CIRA

Annual Report 2007-2008

Cooperative Institute for Research in the Atmosphere

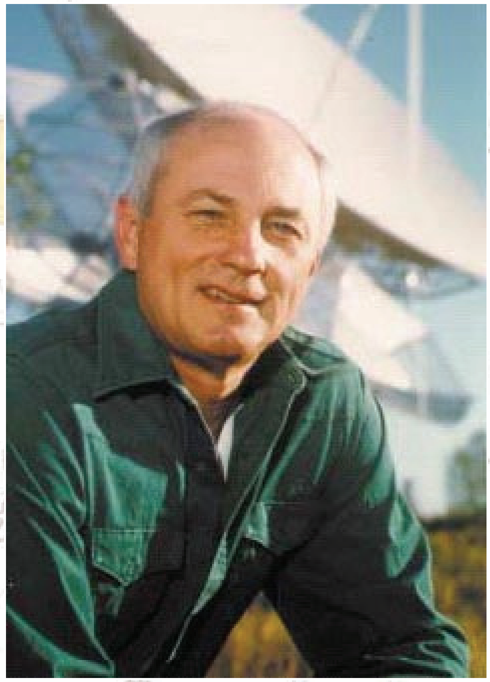



CIRA ANNUAL REPORT FY 07/08

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE

Cover Photos: Scott Longmore, CIRA Research Associate

On May 22, 2008 a powerful EF3 tornado struck the Northern Colorado town of Windsor causing heavy damage to more than 800 homes and businesses.



Thomas H. Vonder Haar
CIRA Founding Director

CIRA…..From a Vision to Reality…….

In the late 1970s, Tom Vonder Haar had a vision of a center for interdisciplinary research. In September 1980, that vision became a reality when the Cooperative Institute for Research in the Atmosphere at Colorado State University opened its doors.

Since that day, CIRA has grown into a prestigious research institute currently employing over 130 people. This, of course, would not have been possible without the orchestration of our Founding Director and the cooperation among NOAA, CSU and our research partners.

Thank you, Tom, for the opportunity you afforded us over the past 28 years.

Intentionally left blank

TABLE OF CONTENTS

Project Title	Page

NOAA

OTHER FUNDING

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, 2007 through June 30, 2008.

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 Thomas H. Vonder Haar, Founding Director

vonderhaar@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.

CIRA EDUCATION, TRAINING AND OUTREACH ACTIVITIES

Advanced Linux Prototype System (ALPS) Visualization Improvements

The ALPS (Advanced Linux Prototype System) provides an ideal platform for prototyping new capabilities and CIRA researchers demonstrated and tested many new features using the ALPS system. Among these is the ability to create graphics in KMZ format and display them on GoogleEarth (TM). Also, the FIM (Finite-volume Icosahedral Model) was integrated and displayed for the entire globe on the ALPS "movable" scale. This same data can be exported and displayed on Science on a Sphere. Another ALPS feature—a "gridded data server"—was implemented to improve the speed with which an ALPS workstation user can view remotely located forecast model grids. This made it possible for selected West Coast offices participating in the NOAA HMT (Hydrometeorological Testbed) to access very high resolution model data generated at GSD in Boulder in real-time.

Autonowcaster System Installed at DFW Airport Weather Forecast Office

An NCAR Autonowcaster display system was installed at the Fort Worth-Dallas Weather Forecast Office. This allows FAA Central Weather Service Unit (CWSU) forecasters to review the several types of Autonowcaster products (real-time and forecast) that are available within the system. In preparation for an operational evaluation, significant software improvements were made during the past year in Data Management, Data Display, Forecaster Interaction (boundary and polygon editing), and Data Dissemination. The significance of this achievement goes beyond providing improved severe weather situational awareness for the CWSU forecasters with operational products to assist in regional air traffic control. These guidance products are now being served using input data provided by NWS forecasters via AWIPS.

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 websites, http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw contain near real-time animations and products used routinely by a growing number of forecasters and even forecasters in other nations. John Forsythe hosted a telecon on the blended TPW products with the NWS forecast office in Miami and the NASA Short-term Research and Prediction (SPoRT) center in Huntsville, AL.

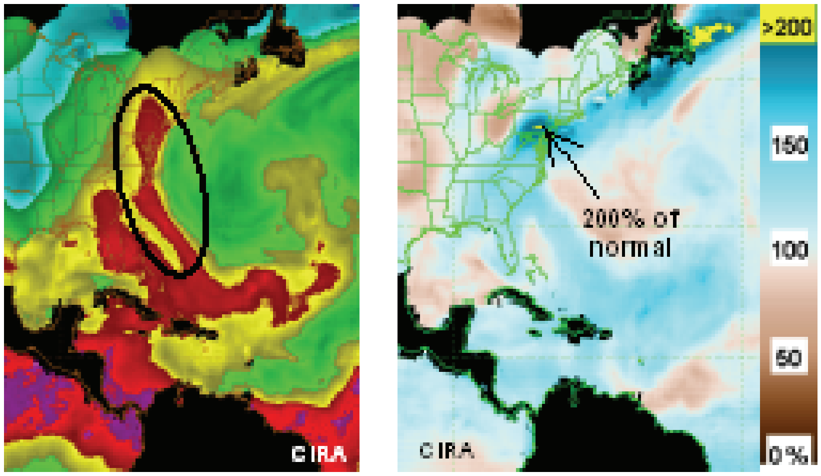


Figure 1. Example of CIRA blended total precipitable water and anomaly field from the website on June 25, 2006 when record flooding occurred in the Mid-Atlantic States.

CIRA Scientist Visits Second-Graders Days After Windsor Tornado

CIRA scientist Louie Grasso visited the second grade class at Bauder Elementary School in May 2008, a few days after a devastating tornado struck Windsor CO. The tornado was only about 10 miles from CIRA Fort Collins and struck during the school day. Dr. Grasso discussed his work at CIRA. The students were very interested in satellites in space and using computers to forecast weather. When Dr. Grasso described how CIRA is researching severe weather, several little hands went up in the air. The second graders could not wait to say that there was a tornado nearby just a few days ago and that they had to go into the hallway. Several children wondered if they could come and see CIRA. Dr. Grasso replied "Next year let's see if we can work out a visit to CIRA."

CloudSat Data Processing Center Increases Web Presence

The CloudSat Data Processing Center (DPC) enters its third year of operation and continues to provide a wide variety of services to show the atmosphere from the unique A-Train satellite formation. Scientists can order data from the ordering system in a shopping cart system. This past year a new page was added to the CloudSat DPC website that can be used to display near-real time Quicklook images. This page automatically refreshes once per minute and includes links to the last few days of Quicklook images. It was designed for use in an educational kiosk, specifically for use by the new CSU University Welcome Center. The link to this page is http://www.cloudsat.cira.colostate.edu/Current_Quicklook.php.

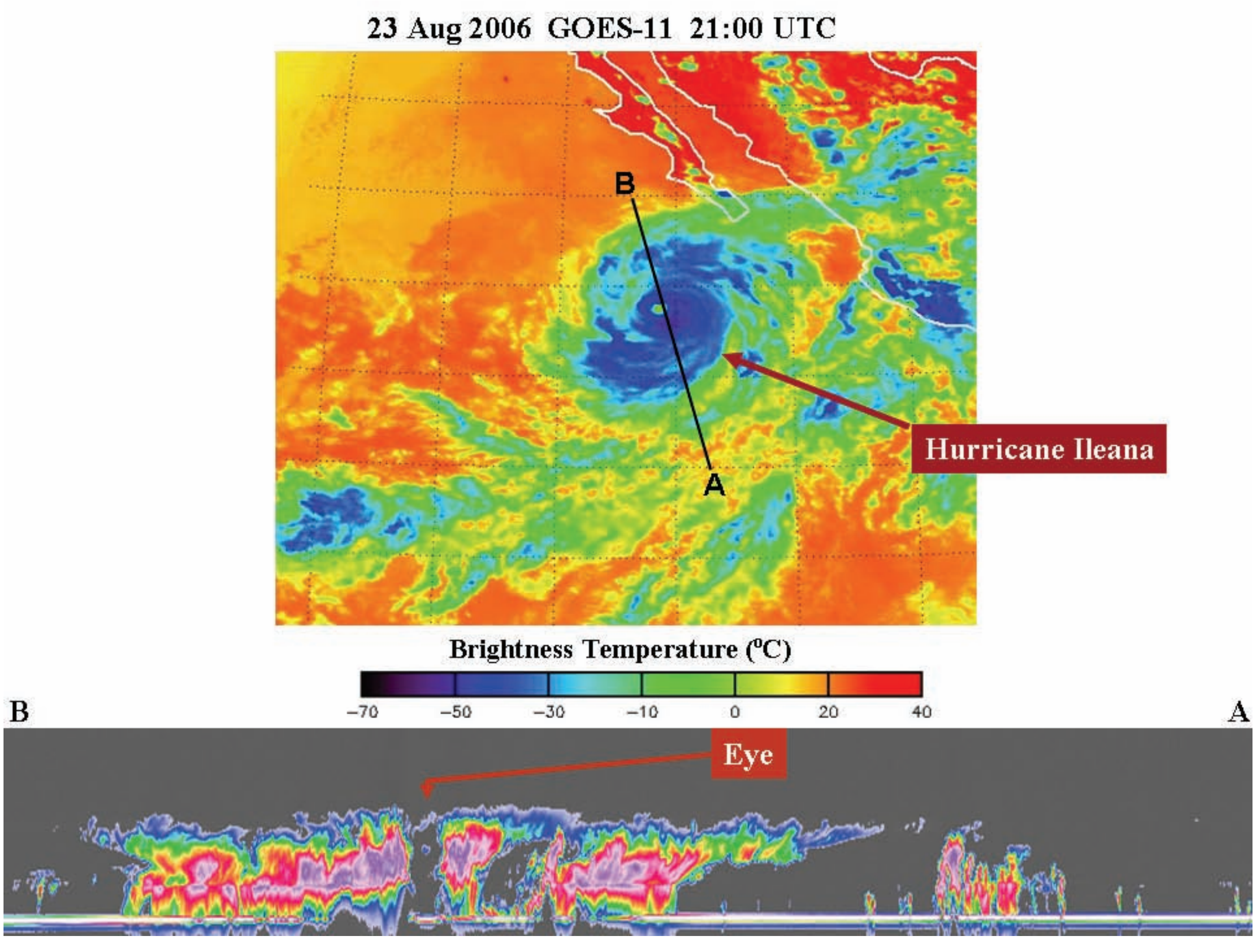


Figure 2. CloudSat Captures the Eye of Hurricane Ileana in August 2006.

The previous CloudSat Quicklook and Case study web pages continue to offer new views of clouds from space. http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php and http://www.cloudsat.cira.colostate.edu/CaseStudies.php. CloudSat has now sampled dozens of hurricanes such as Hurricane Ileana shown above.

Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)

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. 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. A CoCoRaHS display was shown at the 2008 AMS Annual Meeting in New Orleans. CoCoRaHS has been a great success and now has over 10,000 volunteer observers across the U.S.

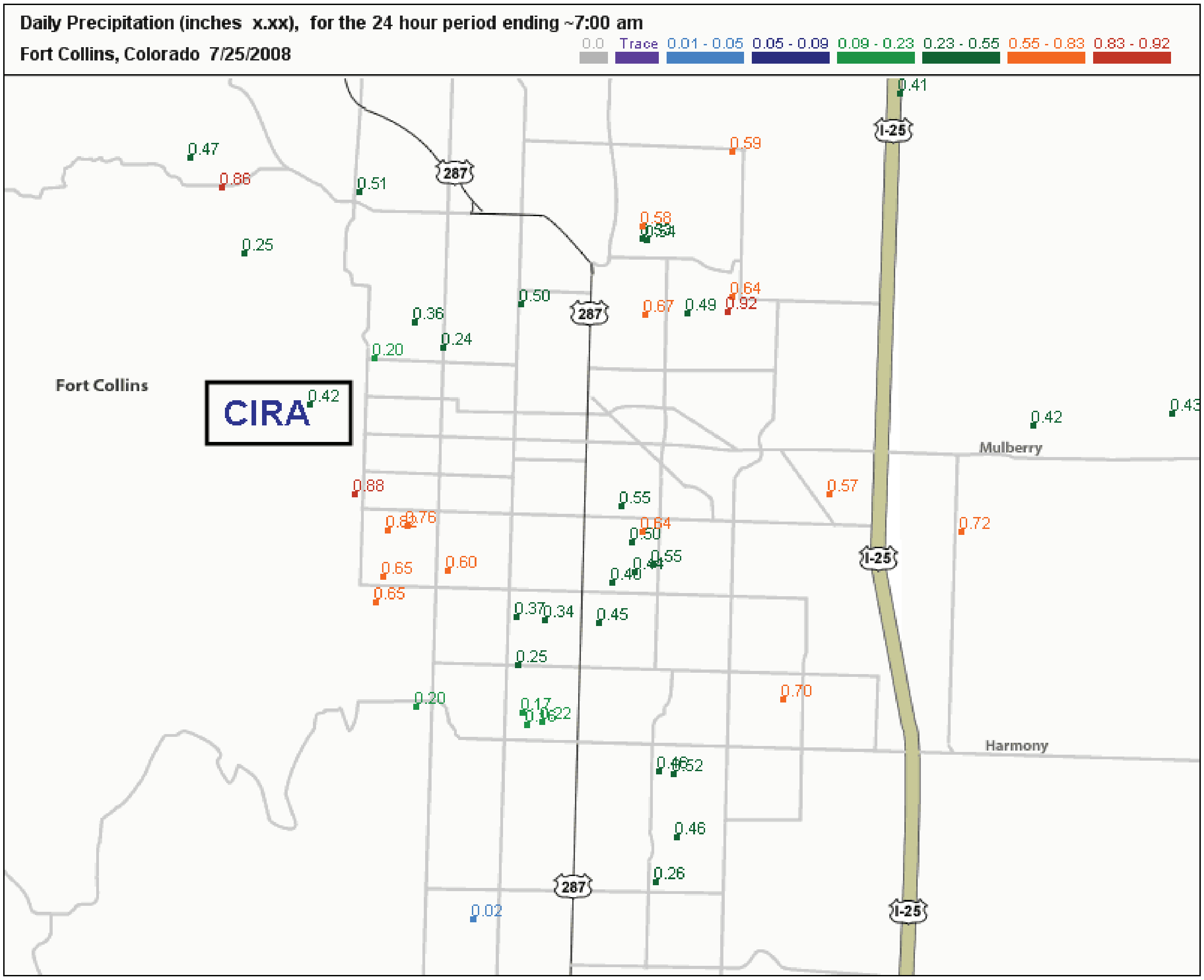


Figure 3.   Rainfall reports (inches) from CoCoRaHS over Fort Collins from a severe thunderstorm. The CSU Foothills Campus where CIRA is located received 0.42”.

