation system for NOAA NCEP Global Data Assimilation System (GDAS)
--Impact study for microwave radiance assimilations in cloudy sky
--GOES-R impacts assessment report

Specific Plans

To accomplish first objective:
--Set up and update the templates required by the GOES-R Program Office
--Report the research progress for all detailed tasks to GOES-R program office every month

To accomplish second objective:
--Putting the cloudy radiance assimilation components in the NOAA's operational forecasting systems (i.e. Gridpoint Statistical Interpolation (GSI) and Global Forecasting System (GFS) for global forecasts, GSI and WRF_NMM for regional forecasts)
--Improving the framework by testing runs (trial and error)

To accomplish third objective:
--Employing the AMSU-A and SSMIS in the OSSE tests
--Assessments the impacts of cloudy microwave radiance assimilation

To accomplish fourth objective:
--Employing the ABI proxy data sets in the OSSE tests
--Assessments of GOES-R impacts

2. Research Accomplishments/Highlights:

Min-Jeong Kim has been working with GSI code developers in JCSDA since September 2007. She is seeking to improve global analysis by including cloud and precipitation affected microwave measurements in NCEP Global Data Assimilation System (GDAS). Radiance measurements over cloudy regions possibly provide us with the atmospheric total liquid/ice water content, humidity, and temperature. This additional information could help to improve the numerical weather forecast skill. To test the benefits of cloud and precipitation affected microwave measurements in NCEP GDAS, Min-Jeong's research during the last quarter has been focused on two projects:

Project I:
Min-Jeong has been developing adoint models consistent with moisture schemes in current Global Forecast System (GFS) model. There adjoint models are crucial to succeed with assimilating the cloud and precipitation measurements in an analysis system. In GFS model, Clouds and precipitation are generated by three separate schemes including subgrid convection (Simplified Arakawa Schubert (SAS) scheme), grid-scale condensation process, and precipitation process. However, these moisture schemes have strong nonlinearities and discontinuities and it is challenging to use these schemes in data assimilation systems.

To develop adjoint models consistent with current GFS moisture schemes, Min-Jeong has

--completed TL linear modeling for SAS convective schemes which was modified to behave more continuously by removing many thresholds. The SAS schemes is ready for AD coding.

--found a serious nonlinear behavior from one part in the current GFS large scale condensation schemes in some data points : The current large scale condensation scheme calculates cloud coverage (CCRIK) with relative humidity and predetermined relative humidity threshold. This cloud coverage (CCRIK) is employed to calculate the condensed amount of cloud (COND) and evaporated cloud amount (E0). The parameterization to calculate condensed amount of cloud (COND) causes the problem.

She is currently working to mitigate the nonlinearity by testing different diagnostic schemes to compute COND with currently available moisture variables. It is challenging because the results should not be different from the behaviors of GFS original schemes while reducing the nonlinearity.

Next steps are to:
--code the adjoint models of SAS convective scheme.
--complete linearizing large scale condensation schemes
--code adjoint models of large scale condensation schemes

--test these adjoint codes in a simple 1D-var system
--test them in GDAS system and evaluate the performance; and
--write a technical report and journal paper(s)

Project II:
Min-Jeong has been seeking to utilize the Microwave Integrated Retrieval System (MIRS) product in NCEP GDAS when the current GDAS system screens out the microwave radiance data in cloudy region through quality control. MIRS has been developed by NOAA NESDIS to improve temperature and moisture profiles in all weather conditions with the extension of the retrieved products to non-standard surfaces including sea-ice and snow-covered land. Considering the lack of atmospheric observations in cloudy conditions, these profiles might have great potential to improve the analysis.

To evaluate the MIRS data performance, Min-Jeong has been testing with MIRS temperature and humidity profiles retrievals in global parallels during the last quarter.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Objective 1: Set up the GOES-R proxy data management systems

Completed

Objective 2:Developing the cloudy radiance data assimilation system for NOAA operational forecasting models

In progress

Objective 3: Impact assessments for microwave cloudy radiance assimilation in NCEP GDAS

In progress

Objective 4:GOES-R impacts assessment report

Not yet started

4. Leveraging/Payoff:

This research will benefit publics by improving the weather forecasting skills especially for severe storms

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

Partnerships with GOES-R Algorithm Working Groups such as CIMSS, NRL, NESDIS, CICS, and NASA LaRc

Partnerships with JCSDA and NOAA NCEP

6. Awards/Honors

AMS full membership

7. Outreach:

Invited seminars at Met Office and ECMWF (July 2008).

8. Publications:

Kim, M-J, Fuzhong Weng, John Deber, and Russ Treadon, 2009. Moisture schemes for Global Data Assimilation System (GDAS): Description and initial tests (to be submitted)

XingMing Liang – NESDIS Post Doc

Project Title: Satellite Radiance Simulation and Physical SST Retrieval for NOAA/AVHRR, GOES-R/ABI

Principal Investigator: Alexander Ignatov

NOAA Project Goal: Climate: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Key Words: Sea Surface Temperature (SST), GOES-R, ABI, AVHRR, Community Radiative Transfer Model (CRTM), MICROS, Physical SST retrieval.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Geostationary Operational Environmental Satellite (GOES) program is a key element of the National Oceanic and Atmospheric Administration's (NOAA) operations. Advanced Baseline Imager (ABI), will be onboard the GOES-R series which includes more spectral bands and higher spatial resolution as well as faster imaging. Improvements to sea surface temperature (SST) retrievals are crucial for applications using newer ABI data. NOAA has provided a 24/7 SST product using the linear split-window technique (SWT) since 1970 and nonlinear SWT since 1990 based on Advanced Very High Resolution Radiometer (AVHRR) sensors onboard NOAA satellites. The heritage AVHRR SST processing system needs to be redesigned and improved in order to obtain more effective and accurate SST product. Development of AVHRR Clear-Sky Processor for Oceans (ACSPO) is underway for next SST product by NOAA/NESDIS/STAR/SST team. Physical SST retrieval is a key part of ASCPO for exploring blending of physical and regression algorithms and improving SST processor performance.

During the 2007-2008 work, community radiative transfer model (CRTM) has been integrated in ACSPO in conjunction with NCEP/GFS upper air data and Reynolds SST. CRTM was used to simulate TOA sensor measurements in clear-sky brightness temperature over oceans for exploring physical SST retrievals, improving cloud detection, evaluating the quality of sensor radiances and CRTM performance. Near-real time (NRT) monitoring of the model (CRTM) minus observation (AVHRR), or M-O BT biases is critically important for these applications. Thus, developing a web-based NRT tool to monitor IR Clear-sky Radiances over Oceans for SST is the main project in the last annual work. When a robust, accurate and highly effective RTM is obtained, physical SST retrieval will be implemented and extended to other sensors.

Specific Plans to Achieve Them:

Establish a web-based NRT tool for Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS) in AVHRR Ch3B (3.7um), Ch4 (10.8um) and Ch5 (12um) onboard NOAA16-18 and MetOp-A. (Status: complete)

Monitor the stability and cross-platform consistency for AVHRR sensor radiance, evaluate and improve CRTM performance in MICROS. (Status: in progress)

Submit a peer-reviewed paper on Monitoring of IR Clear-sky Radiances over Oceans for SST. (Status: complete)

Work as a part of Sea Surface Temperature (SST) on further development of the Advanced Clear-Sky Processor for Oceans (ACSPO). (Status: in progress)

Extend MICROS functionality to include monitoring BTs from AVHRR/NOAA19, SEVIRI/MSG, VIIRS/NPOESS, and ABI/GOES-R. (Status: in progress)

Develop Initial physical SST retrieval product. Make physical SST retrieval from all individual bands. (Status: yet to be started)

Validate single-channel SST retrievals against Regression-SST, REYNOLD-SST and so on. (Status: yet to be started)

Enhance robustness and accuracy of physical SST retrieval product. Explore blending of physical and regression algorithms for improved SST performance. (Status: yet to be started)

Extend physical SST retrieval for ABI/GOES-R, SEVIRI/MSG or other IR sensors. (Status: yet to be started)

2. Research Accomplishments/Highlights:

Established monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS, http://www.star.nesdis.noaa.gov/sod/sst/micros/), a web-based tool to evaluate the BT (model minus observation) and SST (satellite minus Reynolds) biases in the ACSPO product.

Worked to validate and improve the CRTM performance by MICROS analysis:

--NOAA16 Ch3B was found out of M-O bias family of other platforms in ACSPO V1.0. It was due to the out of band effect on the sensor response function of NOAA16 Ch3B. This anomaly was solved when CRTM version was updated from r577 to v1.1 in ACSPO.

--As second author, a paper titled on “Effect of out-of-band response in NOAA-16 AVHRR Channel 3B on top-of-atmosphere radiances calculated with the Community Radiative Transfer Model” has been published on J. Atmos. Oceanic Technol (Liu et al., 2009; http://www.star.nesdis.noaa.gov/sod/sst/micros/pdf/liu_2009.pdf)

--Treatment of solar reflection in CRTM was found inaccurate for oceans. Using the lambert’s surface assumption and not accounting the solar relative azimuth angle dependence in the solar reflectance calculation in current CRTM version result in underestimate in the sun glint field and overestimate in the other area. Work is underway with CRTM team to use Cox-Munk model instead of current CRTM solar reflectance, and to validate and improve CRTM daytime calculation (Figure 1).

--A large negative M-O bias in SEVIRI IR03.9 band (~-1.5 K) was found when extending the MICROS functionality to include SEVIRI/MSG data (Figure 2). Work is underway with CRTM team to discover this mystery.

Added robust statistics and double-differencing technique in MICROS to establishing cross-sensor calibration links for the Global Space-Based Inter-Calibration System (GSICS, Figure 3).

Extended MICROS functionality to include NOAA19 data (Figure 3) and SEVIRI/MSG2 (Figure 2,).

Submitted a peer-reviewed paper on Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS): Near-Real Time Web-Based Tool for Monitoring CRTM – AVHRR Biases on Journal Geophysical Research.
http://www.star.nesdis.noaa.gov/sod/sst/micros/pdf/micros_JGR.pdf

Published a paper titled on "Implementation of the Community Radiative Transfer Model (CRTM) in Advanced Clear-Sky Processor for Oceans (ACSPO) and validation against nighttime AVHRR radiances" on Journal Geophysical Research (Liang et al., 2009, http://www.star.nesdis.noaa.gov/sod/sst/micros/pdf/JGR_2008_CRTM_ACSPO.pdf)

Upgraded ACSPO v1.0 to V1.02 by using CRTM V1.1 instead of CRTM r577, using daily Reynolds SST instead of week SST as CRTM input, and using Planck function weight transmittance coefficient data instead of ordinary. tested out ACSPO v1.02, V1.10 and V1.20 by MICROS analysis.

Participated in AMS annual meeting (2009), as first author or co-author, published five abstract-extends on the AMS 2009 conferences (see the publication section).

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period: None

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking: None.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Dash, P., A. Ignatov, Y. Kihai, J. Sapper, and X. M. Liang, Web-based Global Quality Control and Monitoring of NESDIS AVHRR SST Products for Long Term Stability and Cross-platform Consistency in Near Real-Time. Phoenix, AZ, AMS Annual Meeting, 2009.
http://ams.confex.com/ams/pdfpapers/144238.pdf

Liang, X. M. and A. Ignatov. Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS): Near-Real Time, Web-Based Tool for Monitoring CRTM-AVHRR Biases, submitted to J. Geophys. Res
http://www.star.nesdis.noaa.gov/sod/sst/micros/pdf/micros_JGR.pdf

Liang, X. M., A. Ignatov, and Y. Kihai. Implementation of the Community Radiative Transfer Model (CRTM) in Advanced Clear-Sky Processor for Oceans (ACSPO) and validation against nighttime radiances. J. Geophys. Res, 114, D06112, DOI:10.1029/2008JD010960, 2009.
http://www.star.nesdis.noaa.gov/sod/sst/micros/pdf/JGR_2008_CRTM_ACSPO.pdf

Liang, X. M., A. Ignatov, Y. Kihai, and F. Xu, Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS): Near-Real Time Web-based Tool to Monitor CRTM - AVHRR Biases for Improved Cloud Mask and SST Retrievals. Phoenix, AZ, AMS Annual Meeting, 2009.
http://ams.confex.com/ams/pdfpapers/143875.pdf

Liu, Q. H., X. M. Liang, Y. Han, P. van Delst, Y. Chen, A. Ignatov, and F. Z. Weng. Effect of out-of-band response in NOAA-16 AVHRR Channel 3B on top-of-atmosphere radiances calculated with the Community Radiative Transfer Model. J. Atm. Oceanic Technol, DOI: 10.1175/2009JTECHA1259.1., 2009.
http://www.star.nesdis.noaa.gov/sod/sst/micros/pdf/liu_2009.pdf

Petrenko, B., A. Ignatov, N. Shabanov, X. Liang, Y. Kihai, and A. Heidinger, Cloud Mask and Quality Control for SST within the Advanced Clear Sky Processor for Oceans (ACSPO). Phoenix, AZ, AMS Annual Meeting, 2009.
http://ams.confex.com/ams/pdfpapers/143856.pdf

Shabanov, N., A. Ignatov, B. Petrenko, Y. Kihai, X. Liang, W. Guo, F. Xu, P. Dash, M. Goldberg, and J. Sapper, Prototyping SST Retrievals from GOES-R ABI with MSG SEVIRI Data. Phoenix, AZ, AMS Annual Meeting, 2009.
http://ams.confex.com/ams/pdfpapers/143903.pdf

Xu, F., A. Ignatov, and X. Liang, Towards Continuous Error Characterization of Sea Surface Temperature in the Advanced Clear-sky Processor for Oceans. Phoenix, AZ, AMS Annual Meeting, 2009.
http://ams.confex.com/ams/pdfpapers/143882.pdf

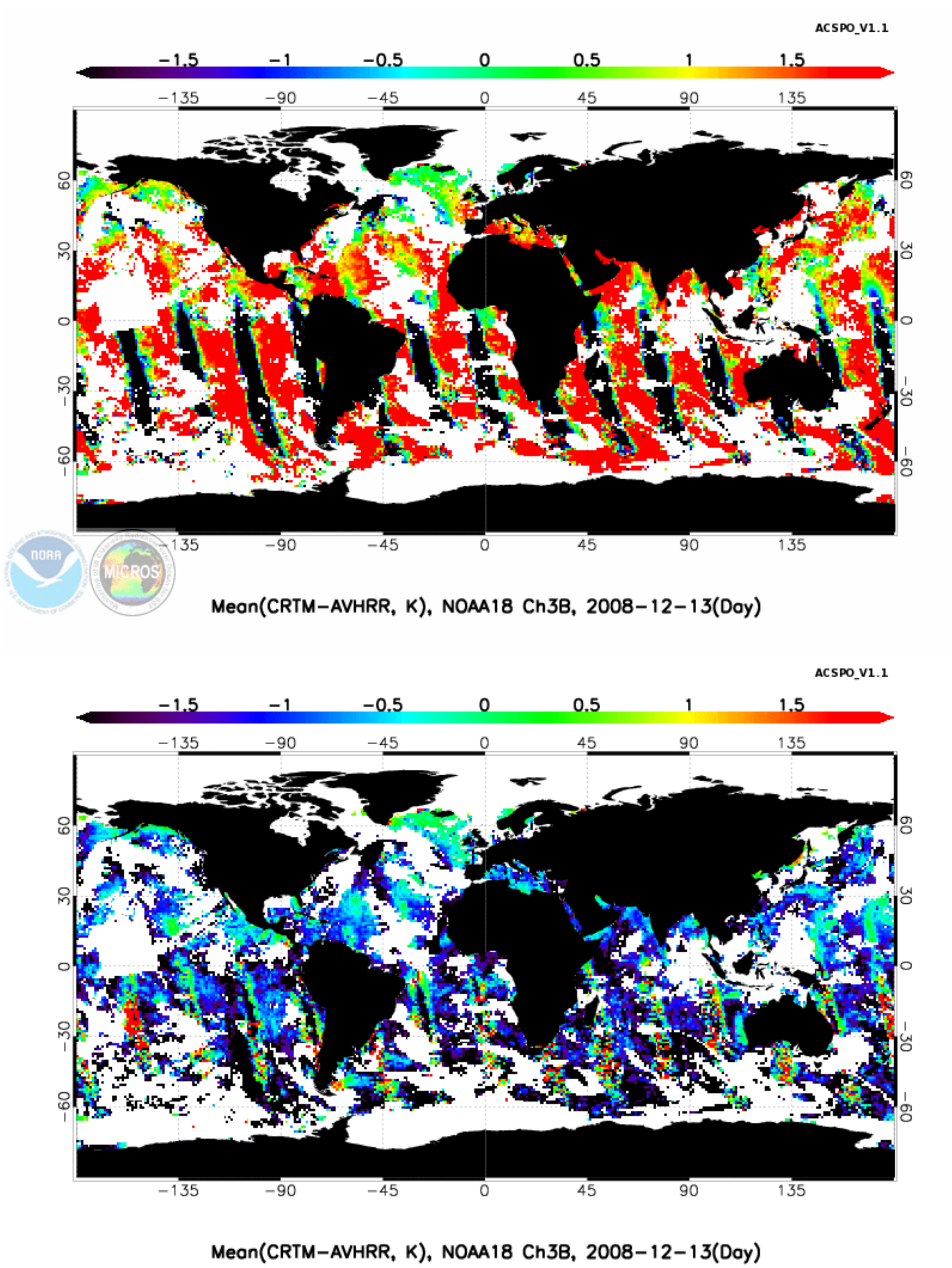

Figure 1. Global geophysical distribution of M-O bias in NOAA18 Ch3B in daytime of Dec. 13, 2008. Upper panel: solar reflectance model used in current CRTM version; bottom panel: Cox-Munk model was used in CRTM.

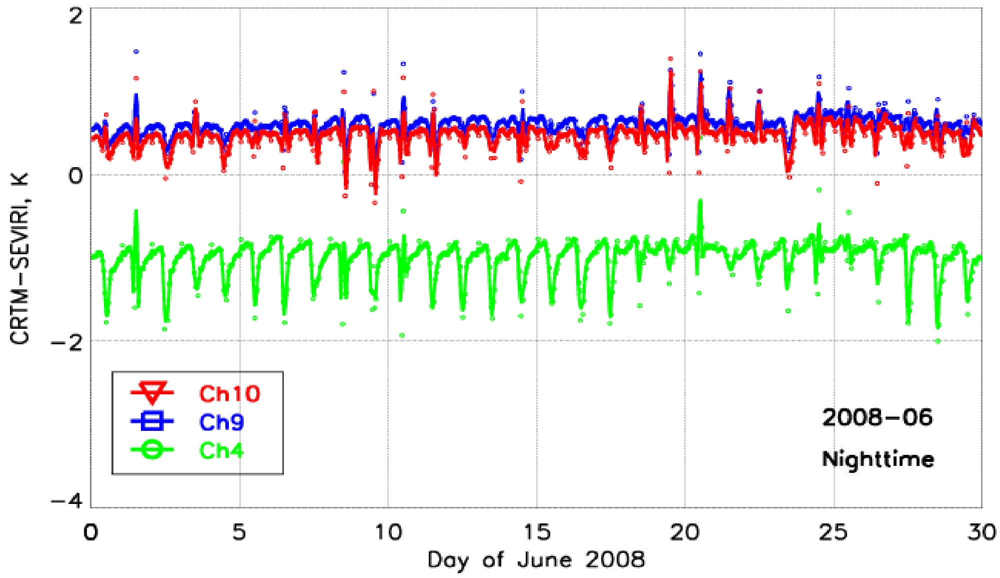

Figure 2. Time series of global M-O bias for SEVIRI/MSG2 Ch4 (3.9um), Ch9 (10.8um) and Ch10 (12um) during the nighttime of June 2008. the SEVIRI IR03.9 band was biased by ~-1.5 K.

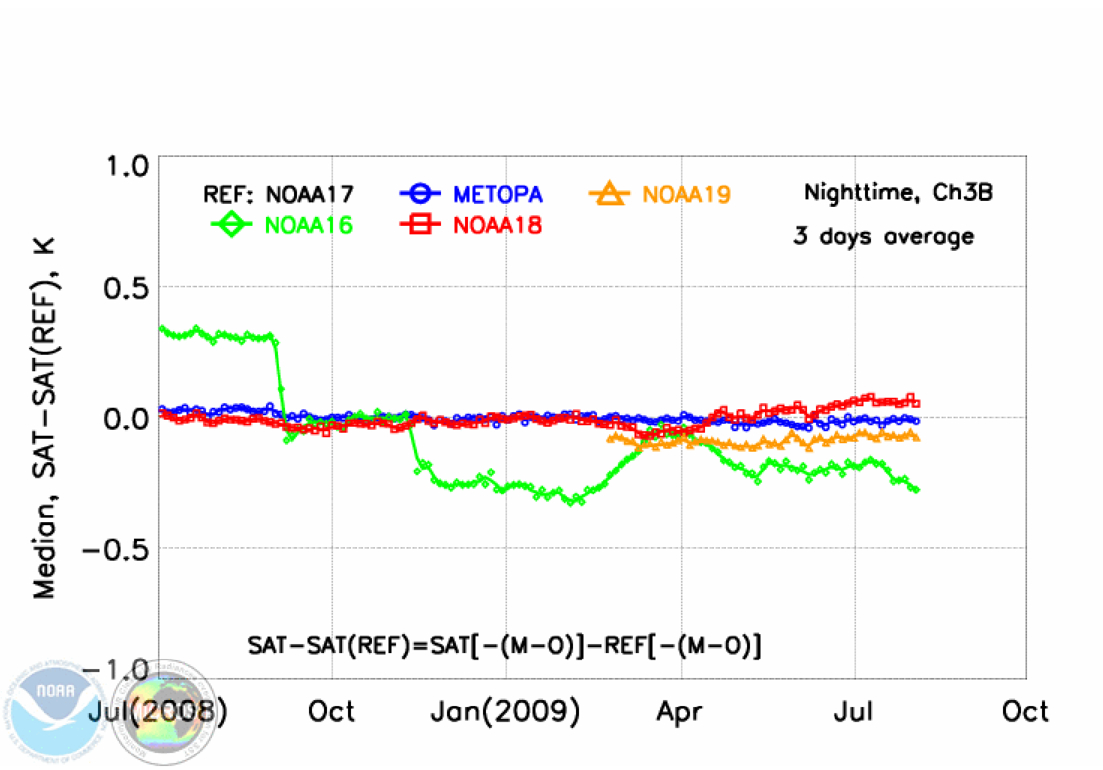

Figure 3. Cross-platform double-differences in AVHRR Ch3b. Data are smoothed out by a three-day moving averaging filter to suppress noise and rectify signal.

Wei Shi – NESDIS Post Doc

Project Title: Ocean color algorithm development and application.

PI: Menghua Wang (NOAA)

NOAA Project Goal:

Key Words: Ocean Color, Coastal Remote Sensing, Marine Ecosystem, Turbid Waters, Harmful Algae Bloom.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Development of new ocean color algorithm for global climate study and coastal and in-land water ecosystem monitoring.

2. Research Accomplishments/Highlights:

SWIR atmospheric correction algorithm developed by Wang and Shi for ocean color remote sensing has extensive application in the coastal regions and in-land waters. During the period of 2008 – 2009, we have demonstrated this algorithm can be applied to derive accurate coastal bio-optical products through a series of publications. It can significantly improve the ability to monitor the physical, geochemical and biological processes in the coastal region.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

See publication list.

4. Leveraging/Payoff:

Due to significant improvement of the SWIR-base ocean color products in the coast region, NOAA Ocean Color Product Oversight Panel (OCPOP) has chosen SWIR/NIR derived ocean color products as NOAA's operational ocean color products for the current and future missions. Related development work for the transition from research to operation is ongoing.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking: None.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications:

Liu, X., M. Wang and W. Shi, A Study of a Hurricane Katrina-Induced Phytoplankton Bloom Using Satellite Observations and Model Simulations, J. Geophys. Res., 114, C03023, doi:10.1029/2008JC004934, 2009.
Shi W. and M. Wang, Three-Dimension Observations from MODIS and CALIPSO for Ocean Responses to Cyclone Nargis in the Gulf of Martaban, Geophy. Res. Lett., V35, L21603, doi:10.1029/2008GL035279, 2008.

Shi W. and M. Wang, An Assessment of the Ocean Black Pixel Assumption for the MODIS SWIR Bands, Remote Sens Environ., V. 113, 1587-1597, doi:10.1016/j.rse.2009.03.011, 2009.

Shi W. and M. Wang, Satellite Observations of Environmental Changes from Tonga Volcano Eruption in the Southern Tropical Pacific, Optics Express, in review, 2009.
Shi W. and M. Wang, Green Macroalgae Blooms in the Yellow Sea during the Spring and Summer of 2008, J. Geophys. Res., in review, 2009.

Shi W. and M. Wang, Satellite Observations of Flood-Driven Mississippi River Plume in the Spring 2008, Geophy. Res. Lett., V. 36, DOI: 10.1029/2009GL037210, 2009.

Wang, M. and W. Shi, Satellite observed blue-green algae blooms in China's Lake Taihu, EOS, Transactions, AGU, edited, pp. 201-202, 2008.

Wang M. and W. Shi, Detection of Ice and Mixed Ice-Water Pixels for MODIS Ocean Color Data Processing, IEEE Transactions on Geoscience and Remote Sensing, in press, 2009.

Wang, M., S. Son and W. Shi, A Validation Study for the SWIR and NIR- SWIR Atmospheric Correction Algorithm Using SeaBASS Data, Remote Sens. Environ., 113, 635 – 644, doi: 10.1016/j.rse.2008.11.005, 2009.

Feng Xu – NESDIS Post Doc

Project Title: GOES-R

Principal Investigator: Alexander Ignatov

NOAA Project Goal: Support NOAA's Mission, Geostationary Satellite Acquisition

Key Words: Sea Surface Temperature, Error Characterization, Quality Control of In Situ SST

1. Long-term Research Objectives and Specific Plans to Achieve Them:

a) SST error characterization.

--Objective:
Describe SST accuracy as a function of retrieval conditions. SST Accuracy in each retrieval point (rather than one global Bias/RMS

--Plan:
Stratify SST residual by retrieval space (angle, SST, water vapor, ambient cloud, ..); Fit analytical curves to Bias/RMS = f (angle, SST, water vapor, ..); Technical issues (Cover retrieval space; multi-dimensional analyses; space/time scales; ..)

b) Quality control of in situ SST
--Objective:
Provide operational quality control system of in situ SST observation
--Plan:
Initially implement quality control method of [Ingleby and Huddleston 2007; Lorenc and Hammon, 1988]; Then build online monitoring and feedback system of in situ SST statistics

c) Evaluation of cloud mask
--Objective:
Provide justification of current cloud mask algorithm and suggestions of improvement.
--Plan:
Evaluate and compare different tests employed in current cloud mask and perform sensitivity analyses versus perturbation in model input and ancillary information

2. Research Accomplishments/Highlights:

--Proposed and preliminary tested a prototype continuous error characterization model for SST
--Initially set up a web presentation of near real-time SST error characterization results;
--Conducted a survey on in-situ SST data from three different sources;
--Prepared and submitted a manuscript on in-situ survey for peer-reviewed publication;
--Presented poster and extended abstract on error characterization result at AMS 2009 conference http://ams.confex.com/ams/pdfpapers/143882.pdf

--Contributed to error characterization analyses of MSG/SEVIRI data and to MICROS analyses
--Co-authored two other AMS posters and extended abstracts
http://ams.confex.com/ams/pdfpapers/143875.pdf
http://ams.confex.com/ams/pdfpapers/143903.pdf

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

a) SST error characterization: in progress. Preliminary analyzed Ambient Cloud dependences and setup a webpage for monitoring.

b) Quality control of in situ SST: in progress. Prepared a manuscript for peer-reviewed publication; Quality control system development undergoing.

c) Evaluation of cloud mask: yet to be started.

4. Leveraging/Payoff:

SST error characterization is useful in 5 aspects:
--Evaluate the performance of the current SST product and identify areas for improvement
--Guide future optimization of SST products
--Provide a generic automatic tool for quick error characterization in SST product
--Provide comprehensive SST error characterization to users
--Facilitate blending with other products (requires error in each retrieval point)

This tool is aimed to provide accuracy information for our ACSPO SST product in its future L2P format which is compatible with GHRSS specification.

Quality control of in situ SST is critically important in ensuring the accuracy and uniformity of in situ SST which are frequently used in the process of calibration and validation of satellite product. It directly determines the quality of satellite SST product. As the new program GOES-R and NPOESS coming up, careful revision of the available in situ SST observations is the key to the improved Cal/Val of the historical data records as well as of the new generation SST products from AVHRR, VIIRS, and ABI.

Evaluation of current cloud mask is expected to give advices on solving problems, such as the ambient cloud detection, cloud leakage and day night discontinuity. This will lead to improvement of accuracy and quality of SST product. All SST data users (different agencies across the country) would be benefited.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

None

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Liang, X., A. Ignatov, Y. Kihai, F. Xu: Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS): Near-Real Time, Web-Based Tool for Monitoring CRTM - AVHRR Biases for Improved Cloud Mask and SST Retrievals, AMS Annual Meeting, Future NPOESS and GOES-R, January 2009, Phoenix, AZ.

Shabanov, N., A.Ignatov, B.Petrenko, Y.Kihai, X.Liang, W.Guo, F.Xu, P.Dash, M.Goldberg, J.Sapper: Prototyping SST Retrievals from GOES-R ABI with MSG SEVIRI data. AMS Annual Meeting, Future NPOESS and GOES-R, January 2009, Phoenix, AZ

Xu, F., A.Ignatov, X.Liang: Error Characterization in the AVHRR Clear-Sky Processor for Oceans (ACSPO) Sea Surface Temperatures. AMS Annual Meeting, Future NPOESS and GOES-R, January 2009, Phoenix, AZ

Hao Zhang – NESDIS Post Doc

Project Title: Evaluating Sun-glitter Models Using MODIS imageries

Principal Investigator: Dr. Menghua Wang (CIRA technical advisor)

NOAA Project Goal: N/A

Key Words: Satellite Remote Sensing, Ocean Color, Sun Glint, Atmospheric Correction

1. Long-term Research Objectives and Specific Plans to Achieve Them:

In ocean color remote sensing it is crucial to mask out sun glint contaminated area to perform meaningful aerosol retrieval and perform atmospheric corrections. In past years we have found that the Cox-Munk anisotropic model has the best performance and thus the isotropic model being used in operational research should be replaced. We are trying to increase the retrievable number of pixels using the anisotropic model.

2. Research Accomplishments/Highlights:

We have found that some glint contaminated pixels may not produce any meaningful aerosol retrievals. This was not caused by strong glint radiance values but possibly by incorrect glint model predictions. This could be attributed to the fact that the ancillary data such as wind speed and direction provided by climate models (NCEP data) may not be very accurate. We are now in the process of evaluating the feasibility of performing meaningful retrievals by modifying the wind speed within the reasonable fluctuation ranges of the NCEP data.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Work in progress.

4. Leveraging/Payoff:

Once completed, this approach may significantly increase the usable number of pixels in ocean color imagery.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

None.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications:

Zhang, H. and M. H. Wang, “Evaluations of sun glint models using MODIS measurement,” submitted;

Zhang, H. and M. H. Wang, “Evaluating sun glitter models using MODIS measurement,” invited talk, 439. WE-Heraeus-Seminar: Determination of Atmospheric Aerosol Properties using Satellite Measurements, Bad Honnef, Germany, August 17-19, 2009

POES-GOES BLENDED HYDROMETEOROLOGICAL PRODUCTS

Principal Investigator: Stan Kidder

NOAA Project Goal: Weather and Water

Key Words: AMSU, SSM/I, GPS, GOES Sounder, Total Precipitable Water (TPW), MiRS, AWIPS, QPF, Flash Flood Forecasting, DPEAS.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This product builds upon earlier NOAA PSDI (Product Services Development Initiative) work at CIRA to deliver operational algorithms for blended total precipitable water (TPW) into AWIPS Operational Build 9 in early 2009. The products were declared operational in Spring 2009 and are being distributed throughout NWS via AWIPS.

Research continues into improving the product with new data sets and scientifically enhanced blending processes. Exploration of creating the TPW over land and in variable topography is of particular interest. The data sets being currently researched are:

--NOAA MiRS microwave TPW product over land
--GPS TPW from an ever-expanding network
--GOES Sounder TPW

An additional research focus is on tailoring the product for mesoscale/nowcasting applications (e.g. NOAA SPC) versus synoptic-scale users (e.g. NOAA TPC).

A blended rainrate product for forecasters from existing retrievals is under investigation as well. Many interesting science questions can be found at the intersection of the water vapor and precipitation fields.

2. Research Accomplishments/Highlights:

The merged TPW and accompanying TPW anomaly product developed at CIRA currently use inputs from four different types of sensors (AMSU, SSM/I, GPS, and GOES Sounder), plus climatology data, to create near real-time blended moisture products. The web sites http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw are routinely accessed by NWS forecasters and the public.

McIDAS files are currently generated at CIRA to serve some users and accessed by the NOAA Satellite Analysis Branch (SAB) and the NASA SPoRT (Short-term Prediction Research and Transition) Center.

A training module on the blended TPW product was created with the NASA SPoRT Center (Kevin Fuell) and also with the NOAA COMET program (Brian Motta, Ross Van Til).

An example of the current blended TPW products from the web site is shown in Figure 1.

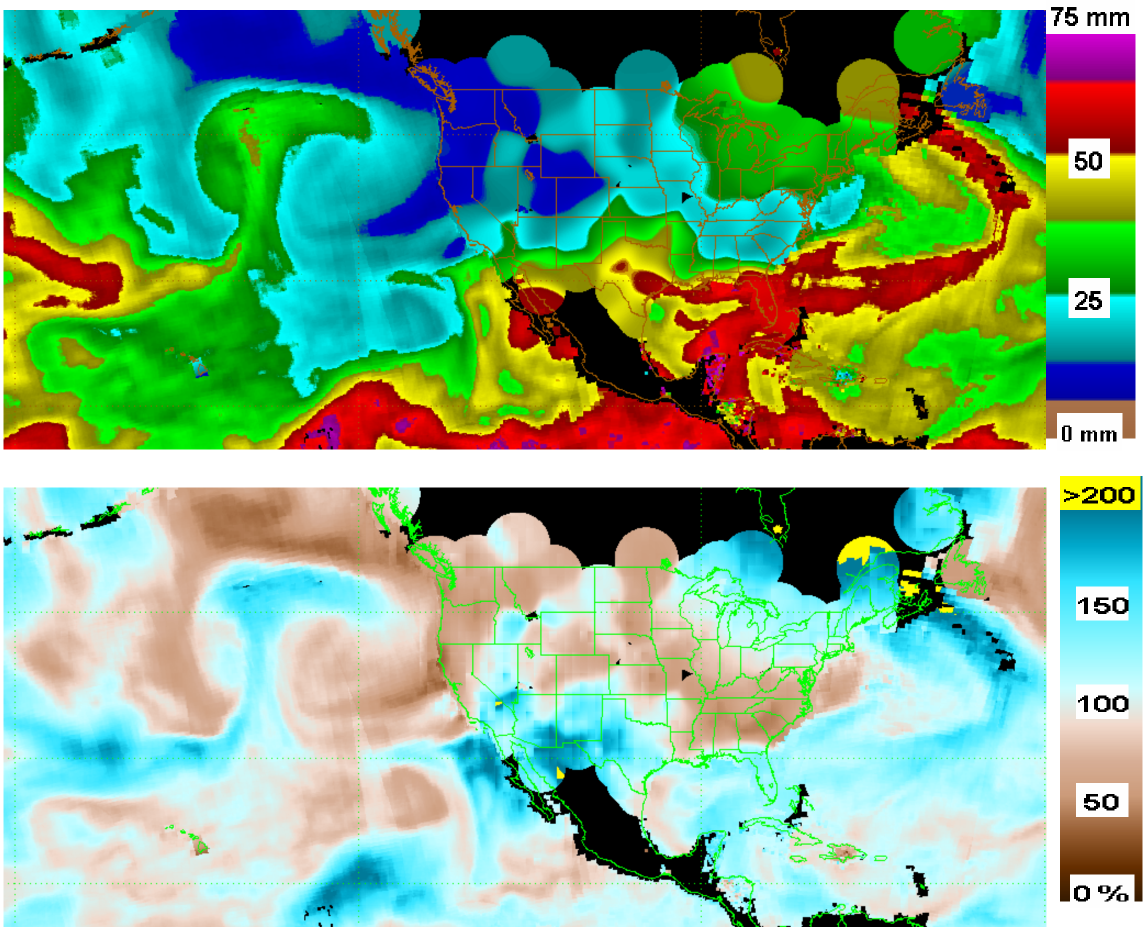

Figure 1: The blended TPW (top, TPW in mm) and TPW anomaly (bottom, percentage of weekly normal) for 12 UTC, June 30, 2009.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Complete: Implementation of the blended TPW product into AWIPS Operational Build 9. All of the production is now running at OSDPD. CIRA maintains a shadow system to serve the website and for scientific experimentation.

Complete: CIRA magazine article (Spring 2008) on the products and their uses.

In Progress: Research on enhanced blended TPW over land. Research on blended rainrate products.

Tech Transferred: Successful implementation into AWIPS Operational Build 9 occurred in Spring of 2009.

4. Leveraging/Payoff:

A coherent analysis of moisture from many sources for forecasters is the goal of this work. Such a product has not previously been available. The blended TPW website http://amsu.cira.colostate.edu/gpstpw is accessed by NWS forecasters on a daily basis. The new product monitoring website http://www.osdpd.noaa.gov/bTPW/ was created by NOAA to monitor the products and provide a variety of display options

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

This work has great bearing on the NPOESS system in development by NOAA/NASA and DoD. How do we provide the forecaster with an easy-to-use view of the meteorological fields of interest from many sensors? How do we account for the strengths and weaknesses of these products? How do we bring together the strengths of the geostationary and polar products? How can we entrain the new NOAA MIRS system results into these products? Can we blend the NPP results in when that data become available to prepare for NPOESS?

6. Awards/Honors: None.

7. Outreach:

The web sites http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw are routinely accessed by NWS personnel. These sites are also available to the public to show a view of atmospheric moisture unavailable elsewhere. For instance, the Dole Fruit Company is a regular user. We have received questions from scientists in Asia and Africa on the products. In February, 2009, we received an email message (Fig. 2) from a meteorologist with the U.S. Army Corp of Engineers explaining how he uses the CIRA Blended TPW products.

8. Publications:

Forsythe, J. M., S. Q. Kidder, A. S. Jones, and S. J. Kusselson, 2008: "CIRA's multisensor blended total precipitable water products serve forecaster needs". CIRA magazine article (Spring 2008 issue).

Forsythe, J. M, S. Q. Kidder, A. S. Jones, S. Kusselson and T. H. Vonder Haar, 2009: Increasing the land coverage of blended multisensor total precipitable water (TPW) products for weather analysis. 16th AMS Satellite Meteorology and Oceanogrphy Conference, Phoenix, AZ.

Kusselson, S.J., L. Zhao, J. Paquette, S. Q. Kidder, J. M. Forsythe, and A. S. Jones, 2009: An Update on the Operational Implementation of Blended Total Precipitable Water (TPW) Products for 2009 with Application Examples. 33rd National Weather Association Meeting.

RESEARCH & DEVELOPMENT FOR GOES-R RISK REDUCTION

Principal Investigators: Steve Miller in collaboration with Mark DeMaria and Don Hillger

NOAA Project Goal: Weather and Water

Key Words: GOES-R, Risk-Reduction, product development, ABI

1. Long-term Research Objectives And Specific Plans To Achieve Them:

The long term research objectives are to identify the utility of GOES-R data along with advanced product development, and Advanced Baseline Imager (ABI) applications.

Specific plans to achieve the above objectives are to focus on mesoscale weather events with fast time scales including hurricanes, severe thunderstorms, lake effect snow, and fog. In addition, long-term objectives include simulating GOES-R data in the following two ways:

--Use existing operational and experimental satellite data.
--Use a numerical cloud model in conjunction with an observational operator— that contains OPTRAN code and radiative transfer models, to produce synthetic GOES-R images.

2. Research Accommplishments/Highlights:

This research is divided into six project areas including I. Data assimilation; II. Hazard studies; III. Severe Weather; IV. Training; V. Tropical Cyclones; and VI. Winter Weather. Further details are described below.

Project I: <u>Data Assimilation: Extracting Maximum Information from the GOES-R Data</u>

The goal of this project is to develop algorithms for data assimilation using the Weather Research and Forecasting (WRF) model and the Maximum Likelihood Ensemble Filter (MLEF).

In order to develop algorithms for assimilation of band-averaged AIRS and/or MSG radiances similar to GOES-R ABI radiances, the MLEF algorithm was updated so it could handle the assimilation of real AIRS, MSG and other satellite radiance observations similar to GOES-R ABI radiances. This was achieved by interfacing the MLEF with the newest version of the Community Radiative Transfer Model (CRTM) code and coefficient files, which were obtained from the JCSDA. The next step was to evaluate information measures of satellite observations similar to GOES-R ABI data (e.g., band-averaged AIRS and/or MSG radiances). Synthetic and real MSG radiances were used to perform the testing of the algorithms. The results were summarized in a manuscript titled "Assimilating synthetic GOES-R radiances in cloudy conditions using an ensemble-based method" and submitted it to the *International Journal of Remote*

Sensing. The results will also be presented at the upcoming EUMETSAT Meteorological Conference.

The algorithm's ability to extract maximum information from the data through the use of various information measures was also successfully evaluated by using the NCEP conventional observations (radiosonde, synop, wind profiler, aircraft) and synthetic GOES-R observations. Two different types of information measures (which have also been successfully used in other data assimilation studies) are being used for this study: *degrees of freedom for signal* and *E-dimension*. The experimental results indicate that the two information measures are similar, but also complementary since the former is more sensitive to the observation errors, while the latter is more sensitive to the model dynamics. Both measures proved to be useful for extracting maximum information from the GOES-R data. So far these data assimilation experiments focused on the study of an extra tropical cyclone named Kyrill (occurred over northern Europe in January 2007). Additional data assimilation results for severe weather cases and hurricanes will be examined in coordination with the JCSDA.

Project II: Hazards Studies with GOES-R Advanced Baseline Imager (ABI)

The focus of CIRA's hazard studies are to exploit the high temporal resolution of GOES-R ABI and its large number of channels which allows for the development of essential new hazard products which require rapid response like fire, volcanic ash and fog.

Product variants to existing fog-stratus and blowing-dust products, both in terms of image combinations/differences and the colors used to display the features of interest in these products, were generated and displayed online for feedback from potential users.

Additional data were collected, processed to test product changes to the existing volcanic ash enhancement product. For this case study, imagery for the Okmok (Alaska Aleutian) volcano eruption from 12/13 July 2008 was analyzed through Principal Component Image (PCI) analysis. PCIs, which extract dominant image combinations from the available GOES bands, are enhanced with RGB (Red, Green, Blue: 3-color) analysis to better show the associated clouds and ash in the images. See Figure 1 and 2 below for an explanation. Real-time animated loops of these PCI and RGB products are available online at
http://rammb.cira.colostate.edu/ramsdis/online/goes-r.asp

Work also begun to build on current forest fire datasets to create new datasets containing smoke and trace gas signatures in relevant channels of GOES-R ABI. The expected product is synthetic imagery for use in developing products for fire, smoke, and trace gas detection to support GOES-R AWG land and air quality teams.

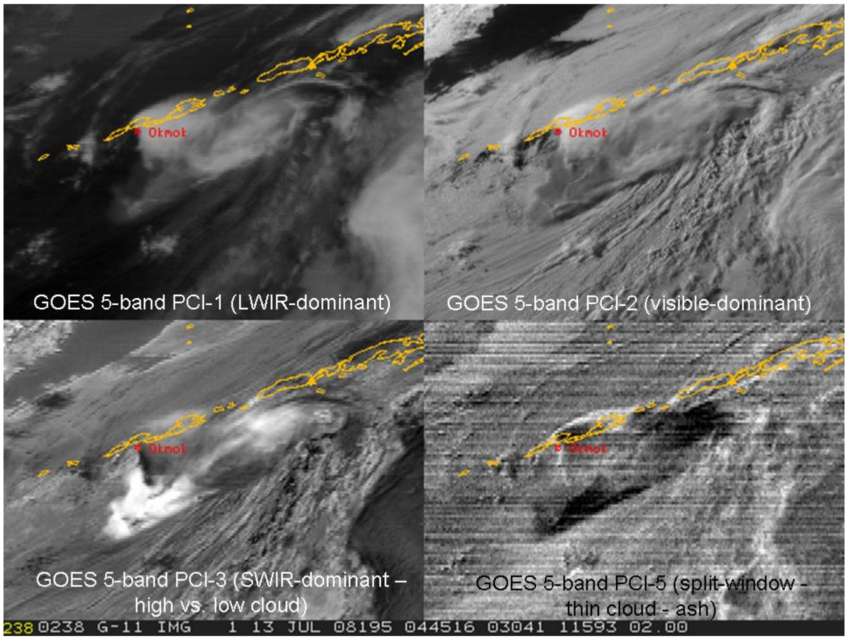

Figure 1. PCI analysis presented in a 4-panel display: The upper-left panel is dominated by the LWIR composite (high clouds are white); the upper-right panel is dominated by the visible band; the lower-left panel is dominated by the SWIR band, showing low (white) vs. high (darker) cloud; and the lower-right panel is dominated by the split-window difference, showing mainly thin cloud and ash (dark areas). PCI-4, which is dominated by the WV band, is not shown.

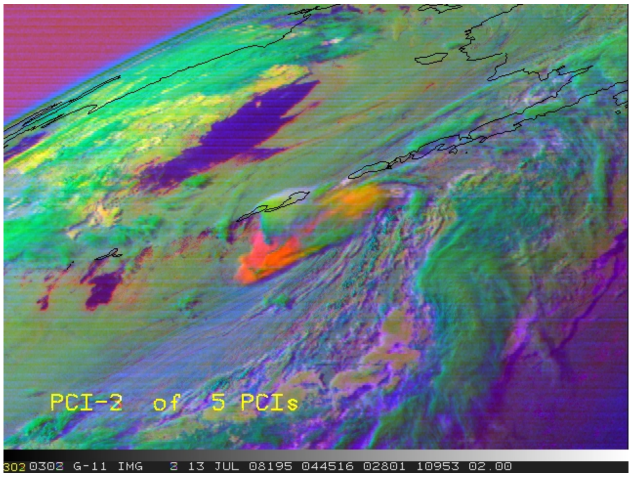

Figure 2. PCIs from Figure 1 are combined in this image using RGB (3-color) analysis. The colors were chosen to enhance the ash cloud, with PCI-3, 2, and 5 as Red, Green, and Blue, respectively. Clear areas in the image are deep purple, high clouds are mainly green, lower clouds are yellow, and heavily-ash-dominated cloud is orange. Note the higher concentration of ash in the plume south of the volcano vs. the plume east of the volcano.

Project III: Severe Weather

GOES-R ABI temporal sampling rate of 5 minutes and the 2 km footprint is well suited for severe weather applications. Our severe weather research took advantage of existing software to generate synthetic GOES-R ABI imagery to support wind requests for severe weather, aviation requests for particle size, proxy data requests for data assimilation studies, and GOES-R AWG proxy data requests for MCS. These proxy datasets also supported the GOES-R algorithm development.

Satellite data were collected from MSG-1 (aka Meteosat-8) for the Kyrill storm. This storm moved over southern England and northern Europe on 18 January 2007. COSMIC sounding data for this case was collected in addition. In order to make synthetic MSG-1 data, we acquired the Community Radiative Transfer Model version 1.1 (crtm_v1.1). This allowed us to obtain gaseous optical depths for specific Meteosat-8 channels. As a first step, synthetic GOES-R imagery was used for the initial assimilation experiments. A manuscript entitled, "Assimilating synthetic GOES-R radiances in cloudy conditions using an ensemble-based method" has been submitted to the *International Journal of Remote Sensing*.

In order to test the synthetic imagery application to MCS, North American Regional Reanalysis and GOES-12 data were collected for the MCS that occurred on 3-4 April 2007. Results from a CSU RAMS model forecast run for this severe weather event were used to produce synthetic GOES-R ABI imagery for the 10 upper GOES-R ABI channels from 3.9 µm to 13.3 µm.