CSU Professor Trains TV Meteorologists on new Dual Polarization Radar

Figure 4. Professor V. Chandrasekar of the CSU Electrical Engineering Department, a leader in weather radar technology.

Professor V. "Chandra" Chandrasekar of CSU's Electrical Engineering Department and a CIRA Fellow, taught a course on dual polarization radar to a nationwide audience of broadcast meteorologists in June at the American Meteorological Society's 36th Conference on Broadcast Meteorology. The CSU CHILL radar, located near Greeley CO, was equipped with dual-polarization capability this spring. Unlike conventional weather radar, a dual polarization radar has the ability to discriminate between precipitation particles with different shapes, allowing for instance the detection of hail versus heavy rain. Dual polarization will be adopted as the National Weather Service standard in 2009.

"Dual-polarization weather radars have become a key operational tool for forecasters, and many TV stations will upgrade to dual-polarization systems," Chandra said. "The goal of the course is to provide sufficient background on the principles and applications of dual-polarized weather radars with introduction to advanced topics such as hydrometeor classification and rainfall estimation." It is expected that many TV stations will upgrade to dual polarization radar in the coming years.

FX-NET Continues to Improve

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.5.1) includes the addition of significant new data analysis and display tools. 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 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.

Geo-Browsers for Education and Outreach: Google Earth Applications

'Geo-browsers' provide a novel, intuitive, and user-friendly way to visualize, navigate, and add geographic context to environmental datasets. They are similar in some respects to NOAA's Science on a Sphere (SOS), in the sense that environmental data are projected upon a rotatable spherical body. However, being purely software applications, geo-browsers offer considerably greater interactive power in terms of physical navigation (e.g., zooming, panning, and flying), a larger diversity of data layers, and ease of set-up and access. Simple (and freely downloadable) interfaces such as Google's 'Earth' (GE) have placed global high resolution satellite imagery, radar altimetry, and a variety of other commerce, transportation, structural and demographic data in form that is accessible, understandable, and useful to both experts and laymen alike. The interface is similar to that of Geographic Information Systems (GIS) in the way data are made available in geo-referenced layers which can be toggled on/off, with the primary difference being that data in the current version of GE is useful for data visualization purposes only (pixel values cannot be interrogated). The 'Keyhole Markup Language' developed for use with GE is highly flexible and adaptable by users who present their own customized datasets within the geo-browser framework. At the 2007 American Geophysical Union annual meeting in San Francisco, a session dedicated to geo-browser technology contained a broad cross section of the many active research-related initiatives in this area. With similar meetings planned at upcoming large scientific gatherings (e.g., the 2009 AMS annual meeting in Phoenix, AZ will include a session on 'Virtual Globes and Mashups'), the trend of applied science within the geobrowser paradigm is expected to grow.

As user familiarity with geo-browser technology increases, the tremendous potential for leveraging this paradigm in education and outreach purposes should not be overlooked. With literally millions of users of GE spanning all ages, gender and ethnicities navigating the virtual planet, the opportunity is there to reach a broad community with relevant environmental information that fits naturally (and in fact augments the user's experience by supplying an increased sense of realism) within the application. Users gain an appreciation and interest for the earth/atmosphere system through osmosis and in an indirect, self-guided sense as opposed to force-feeding. In terms of the National

Research Council's (NRC) recommendations for discovering new ways to reach the next generation of environmental scientists, the introduction of such topics in the classroom using simple geo-browsers to explore the physical world is truly a low hanging fruit. The first and fundamental challenge lies in the ability of subject matter experts to portray information that is salient, intuitive, informative, and relevant to a broad audience. Only after a user becomes comfortable and is ready to explore a concept in more detail should they be introduced (i.e. by manual selection) to more abstract environmental data layers and supporting documentation. A natural place to begin such a process is with a universally familiar globally available weather parameter such as wind, rainfall, surface temperature, or cloud cover. Supplying this information in a time frame making in representative of current conditions ensures its relevance to a broad audience.

At present, there exist very few near real-time updating layers within GE. Through an ongoing collaboration between Dr. Steve Miller (CIRA), Dr. Joe Turk (Naval Research Laboratory (NRL), Monterey) and Mr. Cris Castello (Google Earth), NRL is now supplying (as of Nov 2007) to GE a global cloud layer based on a composite of multiple geostationary and low earth orbiting satellites (Fig. XX). This hourly updating layer exists under the 'Weather' tab on the left panel of the GE interface. It is post-processed (sub-tiled) and served directly from Google, and hence is available to all users who have installed GE Version 4.2 or higher on their personal computer. The clouds layer is rendered as a portable network graphics with alpha-layer (alpha-PNG) file. The alpha layer specifies dynamic transparency (Fig. XX) according to satellite measurements that are correlated with optical thickness, producing the natural effect of opacity for thick/cold-top cloud structures (e.g., cumulus) and semi-transparency for thin clouds (e.g., cirrus). Optimal scaling for the cloud enhancement is assisted by a global numerical weather prediction model analysis of surface temperature, accounting for minor corrections in land surface emissivity variation. Accompanying the cloud layer under the Weather tab are optional radar (continental United States only) and global station observation overlays, supplied by the company WeatherData. The addition of these updating layers to GE has not only added a new dimension of realism and relevance, but also extends the practical utility of the interface to daily planning activities worldwide.

Collaborative work between NRL, Google, and CIRA is ongoing to improve the global cloud product in GE. This includes the introduction of higher spatial resolution visible imagery (during daytime hours) and multi-spectral infrared techniques for enhancing low clouds and fog at night (features that are resolved poorly in the current application owing to low thermal contrast with the background surface temperatures). Introduction of multiple enhancement techniques will require the leveraging of dynamic blending techniques to avoid imagery seams and proper display of overlapping (e.g., high-over-low cloud) layers. In this way, scientific techniques to improve the characterization of complicated environmental scenes are used here to enhance the display of data within the geobrowser framework. As technologies such as Google Earth, NASA World Wind, and Microsoft Virtual Earth continue to grow in popularity and usage by the general public, so will opportunities to increase environmental literacy in this community through high level visualization of scientific data packaged with appropriately crafted discussions that relate the academic pursuits of the science to the 'practical world' we live in.

Geobrowser technologies represent an emerging paradigm for education and outreach which CIRA plans to leverage in new and creative ways for communicating environmental science and, with some optimism, capturing the interest of those representing the next generation of scientists in our field.

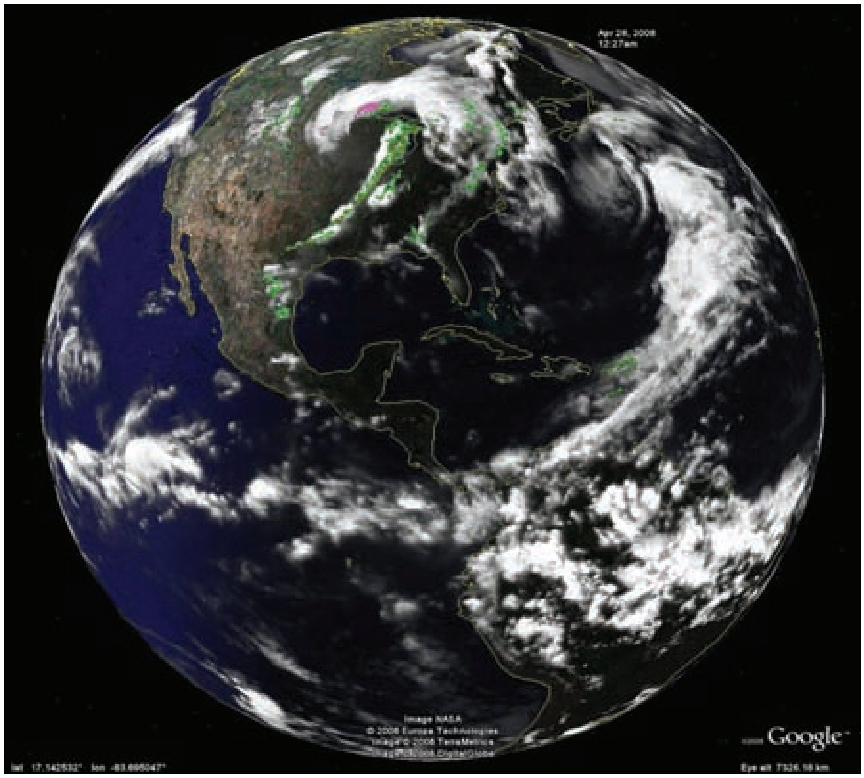


Figure 5. The Google Earth ‘Clouds’ layer, found under the Weather Tab, displays an hourly update of global cloudiness derived from a constellation of geostationary and polar-orbiting passive radiometers. The day/night transition option has been selected and real-time NEXRAD precipitation (a separate ‘weather layer’ in Google Earth) overlaid for the CONUS region.

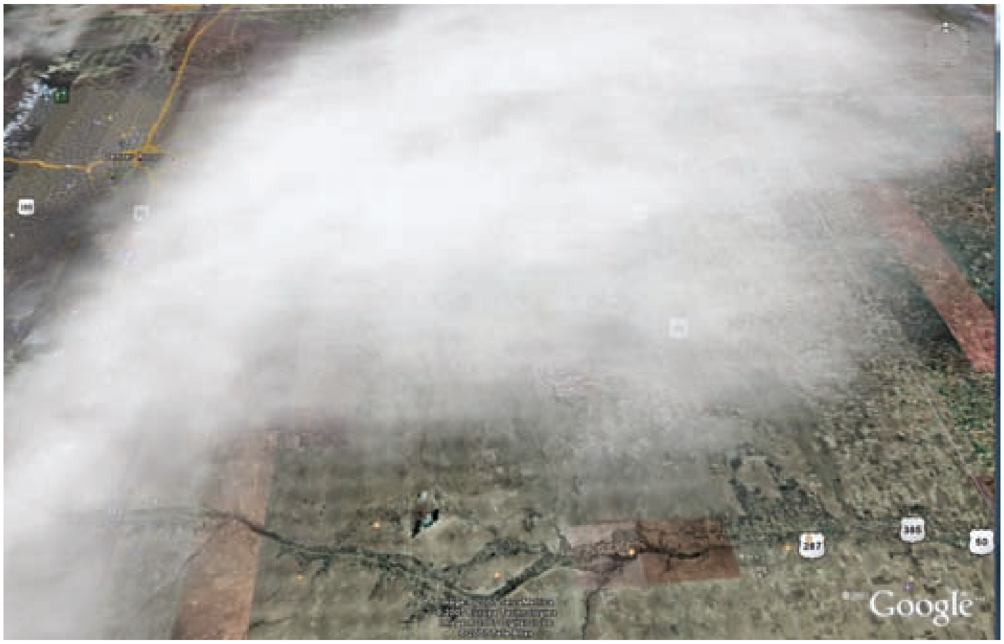


Figure 6: A zoom-in of a cloud layer over eastern Colorado, viewed at approximately 45° inclination, demonstrates the dynamic transparency effect for a mountain wave cloud structure in the lee of the Rockies. Note cloud transparency effects that are achieved through use of the alpha-PNG approach.

GLOBE Website Redesigned by CIRA

The GLOBE (Global Learning and Observations to Benefit the Environment) technology team comprised of 5 CIRA researchers successfully designed and released the new GLOBE Website in June 2007 (http://www.globe.gov). The new Website continues to receive improvements based on the principles of being more user-friendly and better supporting collaborative student research projects, including projects related to the ESSPs (Earth System Science Projects), and local and regional 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 international GLOBE network has grown to include representatives from **110** participating countries and **138** U.S. Partners coordinating GLOBE activities that are integrated into their local and regional communities. Due to their efforts, there are more than **40,000** GLOBE-trained teachers representing over **20,000** schools around the world. GLOBE students have contributed more than **18 million** measurements to the GLOBE database for use in their inquiry-based science projects.

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 might be reading or backing up data, or helping write a web page.

International Polar Year (IPY) South Pole, Antarctica, Research Expedition

Four Americans and eight Norwegians spent 3.5 months (2007-2008) traversing from the Antarctic Coast to the South Pole as part of an International Polar Year (IPY) field expedition. Our scientific measurements included 1) drilling 700 meters of ice cores to measure chemical and physical properties; 2) collecting 2500-km of radar data to map snow and ice accumulation between drill sites; 3) making detailed near-surface physical and chemical snow measurements; 4) installing two automatic weather stations; and 5) making deep-ice temperature measurements. This suite of observations will be used to gain new insights into the paleo-environments and climate change of this virtually unexplored area of Antarctica. Additional information can be found at the expedition website http://traverse.npolar.no/, and a slide-show presentation is available from ftp://ftp.cira.colostate.edu/liston/shows/work_trips/2007-08_South_Pole.ppt. Dr. Glen Liston of CIRA traveled on this exciting expedition.

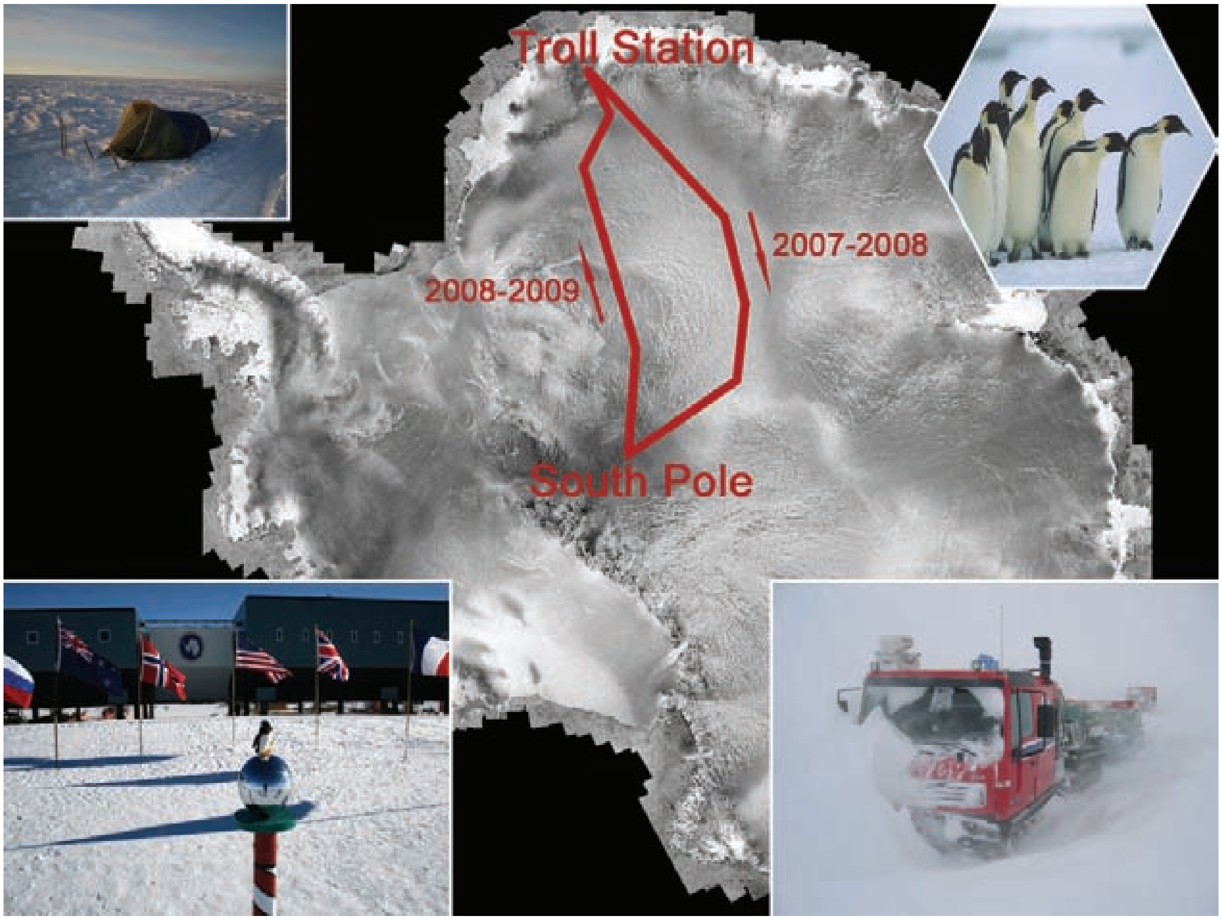


Figure 7. Route of the 2008 IPY expedition to Antarctica and some of the sights.

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. 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. Night Sky Program manager Chad Moore explains telescope operation to a class of 15 park rangers in Death Valley National Park.

Regional Meteorological Training Centers of Excellence-RMTCoE

CIRA collaborates with Regional Meteorological Training Centers of Excellence (RMTCoE) which have been designated by the World Meteorological Organization (WMO). CIRA/NOAA now collaborates with 4 CoEs located in Costa Rica, Barbados, Argentina, and Brazil. Activities with these CoEs 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 via the Internet has become something to look forward to in many countries in Central and South America and the Caribbean. It 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.

CIRA continues to work with the RMTCoE to build case studies of significant weather (i.e., heavy rain events associated with hurricanes, tropical waves, and severe weather). Assistance has also focused on fire detection, volcanic ash detection, satellite rainfall estimation, and satellite cloud climatologies.

See http://rammb.cira.colostate.edu/training/rmtc/ for more information on various RMTC activities.

Figure 9. Participants and instructors at their desks joining in on a virtual training session.

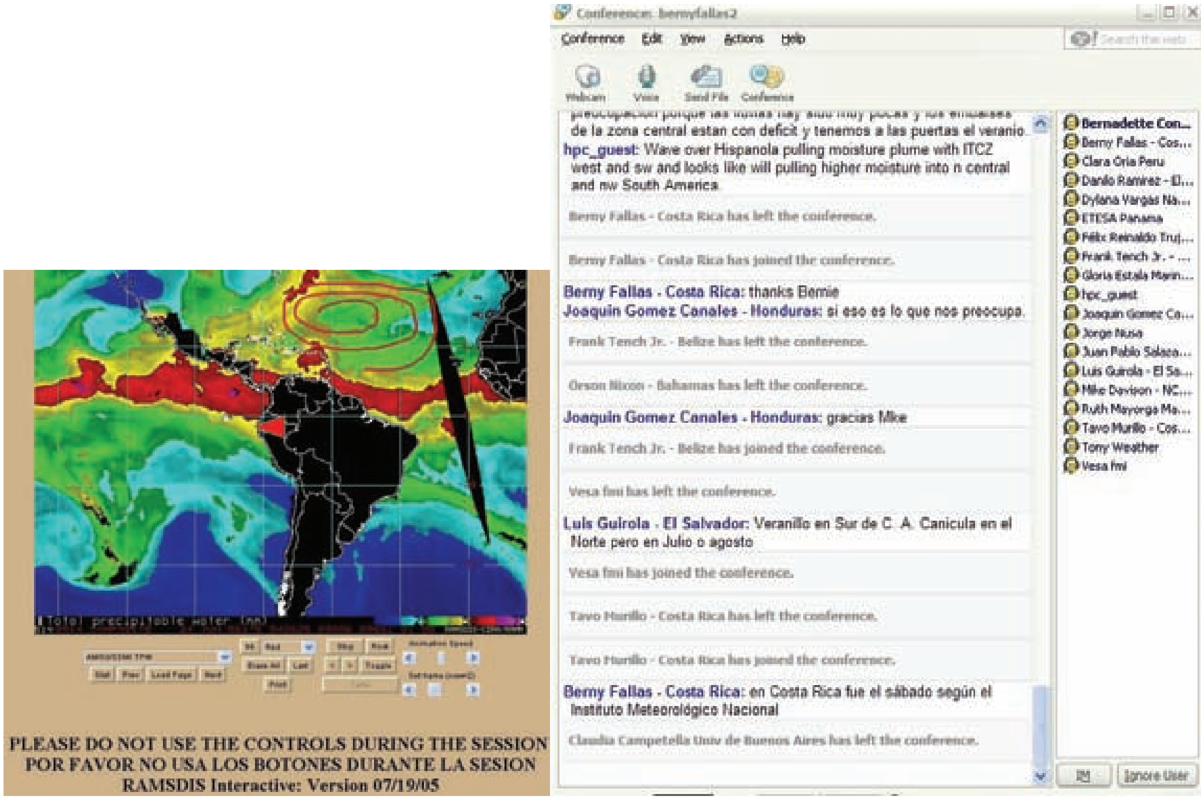


Figure10. (Left) Example screen from the June 2008 session discussing the CIRA multisensor blended total precipitable water product in the tropical Atlantic. (Right) Example of Yahoo Messenger window used to interact with the multinational group. Windows in a session include the VISITview product window, a status window of connections, a product listing, and the Yahoo Messenger window.

Satellite Hydrology and Meteorology (SHyMet) 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.

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.

Science on a Sphere Now Installed at 20 Sites

Science on a Sphere™ (SOS) (see figure below) was installed at four new permanent public venues—NOAA's National Severe Storms Laboratory, Norman, OK; Ocean Explorium, New Bedford, MA; Clark Planetarium, Salt Lake City, UT; and Lawrence Hall of Science, Berkeley, CA—bringing the total to 20 sites where SOS is in operational use. Model output data from the FIM (Finite volume Icosahedral Model) global meteorological model were rendered for display on SOS. Existing NOAA GFS model output was visually enhanced and new and improved planetary data sets were developed. FIM and GFS global model forecast displays on SOS were updated with additional fields and improved color tables. For example, a display that overlays precipitable water with surface pressure is useful for tracking tropical cyclones. The planetary dataset for Mercury was updated based on recent data from the MESSENGER spacecraft as well as Earth-based radar information. A new map of Io from the USGS is also now available for SOS. Updated planetary satellite maps were constructed for several of Saturn's moons, including Dione, Tethys, Enceladus, and Iapetus.

Figure 11. Global atmospheric fields can be displayed on Science on a Sphere.

Tropical Cyclone Forecast Support to NHC and JTWC

CIRA's Regional and Mesoscale Meteorology (RAMM) Branch continues to provide valuable satellite forecast products to the National Hurricane Center (NHC) and the Joint Typhoon Warning Center (JTWC). The Advanced Microwave Sounding Unit (AMSU) is used with scatterometer-derived surface winds to create a blended wind product around a tropical cyclone which is furnished to JTWC. A training module on track models is being developed and will be furnished through CIRA's Virtual Institute for Satellite Integration Training (VISIT) program. The RAMM Branch maintains a real-time experimental webpage at http://rammb.cira.colostate.edu/products/tc_realtime/ which contains many storm-relative products for experimental use.

Virtual Institute for Satellite Integration Training (VISIT) at CIRA

In response to decreased available travel funds for NWS training, VISIT began offering teletraining to NWS weather forecast offices in the spring of 1999. Since that time, VISIT has offered more than 1350 teletraining sessions attended by more than 22,000 participants. This project provides the NWS and other NOAA staff with many training hours (all 122 forecast offices have attended) while minimizing travel and resource costs. VISIT has developed 80 training courses (topics) since 1999 with an emphasis on satellite meteorology. The training is accomplished via the VISITview software and a conference call where a VISIT instructor can communicate with students (see figure). For more information, see the VISIT homepage:
http://rammb.cira.colostate.edu/visit/visithome.asp

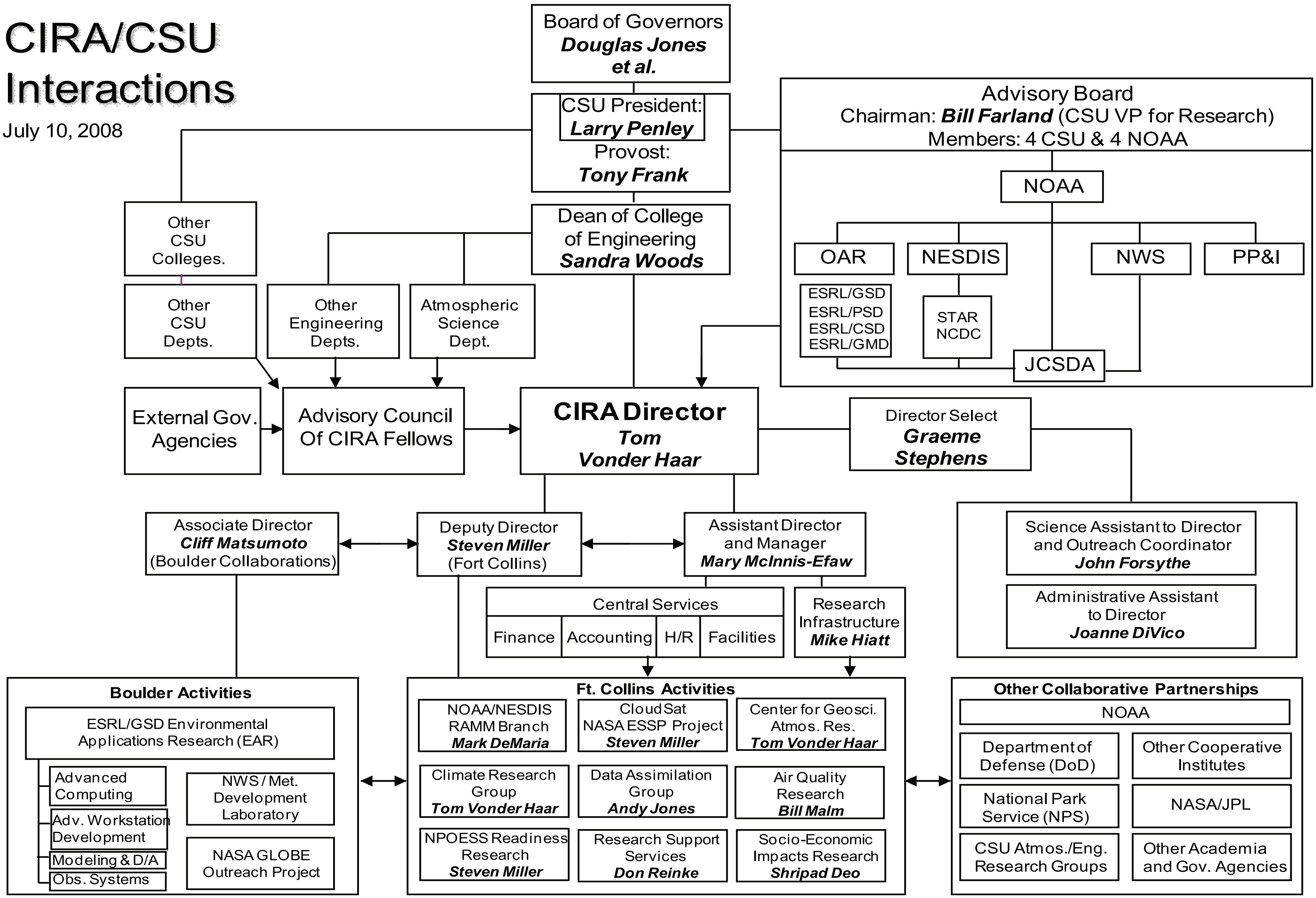
Figure 12. A VISIT instructor leads a teletraining session from CIRA while forecasters at the NWS office in Cleveland watch.