One of our additional research objectives was to investigate particle size in severe thunderstorms. Previously, imagery at 3.9 µm was the smallest wavelength for which imagery was produced. For the investigation of storm particle size, synthetic imagery at 2.25 µm was generated additionally. An interesting consequence of this particular case came about by comparing synthetic and observed GOES-12 imagery at 3.9 µm. As a result, a coding error was detected in RAMS. This highlights the potential use of synthetic imagery to evaluate model performance. A manuscript entitled, "An Example of the use of Synthetic 3.9 µm GOES-12 Imagery for Two-Moment Microphysical Evaluation" was submitted to the *International Journal of Remote Sensing*.

Project IV: Training

Our training project leveraged on and enhanced existing training structure. All training sessions were provided through the VISIT and SHyMet programs. The training objective was to ensure that the future GOES-R dataset user is well informed about the new capabilities and is capable of making decisions on the use of new GOES-R channels and products.

A training module highlighting imagery and products for GOES-R was produced and a beta teletraining of the GOES-R module was held in March. A lot of good feedback was obtained and will be contemplated and incorporated. At this point, there seems to be a need for a shorter training version (45 minutes) for the "general" forecaster. This new

GOES-R module will be included in the soon to be released course “SHyMet for Forecasters”. Much of the rest of the information in the session will be retained for either one longer session (90 minutes) or two shorter sessions that will target SOOs, satellite focal points, managers, and academics who want or need to know a few more of the details of GOES-R.

The CIRA training team continued to participate in monthly conference calls with the NWS Satellite Requirements and Solutions Steering Team (SRSST) to ensure open communications on training issues and in particular to participate in discussions on GOES-R requirements. The team also participated in COMET monthly conference calls with Jim Gurka (NESDIS/OSD/GOES-R), and NRL on progress of GOES-R training. This interaction will continue in order to share information about training activities among the various organizations and thus allow for limited overlap and a better overall program for the users.

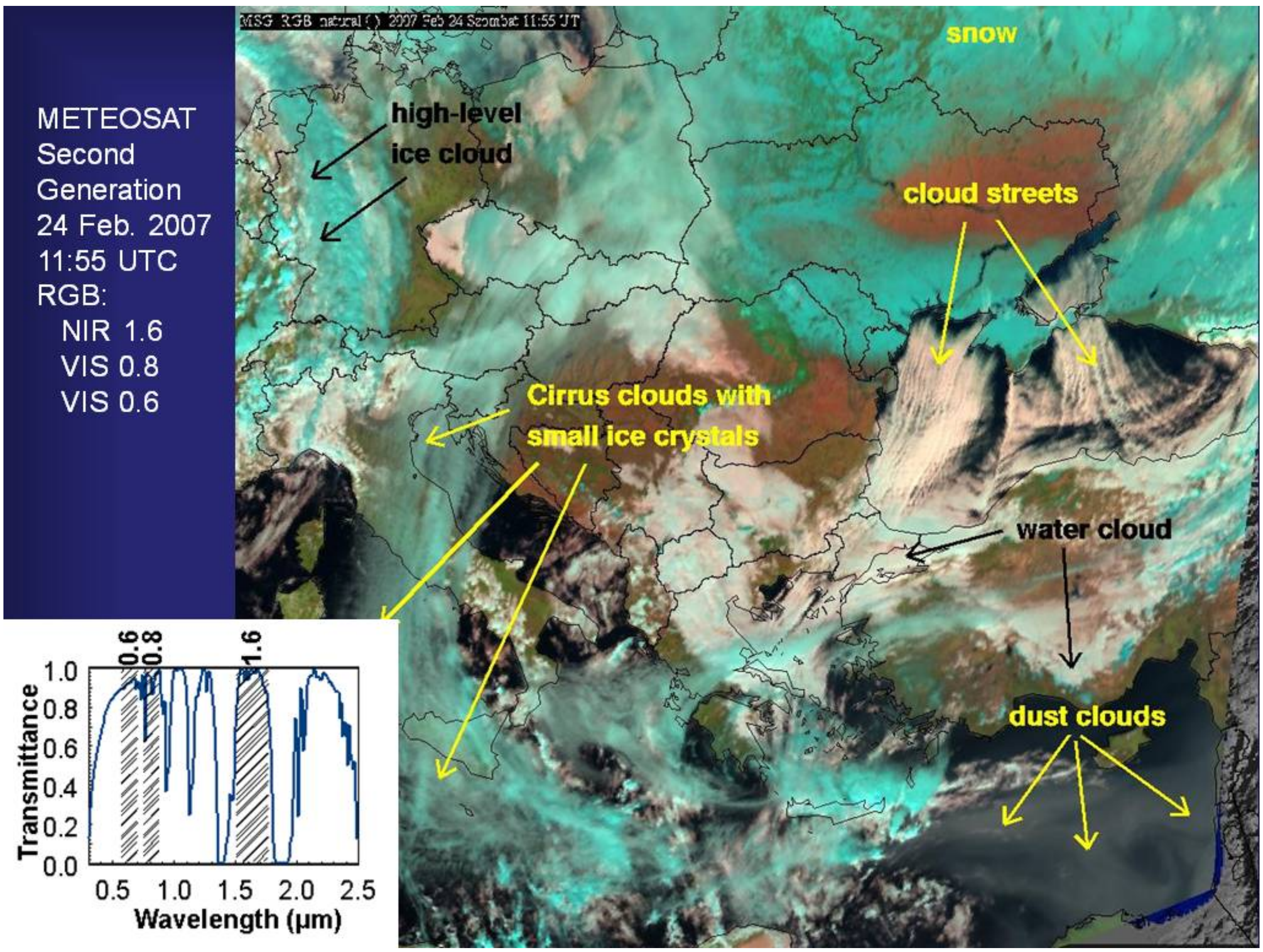

Figure 3. Example from module demonstrating a Red/Green/Blue (RGB) product from METEOSAT Second Generation visible and near infrared channels to highlight ice versus water cloud, snow versus background surface, and dust cloud.

Project V: GOES-R Applications to Tropical Cyclone Analysis and Forecasting

It is known that the tropical cyclone intensity forecast skill still lags that of track forecasting. But unanticipated rapid intensity changes are a major problem for coastal evacuations. In addition TC genesis forecasting capabilities are very limited. We continued our genesis and intensity forecasting studies by expanding the current proxy datasets and by evaluating any impact on forecast algorithms.

We expanded the existing ABI proxy datasets with a collection of the MSG data over tropical cyclone sectors. Simulated ABI channels 7 through 16 were created for seven hurricane cases by using the MSG data collected during the 2006-2008 Hurricane Seasons and the AWG algorithms. These cases are Gordon (2006), Helene (2006), Dean (2007), Karen (2007), Bertha (2008), Ike (2008) and Omar (2008). The 10 channels of storm centered, 500x500 pixel imagery have 3km resolution (i.e., MSG resolution). These imagery allow for the development and evaluation of future ABI-based products, some of which were presented at the Interdepartmental Hurricane Conference in March. The MSG imagery window channel (ABI proxy) is being displayed as part of the RAMMB tropical cyclone experimental products web page for storms in the southern hemisphere and Indian ocean at
http://rammb.cira.colostate.edu/products/tc_realtime/
Scripts were developed to create real-time simulated ABI imagery (channel 7-16) from MSG channels and a local server has been used to enable local sharing of the simulated ABI imagery. Using these data, along with real-time tropical cyclone information, plans are underway to automatically create and display storm centered proxy in real-time during the 2009 hurricane season.

Our research also focused on expanding the proxy lightning dataset. A new version of the World Wide Lightning Locator Network (WWLLN) 2005-2008 dataset was obtained from University of Washington. The new version includes an updated detection algorithm and improved quality control. In addition, the WWLLN processing code has been adapted to include the data from the eastern Pacific so the lightning relationships can be compared with those from the Atlantic.

Emphasis was put on the evaluation of lightning data for tropical cyclone intensity forecasting. The lightning flash density was calculated in storm-relative coordinates for all Atlantic tropical cyclones from 2005-2007 using the reprocessed WWLLN data. This data was composited over 6 h periods in a storm-centered cylindrical coordinate system to provide lightning density in 100 km radial and 45^o azimuthal bins. An adjustment factor was applied for each year based on comparison with the OTD/LIS annual climatology over a tropical and subtropical Atlantic domain to crudely correct for variations in the lightning network over this three year period. Results showed that the azimuthally averaged lightning density is correlated with intensity changes, with the maximum correlation at a radius of about 250 km from the storm center. The correlation closer to the center is complicated by the relationship between lightning and vertical wind shear. Vertical shear tends to increase the lightning density, but is negatively correlated with intensity changes. The sample was stratified into low and high shear regimes, which increased the correlation between the lightning density and intensification, especially close to the storm center.

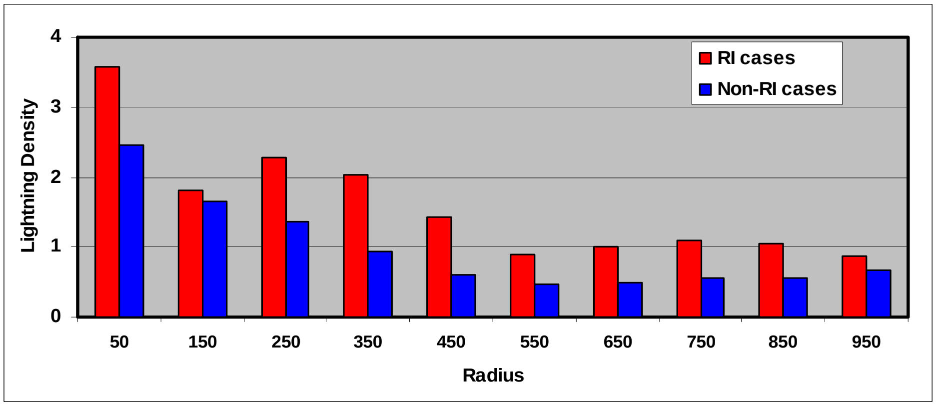

Figure 4. The azimuthally averaged lightning density for the RI and non-RI cases for the 2005-2007 Atlantic sample. Only those storm cases with vertical shear less than the sample mean were included.

The lightning density was also found to be a good discriminator of rapid intensity (RI) changes, especially in the low shear regime. Rapid intensity change is defined as an increase of 25 kt or more of the maximum surface wind in the subsequent 24 hour period. Figure 4 shows the average lightning density as a function of radius for the RI and non-RI cases in the low shear regime. The lightning density is larger for the RI cases than for the non-RI cases, especially near the storm center (r=50 km) and in the region where rainbands typically exist (250-350 km). This result indicates that lightning data may be useful for short-range intensity forecasting, and especially for the detection of rapid intensification, which remains a very challenging forecast problem.

Preliminary work has begun to develop lightning-based tropical cyclone forecast algorithms. These will include possible experimental versions of the SHIPS model and the related Rapid Intensity Index.

A presentation entitled “Developing GOES-R Tropical Cyclone Products via Proxies” was presented by J. Knaff (and with co-authors D. Hillger, M. DeMaria and J. Gurka) at the Interdepartmental Hurricane Conference in St. Petersburg, FL. The presentation can be found at http://www.ofcm.gov/ihc09/Presentations/Session03/s03-05-jknaff.pptx .

Project VI: Winter Weather Studies with GOES-R

Virtually all wintertime, high-impact weather in the United States occurs in association with midlatitude cyclones. We continued our development of the PV/Ozone technique and to compare the potential vorticity fields to total ozone measurements from geostationary satellites.

During the course of the research, it was found that the COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) soundings often contain unstable layers (i.e. layers for which the potential temperature decreases with height). Although many of the layers are not particularly deep, the occurrence is frequent enough that the COSMIC sounding team was notified. The team looked into the issue and came up with the suggestion that until they can refine the retrieval code, the temperature profiles should be screened and the unstable layers be corrected. An initial version of a correction has been developed. In order to best develop a PV/Ozone technique, total ozone from the GOES satellites in digital format is needed. Therefore, an automatic daily ingest of GOES total ozone AREA files was initiated.

As part of the winter weather project, a new cloud climatology for three season test cases was constructed. This dataset allowed for the production of cloud composites using current and new algorithms. Data for February and March 2007 was retrieved from the CIRA archive and the European sector was processed. This data will be used for further testing of the winter season test cases. Me

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

This project is on schedule and milestones have been completed.

4. Leveraging/Payoff:

What NOAA will recieve for resources invested is:

--Advanced product development
--Extended operational use of the GOES-R satellite
--Improved products for severe weather and tropical cyclone analysis and forecasts
--Imrpoved products for fog, volcanic ash and fire detection

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

Our research linkage includes:

--Coordination with CIMSS.
--Coordination with Ben Ruston of the Naval Research Lab.
--The tropical cyclone analysis is being coordinated with OAR/AOML and the NCEP Tropical Prediction Center, and NESDIS with regard to the AIRS retrievals
--The severe weather research is in collaboration OAR/NSSL

6. Awards/Honors: None

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) Four undergraduate students and one high school student are partially supported by this project (Daniel Coleman, Kashia Jekel, Greg DeMaria, Rachel Danner, Justin Riggs).
(b) Presentations

DeMaria, M. gave a guest lecture entitled “Applications of Satellite Data to Tropical Cyclone Forecasting” in Tom Vonder Haar’s AT737 Satellite Meteorology class in the CSU Department of Atmospheric Science (November 2008). Applications to tropical cyclone track, intensity and wind structure forecasting were summarized, include current and planned satellite missions. A class exercise on the Dvorak tropical cyclone classification method was also given.

DeMaria, M., J.A. Knaff, A.B. Schumacher, J. Kaplan, D. Brown, G. Gallina, J. Kossin, 2009: Improved GOES Utilization for Tropical Cyclone Forecasting. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL.

Knaff, J.A., D.W. Hillger, M. DeMaria, J. Gurka, 2009: Developing GOES-R Tropical Cyclone Products vis Proxies. *63rd Interdepartmental Hurricane Conference*, 2-5 March, St. Petersburg, FL.

D. Lindsey gave a presentation entitled "Improving above-surface water vapor analyses using satellite and RUC data" at the *24th Conference on Severe Local Storms*, 27-31 October, Savannah, GA.

Schumacher, A. presented "An Overview of Research to Operations Activities at CIRA for 2008/2009" at the *National Hurricane Center Invited Seminar*. 10 October 2008, Miami, FL.

Seaman, C., 2008: Assimilation of GOES Imager and Sounder Data into the RAMS Model. *CoRP 5th Annual Science Symposium*, 11-14 August, CIOSS, Corvallis, OR.

(c) None
(d) Louie Grasso spoke to a first grade class at Bauder Elementary.
(e) A web site was developed to illustrate the utlility of GOES-R research.

8. Publications:

Refereed Journal Articles

Grasso, L., M. Sengupta, and M. DeMaria, 2009: Comparison between Observed and Synthetic 6.5 and 10.7 µm GOES-12 Imagery of Thunderstorms.” *International Journal of Remote Sensing.* In press.

Grasso, L.D., M. Sengupta, J.F., Dostalek, R. Brummer, and M. DeMaria, 2008: Synthetic Satellite Imagery for Current and Future Environmental Satellites. *International Journal of Remote Sensing*. 29:15, 4373-4384.

Grasso, L. and D. Lindsey, 2009: An Example of the use of Synthetic 3.9 µm GOES-12 Imagery for Two-Moment Microphysical Evaluation. *International Journal of Remote Sensing*.

Knaff, J.A**.,** 2009: Revisiting the Maximum Intensity of Recurving Tropical Cyclones. *Int. J. Climatology*. 29, 827-837.

Lindsey, D. T., and M. Fromm, 2008: Evidence of the cloud lifetime effect from wildfire-induced thunderstorms, *Geophys. Res. Lett.*, 35, L22809, doi:10.1029/2008GL035680.

Schumacher, A., M. DeMaria, J.A. Knaff, 2008: Objective Estimation of the 24-Hour Probability of Tropical Cyclone Formation. *Weather and Forecasting.*

Setvak, M., D.T. Lindsey, R.M. Rabin, P.K. Wang, and A. Demeterova, 2008: Possible moisture plume above a deep convective storm on 28 June 2005 in MSG-1 imagery. *Monthly Weather Review.*

Zupanski D., 2009: Information measures in ensemble data assimilation. Chapter in the book titled "*Data Assimilation for Atmospheric, Oceanic, and Hydrologic Applications,*" S. K. Park and L. Xu, Editors, 85-95, 475 p.

Zupanski M., 2009: Theoretical and practical issues of ensemble data assimilation in weather and climate. Chapter in the book titled "*Data Assimilation for Atmospheric, Oceanic, and Hydrologic Applications,*" S. K. Park and L. Xu, Editors, 67-84, 475 p.

Zupanski, M., D. Zupanski, S. J. Fletcher, M. DeMaria, and R. Dumais, 2008: Ensemble data assimilation with the Weather Research and Forecasting (WRF) model: The Hurricane Katrina case. *J. Geophys. Res.*

Zupanski, D., M. Zupanski, L. Grasso, R. Brummer, I. Jankov, D. Lindsey, M. Sengupta and M. DeMaria, 2009: Assimilating synthetic GOES-R radiances in cloudy conditions using an ensemble-based method. *Submitted to International Journal of Remote Sensing*. Accepted

Conference Proceedings

Brummer, R.L., M. Sengupta, L. Grasso, D. Hillger, D. Lindsey, R. DeMaria, and M. DeMaria: 2009: Synthetic satellite datasets for GOES-R ABI Bands. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

DeMaria, M., 2009: Tropical cyclone applications of NPOESS and GOES-R. *5th AMS Annual Symposium on Future Operational Environmental Satellite Systems - NPOESS and GOES-R*, 11-15 January, Phoenix, AZ.

DeMaria, M., and R. DeMaria, 2009: Applications of lightning observations to tropical cyclone intensity forecasting. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Grasso, L.D., M. Sengupta, R.L. Brummer, R. DeMaria, and D.W. Hillger, 2009: Synthetic GOES-R imagery of fires at 3.9 µm. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Gurka, J., A. Mostek, T.J. Schmit, S.D Miller, A. Bachmeier, M. DeMaria, 2009: GOES-R Proving Ground Program. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Hillger, D.W., M. DeMaria, and R.L. Brummer, 2009: GOES-R ABI product development. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ

Knaff, J.A., 2009: Propagating patterns in 6.7 μm imagery in re-intensifying tropical-to-extratropical cyclone transitions. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Sengupta, M., L.D. Grasso, R.L. Brummer, and D.W. Hillger, 2009: Improving fire detection: Current GOES to GOES-R. *16th AMS Conference on Satellite Meteorology and Oceanography*, 11-15 January, Phoenix, AZ.

Setvák, M., Lindsey, D.T., Novák, P., Rabin, R.M., Wang, P.K., Kerkmann, J., Radová, M., and Stástka, J., 2008: Cold-ring shaped storms in Central Europe. *The 2008 EUMETSAT Meteorological Satellite Conference*, 8-12 September, Darmstadt, Germany.

Informal Publications

Grasso, L.D., M. Sengupta, D.W. Hillger, and R.L. Brummer, 2008: GOES-R Synthetic Imagery and Fire Detection, *CIRA Newsletter*, 30, Fall 2008, 1-3.

Jankov I., Sengupta M., Grasso L.D., Coleman D., Zupanski D., M.Zupanski, Lindsey D.T, and R.L. Brummer 2008: An Evaluation of Various WRF-ARW Microphysics Using Simulated GOES Imagery for an Atmospheric River Event Affecting the California Coast. *CIRA Newsletter*, 30, Fall 2008, 18-23.

SATELLITE ANALYSIS OF THE INFLUENCE OF THE GULF STREAM ON THE TROPOSPHERE: CONVECTIVE RESPONSE

Principal Investigator: Andrea Schumacher

NOAA Project Goal: Climate, Weather and Water

Key Words: QuikSCAT, AMSU, WWLLN, GOES, Gulf Stream

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The interaction between the atmospheric boundary layer and the warm waters of the Gulf Stream has been recognized for decades. However, Minobe et al. (2008) suggested that the influence might extend through the entire troposphere and on time scales of weeks or longer. This result has implications for climate feedbacks due to these air-sea interactions. In their study, satellite observations were used to document the surface wind response from QuikSCAT and the convective response through broad band outgoing longwave radiation, but the tropospheric signal was determined from model analyses. This work will be extended by investigating the response without the use of model fields.

Specifics of the plan to develop this technique include:

Prepare and analyze satellite data composites over the Gulf Stream and surrounding regions for January and Februray 2007.

- --QuikSCAT winds will be used to examine the surface response
- --Advanced Microwave Sounder Unit (AMSU) temperature and wind retrievals will be used to document upper-tropospheric effects
- --Lightning data from the World Wide Lightning Locator Network (WWLLN) and GOES imagery will also be used examine the impact on convection

References Utilized:

Minobe, S., A. Kuwano-Yoshida, N. Komori, S.-P. Xie, and R. J. Small, 2008: Influence of the Gulf Stream on the troposphere. *Nature*, 452, 206-210.

2. Research Accomplishments/Highlights:

Data from January 2007 shows some correlation between the lightning data and SST anomalies (Figure 1).

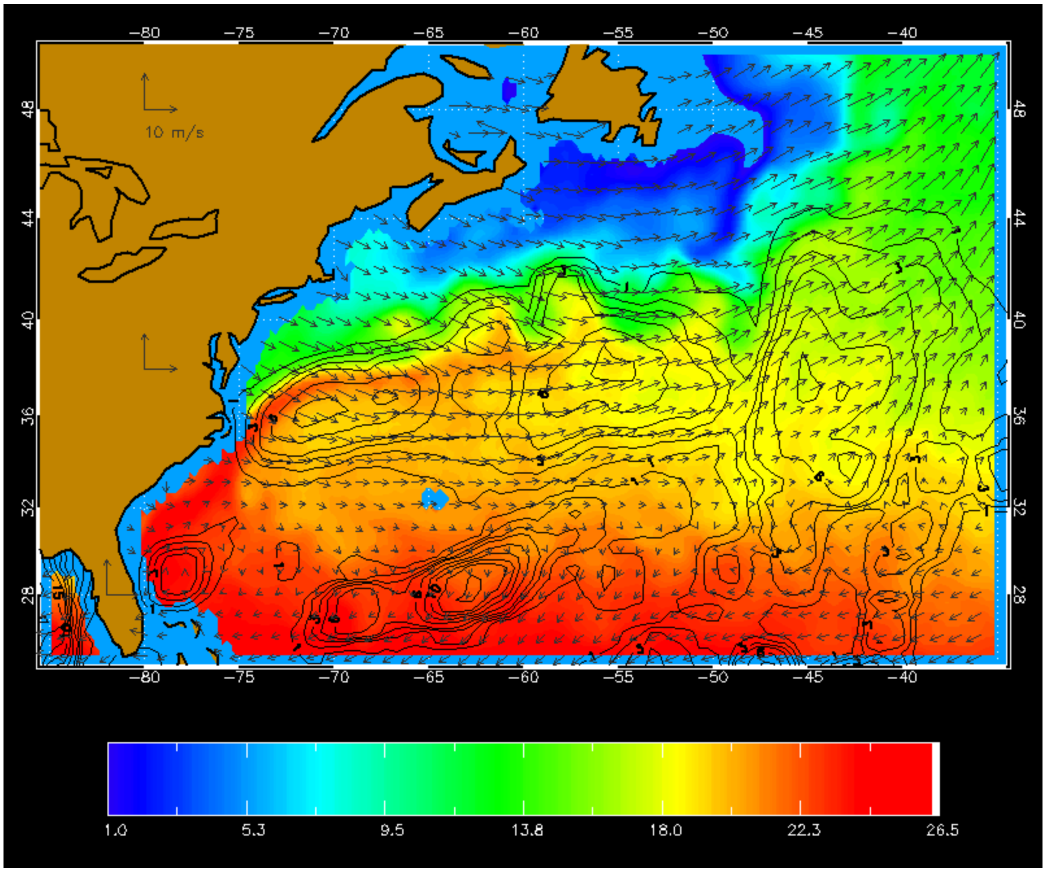

Figure 1. January 2007 monthly mean of sea surface temperature (color fill, deg C), lightning density (strikes/km2-year, black contours), and ocean surface winds (vectors) from QuikSCAT.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The AMSU wind retrievals, and the lightning and GOES analyses are CIRA's contribution to this work. The lightning composites for January and February 2007 have been completed. The software to process the AMSU data has begun to be set up, and the GOES data are available for analysis. The progress in the AMSU and GOES portion of the project lags that of the lightning component due to time constraints. Sufficient progress has been made, however, that the project will be funded for another year. In the next year, the AMSU and GOES portions will be caught up to the lightning portion, and the time frame for the analysis will be extended from January and February 2007 to all of 2007.

4. Leveraging/Payoff:

The results of this study may enhance our knowledge of these air-sea interactions, which may have implications for climate feedbacks.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

This project is a joint effort between CIRA and CIOSS (Cooperative Institute for Oceanographic Satellite Studies) at Oregon State University. CIOSS is responsible for the QuikSCAT analysis, and CIRA is responsible for the AMSU wind retrievals, and the lightning and GOES analyses.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

SIMULATION AND ANALYSIS OF THE INTERACTION BETWEEN AEROSOLS AND CLOUDS, PRECEIPITATION AND THE RADIATION BUDGET OVER THE GULF OF MEXICO AND HOUSTON

Principal Investigators: William R. Cotton and Gustavo Carrió

NOAA Project Goals: Our project targets two of the NOAA's Atmospheric Composition and Climate (ACC) program objectives: i) “research targeting processes or measurements germane to atmospheric composition that contribute to substantial uncertainty in simulations of aerosol/climate interactions” and ii) “analysis and interpretation of data from the GoMACCS 2006 field campaign”.

Key Words: Aerosols, Precipitation and Radiation Budget

1. Long-term Research Objectives and Specific Plans to Achieve Them:

We have completed all the proposed mesoscale simulations varying the size of the city of Houston (including a NO CITY run), considering as well as excluding the indirect effects the urban aerosol enhancement. The corresponding results are summarized in Section 2c.

However, the aforementioned studies focused on the aerosol indirect effects and therefore, we plan to perform a few more mesoscale simulations considering the direct aerosol radiative heating.

We also consider re-running an analogous set of sensitivity runs taking into account urban enhancement of cloud-nucleating aerosol but using an idealized case characterized by higher instability.

2. Research Accomplishments/Highlights:

a) TEB Urban Model in RAMS: The Town Energy Budget (TEB) urban model was coupled to the newest version of RAMS. The coupled model was adapted to run in parallel to maximize the full potential of our computing resources.

b) Landsat Land Use Data: In addition to the the Landsat Thematic Mapper ™ National Land Cover Data (NLCD) corresponding to the year 2001, we processed two additional datasets: 1992, and 2006. The NLCD land use categories were converted into the RAMS land use categories. These dataset were used for the initialization of the two finest grids of series the numerical simulations, enhancing the representation of the land surface heterogeneities with respect to the default RAMS land-use dataset with a pixel size of 1 km. More importantly, the use of these three satellite datasets for the city of Houston allowed a realistic experimental design for sensitivity runs varying the city size

c) Sensitivity experiments: We focused on a convective storm triggered by the sea-breeze circulation (Aug 24 2001). We perform two series of sensitivity experiments with the different land use data sets and considering aerosol sources linked to the urban sub-grid urban fraction. The results of these sensitivity experiments were presented in two talks at AMS annual and the AGU fall meetings, and will soon be submitted for publication (Journal of Applied Meteorology and Climatology). The model configuration, the experimental design, the main results, and some concluding remarks are given in subsections c1, c2, c3, and c4, respectively.

c1. Model Configuration

RAMS@CSU was configured to use three two-way interactive nested model grids with 42 vertical levels and horizontal grid spacings of 15.0, 3.75, and 0.75 km centered over the city of Houston. Grid 1 (71X 61 grid points) and Grid 2 (102X102 grid points) were used to simulate the synoptic and mesoscale environments, respectively. While Grid 3 (202X202 grid points) was used to resolve deep convection as well as the sea-breeze circulation. Figure 1 gives the location of these grids. The mixing ratios and number concentrations of all water species (cloud droplets, drizzle drops, rain, pristine ice, snow, aggregates, graupel and hail) were predicted. CCN, GCCN and IFN concentrations were also considered as prognostic variables.

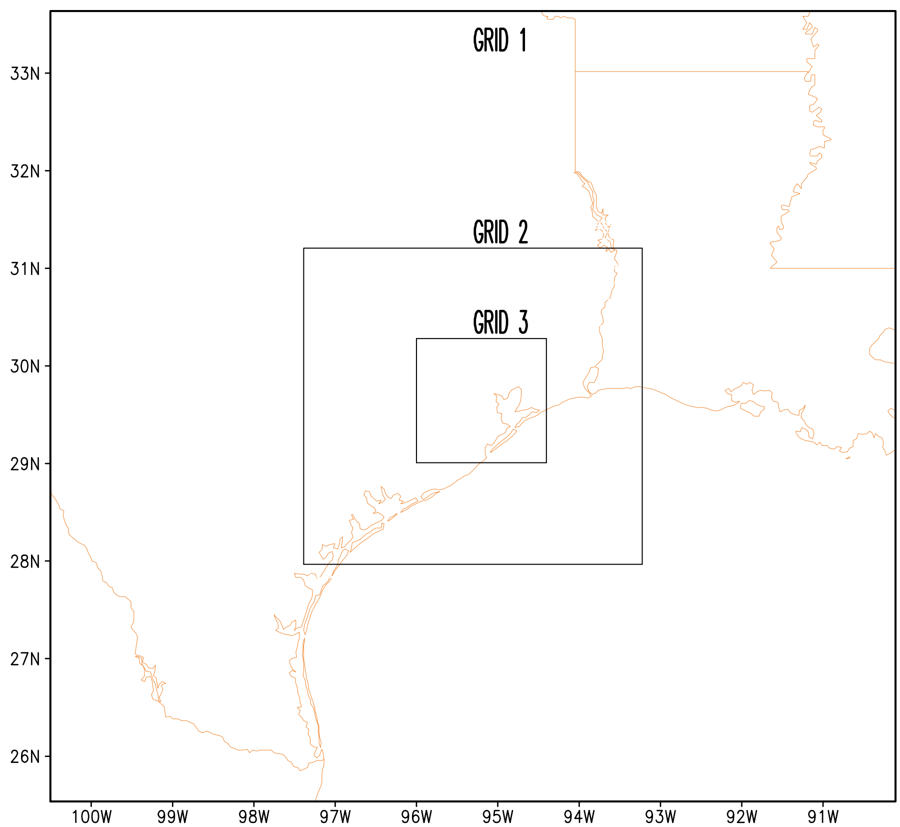

Figure 1. Grid Configuration. The center of all grids coincides with the location of the city.

c2. Experimental Design

We considered the NLCD corresponding to the Houston area as benchmarks for the experimental design of the land-use sensitivity experiments. We also considered a NO CITY run using the satellite data closest to the case we used for this study (2001), but replacing the urban sub-grid patches by the predominant land-use categories in the city surroundings. We considered aerosol observations during theTexAQS/GoMACCS field campaign for the initialization CCN profiles. However, we eventually used lower CCN concentrations to characterize the city aerosol sources over each urban area. Increasing the latter above 4000cm^{-3} did not produce a significant impact on the results. City aerosol sources were considered by nudging these high concentrations at the first model level above the ground multiplied by the sub-grid urban fraction of the corresponding gridcell. In addition to high CCN concentrations over the city, we initialized the surroundings and the gulf area with more moderate and cleaner values, respectively The numerical experiments corresponding to results presented in this report are shown in Table I. The city CCN concentrations listed in this table correspond to the maximum values (entirely urban gridcell) nudged at the first model level to consider aerosol sources.

Table I: Numerical Experiments

Land use	CCN concentrations [cm^{-3}]		
	City	Background	Gulf
1992	1000, 2000,4000	500	200
2001	1000, 2000,4000	500	200
2006	1000, 2000,4000	500	200
NO CITY	500		200

c3. Main Results

In this series of sensitivity experiments, two distinct groups of convective cells were simulated. The location of these two groups is given in figure 2 that compares the spatial distribution of accumulated precipitation for the entire simulation period, to those corresponding to two time intervals. The first group of storm occurred southwest of the city between 16:00 and 20:00 UTC (SE cells) while the second, north of the urban area and between 20:00 and 22:00 UTC (N cells). This figure also compares the time evolution of the precipitated volume for each group (2b). The N cells were within the simulated plume of pollutants as the prevailing wind was SSE. Conversely, the SW cells were virtually not affected by the urban sources of aerosol.

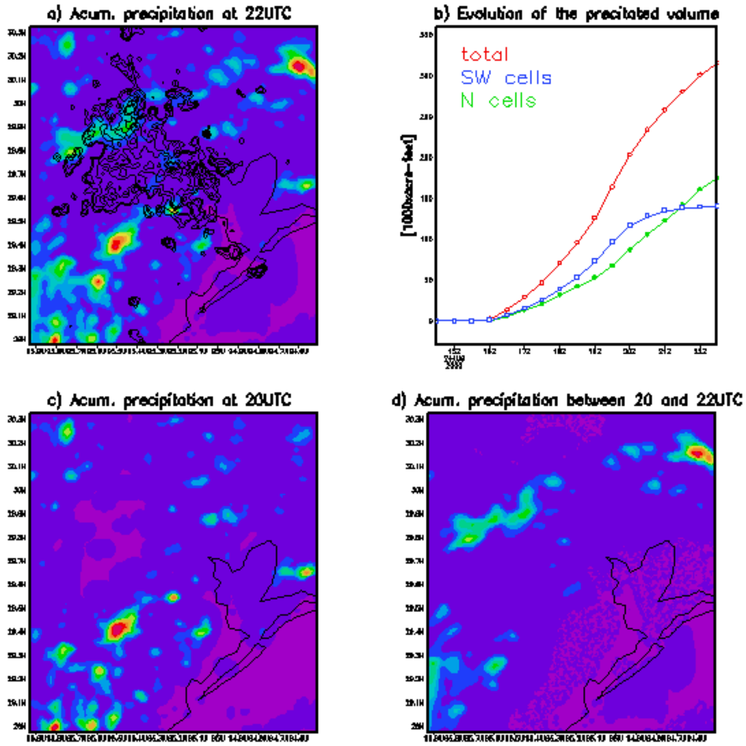

Figure 2. Accumulated Precipitation for the Entire Simulation Period, and for the Periods Ending at 20Z and Between 20 and 22 UTC(a, c, and d, respectively). Evolution of the integral precipitated volume for each group of cells and for both (b).

First we compare the runs corresponding to 1992, 2001, and 2006 satellite data as well as the NO CITY run. As seen in Fig. 3, the SW cells occurred outside the aerosol plume. The shaded area represents CCN concentrations at least 10% above the back ground values one hour before the convective activity develops. The contours denote the position of these cells. As expected, the numerical experiments varying only the intensities of these aerosol sources exhibited negligible differences for the SW cells (not shown). However, increasing the size of the city had a great impact on both precipitation rates and the total volume of precipitation (Fig. 4). Maximum precipitation rates were 50, 40, and 20% higher than the NO CITY run for the 2006, 2001, and 1992 cities, respectively. Differences up to 28% were simulated for the total volume precipitated over the finest grid (grid 3). Figure 5 is analogous to Fig 4 but only for urban gridcells. Precipitation rate maxima were higher and occurred earlier for larger cities although the relative differences were less important (< 10%). For the urban area, differences in precipitated volume were positive only for the 2006 run.

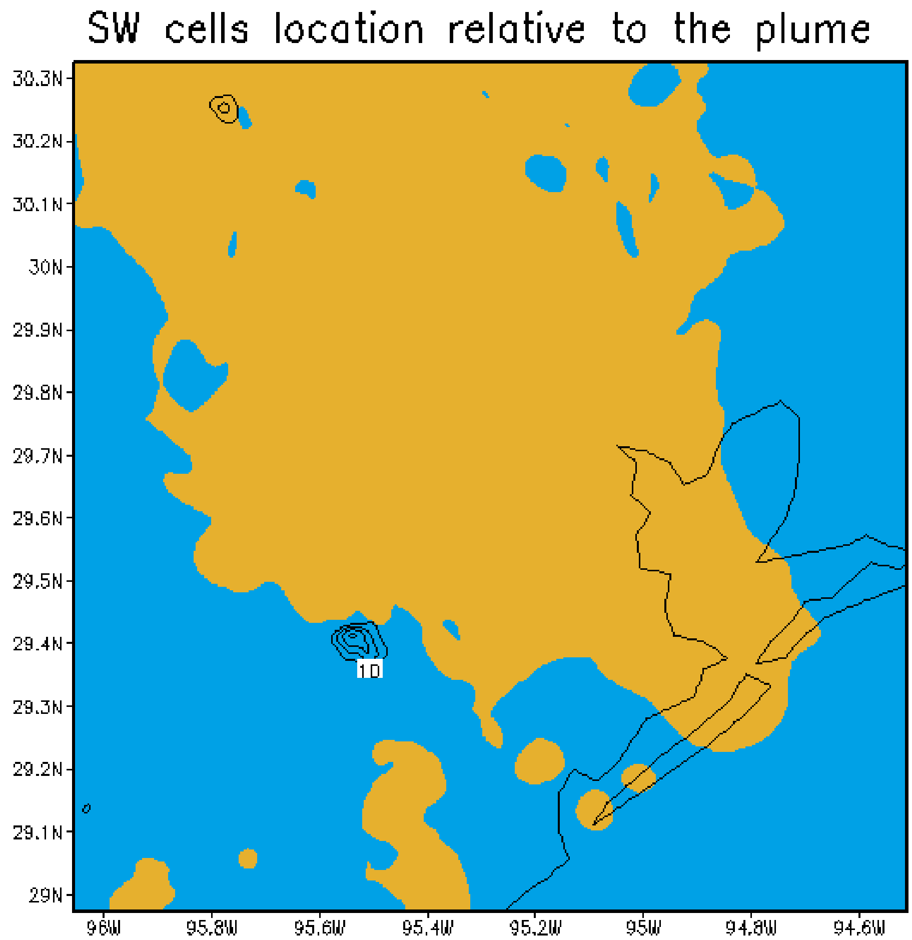

Figure 3. Shaded area Represents the Aerosol Plume One Hour Before the Convective Activity. The Contours Indicate the Position of the SW Cells.

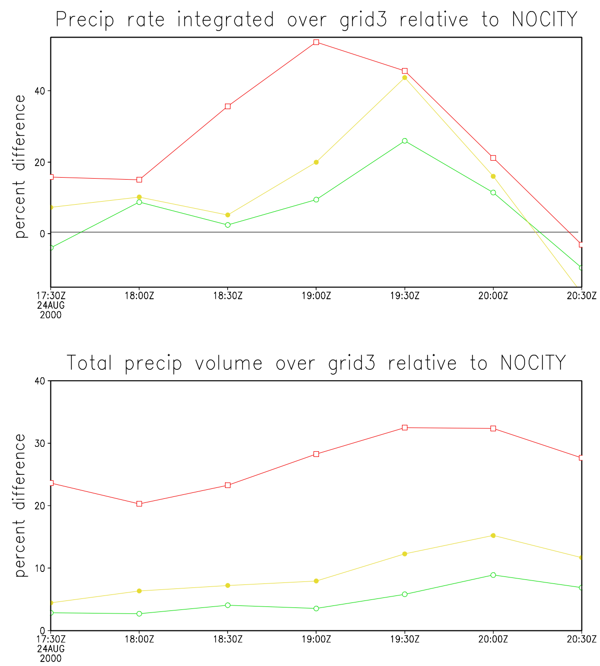

Figure 4. Comparison of Domain Averaged Precipitation Rate and Total Precipitated Volume. Green, yellow and red lines denote experiments using 1992, 2001, and 2006 cities, respectively.

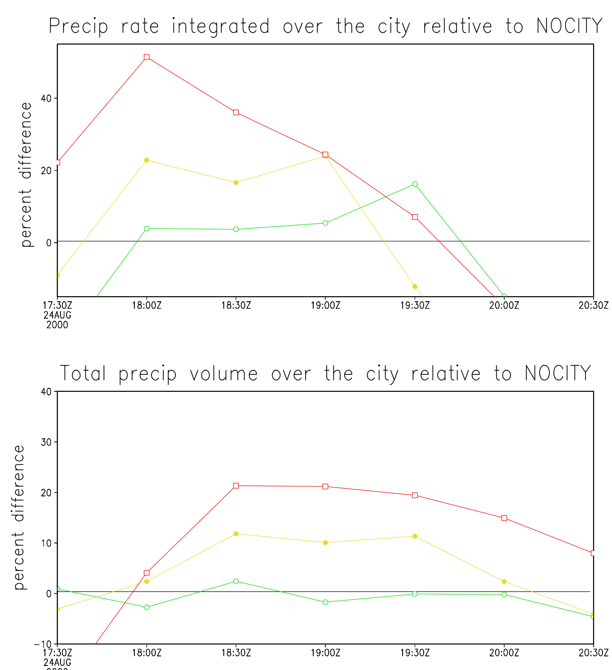

Figure 5. Idem Figure 4 but for Urban Cells.

When comparing 1992, 2001, 2006, and NO CITY runs, the maximum simulated updrafts were comparable, although the area covered by convective cells increases with increasing city size. The probability density functions of vertical motions are compared in Fig. 6a, b for the same set of runs. Although maximum values are comparable, updrafts greater than $5ms^{-1}$ are more frequent for experiments considering larger urban areas. The evolution of the total precipitated volume and the area with precipitation is compared for the same set of sensitivity runs in Figs. 6c and d, respectively. The total precipitated volume monotonically increases with increasing city size (up almost 60%). The area with precipitation behaves in a similar manner with slightly higher relative increases. Therefore, the area average of the precipitation rates does not change significantly and the increase in the precipitated volume in mainly linked to the increase in the storm size.

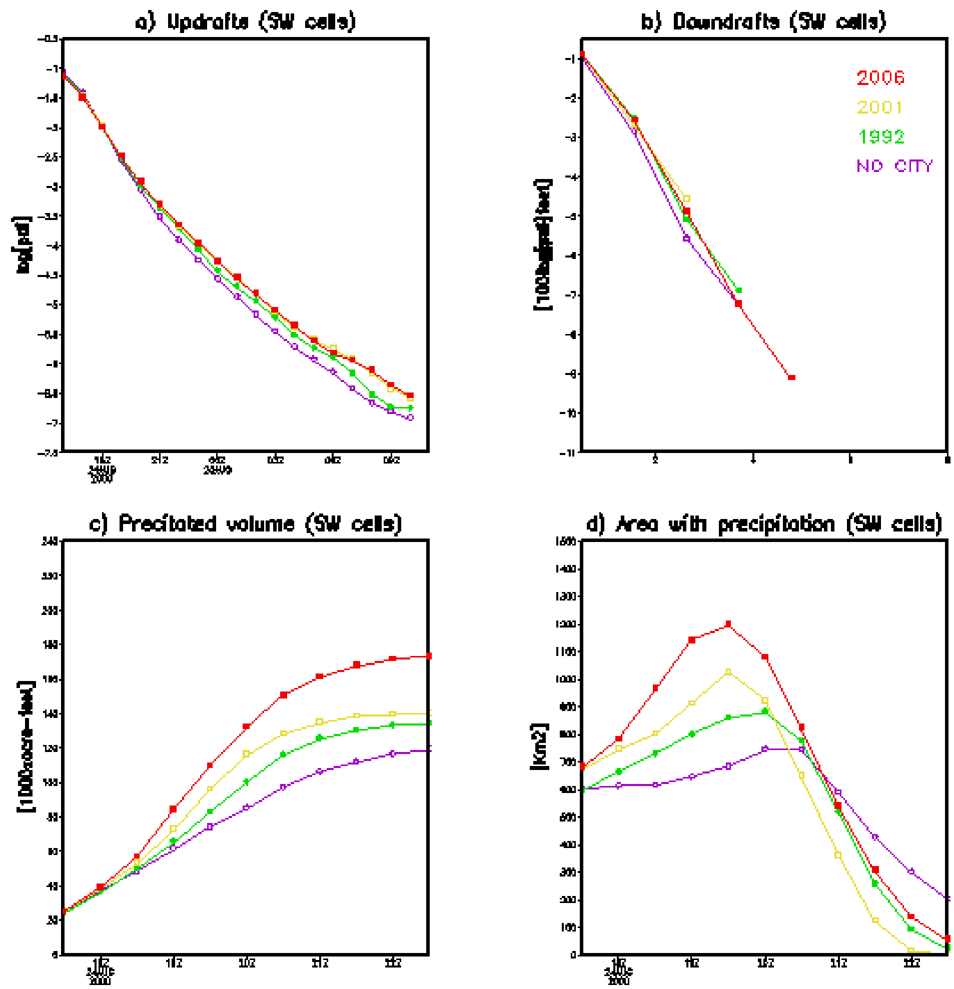

Figure 6. Probability density functions for vertical motions (a and b) for experiments varying city size. Total precipitated volume and area with precipitation for the same set of runs (c and d).

The LWP and IWP maxima were higher for all sensitivity experiments compared to the NO CITY run as seen in Fig7a and b, respectively.

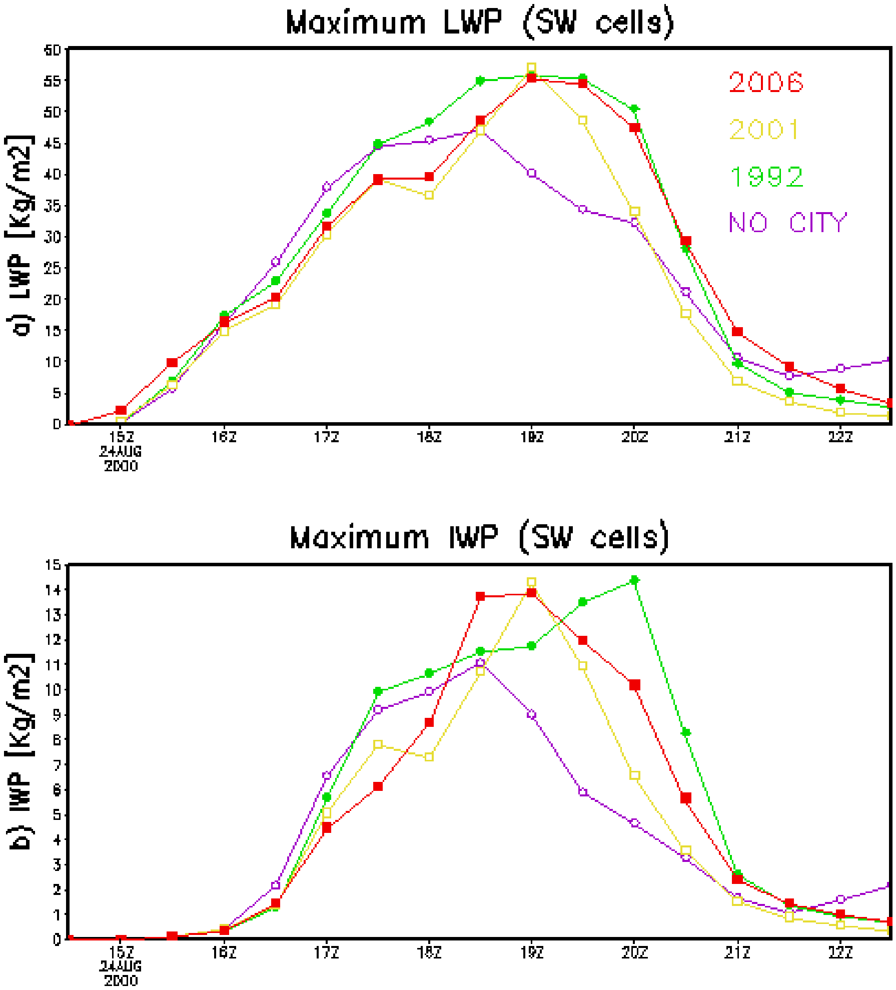

Figure 7. Maximum LWP and IWP for experiments varying city size (a and b, respectively).

Conversely, the group of convective cells that occurred north of the city between 20:00 and 22:00 UTC showed a very distinct behavior. As seen in Fig 8, considering larger cities (with no aerosol sources) produced no monotonic changes and almost no regularities in vertical motions, precipitation rates and total volumes, and water paths. However, it must be noted that the maximum area covered by these cells was between 700 and 800km^2 for 1992, 2001, and 2006 cities, while it was above 1200km^2 for the NO CITY run. The remarkably different response of the SW cells may be explained by a significant intensification of the sea-breeze where they occurred. As seen in Fig 9, the intensity of the sea-breeze (~ SE) increases monotonically for larger urban areas. The SE flux averaged over first 1000m is given in Figs 9b, c, and d for 1992, 2001, and 2006 land use, respectively. These fluxes were computed at a simulation time that corresponds to one hour prior to the most intense convective activity (19:30 UTC); the position of the cells at the latter time is given in Fig.9a.