WRF Portal Beta Version Released

In April 2008, CIRA researchers released a beta version of a Java application called WRF Portal that is a graphical user interface (GUI) to WRF-NMM and WRF-ARW and runs on most computer systems. WRF stands for the Weather Research and Forecasting model, a widely used mesoscale model. WRF Portal also supports 2-D visualization and it includes WRF Domain Wizard as a built-in software component. WRF Domain Wizard enables users to choose a region of the Earth to be their domain, re-project that region in a variety of map projections, create nests using the nest editor, and run the three WRF Preprocessing System programs. Two new features added to the Domain Wizard include a vertical level editor and visualization module that enables users to visualize the NetCDF output. See www.wrfportal.org for more information.

CIRA/CSU Interactions

July 10, 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)
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	June 1, 2007
CIRA Advisory Council and All CIRA Fellows	December 20, 2007

Global and Regional Climate Dynamics

--Code for the generation of synthetic UAS observations were ported to the ESRL/GSD supercomputer system. A method of converting the synthetic UAS observations for ingest into the Gridpoint Statistical Interpolation was developed and testing of the assimilation of the synthetic data into the GSI is currently underway. Evaluations of the Nature Run for the Pacific UAS testbed OSSE (Rossby waves) and Arctic Testbed OSSE were performed.

--Interpolation routines were developed that generate Flow-following Icosahedral Model (FIM) output on a 0.5 degree latitude and longitude grid. These output fields can be plotted using standard contouring packages and compared against other global models such as the Global Forecast System (GFS) model. Currently, a cylindrical equidistant projection is used; however, other projections are being investigated. A website for display of FIM model output has been created and has some preliminary products available for perusal with 3-hourly forecasts going out to 7 days (http://fim.noaa.gov/fimgfs). The website is currently being enhanced to include more output products, GFS model output, and FIM-GFS difference fields.

--A modeling system was developed based on WRF that can be used to perform seasonal to decadal regional simulations of climate. The system will be used to test the utility of downscaling seasonal forecasts from the Climate Forecast System for use in western water management decisions.

--A state-of-the-art, physically-based micrometeorological model (MicroMet) was developed that can serve as an interface between coarse-resolution atmospheric models and fine-resolution hydrological and ecological models. This model is expected to lead to improved local weather and hydrological forecasts.

--GIMPAP plans for the Cheyenne and Eureka NWS forecast offices were developed to produce satellite cloud climatologies. The climatologies were stratified by marine layer depth for the Eureka case. Other examples of completed transitioned work in the project include: improve hurricane intensity forecast models-provided to NWS and fog and volcanic ash detection techniques provided to NESDIS operations.

--GOES-West ISCCP Sector Processing Center- Data collection and quality control for ISCCP. These data were compared with observations from the recently-launched CloudSat and CALIPSO satellites with ISCCP products. CloudSat and CALIPSO data were matched with MODIS data from the Aqua satellite to investigate how well the channels on which ISCCP is predicated sense clouds and cloud layers.

--The purpose of IPCC Studies for Climate Observations research is to examine 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 (CDRs). The involvement of young scientists in this report is also an objective. A major early result of this study was the rescue of 15 months of SSM/T-2 (a passive microwave moisture sounding instrument) data from 1993-1994 to add to NCDC's satellite climate data record archive. The first data exist from late 1991 onwards, but NCDC's archive began in July 1994.

--Monsoon Flow and its Variability during NAME: Observations and Models improve our understanding of the North American Monsoon and its variability on multiple spatial and temporal scales. This research, based on data collected during the 2004 North American Monsoon Experiment (NAME), has provided new insight into the dynamics of Gulf of California surges. The most prominent surge (13-14 July 2004) was found to consist of two stages: A shallow, bore-like disturbance that traveled rapidly (20-25 m s-1) up the Gulf, followed by a Kelvin wave-like disturbance characterized by a deeper layer of sharp cooling and strong moisture transport research on monsoon surges. Peter Rogers, who joined the NWS Phoenix office after completing his M.S. degree at CSU, has collaborated with the Tucson and Phoenix NWS offices for forecasting monsoon surges and associated rainfall.

--Richard Johnson, Atmospheric Science Department Head and Fellow of CIRA, was appointed Chair of the Expert Team on Severe Monsoon Weather, of the WMO/CAS Working Group on Tropical Meteorology

--Collaborative Research: Norwegian-United States International Polar Year (IPY) Scientific Traverse: Climate Variability and Glaciology in East Antarctica: 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 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 websites. Active knowledge sharing and collaboration between pioneers in Antarctic glaciology from Norway and the U.S., 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.

Mesoscale and Local Area Forecasting and Evaluation

--Delivered a new Monte Carlo wind probability estimate to NHC with a 600% improvement in speed estimation. This code was also modified to provide all of the input needed for the wind speed probability table program. This inclusion of GPCE information allows modification of the track probability distributions, which has a significant impact of wind speed probability distribution. The partitioning of the probability distributions into along- and cross-track components is being run at NHC in parallel with the older code for operational verification.

--Added Tropical Cyclone Heat Potential (TCHP) as a predictor to the Statistical Typhoon Intensity Prediction System (STIPS) model. Up to 2.7 percent improvement was made in the subsequent STIPS forecast hour interval forecasts. This research, which uses satellite altimeter data, will help improve the intensity forecasts for hurricanes that have the potential to rapidly weaken or intensify.

--Development and Evaluation of GOES and POES Products for Tropical Cyclone and Precipitation Analysis has three goals/products: (1) the development and operational implementation of an Advanced Microwave Sounding Unit (AMSU) –based global tropical cyclone intensity algorithm, (2) the development and operational implementation of an objective satellite-based tropical cyclone formation prediction for the Atlantic, eastern N. Pacific and the western N. Pacific, and (3) improvements of the already operational NOAA/NESDIS Hydro-Estimator product using cloud resolving numerical modeling. Goals 1 and 3 were completed last year. The pre-operational phase of the new Tropical Cyclone Formation Probability (TCFP) product was successfully completed during this report period. During this phase a new TCFP product, with an updated algorithm and an extended domain that covers the Atlantic, eastern N. Pacific and the western N. Pacific, was run experimentally at CIRA and displayed in real-time on the following website http://rammb.cira.colostate.edu/projects/gparm/index.asp.

--NOAA Bronze Medal, Mark DeMaria, Antonio Irving, Nancy Merckle, John A. Knaff: For the development and operational implementation of the Tropical Cyclone Formation product that quantitatively predicts storm formation probability.

--The Terrain-induced Rotor Experiment (T-REX) project is a testbed for high resolution, nonhydrostatic weather models in order to provide accurate guidance in complex environments. The test area for T-REX is in the vicinity of the Sierra Nevada Mountain Range. Graphical products of extensive model parameters were made available for viewing and comparison on a web page (http://www-frd.fsl.noaa.gov/mab/trex/) following runs of two separate WRF models: Advanced Research WRF (ARW) and National Mesoscale Model (NMM). Both of these models used a 2 km X 2 km domain with 50 vertical levels.

-- A formal assessment to the Aviation Weather Technology Transfer (AWTT) Technical Review Committee (TRC) was provided in support of the operational transition of the Forecast Icing Potential (FIP) product developed by the FAA's Icing Research Team. Attributes of the forecast that were evaluated include icing probability, icing severity, and supercooled large drops (SLD). Findings indicated that FIP showed significant value as a supplement to the AIRMET; and, primarily basing their decision on the study, the TRC formally approved the use of FIP in FAA operations.

--Collaborations with the RTVS group to create and demonstrate a verification framework to support processing of meteorological quality information within NextGen. Critical to the effort is the ability to effectively integrate information from the air traffic planning process. CIRA researchers successfully implemented a proof-of-concept to evaluate and demonstrate the new ideas. This approach proved valuable to the operational community; as a result, work continues on enhancing the capability and integrating the system into the NextGen development.

--CIRA scientists have been an integral part of an on-going Hydrometeorological Testbed (HMT) project that represents a cooperative effort between NWS WFOs in Sacramento and Monterey and the Reno WFO in Nevada, the NOAA California-Nevada River Forecast Center in Sacramento, and the NOAA National Centers for Environmental Prediction (NCEP) Heavy Precipitation Branch. The collaboration focuses on the detailed analysis of the WRF-ARW model with various microphysics and its performance in cases of atmospheric river events. The evaluation consisted of comparisons of the flow and cloud structure against observations from experimental radars deployed for the HMT project.

-- A collaboration between the Hazardous Weather Testbed and Hydrometeorological Testbed was established. CIRA researchers participated in an initial brainstorming session to determine how the two testbeds can work together to accomplish common goals. A primary developmental priority that was identified was the need to advance the use of high-resolution forecasts so that they could be used in an adaptable manner. A pilot test is now underway in which a mesoscale model ensemble forecast is being used to provide initial and boundary conditions to produce a cloud-scale model ensemble forecast.

--Collaboration with AOML to run a LAPS analysis for Hurricane Dennis from 2005, including the use of specially-derived radar observations. This is a proof of concept for using LAPS to initialize the WRF model with current tropical cyclone information to help improve forecasts. The LAPS web interface was improved to be able to plot the densely-packed special observations that support the analysis of tropical storms

--The TAMDAR (Tropospheric AMDAR (Aircraft Meteorological Data Relay)) program underwent a significant milestone when the NWS agreed to purchase the TAMDAR data from the Midwest and mid-CONUS that had been part of the TAMDAR Great Lakes Field Experiment. The objective and subjective evaluation efforts by ESRL/GSD, CIRA, and some NWS WFOs (particularly WFO Green Bay, Wisconsin) were crucial to establishing the usefulness and reliability of the data input that went into the NWS decision.

--Graphics and a website (http://rapidrefresh.noaa.gov) were generated for the Rapid Refresh (RR) model, which is an upgrade to the RUC model that includes assimilation of radar reflectivity, TAMDAR observations, enhanced convection and enhanced land-surface radiation. The RR remains at 13 km resolution; however, the domain covers all of North America rather than just the Continental U.S.

--Analyses using spectral, multi-order structure functions, and multi-fractal methods were conducted to study gravity waves and turbulence interactions in the upper troposphere. A series of WRF model simulations of gravity wave generation, propagation, and dissipation in a baroclinic atmospheric condition were also conducted. These analyses further revealed scale interactions and energy cascade between mesoscale gravity waves and turbulence.

--Over the last few years, development of time-lagged, multi-model ensemble systems and ensemble-based data assimilation systems have been applied to various projects and experiments including QPF, PQPF, and QPE studies. During the past year, a method to construct mesoscale background error covariance was developed for a data assimilation system and global precipitation verification studies using various satellite data and the GFS global atmospheric forecast model.

Applications of Satellite Observations

--Code was developed to compute the location of Atmospheric Rivers. Water vapor fluxes in these rivers are computed for wind fields assuming geostrophic, linear, or nonlinear balance conditions. The analysis revealed problems with ATOVS data and the research is now using AMSU-A/B data instead.

--The Advanced Environmental Satellite Research Program has formed the basis for an international coordination to evolve the Global Earth Observing System (GEOS). Additionally, these coordination efforts, through participation in high-level international committees and WMO groups, is leading to the improved use of space based earth observing data.

--GOES-R ABI analysis and simulated radiance fields were developed as proxy data for Mesoscale weather and hazard events using high-quality simulations of radiance. ABI radiances for one hurricane event and several fire proxy datasets and model fields of “ground truth” were created.

--The blended TPW and TPW anomaly products have been made available to more users. Both the blended GPS-AMSU-SSM/I TPW product and the anomaly product are available on the web (http://amsu.cira.colostate.edu/GPSTPW) and on the McIDAS Server (ULY/AMSU.27 and 28) and are scheduled for AWIPS Operational Build 9.

--Creation of cloud and microwave emissivity verification tools for use in the CRTM has just begun. Delivered the CSU MWLSM v1.0 to the JCSDA for subsequent insertion in the operational CRTM. CloudSat data sets have been matched to the WRF-3DVar data assimilation case studies for future verification work. This work leverages DoD sponsored work with JCSDA support for NOAA's mutual benefit.

--Development of a multi-platform satellite tropical cyclone wind analysis system. The system combines measurements from a number of satellite platforms to estimate the surface wind fields of tropical cyclones. Two important contributions to tropical cyclone wind field outside of the eyewall region of the storm comes from the AMSU instrument and from QuikSCAT. Considerable effort was made to determine the error characteristics of these two wind instruments, and a method was developed to convert the AMSU winds (which are representative of winds above the boundary layer) to the surface. NOAA may view this work as a tool for justifying public investment in science initiatives. Having data available from advanced sensors will allow researchers to develop products for the forecaster to utilize in severe weather situations. It will also allow for preparation of training materials to train the forecaster to use the products. This will in turn lead to better weather/hazard forecasts for the public.