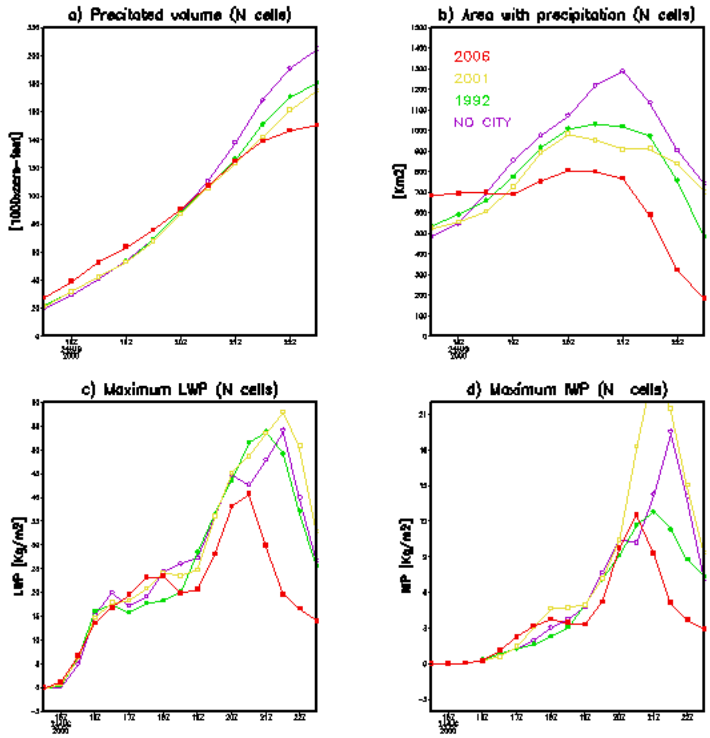

Figure 8. Maximum LWP and IWP for experiments varying city size (a and b, respectively).

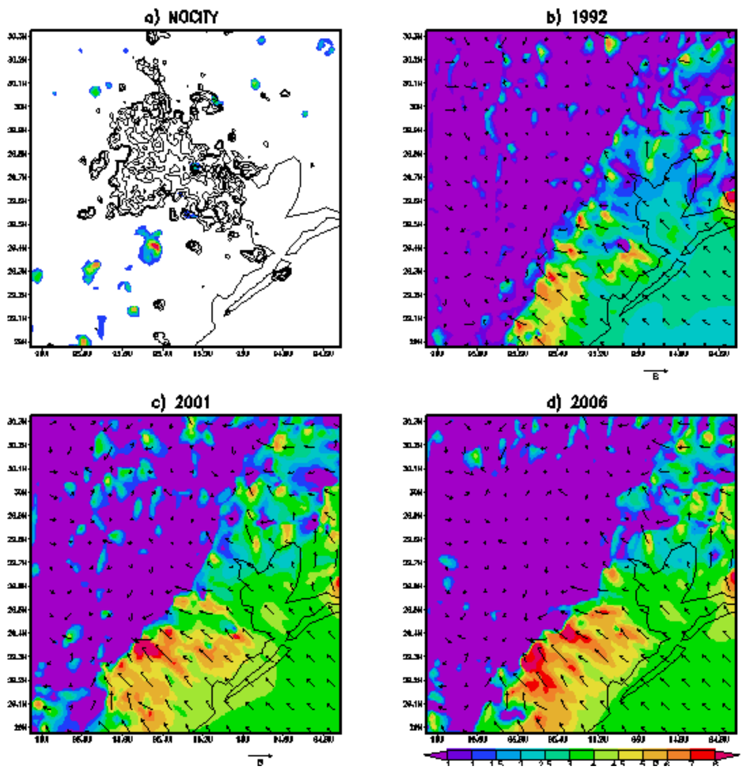

Figure 9. Comparison of the sea-breeze intensity for 1992, 2001, and 2006 runs.

In general, when comparing experiments considering aerosol sources to the corresponding clean cities, the simulated change in the total precipitated volume was small but positive (not shown). The increase for the integral value over finest grid was approximately 1%, however, when comparing only the cells north of the city (downwind), the simulated differences ranged from 1.7 and 9.2% for 1992, and 2006, respectively. However, the accumulated precipitation increased 10, 14 and 26%.

Figure 10 shows the precipitation accumulated over grid 3 between 20:00 and 22:30 UTC and the most intense cells that we used comparisons in the following figures.

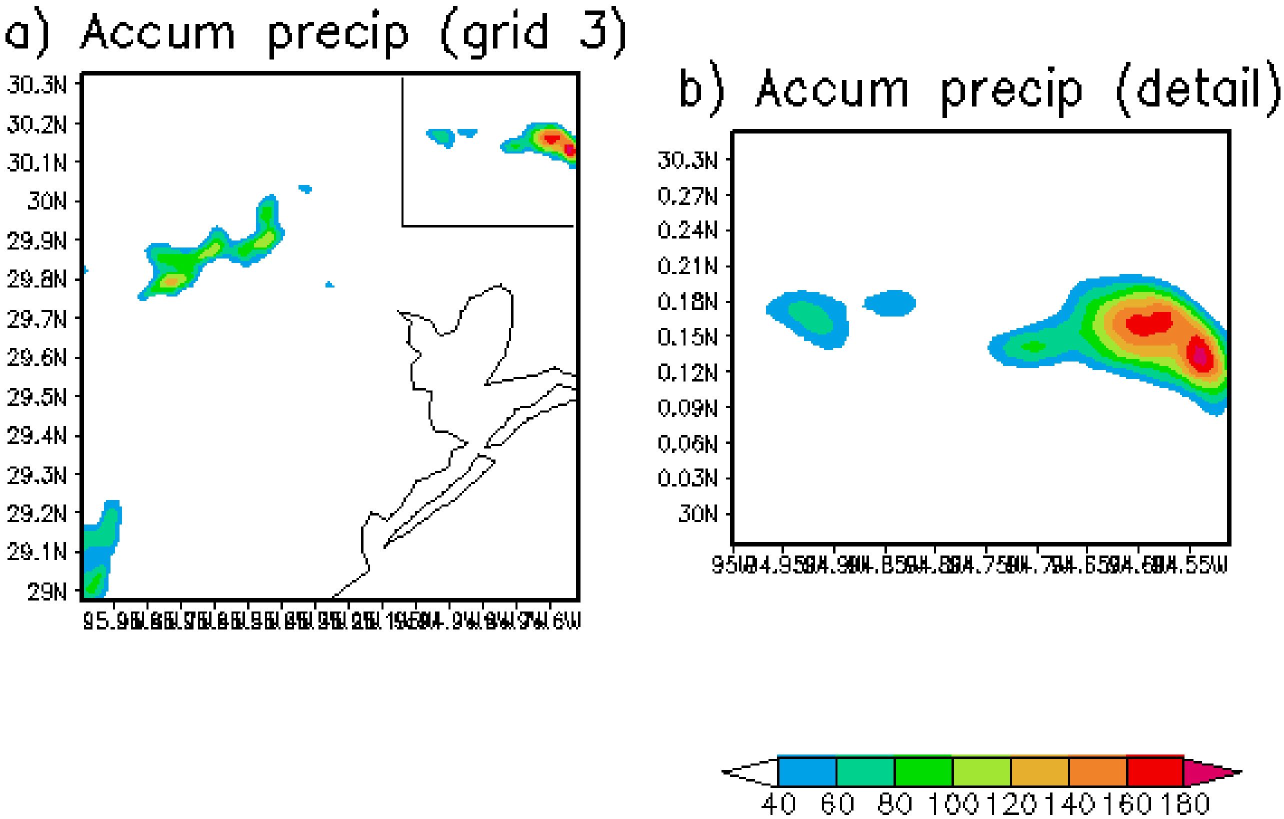

Figure 10. Accumulated precipitation for 2001 with no aerosol sources.

When considering more polluted cities, the simulated maximum updrafts tended to be only slightly higher although they occurred at higher altitudes for all city sizes. This can be seen in Fig 11 that compares the evolution of the maximum updraft (cells in Fig 10b) for runs experiments using 1992, 2001, and 2006 land use. Left panels correspond to clean cities while the analogous runs considering urban aerosol sources are given in the right panels. The occurrence of the maxima at higher levels in linked to greater amounts of liquid water being thrust aloft into supercooled levels which then freezes releasing greater amounts of latent heat of freezing invigorating the convection. The evolution of the liquid water mixing ratio, and supercooled water mixing ratio maxima are compared Fig. 12a and b for two different urban source intensities using 2001 satellite data. The corresponding mean mass diameters are given in panels c and b of this figure. For the polluted city, supercooled water mixing ratio was 15% higher the clean case.

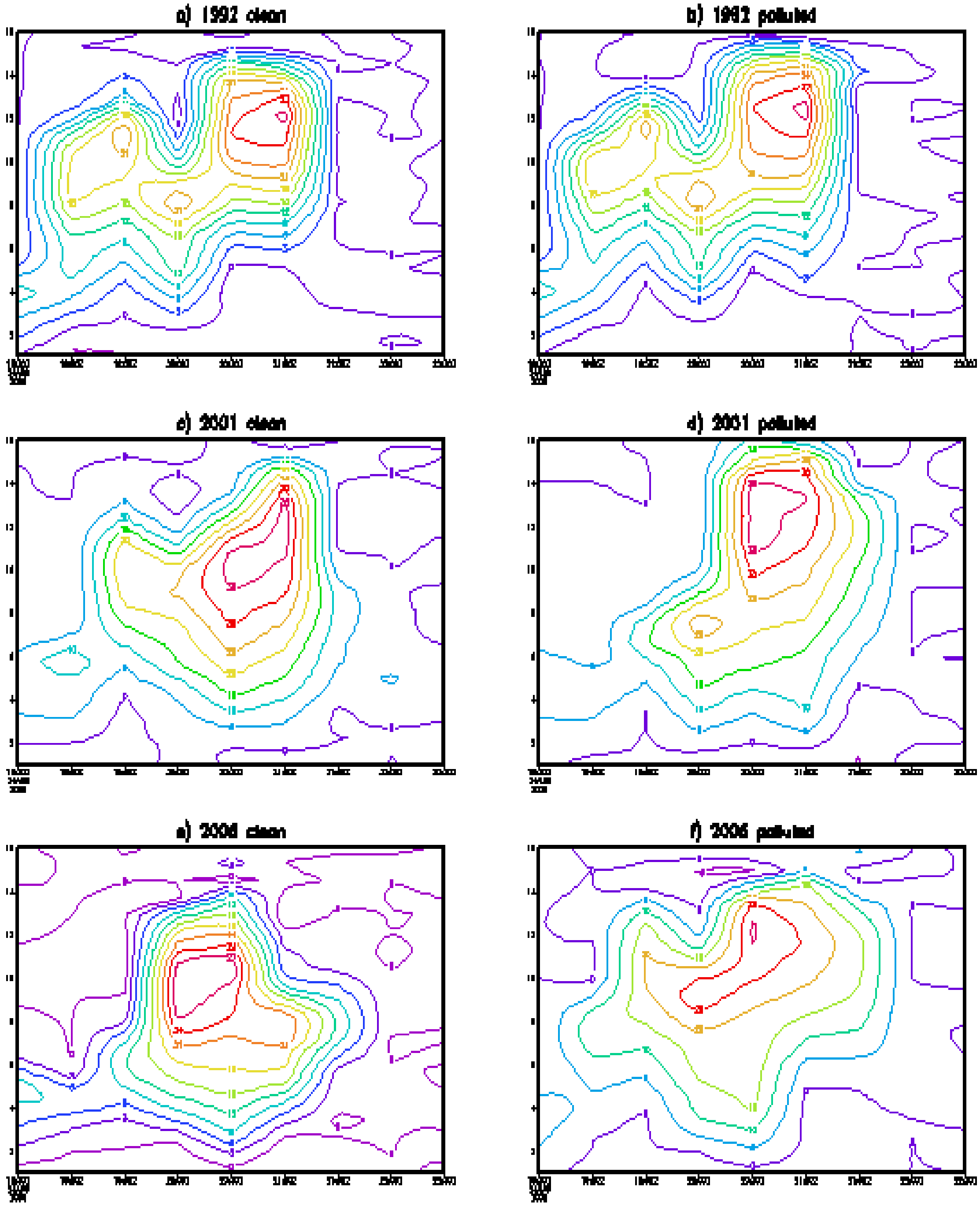

Figure 11. Comparison of maximum simulated updrafts. Ordinates denote altitude in kilometers and contours updrafts in ms^{-1}. Left panels correspond to CCN sources of $2000cm^{-3}$.

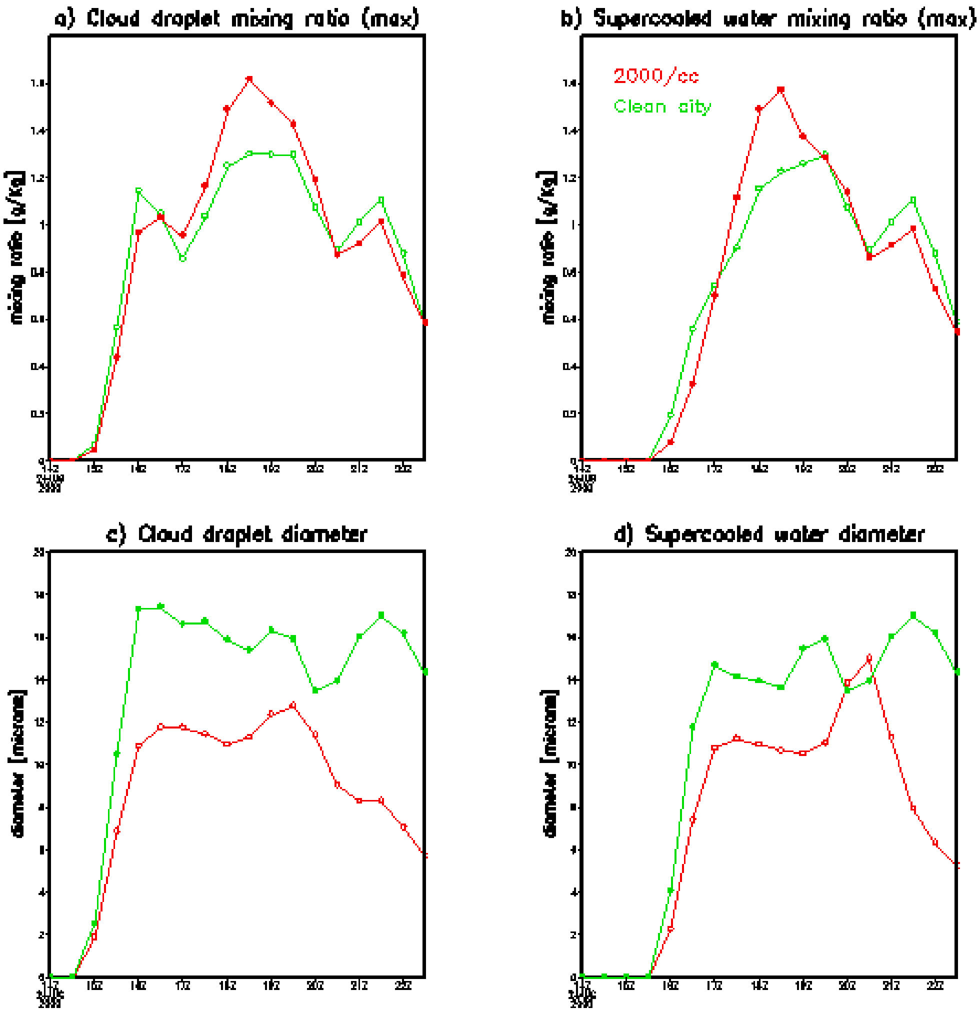

Figure 12. Comparison of liquid water and supercooled liquid water maxima (a and b), and the corresponding mean mass diameters (c and d).

The vertical profiles of the updraft intensity, and the mixing ratios of pristine ice, rain, and the precipitating ice-phase species (hail and graupel) are compared in Fig. 13 for runs considering a clean city (2001), and different aerosol source intensities. These profiles correspond to the time the maximum updraft is attained. Updrafts maxima are slightly higher for “polluted cities” and they occur at a higher altitude. The mixing ratio of pristine ice and hail+graupel monotonically increases for more intense sources. In the case of rain all sensitivity runs produced higher rain mixing ratios but the increase was not monotonic. All runs compared in Fig. 13 used 2001 satellite data, although these results are also valid for 1992 and 2006 cities. Figure 14 compares the pristine and rain mixing ration vertical profiles for clean and polluted (2000cm^{-3}) cities using 1992 and 2006 land-use.

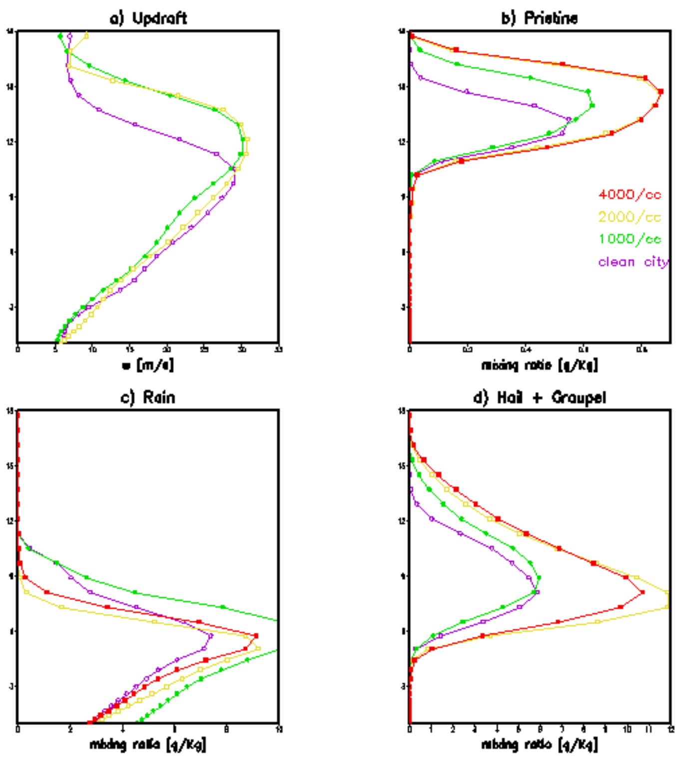

Figure 13. Vertical profiles at the time the maximum updraft is attained (2001 city).

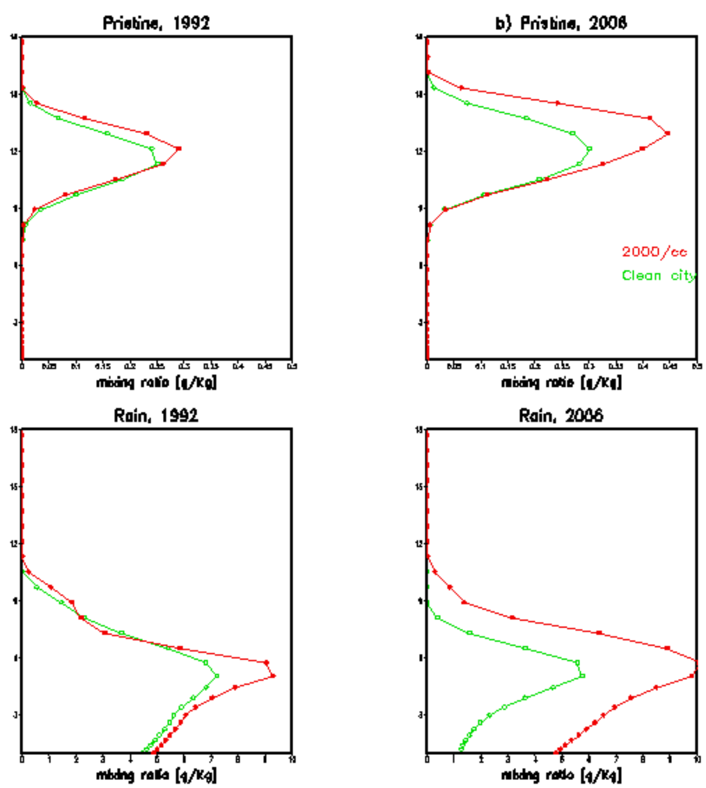

Figure 14. Similar to Fig 13, but for 1992 and 2006 cities.

c4. Concluding Remarks

In summary, considering "larger cities", we simulated:

--higher precipitation rates over the finest grid, the NO CITY run exhibits a maximum much later,

--precipitation rates and accumulated values over urban cells showed lower but also positive differences,

--increased intensity of the sea-breeze,

-- total volume of precipitation (finest grid) increased monotonically 9, 11, and 30% (over NOCITY) for 1992, 2001, and 2006, respectively,

--LWPs and updrafts maxima did not change significantly,

--conversely, the integral value of condensate and maximum downdrafts increased. The latter result is liked to the larger area coverage of the storm.

While "more polluted cities" produced:

--positive differences in LWC maxima

--+4% and 9% difference for supercooled water between -10 and -20°C (~4-8km). It is well know that presence of supercooled liquid water within this temperature range plays an important role in non-inductive charge separation mechanisms,

--maximum accumulated precipitation increased significantly (10, 18, and 26% with respect to the corresponding clean cities).

-- the updraft maxima were slightly higher and occurred at a higher altitude,

-- the mixing ratio of precipitation species as well as the amount of pristine ice crystal transported to higher levels of the storm significantly,

--these results are linked to greater amounts of liquid water being thrust aloft into supercooled levels which then freezes releasing greater amounts of latent heat of freezing invigorating the convection.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

a) TEB Urban Model in RAMS: complete.

b) Processing of Landsat Land Use Data: complete.

c) Sensitivity experiments: complete for the case analyzed.

4. Leveraging/Payoff: None.

5.. Research Linkages/Partnerships/Collaborations, Communication and Networking: None.

6. Awards/Honors: None

7. Outreach:

Two oral presentations at AMS annual and the AGU fall meetings, and AT 712: Storm and Cloud Dynamics

8. Publications:

The results presented in this report are part of a paper in elaboration that will soon be submitted for publication (Journal of Applied Meteorology and Climatology).

SUPPORT OF THE VIRTUAL INSTITUTE FOR SATELLITE INTEGRATION TRAINING (VISIT)

Co-Principal Investigators: Dan Bikos and Steve Miller

NOAA Project Goal: Weather and Water

Key Words: Professional Training, Satellite Interpretation, VISIT, NWS Training, GOES, Rapid Scan Operations

1. Long-term Research Objectives And Specific Plans To Achieve Them:

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.

This objective is achieved by the development and delivery of new satellite-based training sessions at CIRA. New topics for training are suggested by either NWS or VISIT personnel, and are often related to new satellite products available in the Advanced Weather Information Processing System (AWIPS). In the last year, there have been two new teletraining sessions developed at CIRA with an additional three sessions (teletraining and audio / video playback) created by VISIT collaborators. As training needs develop for new research and products, VISIT personnel will address those needs by building new training sessions. For more information on the VISIT program, see http://rammb.cira.colostate.edu/visit

2. Research Accommmplishments/Highlights:

Based on extensive feedback from participants, the VISIT program has fulfilled the original goal identified in 1998. The number of topics addressed, and participating students, has increased appreciably. A typical monthly training calendar now contains about 15 teletraining sessions over a wide variety of topics. To date, over 19,000 training certificates have been awarded (Fig. 1), and most student feedback suggests a direct applicability to current forecast problems. The VISIT program also recognizes the need for flexibility in offering training courses to the busy forecaster. Most of the teletraining sessions have audio / video playback versions that can be viewed at any time. The combination of live teletraining and audio / video playback versions (Fig. 2) reaches out to as broad an audience as possible given the busy schedule of NWS forecasters. VISIT training applications continue to expand as more NOAA offices turn to this approach as a cost-effective solution to the problem of increased training requirements coupled with shrinking training and travel budgets.

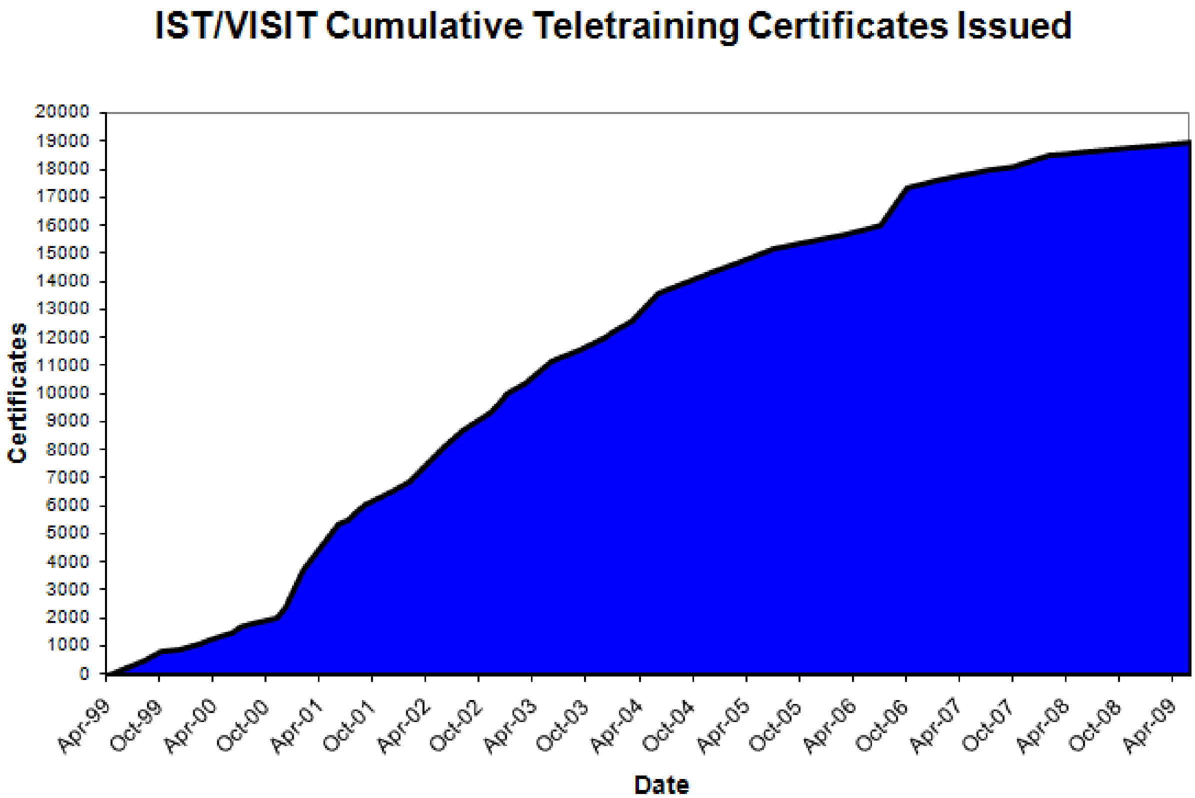

Figure 1. IST/VISIT Cumulative Training Certificates Issued.

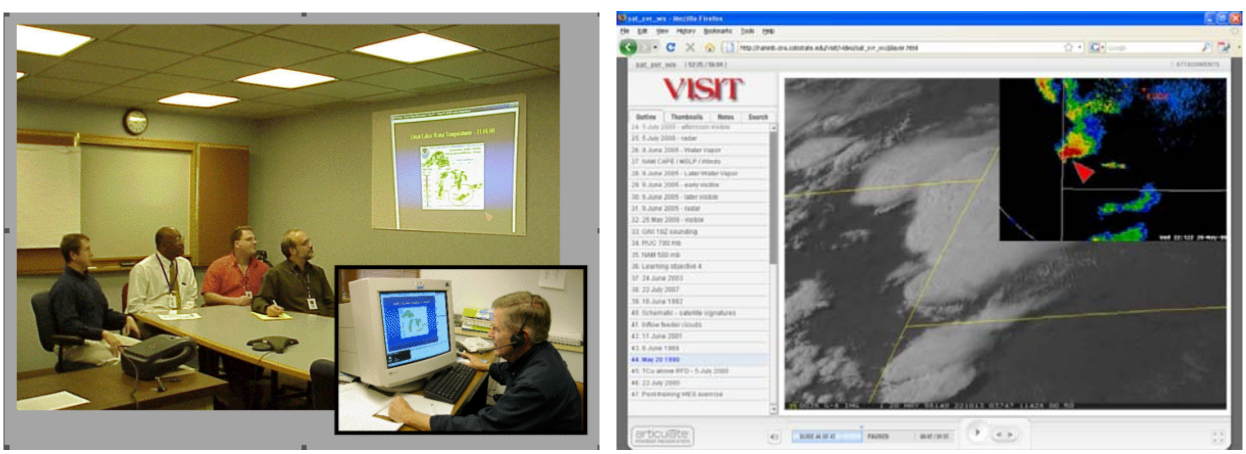

Figure 2. Live VISIT Teletraining (left), and Audio/Video playback VISIT Training Module (right).

3. Comparison Of Objectives Vs. Actual Accomplishments For Reporting Period:

In the last year, the VISIT team at CIRA has developed two new teletraining sessions in order to honor the request made by NWS forecasters for training in these topic areas:

1) "An Overview of Tropical Cyclone Track Guidance Models used by NHC".
2) "An Overview of Tropical Cyclone Intensity Guidance Models used by NHC".

The VISIT team at CIRA also assisted in the development of two new audio / video playback version training modules:

1) "ASCAT Winds".
2) "AWIPS OB9 Blended TPW Products".

All other objectives of the proposal were also accomplished (see section 5 below).

4. Leveraging/Payoff:

The training materials being developed will help the weather forecaster better utilize current satellite products that are available. This will in turn lead to better weather/hazard forecasts for the public.

Live interaction between instructors and students via teletraining is the next best alternative to actual classroom training, and is performed at a fraction of the cost. This also benefits NOAA and the public

5. Research Linkages/Partnerships/Collaborators, Communications And Networking:

The project involves considerable collaboration within the National Weather Service through contributions to training material, input on "beta-tests" of training sessions, feedback following the delivery of the training as well as offering and administering electronic versions of most of the new training through the NOAA/NWS Learning Management System (LMS). The majority of VISIT training sessions are made available in an audio /video playback format. These are quite popular in that they may be taken by the student whenever they want, on their own time, even with the ability to pause during the playback. Once a student goes through this type of training and completes a quiz with a passing grade, this is counted as a completion of the training. Between January 2005 and June 18, 2009 there have been 1130 completions of VISIT training in this format. Of those completions, 297 were between July 1, 2008 and June 18, 2009.

VISIT staff provided continued support for the administration of the SHyMet (Satellite and Hydrology Meteorology) Intern Course Program which was converted from combined training (both live and electronic) to electronic training and tracking only via the NOAA/NWS's Learning Management System (LMS).

Support for the SHyMet Program continues to include such roles as sending and receiving quizes and evaluations for Non NOAA participants; registration and tracking of

NOAA/NWS students through the LMS and their trainingt facilitators; web page maintenence; and correspondence.

The SHyMet/VISIT topics survey was summarized and distributed among the SHyMet/VISIT team members as well as to the NWS Satellite Requirements and Solutions Steering Team (SRSST). (View the survey results here: http://rammb.cira.colostate.edu/visit/Combination_Report_Survey_1.htm)
This promoted two important actions: 1) A member of the VISIT/SHyMet team from CIRA is now participating in the NWS SRSST monthly teleconference meetings as a subject matter expert. 2) The survey results formed the basis for selection of topics for the next version of the SHyMet course.

For more details, see the Project Data Index Sheet for: Getting Ready for NOAA's Advanced Remote Sensing Programs A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal

Coordination also occurs with other agencies involved in satellite training such as NESDIS ORA, DoD and COMET. NOAA is also a member of the World Meteorological Organization's Coordination Group for Meteorological Satellites (CGMS). CGMS supports an International Virtual Laboratory for Training in Satellite Meteorology. In paper 17, which was prepared for the CGMS-XXXII congress in 2004, Appendix B lists the expectations for international "Centres of Excellence", Satellite Operators (ie NOAA), and WMO/CGMS. VISITview has been adopted as an online training tool by CGMS. As such, CIRA, in cooperation with VISIT, has promoted VISITview and shared their expertise in training through:

-- monthly international weather briefings,
--presentations on VISITview and training efforts where appropriate, and contributions to international training materials

6. Awards/Honors: None

7. Outreach:

(a) Two college undergraduate students (Daniel Coleman and Molly McClurg) are supported by this project.

(b) D. Bikos, and J. Braun July 1, 2008 – June 18, 2009: 91 VISIT teletraining sessions delivered to NWS offices, and others (479 participants). CIRA, Fort Collins, CO.

Presentations

D. Bikos attended the AMS / NWA High Plains conference in Hays, Kansas on September 4-5, 2008. He was a co-presenter (along with Jonathan Finch – NWS Dodge City, KS) of a presentation titled "The Colorado-Wyoming Long-Lived Tornadic Supercell of May 22, 2008". A publication is planned based on this presentation.

A presentation on “Satellite Training Activities at CIRA”, which included activities under VISIT, was given at NOAA’s Satellite Direct Readout Conference held in Miami, Florida in December 2008.

Braun, J. was asked to “talk about the weather” on two separate occasions to students of Rocky Mountain High School who attend the Introduction to Chemistry, Physics, and Earth Sciences (ICPE) classes - November 13 and December 9, 2008.

Connell, B. traveled to Miami, Florida to present a talk at NOAA’s 2008 Satellite Direct Readout Conference (December 8-11). She gave a presentation on “Satellite Training Activities at CIRA.” The conference was an excellent venue to find out more information on direct readout capabilities and to meet with international partners.

Connell, B. gave a presentation on the GOES and the characteristics of its channels to a Remote Sensing class at the Metropolitan State College of Denver on November 10, 2008. Since the Remote Sensing class focuses mainly on earth resource topics, the students were presented with the perspective of how meteorologists view and use satellite imagery.

D. Bikos was an invited speaker for a seminar at the University of Wyoming Department of Atmospheric Science in October 2008. The title of the presentation is “The Colorado-Wyoming Long-Lived Tornadic Supercell of May 22, 2008”.

(c) None

(d) J. Braun –. A presentation with general guidelines to “talk about the weather”, was given on five separate occasions in 2008 to students of Rocky Mountain High School who attend the Introduction to Chemistry, Physics, and Earth Sciences (ICPE) classes.

(e) VISIT training material is available to the public via the Internet.

8. Publications:

Refereed Journals
none

Conference Proceedings

Guch, I., S.Q. Kidder, P. Menzel, R. Ferraro, S. Ackerman, D. Khanbilvardi, T. Strub, B. Vant Hull, R. Hudson, and M. DeMaria, 2009: Collaborative training efforts at the NESDIS Cooperative Institutes. 16th AMS Conference on Satellite Meteorology and Oceanography, 11-15 January, Phoenix, AZ.

Mostek, A., M. DeMaria, J. Gurka, T.J. Schmit, 2009: NOAA Satellite Training. 16th AMS Conference on Satellite Meteorology and Oceanography, 11-15 January, Phoenix, AZ.

TRANSITIONING ISCCP GOES-WEST PROCESSING FROM CIRA TO NCDC

Principal Investigator: Stanley Q. Kidder

NOAA Project Goal: Climate. Program: Climate Observations and Analysis.

Key Words: ISCCP, GOES Transitioning

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Since 1983 the Cooperative Institute for Research in the Atmosphere (CIRA) has served as the International Satellite Cloud Climatology Project (ISCCP) processing center for GOES-West data. We receive GOES data (currently GOES-11 data) from our ground station, convert them into ISCCP B1 and B2 formats, and deliver them to the Goddard Institute for Space Studies (GISS, http://www.giss.nasa.gov/) for processing into the ISCCP products and to the National Climatic Data Center (NCDC) for archiving. We also provide calibration sectors (small samples of GOES-11 and GOES-12 data) for comparison with observations from polar-orbiting satellites.

The objective of this project is to transition this ISCCP processing from a research setting (CIRA) into an operational setting (NCDC). This involves transferring our processing code to NCDC and working with NCDC personnel to implement the processing there. After that, we will quality check the NCDC produced files by comparing them with the files produced at CIRA.

2. Research Accomplishments/Highlights:

We have transitioned our code to NDCD, and it is running there. Now we need to certify the products produced at NCDC before handing over production to them.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

So far we are on track to accomplish all of our objectives by the end of calendar year 2009. As stated above, the code transition is complete.

4. Leveraging/Payoff:

This work will contribute to NOAA's attempt to form a National Climate Service. The International Satellite Cloud Climatology Project (ISCCP) is one of the premier climate observation programs in the world. If NOAA is to become the nation's climate agency, ISCCP processing needs to be made operational at NOAA.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Our chief collaborator is Ken Knapp of NCDC.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

VALIDATION OF SATELLITE-BASED THERMODYNAMIC RETRIEVALS IN THE TROPICS

Principal Investigator: John Dostalek

NOAA Project Goal: Weather and Water

Key Words: Tropical Meteorology, Satellite Retrievals

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The validation of satellite retrievals typically involves comparison with global radiosonde data or model background fields. However, the thermodynamic properties of the atmosphere show considerable regional variability. For example, the tropical atmosphere has a much higher moisture content, especially in the lower troposphere and has unique structures such as the trade wind inversion and very high moisture regions associated with the Inter-Tropical Convergence Zone (ITCZ) and monsoon troughs. The tropics also generally have a deeper troposphere and colder tropopause temperatures. In addition, most of the tropics are over the ocean where the error characteristics of the global model analyses often used for retrieval first guess estimates are different than over the mid-latitudes. The goal of this research is to perform a satellite retrieval validation specific to the tropics. Radiosondes and dropsondes from the Gulfstream IV, as well as radio occultation retrievals from the COSMIC program will be used to validate various polar-orbiting satellite retrieval techniques including: ATOVS from Met-OP and NOAA-18, MIRS from Met-Op and NOAA-18, and AIRS from AQUA. Additional satellite-based retrievals may also be added. In addition, the quality of the GFS temperature and moisture profiles will be assessed.

Specifics of the plan include:

--Performing standard statistics to assess the quality of the satellite retrievals and GFS data (e.g. bias, mean absolute error)

--Assess the capabilities of the different retrievals to capture specific features such as the height of the tropopause, the height of the trade-wind inversion, low-level moisture, and CAPE

2. Research Accomplishments/Highlights:

Data gathering and software procurement and installation were performed. Data from the GPS soundings dropped from the NOAA Gulfstream IV for the 2008 Atlantic hurricane season were collected. As an example, the locations of the dropsondes deployed over Hurricane Gustav on 30 August 2008 are overlaid on top of a GOES 10.7 μm image (Figure 1).

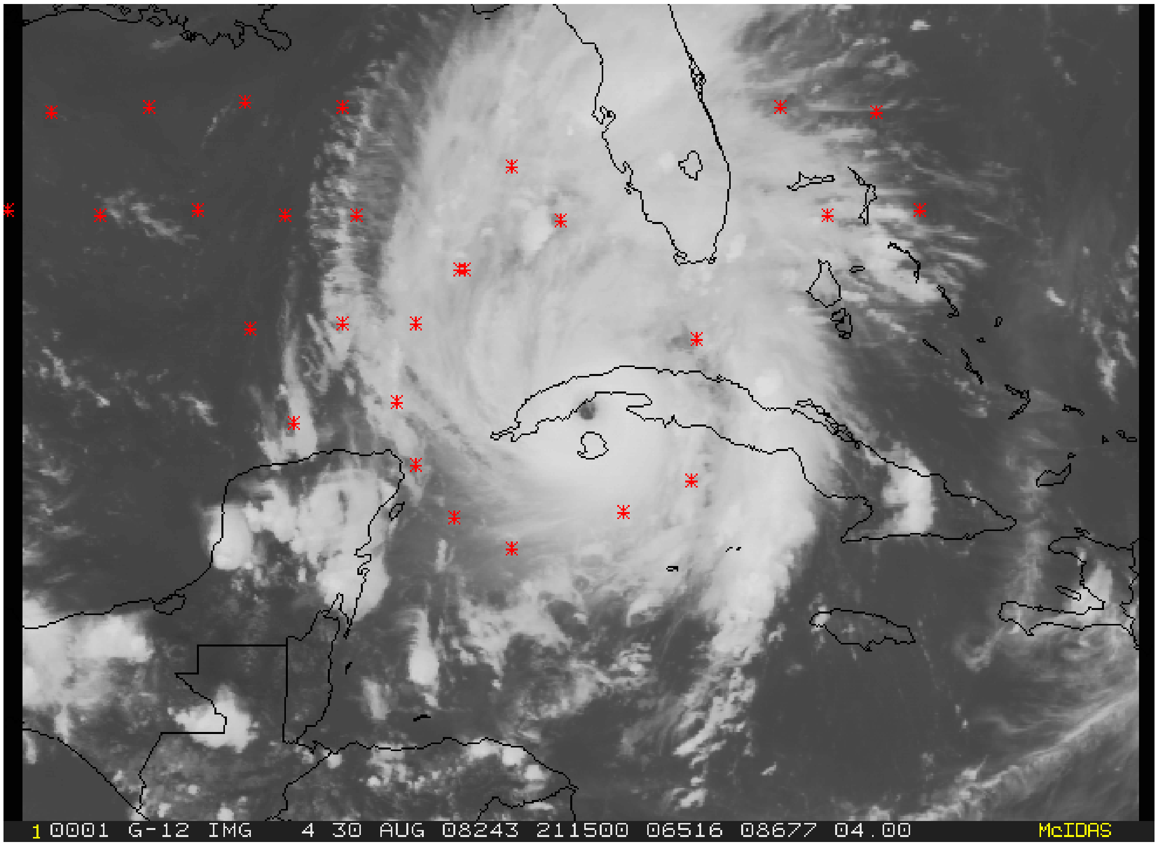

Figure 1. Dropsonde locations from 30 August 2009 overlaid on a 10.7 μm image of Hurricane Gustav.

The NPROVS (NOAA Product Validation System) graphical software was obtained from NESDIS and installed at CIRA. NPROVS is a powerful tool which consists of a database of radiosonde profiles, satellite soundings, and model data. Collocated datasets can be compared visually and statistically. An example page from the NPROVS system is shown in Figure 2.

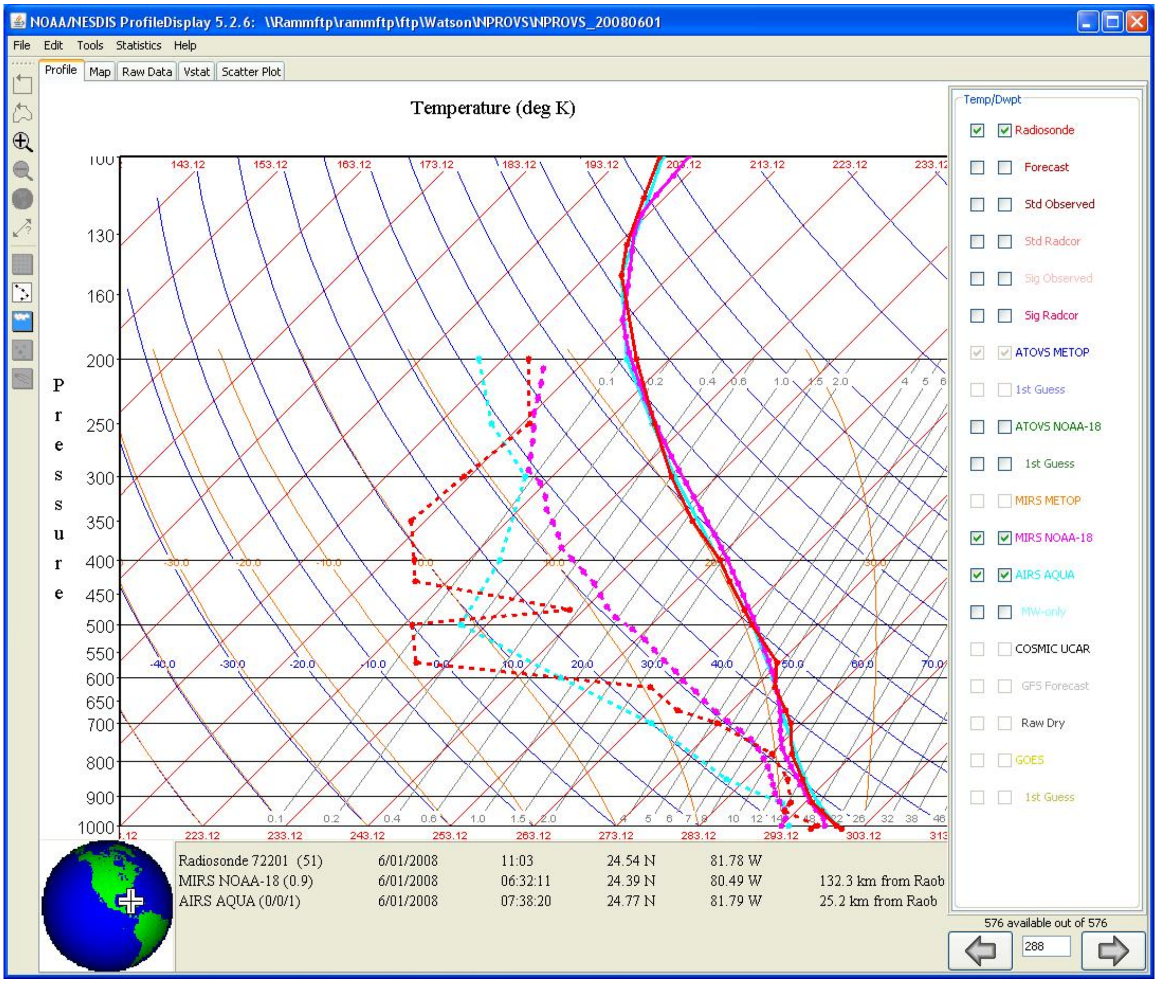

Figure 2. Comparison among the 1200 UTC radiosonde (red) from Key West, FL and the collocated MIRS (NOAA-18, dark pink) and AIRS (AQUA, cyan) retrievals for 1 June 2008. Temperature retrievals are solid, dewpoint temperature retrievals are dashed.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The work of validating the satellite retrievals is in progress. Time constraints prevented the full completion of the project. Sufficient progress was made, however, that additional funding for the work was secured for 2009-2010. The acquisition and installation of the NPROVS system negates the need to develop the software to do the retrieval/radiosonde collocations.

4. Leveraging/Payoff:

The satellite retrievals in the tropics are used in a number of tropical cyclone products, including the operational tropical cyclone intensity and structure algorithms run at the NCEP Tropical Prediction Center and the multi-platform tropical cyclone surface wind analysis product that is planned to become operational at NESDIS in the summer of

2010. Assessing the quality of the retrievals as well as the GFS fields will help to determine which profiles to use in the tropical cyclone products.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Communication with NESDIS employees on the use of the NPROVS system has occurred and will continue during this work.

6. Awards/Honors: None

7. Outreach: None

8. Publications: None

WEATHER SATELLITE DATA AND ANALYSIS EQUIPMENT AND SUPPORT FOR RESEARCH ACTIVITIES

Principal Investigator/Group Manager: Michael Hiatt

NOAA Project Goal: Geostationary Satellite Acquisition, Polar Satellite Acquisition, Information Technology Services

Key Words: IT, Computers, Technology, Earthstation, GOES, MSG, AVHRR, DOMSAT, ISCCP, Security, Cluster, Satellite Data, Archive, Cloudsat, OCO, Network, Windows, Linux

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Continue excellence in infrastructure operations, maintenance, research, and development.

2. Research Accomplishments/Highlights: See text below.

3. Comparison of Objectives vs. Actual Accomplishments for Reporting Period: None

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking: None.

6. Awards/Honors:

Michael Hiatt received the Colorado State University Distinguished Administrative Professional award

7. Outreach: None.

8. Publications: None.

9. Additional Information:

The CIRA Infrastructure provides all planning, development, acquisition, deployment, maintenance, and support for CIRA's information technology including computer resources, networking, security, satellite earthstation, data archive, technical innovations, and project support.

This group is staffed by three employees; an Electrical Engineer, a PC technician, and a Linux administrator. Two part time students assist with the data archive. 90% of staff time is spent performing operations and maintenance.

Computer Resources

CIRA currently has approximately 200 systems that represent CIRA's core computer base. These systems are custom designed, assembled, and maintained by the group. The following list gives a brief overview of the infrastructure resources managed by this group:

--Complete system management: Intel servers/workstations using the Microsoft Windows XP/2003/Vista operating system, hardware acquisition and installation, user support and training, system upgrades, software acquisition and installation, service packs

--Central services: E-mail, website, accounts, accounting, domain, FTP, printing, remote access, power control, property accounting

--Security: firewall, NTFS, antivirus, antispam

--Network: LAN, WAN, cabling, switches, firewall, DHCP, DNS

--Infrastructure budget and expenditures: $100k/year hardware/software budget

--Technical group consulting: RAMM, NPS, AMSU, OCO, ISCCP, Geosciences, CloudSat, students, visiting scientists, training

--Linux modeling clusters: (1) 64-bit, 40 processor cluster, (1) 32-bit 24 processor cluster, RAMM model, WRF model

--Documentation: reports, web, diagrams, posters

Earthstation

The satellite earthstation provides key metrological data for CIRA research. The group operates and maintains both current operations and the data archive. CIRA currently collects over 30 products including:

--GOES-10
--GOES-11
--GOES-12
--GOES-13 (experimental)
--NOAA-16/17
--MSG-1
--MSG-2
--FY2C
--MTSAT

CIRA's Meteorological archive contains over 200TB dating back to 1994. This data is archived on DVD and searchable via a web based database.

Special Projects

CloudSat

The group continues to support the CloudSat DPC (Data Processing Center). This infrastructure contains 45 servers and 23 storage units (60TB RAID6). The CloudSat DPC was designed using SFF (Small Form Factor) PC's and NAS (Network Attached Storage) units as these systems have proven successful in other CIRA projects. SFF systems consume less power, generate less heat, and are less than half the price than comparable "pizza box" servers. By consuming less power and generating less heat, the room requirements are much lower further saving the CloudSat project significant funds.

Additional SFF systems were built this year to support the re-processing phase of the CloudSat mission. 30 additional servers and 15 additional NAS storage units were built and deployed.

The CloudSat DPC continues to perform above design specifications. Additional ancillary data sets are being processed and stored. NASA and JPL continue to recognize this award winning DPC.

OCO

The group supplied the OCO project with design and near-implementation of a 600 node high performance cluster. The OCO mission is on hold due to a failed satellite launch.

Archive

CIRA has 400 8mm tapes remaining which contain meteorological data from the past decade. These tapes are at risk since tape technology does not last indefinitely, tapes drives to read the tapes are no longer available, and software to read the tapes may not run on future systems. Using in-house developed software, automated systems, and student help, the tapes are being converted to DVD. The group completed the remaining tapes this year.

The physical space savings gained by DVD's have opened up space in the archive. This space is being upgraded with additional power and air conditioning for additional servers and online storage.

Technology

Upgraded NAS systems were researched and deployed this year. The new units have the same power and cooling requirements but have four times the storage capacity. CIRA now has a reliable RAID6 storage solution that holds 9.6TB for less than $3000.00.

Earthstation

GOES-O hardware and software development completed this year. CIRA also upgraded one of the three GOES antenna's with a new fiberglass reflector.

Network

CIRA will be increasing the WAN connection to main campus from 100MB/s to 1GB/s. This will support the increasing bandwidth requirements needed by CIRA projects. CIRA is part of the Front Range GigaPOP and therefore connects to the commodity Internet, LambdaRail, and Abilene networks.


Thecus
Shuttle
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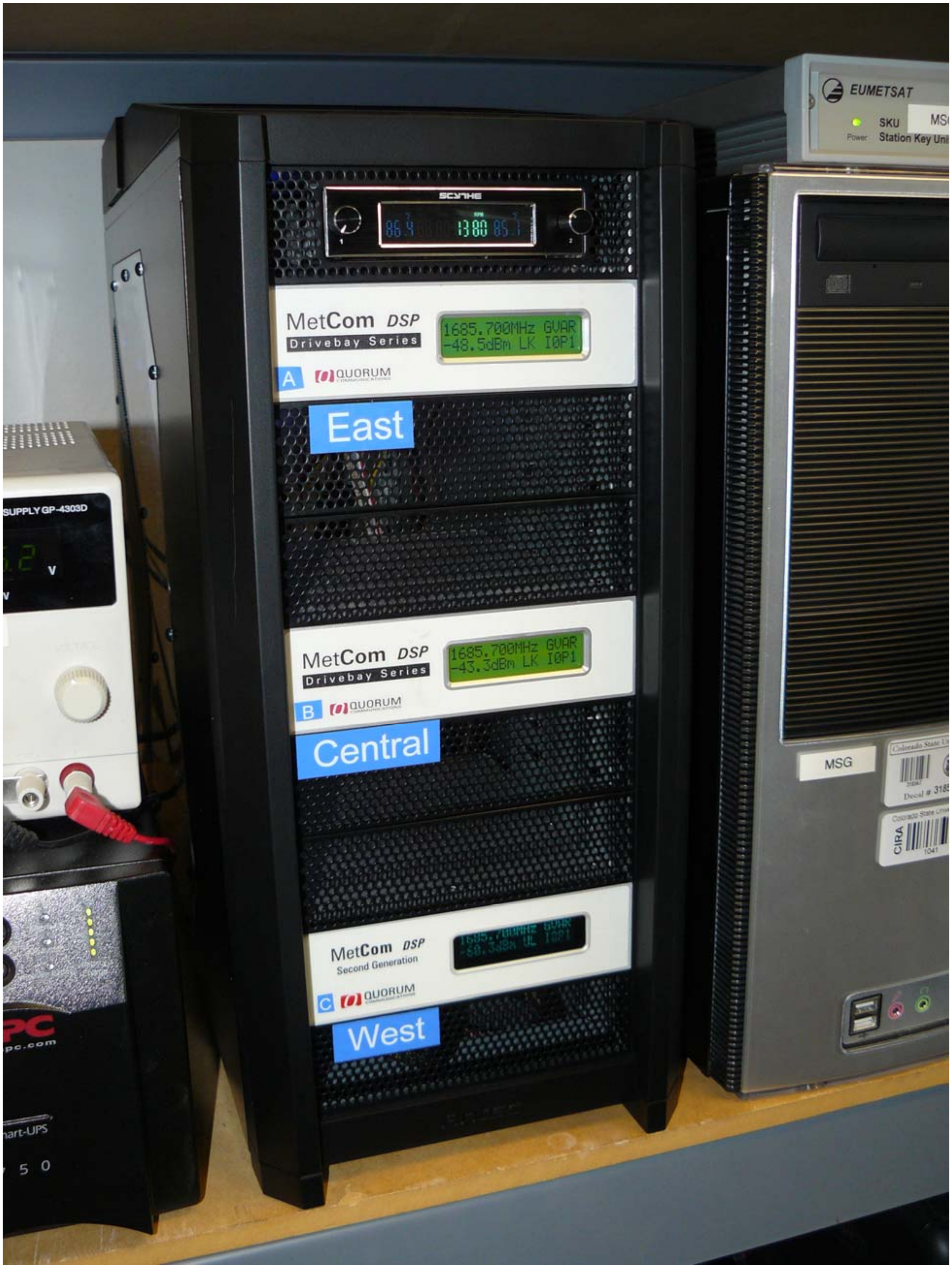
Shuttle


EUMETSAT
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-43.3dBm LK I0P1
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Central
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Second Generation
C
QUORUM
West
MSG

ADDITIONAL CIRA FUNDING

DEPARTMENT OF DEFENSE

DoD Center for Geosciences/Atmospheric Research (CG/AR)

Principal Investigator: Thomas H. Vonder Haar

NOAA Project Goal: see separate research theme areas

Key Words: Hydrology, Data Assimilation and Modeling, Data Fusion, Aerosols, Climatology, Cloud Physics

1. Long-term Research Objectives and Specific Plans to Achieve Them:

CG/AR is a DoD sponsored research activity at CIRA that has been ongoing since 1986. CG/AR research reflects DoD priorities and interests, but to a large degree also addresses NOAA-relevant concerns. The five CG/AR research theme areas all relate to NOAA's Climate, Weather and Water, and Commerce & Transportation Goal areas. They are:

--Hydrometeorology
--Clouds, Icing, and Aerosols Effects
--Environmental Modeling and Assimilation
--Urban and Boundary Layer Environment
--Remote Sensing of Battlespace Parameters

The leveraged payoff on these DoD-funded projects has had significant impacts on CIRA's NOAA research. Specifically the data assimilation work funded by CG/AR was well ahead of NOAA's interest in this area. The skills and infrastructure developed in this area have allowed CIRA to address the NOAA assimilation problems with minimum spin up and have allowed CIRA to contribute at a more significant level of effort then would have been possible with NOAA-only assimilation research funding. Likewise, CG/AR research in Homeland Defense related activities is proving to be of interest to both DoD and NOAA.

2. Research Accomplishment/Highlights:

The following information was extracted from the CG/AR Annual Review. For more detail on any of the topics please contact Tom Vonder Haar (vonderhaar@cira.colostate.edu) or Loretta Wilson (wilson@cira.colostate.edu). This information has been limited to NOAA-relevant research and activities not relevant to one of NOAA's goals are not included.

<u>Dust Transport and Aerosol Data</u>

Objectives:

1. To use the COAMPS model, together with resolved aerosol source functions, to study the lofting and transport of dust (and other) aerosol types in the Iraq /

Afghanistan regions. COAMPS data will be archived for at least a full year, beginning Summer 2009, for this study.

2. To use NAAPS global model output, available from the archive, to study the annual cycles of dust events in the regions of interest.
3. To use NAAPS / COAMPS output, as available, for classification of transport pathways and association with synoptic patterns and climate indices
4. To combine NAAPS output with other data (satellite imagery, in situ data) to support Cahill air mass classifications / dust source region identifications for 2008, and for 2009, to add COAMPS information in support of the classifications.

Tasks:

The study will represent the work for a M.S. thesis in the Dept of Atmos. Sci. We propose collaborative research with the Naval Research Laboratory, Monterey, CA and with Prof. Cathy Cahill of Fairbanks, AK to address the stated objectives. The overall theme is to use output from global and regional models, that include dust and other aerosol sources, to help interpret ground-based measurements of aerosol "events".

<u>Assimilation of Geostationary Infrared Satellite Data to Improve Forecasting of Mid-level Clouds</u>

Objectives:

1. Improve forecasting of mid-level clouds
2. Assimilate GOES Imager and Sounder data into the 4-DVAR RAMDAS
3. Compare results with observations from CLEX-9
4. Investigate the assimilation of cloudy-scene radiances into a cloud-free model state

Results:

--GOES Imager experiment

1. Cooled the surface, increased upper-tropospheric humidity
2. Increased fog
3. No closer to producing mid-level cloud

--GOES Sounder experiment

1. Produced subsidence inversion
2. Cooled, humidified atmosphere near 2 km AGL
3. Some surface cooling
4. No mid-level cloud, but closer to producing one

Conclusions:

--RAMDAS is designed to minimize the difference between the modeled and observed brightness temperatures

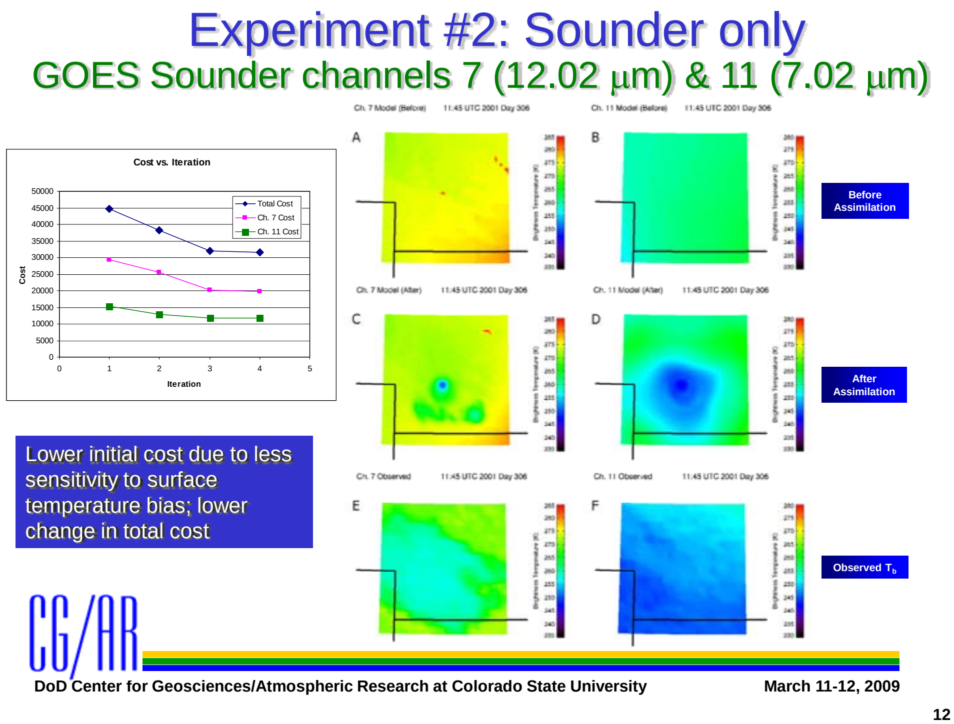
1. The assimilation can only modify the model state where the observations are sensitive to model variables

--When no cloud is present in the model, the adjoint calculates sensitivities based on having no cloud

1. In the GOES Imager case, ch. 4 is most sensitive to surface temperature in the absence of cloud, ch. 3 is most sensitive to upper-tropospheric humidity

2. GOES Sounder ch. 7 & 11 are more sensitive to low- to mid- troposphere temperature and humidity

--Additional constraints are needed to ensure an appropriate physical solution



Parameterizing Aerosol and Sub-grid Cloud Properties in a Mesoscale Model

Objectives:

--Develop a boundary layer model for use in a mesoscale forecast model that is able to predict ceilings, precipitation, and visibility including visibility reductions due to dust.

Soil Moisture Detection

Objectives:

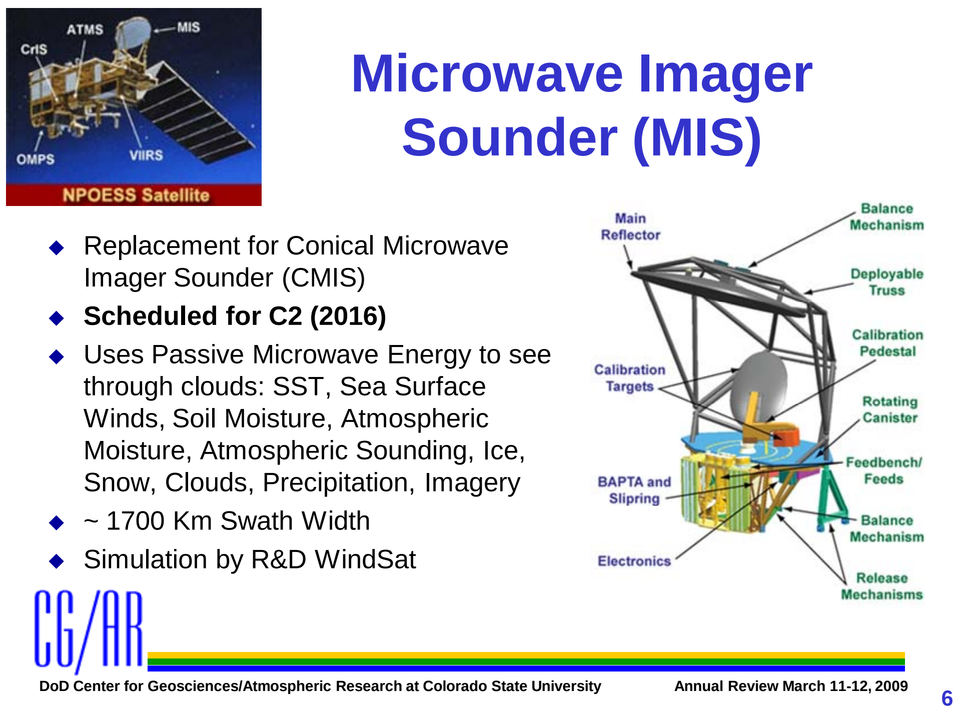
--To extend the NPOESS MIS Surface Soil Moisture Environmental Data Record (EDR) to deep soil levels (> 80 cm depths) using a temporal variational data assimilation method (2/4DVAR) to meet U.S. Army needs

--Support NPOESS MIS algorithm needs:

--Participate in MIS Land Performance Team interactions

--Sensor Trade Studies (joint work with NRL/DC)
(e.g., estimates of RFI and 6/10 GHz impacts)
--Error Budget Estimates
--System/Requirement/Algorithm Review Preparations
--Delivery of working algorithm software to the IPO

--Supporting data and algorithm analysis
--Geostatistical analysis for estimating model/data errors
--AGRMET Land Surface Model performance characterization
--New USAF Land Information System (LIS) performance characterization will begin soon (AFWA LIS became operational Feb. 2009)



<u>Towards Improving the Satellite Remote Sensing of Mixed Phase Cloud: A Study on its Microphysical and Optical Properties</u>

Objectives:

--Understand mixed phase cloud microphysics and the ice/water distribution within the cloud.
--Investigate the impact on radiative transfer from a vertically inhomogeneous mixed phase cloud.
--Establish a database of mixed phase cloud microphysical and optical properties with a typical vertical structure for further remote sensing and theoretical simulation use.

Principal Results and Deliverables:

--About 2/3 of the sampled mid-level cloud profiles sampled during CLEX-9 were mixed phase, typically super-cooled liquid topped altocumulus.

--A case with NASA TERRA MODIS overpass was thoroughly investigated on its microphysical and optical properties.

--Inhomogeneous (layer) model of mixed phase clouds is essential for the accurate representation of bulk scattering properties and radiative transfer in the Infrared (IR) region.

--The derived microphysical and optical databases are available for further remote sensing and modeling applications or theoretical studies (e.g., validation of MODIS or other satellite retrieval algorithms).

8. Publications:

Carey, L.D., J. Niu, P. Yang, J.A. Kankiewicz, V.E. Larson, and T.H. Vonder Haar, 2008: The vertical profile of liquid and ice water content in mid-latitude mixed-phase altocumulus clouds. *J. Appl. Meteor. Clim.*, 47, 2487-2495 (doi: 10.75/2008JACM885.1).

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Jones, A.S., 2008: What is data assimilation? A tutorial. AMS Data Assimilation Education Forum, January 21, New Orleans, LA.

Jones, A.S., T. Lakhankar, C. Combs, S. Longmore, G. Mason, G. McWilliams, M. Mungiole, M. Sengupta, and T.H. Vonder Haar, 2008: An NPOESS feasibility study to retrieve deep soil moisture using WindSat data and a temporal variational data assimilation method. Pre-print CD-ROM, 4th Annual Symposium: Future National Operational Environmental Satellite Systems - Research to Operations, January 22, New Orleans, LA (AMS).

Jones, A. S., T. Lakhankar, C. Combs, S. Longmore, M. Sengupta, and T.H. Vonder Haar, 2008: Retrieval and verification of deep soil moisture using passive microwave data and a temporal variational data assimilation method. International Workshop on Microwave Remote Sensing for Land Hydrology, Research and Applications, October 20-22, Oxnard, CA (poster).

Jones, A. S., L. Li, G. McWilliams, C. Smith, 2008: MIS Soil Moisture Error Budget Whitepaper submitted to the NPOESS Integrated Projects Office*,* December 15, 4 pp.

Klein, S.A., R.B. McCoy, H. Morrison, A.S. Ackerman, A. Avramov, G. de Boer, M. Chen, J.N.S. Cole, A.D. Del Genio, M. Falk, M.J. Foster, A. Fridlind, J-C. Golaz, T. Hashino, J.Y. Harrington, C. Hoose, M.F. Khairoutdinov, V.E. Larson, X. Liu, Y. Luo, G.M. McFarquhar, S. Menon, R.A. J. Neggers, S. Park, M.R. Poellet, J.M. Schmidt, I. Sednev, B.J. Shipway, M.D. Shupe, D.A. Spangenberg, Y.C. Sud, D.D. Turner, D.E. Veron, K. von Salzen, G.K. Walker, Z. Wang, A.B. Wolf, S. Xie, K-M. Xu, F. Yang, and G. Zhang, 2008: Intercomparison of model simulations of mixed-phase clouds observed during the ARM Mixed-Phase Arctic Cloud Experiment. Part I: Single layer cloud. *Quarterly Jou. Royal Meteor. Soc.,* (submitted).

Lakhankar, T., A.S. Jones, C.L. Combs, M. Sengupta, T.H. Vonder Haar, 2008: Analysis of large scale spatial variability of soil moisture data using a geostatistical method. 22nd Conf. on Hydrology, January 20-24, New Orleans, LA.

Lakhankar, T., A.S. Jones, M. Temimi, T.H. Vonder Haar, and Khanbilvardi, 2008: Variational data assimilation method for soil moisture estimation using active microwave data. International Workshop on Microwave Remote Sensing for Land Hydrology, Research and Applications, October 20-22, Oxnard, CA (poster).
Larson, V.E., K.E. Kotenberg, N.B. Wood, 2007: An analytic longwave radiation formula for liquid layer clouds. *Mon. Wea. Rev.,* 135, 689-699.

Leoncini, G., R.A. Pielke Sr., and P. Gabriel, 2008: From model-based parameterizations to Look Up Tables: An EOF approach. *Wea. Forecasting*, (23), 1127-1145, doi: 10.1175/2008WAF2007033.1.

McCarron, M., 2009: Adaptive methods for rapid acoustic transmission loss prediction in the atmosphere. Masters thesis, Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, CO, 127 pp.

Morrison, H., R.B. McCoy, S.A. Klein, S. Xie, Y. Luo, A. Avramov, M. Chen, J.N.S. Cole, M. Falk, M.J. Foster, A.D. Del Genio, J.Y. Harrington, C. Hoose, M.F. Khairoutdinov, V.E. Larson, X. Liu, G.M. McFarquhar, M.R. Poellet, K. von Salzen, B.J. Shipway, M.D. Shupe, Y.C. Sud, D.D. Turner, D.E. Veron, G.K. Walker, Z. Wang, A.B. Wolf, K-M. Xu, F. Yang, and G. Zhang, 2008: Intercomparison of model simulations of mixed-phase clouds observed during the ARM Mixed-Phase Arctic Cloud Experiment. Part II: Multi-layered cloud. *Quarterly Jou. Royal Meteor. Soc.,* (submitted).

Niu, J., L.D. Carey, P. Yang, and T.H. Vonder Haar, 2008: Optical properties of a vertically inhomogeneous, midlatitude, mid-level, mixed-phase altocumulus in the infrared region. *Atmos. Res.*, 88, 234-242**.**

Noh, Y.-J., J.A. Kankiewicz, S.Q. Kidder, T.H. Vonder Haar, 2008: A study of wintertime mixed-phase clouds over land using satellite and aircraft observations. Preprint CD-ROM, Symposium on Recent Developments in Atmospheric Applications of Radar and Lidar at the 88th AMS Annual Meeting, January 20-24, Pielke Sr., R.A. and T. Vukicevic, 2005: Forum on modeling the atmospheric boundary layer. *Bull. Amer. Meteor*. *Soc*., 86, 95-96.

Ostashev, V.E., M.V. Scanlon, C. Reiff, D.K. Wilson, and S.N. Vecherin, 2008: The effects of uncertainties in meteorological profiles on source localization with elevated acoustic sensor arrays. Proceedings, 13th International Symposium on Long Range Sound Propagation, Lyon, France.

Rojas, R., M. Velleux, P.Y. Julien, and B.E. Johnson, 2008: Grid scale effects on watershed soil Erosion Models. *J. Hydrol. Eng.*, Sept., 793-802, doi: 10.1061/(ASCE)1084-0699(2008)13:9(793).

Seaman, C. J., J.A. Kankiewicz, S. Longmore, M. Sengupta, and T.H. Vonder Haar, 2008: Assimilation of GOES radiances to improve understanding and forecasting of mid-level, mixed-phase clouds. Preprint CD-ROM, 12th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS) (poster), January 20-24, New Orleans, LA.

Shah-Fairbank, S.C., 2009: Series expansion of the modified Einstein procedure. PhD dissertation, Civil and Environmental Engineering Department, Colorado State University, Fort Collins, CO, 238 pp.

<u>JPL</u> – Monitoring Future Carbon Controls

Principal Investigator: Graeme Stephens (David Baker performing the work)

NOAA Project Goal: Mission Support (Satellite Subgoal)

Key Words: CO_2 Flux, OSSE, Mission Design, Fine-scale

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This study examines what sort of satellite network (number of satellites, orbital configuration, precision of measurements) is required to allow surface CO_2 fluxes to be estimated at fine, grid-scale resolutions (e.g., 2°x2° in longitude/latitude). Observing system simulation experiments (OSSEs) are performed, globally, with our variational carbon data assimilation system (Baker, et al, 2009) to do this.

2. Research Accomplishments/Highlights:

A number of satellite networks (including dawn/dusk and other sun-synchronous orbits) have been examined. We find that the total flux constraint provided per satellite does not depend strongly on the orientation of a sun synchronous orbit (local time of ascending node) -- even dawn/dusk orbits provide much information, despite the high solar zenith angles and long atmospheric paths that affect their measurements. A fleet of four appropriately-spaced sun-synchronous satellites with measurements similar to those planned for the Orbiting Carbon Observatory (OCO) could potentially improve surface CO_2 flux estimates by 50-60% where our current understanding is worst.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

We had hoped to perform this study at horizontal resolutions as fine as 1°x1° or 2°x2°. Our current results are at 5°x2° (long/lat), and we are working on refining these at finer resolutions now.

4. Leveraging/Payoff:

This work is of interest not only for understanding the functioning of the global carbon cycle (and its implication for predicting future levels of global warming), but also for use in monitoring compliance with international CO_2 emissions treaties.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

While this project is funded by NASA, we work closely with carbon cycle modelers at NOAA/ESRL in Boulder, CO.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: We plan to publish our results in peer-reviewed journals.

NASA - CloudSat

Report Provided by: Don Reinke

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Continue excellence in infrastructure operations, maintenance, research, and development.

2. Research Accomplishments/Highlights: See text below.

3. Comparison of Objectives vs. Actual Accomplishments for Reporting Period: See below.

4. Leveraging/Payoff: See below

5. Research Linkages/Partnerships/Collaborators, Communications and Networking: None

6. Awards/Honors: See below

7. Outreach: See below

8. Publications:

9. Additional Information:

CIRA provides the operational data processing center for this NASA Earth System Science Pathfinder (ESSP) satellite mission. NOAA relevance is illustrated by the mission's basic science products that fit into the NOAA Climate Goal.

Year-in-Review Summary

CloudSat launched on April 28th, 2006 and the CloudSat Data Processing Center (DPC) has been fully operational since the first CloudSat data were downlinked on May 20th 2006. Since that date, the CloudSat data downlink system has collected 99.9% of the available data, and the CIRA CloudSat Data Processing Center has processed 100% of the available input data to Level 2 products.

Because of the success of the baseline 22-month mission, NASA has extended the mission for an additional 3 years, including support of the CIRA CloudSat DPC.

Cloudsat Mission Overview and the CloudSat Data Processing Center (DPC)

CloudSat is a satellite experiment designed to measure the vertical structure of clouds from space and, for the first time, will simultaneously observe cloud phase and radiative properties. The primary CloudSat instrument is a 94-GHz, nadir-pointing, Cloud Profiling Radar (CPR). A unique aspect of this mission is the fact that CloudSat is flying in formation with other Earth

Sciences missions dubbed the A-Train (fig 1). CloudSat will be a part of a constellation of satellites that currently include NASA's EOS Aqua and Aura satellites as well as a NASA-CNES lidar satellite (CALIPSO), and a CNES satellite carrying a polarimeter (PARASOL).

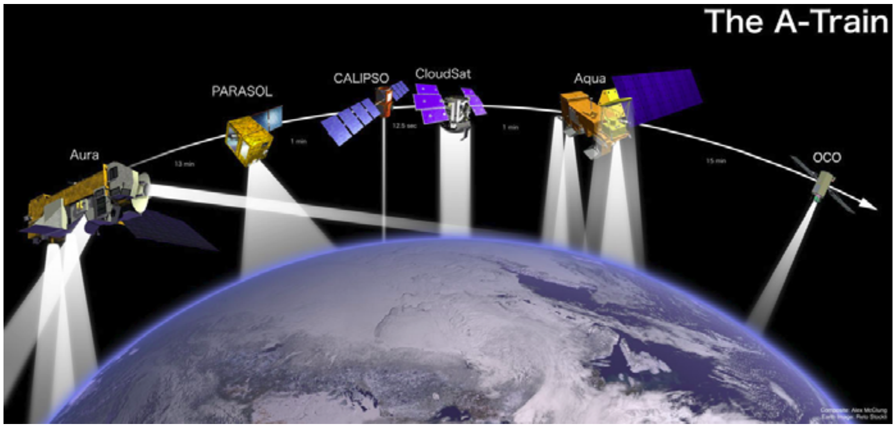

Figure 1. "A-Train" satellite constellation

CloudSat must fly a precise orbit to enable the field of view of the CloudSat radar to be overlapped with the lidar footprint and the other measurements of the constellation. The precision of this overlap creates a unique multi-satellite virtual platform observing system for studying the atmospheric processes of the hydrological cycle. Additional information about the CloudSat mission may be found at http://cloudsat.atmos.colostate.edu .

CIRA provides all of the science data processing support for the mission. Four universities and the NASA Jet Propulsion Lab (JPL) are participants on the CloudSat algorithm development team. During the current Operational (on-orbit) Phase, the DPC is staffed by CIRA employees, Science and Technology Corporation personnel (under a sub-contract to CIRA), and part-time CSU or High School students. More information about the DPC can be found at http://www.cloudsat.cira.colostate.edu

Figure 2 shows the flow of CloudSat data from the satellite to the USAF Research Testing Development and Evaluation (RTD&E) Support Center at Kirtland AFB NM.

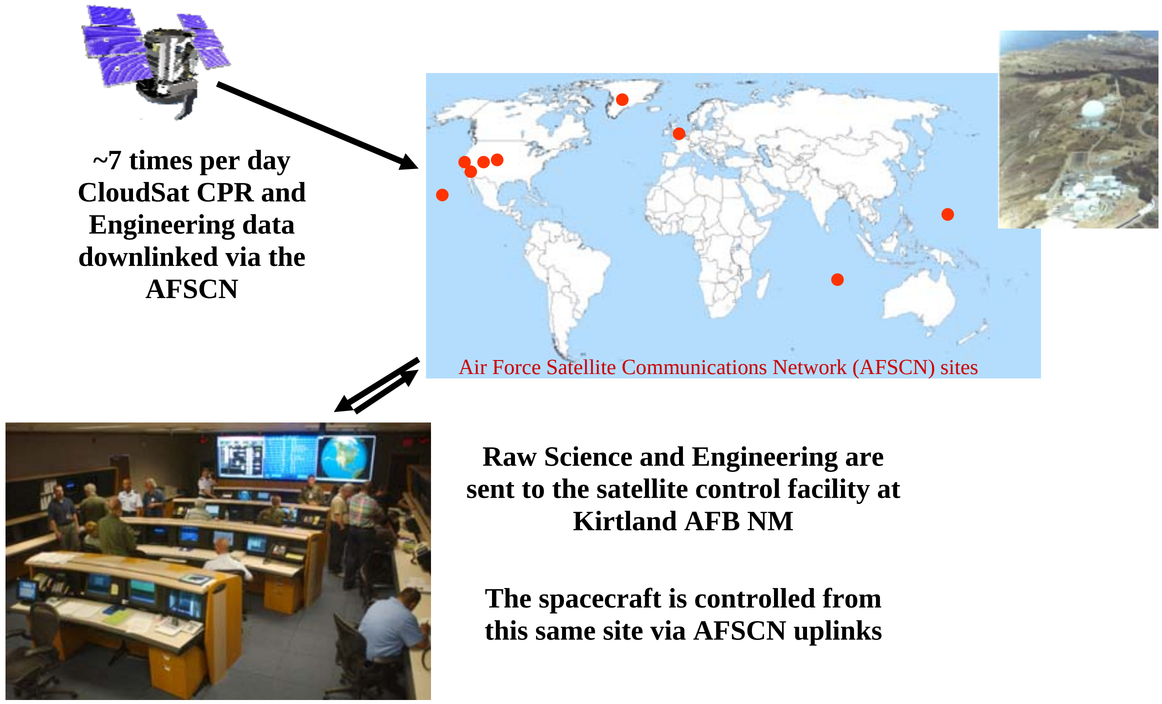

Figure 2. CloudSat Data Flow – Satellite to USAF site at Kirtland AFB.

Figure 3 shows the flow of CloudSat data from the RTD&E Support Center (RSC) to CIRA; from several remote environmental data centers to CIRA; and the flow of ancillary data and CloudSat products through the DPC system. CloudSat data are pulled from the RSC approximately 7 times per day.

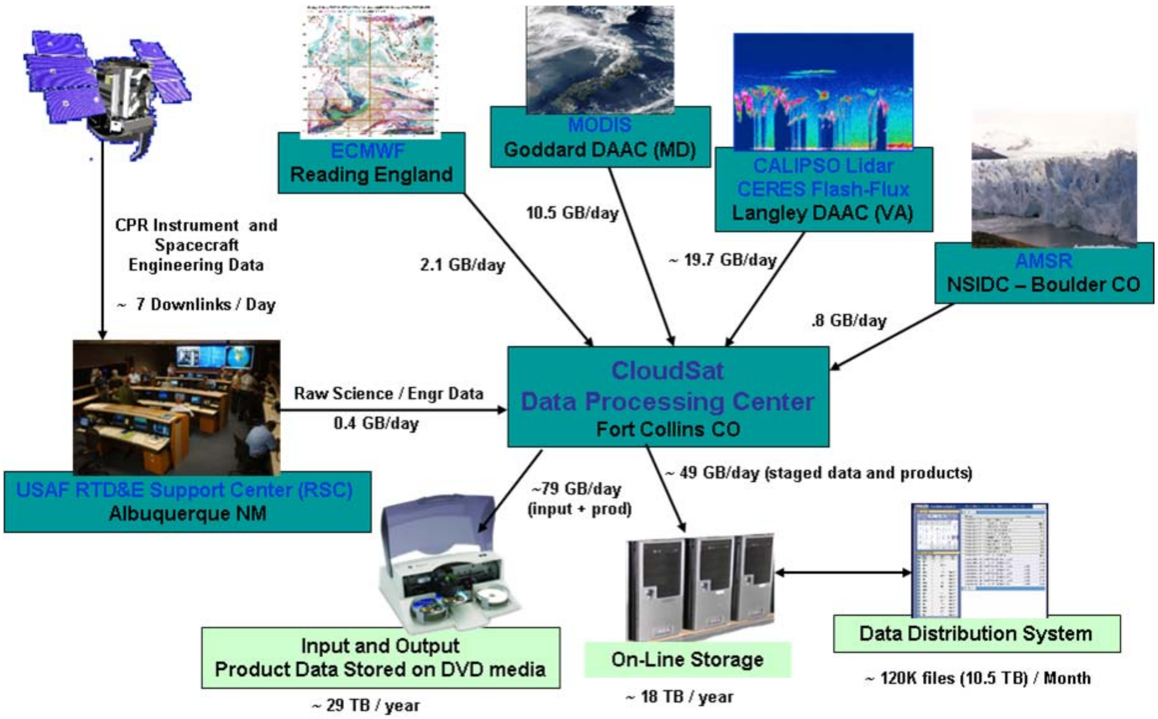

Figure 3. Data Flow through the CloudSat Data Processing Center.

Over the past year, the RSC has collected 99.9% of the possible CloudSat Data downlink opportunities and the CloudSat DPC has ingest and processed 100% of the CloudSat Science and Engineering data provided by the RSC.

Data Distribution

The CloudSat DPC is also responsible for maintaining an archive of the CloudSat data products and the distribution of products to the science community. As of December 31st, 2008, the data distribution system has provided data to over 712 users/groups in 50 different countries. Some pertinent statistics as of 12/31/2008:

Granules (Orbits) Processed	Profiles (37,088/Granule)	240-m Vertical Bins (125/Profile)
13,385	496,422,880	62.1 Billion

Cumulative data distribution through Dec 31st 2008	Product Files	Data Volume (TB)
	3,009,018	232.1

Accomplishments of Note

The DPC was given a requirement to provide Level 0 and Level 1 products within 30 days of the receipt of data. We are currently generating both products, and displaying a geolocated browse image of the CPR science data within 2 minutes. This quick turnaround of data and the generation of the “quicklook images” (fig 4) was identified as one of two NASA “Firsts” for this mission. (The other being the accomplishment of formation flying.)

A second mission requirement calls for CIRA to maintain 60 days of on-line raw data and data product storage. The DPC has maintained on-line data storage from the beginning of the mission with over 2 ½ years of data on-line as of the end of this past calendar year.

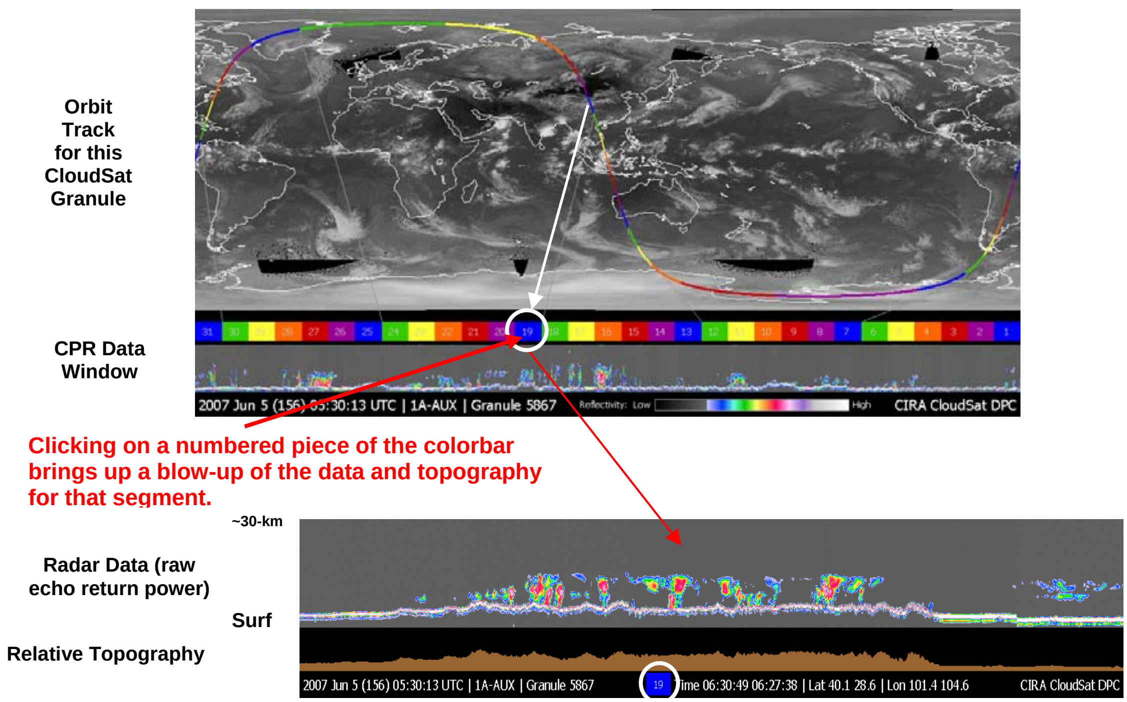

Figure 4. CloudSat “Quicklook” imagery. To view these images and learn more about the content, visit the quicklook page at http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php .

During the past year, the CloudSat DPC has received a NASA Group Achievement award and Mr. Phil Partain (Lead Software Developer) received the NASA Public Service Medal.

The CloudSat DPC web site contains a wealth of information about the mission, data products, interesting case studies, detailed product specifications, and instructions for ordering data. Visit http://www.cloudsat.cira.colostate.edu for all of this and more.

<u>NASA</u> – Defining Subgrid Snow Distributions Within NASA Remote-Sening Projects and Models

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond.

Key Words: Snow, Remote Sensing, Modeling, Spatial Distribution, Water Equivalent, Subgrid Distributions.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

NASA's merging of hydrologic science with global remote sensing has been hampered by an inherent mismatch in spatial scales between the two disciplines. For example, while NASA AMSR-E snow water equivalent data are available on 25-km grids, important snow-related hydrologic features and processes are known to exist on spatial scales of less than 100 m. This disparity in spatial scales is considerable, and any successful Earth-system remote-sensing and modeling program must offer a solution. This work endeavors to reconcile scaling disparities between the relatively coarse resolution NASA AMSR-E snow-water-equivalent remote-sensing products and naturally occurring snow-related processes. The foundation of our AMSR-E snow-water-equivalent data assimilation system is SnowModel, a 1- to 100-m grid increment, spatially distributed snow-evolution model. SnowModel accounts for an array of physical processes known to play important roles in snowpack formation and evolution, and includes critical features omitted in NASA AMSR-E remote sensing snow products. In addition, the AMSR-E within-pixel snow variability information that will be provided by this proposal is required for NASA to fully understand AMSR-E remote-sensing signatures. Effectively, our NASA AMSR-E snow-water-equivalent data assimilation system produces a "value-added" AMSR-E product that includes AMSR-E sub-pixel snow-water-equivalent distribution information.

2. Research Accomplishments/Highlights:

In order to meet these objectives we are developing methodologies to assimilate NASA snow remote sensing products in our snow-evolution model.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Modify our high-resolution snow-evolution modeling system to assimilate NASA ground-based observational datasets. "In progress."

Modify our high-resolution snow-evolution modeling system to assimilate NASA AMSR-E snow remote-sensing products. "In progress."

Use our modeling system to provide added value to NASA AMSR-E snow remote-sensing products by defining the sub-pixel distributions within those products. "In progress."

Use the high-resolution snow distribution data to develop a globally applicable subgrid-scale parameterization that accounts for key snow-related features and processes. “Yet to be started.”

4. Leveraging/Payoff:

Our improved, high-resolution remote-sensing and snow data assimilation system is expected to lead to improved local surface-flux and hydrologic forecasts, and improved understanding of, and the ability to simulate, the spatial variability of atmospheric and hydrologic processes and features.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As part of our model development and testing, and field work, we have been collaborating with Dr. Kelly Elder, USFS.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

NASA - The GLOBE Program

Principal Investigator: Cliff Matsumoto
Team Members: Travis Andersen, Mike Leon, Karen Milberger, Maureen Murray, and Dave Salisbury

Key Words: International Education and Science Program; Student Research; Climate Research; Online Social Collaboration; Science Protocols; Observations and Reporting of Environmental Data; Data Access; Teachers; Students

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The GLOBE Program® is an international education and science program. Its goals are to increase environmental awareness of people throughout the world, contribute to a better understanding of Earth, and help all students reach higher levels of achievement in science and mathematics. Under the guidance of their teachers, students worldwide conduct scientific investigations to learn about the Earth system. These student investigations are facilitated through the GLOBE database and web site (www.globe.gov) which includes tools for posting and retrieving environmental observations and measurements collected around students' schools. GLOBE scientists design protocols for measurements that are appropriate for K-12 students to perform and are also useful in scientific research. As scientists respond to the major environmental issues of today, laboratory and classroom collaboration will help unravel how complex, interconnected processes affect the global environment. GLOBE's unique global database holds more than 19 million student measurements of atmospheric, soil, land cover, hydrological, and phenological data, all of which are universally accessible on the website for research. GLOBE is now developing web applications to enable geographically dispersed students to work collaboratively on research projects. Since it was initiated, the GLOBE Program has grown from 500 U.S. schools in 1995 to more than 20,000 GLOBE schools located in 110 countries.

In spring 2003, NASA announced that a partnership between the University Corporation for Atmospheric Research (UCAR) and Colorado State University (CSU) was selected as the winning proposal for the operation of the GLOBE Program. CIRA now comprises the CSU team. On the UCAR side, representatives from UCAR Community Programs (UCP) are part of the GLOBE staff.

The Next Generation GLOBE (NGG) plan was approved in September 2005 by NASA and NSF. In response, the GLOBE Program Office (GPO) aligned its major areas of work to achieve GLOBE's vision of being a worldwide community of students, teachers, scientists, and citizens working together to better understand, sustain, and improve Earth's environment at local, regional, and global scales.

In the summer of 2007, NASA began a review process that continued through the end of the year. This review assessed GPO's management and operation of the GLOBE Program throughout the previous 4 years. An external panel of education, science, and technology experts convened to provide input to NASA. The panel reviewed

GLOBE's recent accomplishments and challenges. They looked at how program goals have been met and how funding has been allocated since GLOBE was awarded to the UCAR/CSU partnership in 2003. In conjunction with the review process, a new organization, The Learning Partnership, began to work with GPO in evaluating GLOBE's value and impact around the world. The review process concluded with NASA's decision to have UCAR continue to manage the GLOBE Program and the determination of funding levels that they will provide over the next five years. In 2008, a proposal was submitted by UCAR to NASA for a new Cooperative Agreement for the operation of the GLOBE Program for the years 2009 – 2013. It is expected that the resulting agreement will be finalized soon.

2. Research Accomplishments/Highlights:

In 2008, GPO's attention shifted towards providing a more collaborative space to promote student research around various themes such as climate research and sustainability.

Major areas of work towards the GLOBE vision in the past year:

Support for the GLOBE Learning Expedition (GLE) and Annual Conference which took place 22-27 June 2008 in Cape Town, South Africa and brought together over 500 students, teachers, scientists, partners and guests from 51 countries. The GLE provided opportunities for students to present their research to an international audience, participate in field studies led by master teachers, and build networks for future collaborative activities. (See Fig. 1)

Fig. 1. 2008 GLOBE Learning Expedition.

Establishment of Regional Offices in Africa, Asia and the Pacific, Europe and Eurasia, Latin America and the Caribbean, and the Near East and North Africa. Each of these Regional Offices has a Regional Desk Officer who provides support services to all countries in their region (answers questions, promotes implementation and collaborations, assists in record keeping); and will work collaboratively with all countries and the governance boards in their region to implement a transition to sustainable operations over the next two years. The North America region continues to be managed at UCAR. (See Fig. 2)

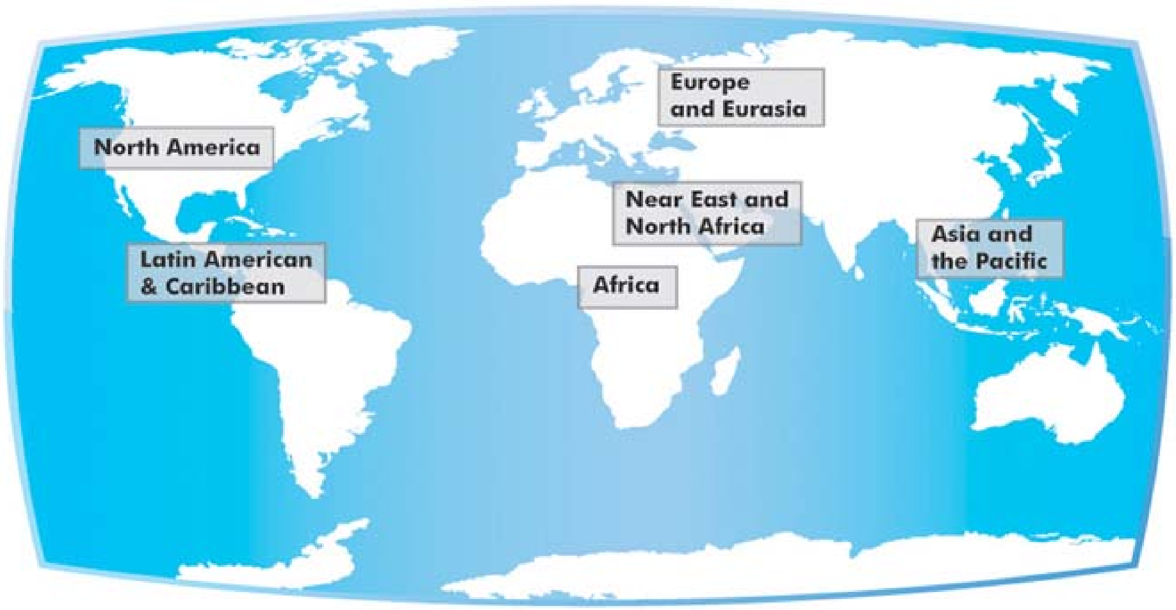

Fig. 2. GLOBE's Six Regional Offices.

Continue to provide quality and timely core services to the GLOBE community. The new GLOBE web site that was released in June 2007 has continued to receive improvements based on the principles of being more user-friendly and better supporting collaborative student research projects. Future development will include content and tools specifically designed for students based on pedagogical principles (in addition to sections for teachers, partners, scientists, etc.). The site is being developed using modern technology to support rapid development and easier maintenance of applications. (See Fig. 3)

Fig. 3. Homepage of GLOBE website.

The Technology Team's (CIRA) central tasks are the support of the Student Research (previously "Education and Science") and Regionalization (previously "Partner") teams of the program, and updating the GLOBE technical infrastructure with new and emerging technologies to ensure that the GLOBE Program remains on the cutting edge of education and science technology in the classroom.