--Produced an updated and quality-controlled archive of SSM/I antenna temperature data in Wentz and TDR formats from DMSP F08, F10, F11, F13, F14, and F15 for the period July 1987 through the present. Developed software for the processing of both the Wentz and TDR formats. Developed a technique for intercalibrating the SSM/I brightness temperatures with TRMM TMI in order to produce a consistent multi-sensor climate data record. Currently working with the intercalibration working group within the NASA Precipitation Measurement Mission (PMM) science team to refine this approach. Received certificate of appreciation from the director of NOAA's National Climatic Data Center for providing a comprehensive archive of SSM/I data and associated documentation.

--Satellite-derived wind measurements are most valuable over the oceanic regions where fewer conventional observations exist. This lack of observational data extends over all latitudes, from the tropics to the Polar Regions. The polar winds project involves collaborations with other agencies including the National Environmental Satellite, Data, and Information Service's Office of Research and Applications (NESDIS/ORA), and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) located at the University of Wisconsin – Madison

--Evaluation of GOES-13 Imager and Sounder during NOAA's Science Test: Collection and Analysis of Data Science Test indicates that the GOES-13 instruments (Imager and Sounder) are less noisy than previous GOES. On the other hand, the potential reduction in striping (to be achieved through increasing the Imager scan-mirror dwell time on the blackbody from 0.2 sec to 2 sec) has not been realized. Improvements were noted in both the navigation and registration of GOES-13 imagery. Frame-to-frame registration of the imagery appears to be improved as well.

--To assess the utility of NPOESS instruments for tropical cyclone applications, proxy data from currently available satellites and synthetic data from mesoscale and radiative transfer models are being used. AIRS/AMSU retrievals (proxy for ATMS/CrIS) from the AIRS Science Team were collected in the environment of 11 tropical cyclones. In situ soundings from the NOAA Gulfstream Jet were also available as ground truth. The VIIRS proxy dataset was used to study the impact of resolution on the Dvorak intensity estimation technique. A method to estimate tropical cyclone wind structure from temperature and moisture retrievals was also evaluated. This algorithm is now being run in real time using AMSU temperature retrievals for all tropical cyclones around the globe. The retrievals are now available to forecasters at the National Hurricane Center in Miami and the Joint Typhoon Warning Center in Honolulu via the following web page: http://rammb.cira.colostate.edu/products/tc_realtime/.

--POES-GOES Blended Hydro-Meteorological Products builds upon earlier NOAA Product Services Development Initiative (PSDI) work at CIRA to deliver operational algorithms for blended total precipitable water (TPW) into AWIPS Operational Build 9, targeted for early 2009. The merged TPW and accompanying TPW anomaly products developed at CIRA currently use inputs from four different types of sensors (AMSU, SSM/I, GPS, and GOES Sounder) along with climatology data to create near real-time blended moisture products. The websites hosting these demonstrations, http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw, are routinely accessed by NWS forecasters. The demand to make these products fully operational has spurred this technology transition effort.

--WindSat RTM Intercomparisons: Microwave Land Surface Model (MWLSM/CSU) fields were compared to Conical Microwave Imager Sounder Model (CM/AER). The study found that the MWLSM is, in fact, a generalized research version of the NPOESS CM model code. Results are very similar between systems if MWLSM parameters are adjusted to match the CM parameter assumptions (details are found in Rapp et al., 2006):

- --Absolute brightness temperature differences < 3K.
- --Normalized sensitivities < 0.5 K.
- --Forward RTM models are in good agreement, primary focus should be observational validation of the underlying RTM theory using WindSat data (part of Rapp MS Thesis topic).The MWLSM gives physically expected results
- --Most sensitive to soil moisture.
- --Sensitive to vegetation and roughness effects.
- --Soil moisture ranges are similar to expected soil moisture ranges.

--Research & Development for GOES-R Risk Reduction: this project developed algorithms for data assimilation using the Weather Research and Forecasting (WRF) model and the Maximum Likelihood Ensemble Filter (MLEF). The impact of covariance localization (based on employing local sub domains) on the information measures was examined. A simulated GOES-R Product Web using ABI-equivalent MSG data was developed (see http://rammb.cira.colostate.edu/products/goes-r/). Currently the page shows experimental products developed for fog/stratus discrimination and blowing dust, as well as a GOES-11 version of the blowing dust product that uses the same split-window difference still available with GOES-10 (West). The development of the GOES-R proxy tropical cyclone database for Dvorak intensity estimation studies was completed. About 400 IR images from AVHRR and MODIS were collected from 11 tropical cyclones from 2002-2005 at 1 km resolution. These were remapped to 2 and 4 km resolution and companion GOES imagery was obtained. These data will be used to develop new tropical cyclone intensity algorithms for GOES-R as part of the Algorithm Working Group project.

Applied Cloud Physics

--A synchronized data set of pertinent cloud and aerosol microphysical properties at a temporal resolution of 20s was created based on the experimental set-up at Point Reyes, CA during 2005. Aerosol fields measured at coarser temporal resolution have been interpolated to 20s, recognizing that the temporal changes in aerosol are much slower than those of clouds . Although the various measures of aerosol effects on cloud microphysics are consistent, they were demonstrated to likely be too low. Radiative transfer modeling also demonstrated that uncertainties in these measures will translate to large uncertainties in radiative forcing estimates.

--Comparisons were performed between the statistical properties of Large Eddy Simulations (LES) and aircraft observations of non-precipitating, warm cumulus clouds that were observed in the vicinity of Houston, TX during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS). Comparisons have focused on the statistical properties of a set of dynamical and thermodynamical variables. For all variables, good agreement between the simulated and observed clouds was found. These comparisons, together with the excellent agreement found between observed and simulated cloud size distributions, suggest that the LES is able to successfully generate the cumulus cloud populations that were present during GoMACCS.

--CloudSat has completed its nominal 22-month mission and has been approved for a 3-year, on-orbit mission extension. CIRA's Data Processing Center has received several NASA awards for excellence in its support of the science teams who are pushing the boundaries of our understanding of cloud physics, morphology, layering, and interactive role in the climate system.

Air Quality and Visibility

--Investigation of SMOKE Aerosol-Cloud-Radiation and Surface Interactions using Large Eddy Simulations: this project examines aerosol-cloud interactions between clouds, aerosols, radiation, surface fluxes and boundary layer processes in warm convective clouds in the Houston area. Comparisons of the statistical properties of Large Eddy Simulations (LES) with aircraft observations were done for non-precipitating, warm cumulus clouds observed in the vicinity of Houston, TX during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS).

--Processing of organic aerosols by heterogeneous and multiphase processes: Particulate organic carbon has been shown to be an important component of the global aerosol system, and yet its physical and chemical sources are poorly understood. The long-term objective of this project is to improve the representation of the properties and formation processes of organic aerosols in chemical and climate models, including their role in aerosol indirect forcing. Ervens et al., (2008) is a collaborative work on aqueous phase modeling of SOA formation. Our modeling studies have shown that SOA yields from isoprene (i) depend strongly on the initial volatile organic carbon (VOC)/NOx ratio resulting in 42% > Yc > 0.4% over the atmospherically-relevant range of 0.25 < VOC/NOx < 100; (ii) increase with increasing cloud-contact time (iii) are less affected by cloud liquid water content, pH, and droplet number. The uncertainty associated with gas/particle-partitioning of semivolatile organics introduces a relative error Yc of -50% ≤ < +100 %. The reported yields can be applied to air quality and climate models as is done with SOA formed on/in concentrated aerosol particles (SOAaer). The paper by Ervens et al., (2008) has been selected as 'Editor's Highlight' by the editor of Geophysical Research Letters. In addition, it has been mentioned on 'Science Daily' ("Cloud Chemistry Concocts Aerosols").

--CIRA has headed efforts to improve WRF-Chem forecasts with data assimilation using the Gridpoint Statistical Interpolation (GSI). One effort concentrated on the development of background error covariances for ozone and its implementation in the GSI. The assimilation cycle was also implemented for WRF-Chem (NMM version). The results of data assimilation of surface ozone observations with WRF-Chem NMM and GSI have been evaluated over a period of three weeks in August 2006.

Numerical Modeling

--CIRA researchers have been an integral part of the team that has brought the ESRL Finite-volume Icosahedral Model (FIM) code to its current level of maturity where the global model produces daily weather forecasts. They improved the software engineering processes used during FIM development by creating source code repositories, developing an automated test suite for FIM, and implementing a lightweight software engineering process tailored to FIM requirements. With the new process, test suite, and repositories in place, FIM software engineering practices are now on a par with other major production NWP and climate codes such as CCSM and WRF. CIRA scientists also refactored upper levels of FIM software to allow interoperability with NCEP's NEMS architecture implemented via the Earth System Modeling Framework. They created a prototype FIM ESMF component and are implementing the functional details to permit coupling of FIM physics and dynamics within the NEMS architecture. CIRA researchers also assisted GSD scientists to incorporate aspects of WRF-CHEM into FIM.

--Impact of fundamental assumptions of probabilistic data assimilation/ensemble forecasting: Conditional mode vs. conditional mean explores the possibility for NOAA operational use of ensemble assimilation/prediction system. This implies the assimilation of NCEP operational observations (including satellite radiances), and the use of NCEP Global Forecasting System (GFS) spectral model, at resolution T126. The NCEP operational observations are accessed using NCEP infrastructure, i.e. using the forward component of the operational Grid-point Statistical Interpolation (GSI) system. The prototype ensemble data assimilation (EnsDA) system has been developed and tested. The EnsDA system generally outperforms the operational GSI (3D-Var) system. In terms of the root-mean-squared errors, the results are especially improved at upper levels of the troposphere.

--Ensemble Data Assimilation of Precipitation Observations: CIRA has developed the basic version of the data assimilation algorithm and tested it in assimilation of the real satellite precipitation observations (TRMM and SSM/I data). In particular, we developed and evaluated a smoother, the Maximum Likelihood Ensemble Smoother (MLES), which was especially useful for assimilation of precipitation data. The data assimilation algorithm is installed on the NASA Columbia computer and made available to the NASA GPM research. The results indicate positive impact of assimilation of precipitation data, especially in producing dynamically balanced precipitation analyses (e.g., precipitation analyses in agreement).

--CIRA-NCAR/MMM WRF-Var Collaboration Work Plan: CIRA determined several new methods for the WRF-Var preconditioner and determined that the WRF-Var Empirical Orthogonal Functions (EOFs) were hindering the use of the Zupanski preconditioner methods which are used successfully in the CIRA 4DVAR data assimilation system. Several alternate recommendations were presented to NCAR for consideration.

--CIRA delivered to NCAR new WRF-Var codes that allow the insertion of satellite microwave emissivities into the WRF-Var framework. This also includes the addition of a new satellite data interpolation scheme to handle missing satellite field-of-views.

--Implementation and Evaluation of an Improved Mellor-Yamada level-3 Turbulence Closure in WRF: The scheme evaluated positively against LES and was successfully used in modeling of radiation fog. The potential benefit to WRF from this enhancement is considered as high, especially in conditions when phase changes in the boundary layer occur. The scheme has been implemented in WRF and is being evaluated. Meetings with NCAR staff are planned to discuss results.

Education, Training, and Outreach

--CIRA has upgraded all software on the AWIPS data server, AWIPS workstation, and WES workstation. An experimental workstation has been configured to assist the transition of RAMMB products to AWIPS. We have also developed a Coastal Effects WES training course. All of these efforts are intended to augment the minimal satellite data set in the current AWIPS configuration with techniques developed by RAMMB/CIRA.

--CoCoRaHS is a community outreach effort to educate the public about climatology and weather, with an emphasis on the collection of precipitation data. CoCoRaHS celebrated its 10th anniversary as a network in 31 states, with 4 more states being added in 2008. Over 5,000 volunteers are reporting precipitation daily and 5,000 more have contributed occasionally. Many educational programs and web-based tutorials have been used in conjunction with NWS' SKYWARN spotter training. Observational activities have focused on precipitation which has formed a basis for collaboration with many organizations at the local and state level. CoCoRaHS provides high density data critical to meteorological and hydrological climate records. It works as a low cost gap filler for NOAA's COOP program. This program's lead and PI, Nolan Doesken, was a recipient of the NOAA 2007 Environmental Hero award

--The AutoNowcast prototype is up and running at the Fort Worth WFO. CIRA consulted and prepared the installation packages and did trouble-shooting for communications problems during the installation.

--The Next Generation GLOBE (NGG) plan was approved in September 2005 by NASA and NSF. In response, the GLOBE Program Office (GPO) has 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 2008, GPO's attention is shifting towards providing a more collaborative space to promote student research around various themes such as climate change and sustainability.

--The overall objective of the Satellite Hydrology and Meteorology (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 SHyMet Intern course was offered online. It consisted of 9 modules, accessible via the following website: (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 April 2007 – March 2008 (compared to entire period April 2006 – March 2008). Thirty-seven new NOAA/NWS employees/participants have registered at CIRA (144 total for period April 2006 – March 2008). Seven of the new NOAA/NWS individuals have completed SHyMet Intern Course (60 total for period April 2006 – March 2008). Eight non-NOAA participants have registered at CIRA (National Environmental Satellite, Data, and Information Service / Satellite Applications Branch (NESDIS/SAB) contractors, and Korean Meteorological Service) (22 total for period April 2006 – March 2008).

--Support of the Virtual Institute for Satellite Integration Training (VISIT): 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 have increased appreciably. A typical monthly training calendar now contains about 15 teletraining sessions over a wide variety of topics. To date, over 18,000 training certificates have been awarded.