The Technology Team, together with the GLOBE Operations Manager, created a GLOBE Technical Architecture Requirements and Plan for the modernization and future development of GLOBE technical systems. This plan was submitted to NASA and the Technical Review Committee convened by NASA to review and advise on the plan. Its essential features include: (1) technical infrastructure improvements to GLOBE web, database, and email systems; (2) development of an online collaborative environment to facilitate student scientific research projects centered around the GLOBE Model for Student Scientific Research (see Fig. 4); and (3) facilitation of greater regional autonomy in the management of GLOBE activities within the region.

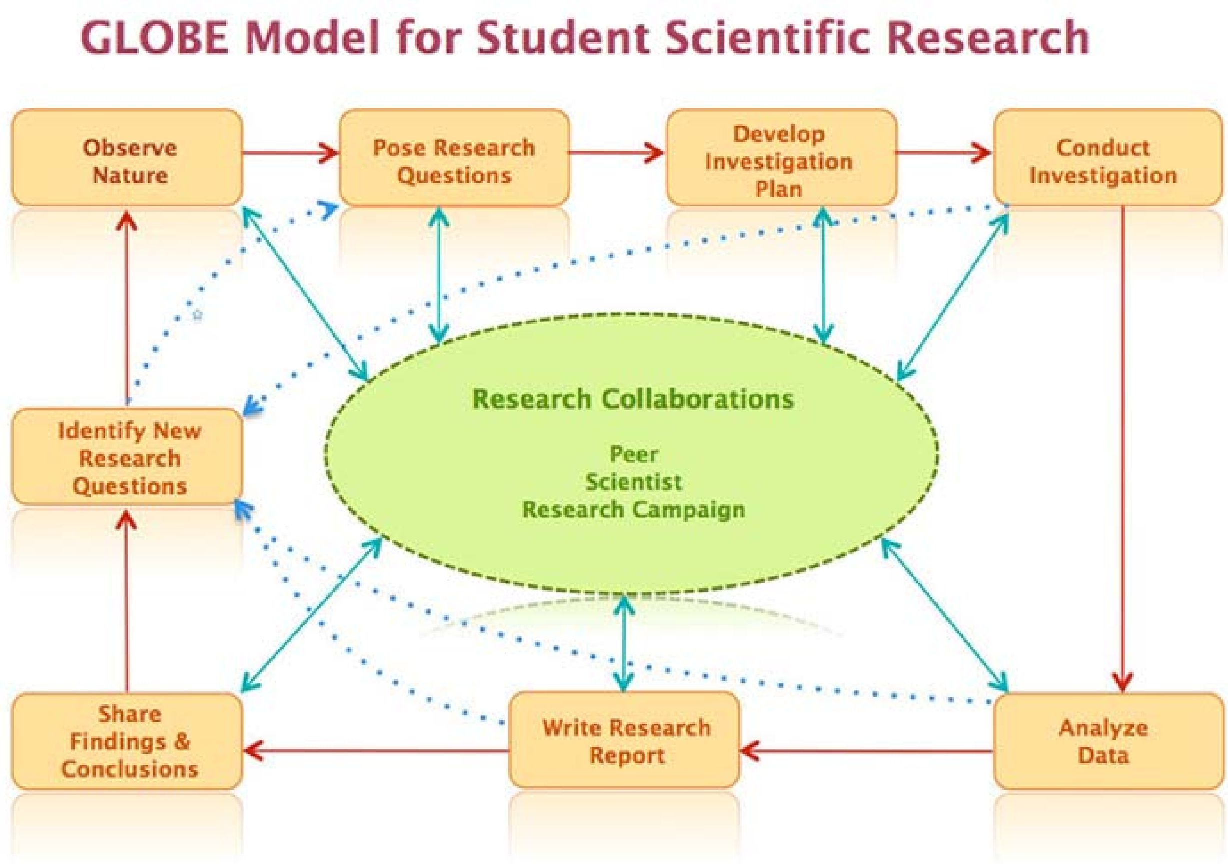

Fig. 4. GLOBE Model for Student Scientific Research

Work has begun on the initial projects in this plan, primarily in the area of infrastructure improvements necessary to complete the remaining projects in the plan.

To achieve GPO strategic objectives, it has become necessary to shift the balance of technical work away from predominantly maintenance of legacy systems towards a larger amount of work invested in new development. This is starting to be achieved through infrastructure improvements to support more rapid application development, offloading work that previously required technical staff to non-technical staff, and easier integration with third-party tools and services (see Fig. 5). For example, the recent implementation of automated web content uploading for various categories of pages (GLOBE Stars, News and Events, ESSP pages: Seasons and Biomes, Carbon

Cycle, Watershed Dynamics, and From Local to Extreme Environments) on the GLOBE web site has reduced the work of technical staff on this content from many hours each week to only needing to answer occasional questions. As additional parts of the web site are migrated into a content management system, this savings will continue to increase.

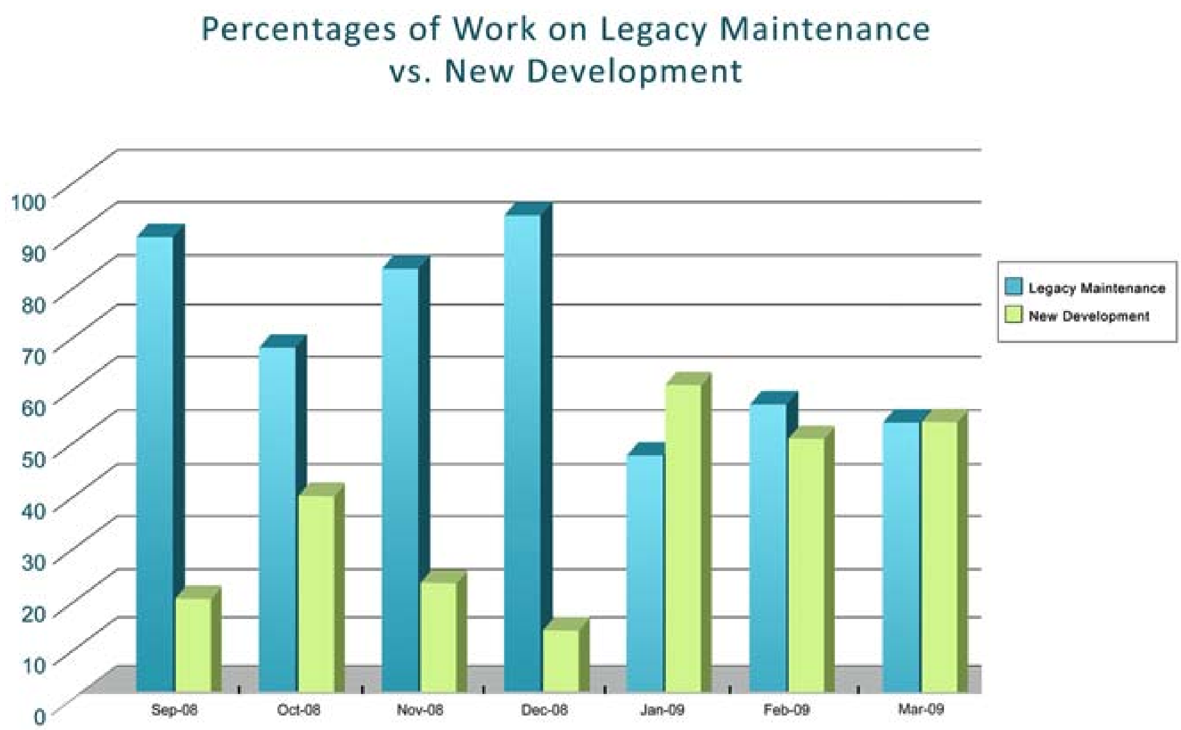

Fig. 5. Percentage of Work on Legacy Maintenance vs. New Development

Another primary focus of technical infrastructure improvement is in the management of user data. GLOBE currently maintains data on schools, teachers, trainers, scientists, partners, and country and regional coordinators. For the collaborative environment for students to be developed, it will be necessary to add separate student logins in addition to school logins, while adhering to child privacy requirements. User login, profile, and role information for all categories of users needs to be consolidated and standardized for future maintainability of GLOBE systems and secure controlled integration with third party tools and products. Infrastructure improvements in the management of user data underlie future development of the Administrative section of the GLOBE website used by GPO staff, Regional Offices, Country Coordinators, and U.S. Partners to administer and monitor the GLOBE Program in their respective areas of responsibility. These users maintain their own contact and profile information; create and edit information for teachers/schools that they train; maintain history, evaluation, and planning information for their own management use; and have access to appropriate logos, certificates, etc. to use for schools in their regions.

In early 2009, the annual GLOBE partnership survey was conducted entirely on-line for the fourth year. The work required by the Technology Team for the survey operation and data analysis was significantly decreased compared to previous years by automation of annual updates to make the survey applicable to each year and data analysis automation. The outcome of this survey is for the GPO to better support partnerships and regional collaboration around the world. The survey includes over 100 questions on topics such as funding and sustainability, program implementation, and teacher/trainer support.

During the last few months of 2008 and continuing through the beginning of 2009, the GLOBE Technology Team worked closely with one of the four NSF projects, FLEXE, to develop and deliver an online, collaborative application designed to encourage learning and facilitate teacher evaluation. The application included, among its many activities, a student report writer tool, along with a system that allows students to peer review each other's work, and finally revise their original report based on the reviews they received. The application provided ways for students to interact with scientists in learning more about the project-specific research topics. Profiles and data for each participating classroom were shared and compared with other classrooms in distant countries via a sophisticated class-level partnering mechanism. Flexible evaluation reports were designed and made available for teachers, and project managers to facilitate the understanding and analysis of the data produced by the participants and to help guide future revisions of the application.

Graphics support continues to be a significant contribution to the program and help ensure that the GLOBE brand is preserved. Graphics products produced include web graphic artwork, web page layouts, and print graphics such as GLOBE brochures and flyers in six languages, certificates, bi-annual NASA performance reports, business cards, special images and photos for presentations, and high-resolution posters. Significant accomplishments during the past year include the design of numerous web and print graphics for the 2008 GLOBE Learning Expedition and Annual Conference; design of new exhibit posters to represent the GLOBE Program at conferences and meetings that communicate the benefits of GLOBE to educators; and new web page designs which are helping to make the GLOBE web site more user-friendly.

A large portion of time will be invested in the coming year towards streamlining existing applications and processes – related to both the backend technical systems as well as the user-facing interfaces seen by students, teachers, and partners. The beginnings of integration with 3rd party tools services used for social networking and data analysis will be getting underway by the end of the coming year. Efforts are currently underway to look at a way in which students can report data through cell phone text messaging (SMS). This is being done in partnership with RANET which is an international collaboration of meteorological and related national services (including NOAA and USAID) and NGOs whose mission is to make weather, climate, and environmental information accessible to rural populations (focusing primarily on Africa and Asia). As part of their technology initiative, they are looking at offering text messaging as a way to send and receive short messages of data. GLOBE data can be one of these.

In addition to the above list of accomplishments, ongoing tasks, including daily systems administration and configuration of the web and database servers, updates to website content, running administrative database queries for other staff as needed, and investigating new technology and equipment to enhance the Program, contribute to a consistently demanding environment.

3. Comparison of Objectives Vs Actual Accomplishments for Reporting Period:

In Progress.

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking: None.

6. Awards/Honors: None.

7. Outreach:

K-12 Outreach
Today, the international GLOBE network has grown to include representatives from 110 participating countries and 139 U.S. Partners coordinating GLOBE activities that are integrated into their local and regional communities. Due to their efforts, there are more than 50,000 GLOBE-trained teachers representing over 20,000 schools around the world. GLOBE students have contributed more than 19 million measurements to the GLOBE database for use in their inquiry-based science projects.

8. Publications: None.

<u>NASA</u> – High Resolution Dynamic Precipitation Analysis for Hydrological Applications

Principal Investigators: Christian D. Kummerow, Dusanka Zupanski and Milija Zupanski

NOAA Project Goal: Weather and Water

NOAA Programs: Environmental Modeling, Weather Water Science, Technology, and Infusion

Key Words: Ensemble data assimilation, Global Precipitation Measurement (GPM) mission, dynamic precipitation analysis

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This is a collaborative research, supported by the Global Precipitation Measurement (GPM) Mission Program. It involves researchers from CSU (D. Zupanski, M. Zupanski and C.D. Kummerow), NASA/GMAO (Arthur Y. Hou and Sara Q. Zhang) and University of California (Samson H. Cheung). Since this research uses the NCEP operational observations and forward observational operators, it relies on some help from the NCEP personnel, which is coordinated by Zoltan Toth, the NCEP ensemble-forecasting leader. The research is expected to last two years. The main goal is to develop an ensemble data assimilation system to downscale satellite precipitation observations and to produce high-resolution dynamic precipitation analysis for hydrological applications.

2. Research Accomplishments/Highlights:

During the first year of this research (previous report period) we have successfully finished the first major task: implemented the NCEP's operational GSI codes and a sub-set of the NCEP's observations (including conventional and satellite data) on the NASA Columbia supercomputer. During the second year (which coincides with the current report period), we interfaced the MLEF algorithm with the GSI forward operators. We also made a major upgrade to this system by including a capability for assimilation of precipitation sensitive satellite radiances. This was achieved by interfacing the MLEF with the NASA Satellite Data Simulation Unit (SDSU), which is used as a forward operator. We performed data assimilation experiments with assimilation of AMR-E and TMI radiances for a tropical cyclone case in fine spatial resolution (3 km grid distance in the inner nest). The experimental results indicated positive impact of data assimilation on the analysis and forecast of the cyclone intensity and location and the associated cloud microphysical variables and precipitation. An example of results is shown in Figure 1.

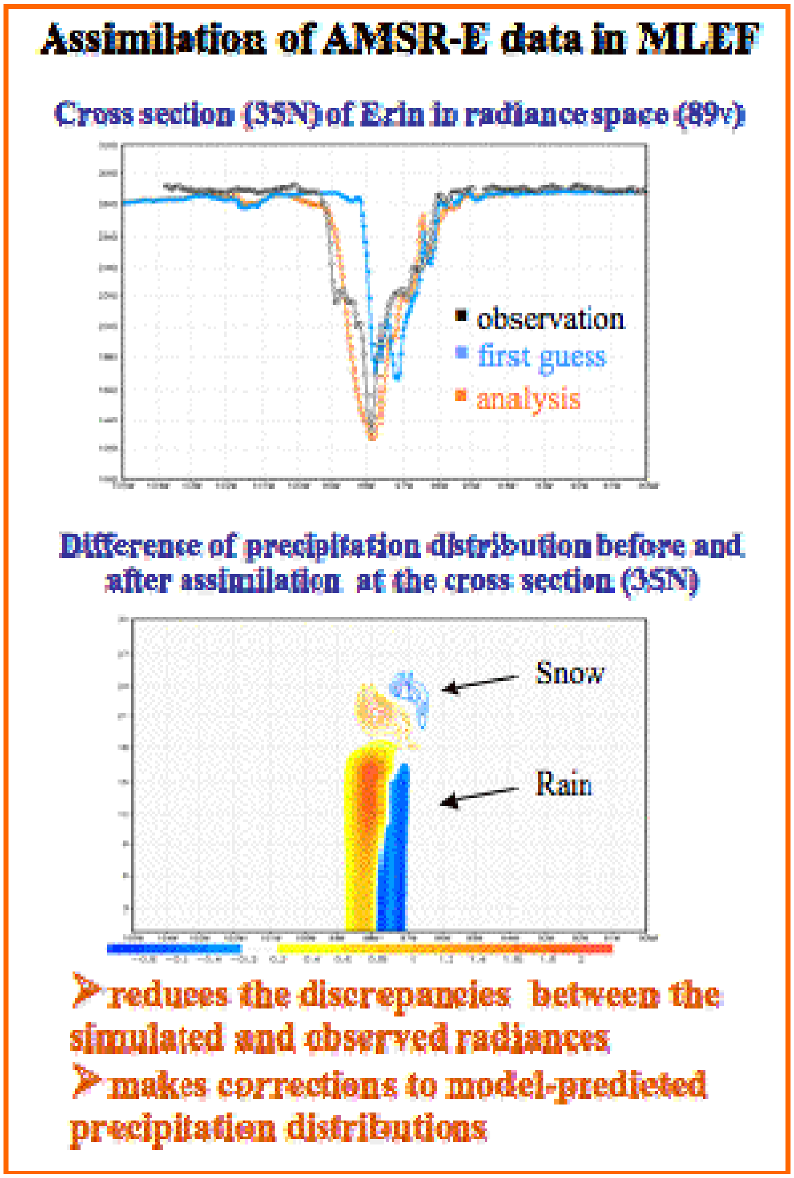

Figure 1. Impact of assimilation of AMSR-E radiance data on cloud microphysical variables (snow and rain) for tropical cyclone Erin (2007). To improve analysis fit to the observed AMSR-E radiance (upper panel) data assimilation shifts the snow and rain patterns in the right direction (lower panel).

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The objectives for this year were fully accomplished.

4. Leveraging/Payoff:

This research project will contribute to improved use of precipitation observations, especially for the hydrological component of the GPM Program. Technology transfer is being accomplished by employing NASA and NOAA models and data and by implementing the algorithms on the NASA supercomputer Columbia. This research can be used as a pilot project for assimilation of the future GPM satellite observations.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking: None.

6. Awards/Honors: None.

7. Outreach:

One M.S. level Graduate Student: Veljko Petkovic. Also see Publications/ Presentations in the next paragraph.

8. Publications:

Zhang, S.Q., D. Zupanski, A.Y. Hou and M. Zupanski, 2008: Application of an ensemble smoother to precipitation assimilation in NASA GEOS-5. PMM Science Team Meeting, 4-7 August 2008, Fort Collins, CO.

Zupanski D., 2008: Atmospheric data assimilation. Lecture presented at the third ICTP workshop on “The Design and Use of Regional Weather Prediction Models”. September 29 - October 7, 2008, Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy. (Invited)

Zupanski D., 2008: Maximum Likelihood Ensemble Filter. Lecture presented at the third ICTP workshop on “The Design and Use of Regional Weather Prediction Models”. September 29 - October 7, 2008, Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy. (Invited)

Zupanski, D., S.Q. Zhang, M. Zupanski, A.Y. Hou and S.H. Cheung, 2008: Development of an ensemble based algorithm for downscaled precipitation analysis using WRF model. PMM Science Team Meeting, 4-7 August 2008, Fort Collins, CO.

Zupanski, D., S.Q. Zhang, M. Zupanski, A.Y. Hou and S.H. Cheung, 2009: Development of ensemble data assimilation for high-resolution dynamically balanced precipitation analysis. EGU General Assembly, AS1.3 Precipitation: Measurement, Climatology, Remote Sensing, and Modeling, 19-24 April 2009, Vienna, Austria.

Zupanski, M., I. M. Navon, and D. Zupanski, 2008: The maximum likelihood ensemble filter as a non-differentiable minimization algorithm. Quart. J. Roy. Meteor. Soc., 134, 1039-1050.

NASA - Improving An Air Quality Decision Support System Through the Integration of Satellite Data With Ground-based, Modeled, and Emissions Data

Principal Investigator: Shawn McClure

NOAA Project Goals: The Air Quality and Environmental Modeling programs under the Weather and Water Goal.

Key Words: Satellite Data, Air Quality Research, Air Quality Modeling, Air Quality Planning;

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Clean Air Act (CAA) amendments of 1990 were designed to protect human health and welfare by establishing the National Ambient Air Quality Standards (NAAQS). Subsequently, the EPA Regional Haze Rule of 1999 added long-term targets to prevent future visibility impairment, and a national goal of restoring visibility to natural conditions by 2060 in 156 national parks and wilderness areas. These regulations require states and tribal associations to prepare Implementation Plans demonstrating attainment of the NAAQS standards and reasonable progress toward visibility targets. There are many systems and products to help develop these plans, but given the complexity of the process involved, decision makers need to have more than just the raw materials, i.e, collections of data, products, and interesting images. What is needed in addition is a synergistic integration of data and analysis resources into a “system of systems” that improves air quality decision-making by presenting the data and the tools for their analysis in a framework designed to serve a diverse group of end users. The goal of this project is, therefore, to enhance the capabilities of the Visibility Information Exchange Web System (VIEWS) and its associated Technical Support System (TSS) through the integration of NASA satellite data products relevant to air quality and visibility with surface-based monitor data, air quality model output, and advanced analysis tools for intercomparing and interpreting the data.

The project objectives in support of this goal are: (a) routine capture, analysis, and processing algorithms with high temporal and spatial resolution to provide land use/land cover data as inputs to emissions and air quality modeling analyses; (b) acquisition of satellite data to obtain increased temporal and spatial resolution of activity data and emission rates from natural and anthropogenic area and point sources (both individual and clustered) in remote and urban areas; (c) incorporation of three- to four-dimensional (2-3 spatial, 1 temporal) pollutant fields (e.g., aerosol extinction profiles, column NO_2 and O_3), into VIEWS-TSS to improve boundary inputs and evaluation of outputs from regional-scale chemistry- transport models (CTMs); (d) development of advanced analysis tools for examining the satellite data to better understand the relevant atmospheric processes and their representation in the CTMs, and (e) visualization and quantitative analysis of satellite data in combination with existing monitoring and emissions data, and modeling results within a unified data analysis and decision support platform.

2. Research Accomplishments/Highlights:

In the first year (1) a Design Workshop was convened to refine the project scope based on end user feedback; tasks involving future-year modeling of fires were replaced with tasks on hind-cast modeling and analysis of relevance to end users, and investigating synergies with other data systems; (2) a project wiki was created for information exchange; (3) satellite data provided by collaborators at the Joint Center for Earth Systems Technology were added to VIEWS-TSS databases for 2006-8 from OMI and MODIS; CALIPSO lidar and MISR data are forthcoming; (4) a prototype visualization tool for satellite data, as well as other improved tools for data queries and browsing were implemented in VIEWS-TSS; (5) metadata were added for the satellite data; (6) synergies and interoperability of VIEWS-TSS with the Remote Sensing Information Gateway and the Community Modeling and Analysis System began to be explored; (7) the groundwork was laid for modifying and porting the Atmospheric Model Evaluation Tool and the python-based Process Analysis tool to VIEWS-TSS; (8) work began on a use case with the Rocky Mountain Air-borne Nitrogen and Sulfur study to demonstrate these analysis tools; (9) a NASA satellite data training pilot course for air quality analysis was organized and offered to project end users and team members, and (10) overviews of VIEWS-TSS capabilities were presented at various meetings, including two conferences, throughout the performance period.

EPA OAQPS held a Data Summit in February 2008. Participants engaged in developing, distributing and using data from air quality modeling and monitoring in applications ranging from air quality planning and rule-making to impact assessments, to explore efficient ways to leverage existing efforts for data sharing across multiple systems. The participants continued to explore the mechanisms and potential opportunities for interoperability between these systems via biweekly teleconferences. Co-PIs McClure and Shankar have assisted OAQPS through these exchanges in honing its role in the larger earth systems observation community to establish a community-wide strategy for responding to user-defined needs for data and services. The details of this effort can be seen at http://wiki.esipfed.org/index.php/Data_Summit_Workspace. As a result of the contacts made in this project, we also began extensive discussions with the developers of RSIG to explore synergies and complementary tasks in our respective projects.

Global Earth Observation group members are actively engaged in soliciting and contributing components to the GEOSS registry towards standardizing and streamlining data discovery and exchange in 9 thematic areas; disaster management, energy, climate, health, water, weather, biodiversity, agriculture and ecosystems. The co-PIs were invited to participate in AIP-2, in which VIEWS-TSS was selected as a “persistent operational exemplar” of the GEOSS architecture. We attended the kick-off workshop at the National Center for Atmospheric Research (NCAR) in Boulder CO, in September 2008, and have been periodically attending teleconferences since then with other members of the Air Quality and Health working group to discuss standards for metadata and web services, and use cases for these standards. We will also attend a more focused follow-up workshop scheduled for July 2009 in Santa Barbara, CA.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In Year 1, with the exception of future-year fire modeling, which was replaced with other tasks upon recommendation of the end users during the Design Workshop, progress was made on all tasks originally proposed for Year 1.

--A Design Workshop was convened and the project scope was refined based on the end user feedback; tasks involving the future-year modeling of fires originally proposed were replaced with additional tasks on hind-cast modeling and analysis of relevance to end users, and investigating synergies with other data systems (Task 8)

--A project wiki was created for information exchange among team members and end users (Task 8)

--A number of satellite data products for air quality, meteorology and land use/land cover were acquired in collaboration with JCET for multiple years (2006-8) from OMI and MODIS Terra and MODIS Aqua, and loaded into VIEWS-TSS (Tasks 1 and 5).

--A prototype visualization tool for satellite data products was implemented in VIEWS, along with many other improved tools for browsing existing data (Task 2).

--Metadata were added for satellite data and browsing of data catalogs was improved (Task 3)

--Synergies and interoperability with RSIG and CMAS are being explored within the VIEWS-TSS framework (added; Tasks 3 and 4)

--The groundwork was laid for modifying and porting AMET and pyPA to VIEWS-TSS (Task 6)

--Work began on data acquisition to model the RoMANS study as a use case for a demonstration of the analysis tools (replaces future-year fire modeling; Task 7)

--A NASA satellite data training pilot course for air quality analysis was organized and offered to project end users and team members (Task 8)

--Overviews of VIEWS-TSS capabilities were presented at two conferences, at the start and end of the performance period respectively (Task 8)

4. Leveraging/Payoff:

While VIEWS-TSS currently includes a solid suite of qualitative and quantitative databases and tools for state and regional air quality planning, it needs to address some significant user needs in data and analysis tools: (1) Observational data: Surface measurements are currently the staple of observational data in TSS for planning applications and control strategy development to address regional haze. However, they provide little insight into the source and spatial distribution of significant aerosol events, such as large fires and dust storms, which transport pollutants far away from source regions and seriously impair regional visibility. As it is impossible to infer the aerosol vertical profiles and compositional variability aloft solely from ground-based measurements, long-range transport and vertical mixing of pollutants cannot be adequately characterized during such events. This makes it difficult to properly attribute local vs. remote sources of pollution, and track pollutant precursors, both of which are important steps in effective control strategy development. (2) Emissions data: Currently available data in VIEWS-TSS include emissions from wild and prescribed fires that are important for visibility impairment. Trends in fire occurrence indicate that emissions from wild fires will continue to increase in strength and frequency in future years. Better information, especially near real-time data on fire areas burned, and fire counts is needed as inputs to fire emissions models used in the current bottom-up inventories compiled for inputs to air quality models used in SIPs. Similarly, dust emissions from far-away sources have a significant impact on air quality over the U.S., and are poorly characterized in most inventories. While wind-blown dust models have recently been developed to improve dust emission fluxes, they need to be evaluated against observations that adequately capture the origin and transport pathways of the dust plumes. Updated information on land use and land cover would help improve the characterization of both fire and dust emissions. (3) Model data: To improve the reliability of their predictions, air quality models must also be thoroughly evaluated against observations. Absent the knowledge of how model results aloft compare with observations, model evaluation studies undertaken to considerable expense by air quality planners are incomplete at present. Further, ground-based networks are resource-intensive, and thus lack extensive spatial and temporal coverage. Data from the periphery of these networks (especially over the oceans) are often sparse, making it difficult to specify adequate model boundary inputs that capture the effects of emissions from offshore sources. (4) Analysis tools: VIEWS-TSS provides visualization of emissions data so that planners can get a qualitative sense of source locations, geographic distribution of pollutants, and the transport pathways for the emissions. However, analyses of primary emissions are in themselves insufficient for understanding the secondary production mechanisms in the atmosphere between the source and receptor sites. For example, three key atmospheric constituents responsible for regional haze, namely sulfate, nitrate and ammonia are governed by highly nonlinear and complex chemical interactions that cannot be understood solely by examining source-level emissions of precursors. Access to tools that can perform more in-depth process-level analyses of model results and observations, both together and separately, is needed to understand the physical and chemical mechanisms responsible for the measured pollutant levels and their effects, and to propose effective control measures.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

The design of the VIEWS-TSS system architecture already supports multiple levels of interoperability with systems within the WRAP RPO domain of air quality decision-making activities. These include the WRAP Emissions Data Management System (EDMS) and the Fire Emissions Tracking System (FETS), as well as the Regional Modeling Center (RMC). New systems being connected to VIEWS include EPA's Air Quality System, Air Quest, AirNow, DataFed, Giovanni, RSIG, and NASA DAACS. These will be interoperable with VIEWS for outgoing IMPROVE monitor data and various incoming data products from ground-based air quality monitors and satellite platforms. Toward addressing Task 3, other levels of interoperability are planned and being implemented in VIEWS-TSS for information exchange with a wider network of earth observing systems and data clearinghouses as shown in Figure 1. In Year 1 of the project the project team began participating in three major interoperability efforts by the air quality and earth observations communities.

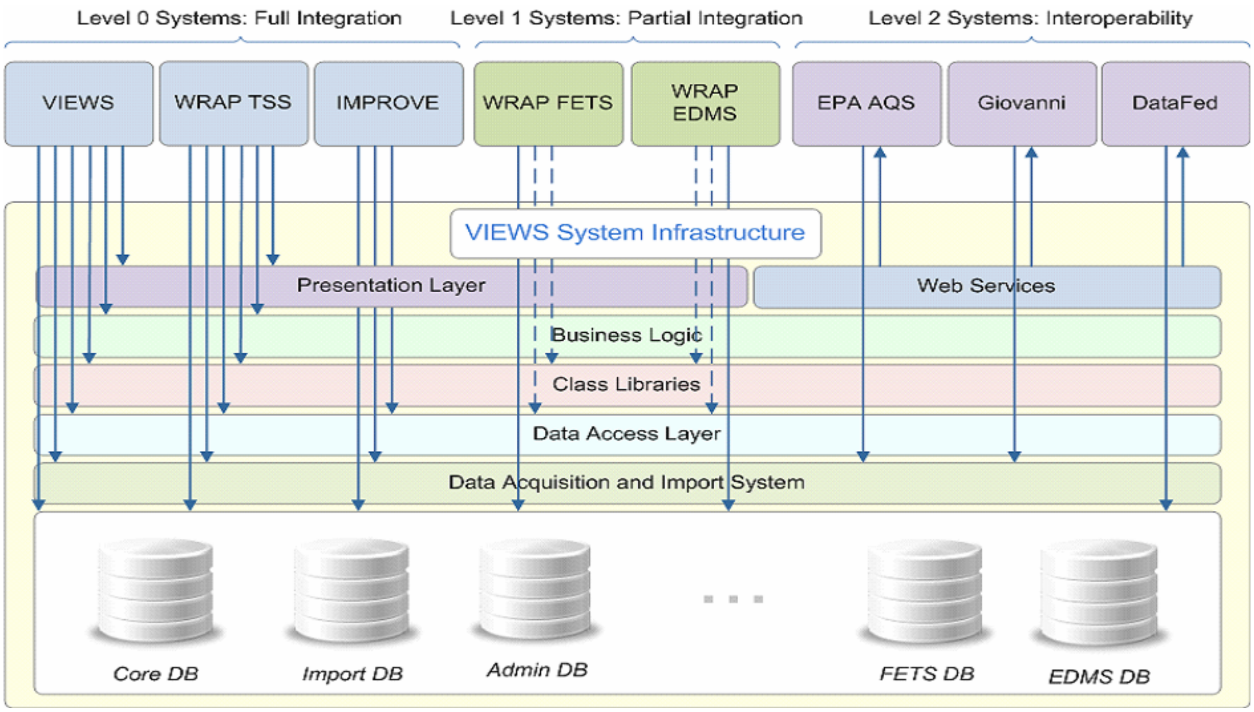

Figure 1. VIEWS-TSS Interoperability With Other Data Systems

6. Awards/Honors: None.

7. Outreach:

At the beginning of the project period in May 2008 the co-PIs attended the A&WMA Specialty Conference on Aerosol and Atmospheric Optics; Visual Air Quality and Radiation held in Moab, UT. PI Shankar attended a course on satellite data in air quality analyses. Co-PI McClure presented an overview of the VIEWS-TSS baseline system. The conference also provided an opportunity to discuss the project goals with the Program Officer and some of the end users who attended the conference, and meet developers of other decision support systems.

In March 2009 the PI attended and presented a poster on the current status of VIEWS-TSS at the EPA National Air Quality conference in Addison, TX. She also interacted with representatives from parallel projects such as RSIG, the BAMS Real-time Air Quality Forecasting System, and Sonoma Technology Inc.'s BlueSky Smoke Modeling Framework.

Under funding from NASA, co-investigator Dr. Prados has designed a course on the use of satellite data in air quality analyses. In coordination with the Program Officer and the CMAS Center, PI Shankar organized a 1½-day pilot version of this course, tailored somewhat to an invited audience consisting of VIEWS-TSS end users and project team members, as well as other CMAQ modelers and analysts from EPA. The agenda included visualization demonstrations of the MISR, MODIS and OMI data products, product websites (Giovanni, NASA DAACS), hands-on analyses of pollution episodes and qualitative comparisons with CMAQ output, and overviews of VIEWS-TSS and RSIG. We solicited feedback at the end from the attendees to address problems and develop a more expanded version of the course that will be offered by the CMAS Center in addition to its other training courses around the time of its annual conference in October 2009.

8. Publications:

EPA, U.S. Environmental Protection Agency, *Draft Guidance for Demonstrating Attainment of Air Quality Goals for PM2.5 and Regional Haze*, 2001.

EPA, U.S. Environmental Protection Agency, *Regional Haze Regulations: Final Rule*. 40 CFR Part 51; Fed Regist. 64, (126) 35714-35774, July 1999.

Levin, E.J.T., S. M. Kreidenweis, G.R. McMeeking, C.M. Carrico, J.L. Collett, and W.C. Malm, Aerosol physical, chemical and optical properties during the Rocky Mountain Airborne Nitrogen and Sulfur study, *Atmos. Environ., 43*(11), 1932-39, 2009.

NAS, National Academy of Sciences, *Air Quality Management in the United States*, Washington, D.C., 2004.

NASA – Improving the Representation of Global Snow Cover, Snow Water Equivalent, and Snow Albedo in Climate Models by Applying EOS Tera and Aqua Observations

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond.

Key Words: Winter, Snow, Snow Cover, Data Assimilation, MODIS, EOS.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

One of the big unanswered questions within the snow modeling and snow remote sensing communities is how to best and fully assimilate high-resolution snow-covered area observations, like those provided by MODIS, within the context of snow, atmospheric, and hydrologic models. We are currently developing improved methods to assimilate AMSR-E snow-water-equivalent observations within a high-resolution snow-evolution modeling system (MicroMet/SnowModel). These assimilations result in detailed subgrid snow distributions for each AMSR-E pixel. A by-product of these simulations is subgrid snow-covered area; this is particularly important during melt. As part of this EOS project we will use MODIS snow-cover data to compare against our simulated snow-cover outputs, and we will also develop ways to assimilate MODIS snow-covered area information into our model simulations, with and without the AMSR-E assimilations, taking advantage of the strengths and characteristics of each dataset. Liston (1999) showed the exact mathematical interrelationships among the snow distributions (such as that provided by our SnowModel and AMSR-E assimulations), melt (such as simulated by SnowModel), and snow-covered area (provided by MODIS). These interrelationships will be tested as part of this project, and the associated analysis is expected to lead to improvements in our assimilation methods and the quality of our model simulations.

2. Research Accomplishments/Highlights:

Model simulation domains have been defined and preliminary model simulations and the associated data assimilation developments have begun.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Develop a merged SnowModel-MODIS data assimilation system and test it against available independent snow water equivalent datasets. "In progress."

4. Leveraging/Payoff:

Our improved, snow-cover data assimilation system is expected to lead to improved local surface-flux and hydrologic forecasts, and improved understanding of, and the ability to simulate, the spatial variability of atmospheric and hydrologic processes and features.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

6. Awards/Honors: None

7. Outreach:

<u>Conference and Meeting Presentations</u>

Fletcher, S., G. E. Liston, C. A. Hiemstra, and S. Miller, 2009: Assimilation of MODIS snow cover data into SnowModel. 8th Adjoint Model Application in Dynamic Meteorology, Tannersville, PA, 18-22 May.

Fletcher, S., G. E. Liston, C. A. Hiemstra, and S. Miller, 2009: Assimilation of MODIS snow cover data and AMSR-E snow water equivalent data in SnowModel. 5th WMO Symposium on Data Assimilation, 5-9 October, Melbourne, Australia.

8. Publications: None.

NASA – Inspiring the Next Generation of Explorers: The GLOBE Program—Help Desk & GLOBE Partner Support (North America Regional Desk Office)

Principal Investigator: Cliff Matsumoto
Team Members: Nan McClurg, Gary Metzger, Noah Newman

Key Words: International Education and Science Program; Student Research; Climate Change; Science Protocols; Observations and Reporting of Environmental Data; Data Access; Teachers; Students; Hands-on Science; Inquiry-based Learning; ACTFL,; Earth Systems; Teacher Professional Development.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The GLOBE Help Desk is the first point of contact (through phone and Email) for ANY questions/comments or concerns that come up regarding the GLOBE Program. Our clients consist of all ESSP participants, GLOBE and ESSP Scientists, Partners, Trainers, Educators and Learners in formal and informal sectors.

The GLOBE Help Desk is a strong source of valuable information regarding the client traffic to the GLOBE web site, the needs of the clients, the usage of GLOBE products, the strength of the products used and inputs received, the activities of the GLOBE schools network and international inquiries regarding the GLOBE Program.

As the GLOBE Help Desk, we facilitate and strengthen the knowledge base of our clients and their questions / concerns, so that the GLOBE Program Office (GPO) teams can provide proper support and resolution. We facilitate and strengthen the connection between GLOBE countries and their Regional Desk Officers within GPO, between GLOBE schools / teachers in the U.S. and their Partners and between student projects and scientists / GPO Science Teams. We do this by resolving client inquiries whenever possible and by routing inquiries from the clients to the respective support teams such as Partner Support Team, Systems Team, GLOBE Partners, Regional Desk Officers, etc. We manage and disperse knowledge and information gathered from these teams and sources throughout the GLOBE community, thereby supporting Student Research and program sustainability.

The GLOBE Partner Support functions specifically support partnerships in US and Canada in their efforts of recruiting, training and mentoring educators in their target areas.

The Regional Desk Office for North America is the main point of contact for guidance in forming new partnerships, strengthening existing partnerships and gaining vital information about GPO training events and annual meeting events as well as reporting questions/concerns and feedback about the status of the partnerships.

As the North America Regional Desk Office, we work one-on-one with over 130 GLOBE Partners in the US and in Canada to provide guidance to maintain an active GLOBE partnership through recruit, train and mentor events as prescribed by proposal submitted to GPO in forming the partnership.

139 Active U.S. GLOBE Partners

Partner Type:	Number	Percent
Higher Education (Universities and Colleges)	78	56%
Office of Education	19	14%
School Districts	8	6%
Non-Profit Organizations	13	9%
NASA Centers and Affiliates (Glenn, Langley, Stennis, and 3 ERCs)	6	4%
State-Funded Organizations (Institutes)	5	4%
Learning Centers	3	2%
Educational Consortia	4	3%
Museums	2	1%
Private (School)	1	1%
Total U.S. Partners:	139	100%

Data gathered on 8 March 2009

The GLOBE Program

Fig. 1. Breakdown of GLOBE US Partners by Partner Type.

GLOBE Partners, Trainers, Teachers and Students are assisted as required, in support of Sustainability and to develop GLOBE Schools Network (GSN), in topics pertaining but not limited to:

--GLOBE Collaboration avenues.
--Science/and or scientific instruments.
--Navigating the GLOBE web site for protocol implementation guidelines, locating workshops in their area, contact information for GLOBE Partners and trainers, clarification on processes and procedures, understanding GLOBE specifications, etc.
--Login/ Passwords.
--Processes to define observation sites.
--Data Entry and resolving errors encountered during this step.
--Data Access, Mapping and Graphing GLOBE Data.
--Funding opportunities.
--Student Investigations.
--GLOBE Stars to highlight successful GLOBE students, teachers and partners.
--Special events such as GLOBE Campaigns or one-time participation events with ESSPs.

Because the GLOBE web site is so robust, it requires an intricate understanding and knowledge of how to navigate successfully. The GLOBE Help Desk and the Regional Desk Officer provides extensive assistance (including internally) for topics such as:

--How to locate active GLOBE schools, teachers, Partners for a special project.
--How to locate a training workshop.
--How to find a GLOBE Partner in a specific region
--How to access data.
--How to enter data.
--How to implement a protocol.
--Clarification on Protocol Implementation.
--GLOBE Instrument specifications.
--Topics and instructions related to Teacher's Guide.
--Elementary GLOBE products.
--International Partner contacts.

The GLOBE Help Desk and North America Regional Desk Office staff members are highly skilled in customer service, professional communications with clients, science protocols, GLOBE processes and procedures and sustaining different networks in support of the GLOBE Program. These staff members are constantly strengthening their knowledge base to further facilitate and support GLOBE Campaigns, ESSP activities, Student Research Projects, Capacity building, Regionalization of GLOBE activities, Sustainability of the GLOBE Program, and GLOBE Schools Networks.

Further assistance and support to strengthen GPO's efforts and GLOBE clients' efforts is provided by:

--Maintaining training history for Teachers and Trainers.
--Developing canned responses for special campaigns.
--Testing new product links.
--Validating Trainer certifications.
--Providing Letters of Support for grant applications.
--Connecting projects within US and internationally for successful outcomes.
--Sharing best practices with examples gathered through interactions with clients.
--Providing timely response and resolution to all inquiries.

The GLOBE Help Desk and North America Regional Desk Office staff members have attended several of the GLOBE teacher trainings as well as trainer training workshops and have assisted GPO staff in conducting trainings for staff and for GPO sponsored training events for US and International Partners. These staff members have also developed tools such as a tutorial for training Partners and Country Coordinators to facilitate Partner Administration page trainings without being in a workshop. These tools were tested at international Regional Meetings and were well received. Additional tools will be developed for advanced use of the GLOBE web site and database tools.

2. Research Accomplishments/Highlights:

--FAQs developed tasks conducted in support of ESSP events:

1. Seasons and Biomes events in Alaska
2. Watershed Dynamics workshops in Colorado (with CSU credits for participants)
3. FLEXE Energy Unit Pilot on-line workshop for participants in the US and international.
4. GLOBE/ESSP/DLESE workshop for US and International trainers, held in Boulder.

--Presentations and GLOBE information booth at NSTA events (Regional and National).
--Trainer workshop and presentations at North America Regional Meeting at NSTA
--Presentations and GLOBE booth at NAAEE event.
--Presentations at SACNAS and Tribal Forum.
--Partner (US and International) training and logistical support to GPO at GLOBE Annual Meeting.
--Continuous support and FAQ development for:

5. General questions regarding the GLOBE Program.
6. Questions pertaining specifically to the 54 'Legacy' GLOBE Protocols.
7. Questions pertaining to GLOBE Workshops and Training schedule.
8. Questions pertaining to GLOBE Equipment (Tool kit and Vendors).
9. Inquires regarding GLOBE Field Campaigns.

--Continuous support and dispersal of information through client Mass Mails:

Jan 2008	GLOBE Program Office Update
Jan 2008	GIAC nominations and GLOBE Annual Survey distribution
Jan 2008	GLE Student Speaker Competition
Jan 2008	Volvo Adventure Programme Opportunity
Jan 2008	Florida Dark Sky Festival
Feb 2008	NSTA events in Boston
Feb 2008	Summer research with SPHERE program in VA
Feb 2008	GLOBE at Night Campaign
Feb 2008	GLE Annual Conference and Registration for South Africa
Feb 2008	North America Regional Meeting at NSTA
Mar 2008	2008 Thacher Scholars Award Opportunity
Mar 2008	TERC's Earth Exploration Toolbook (EET) Workshop
Apr 2008	Earth Day 2008
Apr 2008	Information on GLOBE Parent Council (GPC)
Apr 2008	Watershed Dynamics (ESSP) workshop
Apr 2008	IPY and Artic POP create Global POP
May 2008	FLEXE Workshop announcement
May 2008	International School Science Congress in New Delhi
May 2008	GLOBE web site maintenance and update
Jun 2008	Weather Channel's Forecast Earth Summit
Jul 2008	FLEXE Energy Unit Pilot workshop

Aug 2008	ENO Tree Planting Day
Aug 2008	UN International Children's painting competition.
Sep 2008	Mickelson ExxonMobil Teachers Academy opportunity
Oct 2008	NASA Scientists addressing 5 big questions in Earth Science
Oct 2008	Opportunity to participate in NASA's ISS EarthKAM activities
Oct 2008	Transition of GLOBE International Regional Office
Nov 2008	November GLOBE News Brief
Nov 2008	ENO Climate Change Campaign
Dec 2008	NOAA B-Wet funding opportunity
Dec 2008	Siemens / Discovery Education / NSTA competition
Dec 2008	December GLOBE News Brief
Jan 2008	New Year's wishes to Partners
Jan 2009	January GLOBE News Brief
Jan 2009	Partner Survey and Recommitment for 2009
Jan 2009	Funding Opportunities and North America Annual Meeting
Feb 2009	February GLOBE News Brief
Mar 2009	New Climate Research Project Coordinator
Mar 2009	Announcement of new Regional Desk Offices
Mar 2009	March GLOBE News Brief
May 2009	Change in GLOBE Annual Meeting in Calgary, Canada
May 2009	May GLOBE News Brief
Jun 2009	Climate Literacy Course offered at CU by CIRES.
Jun 2009	June GLOBE News Brief

--Development of Tutorial CDs for use in training of new Regional Desk Officers.
--Continuous support and collaborations with GLOBE Systems Team in maintaining integrity of data and client database.
--Continuous support and collaborations with GLOBE Systems Team in maintaining integrity of client list servs.
--Develop quarterly metrics report of Help Desk traffic and activities (see attached below)

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

In progress.

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communications & Networking: None.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

<u>NASA</u> – NRA/NASA – Modeling, Analysis and Prediction

Principal Investigator: Denis O'Brien

NOAA Project Goals: Climate and Mission Support (Satellite Sub-goal)

Key Words: Carbon Cycle, Data Assimilation, CO_2 Flux, Remote Sensing

1. Long-term Research Objectives and Specific Plans to Achieve Them:

In this project, we hope to obtain new information on the functioning of the global carbon cycle using column-integrated CO_2 concentration measurements from satellites. To do this, we have developed efficient methods for deriving column-CO_2 concentrations from satellite-measured radiances, as well as a variational data assimilation method (based on an atmospheric transport model) to infer surface CO_2 fluxes from these concentration retrievals.

2. Research Accomplishments/Highlights:

In the past year, we published in Baker, et al. (2008) the results of previous work in which we used our variational data assimilation system to perform observing system simulation experiments (OSSEs) for the Orbiting Carbon Observatory (OCO). The measurement uncertainties used were taken from a linear error analysis of OCO concentration retrievals done by Dr. Hartmut Bösch using the `full-physics' retrieval algorithm for OCO (surface properties, aerosol effects, and viewing geometry were considered). In addition to quantifying the impact of random measurement errors, the effects of a variety of systematic error sources also were examined.

The assimilation software used for this OSSE study assumed climatological conditions for most quantities. Over the past year, we have modified this software so that it can be used to produce a CO_2 flux product from operational satellite data with a lag time of only days to weeks after the data are observed. This process has involved replacing the climatological quantities assumed before with actual values appropriate for the time period in question (taken either from measurements or models, as appropriate). These quantities include analyzed meteorology products to drive the atmospheric transport model, and *a priori* estimates of the surface fluxes (including those from the land biosphere, oceans, fossil fuel burning, and biomass burning/wildfires).

At a September 2008 meeting of the Pawson team in Greenbelt, Maryland, arrangements were made to obtain land biospheric fluxes from two sources for use in processing OCO data: SiB3 fluxes from Scott Denning and Nick Parazoo (CSU), and CASA/GFED fluxes from Jim Collatz and Randy Kawa (NASA/Goddard), including wildfire fluxes. Also at this meeting, arrangements were made with Michelle Reinecker and Steven Pawson (NASA/Goddard) to obtain GEOS5 analyzed meteorological products at 0.5°x0.66° resolution; these are to be used both to drive the PCTM atmospheric transport model during the assimilation, as well as to provide needed parameters for generating the SiB3 *a priori* fluxes in near-real-time (precipitation, temperature, radiation, etc). Working with Nick Parazoo (CSU), we set up an automatic interface to move these fields onto local CSU computers within a day of their generation. Later, we discussed obtaining suitable ocean fluxes from Scott Doney and Ivan Lima (Woods Hole Oceanographic Institute), and an improved global fossil fuel product with Kevin Gurney (Purdue Univ.) for use outside of North America (inside of which his Vulcan product would be used).

To model the OCO concentrations as well as possible, one would like to run the transport model and estimate fluxes at as fine a spatial resolution as possible. Running a full assimilation at the 0.5°x0.66° resolution provided by the GEOS5 analysis products is expected to be prohibitively expensive with the computational resources available, however. To get around this, we have developed a grid refinement approach for executing the assimilation efficiently: the coarser-scale flux features are converged fully first by running the assimilation at a coarser resolution (7.5°x10.0°, then 4.5°x6.0°), then the finer-scale details are resolved (at 1.5°x2.0° and 0.5°x0.66°) with a more-limited number of additional iterations of the method. Besides being computationally tractable, this approach has two added advantages:

•the lower-magnitude ocean fluxes, which require many iterations of the optimization method to converge, are fully converged; and

•since the resolution of the satellite data is not fine enough to constrain fluxes for all the grid boxes at the finer resolutions, only those areas closest to the measurements are updated during the later iterations.

We are now testing the assimilation system at these GEOS5-based resolutions and evaluating the performance of this grid refinement approach.

In support of the OCO project, much progress has been made in the past year in characterizing the errors expected in the OCO column-CO_2 measurement. The data analysis planned for the early stages of OCO was to use the fast Apparent Optical Path Difference (AOPD) algorithm proposed by O'Brien (2004), with the full-physics OCO algorithm employed for validation. While it was hoped that in the longer term speed gains in the full-physics algorithm and access to increased computing power would enable the full-physics algorithm to be used for routine processing, the immediate priority was to characterize the errors associated with the AOPD algorithm, as knowledge of these errors is critical to any assimilation effort.

In the absence of an airborne prototype for OCO, our main tool for characterizing the OCO errors has been our OCO simulator. Minor modifications were made to the simulator over the past year, mostly associated with the polarizing effects of land surfaces, instrument artifacts (such as misalignment of the spectrometers), target mode and faster radiative transfer, but the essential features remain as reported last year. Documentation of the simulator, including the recent updates, has been prepared as a technical report (O'Brien, et al., 2009).

In order to assess the errors of the AOPD retrieval algorithm, simulations of OCO spectra were performed for twenty orbits in nadir mode and eight orbits in glint mode.

The AOPD retrieval algorithm was run on every sounding, and then the results were screened according to the optical thickness of cloud. The results were binned into 10° latitude bands along orbit tracks, and global maps of the error were produced. Regional biases are apparent in the range ~2 ppmv, but mostly less than 1 ppmv. There is little or no correlation of the errors with either the surface pressure or the cloud/aerosol optical thickness, and only a weak correlation with the solar zenith angle. The most significant correlation is between the X_{CO2} error and column water vapor, which is surprising because the algorithm should be almost insensitive to water vapor. It suggests that a bias has been introduced inadvertently during the training stage of the algorithm. If so, the bias should be removable, and work is in progress to resolve this issue. The situation is similar for both nadir and glint modes. The error characterization has been written up as an algorithm theoretical basis document for OCO (Polonsky and OBrien, 2009) and a journal article is in preparation.

Even if the regional biases that appear to be associated with water vapor can be removed, there will remain residual regional biases that, as yet, are unexplained. The magnitudes of the errors are larger than those assumed in the earlier work by Baker, et al (2008). Why the errors are larger than those derived from the linear error analysis is under investigation, and assimilations will be conducted with higher biases to see the impact upon source and sink flux inversions.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

We had hoped to be using our column-CO_2 retrieval and CO_2 flux assimilation methods to process real OCO data by this point. With the demise of the OCO satellite in February 2008, we have shifted our focus towards interpreting the data from the Greenhouse-gases Observing Satellite (GOSAT). We also hope to use our atmospheric CO_2 flux assimilation system to perform OSSEs for other CO_2 satellite missions in the planning stage, such as NASA's ASCENDS mission or various OCO re-flight options.

4. Leveraging/Payoff:

Much of the insight we have gained in interpreting and processing pre-launch OCO data should be helpful in supporting other trace-gas-measuring satellites, such as GOSAT or ASCENDS. On a broader level, the information such satellites will shed on the working of the global carbon cycle should be crucial for refining our predictions of global warming, and may be useful in monitoring compliance with global greenhouse-gas emission treaties.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

As noted above, we have worked with researchers from NASA's Goddard Space Flight Center and Jet Propulsion Laboratory, the Woods Hole Oceanographic Institute, the University of Leicester, Purdue University, Colorado State University, and the National Center for Atmospheric Research in this research. Dr. Fu-Lung Chen of the National Institute of Aerospace also contributed his MODIS cloud database to our effort.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications:

Baker, D. F.**,** H. Bösch, S. C. Doney, and D. S. Schimel, Carbon source/sink information provided by column CO_2 measurements from the Orbiting Carbon Observatory, *Atmos. Chem. Phys. Discuss.*, **8**, 20051-20112, 2008.

O'Brien, D.M., An end-to-end simulation of an airborne spectrometer to measure column averaged mixing ratio of CO_2, Technical report, Colorado State University, 52 pp., 2004.

O'Brien, D.M., Polonsky, I., O'Dell, C., and Carheden, A., The OCO Simulator, OCO Algorithm Theoretical Basis Document, Colorado State University, 2009.

Polonsky, I., and O'Brien, D.M., The 'Golden Pairs' Apparent Optical Path Difference (AOPD) Retrieval Algorithm, OCO Algorithm Theoretical Basis Document, Colorado State University, 61 pp., 2009.

NASA – Parameterizing Subgrid Snow-Vegetation-Atmosphere Interactions in Earth-system Models

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond.

Key Words: Snow, Shrubland, Modeling, Spatial Distribution, Energy Budget, Surface Fluxes.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project will develop a subgrid surface energy and moisture flux parameterization, for use within weather and climate models, to account for the impact of grassland and shrubland vegetation protruding through snow covers. The general objective of this project is to improve our understanding of and ability to model interactions among a) large-scale atmospheric circulations, and b) local-scale ecological and hydrologic features that exist on Earth's winter terrestrial surface. We will achieve these goals by using a collection of atmospheric and snow models describing key biosphere, hydrosphere, and cryosphere processes, and their key interrelationships. In addition, we will employ a wide assortment of ground-based observations and remote-sensing data, including the measurement of vegetation characteristics required for parameterization. This merging of modeled and observed data will: 1) improve our understanding of interrelationships between biological and physical systems, 2) require our model developments to be strongly tied to the natural systems, and 3) provide the required model inputs and data for testing model outputs.

2. Research Accomplishments/Highlights:

In order to meet these objectives we developed a state-of-the-art, physically based, snow-evolution model (SnowModel), and are merging it with our field observations. As part of this development we have published papers summarizing its performance.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Develop a subgrid surface energy and moisture flux parameterization, for use within weather and climate models, to account for the impact of grassland and shrubland vegetation protruding through snow covers. "Complete."

Improve our understanding of, and ability to model, interactions among large-scale atmospheric circulations and local-scale ecological and hydrologic features that exist on Earth's winter terrestrial surface. "Complete."

Implement a collection of atmospheric and snow models (e.g., MicroMet and SnowModel) describing key biosphere, hydrosphere, and cryosphere processes, and their key interrelationships, across our observation domains. "Complete."

Employ a wide assortment of ground-based observations and remote-sensing data, including the measurement of vegetation characteristics, as part of our parameterization developments. “Complete.”

4. Leveraging/Payoff:

Our improved, high-resolution snow modeling system is expected to lead to improved local surface-flux and hydrologic forecasts, and improved understanding of, and the ability to simulate, the spatial variability of atmospheric and hydrologic processes and features.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As part of our model development and testing, and field work, we have been collaborating with Dr. Kelly Elder, USFS.

6. Awards/Honors: None

7. Outreach:

<u>Conference and Meeting Presentations</u>

Liston, G. E., and C. A. Hiemstra, 2007: Using high-resolution atmospheric and snow modeling tools to define spatially-variable snow distributions. International Symposium on Snow Science, 3-7 September, Moscow, Russia.

Liston, G. E., C. A. Hiemstra, S. Berezovskaya, S. H. Mernild, and M. Sturm, 2007: Using high-resolution atmospheric and snow modeling tools to define pan-arctic spatial and temporal snow-related variations. Proceedings of the 16th Northern Research Basins International Symposium and Workshop, 27 August -2 September, Petrozavodsk, Russia.

Randin, C. F., H. C. Humphries, G. E. Liston, C. A. Hiemstra, N. G. Yoccoz, W. D. Bowman, T. R. Seastedt, K. N. Suding, and M. W. Williams, 2008: Spatio-temporal evolution of the alpine tundra over two decades in the Rocky Mountains: natural variability or climate change impact? MTNCLIM, Mountain Climate Research Conference, 9-12 June, Silverton, Colorado.

Strasser U., M. Bernhardt, M. Weber, G. E. Liston, and W. Mauser, 2008: On the role of snow sublimation in the alpine water balance. European Geosciences Union General Assembly, 13-18 April, Vienna, Austria.

Bernhardt, M., U. Strasser, W. Mauser, and G. E. Liston, 2008: Parameterization of the subscale snow distribution for regional scale land surface models. European Geosciences Union General Assembly, 13-18 April, Vienna, Austria.

Hiemstra, C. A., and G. E. Liston, 2007: Using high-resolution atmospheric and snow modeling tools to define spatially-variable snow distributions. North American Mountain Hydroclimate Workshop, 17-19 October, Boulder, Colorado.

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Snow cover distribution on Alaska's Arctic Slope: modelling under changing climate. International Symposium on Snow Science, 3-7 September, Moscow, Russia.

Hiemstra, C. A., and G. E. Liston, 2007: Snow measurements and modeling in sagebrush steppe. Ecological Society of America Annual Meeting, 5-10 August, San Jose, California.

Marsh, C., S. Pohl, and G. E. Liston, 2007: Impact of increased shrub density on snow accumulation and melt in the Arctic tundra. XXIV General Assembly of the International Union of Geodesy and Geophysics, 2 13 July, Perugia, Italy.

Bernhardt, M., U. Strasser, G. E. Liston, and W. Mauser, 2007: On snow cover variability in alpine terrain. XXIV General Assembly of the International Union of Geodesy and Geophysics, 2 13 July, Perugia, Italy.

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Determining solid precipitation on Alaska's Arctic Slope. XXIV General Assembly of the International Union of Geodesy and Geophysics, 2 13 July, Perugia, Italy.

Sawyer, A. E., K. J. Elder, S. R. Fassnacht, G. E. Liston, and S. Frankenstein, 2007: Simulation of snowpack ablation at two mid-latitude subalpine sites using SnowModel and Fast All-Season Soil STrength (FASST). 27th Annual American Geophysical Union Hydrology Days, 19-21 March, Colorado State University, Fort Collins, Colorado.

8. Publications:

Liston, G. E., and C. A. Hiemstra, 2008: A simple data assimilation system for complex snow distributions (SnowAssim). J. Hydrometeorology, 9, 989-1004.

Liston, G. E., C. A. Hiemstra, K. Elder, and D. W. Cline, 2008: Meso-cell study area (MSA) snow distributions for the Cold Land Processes Experiment (CLPX). J. Hydrometeorology, 9, 957-976.

Liston, G. E., D. L. Birkenheuer, C. A. Hiemstra, D. W. Cline, and K. Elder, 2008: NASA Cold Land Processes Experiment (CLPX): Atmospheric analyses datasets. J. Hydrometeorology, 9, 952-956.

Liston, G. E., R. B. Haehnel, M. Sturm, C. A. Hiemstra, S. Berezovskaya, and R. D. Tabler, 2007: Simulating complex snow distributions in windy environments using SnowTran-3D. Journal of Glaciology, 53, 241-256.

NCAR – AFWA Coupled Assimilation and Prediction System Development at CIRA

Principal Investigator: Andrew Jones

NOAA Project Goal: Weather and Water

Key Words: Satellite Data Assimilation, Clouds, Microwave Emissivities, WRF, 3DVAR, 4DVAR

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Air Force Weather Agency plans to build the AFWA Coupled Assimilation and Prediction System (ACAPS). This system is designed to facilitate the coupling of land surface models with their atmospheric weather models for assimilation and prediction of clouds and many other battlefield environmental parameters of interest to the DoD. Fundamental to this effort is an assessment of the scientific knowledge needed to create such a system. CSU's experiences using the Regional Atmospheric Mesoscale Data Assimilation System (RAMDAS) 4DVAR system for cloudy satellite data assimilation will be leveraged into the ACAPS planning process. ACAPS workshops are planned, as well as initial WRF-4DVAR system reviews, and satellite data set assessments obtained.

2. Research Accomplishments/Highlights:

The AFWA Cloud Analysis Workshop is scheduled for Sep. 1-3, 2009 at Boulder, CO. Drs. Jones and Fletcher contributed to the design of the workshop. Mr. Longmore is performing initial WRF data assimilation (DA) 4DVAR optimization experiments to improve the efficiency of the WRF DA system.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The Workshop and DA optimization research is on schedule.

4. Leveraging/Payoff:

The WRF data assimilation system is a national research asset. WRF DA is the now known as the WRFPLUS system, and is incorporating national DA standards for interoperability between major NWP DA centers. Our activities leverage our DoD-based DA funded research into the WRF DA system which is used by many NOAA and University collaborators.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

WRF is jointly funded by many agencies, and the workshops are instrumental to its future development as a data assimilation system. Project activities are in close collaboration with NCAR. We anticipate stronger interactions with the WRF Development Testbed Center (DTC) and the WRF Data Assimilation Testbed Center

(DATC). Both centers have significant NOAA interactions via NOAA/GSD and NOAA/NCEP.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

NPS – Airborne Nitrogen Concentrations and Deposition in Rocky Mountain National Park

Principal Investigators: Jeffrey L. Collett, Jr. and Sonia M. Kreidenweis

NOAA Project Goal: Air Quality

Key Words: Nitrogen Deposition, Visibility, Acid Deposition, Aerosol, Precipitation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project has several objectives. The first objective is to characterize nitrogen transport and deposition in Rocky Mountain National Park. A second objective is to develop and test methods for characterizing organic nitrogen deposited within the park. The third objective is to develop and evaluate methods for routine measurement of gaseous ammonia, a species which is rarely measured but is likely a major contributor to nitrogen deposition. The objectives are to be achieved through a combination of field measurements and analysis and by design followed by laboratory and field testing of new measurement approaches.

2. Research Accomplishments/Highlights:

Two large field campaigns, comprising the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study, were conducted in spring and summer 2006. The purpose of these campaigns was to characterize spatial and temporal patterns in N and S species concentrations and to evaluate dominant pathways for N deposition within Rocky Mountain National Park (RMNP). Recent work has focused on analyzing results from the RoMANS field campaigns and developing new methods for improved measurements of ammonia and organic nitrogen.

Measurements from the RoMANS field campaigns revealed that reactive nitrogen concentrations were much higher, on average, to the east of RMNP than to the west. This was true both for oxidized and reduced forms of nitrogen. Reduced nitrogen, in the form of ammonia plus particulate ammonium, was highest in NE Colorado. Semi-continuous measurements of fine particle concentrations at the RoMANS core study site in RMNP revealed a common pattern where nitrogen species concentrations increased when transport came from the east.

Precipitation measurements during RoMANS were used to determine wet deposition fluxes of key nitrogen and sulfur species. During the 6-week spring measurement campaign, total flux was strongly dominated by a single upslope snowstorm in late April. During this event, material was transported into RMNP from the east and efficiently scavenged and deposited by heavy snowfall. Summer wet deposition fluxes were more widely spread across several events. Overall wet deposition fluxes in summer were significantly higher than measured in spring. Organic nitrogen was observed to be a substantial contributor to total N wet deposition.

Dry deposition fluxes of key species were estimated from measured 24 hr concentrations of key trace gases and particle species and dry deposition velocities derived from on-site meteorological measurements by the Clean Air Species and Trends Network (CASTNet). The highest dry deposition fluxes were observed for ammonia and nitric acid, followed by particulate ammonium and nitrate.

Measurements of particle size distributions and composition were used to estimate extinction properties of aerosol during the RoMANS spring and summer study periods. Good closure was obtained between these estimates and measured particle scattering. Multiple species were important contributors to light extinction, including sulfates, nitrates, organics, and dust.

The discovery that organic nitrogen and ammonia are important contributors to total N deposition in RMNP is important, given that routine concentration and deposition network measurements do not include these species. Work is underway as part of this and related projects to design and evaluate methods for accurately measuring these species. Work was also conducted to investigate the composition of organic nitrogen in precipitation in order to better understand its natural or anthropogenic sources.

During 2007/08 our team cooperated with NPS/CIRA researchers on an intercomparison of measurement methods for gaseous and particle phase inorganic nitrogen species.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The status of our 3 key project objectives is as follows:

a. Characterizing N transport and deposition in RMNP during the RoMANS study (complete)
b. Development and testing of methods for organic N measurement (complete)
c. Development and evaluation of methods for ammonia measurement (in progress)

4. Leveraging/Payoff:

Plans are underway to incorporate evaluated ammonia measurement methods in a pilot field program in the Interagency Monitoring of PROtected Visual Environments (IMPROVE) program.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Results of this work have been discussed with USEPA, with the Colorado Department of Public Health and Environment (CDPHE), with the National Park Service and with various stakeholder groups.

6. Awards/Honors: None.

7. Outreach:

The following students were partially or fully supported by this project: Katie Beem (MS), Amanda Holden (MS), Misha Schurman (MS), Ezra Levin (MS), Gavin McMeeking (PhD), Laurie Mack (MS), and Nick Powers (BA).

--Atmospheric nitrogen and sulfur deposition in Rocky Mountain National Park, M.S. Thesis, CSU, Katie Beem, Fall 2008

--The role of aerosols on visibility degradation during two field campaigns M.S. Thesis, CSU, Ezra Levin, Fall 2008

Public presentations and findings from this work were presented at the following:

Collett, J., Jr., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A., Taylor, C., Carrico, C., McMeeking, G., Kreidenweis, S., Day, D., Hand, J., and Malm, W., Transport and deposition of airborne nitrogen in Rocky Mountain National Park, Presented to representatives of the National Park Service in Lakewood, CO. May 22, 2008

Collett, J.L., Jr., Beem, K., Raja, S., Schwandner, F., Carrico, C., Lee, T., Taylor, C., Sullivan, A., McMeeking, G., Levin, E., Kreidenweis, S., Day, D., Hand, J., Schichtel, B., and Malm, W., Observations of airborne pollutants and deposition during the 2006 Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study, Invited presentation at the Regional Meeting of ACS held in Park City, Utah, June 15-18 2008

Collett, J.L., Jr., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A., Taylor, C., Carrico, C., McMeeking, G., Kreidenweis, S., Day, D., Hand, J., and Malm W., Transport and deposition of airborne nitrogen in Rocky Mountain National Park, Presented at the CDPHE Rocky Mountain National Park Agriculture Subcommittee meeting, Greeley, CO July 30

Schwandner, F.M., Beem, K.B., Raja, S., Desyaterik, Y., Kreidenweis, S., Malm, W., and Collett, J.L., Jr., Organic nitrogen (ON) in wet deposition in Rocky Mountain National Park, Poster presented at NADP Annual Meeting, Madison Wisconsin, October 14-16, 2008

Collett, J., Beem, K., Raja, S., Talyor, C., Carrico, C., Schwandner, F., Lee, T., Sullivan, A., Day, D., McMeeking, G., Mack, L., Kreidenweis, S., Hand, J., Schichtel, B., and Malm, W., Nitrogen deposition budgets for Rocky Mountain National Park, Abstract presented at AGU Conference, San Francisco, CA, December 15-19, 2008

Beem, K., Collett, J., Raja, S., Schwandner, F., Carrico, C., Taylor, C., Lee, T., Sullivan, A., Day, D., McMeeking, G., Mack, L., Kreidenweis, S., Hand, J., Schichtel, B., and Malm, W., A spatial analysis of precipitation chemistry coupled with aerosol and gas concentrations during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) Study, Poster presented at AGU Conference, San Francisco, CA, December 15-19, 2008.

Malm, W.C., Schichtel, B.A., Barna, M.G., Gebhart, K.A., Collett, Jr., J.L., and Kreidenweis, S.M., Source apportionment of sulfur and nitrogen species at Rocky Mountain National Park using modeled conservative tracer releases and tracers of opportunity, Abstract presented at AGU Conference, San Francisco, CA, December 15-19, 2008.

Collett, Jr., J.L., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A., Taylor, C., Carrico, C., McMeeking, G., Kreidenweis, S., Day, D., Hand, J., and Malm, W., Transport and deposition of airborne nitrogen in Rocky Mountain National Park, Invited presentation at Sonoma Technology, Inc., December 18, 2008.

8. Publications:

Lee, T., Yu, X.-Y., Kreidenweis, S. M., Malm, W. C., and Collett, Jr., J. L. (2008) Semi-continuous measurement of PM2.5 ionic composition at several rural locations in the United States. Atmos. Environ., 42:6655-6669; doi:10.1016/j.atmosenv.2008.04.023.

Levin, E.J.T., Kreidenweis, S.M., McMeeking, G.R., Carrico, C.M., and J.L. Collett, Jr. (2009) Aerosol physical, chemical and optical properties during the Rocky Mountain Airborne Nitrogen and Sulfur study. Atmos. Environ. 43:1932-1939, doi:10.1016/j.atmosenv.2008.12.042.

Malm, W.C., McMeeking, G.R., Kreidenweis, S.M., Levin, E., Carrico, C.M., Day, D.E., Collett, Jr., J.L., Lee, T., Sullivan, A.P., and Raja, S., Using high time resolution aerosol and number size distribution measurements to estimate atmospheric extinction, J. of Air, Waste, Mange., accepted, 2009

NPS - Analysis of Levoglucosan K+ and Water Soluble Organic Carbon in Activated Filter Samples

Principal Investigators: Jeffrey L. Collett, Jr. and Amy Sullivan

NOAA Project Goal: Air Quality

Key Words: Smoke, Visibility, Air Quality, Particles

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Two main objectives were identified for this project. First, we sought to test application of a new method for smoke marker measurement for analysis of archived filter samples from the EPA national fine particle monitoring network. Second, we sought to examine the influence of biomass burning on airborne fine particle concentrations at urban and rural locations throughout the Midwestern U.S. The approach to achieving both goals was to obtain archived $PM_{2.5}$ filter samples from several USEPA Federal Reference Method fine particle measurement sites at locations throughout the Midwest and to analyze them for smoke markers, including levoglucosan and water soluble potassium.

2. Research Accomplishments/Highlights:

Through cooperation with USEPA, the Lake Michigan Air Director's Consortium (LADCO), and various state agencies, archived filters were obtained for the full 2004 calendar year from several urban and rural sites in the Midwest U.S. These filters were extracted and analyzed for various species of interest. Anhydrosugars, including levoglucosan, were analyzed by High Performance Anion Exchange Chromatography with Pulsed Amperometric Detection (HPAEC-PAD). HPAEC-PAD analysis also revealed important concentrations of other sugar alcohols that are signatures of fungal spores. Potassium ion was measured by ion chromatography and water soluble organic carbon was measured using a Total Organic Carbon analyzer. Seasonal and spatial trends in biomass burning activity and its influence on regional air quality were examined.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The two key project objectives for this project have been achieved:

a. Test application of HPAEC-PAD for smoke marker analysis on archived EPA network filter samples (complete)

b. Analyze archived filters from several urban and rural Midwest U.S. sites for anhydrosugars, K^+, and water soluble organic carbon (complete)

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

This work was conducted in close cooperation with USEPA, LADCO, and various Midwestern state air quality agencies.

6. Awards/Honors: None.

7. Outreach:

Public presentations and findings from this work were presented at the following:

Sullivan, A.P., Frank, N., and Collett, J.L., Jr., An alternative method for determining the impact of biomass burning, Abstract presented at the 27th Annual AAAR Conference, Orlando, Florida, October 20-24, 2008

8. Publications: None.

<u>NPS</u> - Assistance for Visibility Data Analysis & Image Display Techniques

Principal Investigator: Jenny Hand

NOAA Project Goal: Weather and Water, specifically, the Air Quality component under the Goal

Key Words: Air Quality Research, Visibility Research; Visibility Monitoring; Aerosol Research, Aerosol Monitoring; Rural Air Quality; Air Quality Modeling.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The long-term objectives of the team are to understand the causes of all air pollution, including impaired visibility, in national parks and other pristine lands in the United States. Since the early 1980s, CIRA has supported the National Park Service (NPS) visibility research program directed by Dr. Bill Malm. Through these years, this group has conducted research that has helped in formulating and implementing the Clean Air Act mandate to protect the visual resources of national parks and wildernesses, known as class I areas. In April 1999, the Environmental Protection Agency (EPA) promulgated "regional haze" regulations (RHRs). RHRs require that states (and Indian tribes) develop plans (subject to 10-year review and revision) that will show reasonable progress toward returning class I areas to "natural" visibility conditions over the next 60 years. Recently, research has expanded with support from the Regional Planning Organizations (RPOs), established to help states and tribes manage regional air quality. Specifically, we are now also supported by the Western Regional Air Partnership (WRAP), an activity of the Western Governor's Association, to develop and dispense technical information on regional air quality. In addition, it has recently been shown that excess nitrogen deposition in Rocky Mountain National Park, Colorado, has adversely affected its sensitive alpine ecosystems. It is believed that other class I areas may also be adversely affected by excess nitrogen deposition. In response to this issue the NPS/CIRA research group has participated in a study to better quantify the deposition of all nitrogen species and identify the sources contributing to the nitrogen deposition.

2. Research Accomplishments/Highlights:

The NPS/CIRA research group has been instrumental in advancing the science and developing the methodologies enabling the RHR. Included in past accomplishments are developing the appropriate metrics to use for characterizing visibility, determining the most appropriate instruments to measure visibility for this application, and designing and implementing the national monitoring network for visibility, the IMPROVE(Interagency Monitoring of Protected Visual Environments) network. In addition to research on the IMPROVE network, the group conducts special studies, generally associated with specific national parks, that help to understand relative contributions of pollution sources to visibility. Currently, the group is studying the region associated with Rocky Mountain National Park in Colorado, with a field experiment known as RoMANS. As part of this study, the group has developed the required input data and air quality modeling capabilities to simulate and study the long-range transport of pollutants that potentially affect the visibility and nitrogen deposition in this park. The group has also led the development of interactive web-based data archival and analysis tools through implementation of the VIEWS (Visibility Information Exchange Web System, http://vista.cira.colostate.edu/views) and similar web sites for the IMPROVE program (http://vista.cira.colostate.edu/improve) and for toxic air pollutants (Http://vista.cira.colostate.edu/ATDA). Most recently, we have undertaken development of the Technical Support System for WRAP (http://vista.cira.colostate.edu/TSS). The recent addition of the Night Sky program staff to the NPS/CIRA group has added another dimension to the body of visibility research data.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Specific objectives for this year have included

(in progress)

--Continued work on the apportionment of light extinction among chemical species, using statistical and deterministic methods. We investigated the roles of particle composition, size distribution, and relative humidity on the optical effects of aerosols. When appropriate, we applied new models derived from special studies that reflect the latest state of the science in air pollution and visibility. We also continued to identify reasons for differences between reconstructed and measured fine particle mass and between reconstructed and measured and light extinction in both rural and urban settings.

--Continued research into aerosol source apportionment techniques, which include trajectory mass balance, source contribution functions, conditional probabilities, and empirical orthogonal functions to assess the appropriateness of using these techniques for pollutants such as ozone and organic and elemental carbon. We also continue to develop and use receptor models to determine transport pathways and estimate the proportion of a measured pollutant that can be attributed to each of several sources.

--Continued implementation and development of the IMPROVE (Interagency Monitoring of Protected Visual Environments) website, including developing an interactive database, allowing users to download data and selected analyses of these data, including appropriate quality assurance information, directly from the web, a display of current IMPROVE graphics, up-to-date information about the visibility regulations, and a growing bibliographic reference site for visibility and IMPROVE scientific information. (http://vista.cira.colostate.edu/improve)

--Continued data analyses from the RoMANS special study field campaign, including posting of final datasets containing precipitation chemistry observations and $PM_{2.5}$ and trace gas observations.

--Continued CAMx model evaluation and process analysis to better understand the model performance during RoMANS.

--Continued to evaluate 2002 annual CAMx simulation in terms of estimated total nitrogen budgets to determine the relative magnitudes of organic versus inorganic nitrogen, as well as oxidized versus reduced nitrogen in the Rocky Mountain National Park study region.

--Continued work on the source apportionment for the RoMANS study.

--Continued work on the integration of IMPROVE and CSN (Chemical Speciation Network) network-wide data.

--Continued the work on lab and field studies to better understand the physical/chemical/optical properties of particulate matter from forest fire emissions, including developing smoke marker species for use in source apportionment models.

--Continued work on developing hybrid-receptor source apportionment models to estimate the contributions of primary and secondary particulate matter from biomass burning.

--Continuing work on the analysis of aerosol composition and hygroscopicity data from the second phase of laboratory measurements of biomass smoke.

--Continued to develop and implement the interactive multimedia "Introduction to Visibility". This web document will introduce basic visibility science and monitoring concepts as well as the regional haze regulations to the regulatory community and the general public.

--Continued to provide graphics support, graphs, posters, etc., to the NPS researchers in the Air Resources Division and CIRA.

--Continuing to prepare data for inclusion on VIEWS website and assist with development of geographic data presentation.

--Continuing development of instrumentation to assess night sky visibility and further understanding of light pollution physics. Provide input on models being developed by the NPS, EPA, and other cooperators.

(completed)

--Conducted a sampling study with URG, IMPROVE, CASTNet, and passive samplers to compare ammonia concentrations measured by these different sampling systems.

--Summarized and published results from the RoMANS study in a final report (in review).

--Produced videos and CDs showing the impact of pollution on various parks. Generated park service training films. Duplicated and distributed videos and CDs as necessary. Developed custom graphic materials for presentation purposes.

--Produced the 2009 IMPROVE calendar.

--Produced an interactive tutorial describing the cycling of reactive nitrogen through the environment, showing basic concepts such the sources of reactive nitrogen, its effects in the atmosphere, and the consequences of its deposition to our environment.

--Conducted field visits to national park sites for inventory and quantification of night sky visibility. Provide other technical assistance as needed to agency on topics such as light pollution physics, outdoor lighting mitigation, ecological impacts of artificial light, and outreach strategies.

4. Leveraging/Payoff:

Having the NPS research team at CIRA provides a significant opportunity for NOAA to leverage this research for air quality forecasting and related areas of contaminant dispersal. The NPS group is among the nation's leaders in air pollution research, especially for aerosols and their effects on visibility and other air-quality-related values. Current research in model evaluation and validation is setting the standard for air quality applications internationally. The group works closely with the RPOs, which are a national coordinating group of state air quality agencies for the purpose of looking at trans-state border air pollution issues. VIEWS is specifically funded by the RPOs.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

The NPS group works cooperatively with the other land managers (the USDA and other agencies in the Department of the Interior—FWS, BIA, BLM), with the EPA, with most of the states and with the RPOs as mentioned above, with a host of universities, national laboratories, and private sector air quality companies to study and provide technical and research background for implementing the visibility provisions of the Clean Air Act and the regional haze regulations.

6. Awards/Honors:

William C. Malm:

--National Park Service 2008 Director's Award for Excellence in Natural Resource Research; presented at the George Wright Society Biennial Conference, Portland, Oregon, March 5, 2009.

--Environmental Protection Agency's Thomas W. Zosel 2008 Outstanding Individual Achievement Award; presented at the 2008 Clean Air Excellence Awards Ceremony, Washington DC, May 13, 2009.

--Air & Waste Management Association's Frank A. Chambers Excellence in Air Pollution Control Award; presented at the A&WMA Annual Conference, Detroit, Michigan, June 25, 2009.

7. Outreach

(b)Seminars, symposiums, classes, educational programs;

--Moore, C., Richman A, and Jiles, T. *Astronomy and Stargazing for Rangers*. Training Course for Park Interpreters. May 10-13, 2009. Interior, SD.

--Participated in Dark Skies Awareness Workgroup, one of eleven cornerstone projects planning for the 2009 International Year of Astronomy.
http://www.darkskiesawareness.org/

(d) K-12 outreach;

--Jiles, T. "The Endangered Night Sky", presented to the 5th and 6th grades, Oakwood Elementary School, Fort Collins, CO, March 9, 2009.

(e) Public awareness.

--IMPROVE Site Operator Calendar 2009: Each year the group produces a high quality calendar in support of the IMPROVE national monitoring program. With a distribution of 1000 copies, the calendar remains one of the best avenues of providing outreach materials in support of the IMPROVE program, reaching a broad-based multidisciplinary audience as well as providing education material to operators in the field.

--Web-Based Presentation—Nitrogen Emissions, Atmospheric Processes, and Deposition: A nontechnical public education program has been developed to communicate the sources and storage mechanisms of reactive nitrogen, the chemical changes that occur in the environment, and the consequences for people and ecosystems as it deposits into ecosystems. The program is currently under review and will be launched this summer.

--Junior Ranger Night Explorer, produced with the National Park Service Intermountain Region Office of Interpretation, June 2009.

--Boyle, R. *Army of Darkness*. Article and Interview with Chad Moore, NPS Night Sky Program. Fort Collins Now. Fort Collins, CO. January 16, 2009.

--National Park Service rack card "*Enjoying The Night*" (June 2009), produced by the NPS Night Sky Program.

--National Park Service rack card "*Meteors*" (April 2009), produced by the NPS Night Sky Program.

--National Park Service rack card "*Experiencing Dark Night Skies*" (January 2009), produced by the NPS Night Sky Program.

--Moore, C. *The Greatest Show above Earth*. In Utah Guidebook. American Park Network, Redmond, OR. 2009.

--*The Good, the Bad, and the Ugly of Outdoor Lighting*, Narration by Teresa Jiles and Dan Duriscoe, 365 Days of Astronomy- 2009 International Year of Astronomy, Podcast aired April 25, 2009. http://365daysofastronomy.org/2009/04/25/april-25th-the-good-the-bad-and-the-ugly-of-outdoor-lighting/).

8. Publications:

Publications

Brewer, P. and Moore, C. T. 2009. Source contributions to visibility impairment in the southeastern and western United States. Air & Waste Management Association Environmental Manager magazine, in press.

Carrico, C. M., Petters, M. D., Kreidenweis, S. M., Collett, J. L., Engling, G., and Malm, W. C. 2008. Aerosol hygroscopicity and cloud droplet activation of extracts of filters from biomass burning experiments. Journal of Geophysical Research-Atmospheres, 113, D8.

Christopher, S. A., Gupta, P., Nair, U. S., Jones, T. A., Kondragunta, S., Wu, Y. L., Hand, J. L., and Zhang, X. 2009. Satellite remote sensing and mesoscale modeling of the 2007 Georgia/Florida fires. Accepted by the Journal of Selected Topics in Earth Observations and Remote Sensing.

Jiles, T. and Moore, C. W. 2008. Night sky visibility - Investigating the link between air quality and night sky visibility. CIRA Magazine, 30, 8-11.

Levin, E. J. T., Kreidenweis, S. M., McMeeking, G. R., Carrico, C. M., Collett, J. L., Jr., and Malm, W. C. 2009. Aerosol physical, chemical and optical properties during the Rocky Mountain Airborne Nitrogen and Sulfur study. Atmospheric Environment, in press.

Lewis, K., Arnott, P. W., Moosmüller, H. S., Chakrabarty, R. K., Carrico, C. M., Kreidenweis, S. M., Day, D. E., Malm, W. C., Laskin, A., Jimenez, J. L., Huffman, J. A., Ulbrich, I. M., Onasch, T. B., Trimborn, A., Liu, L., and Mishchenko, M. I. 2009. Reduction in biomass burning aerosol light absorption upon humidification: Roles of inorganically induced hygroscopicity, particle collapse, and photoacoustic heat and mass transfer. Submitted to Atmospheric Chemistry and Physics.

Luginbuhl, C. B., Duriscoe, D. M., Moore, C. W., Richman, A., Lockwood, G. W., and Davis, D. R. 2009. From the ground up II: Sky glow and near-ground artificial light propagation in Flagstaff, Arizona. Publications of the Astronomical Society of the Pacific, 121, 204-212.

Malm, W. C., Collett, J. L., Jr., Barna, M. G., Gebhart, K. A., Schichtel, B. A., Beem, K., Carrico, C. M., Day, D. E., Hand, J. L., Kreidenweis, S. M., Lee, T., Levin, E. J. T., McDade, C. E., McMeeking, G. R., Molenar, J. V., Raja, S., Rodriguez, M. A., Schwandner, F., Sullivan, A. P., and Taylor, C. 2009. RoMANS: Rocky Mountain Atmospheric Nitrogen and Sulfur Study Report. CIRA (Cooperative Institute for

Research in the Atmosphere), Colorado State University, Fort Collins, Colorado, ISSN 0737-5352-84, draft in review.

Malm, W. C., McMeeking, G. R., Kreidenweis, S. M., Levin, E., Carrico, C. M., Day, D. E., Collett, J. L., Jr., Lee, T., Sullivan, A. P., and Raja, S. 2009. Using high time resolution aerosol and number size distribution measurements to estimate atmospheric extinction. Submitted to the Journal of the Air & Waste Management Association.

McMeeking, G. R., Kreidenweis, S. M., Baker, S., Carrico, C. M., Chow, J. C., Collett, J. L., Jr., Hao, W. M., Holden, A. S., Kirchstetter, T. W., Malm, W. C., Moosmüller, H. S., Sullivan, A. P., and Wold, C. E. 2-3-2009. Emissions of trace gases and aerosols during the open combustion of biomass in the laboratory. Submitted to the Journal of Geophysical Research.

Petters, M. D., Parsons, M. T., Prenni, A. J., DeMott, P. J., Kreidenweis, S. M., Carrico, C. M., Sullivan, A. P., McMeeking, G. R., Levin, E. J. T., Wold, C. E., Collett, J. L., Jr., Moosmüller, H. S., Arnott, P. W., Malm, W. C., and Hao, W. M. 2009. Ice nuclei emissions from biomass burning. Submitted to the Journal of Geophysical Research.

Pitchford, M. L., Poirot, R. L., Schichtel, B. A., and Malm, W. C. 2009. Characterization of the winter Midwestern particulate nitrate bulge. Accepted by the Journal of the Air & Waste Management Association, in press.

Rivera-Rivera, N. I., Gill, T. E., Gebhart, K. A., Hand, J. L., Bleiweiss, M. P., and Fitzgerald, R. M. 2009. Wind modeling of Chihuahuan desert dust outbreaks. Atmospheric Environment, 34, 347-354.

Rodriguez, M. A., Barna, M. G., and Moore, C. T. 2009. Regional impacts of oil and gas development on ozone formation in the western United States. Accepted by the Journal of the Air & Waste Management Association.

Sullivan, A. P., Holden, A. S., Patterson, L. A., McMeeking, G. R., Kreidenweis, S. M., Malm, W. C., Hao, W. M., Wold, C. E., and Collett, J. L., Jr. 2008. A method for smoke marker measurements and its potential application for determining the contribution of biomass burning form wildfires and prescribed fires to ambient PM2.5 organic carbon. Journal of Geophysical Research, 113, D22302, doi:10.1029/2008JD010216.

Presentations and Conferences

Beem, K., Collett, J. L., Jr., Raja, S., Schwandner, F., Carrico, C. M., Taylor, C., Lee, T., Sullivan, A. P., Day, D. E., McMeeking, G. R., Mack, L., Kreidenweis, S. M., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2008. A spatial analysis of preciptation chemistry coupled with aerosol and gas concentrations during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Carrico, C. M., Petters, M. D., Kreidenweis, S. M., Prenni, A. J., DeMott, P. J., McMeeking, G. R., Levin, E. J. T., Mack, L., Sullivan, A. P., Holden, A. S., Collett, J. L., Jr., Day, D. E., Hand, J. L., Malm, W. C., Wold, C. E., and Hao, W. M. 2008.

Physicochemical properties of fresh biomass smoke aerosols. Invited talk presented at the NOAA Earth System Research Lab Chemical Sciences Division, October 29.

Carrico, C. M., Collett, J. L., Jr., Kreidenweis, S. M., Schwandner, F., Levin, E. J. T., Schurman, M., Beem, K., Sullivan, A. P., Ray, J., and Malm, W. C. 2009. High time resolution measurement of atmopheric nitrogen species at Rocky Mountain National Park. Presented at the Air & Waste Management Association Annual Conference, Detroit, June.

Collett, J. L., Jr., Beem, K., Raja, S., Taylor, C., Carrico, C. M., Schwandner, F., Lee, T., Sullivan, A. P., Day, D. E., McMeeking, G. R., Mack, L., Kreidenweis, S. M., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2008. Nitrogen deposition budgets for Rocky Mountain National Park. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Collett, J. L., Jr., Beem, K., Raja, S., Schwandner, F., Carrico, C. M., Lee, T., Taylor, C., Sullivan, A. P., McMeeking, G. R., Levin, E., Kreidenweis, S. M., Day, D. E., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2008. Observations of airborne pollutants and deposition during the 2006 Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. Presented at the American Chemical Society Joint 63rd Northwest/21st Rocky Mountain Regional Meeting, June 15-18, Park City UT.

Collett, J. L., Jr., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A. P., Taylor, C., Carrico, C. M., McMeeking, G. R., Kreidenweis, S. M., Day, D. E., Hand, J. L., and Malm, W. C. 2008. Transport and deposition of airborne nitrogen in Rocky Mountain National Park. Presented at Sonoma Technology, Inc. December 18.

Collett, J. L., Jr., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A. P., Taylor, C., Carrico, C. M., McMeeking, G, Kreidenweis, S. M., Day, D. E., Hand, J. L., and Malm, W. C. 2008. Transport and deposition of airborne nitrogen in Rocky Mountain National Park. Presented at the National Park Service Air Resources Division, Lakewood, May 22, 2008.

Collett, J. L., Jr., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A. P., Taylor, C., Carrico, C. M., McMeeking, G. R., Kreidenweis, S. M., Day, D. E., Hand, J. L., and Malm, W. C. 2008. Transport and depostion of airborne nitrogen in Rocky Mountain National Park. Pesented at the Colorado Department of Public Health and Environment Rocky Mountain National Park Agriculture Subcommittee meeting, Greeley, July 30.

Gebhart, K. A., Barna, M. G., Malm, W. C., Schichtel, B. A., and Rodriguez, M. A. 2009. Comparison of MM5 winds to Estes Park profiler and MM5 Hysplit back trajectories for source attribution. Presented at the Ad-Hoc Meteorological Modeling Group meeting, National Center for Atmospheric Research, Boulder, June 25-26.

Holden, A. S., Sullivan, A. P., Patterson, L. A., Schichtel, B. A., Malm, W. C., Kreidenweis, S. M., Bench, G., and Collett, J. L., Jr. 2008. Estimating contributions of primary biomass burning to fine particulates in ambient aerosol in the western United States. Presented at the American Association for Aerosol Research 27th Annual Conference, Orlando, October 20-24.

Jiles, T. 2009. Nights in the national parks. Presented at the Dark Skies Awareness Workshop, 213th American Astronomical Society Meeting, Long Beach, January 4.

Mack, L., Obrist, D., Moosmüller, H. S., Lewis, K., Arnott, P., McMeeking, G. R., Levin, E. J. T., Kreidenweis, S. M., Wold, C. E., Hao, W. M., Collett, J. L., Jr., and Malm, W. C. 2008. Optical closure experiments of biomass smoke aerosols. Presented at the American Association for Aerosol Research 27th Annual Conference, Orlando, October 20-24.

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Moore, C. W. 2008. Outdoor lighting in parks. Presented at the Alaska and Pacific West Region Facility Managers Conference, San Diego, December 3.

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Moore, C. W. 2009. Sustainable skies. Presented at Missouri State University Sustainability Coloquia, Springfield, February 5.

Moore, C. W. 2009. Protecting park night skies. Presented to the National Park Service Cooperative Ecosystem Studies Unit participants, Denver, February 19.

Moore, C. W. 2009. Dark sky reserves in the United States. Presented at the Starlight 2009 Conference, Fuerteventura, Canary Islands, Spain, March 9.

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Schichtel, B. A., Malm, W. C., Barna, M. G., Gebhart, K. A., Collett, J. L., Jr., and Kreidenweis, S. M. 2008. Source apportionment of sulfur and nitrogen species at Rocky Mountain National Park using modeled conservative tracer releases and tracers of opportunity. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

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NPS – Characterizing Pollutant Deposition to Rocky Mountain National Park

Principal Investigators: Jeffrey L. Collett, Jr.

NOAA Project Goal: Air Quality

Key Words: Ammonia, Visibility, Air Quality, Particles

1. Long-Term Research Objectives and Specific Plans to Achieve Them:

The primary goal of this project is to design and test a robust, compact system for sampling atmospheric ammonia in urban and rural environments.

2. Research Accomplishments/Highlights:

Two generations of prototype samplers were designed, built and tested. Both employ a parallel plate denuder with coated quartz collection plates. Ammonia gas is collected by an acid coating applied to the denuder and aerosol particles are collected on a backup filter. The second generation system provided higher collection efficiency and greater capacity for ammonia collection.

3. Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

Sampler system design and lab testing is complete. Field testing of the 2nd generation sampler is underway.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Sampler design and testing efforts have been conducted in close collaboration with Aerosol Dynamics, Inc., Met One, Inc., with the National Park Service, and with USEPA, including officials from the Clean Air Status and Trends Network (CASTNet) and Chemical Speciation Network.

6. Awards/Honors: None

7. Outreach:

The following students were partially or fully supported: Misha Schurman (MS)

Public presentations and findings from this work were presented at the following:

Schurman, M., Collett, J.L., Jr., Hering, S.V., Day, D.E., Malm, W.C., and Lee, B., Developing and testing prototype compact denuders for ambient sampling applications, Abstract presented at the 27th Annual AAAR Conf., Orlando, FL, October 20-24, 2008

8. Publications: None.

<u>NPS</u> – Characterizing Wildland Fire Particulate Matter Emissions and Their Air Quality/Visibility Impacts

Principal Investigators: Sonia M. Kreidenweis and Jeffrey L. Collett, Jr.

NOAA Project Goals**:** Ecosystems; Climate; Weather and Water. *Programs*: Ecosystem Research; Climate Observations and Analysis; Climate Forcing; Climate Predictions and Projections; Regional Decision Support; Air Quality; Environmental Modeling

Key Words: Wildland Fire, Smoke, Visibility, Aerosol, Source Apportionment, Prescribed Burning

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project, sponsored by the Joint Fire Science Program and the National Park Service, is designed to investigate the chemical, physical and optical properties of particulate emissions from the burning of various U.S. wildland fuels.

Carbonaceous aerosols, which include contributions from industrial and mobile source emissions and biomass combustion, exert a significant impact on regional air quality. Smoke from fire-related activity, including prescribed burning to manage ecosystems, may contribute significantly to observed organic mass concentrations across the U.S. Further, these emissions have resulted in increased conflicts with the need to attain air quality standards, especially for particulate matter (PM) and visibility, as mandated by the Clean Air Act. However, federal land managers and policy makers currently lack several important tools needed for air quality assessments: composition profiles and analytical techniques necessary to differentiate carbonaceous aerosols originating from industrial and mobile source activity and those from fire emissions; measurement-based PM mass emissions rates for relevant fuels and combustion conditions; and reasonable optical properties and optical property emission rates to attach to fire emissions. This project addressed these needs via a comprehensive, multi-investigator approach that includes laboratory and field measurements.

2. Research Accomplishments/Highlights:

The focus of Year 3 was to conduct a field study to measure smokes from prescribed burns, of vegetation for which we have gathered source profile information in the laboratory. One objective of the field study was to test the applicability of our emissions profiles to atmospheric conditions. The field experiment was planned for May 2008 in Forest Service lands in Montana. Our team deployed to the site and waited for over 2 weeks. Unfortunately, each planned burns was postponed and ultimately cancelled because of exceptionally cool and rainy weather in the region.

We conducted several successful, smaller-scale sampling efforts in locations in California and the Southeast to test the applicability of source profiles obtained in our lab studies.