--In April 2008, CIRA researchers released a beta version of a Java application called WRF Portal, a graphical user interface (GUI) to WRF-NMM and WRF-ARW. WRF Portal now runs on most computer systems. It supports 2D visualization and includes WRF Domain Wizard as a built-in software component. WRF Domain Wizard enables users to choose a region of the Earth to be their domain, re-project that region in a variety of map projections, create nests using the nest editor, and run the three WRF Preprocessing System Programs. Two new features added to the Domain Wizard include a vertical level editor and visualization module that enables users to visualize the NetCDF output. See www.wrfportal.org

--Aviation-specific enhancements regarding icing, turbulence, convection, ceiling, and visibility were successfully integrated into AWIPS versions being prepared for field deployment in 2008. For the first time, NWS Center Weather Service Units will be able to use the AWIPS Remote Display (ARD) to view aviation weather products and map backgrounds for use in their aviation forecasting and briefings to the FAA's Traffic Management Units (TMU). These products give visual references to affected airspace that words alone sometimes do not capture.

--Support continued on a web interface recently developed that allows an end user (e.g. Redzone Inc.) to automatically move a fire analysis/forecast domain to permit quick response to evolving fire situations. 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.

--FIM and GFS global model forecast displays on Science On a Sphere™ (SOS) were updated with additional fields and improved color tables. For example, a display that overlays precipitable water with surface pressure is useful for tracking tropical cyclones. The dataset for Mercury was updated based on recent data from the MESSENGER spacecraft as well as Earth-based radar information. A new map of Io from the USGS is also now available for SOS. Updated planetary satellite maps were constructed for several of Saturn's moons, including Dione, Tethys, Enceladus, and Iapetus.

--A GLOBE technology team comprised of 5 CIRA researchers successfully designed and released the new GLOBE website in June 2007. The new website continues to receive improvements based on the principles of being more user-friendly and better supporting collaborative student research projects, including projects related to the Earth System Science Projects (ESSPs), and local and regional 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 international GLOBE network has grown to include representatives from 110 participating countries and 138 U.S. Partners coordinating GLOBE activities that are integrated into their local and regional communities. Due to their efforts, there are more than 40,000 GLOBE-trained teachers representing over 20,000 schools around the world. GLOBE students have contributed more than 18 million measurements to the GLOBE database for use in their inquiry-based science projects.

--CIRA made significant changes to the basic FX-Net system 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.5.1) includes the addition of significant new data analysis and display tools.

--Enhancements to the Gridded FX-Net Forecaster Workstation included a new capability to compress grid data sets with irregular boundaries, such as potential temperature fields. The newly designed algorithm and implemented encoding/

decoding software provide good compression performance at the expense of minimum additional computation.

--Science on a Sphere™ (SOS) was installed at four new permanent public venues—NOAA's National Severe Storms Laboratory, Norman, OK; Ocean Explorium, New Bedford, MA; Clark Planetarium, Salt Lake City, UT; and Lawrence Hall of Science, Berkeley, CA—increasing to 20 the number of sites where SOS is in operational use. Model output data from the FIM global meteorological model were rendered for display on SOS. Existing GFS model output was visually enhanced and new and improved planetary data sets were developed.

--CIRA researchers continued their participation in the 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. Work was completed on developing metrics for the new AWIPS which will serve as a benchmark for evaluating the performance of the future AWIPS II.

--As part of the AWIPS Evolution—Web Service Development project, CIRA researchers participated in several efforts including: 1) development of prototype software for the distributed retrieval and processing of ensemble model data; 2) development of prototype web service software using OGC standards; and 3) development of modules for the Earth Information Services prototype that includes data retrieval from new sensors, analysis module, and work-flow module.

--CIRA researchers contributed to a number of changes made to the AWIPS workstation including the ability to view dual polarized radar data. This capability provides significant additional information for estimating the amount of precipitation present in a radar echo, identifying the presence of hail, and discerning ground clutter from real hydrometeor data.

--The ALPS (Advanced Linux Prototype System) provides an ideal platform for prototyping new capabilities. CIRA researchers demonstrated and tested many new features using the ALPS system, including the ability to create graphics in KMZ format and display them on GoogleEarth (TM). Also, the FIM (Flow-Following Finite-volume Icosahedral Model) was integrated and displayed for the entire globe on the ALPS "movable" scale. This same data can be exported and displayed on Science On a Sphere ™ (SOS).

--A "gridded data server" feature on ALPS was implemented to improve the speed with which an ALPS workstation user can view remotely located forecast model grids. This innovation made it possible for selected West Coast offices participating in the HMT (Hydrometeorological Testbed) to access very high resolution model data generated at GSD in Boulder in real time.

--An NCAR AutoNowcaster display system (Configurable Interactive Data Display--CIDD) was installed at the Fort Worth-Dallas WFO. This allows FAA Central Weather Service Unit (CWSU) forecasters to review the several types of AN products (real-time and forecast) that are available within the system. In preparation for an operational evaluation, significant software improvements were made during the past year in Data Management, Data Display, Forecaster Interaction (boundary and polygon editing), and Data Dissemination. The significance of this achievement goes beyond providing improved severe weather situational awareness for the CWSU forecasters with operational products to assist in regional air traffic control, but that this guidance is now being served using input data provided by NWS forecasters using AWIPS.

Societal and Economic Impacts

--The objective of the FX-Collaborate (FXC) project is to develop an interactive display system that allows forecasters/users at different locations to collaborate in real time on a forecast for a particular weather or weather-dependent event. FXC is currently being implemented and/or evaluated for several outside projects and organizations. One significant application in particular, Geo-targeted Alerting System (GTAS), involves the development of a prototype public notification system to be used by NOAA and the DHS Operations Centers in the event of a biological, chemical or radiological release in the National Capital Region. The emphasis this year changed from building and installing prototype systems to developing a deployment strategy. Thus, much of this year's work consisted of coordinating with NOAA HQ and DHS staff on defining the future expansion of GTAS. Several demonstrations of the system were given to DHS staff in Washington and to other visitors in Boulder. CIRA started coordination with Lawrence Livermore National Laboratory, developers of the NRAC dispersion model, to define the interface between GTAS and NRAC. NRAC is currently being used by DHS and several other government agencies instead of the HYSPLIT model now running on GTAS.

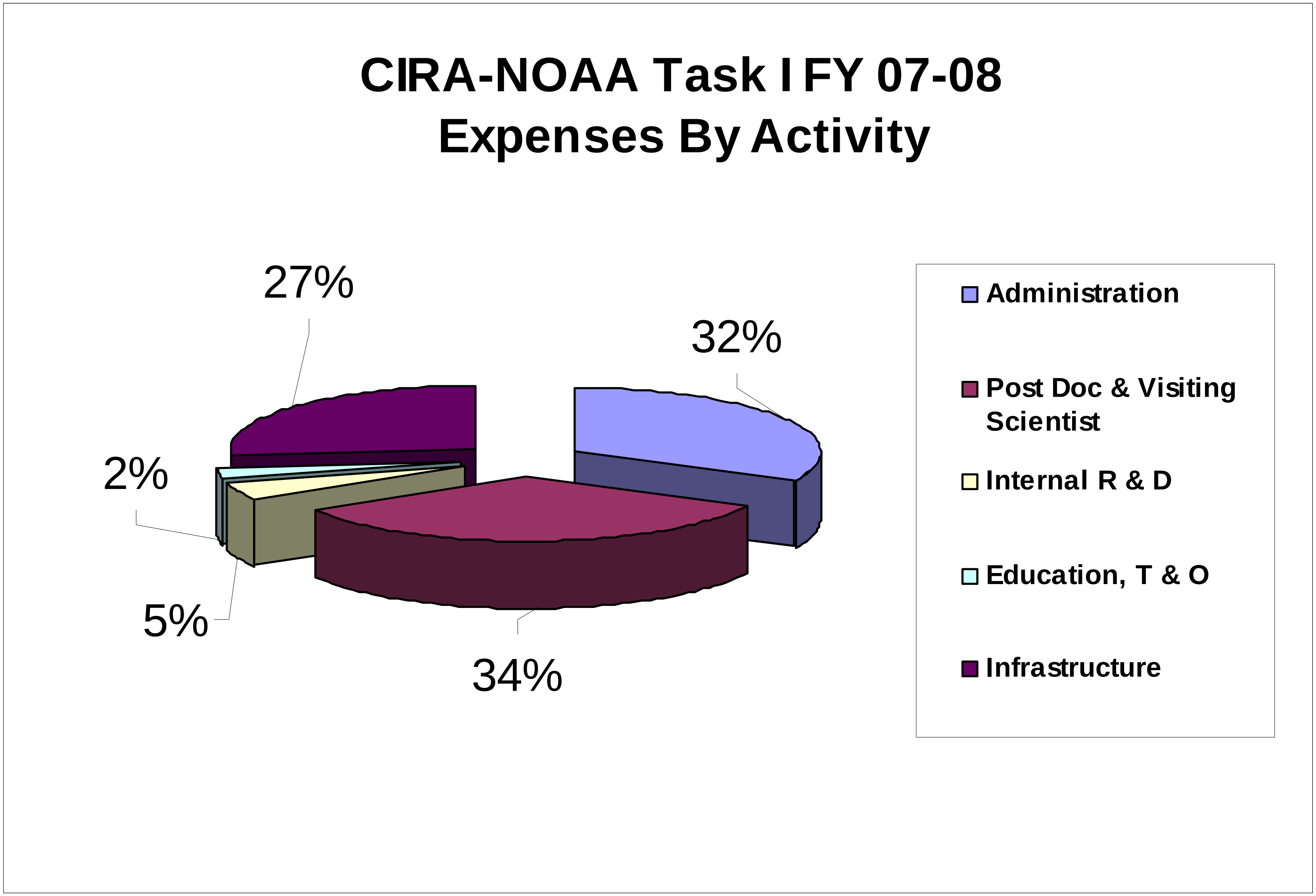
--Applied social science connected to the Advance Hydrologic Automated Prediction System (AHAPS) has improved the effective distribution of water resources information through improved organization of dissemination web-based tools. These advanced approaches were presented at the Weather And Society Integrated Studies (WAS*IS) program workshop.

--Sociological research in collaboration with NIDIS improved its web portal for the Dec 07 completion. Initial public comment was favorable. This approach can provide a template for a similar approach in severe weather product utility analysis beyond just economic analysis.

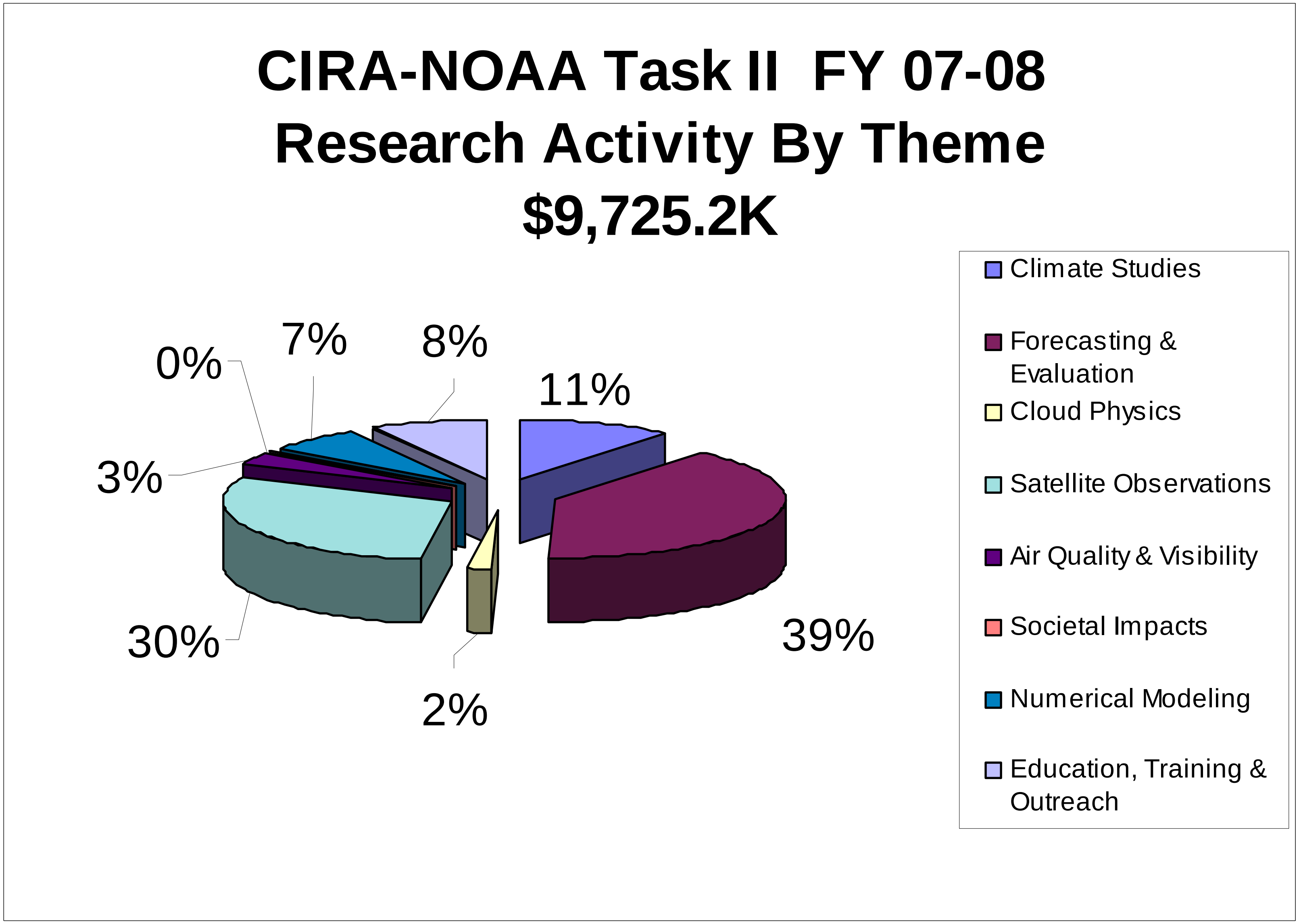
Infrastructure

--The CIRA Data Systems Group at ESRL/GSD continued to design and develop new software to streamline the acquisition and processing of data. An “Object Data System” technique was applied to develop a new maritime data decoder to replace legacy software. Other decoders and translators underwent significant updates. Data acquisition and processing affecting virtually all GSD projects—from Nexrad surface radar and environmental satellite observations to profiler and mesonet data—were developed or enhanced.

--Expansion of CIRA Research Collaboration with the NWS Meteorological Development Lab: The objectives of this project for this year were met when the software was installed operationally, and NCAR reconfigured their operational software to use the AWIPS forecaster input data (boundaries, polygons, regime changes). The significance of this achievement goes beyond providing improved severe weather situational awareness in that NCAR provides the FAA Central Weather Service Unit (CWSU) at Fort Worth (ZFW) with operational products to assist in regional air traffic control. These data are now being served using input data provided by NWS forecasters using AWIPS.



CIRA-NOAA Task I FY 07-08
Expenses By Activity
27%
32%
2%
5%
34%
Administration
Post Doc & Visiting Scientist
Internal R & D
Education, T & O
Infrastructure


CIRA-NOAA Task II FY 07-08
Research Activity By Theme
$9,725.2K
0%
7%
8%
11%
3%
30%
2%
39%
Climate Studies
Forecasting & Evaluation
Cloud Physics
Satellite Observations
Air Quality & Visibility
Societal Impacts
Numerical Modeling
Education, Training & Outreach

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 as yet

7. Outreach:

Conference and meeting presentations:

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., and C. A. Hiemstra, 2008: A simple data assimilation system for complex snow distributions (SnowAssim). J. Hydrometeorology, in press.

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, in press.

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, in press.

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.

A SATELLITE ANALYSIS OF ATMOSPHERIC RIVERS

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: POES, AMSU, Satellite-Derived Wind Measurements

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

Filaments of high water vapor content, termed “atmospheric rivers” are often observed ahead of cold fronts in midlatitude cyclones. Temperature and moisture profiles from the ATOVS (Advanced TIROS Operational Vertical Sounder) product suite available from the NOAA series polar-orbiting satellites are being used to observe atmospheric rivers occurring over the eastern North Pacific Ocean.

Specifics of the plan to develop this technique include:

Using the hydrostatic assumption and a 100-hPa height field from a global model as a boundary condition, the virtual temperature profile will be used to compute the height field as a function of pressure, as well as the surface pressure. A balance equation is then solved for the streamfunction, from which the u and v components of the nondivergent wind may be calculated.

An omega equation and the equation of continuity will be used to compute the velocity potential, from which the u and v components of the irrotational winds may be calculated. When combined with the nondivergent wind, an estimate of the total wind field will be made throughout the depth of the troposphere.

A moisture budget derived from satellite observations will be performed.

The quality of the satellite measurements will be assessed through comparison to dropsonde data.

2. Research Accomplishments/Highlights:

Before the problems with the ATOVS data were uncovered (See #3 below), the code had been developed to the point where water vapor fluxes from atmospheric rivers could be computed for wind fields under geostrophic, linear, or nonlinear balance conditions. Figure 1 shows an example from 7 November 2006.

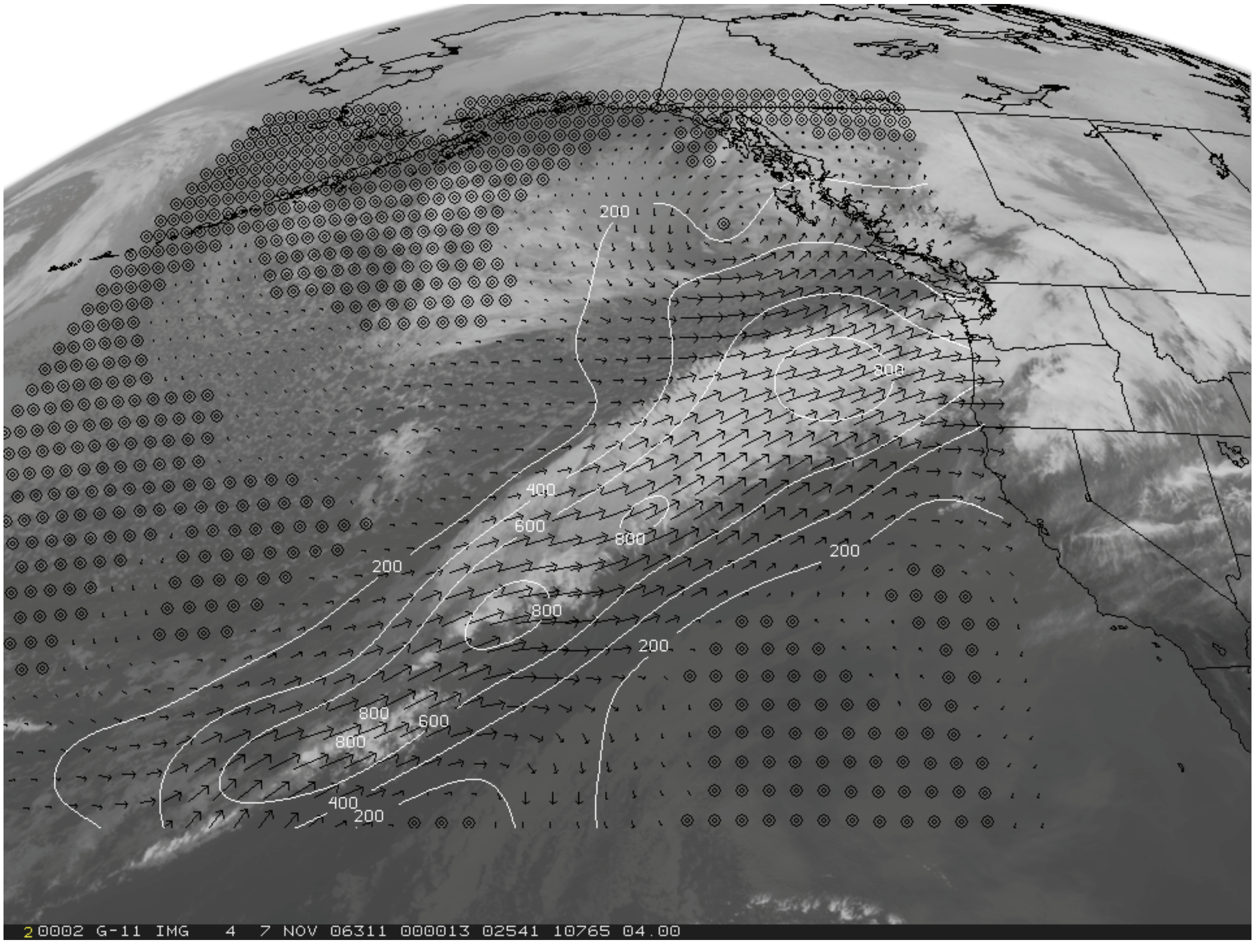


Figure 1. Total column water vapor flux vectors for the 7 November 2006 atmospheric river event. The winds used in the computation are from the nonlinear balance equation. The magnitude of the flux is contoured in units of kg m^{-1} s^{-1}.

As the problems with the ATOVS data began to appear, a decision was made to switch to a new dataset (See #3 below). The code then had to be reformulated to work with the new data. As part of the effort, the various balance approximations derived using the GFS heights were compared to the GFS winds (Figure 2). As the balance approximation becomes more accurate, the quality of the computed winds increases as expected. This result is a good indication that the code is working properly.

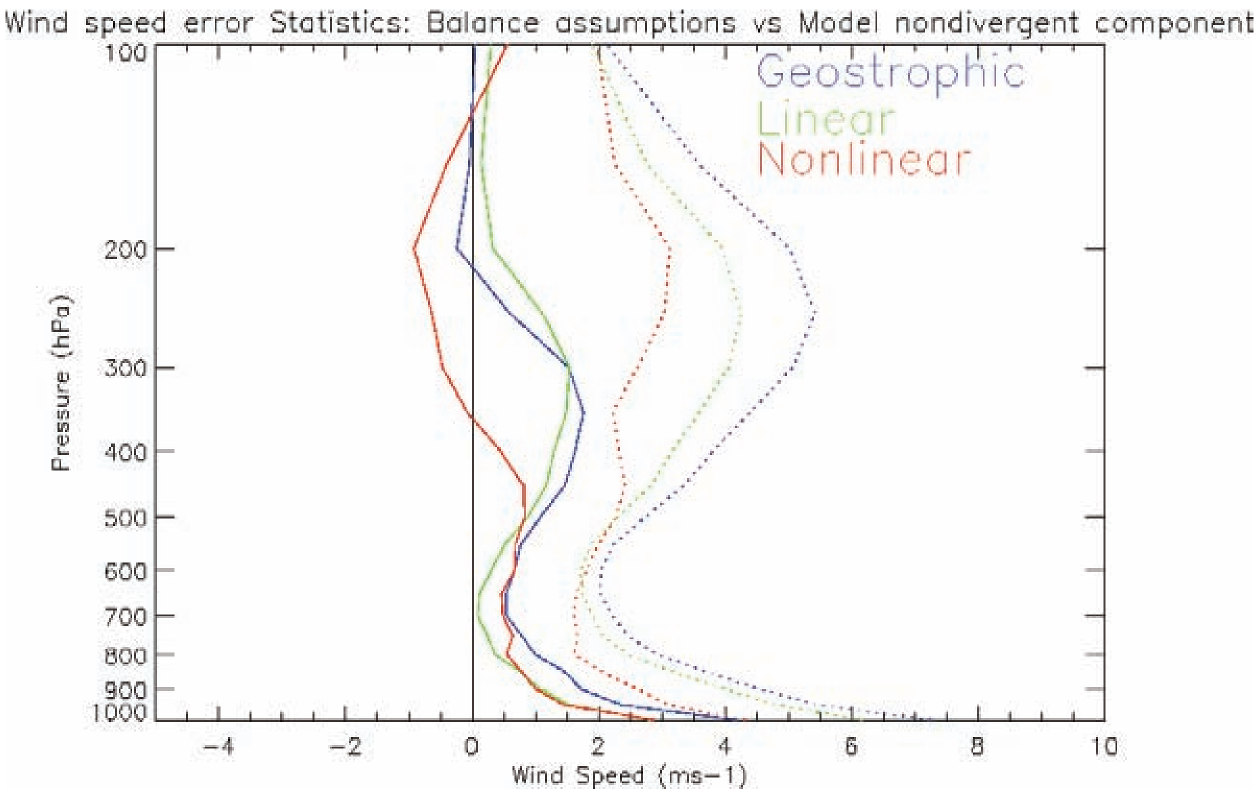


Figure 2. Using the height field from the GFS model, the winds associated with the geostrophic, linear, and nonlinear balance were compared to the model's nondivergent wind component.

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

During the course of the research, it was determined that the ATOVS data are likely of insufficient quality to analyze the characteristics of atmospheric rivers. Specifically, results of the work here, as well as information gathered from other researchers from CIRA, NESDIS, and the Naval Research Laboratory brought into question the quality of the temperature, total precipitable water (TPW), water vapor, and cloud liquid water retrievals from the ATOVS product suite. The problem with the TPW is illustrated in Figures 3a-3c, supplied by John Forsythe of CIRA. The plots show comparisons of TPW between AIRS (Atmospheric Infrared Sounder) and SSM/I (Special Sensor Microwave Imager) (Fig. 3a), AIRS and TMI (TRMM Microwave Imager) (Fig. 3b), and AIRS and ATOVS (Fig. 3c) for January 2003. AIRS, SSM/I, and TMI are in general agreement, but the ATOVS behaves as an outlier. Because the TPW given in the ATOVS datafiles is an integration of the vertical profile of water vapor retrievals, the questionable quality of the TPW indicates problems with the water vapor retrievals at the individual levels. The result could also be due to an error in the integration code, but this was checked and found not to be the problem.