A secondary focus of Year 3 was to complete sample analyses, data processing, and preparation of manuscripts. A paper describing both laboratory campaigns, that includes tabulations of all of our gaseous- and particulate-phase emissions data, was submitted to *J. Geophysical Research* (McMeeking et al., 2009). Several other papers that describe our findings have been published, submitted, or are in preparation.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

1. Sample analysis from Year 2 FSL burn experiments. *Completed.*
2. Peer-reviewed journal articles describing smoke source profiles measured at FSL. *Completed, with additional articles in progress.*
3. Year 3 field study of prescribed burn smoke*. Planned for May 2008 in Montana; burns cancelled due to weather; smaller-scale studies completed in alternate locations.*

4. Leveraging/Payoff:

Findings from the study are being communicated to air quality regulators, policymakers, and other stakeholders to improve understanding of the characteristics of smokes from various fuels.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Partners in the study included the National Park Service, University of Nevada Desert Research Institute, and USDA / USFS Fire Sciences Laboratory. Separately-funded collaborative participants in the field studies included Aerodyne Research Inc., University of Colorado, Pacific Northwest Laboratory, Lawrence Berkeley Laboratory, USEPA, Academica Sinica Taiwan, and Montana State University.

6. Awards/honors: None.

7. Outreach:

The following students were partially or fully supported by this project: Amanda Holden (MS), Ezra Levin (MS), Gavin McMeeking (PhD), Laurie Mack (MS), and Leigh Patterson (MS). The following theses and dissertations acknowledge support:

--The optical, chemical, and physical properties of aerosols and gases emitted by the laboratory combustion of wildland fuels, Ph.D. Dissertation, CSU, Gavin McMeeking, Fall 2008

--The retrieval of aerosol optical properties from biomass burning during FLAME2, M.S. Thesis, CSU, Laurie Mack, Fall 2008

--Estimating contributions of primary biomass combustion to fine particulate matter at sites in the Western United States, M.S. Thesis, CSU, Amanda Holden, Fall 2008

Web site: http://chem.atmos.colostate.edu/FLAME/

Presentations

Sonia Kreidenweis, Water interactions of biomass burning aerosols. Telluride Science Research Center workshop, Organic Particles in the Atmosphere: Formation, Properties, Processing, and Impact, Telluride, CO, August 4-8, 2008.

McMeeking, G. R., Carrico, C.M., Petters, M.D., Parsons, M., Prenni, A.J., Sullivan, A.P., DeMott, P.J., Kreidenweis, S.M., Collett, Jr., J.L., Kirchstetter, T.W., Lunden, M.M., Moosmüller, H., Arnott, W.P., Lewis, K., Baker, S., Wold, C.E., Hao, W.M., Characterization of emissions from the laboratory combustion of wildland plant species. 9th International Conference on Carbonaceous Particles in the Atmosphere (ICCPA), Berkeley, CA, August 12-14, 2008

McMeeking, G. R., Sullivan, A.P., DeMott, P.J., Kreidenweis, S.M., Collett, Jr., J.L., Kirchstetter, T.W., Lunden, M.M., Moosmüller, H., Arnott, W.P., Lewis, K., Hao, W.M., and Malm, W.C., The light attenuation spectral dependence of organic carbon emitted by biomass burning. 9th International Conference on Carbonaceous Particles in the Atmosphere (ICCPA), Berkeley, CA, August 12-14, 2008

Petters, M., Parsons, M., Prenni, A., DeMott, P., Carrico, C., and Kreidenweis, S., Do biomass burning aerosols nucleate ice? Abstract presented at the 27th Annual AAAR Conference, Orlando, Florida, October 20-24, 2008

Holden, A.S., Sullivan, A.P., Patterson, L.A., Schichtel, B., Malm, W., Kreidenweis, S., and Collett, Jr., J.L., Estimating contributions of primary biomass burning to fine particulates in ambient aerosol in the Western United States. Poster presented at the 27th Annual AAAR Conference, Orlando, Florida, October 20-24, 2008

Mack, L., Obrist, D., Moosmuller, H., Lewis, K., Arnott, P., McMeeking, G., Levin, E., Kreidenweis, S., Wold, C., Hao W-M., Collett, J.L., Jr., and Malm W., Optical closure experiments of biomass smoke aerosols. Poster presented at the 27th Annual AAAR Conference, Orlando, Florida, October 20-24, 2008

Sullivan, A.P., Kenski, D.M., and Collett, J.L., Jr., Spatial and temporal impacts of biomass burning on the Upper Midwest, Abstract presented at the 27th Annual AAAR Conference, Orlando, Florida, October 20-24, 2008

Carrico, C.M., Petters, M.D., Kreidenweis, S.M., Prenni, A.J., DeMott, P.J., McMeeking, G.R., Levin, E., Mack, L., Sullivan, A., Holden, A., Collett, J.L., Day, D., Hand, J., Malm, W.C., Wold, C., and Hao, W.-M., Physicochemical Properties of Fresh Biomass Smoke Aerosols. Invited Talk, NOAA Earth System Research Lab Chemical Sciences Division, 29 October 2008.

Patterson, L.A., Schichtel, B.A., Sullivan, A.P., Collett, Jr., J.L., Holden, A.S., Kreidenweis, S.M., and Malm, W.C., Development of a wildland fire smoke marker emissions map for the contiguous United States. Poster presented at AGU Conference, San Francisco, CA, December 15-19, 2008.

8. Publications:

<u>Peer-Reviewed Articles</u>

Carrico, C.M., Petters, M.D., Kreidenweis, S.M., Collett, Jr., J.L., Engling, G. and Malm, W.C., Aerosol hygroscopicity and cloud droplet activation of extracts of filters from biomass burning experiments, *J. Geophys. Res*, 113, D08206, doi:10.1029/2007JD009274, 2008.

DeMott, P.J., Petters, M.D., Prenni, A.J., Carrico, C.M., Kreidenweis, S.M., Collett, Jr., J.L., and Moosmüller, H., Ice nucleation behavior of biomass combustion particles at cirrus temperatures, *J. Geophys. Res.,* submitted, 2009.

McMeeking, G.R., S, M. Kreidenweis, S, Baker, C. M. Carrico, J. C. Chow, J. L. Collett, Jr., W. M. Hao, A. S. Holden, T. W. Kirchstetter, W. C. Malm, H.Moosmüller, A. P. Sullivan, and C. E. Wold, Emissions of trace gases and aerosols during the open combustion of biomass in the laboratory, *J. Geophys. Res.,* submitted, 2009.

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Petters, M.D., Parsons, M.T., Prenni, A.J., DeMott, P.J., Kreidenweis, S.M., Carrico, C.M., Sullivan, A.P., McMeeking, G.R., Levin, E., Wold, C.E., Collett, Jr., J.L., Moosmuller, H.S., Arnott, P.W., Malm, W.C., and Hao, W-M., Ice nuclei emissions from biomass burning, *J. Geophys. Res.*, 114, D07209, doi:10.1029/2008JD011532, 2009.

Sullivan, A.P., Holden, A.S., Patterson, L.A., McMeeking, G.R., Kreidenweis, S.M., Malm, W.C., Hao, W.M., Wold, C.E., and Collett, Jr., J.L., A method for smoke marker measurements and its potential application for determining the contribution of biomass burning from wildfires and prescribed fires to ambient PM2.5 organic carbon, *J. Geophys. Res.*, doi:10:1029/2008JD010216, 2008.

<u>NPS</u> – Transport and Deposition of Airborne Nitrogen and Sulfur in Rocky Mountain National Park

Principal Investigators: Jeffrey L. Collett, Jr. and Sonia M. Kreidenweis

NOAA Project Goal: Air Quality

Key Words: Nitrogen Deposition, Visibility, Acid Deposition, Aerosol, Precipitation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

This project is an extension of previous efforts to characterize transport and deposition of airborne nitrogen and sulfur in Rocky Mountain National Park. Key objectives for this new task include studying airborne concentrations and deposition throughout a full annual cycle in order to evaluate seasonal trends in pollutant concentrations, transport patterns and deposition fluxes as well as the addition of new methods for continuous measurement of trace oxidized nitrogen species in the gas phase. A field project was planned to accomplish these objectives.

2. Research Accomplishments/Highlights:

A field project in Rocky Mountain National Park was begun in November 2008 and will run through fall 2009. Daily or higher time resolution measurements are being made of fine particle composition, particle size distributions, concentrations of key trace gases (esp. NH_3, HNO_3, NO_x, and NO_y), and wet deposition fluxes of inorganic ions, organic nitrogen and organic carbon.

Measurements during winter 2008/09 revealed generally low pollutant concentrations within the park, with the exception of a few “episode” days. Concentrations of airborne particles and gases, especially ammonia, show an increasing tendency moving into the spring season. This increase may be associated with increased local emissions, increased transport, or both.

3. Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

Key objectives for this study are still in progress. These include:

a. Design, testing and deployment of a system for continuous measurement of reduced and oxidized gas phase nitrogen species (in progress)
b. Quantification of annual deposition budgets and seasonal trends for nitrogen and sulfur species in Rocky Mountain National Park (in progress)

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

Results of this work have been discussed with USEPA and with the Colorado Department of Public Health and Environment (CDPHE).

6. Awards/Honors: None.

7. Outreach:

The following students were partially or fully supported by this project: Katie Beem (Ph.D), Misha Schurman (MS), Ezra Levin (Ph.D), Laurie Mack (Ph.D), and Nick Powers (BA).

8. Publications: None.

NSF – Collaborative Research: Norwegian-United States IPY Scientific Traverse: Climate Variability and Glaciology in East Antarctica

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond.

Key Words: Weather, Ice Sheet, Modeling, Antarctica, Precipitation.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

One of the most pressing environmental issues of our time is the need to understand the mechanisms of current global climate change and the associated impacts on global economic and political systems. In order to predict the future with confidence, we need a clear understanding of past and present changes in the Polar Regions and the role these changes play in the global climate system. A significant portion of the fresh water on Earth exists as snow and ice in the Antarctic ice sheet. A massive, largely unexplored region, the East Antarctic ice sheet looms large in the global climate system, yet relatively little is known about its climate variability or the contribution it makes to sea level changes.

The core of this project involves scientific investigations along two overland traverses in East Antarctica: one going from the Norwegian Troll Station (72º S, 2º E) to the United States South Pole Station (90º S, 0º E) in 2007-2008; and a return traverse starting at South Pole Station and ending at Troll Station by a different route in 2008-2009. The project will start in 2006-7 with a year of testing equipment and techniques near Troll, and positioning fuel along the first year route. This project will investigate climate change in East Antarctica, with the goals of: (1) Understanding climate variability in Dronning Maud Land of East Antarctica on time scales of years to centuries, (2) determining the surface and net mass balance of the ice sheet in this sector to understand its impact on sea level, (3) investigating the impact of atmospheric and oceanic variability on the chemical composition of firn and ice in the region, and (4) revisiting areas and sites first explored by traverses in the 1960's, for detection of possible changes and to establish benchmark datasets for future research efforts.

2. Research Accomplishments/Highlights:

Our 2007-2008 and 2008-2009 Antarctic field expeditions were executed as scheduled.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Prepare and ship scientific equipment and supplies for the 2007-2008 overland traverse to the South Pole. "Complete."

Participate in the 2007-2008 South Pole traverse, making surface and near-surface snow measurements. "Complete."

Analyze snow data collected during the traverse to understand snow accumulation spatial variability across the East Antarctic Ice Sheet, in support of the rest of the project team and research program. “In progress.”

4. Leveraging/Payoff:

The results of this investigation will add to understanding of climate variability in East Antarctica and its contribution to global sea level change. The project includes extensive outreach to the general public both in Scandinavia and North America through the press, television, science museums, children’s literature, and web sites. Active knowledge sharing and collaboration between pioneers in Antarctic glaciology from Norway and the US, with the international group of scientists and students involved in this project, provide a unique opportunity to explore the changes that half a century have made in climate proxies from East Antarctica, scientific tools, and the culture and people of science.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

As part of our field expedition planning, we have been working with project collaborators from both Norway and the United States.

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

<u>NSF</u> – Improving Parameterizations of Non-convective Precipitation Processes by Data Assimilation

Principal Investigator: Isidora Jankov

NOAA Project Goal: Serve Society's needs for water and weather information

Key Words: Modeling, Microphysics, Data Assimilation, Radar

1. Long-term Research Objectives and Specific Plans to Achieve Them:

<u>Project Activities</u>

a. Model simulations and verification

b. Using model verification results to define an optimal measure of distance between model and radar observations with respect to correcting bulk microphysical parameterizations by radar data assimilation

c. Learning WRF-4DVar data assimilation algorithm

d. Modeling of radar reflectivity

e. Graduate student training

<u>Model Simulations and Verification</u>

In order to develop an optimal approach to correcting deficiencies in bulk explicit parameterizations of precipitation processes in mesoscale forecasting by radar data assimilation, it is necessary to first evaluate model performance relative to radar observations and to diagnose model errors and an optimal measure of distance from these observations to use in the data assimilation. We start the study with model verification on examples of IHOP (International H2O Project) cases because of rich observational coverage during this observation campaign and readily available data archives. Besides, the IHOP cases provide diversity of summer storm systems to ensure robust diagnostic analysis for that type of system.

a) WRF model simulations

So far, we performed simulations of a sequence of storms during June 13 2002 in Central Great Plains. The simulations were performed with Advanced Research WRF (ARW) community model with 4-km horizontal grid spacing and 51 vertical levels and three available microphysics options. The three different microphysical schemes used were Lin, WSM6 and Schultz.

For each of the three microphysics configurations, non-local mixing Yonsei University (YSU) PBL scheme– as an improved version of the Medium-range Forecast Model

(MRF) PBL scheme– was used. The model runs were initialized at 00 UTC and run for six hours. Local Analysis and Prediction System (LAPS) diabatic was used for the model initialization. The LAPS diabatic initialization is based on a three-dimensional analysis of cloud attributes (*i. e.*, coverage, type and mixing ratios) that includes methods for estimating in-cloud vertical motions. By using a variational adjustment procedure (involving dynamic balancing and a mass conservation constraint), horizontal wind fields and the mass field are adjusted to produce divergence consistent with the specified cloud updraft properties (depth, magnitude, and shape of the updraft profiles). Essentially, the LAPS procedures enable the initialization of hydrometeors and balanced circulations driven by latent heating. This triggers an immediate activation of microphysical schemes and the development of grid-resolved precipitation at early forecast times of runs initialized with LAPS analyses. Global Modeling Forecast System (GFS) analyses and forecasts were used for lateral boundary conditions for all model runs.

b) Verification data from LAPS system

Evaluation of the model simulations was done by comparison of simulated 3-dimensional reflectivity to corresponding LAPS reflectivity analyses. Model forecast fields were converted into radar reflectivity using an empirical relationship between mixing ratio of modeled hydrometeors and radar reflectivity after publication by Kessler in 1969 and Rogers and Yau in 1989. The verifying LAPS radar fields were generated as part of the cloud analysis package. WSR-88D full volume reflectivity data were mapped onto the LAPS grid using a polar-to-cartesian remapping program that operates on NetCDF files created using Level-II data from individual WSR-88D Doppler radars.

For each LAPS grid point, the remapping algorithm computes reflectivity by taking the mean Z value of all gates lying within a grid volume centered on the LAPS grid point. The use of all gates (rather than just the nearest neighbors) is advantageous in that it allows all of the radar information to influence the analysis and mitigates any noise that could be introduced by sub-sampling or spatial aliasing. The radar beam-width is assumed to be zero at this stage and only those grid volumes directly illuminated by the gates within the beam are filled in. We thus have the potential to produce a sparse array if the grid-resolution is < 10km or so. The average Z is converted to dBZ prior to output. When the mean reflectivity is less than a user adjustable QC threshold (e.g. 0 dBZ), it is set to a flag no echo value (e.g. -10 dBZ). If the data are nearly free of echoes, an output file is not written in order to save disk space. Another QC requirement is that at least 4 gates in the grid volume contain valid reflectivity data. This criterion is normally relaxed when the grid spacing is less than about 4km.

For high resolution grids, a post-process running within the remapper executable does horizontal filling between radials. This is currently a simple average of the nearest neighbors done only where gaps between radials are one grid-point across. The size of the filter kernel is adaptable as it is determined by the angular beam width (i.e. separation between successive radials, a run-time input parameter) and range from the radar. Since we often encounter gaps/holes covering only one grid-point (with 8 adjacent neighbors), this simple algorithm provides results largely equivalent to a Barnes weighting.

Vertical gaps in the reflectivity of up to 2 km are filled using linear interpolation. The gaps occur in the space between successive radar sweeps with increasing antenna elevation. The routine also has the option of filling in echo in low levels judged to be either below the radar horizon (due to the earth's curvature) or blanked out by mountains or ground clutter. Any echo whose base is within two LAPS grid levels (100 hPa) of the local terrain is assumed by the fill routine to extend down to the ground in reality. The 3-D mosaic is generated by considering the nearest radar to each LAPS grid point. This is advantageous since it avoids issues relating to movement of echoes if we wanted to use a weighted average of several of the nearest radars. A time window of +/- 600s is allowed for radar inclusion. Additional quality control is applied to the 3-D radar field within the LAPS cloud analysis. If the echo top is below 3000m AGL, or no pre-existing cloud-base is found (based on IR satellite and other data), no cloud is added and the radar echo is blanked out. Visible satellite is also used to flag false echoes. The cloud and precipitation analysis package can also operate with reduced capability using two-dimensional radar reflectivities, such as that provided by NOWRAD radar data over the continental United States. The low-level radar dataset is blended in a limited area that isn't covered by the full volume data.

c) Derived diagnostic data

Using the forecast and verifiying gridded reflectivity fields mentioned above several diagnostics were computed including, number of occurrences of binned values of reflectivity over the volume of the model domain that exceed a specified threshold (i.e. the histogram data), contingency tables and skill scores. The diagnostics were calculated for the simulated and observed fields for each model microphysics and each hourly output time step. Simulated vs observed contingency tables were calculated from the histogram data. The contingency table data were used to compute the skill scores. These include bias (ratio of simulated to observed number of points exceeding a reflectivity threshold) and Equitable Threat Score (ETS). To aid interpretation the histograms and contingency tables were visualized in several ways including 3-dimensional animations.

The standard LAPS algorithm was modified to compute these diagnostic quantities. This project data are now available via 'laps.noaa.gov' web site including all model forecasts, verifying analysis data as well as the observation and diagnostic data. The LAPS web site includes a separate sub-page for this project, through which the data can be visualized on-line using state of the art graphical display for the meteorological data (e.g., 2D figures of forecast and analysis fields, their differences and a set of standard derived diagnostic fields). The site could be reached via http://laps.noaa.gov, "On-the-fly Analyses/Forecasts". The project is under domain labeled NSF

<u>Approach to defining an optimal distance to use in radar data assimilation with respect to errors in cloud microphysical parameterizations</u>

Model evaluation by global diagnostics such as reflectivity histograms, 3D contingency tables and standard skill scores in the radar reflectivity space as well as comparison of 2D cross-sections of the reflectivity fields between the model and LAPS analysis show (next section) that the model forecast has very low skill relative to the observations on point-by-point bases. This result is expected and reflects among other factors presence of phase errors in the forecast. The phase errors are influenced by model dynamics and do not necessarily correlate directly with deficiencies in bulk microphysics parameterization, except through physics-dynamics feedbacks. In order to define a measure of distance between the modeled and observed radar reflectivities that would reflect primarily the impact of errors in modeling of the precipitation microphysics we designe the following analysis

Step 1 - 2D radar reflectivity fields from model and LAPS analysis are compared for each forecast output time (currently every 1 h) and each version of the model microphysics to identify sub-regions of corresponding coherent 2D reflectivity structures. We denote the sub-regions $S^i_{M\,j}(\tau_n)$ and $S^i_A(\tau_n)$ for the model and LAPS analysis, respectively; where i is the sub-region index, j is model version index ($j \in [1,3]$, for three different microphysical parameterizations used), and τ_n is time instance. The specific sub-regions for the modeled June 13 case were identified manually (by eye) and are discussed in the next section (Major findings). In the next phase of the project we will test using "automatic feature identification" approach (research in 2009).

Step 2 - For each sub-region the histograms of binned reflectivity values for each vertical level are computed

Step 3 - Normalized histograms are used to compute area average reflectivity per level and region in the following way

$$R^i_{M(A)_j}(\tau_n, l) = \sum_k r_k p_k \qquad (1)$$

where r_k is bin value and p_k is normalized count in the bin for each set (i, j, n, l); l is vertical index. Application of the expression (1) to the modeled and observed reflectivity would result in vertical profiles of horizontal weighted average of reflectivity from the model and observations.

Step 4 - L^2 norm distance between the modeled and observed reflectivities per level, model version and verification time could be then evaluated as follows

$$d^i_j(\tau_n, l) = \left[R^i_{M_j}(\tau_n, l) - R^i_{A_j}(\tau_n, l) - \right]^2 \qquad (2)$$

This procedure would result in a time sequence of vertical profiles of square differences of weighted average reflectivities within the equivalent coherent reflectivity structures. If these profiles are similar between different regions and times, then the distance function (2) could be employed as a measure of model error that primarily reflects systematic errors in vertical distribution of hydrometeor type and mass. Because the vertical distribution of the hydrometeor mass and type depends directly on the microphysical parameterization, this measure should correlate directly with the model errors in the parameterization. Also, sensitivity of the distance (2) to the model version (i.e., the microphysical parameterization) would indicate differences in errors from the different parameterizations.

Assuming validity of the condition in Step-4, the horizontally integrated reflectivity profiles by the expression (1) should be used to form cost function for the radar data assimilation with respect to correcting the microphysical parameterizations. We are currently evaluating the integral reflectivity profiles using the expression (1) and the associated distance function for the IHOP cases we are modeling.

<u>Learning WRF-ARW-4DVar system</u>

--Vukicevic and Jankov attended WRF-Var tutorial in July 2008 at NCAR. This tutorial included only 3DVar version of the WRF-Var system because this version is currently the public version. Because many components of the WRF-4DVar system are shared with the 3Dvar system, the tutorial provided useful instructions with respect to using the former.

--Vukicevic acquired WRF-4DVar algorithm from NCAR in Fall 2008, and received individual instruction on 4DVar components from collaborators at NCAR. An untested version of tangent linear and adjoint codes for the WSM6 microphysical parameterization was also acquired from the NCAR collaborators. Testing of this code will be done in Spring 2009.

--Vukicevic started code modifications in the 4DVar system regarding adding new control variables and cost function.

<u>Modeling of radar reflectivity</u>

The radar reflectivity model that is currently used to map the model hydrometeor data fields into the reflectivity space inside LAPS algorithm is based on empirical formula that is not representative of diversity of hydropmeteor particle distributions that are present across broad range of storm cases. Also, the radar data spatial mapping in the current analysis does not include geometry of the radar measurements. The accuracy of overall transformation of the forecast data into the reflectivity space for the purpose of computing distance between the model and observations may be significantly affected by errors in the physical and geometric mapping procedures. This could in turn affect the accuracy of data assimilation with the radar data.

To evaluate sensitivity of transformation of the model forecast to the radar reflectivity we plan to compare the current simple model results with state of the art physically based radar model which includes options for different hydrometeor distribution parameters and careful modeling of radar measurement's geometry. The model we plan to use is developed at the DLR-Institute of Atmospheric Physics, Oberpfaffenhofen, Germany, by M. Pfeifer and collaborators for studies in radar meteorology and for mesoscale forecast model validation. We have acquired the model from the developers by contact through Prof. Katja Frierdich of department of Atmospheric and Oceanic Sciences at CU, Boulder.

Marcus Van Lier-Walqui, the new graduate student who joined the current project in December 2009, will start implementation of the radar model by Pfeifer et al. in July of 2009.

Graduate student training

Marcus Van Lier-Walqui, first year graduate student in ATOC joined the project in December 2008. Marcus has been trained in the following: a) acquire and visualize the project data from the LAPS analysis system; He already developed 3D visualization template using Matlab (example Figure 1 in section on Major findings), b) acquire and analyze observation data from the IHOP archive, c) perform literature search and summarize findings from publications and d) obtain major new software from outside sources (previous section).

2. Research Accomplishments/Highlights *and*

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

Model verification and forming hypothesis about modeling errors

Model evaluation for the June 13 case by global diagnostics such as reflectivity histograms and 3D contingency tables in the radar reflectivity space indicate that the model forecast has extremely low skill relative to radar observations at point-by-point bases. For example, the 3D contingency tables in the binned reflectivities in Figure 1, for 3 different microphysical parameterizations, show that the model does not agree with the observations at more than 90% of the points in 3D domain only few hours into the forecast, despite almost perfect agreement at the initial time. The agreement at the initial time results from initialization with LAPS analysis which includes observed reflectivities. This initialization provides “hot start” to the forecast. The “hot start” initial model data include cloud and precipitation hydrometeor fields with adjusted wind, humidity and temperature fields.

In contrast to the point-vise diagnostics which show low forecast skill, comparison of 2D reflectivity horizontal cross-sections between the model and LAPS analysis indicates that the model captures some general features of the observed evolution of the storm system. For example, in the model and observations, the squall line which is present at the beginning of forecast for the June 13 case (0000 UTC) across Northern Texas, Western Oklahoma and South-East Kansas (shown in Figure 2) splits into two branches, denoted here SW (South-West) and NE (North-East). Both of the branches then persists over about 2 hours, moving in SE direction in the model and observations (illustrated in Figure 3). The movement of the storm front is somewhat faster in the model than in observations. Consecutive evolution, after 0200 UTC, includes dissipation of the SW branch both in the observations and model, but in the model there is secondary storm development ahead of the front, which is not present in the observations (Figure 4). Regarding the storm that is associated with the NE branch of the initial squall line, it intensifies and continues to move in S-SE direction in both the model and observations, but the observed is characterized with the squall line shape while modeled storm is not. The modeled storms also include much less area and weak secondary developments to the NE (Figure 4). These general features of the storm evolution are present in each model simulation with different microphysical parameterizations but intensity of storms and aerial coverage differ between the different schemes. For example, the Schultz scheme produces least aerial coverage and least skilled forecast. These results indicate that comparison of the modeled to observed reflectivity fields for the purpose of data assimilation with respect to the microphysical parameterizations should include only regions with equivalent coherent structures and only over the associated life time of few hours.

In addition to verification with the reflectivity data we compared 2D fields of temperature, horizontal wind and humidity between the forecast and LAPS analysis. This comparison indicates that the model has tendency to generate strong cold pool where there is storm activity in all regions and with all schemes, much stronger than the equivalent in the observationally-based analysis data. For example, the SW branch which dissipates entirely in the SW Oklahoma in the observations, intensifies in the model further south because the model generated cold pool interacts with warm environment forming strong convergence zone south of the storm and near the surface. This overcooling in the lower troposphere in the model forecast, that occurs from the onset with the initialized squall line, suggests that the cloud microphysical parameterizations control the forecast error by feedback with the dynamics. The overcooling in the model due to activated microphysical parameterizations early in the simulations in illustrated in Figure 5.

To better understand the model errors associated with the cooling due to the microphysics we plan to perform analysis of time tendency of temperature perturbations due to the parameterized microphysical processes in the three schemes. For this purpose we need to generate additional model simulations to extract data that are not available in the standard output. In addition, because the LAPS analysis is relatively crude above the surface due to insufficient observation coverage, further identification of discrepancies between the model and reality regarding mesoscale interactions between the microphysical parameterization results and perturbations in temperature, humidity and wind within the regions of storm activity requires use of more observations. We are currently making selection of observations from the IHOP archive for this purpose.

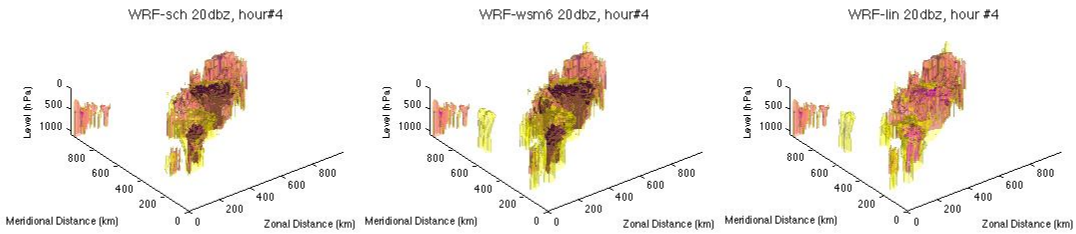

Figure 1: 3D contingency tables (model/observation “yes” or “no” occurrence in each spatial point) in radar reflectivity field for threshold of 20 dbz, for three model simulations using different cloud microphysics parameterizations at verification time 04 UTC June 13 2004 within model domain (model domain is depicted in next figures). White color indicates no/no (model/observation), black yes/yes, yellow (no/yes) and pink yes/no. Version of the precipitation microphysical parameterization is indicated in the panel title.

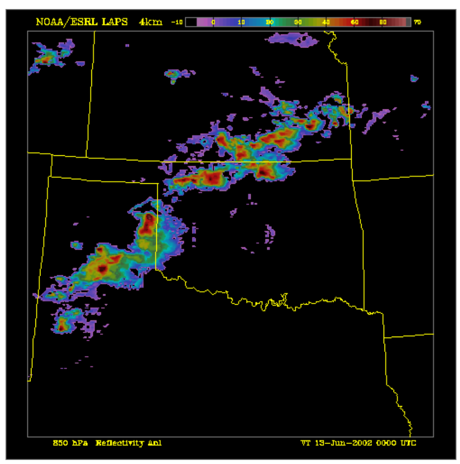

Figure 2: Observed reflectivity at 850 hPa level at initial time for June 13 case (0000 UTC, June 13, 2002).

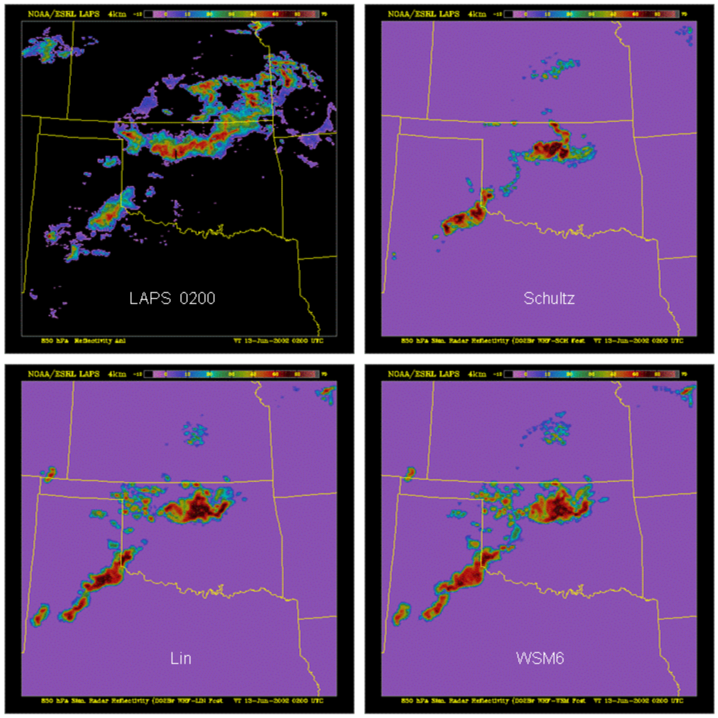

Figure 3: Observed and modeled reflectivity at 850 hPa level at 2 hours into the simulation (0200 UTC, June 13, 2002).

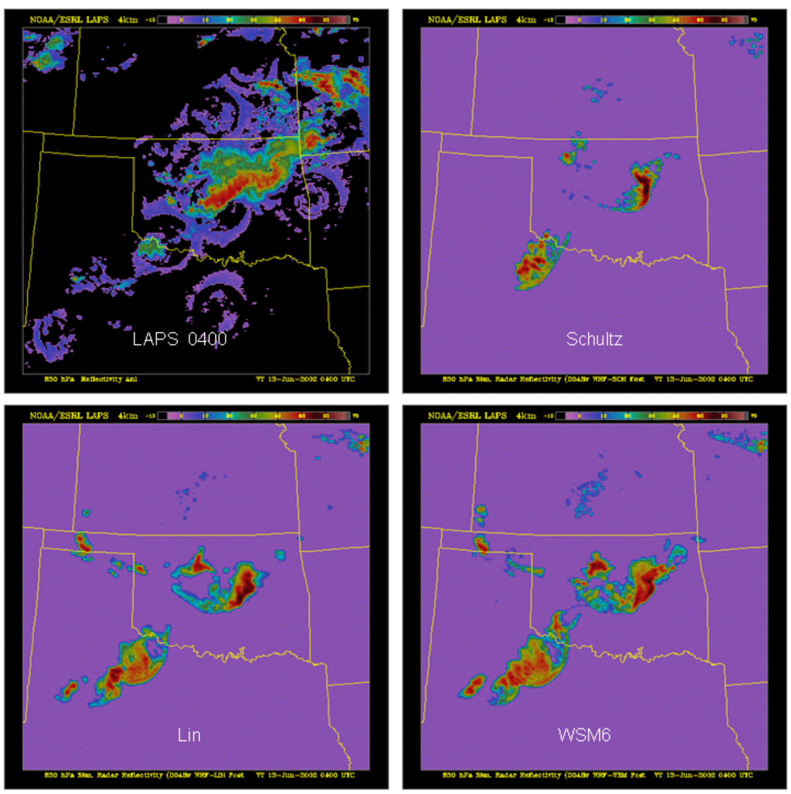

Figure 4: Observed and modeled reflectivity at 850 hPa level, at 4 hours into the simulation (0400 UTC, June 13, 2002).

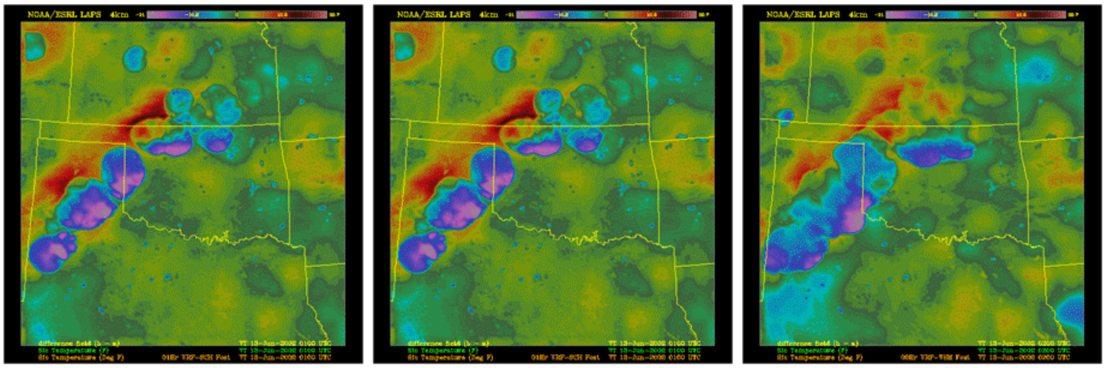

Figure 5: Differences in surface temperature between model simulations and LAPS analysis one hour into the simulations (0100 UTC, June 13, 2002). Cold colors are negative and near zero values are green. Maximum negative difference is about -15 C. Left panel is for WSM6, middle for Lin and right for Shultz microphysical parameterization.

4. Leveraging/Payoff: None.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

The project includes collaborations with various institutes and scientists (e.g. a professor at CU Boulder Katja Friedrich, data assimilation group at NCAR, M. Pfeifer and collaborators from the DLR-Institute of Atmospheric Physics, Oberpfaffenhofen, Germany).

6. Awards/Honors: None.

7. Outreach:

Marcus van Lier-Walqui, a first year graduate student with ATOC CU, Boulder joined the project in December 2008. Marcus has worked on data analysis and visualization and will continue to work with our group on research which will become the foundation of his PhD thesis.

8. Publications:

Preliminary results titled: Evaluation of model performance and possible improvements of microphysical parameterizations by using radar data were presented at the recent WAF conference in Omaha (5A.5).

NSF – IPY: COLLABORATIVE RESEARCH: A PROTOTYPE NETWORK FOR MEASURING ARCTIC WINTER PRECIPITATION AND SNOW COVER (SNOW-NET)

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond.

Key Words: Precipitation, Snow, Sublimation, Snowfall, Modeling, Arctic.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Temperature and precipitation are the most important metrics of climate change, yet a strong case can be made that our ability to produce accurate and reliable records of arctic precipitation is poor. The root of the problem is that for 8 to 10 months of the year, precipitation falls as a solid (snow, hail, diamond dust, sleet, and rime). Wind, drifting snow, and the propensity for snow to stick to gauges, combine to make monitoring solid precipitation a difficult task. In addition, solid precipitation accumulates and forms a long-lasting snow cover that, if anything, impacts the arctic system even more than the precipitation amount. Both snowfall and snow on the ground are changing, yet we are in a poor position to monitor this change. Part of the problem is that winter precipitation and snow on the ground are currently monitored by two separate systems. Here we propose a prototype international network where we will measure snowfall and snow on the ground concurrently, thereby improving our ability to monitor both of these better. At 5 arctic sites (all identified as key locations in a pan-arctic monitoring network), we will augment existing meteorological and snow measuring instrumentation with solid-state snow pillows, heated plate precipitation sensors, snow fences (to capture the wind-blown flux), and eddy correlation towers for computation of sublimation. Several times a winter at the sites we will conduct ground surveys of snow cover depth, water equivalent, and other properties using tools that allow rapid collection of extensive data. These will be augmented with aerial photography and airborne remote sensing from inexpensive platforms to visualize drift and deposition patterns. The combined suite of instruments and measurements is designed to allow us to close the winter water balance at each site, for the first time balancing the precipitation with measured accumulation. Using a set of modeling tools (e.g., a melt model, and a transport model for blowing snow), we will a) develop methods and algorithms for quality checking both meteorological and snow data by cross-comparison between sensors and instruments, b) close the water balance in a way that produces more accurate values of winter precipitation and snow on the ground than are currently being collected, and c) apply our methodology to historical data from the existing gauge network to produce better estimates of past trends.

2. Research Accomplishments/Highlights:

Field instruments were installed during 2007 and measurements were made during winter 2007-2008 and 2008-2009.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

--Install instrumentation at our field-measurement sites. “Complete.”
--Develop methods and algorithms for quality checking both meteorological and snow data by cross-comparison between sensors and instruments. “In progress.”
--Close the water balance in a way that produces more accurate values of winter precipitation and snow on the ground than are currently being collected. “Yet to be started.”
--Apply our methodology to historical data from the existing gauge network to produce better estimates of past trends. “Yet to be started.”

4. Leveraging/Payoff:

The proposed project will substantially advance our understanding of how best to monitor arctic precipitation and will result in better knowledge of the spatial and historic trends in arctic winter precipitation and snow cover. Within the U.S., this understanding will directly benefit the National Resource Conservation Service (NRCS), one of the prime agencies charged with monitoring precipitation and snow cover.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As part of our field project planning, we have been working with project collaborators from the Cold Regions Research and Engineering Lab (CRREL) and the University of Alaska, Fairbanks (UAF).

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

NSF - THE WHITE ARCTIC: A SNOW-IMPACTS SYNTHESIS FOR THE TERRESTRIAL ARCTIC

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond.

Key Words: Precipitation, Sublimation, Snow, Arctic, Modeling.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

A defining feature of the Arctic is a long-lasting snow cover. It persists 7 to 10 months of the year, making white the dominant surface color of both Arctic marine and terrestrial systems. On land, snow impacts the Arctic System in four essential ways: by increasing albedo, by insulating the ground, by affecting mobility and foraging of animals and human transportation and commerce, and by playing a key role in the freshwater cycle. While snow has been discussed in literally hundreds of papers and appears in dozens of models (from process-level to GCM), a comprehensive, snow-centric synthesis has never been undertaken. Current information and knowledge related to snow tends to be compartmentalized by discipline, dispersed throughout the literature, and rarely inclusive. Such a synthesis is needed now more than ever because both the duration and the nature of the arctic snowpack are changing. The snow-cover season has decreased 3 days per decade since the 1970s, rain-on-snow events are increasing in frequency and extent, and future snowpacks are likely to be composed of more wind slab and depth hoar than in the past. Increasing shrubs on the tundra and decreasing trees in the taiga will also alter the nature of the snowpack, which in turn could amplify, or dampen, the vegetation response. In the proposed work, we take a comprehensive approach to snow that will produce a better understanding of how changing snow conditions will affect the Arctic System. The proposed terrestrial snow work completes the suite of synthesis studies on the Arctic System undertaken in the first phase of the SASS Program by combining with an existing study of snow on sea ice, thereby producing a full system-wide assessment of snow impacts. The proposed synthesis is organized into five tasks designed to provide answers to several pressing snow-related questions: 1) collect pan-Arctic datasets, 2) merge tools and models to simulate Arctic snow-related features, 3) produce spatially distributed time-evolving distributions of snow properties and characteristics for the terrestrial pan-Arctic System, 4) from these distributions develop a set of integrated indices and derived products that capture the essential snow-related impacts, and 5) use the impact indices to better understand the Arctic System.

2. Research Accomplishments/Highlights:

Our model simulation domains, grid increments, and general simulation protocols have been defined and model simulations have been run.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

--Collect pan-Arctic datasets. “Complete.”
--Merge tools and models to simulate Arctic snow-related features. “Complete.”
--Produce spatially distributed time-evolving distributions of snow properties and characteristics for the terrestrial pan-Arctic System. “Complete.”
--Use these distributions to develop a set of integrated indices and derived products that capture the essential snow-related impacts. “In progress.”
--Use the impact indices to better understand the Arctic System. “In progress.”

4. Leveraging/Payoff:

The proposed synthesis will substantially advance our understanding of the complex role of snow in the Arctic System. The datasets and process-oriented modeling produced by this synthesis will be of particular value in advancing large-scale climate models, terrestrial ecology, and atmospheric chemistry. Through our interactions with these communities we will provide datasets that can be directly employed to examine problems in a wide range of interdisciplinary studies.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As part of our field project planning, we have been working with project collaborators from the Cold Regions Research and Engineering Lab (CRREL).

6. Awards/Honors: None.

7. Outreach: None.

8. Publications: None.

NSF - USING A REGIONAL-SCALE MODEL TO ANALYZE THE SCALE DEPENDENCE OF CONVECTION, CLOUD MICROPHYSICS, AND FRACTIONAL CLOUDINESS

Principal Investigator: Dr. Laura D. Fowler

NOAA Project Goal: Weather and Water

Related Programs: Local Forecasts and Warnings, Hydrology, Environmental Modeling, Weather Water Science

Key Words: Convection, Cloud Microphysics, Fractional Cloudiness, Interactions, Scale-dependence.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

Summary

The proposed research focuses on the analysis of the spatial scale dependence of convection, cloud microphysics, and fractional cloudiness, from the results of short-term experiments with varying resolutions using the Weather Research Forecast (WRF) model. First, it is proposed to implement a set of unified prognostic parameterizations that simulate moist convective and cloud microphysics processes, from cloud resolving to low resolution regional modeling scales. Second, it is proposed to run a series of numerical experiments with decreasing horizontal resolutions with the aim to define the spatial scale at which parameterized convection and fractional cloudiness are both needed. The numerical experiments will be run over the Continental United States for which observations and small-scale forecasts are abundant and readily available.

The proposed research activity aims at quantifying the impact of horizontal resolution on the simulations of cloud systems in WRF, using parameterizations of moist processes which interact between each other in a consistent manner. Using a high resolution numerical experiment as a reference, the proposed research addresses the questions 1) What is the horizontal resolution at which parameterized convection becomes needed, and how to best simulate interactions between convection and cloud microphysics processes?; and 2) What is the horizontal resolution at which parameterized fractional cloudiness becomes needed, and how to best simulate the cloud amount as a function of cloud microphysics sources and sinks?
The proposed research addresses the need of the WRF Users' community by providing a set of parameterizations of moist processes that were consistently developed, and can be used at different horizontal scales.

Approach

The spatial scale dependence of convection, cloud microphysics, and fractional cloudiness is assessed from a set of three experiments representative of the cloud resolving scale, meso scale, and regional scale over the Continental United States (CONUS domain). By varying the horizontal resolution of the numerical domain, the objectives are to 1) test each parameterization individually; and 2) test how each parameterization interacts with each other. Each experiment is initialized as in the Core Test project for synoptic conditions favorable to the development of late spring and

Great Plains (communication from Ligia Bernadet from the WRF Data Testbed Center).summer convection over the Central

For the first year of funding, we proposed to implement the parameterization of convection, cloud microphysics and fractional cloudiness in WRF and test the parameterizations for idealized simulations.

2. Research Accomplishments/Highlights:

--We have implemented the parameterizations of cloud microphysics and fractional cloudiness in version 3.0, of the Advanced Research WRF (ARW) model.

--We are in the process of testing the parameterization from a series of experiments conducted over the Continental United States.

We ran a numerical experiment over the eastern half of the continental United States, starting January 24th 2001 at 12:00Z. We used ETA212-AWIP data to initialize the entire domain and to update the lateral boundaries every six hours. The horizontal resolution is 30 km. To illustrate our results, Figure 1 shows the accumulated grid-scale precipitation simulated by our cloud microphysics precipitation. Precipitation initiates along the eastern coast of Florida and intensifies as it moves northward along the Atlantic coast.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The parameterization of convection remains to be implemented and tested. We focused our efforts on comparing our parameterization against other cloud microphysics parameterization available in ARW.

4. Leveraging/Payoff: None

5. Research Linkages/Partnerships/Collaborators:

This work is funded by the National Science Foundation under the grant ATM-0717597. Our objective is to provide to the WRF Users' community parameterizations of moist processes that were developed consistently, and that can used at various spatial scales.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Fowler, L.D., 2009: Implementation of a prognostic parameterization of fractional cloudiness in the weather research forecast model (In preparation for *the Journal of Atmospheric Sciences*).

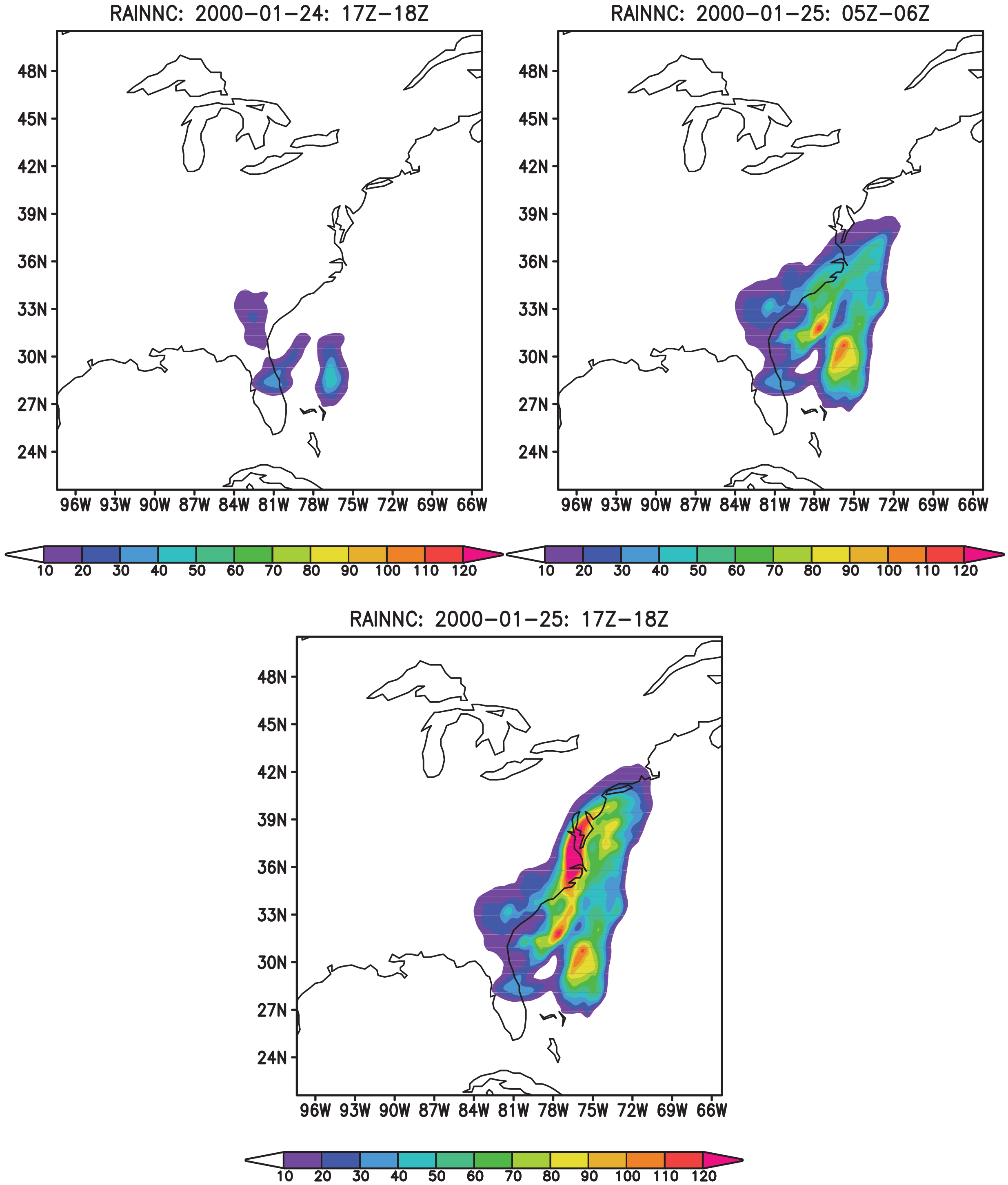

Figure 1. Geographical distribution of the hourly-averaged accumulated grid-scale precipitation simulated between January 24th 2001 at 12:00Z and January 25th 2000 at 18:00Z.

NSF - WINTER PRECIPITATION, SUBLIMATION, AND SNOW-DEPTH IN THE PAN-ARCTIC: CRITICAL PROCESSES AND A HALF CENTURY OF CHANGE

Principal Investigator: Glen E. Liston

NOAA Project Goal: Climate: Understand climate variability and change to enhance society's ability to plan and respond

Key Words: Arctic, Winter, Snow, Precipitation, Sublimation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

In the Arctic, the simplest way to describe the winter surface moisture budget (in the absence of any net horizontal transport) is: snow-water-equivalent on the ground (□) equals precipitation (P) minus sublimation (S). These three terms, □, P, and S, are the most fundamental components of the winter Arctic hydrologic cycle, and understanding them is essential to understanding Arctic moisture-related processes. Accurate solid-precipitation (P) measurements have proven nearly impossible to achieve in the Arctic, because this precipitation generally falls when it is windy. In most cases, these winds lead to a significant precipitation underestimate (undercatch as high as 55 to 75% depending on the gauge type and wind conditions). In addition, arctic precipitation networks are very sparse. The state of knowledge for winter sublimation (S) is even more limited. Sublimation is not routinely monitored anywhere. The few measurements that exist come from research projects, not monitoring programs, and they are spread widely in both space and time. More often than not, these "measurements" are instead physical model results, and therefore subject to modeling errors. Moreover, fundamental questions concerning the boundary-layer physics of arctic winter sublimation remain unanswered. Resolving these is essential to closing local, regional, and pan-Arctic moisture budgets because sublimation can be as much as 50% of the total winter precipitation and 35% of the annual precipitation.

We propose to investigate winter sublimation processes in order to improve and develop models and methods that will allow us to evaluate sublimation quantities with accuracy and reliability. We will implement a multi-year field campaign using eddy correlation towers to measure surface fluxes of heat, moisture, and momentum. Eddy correlation observations will provide the total moisture flux from the snow surface, which can be attributed to sublimation in cold conditions. The field-measurement program is designed to cover the key environments found throughout the Arctic, and will be conducted during a wide range of temperature, humidity, and wind conditions. These observations will be used to test and improve our physically-based sublimation models.

2. Research Accomplishments/Highlights:

In order to meet these objectives we have collected our field data and implemented a state-of-the-art, physically based, snow-sublimation sub-model in SnowModel, and have compared it with our field observations.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

--Implement a multi-year field campaign using eddy correlation towers to measure surface fluxes of heat, moisture, and momentum. “Complete.”
--Use these observations to test and improve our physically-based sublimation models. “Complete.”

4. Leveraging/Payoff:

Our improved, snow-sublimation model is expected to lead to improved local surface-flux and hydrologic forecasts, and improved understanding of, and the ability to simulate, the spatial variability of atmospheric and hydrologic processes and features.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

As part of our model development and testing, and field work, we have been collaborating with Dr. Matthew Sturm, Cold Regions Research and Engineering Lab (CRREL).

6. Awards/Honors: None.

7. Outreach:

Conference and meeting presentations:

Liston, G. E., and C. A. Hiemstra, 2007: Using high-resolution atmospheric and snow modeling tools to define spatially-variable snow distributions. International Symposium on Snow Science, 3-7 September, Moscow, Russia.

Liston, G. E., C. A. Hiemstra, S. Berezovskaya, S. H. Mernild, and M. Sturm, 2007: Using high-resolution atmospheric and snow modeling tools to define pan-arctic spatial and temporal snow-related variations. Proceedings of the 16th Northern Research Basins International Symposium and Workshop, 27 August -2 September, Petrozavodsk, Russia.

Strasser U., M. Bernhardt, M. Weber, G. E. Liston, and W. Mauser, 2008: On the role of snow sublimation in the alpine water balance. European Geosciences Union General Assembly, 13-18 April, Vienna, Austria.

Hiemstra, C. A., and G. E. Liston, 2007: Using high-resolution atmospheric and snow modeling tools to define spatially-variable snow distributions. North American Mountain Hydroclimate Workshop, 17-19 October, Boulder, Colorado.

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Snow cover distribution on Alaska’s Arctic Slope: modelling under changing climate. International Symposium on Snow Science, 3-7 September, Moscow, Russia.

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Determining solid precipitation on Alaska's Arctic Slope. XXIV General Assembly of the International Union of Geodesy and Geophysics, 2 13 July, Perugia, Italy.

8. Publications:

Liston, G. E., R. B. Haehnel, M. Sturm, C. A. Hiemstra, S. Berezovskaya, and R. D. Tabler, 2007: Simulating complex snow distributions in windy environments using SnowTran-3D. Journal of Glaciology, 53, 241-256.

OSU – East Pacific Intraseasonal Oscillations and Air-Sea Interaction During Northern Hemisphere Summer

Principal Investigator: Eric D. Maloney

NOAA Project Goal: Climate Goal: Understanding Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Key Words: Intraseasonal, Hurricanes, East Pacific, Precipitation

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The long-term research objective was to determine the regulatory mechanism for subseasonal precipitation variability in the east Pacific warm pool during Northern Hemisphere summer. This work is important because predicting subseasonal precipitation variability in the east Pacific is crucial for predicting periods of enhanced tropical cyclone formation not only over the east Pacific, but also over the Gulf of Mexico and Caribbean Sea. And such basic understanding may also lead to improved parameterization in our climate models. Specific plans included using satellite and surface observation datasets to quantify the relationship between intraseasonal precipitation, winds, and sea surface temperatures in the Western Hemisphere. Limited modeling was also proposed.

Objective 1: Forge a basic observational and physical understanding of intraseasonal precipitation and wind variability in the east Pacific warm pool during boreal summer, using satellite and buoy observations, and models.

Objective 2: Characterize and understand SST variability in the east Pacific warm pool during boreal summer and its relationship to precipitation. TRMM satellite and buoy observations were to be the primary tools used in this study.

Objective 3: Understand how the Madden-Julian oscillation (MJO) impacts tropical cyclone, wind, and precipitation variability in the Atlantic. Satellite and reanalysis datasets, accompanied by statistical analyses, were to be used for this task.

Objective 4: Documentation of climate and forecasting model performance in simulating tropical intraseasonal variability. Develop a series of observational metrics in association with the CLIVAR MJO Working Group and apply these to state-of-the-art climate simulations.

Objective 5: Forge a general understanding of what regulates intraseasonal variability in the tropics. Mechanism denial experiment with models and observations will be used to determine the role of wind-evaporation and other feedbacks for generating tropical intraseasonal variability.

Objective 6: Determine the regulatory mechanisms for intraseasonal SST variability in the east Pacific warm pool during Northern Hemisphere summer. A one-dimensional mixed layer ocean model forced by buoy surface observations will be used to determine what controls intraseasonal SST variability.

2. Research Accomplishments/Highlights:

In this reporting period, we showed that:

--Bursts of Atlantic tropical cyclone activity are preceded by the propagation of MJO-induced Kelvin waves from the Pacific into the Atlantic. This may foster significant prediction lead time for Atlantic hurricane activity (Maloney and Shaman 2008)

--Rossby wave propagation was determined to be the dominant means by which ENSO affects Atlantic hurricanes (Shaman et al. 2009)

--It was shown using TMI satellite data that subseasonal SST variability in the east Pacific warm pool is much greater than once suspected, possibly playing an important role in forcing convection that affects the predictability of the North American monsoon region (Maloney et al. 2008)

--One-dimensional ocean modeling showed that an ocean model with a dynamical mixed layer is necessary to capture realistic subseasonal SST variability in the east Pacific warm pool (Maloney and van Roekel 2009, manuscript in progress). Further, surface latent and shortwave radiation fluxes appear to be at the root of intraseasonal SST variability in the east Pacific.

--MJO climate model diagnostics were developed by the CLIVAR MJO Working Group, and applied to eight models (U.S. CLIVAR MJOWG 2009, Kim et al 2009). Model performance at capturing realistic intraseasonal variability is highly variable.

--Several climate models exhibit a strong sensitivity of tropical intraseasonal variability to wind-induced surface heat exchange (Sobel et al. 2008, 2009). These finding suggest that surface flux forcing may be a key underlying mechanism of the MJO, a phenomenon whose physical origins have remained elusive since the early 1970s.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

The information presented in this section relates to the objectives listed in section 1 above:

Objective 1: Complete, Forge a basic understanding of what regulates intraseasonal precipitation and wind variability in the east Pacific warm pool during boreal summer, using satellite and buoy observations, and models. Extensive diagnosis was conducted in Maloney and Esbensen (2007) using QuikSCAT winds and TRMM precipitation showing that wind-induced surface heat exchange is a strong regulator of intraseasonal precipitation in the east Pacific warm pool. Further, Maloney et al. (2008) used TMI SST data to describe a strong role for SST variability in contributing to these intraseasonal precipitation variations.

Objective 2: Complete. Characterize and understand SST variability in the east Pacific warm pool during boreal summer and its relationship to precipitation. It was shown using TMI satellite data that subseasonal SST variability in the east Pacific warm pool is much greater than once suspected, possibly playing an important role in forcing convection that affects the predictability of the NA monsoon region (Maloney et al. 2008)

Objective 3: Complete. Understand how the Madden-Julian oscillation (MJO) impacts tropical cyclone, wind, and precipitation variability in the Atlantic. Satellite and reanalysis datasets and statistical analyses were used for this task. It was shown using TRMM precipitation, NCEP reanalysis data, and Atlantic hurricane tracks that bursts of Atlantic tropical cyclone activity are preceded by the propagation of MJO-induced Kelvin waves from the Pacific into the Atlantic. This may foster significant prediction lead time for Atlantic hurricane activity (Maloney and Shaman 2008). It was determined that vertical shear variations are an important hurricane regulatory mechanism associated with the MJO. Further, we showed a new paradigm for how El Nino affects hurricane activity in the Atlantic, through teleconenctions along the North African-Asian jet (Shaman et al 2009).

Objective 4: Complete. Documentation of model performance at simulating tropical intraseasonal variability. Develop a series of observational metrics in association with the CLIVAR MJO Working Group and apply these to state-of-the-art climate simulations. MJO climate model diagnostics were developed by the CLIVAR MJO Working Group, and applied to eight models (U.S. CLIVAR MJOWG 2009, Kim et al 2009). Model performance at capturing realistic intraseasonal variability is highly variable.

Objective 5: Complete. Forge a detailed understanding of what regulates intraseasonal variability in the tropics. Mechanism denial experiment with models and observations will be used to determine the role of wind-evaporation and other feedbacks for generating intraseasonal variability in the tropics. It was demonstrated that several climate models exhibit a strong sensitivity of tropical intraseasonal variability to wind-induced surface heart exchange (Sobel et al. 2008, 2009). These finding suggest that surface flux forcing may be a key underlying mechanism of the MJO, a phenomenon whose physical origins have remained elusive since the early 1970s.

Objective 6: In Progress. Determine what controls intraseasonal SST variability in the east Pacific warm pool during Northern Hemisphere summer. Thus far, we have shown using one-dimensional ocean modeling that an ocean model with a dynamical mixed layer is necessary to capture realistic subseasonal SST variability in the east Pacific warm pool (Maloney and van Roekel 2009, manuscript in progress). Further, surface latent and shortwave radiation fluxes appear to be at the root of intraseasonal SST variability in the east Pacific. This objective is listed as still in progress because some last minute analysis and a journal article are still in progress. Preprints of the draft manuscript are available upon request.

4. Leveraging/Payoff:

Our work has profound implications for the prediction of tropical cyclones in the Atlantic, Gulf of Mexico, and Caribbean Sea. Modes of tropical intraseasonal variability such as the Madden-Julian oscillation that have been demonstrated through this work and previous work to strongly influence Western Hemisphere hurricanes may be predictable a few weeks in advance. Hence, gaining a better understanding of what regulates east Pacific and Atlantic precipitation variability so that we can improve model parameterizations of precipitation, as well as developing better statistical models of tropical intraseasonal variability, can aid prediction of periods of enhanced cyclogenesis.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

Some NSF funding through the Climate and Large-Scale Dynamics program was leveraged in the completion of some of this work.

6. Awards/Honors: None.

7. Outreach:

Formal Conference Presentations:

Maloney, E. D., and J. Shaman, 2008: Intraseasonal variability of the west African monsoon and Atlantic ITCZ. Abstracts, 28th Conference on Hurricanes and Tropical Meteorology, April 28-May 2, 2008, Orlando, Florida.

Maloney, E. D., 2008: Tropical Interactions Among Different Time and Space Scales. Proceedings: 8th Summer Institute of the NOAA Climate and Global Change Postdoctoral Fellowship Program. July 13-17 2008, Steamboat Springs, Colorado.

Shaman, J., S. Esbensen, and E. D. Maloney, 2008: Dynamics of the ENSO-Atlantic Hurricane Teleconnection: ENSO-related changes to the North African-Asian Jet affect Atlantic Basin Tropical Cyclogenesis, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract U11A-0006.

Sobel, A. H., E. D. Maloney, G. Bellon, and D. M. Frierson, 2008: The role of surface fluxes in tropical intraseasonal oscillations, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract A51K-06.

Sobel, A. H., E.D. Maloney, G. Bellon, D.M. Frierson, 2009: Dynamics of Intraseasonal Oscillations. MOCA-09, Joint Assembly, July 19-29, 2009, Montreal, Canada.

Waliser and others, 2009: US CLIVAR MJO Working Group: MJO Climate Simulation Diagnostics Abstracts, 88th AMS Annual Meeting, 20-24 January 2008, New Orleans, LA.

Informal Talks, Meeting presentations:

2008 CPPA PI's Meeting, September 29- October 1, Silver Spring, MD, Presentation: Mixed layer modeling of the east Pacific warm pool during boreal summer.

DYNAMO Workshop April 13-14, 2009, NOAA ESRL, Boulder CO, Presentation: Outstanding Issues in MJO Simulation and Initiation (NCAR CAM)

CMMAP July 2009 Team Meeting, July 28-30, 2009, Fort Collins, CO. Poster: Co-author with Heather Morgan (CMMAP summer intern): Improving Atlantic Hurricane Predictions with the Madden-Julian Oscillation. Led MJO Breakout session

8. Publications:

Maloney, E. D., D. B. Chelton, and S. K. Esbensen, 2008: Subseasonal SST variability in the tropical eastern north Pacific during boreal summer. J. Climate, 21, 4149-4167.

Maloney, E. D., and J. Shaman, 2008: Intraseasonal variability of the west African monsoon and Atlantic ITCZ. *J. Climate*, 21, 2898-2918.

Sobel, A. H., E. D. Maloney, Bellon, G., and D. M. Frierson , 2008: The role of surface heat fluxes in tropical intraseasonal oscillations, Nature Geoscience, 1, 653 – 657.

Shaman, J., S. K. Esbensen, and E. D. Maloney, 2009: The dynamics of the ENSO-Atlantic hurricane teleconnection: ENSO-related changes to the North African-Asian Jet affect Atlantic basin tropical cyclogenesis. J. Climate, 22, 2458–2482.

US CLIVAR MJO Working Group, 2009: MJO Simulation Diagnostics, J. Climate, 22, 3006-3030.

Sobel, A. H., E. D. Maloney, Bellon, G., and D. M. Frierson, 2009: Surface fluxes and tropical intraseasonal variability: a reassessment. Journal of Advances in Modeling Earth Systems, in press.

Kim, D., and others, 2009: Application of MJO simulation diagnostics to climate models. J. Climate, in press.

WGA - Western Regional Air Partnership (WRAP) Technical Support System (TSS): A Web-Based Air Quality Information Delivery System

Principal Investigator: Shawn McClure

NOAA Project Goals: The Air Quality and Environmental Modeling programs under the Weather and Water Goal.

Key Words: Air Quality Research, Air Quality Modeling, Air Quality Planning; Visibility Monitoring; Aerosol Research, Aerosol Monitoring; Emissions Reduction, Source Apportionment; Regional Haze Rule.

1. Long-term Research Objectives and Specific Plans to Achieve Them:

The Technical Support System (TSS) is an extended suite of analysis and planning tools designed to help planners develop long-term emissions control strategies for achieving natural visibility conditions in class I areas by 2064. The TSS is intended to provide state and tribal governments in the Western Regional Air Partnership's (WRAP) region with the emissions, modeling, and monitored air quality data and analysis tools necessary for the completion of their State and Tribal Implementation Plans (SIPs and TIPs), in accordance with the Environmental Protection Agency's (EPA) Regional Haze Regulations (RHR). The TSS is also designed to facilitate the ongoing tracking and assessment of the emissions control strategies codified in these plans and to manage and deliver ongoing monitoring data results to assess progress in improving regional visibility. To achieve these objectives, the TSS consolidates the data resources of the Visibility Information Exchange Web System (VIEWS) and the WRAP's Emissions Data Management System (EDMS), Regional Modeling Center (RMC), and Fire Emissions Tracking System (FETS) into an online suite of data access, visualization, and analysis tools on the TSS website (http://vista.cira.colostate.edu/tss), together with the technical information and guidance to apply these data and tools to state, local, and regional air quality planning. The TSS represents an integrated system solution that supports a unique synergy of national and regional air quality objectives by providing a consolidated, online system of data access and decision-making tools to planners, researchers, stakeholders, policy makers, and federal agencies across the nation.

2. Research Accomplishments/Highlights:

To facilitate the complex array of decisions involved in air quality planning pursuant to RHR compliance, TSS employs an advanced data acquisition and import system to integrate data from several air quality data centers into a highly optimized data warehouse. Data are imported from 36 ground-based monitoring networks, air quality models, and emissions inventories and are updated on a regular basis using a uniform data model and carefully standardized metadata. Names, codes, units, and data quality flags from the source datasets are mapped to a unified paradigm, and native formats and organizations are transformed into a common, normalized database schema. This design enables users to explore, merge, and analyze datasets of widely varying origin in a consistent, unified manner with a common set of tools and web services. This degree of interoperability allows decision makers to analyze diverse datasets side-by-side and focus on high-level planning strategies without having to contend with the details of how the data are managed.

The TSS web site provides graphing, charting, mapping, and data query tools to help planners 1) analyze current and historic air quality conditions (including aerosol composition for the best and worst visibility days, natural background visibility conditions estimates, and modeled projections of visibility in future years), 2) identify pollutant sources among biogenic, federal and international, and controllable anthropogenic categories and their relative contributions to visibility impairment in class I areas, 3) determine Reasonable Progress goals for reducing emissions, and 4) develop long-term control strategies for achieving natural visibility conditions in protected ecosystems by 2064.

The ongoing integration of monitored, modeled, and emissions data into the TSS from many disparate sources provides developers with frequent opportunities to make advancements in air quality data management and analysis techniques. Feedback from users is continuously gathered, organized, and assessed in order to refine and improve the online presentation and dissemination of data and results. As a result of these ongoing lessons and subsequent improvements, the TSS provides WRAP and other Regional Planning Organizations (RPOs), as well as the air quality community in general, with a dynamic case study in online air quality planning and management.

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:

--Launch of first production version of the TSS website: COMPLETE

--Integration of monitored, modeling, and emissions data for the baseline planning period of 2000-2004; Integration of emissions modeling projections for 2018: COMPLETE

--Integration of raw data from monitoring operations: ONGOING

--Implementation of web site usage and tracking system: COMPLETE

--Implementation of upload and presentation system for user-generated results, content, and case studies: IN PROGRESS

--Full integration of the WRAP's Emissions Data Management System (EDMS) and Fire Emissions Tracking System (FETS): IN PROGRESS

--Refinement of monitored and modeled data visualization and analysis tools: ONGOING

--Implementation of emissions data analysis tools: IN PROGRESS

4. Leveraging/Payoff:

Developing and maintaining the TSS at CIRA allows the TSS development team to more easily leverage the efforts of other key projects to maximize the resources of project sponsors for benefiting an audience comprising local, national, and international users. The TSS is currently used by state and local agencies in all fifteen of the WRAP states, and other RPOs have also expressed interest in funding and participating in ongoing and future efforts. In addition, international researchers, students, stakeholders, and regulators are frequent users of the TSS and its underlying VIEWS databases. This large and diverse user base benefits from the consolidated suite of online resources provided by the TSS and encourages the ongoing development of robust planning standards and data formats. Interagency cooperation is facilitated through the need to incorporate ongoing research and procedural guidance into the development, application, and interpretation of TSS data and results. Ultimately, the data, tools, and guidance provided on the TSS website facilitate the development of realistic and successful emissions control strategies that can achieve natural visibility conditions in federally protected ecosystems by 2064. Data, expertise, and research available from other CIRA projects are key to achieving these goals.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:

The TSS project team at CIRA currently collaborates with several other organizations to design and develop the technical infrastructure for the TSS, including Air Resource Specialists, Inc. (ARS), ENVIRON, and Air Sciences, Inc. Partnerships with the WRAP's Regional Modeling Center (RMC) and Emissions Data Management System (EDMS) are key to obtaining the modeling and emissions data managed by the TSS. In addition, the TSS project team works closely with representatives from state and local agencies, tribes, and federal land managers to design the content and results offered on the TSS website and to develop the policies and procedures for applying TSS data and tools. A proposal to collaborate with the National Aeronautics and Space Agency (NASA) to incorporate relevant satellite data in the TSS has been awarded*, and ongoing cooperation with the EPA is fostered to ensure the convergence and synergy of the TSS resources with those offered by the EPA.

* Shankar, U., McClure, S.E., et al. 2008. Improving an Air Quality Decision Support System through the Integration of Satellite Data with Ground-based, Modeled, and Emissions Data. *NASA ROSES Proposal (Awarded).*

6. Awards/Honors: None.

7. Outreach:

It is important that users be fully trained on the use of TSS resources and offered ample opportunities to ask questions, offer suggestions, and contribute to the ongoing refinement of the TSS. To facilitate this, TSS project members conduct monthly teleconference sessions with users to introduce new features, provide updates on status and progress, and conduct walkthroughs and tutorials on the use and application of TSS tools. To raise awareness of TSS resources within the larger air quality community, project members give frequent presentations to various organizations that might benefit from or be interested in using TSS resources. The TSS website is continuously advertised and listed with relevant online catalogs, indexes, and related web resources, and a responsive system for responding to user questions and feedback is followed.

8. Publications:

McClure, S. E. 2007. Review of WRAP (Western Regional Air Partnership) technical data and decision support web tools. Training session conducted at the Environmental Protection Agency, Research Triangle Park, NC, December 5-6.

-----. 2008. Integrated Decision Support: A Tale of Two Systems (http://wiki.esipfed.org/images/5/58/VIEWS_TSS.ppt). Presented at the Environmental Protection Agency's Air Quality Data Summit, Research Triangle Park, NC, February 11-13.

Moore, T., McClure, S. E., Adlhoch, J., and Mansell, G. 2008. WRAP TSS – A Decision Support System for Regional Haze Planning in the Western United States. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Moore, T., Fox, D. G., and McClure, S. E. 2007. The Western Regional Air Partnership Technical Support System. CIRA Magazine, 27.

NOAA PROGRAMS VS. CIRA PROJECTS COMPARISON MATRIX

		Weather and Water							Climate				Commerce and Transportation				Supporting NOAA's Mission					
CSU Project Number	Title	Local Forecasts and Warnings	Hydrology	Air Quality	Environ-mental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observa-tions and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transpor-tation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geosta-tionary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services	Education and Outreach
5-31103	East Pacific Intraseasonal Oscillations and Air-Sea Interaction During Northern Hemisphere Summer				X	X			X						X							
5-31130	Funds for the Cooperative Institute for Research, Task 1	X			X												X		X	X	X	X
5-31144	Environmental Applications Research	X	X	X	X	X	X		X	X				X				X	X			X
5-31152	Satellite Data Reception and Analysis Support					X											X	X	X	X	X	
5-31194	Research & Development for GOES-R Risk Reduction												X	X	X		X				X	
5-31198	Investigation of smoke aerosol-cloud interactions using large eddy simulations			X	X	X				X												
5-31199	Evaluation of Hurricane Mitigation Hypotheses Through an Interactive Program of Observational Analyses and Numerical Simulation	X			X	X									X							
5-31202	Getting Ready for NOAA's Advanced Remote Sensing Programs A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal		X			X																
5-31203	Advanced Environmental Satellite Research Support					X											X			X		
5-31206	Support of the Virtual Institute for Satellite Integration Training (VISIT)					X																X
5-31208	NESDIS Postdoctoral Program	X	X		X	X		X	X	X	X											
5-31209	Expansion of CIRA Research Collaboration with the NWS Meteorological Development Lab	X	X											X								X
5-31214	Analysis of Simulated Radiance Fields for GOES-R ABI Bands for Mesoscale Weather and Hazard Events	X				X	X		X			X		X	X		X				X	
5-31218	Analysis of Clouds, Radiation and Aerosols From Surface Measurements and Modeling Studies								X													
5-31222	Weather Satellite Data and Analysis Equipment and Support for Research Activities	X				X											X		X		X	

NOAA PROGRAMS VS. CIRA PROJECTS COMPARISON MATRIX

		Weather and Water							Climate				Commerce and Transportation				Supporting NOAA's Mission					
CSU Project Number	Title	Local Forecasts and Warnings	Hydrology	Air Quality	Environ-mental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observa-tions and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transpor-tation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geosta-tionary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services	Education and Outreach
5-31225	Development and Evaluation of GOES and POES Products for Tropical Cyclone and Precipitation Analysis	X	X			X	X					X		X	X		X			X	X	
5-31227	CoCoRaHS: The community collaborative rain, hail and snow network--enhancing environmental literacy through participation in climate monitoring and research		X			X	X					X										X
5-31228	IPCC Studies for Climate Observations								X	X												
5-31229	Cloud and Microwave Emissivity Verification Tools for Use Within the CRTM	X	X		X	X								X	X					X	X	
5-31231	Simulation and Analysis of the Interaction Between Aerosols and Clouds, Precipitation and the Radiation Budget Over the Gulf of Mexico and Houston	X	X			X																
5-31232	Development of an improved climate rainfall dataset from SSM/I		X			X			X													
5-31234	Blended AMSU, SSM/I, and GPS Total Precipitatable Water Products		X			X			X													
5-31235	Monsoon Flow and Its Variability During NAME: Observations and Models		X		X	X																
5-31236	An Improved Wind Probability Estimation Program	X			X																	
5-31237	Continuation of CIRA Research Collaboration with the NWS Meteorological Development Lab	X												X								
5-31238	POES-GOES Blended Hydrometeorological Products		X			X			X													
5-31239	Development of a Polar Satellite Processing System for Research and Training																			X		
5-31240	A GOES-R Proving Ground for National Weather Service Forecaster Readiness	X											X	X	X	X	X				X	X
5-31241	Transitioning ISCCP GOES-West Processing from CIRA to NCDC								X								X					
5-31242	Validation of Satellite-Based Thermodynamic Retrievals in the Tropics					X	X															
5-31243	Satellite Analysis of the Influence of the Gulf Stream on the Troposphere: Convective Response					X	X	X														

NOAA PROGRAMS VS. CIRA PROJECTS COMPARISON MATRIX

		Weather and Water							Climate				Commerce and Transportation				Supporting NOAA's Mission					
CSU Project Number	Title	Local Forecasts and Warnings	Hydrology	Air Quality	Environ-mental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observa-tions and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transpor-tation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geosta-tionary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services	Education and Outreach
5-31246	Advanced Verification Techniques for the Hurricane Weather Research and Forecast (HWRF) Model	X			X										X	X						
5-31247	Data Fusion to Determine North American Sources and Sinks of Carbon Dioxide at High Spatial and Temporal Resolution from 2004 to 2008					X					X											
5-31862	Assistance for Visibility Data Analysis and Image Display Techniques			X																		
5-31879	Characterizing Wildland Fire Particulate Matter Emissions and Their Air Quality/Visibility Impacts			X										X								
5-31920	The Role of Atmospheric Water Content in Climate and Climate Change (NASA)		X			X			X	X												
5-31927	High Resolution Dynamic Precipitation Analysis for Hydrological Applications. Stage I: Development of a Basic WRF-MLEF-NCEPos DAS	X	X		X	X	X		X			X		X	X			X			X	
5-31955	Defining Subgrid Snow Distributions within NASA Remote-Sensing Products and Models		X								X											
5-31960	A-Train Data Depot: Integrating Atmospheric Measurements Along the A-Train Tracks Utilizing Data from the Aqua, CloudSat and CALIPSO Missions		X			X			X	X											X	
5-31981	Parameterizing Subgrid Snow-vegetation-atmosphere Interactions in Earth-system Models		X		X																	
5-32708	Evaluation of GPM Precipitation Estimates for Cross-cutting Earth Science Applications Via Land Data Assimilation Studies		X		X	X					X											
5-32714	A Rapid Prototyping Capability Experiment to Evaluate Potential Soil Moisture Retrievals of Aquarius Radiometer and Scatterometer		X			X																
5-32719	Monitoring Future Carbon Controls								X		X											
5-32723	Optimizing GPM Precipitation Estimation Using High Resolution Land Surface Modeling for Decision Support		X			X					X											
5-32724	Improving an Air Quality Decision Support System Through the Integration of Satellite Data with Ground-Based, Modeled, and Emissions Data			X																		
5-32730	GLOBE: Inspiring the Next Generation of Explorers (UCAR-NASA)					X																X

NOAA PROGRAMS VS. CIRA PROJECTS COMPARISON MATRIX

		Weather and Water							Climate				Commerce and Transportation				Supporting NOAA's Mission					
CSU Project Number	Title	Local Forecasts and Warnings	Hydrology	Air Quality	Environ-mental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observa-tions and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transpor-tation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geosta-tionary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services	Education and Outreach
5-32733	Inspiring the Next Generation of Explorers: The GLOBE Program																					X
5-33042	Collaborative Research: Norwegian-United States IPY Scientific Traverse: Climate Variability and Glaciology								X	X	X											
5-33116	IPY: Collaborative Research: A Prototype Network for Measuring Arctic Winter Precipitation and Snow Cover (Snow-net)		X				X		X		X											
5-33238	The White Arctic: A Snow-Impacts Synthesis for the Terrestrial Arctic		X		X		X					X										
5-33409	Improving Parameterizations of Non-Convective Precipitation Processes by Data Assimilation				X	X																
5-33435	AFWA Coupled Assimilation and Prediction System Development at CIRA				X																	
5-33567	Using a Regional-scale Model to Analyze the Scale Dependence of Convection, Cloud Microphysics, and Fractional Cloudiness	X			X	X																
5-33622	Winter Precipitation, Sublimation, and Snow-Depth in the Pan-Arctic: Critical Processes and a Half Century of Change		X		X						X											
5-34107	Airborne Nitrogen Concentrations and Deposition in Rocky Mountain National Park			X							X											
5-34135	Characterizing Pollutant Deposition to Rocky Mountain National Park			X							X											
5-34152	Transport and Deposition of Airborne Nitrogen and Sulfur in Rocky Mountain National Park			X							X											

NOAA PROGRAMS VS. CIRA PROJECTS COMPARISON MATRIX

		Weather and Water							Climate				Commerce and Transportation				Supporting NOAA's Mission					
CSU Project Number	Title	Local Forecasts and Warnings	Hydrology	Air Quality	Environ-mental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observa-tions and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transpor-tation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geosta-tionary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services	Education and Outreach
5-34164	Analysis of Levoglucosan, K+, and Water Soluble Organic Carbon in Archived Filter Samples			X							X											
5-36336	FX-Net and FX-C Enhancements for Applications and Technical Transfer to ENSCO's METWise(TM) System																		X			
5-36507	Improving the Representation of Global Snow Cover, Snow Water Equivalent, and Snow Albedo in Climate Models by Applying EOS Tera and Aqua Observations		X				X		X		X											
5-36599	NRA/NASA-Modeling, Analysis and Prediction				X																	
5-37402	Five Year Cooperative Agreemnt for Center for GeoSciences/Atmospheric Research	X	X			X	X					X	X	X	X		X			X	X	

CIRA AWARDS

- **2008 OAR Outstanding Scientific Paper Award**

A measure of the effectiveness of a research organization is the number and quality of its scientific publications. The Outstanding Scientific Paper Awards were established to recognize the NOAA Office of Oceanic and Atmospheric Research (OAR) Federal employees, and Cooperative Institute (CI) scientists associated with OAR who published outstanding scientific peer-reviewed research papers, review papers, books, monographs, and chapters of books that have contributed to or contain the results of research sponsored by OAR.

Congratulations to **Tracy Smith**, **Stan Benjamin**, **Seth Gutman**, and **Susan Sahm** of GSD for having been awarded the 2008 OAR Outstanding Scientific Paper Award. This is one of three papers that we submitted for consideration, and two of the three were awarded to GSD scientists. This is truly a remarkable achievement for GSD!"

The paper describes the results of experiments on the improvement of weather model forecasts using GPS integrated precipitable water (GPS-IPW). It uses an innovative evaluation technique, and is particularly broad in the duration of the study. The Rapid Update Cycle (RUC) hourly data assimilation has already had huge operational significance, and this paper clearly shows that RUC forecasts are improved by assimilation of GPS-IPW observations. This impact of GPS-IPW observations in the RUC is extensive, affecting guidance for forecasters from the National Weather Service forecast offices who use the RUC routinely for short-range guidance, and also for forecasters from the NOAA Storm Prediction Center producing severe weather watches and NOAA Aviation Weather Center for making aviation weather advisories. The published results of this paper have been instrumental in considering NOAA adoption of GPS-IPW observations.

- **2008 CIRA Research Initiative Award Winners**

Paul Hamer
Paul, an employee of CIRA in Boulder, has been instrumental in developing and supporting the Object Data System (ODS) software architecture that underlies the success of the Central Facility data system of the NOAA ESRL Global Systems Division (GSD). As a result of Paul's work, the ODS methods routinely and reliably accommodate ingest data formats such as GOES GVAR, WSR-88D Level-II, GRIB Edition-1 and -2, BUFR and ASCII. Paul's leadership in developing ODS has provided GSD with an asset that is the foundation upon which many of GSD's successful projects rely.

Andrea Schumacher
Andrea, an employee of CIRA in Fort Collins, worked as part of a NESDIS team on the development and transition of a new operational NESDIS product for estimating the probability of tropical cyclone formation. Andrea took the lead on generalizing the product to include the central and western north Pacific, and at present the final product is in the final stages of transition to NESDIS operations. The NOAA members of the

NESDIS team on which Andrea worked, received the NOAA Bronze Medal for their work. (Unfortunately Andrea could not receive this same honor because she was not an employee of NOAA.)

Jeff Smith
Jeff, an employee of CIRA in Boulder, has significantly impacted the Global Systems Division in respect to web applications, web services, and java programming. He led the design and development of Weather Research and Forecast Domain Wizard, (a graphical tool used to define the spatial domain needed to run the new WRF Pre-processor System), he helped to design and develop the WRF Portal (a java application which allows users to develop, configure, run, and monitor the execution of complex WRF model workflows), he developed a java training course for the ESRL staff, and he won a web award for his work on Data Locator (a web services based data access and display cabability, which was an inegral part of exploratory work on the Open Geospatial Consortium Web Coverage Service).

- **2008 GSD Web Award ("Webbie") Winner – Brian Jamison**

Best New Site – Brian Jamison for the FIM Real-Time Model Graphics Sites.
These sites provide real-time images of FIM global model output for the entire globe and selected sub-regions such as the CONUS, Africa, the Arctic, and Atlantic and Pacific basins. The web pages have options for several kinds of images, available in an easy to navigate menu. These plots have been invaluable for making real-time images available to developers, both here at GSD and elsewhere. Brian's FIM graphics have been critical in showing that the FIM can be competitive with operational models for hurricane track forecasting. Check out Brian's sites.

http://fim.noaa.gov/fimgfs/
http://fim.noaa.gov/fimconusTACC/

- **2008 Thomas W. Zosel Outstanding Individual Achievement Award - William Malm – CIRA NPS Partner**

While some call him Dr. Visibility in the United States, Dr. William Malm of the National Park Service is more formally recognized as the leading scientist behind the visibility protection provisions of the Clean Air Act. His science-driven policies are a testament to his dedication to the environment and his perseverance in bringing science to the issue of air quality.

Since making some of the first visibility and air quality measurements in the National Park Service system at the Grand Canyon in 1972, he has designed and built instrumentation to measure the effects of atmospheric aerosols on the scenic qualities of landscape features, as well as their optical and chemical properties. By linking visibility impairment to specific sources, Dr. Malm's studies have lead to requirements for pollution reduction at major power plants in the Southwest. Through his formulation of radiation transfer algorithms, his pioneering of visibility perception studies, and his leadership in collaborative efforts, Dr. Malm has also played an integral role in improving air quality by significantly reducing sulfur emissions.

In addition to his technical achievements, Dr. Malm serves as the intellectual leader responsible for the Interagency Monitoring of PROtected Visual Environments (IMPROVE) Network.

From the establishment of the IMPROVE monitoring network, to the development of the IMPROVE equation (which is the basis for EPA regional haze regulations), to the very metrics used to characterize visibility, he has applied sound science to protecting our nation's most treasured vistas.

Dr. Malm has demonstrated leadership, outstanding achievement, and lasting commitment to promoting clean air and helping to achieve better air quality for 30 years. The steadily improving visibility we enjoy in many parts of the U.S. is largely due to the research and advocacy of Dr. William Malm.

- **2008 National Park Service Director's Award for Excellence in Natural Resource Research – William Malm – CIRA NPS Partner**

presented at the George Wright Society Biennial Conference, Portland, Oregon, March 5, 2009.

- **Air & Waste Management Association's Frank A. Chambers Excellence in Air Pollution Control Award – William Malm – CIRA NPS Partner**

presented at the A&WMA Annual Conference, Detroit, Michigan, June 25, 2009.

- **January 2009 GSD Team Member of the Month – Jim Ramer**

Jim has been an extremely productive member of ISB providing much of the display functionality of AWIPS, including the improvements allowing NWS to move to storm based warnings this past year.

More recently, Jim has developed tools to allow forecasters to explore model ensemble data in an innovative way. At a recent workshop on probability forecasting, NWS forecasters were highly complimentary of the new tools and were anxious to use them in their day-to-day operations.

Jim has also played a key role in getting the data flowing to the Hydrometeorological Testbed systems for the winter experiment.

- **February 2009 GSD Team Member of the Month – Tom Henderson**

Tom Henderson is being recognized as GSD's February 2009 Team Member of the Month for his significant contributions in several critical areas – modeling frameworks, FIM software development and the Scalable Modeling System (SMS) redesign. Modeling frameworks help NOAA and its collaborators more easily use and integrate their work into larger modeling systems such as ensembles, coupled models, and complex earth system models. Since being re-hired in November 2007, Tom has (1) put FIM and WRF-RR into the Earth System Modeling Framework (ESMF), (2) worked with NCEP on the NCEP Environmental Modeling System (NEMS), and (3) collaborated with NASA, the Navy, and NOAA on the design and development of National Unified Operational Prediction Capability (NUOPC).

Tom has also established a software infrastructure for the FIM model. He utilized both GForge and Subversion for software development, and built a testing infrastructure to ensure upgrades to FIM are tested. Since the FIM software repository has been established over nine months ago, there have been almost 500 commits by members of the FIM team. Tom also recently redesigned and modernized the Scalable Modeling System I/O capabilities to support the ability to efficiently run the 15km version of FIM on wjet and the TACC machines. Tom's work led to over 50,000 lines of code being removed from SMS.

- **June 2009 GSD Team Member of the Month - Kevin Brundage**

Kevin, as a computer scientist, has been a critical member not only of the Assimilation and Modeling Branch, but also of GSD, ESRL, and NOAA. For RUC, Rapid Refresh, HRRR, and FIM development, Kevin has repeatedly found more efficient designs for scripts, code, post-processing, and grid transfer that have been very important for reliability of these complicated model/assimilation systems. Kevin is also a critical member of the ESRL High-Performance Computing (HPC) (jet) management team, including developing benchmarks for overall NOAA HPC requests for proposals."

- **2009 Mark DeMaria of NOAA/NESDIS/RAMM Branch Receives the Richard H. Hagemeyer Award**

Presented at the 63rd Interdepartmental Hurricane Conference, which is given annually to honor people who have made sustained contributions to the U.S. Hurricane Program. The primary basis of the award was a long history of successful development and operational transition of tropical cyclone forecast products, including the SHIPS and LGEM intensity models, the rapid intensity index (co-developed with HRD), the NHC wind speed probability program and the NESDIS tropical cyclone formation probability product. Previous winners of the award include Joanne Simpson, Max Mayfield and Chris Velden.

The paper "Stratospheric impact of the Chisholm pyrocumulonimbus eruption: Part 1. Earth-viewing satellite perspective," by M. Fromm (NRL) et al., for which Dan Lindsey is a co-author, has been selected to receive an Alan Berman Research Publication Award at the Naval Research Laboratory.

- **2009 Michael Hiatt Honored at the "Celebrate Colorado State!" Awards Ceremony with 2009 Distinguished Administrative Professional Award**

The award is presented to Administrative Professional staff for continuing meritorious and outstanding achievement in the areas of outreach, teaching, administration and/or research and is awarded by the Administrative Personnel Council.

As Infrastructure Manager, Michael leads CIRA's technology support team and works with project leaders to strategize and incorporate technology in CIRA's research projects. His ability to assess technology needs and execute efficient and timely solutions is a valued skill to the organization. He accomplishes goals within the project budget with a history of successful projects.

- **2009 Don Reinke Awarded "NASA Exceptional Public Service Medal**"

For leadership and tireless efforts on behalf of the CIRA CloudSat Data Processing Center! Don's contributions to the CloudSat mission have been truly exceptional and have led to a cost-effective, robust, and flexible data processing operation that has been praised by several NASA review boards. This award recognizes your exemplary performance as the manager of the CloudSat data processing center during system design, development, and operations.

- **2009 CIRA Research and Service Initiative Award**

Linn Barrett
For outstanding performance, dedication to the people of CIRA in successfully managing the complex Human Resources function and contributions to the administrative team

Jacques Middlecoff
For outstanding performance as an integral part of the development of GSD's state-of-the-art global weather and climate predication model

Sher Schranz
For outstanding leadership of researchers and software developers in the design, development, testing, deployment and operational support for the FX-Net, Gridded FX-Net and Fire Weather Projects

Ning Wang
For outstanding performance as an integral part of the development of GSD's state-of-the-art global weather and climate prediction model

- **Frank Kelly Former CSU/ATS Student Named NWS Director - Alaska Region**

Dr. Frank P. Kelly assumed responsibilities as Regional Director for the Alaska Region at the National Weather Service (NWS) on October 27, 2008. In this position, Dr. Kelly oversees the management of all operational and scientific meteorological, hydrologic, and oceanographic programs of the region including observing networks, weather services, forecasting, climatology, and hydrology. Prior to assuming this position, Dr. Kelly served as the head of the Programs and Plans Division of the Office of Science and Technology at NWS since 2002. His education includes both Ph.D. and M.S. degrees in Atmospheric Science from Colorado State University and a B.S. in Earth Science from Montana State University.

- **Steve Koch, CIRA Fellow and Council Member Becomes Fellow of AMS**

The American Meteorological Society announced that Steven E. Koch, Director of the Global Systems Division at the National Oceanic and Atmospheric Administration's Earth System Research Laboratory in Boulder, has become a fellow of the society. Koch joined the ESRL Global Systems Division in 2006 after leading the Forecast Systems Laboratory, also in Boulder. Koch is a CIRA Fellow and member of the CIRA Advisory Council. Koch's area of expertise is in numerical weather prediction, data assimilation, predicting turbulence and understanding large-scale meteorological events.

- **Robert Maddox Former CIRA Ph.D. Student Receives The Cleveland Abbe Award**

Former NSSL Director Robert Maddox, now a Professor at the University of Arizona, Tucson, AZ is honored for a lifetime of service to Atmospheric Science through seminal contributions to scientific research, inspirational leadership, and exemplary program management that promoted important interactions between research and operations. The Cleveland Abbe Award for Distinguished Service to Atmospheric Sciences by an Individual is presented on the basis of activities that have materially contributed to the progress of the atmospheric sciences or to the application of atmospheric sciences to general, social, economic, or humanitarian welfare.

Dr. Robert Maddox is internationally recognized as an expert on mesoscale cloud systems who has worked at the National Severe Storms Lab in Norman Oklahoma, and is now at the University of Arizona in Tucson. His characterizations of mesoscale convective complexes (MCCs) were pioneering. Dr. Maddox was a CIRA PhD student in the early 1980s under Professor Thomas Vonder Haar.

- **Tom Peterson, Award Winning ATS Alumnus and Former CIRA-supported Student Has Many Accomplishments:**

NOAA Administrator's Award "for outstanding leadership in and dedication to developing U.S. CCSP Synthesis & Assessment Products integrating climate research for decision support," with Harold E. Brooks, Roger Pulwarty, Ronald J. Stouffer, Thomas L. Delworth, Robert S. Webb, Douglas Marcy, Robb Wright, Neil Christerson, Adrienne Sutton, Thomas Knutson and Kent Laborde.

United States Department of Commerce Gold Medal Award for Scientific/Engineering Achievement "for improving the understanding of observed climate change and causes by showing that global average atmospheric warming is similar to surface warming" with Thomas R. Karl, Christopher D. Miller, Venkatachalam Ramaswamy, John R. Lanzante, Dian J. Seidel, Russell S. Vose and Richard William Reynolds.

United States Department of Commerce Bronze Medal Award for Superior Federal Service "for developing research-quality radiosonde atmospheric temperature datasets for reliably monitoring climate variations and change," with Imke Durre, Melissa Free, John Lanzante, Jay Lawrimore, and Dian Seidel, 2007.

United States Department of Commerce Bronze Medal Award for Superior Federal Service "for innovative research which led to the production of a unique blended (satellite and ground based) global surface temperature data set," with Alan Basist, Norm Grody and Claude Williams, 2001.

United States Department of Commerce Bronze Medal Award for Superior Federal Service in 1996 "for developing revolutionary new climatological baseline data sets and statistical techniques that reveal accurate long-term climatic trends," with David Easterling.

- **Jim Purdom, CIRA Retiree, Awarded, Cosmonautics Federation of Russia Yuri Gagarin Medal**

PUBLICATIONS

	Institute Lead Author					NOAA Lead Author					Other Lead Author				
	2004	2005	2006	2007-08	2008-09	2004	2005	2006	2007-08	2008-09	2004	2005	2006	2007-08	2008-09
Peer-Reviewed	29	70	42	46	37	20	14	30	26	21	40	25	71	80	35
Non Peer-Reviewed	82	128	40	6	58	48	52	91	2	34	53	46	64	5	49

CIRA EMPLOYEE MAXTRIX

Employees who received 50% support or more		**Degree**			
Category	**Number**	**Bachelors**	**Masters**	**Doctorate**	**Non-Degreed**
Research Scientists	12	0	0	12	0
Visiting Scientists	3	0	0	3	0
Postdoctoral Fellows	8	0	0	8	0
Research Support Staff*	58	25	19	6	8
Administrative Personnel	3	1	2	0	0
Total	84	26	21	29	8
Employees who received less than 50% support		**Degree**			
Category	**Number**	**Bachelors**	**Masters**	**Doctorate**	**Non-Degreed**
Research Scientists	17	0	0	17	0
Visiting Scientists	0	0	0	0	0
Postdoctoral Fellows	1	0	0	1	0
Research Support Staff*	36	16	11	1	8
Administrative Personnel	8	4	2	0	2
Total	62	20	13	19	10
Supported Students		**Degree**			
Category	**Number**	**Bachelors**	**Masters**	**Doctorate**	
Undergraduate	8	8	0	0	
Graduate	27	15	12	0	
Total	35	23	12	0	
Employees located at NOAA Laboratories		**GSD**	**MDL**	**CSD**	**NGDC**
Total	49	44	2	1	2
Obtained NOAA Employment within the last year					
Total	0				

***Equivalent to Research Associate in CIRA/CSU parlance**