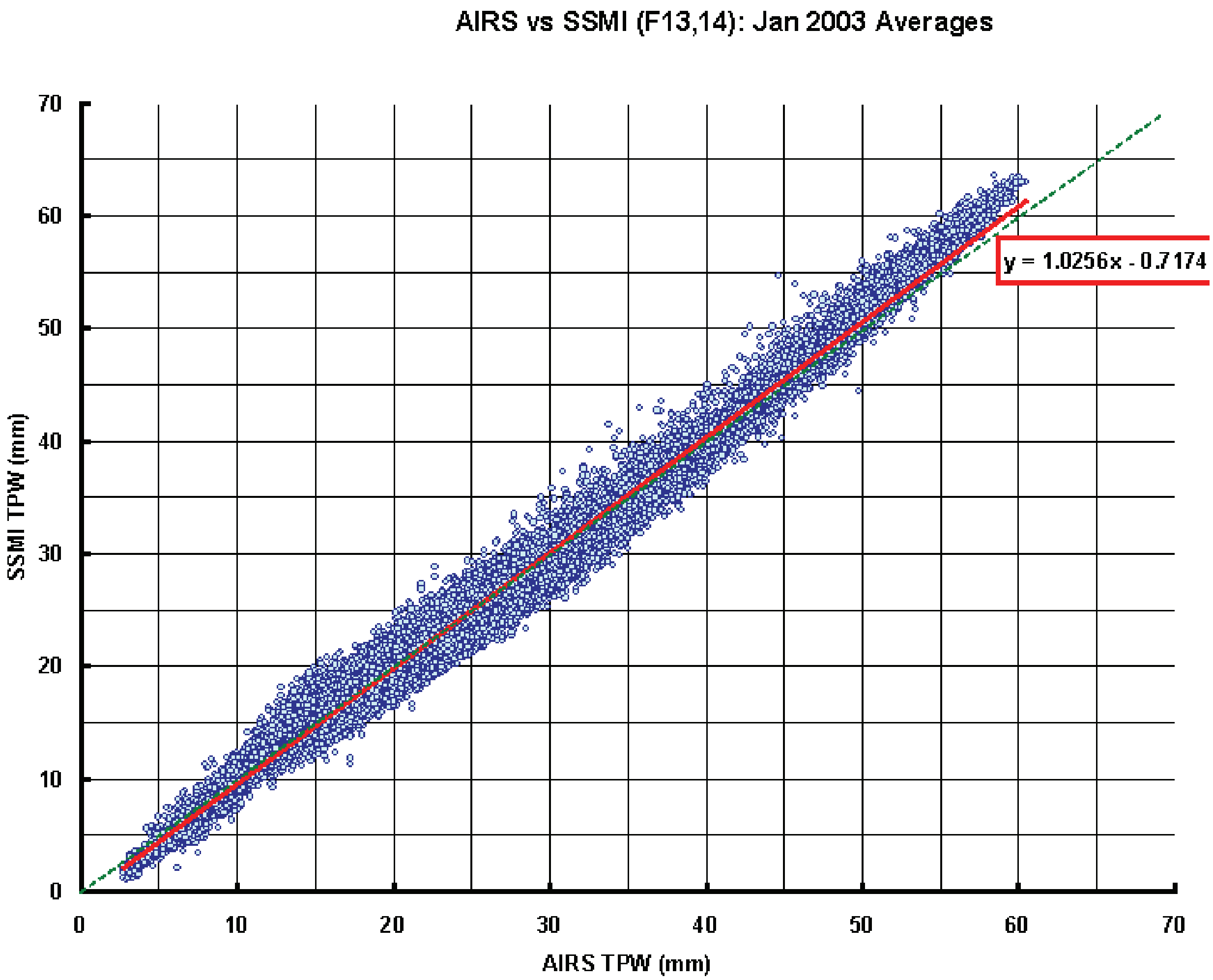


Figure 3a. Comparison of TPW as measured from AIRS and SSM/I.

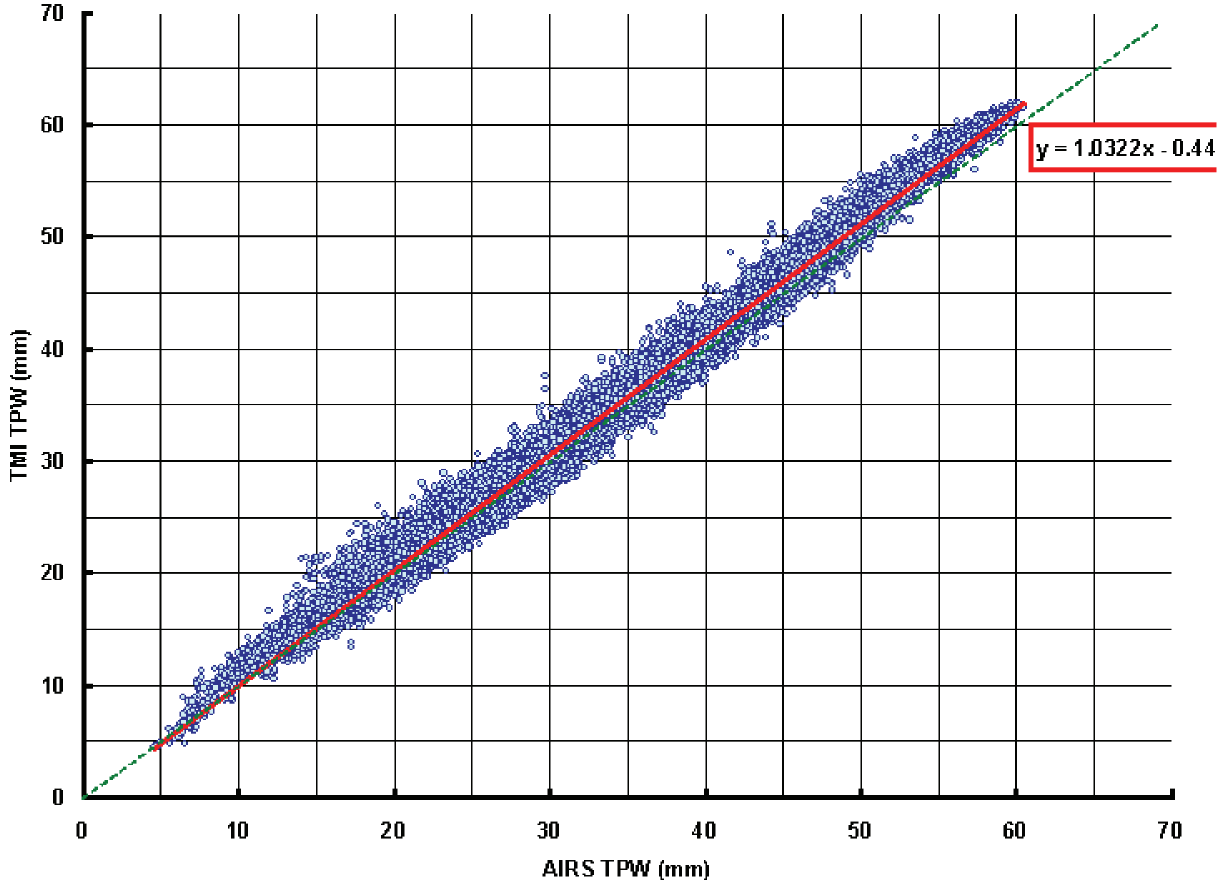


Figure 3b. Comparison of TPW as measured from AIRS and TMI.

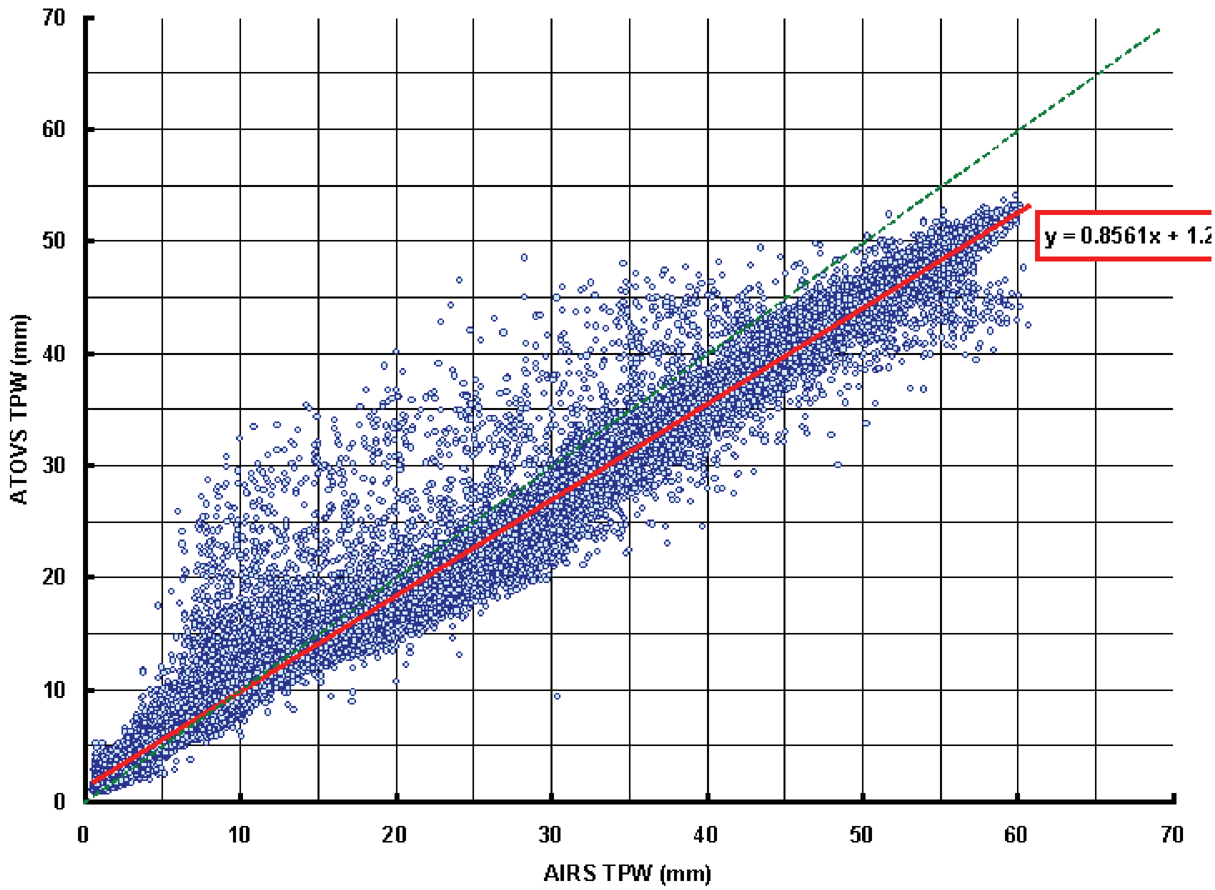


Figure 3c. Comparison of TPW as measured from AIRS and ATOVS.

A new retrieval method which is being developed at CIRA may very well be able to replace the ATOVS as the data used to analyze atmospheric rivers using satellite retrievals. The method, called C1DOE (CIRA 1-D Variational Optimal Estimator) uses information from both the AMSU-A and AMSU-B instruments and is currently undergoing development in order to be used in the study of atmospheric rivers.

4. Leveraging/Payoff:

Upon landfall, atmospheric rivers which form over the eastern North Pacific Ocean can contribute to heavy precipitation and flooding in the heavily-populated regions of the west coast of the United States. Because they form over the ocean, atmospheric rivers are poorly measured by conventional observations, if at all. Making the most of the information provided by satellite measurements could positively impact the quality of the forecasts of heavy precipitation along the Pacific Coast of the United States.

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

This project began due to communication with scientists at NOAA's Earth System Research Laboratory (ESRL) in Boulder, CO. A trip to Boulder to discuss atmospheric rivers with scientists at ESRL occurred in October 2006. Continued collaboration is expected.

6. Awards/Honors: None as yet

7. Outreach:

One college undergraduate assisted in the project. (Kashia Jekel)

Collaboration has occurred with CSU Masters student Brant Dodson, who is researching atmospheric rivers using the data from the CloudSat instrument. He participated in the October 2006 discussion in Boulder as well as the CoRP Symposium in College Park, MD.

<u>Conference Presentations</u>

Dostalek, J. F., 2006: Analysis of Midlatitude Cyclones and Fronts Using ATOVS Soundings. *13th Cyclone Workshop.* 22-27 October 2006, Pacific Grove, CA.

Dostalek, J. F., 2007: Analysis of Atmospheric Rivers in the Northeast Pacific Using AMSU Data. *NOAA/NESDIS/StAR 4th CoRP Symposium.* 19-20 June 2007, College Park, MD.

8. Publications: None as yet

ADVANCED ENVIRONMENTAL SATELLITE RESEARCH

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 U.S. Permanent representative to WMO

Advisor and U.S. 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 as yet

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 audiences 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. 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.

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.

ADVANCED HYDROLOGIC PREDICTION SERVICE (APPLIED SOCIAL SCIENCE RESEARCH IN COLLABORATION WITH NATIONAL WEATHER SERVICE'S (NWS) ADVANCED HYDROLOGIC PREDICTION SERVICE)

Principal Investigator: Shripad D. Deo

NOAA Project Goal: Weather and Water (Serve society's needs for weather and water information)

Key Words: Science, Communication, Education

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

To develop new understanding of how science and technology interface with society to enhance the quality of water resources information;

To suggest ways to improve the understanding of how science-based information is used by diverse user groups served by NOAA's National Weather Service; and

To improve usability of information by making it socially robust.

During the reporting period, the focus was on ways in which NWS needs to improve the understanding of the institutional, economic, and cultural constraints and contexts within which decisions are made by the users of their information. To provide useful and usable information, the NWS, as producer of information, needs to cultivate socio-technical networks, develop appropriate information tools, and understand the context in which these tools are used.

We have suggested different tools for NWS and users of water resources information. These tools are developed on the basis of controlled interaction and feedback. Focus groups, usability exercises, and workshops were conducted in different locations. The tools for forecasters include slide shows and web-based learning tools explaining the context in which users make decisions and their informational needs. The tools for the users include informational slide shows explaining the nature of uncertainties in hydrologic forecasting, the content of the forecast graphics, and organization of information on web pages.

2. Research Accomplishments/Highlights:

Effective distribution of water resources information through improved organization of dissemination tools, primarily, the web pages.

Increased awareness and appreciation of systematic collection and analysis of user information needs to enable them to make better decisions through qualitative social science research methods.

Increased awareness and recognition by forecasters and managers of social science perspective on science, technology, and society.

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

The primary objective of providing social science research input to enhance the quality and understanding of information for better decision-making was achieved during this reporting period through training workshops, focus groups, usability exercises at five locations and a new prototype design for web dissemination. The project is complete.

4. Leveraging/Payoff:

The work done with AHPS and water resources information has provided a template for social science perspective to pursue a similar approach in weather (severe weather warnings) and climate (information resources and drought) services.

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

The social science collaborative research work in water resources has attracted interest of the National Integrated Drought Information System (NIDIS) in using a similar approach to develop this new information portal.

6. Awards/Honors:

The project was recognized with a Regional Excellence Award in 2001 and 2002; NOAA Administrator's Award in 2004 and attracted the interest of Climate Services Division for social science research input. The efforts were recognized by a Regional Excellence Award for collaborative efforts with Climate Services Division in August 2004 and 2006.

7. Outreach:

The approaches and experiences gained from AHPS projects were presented to the interdisciplinary workshop organized by Weather and Society Integrated Studies (WAS*IS) program of NCAR at Boulder, CO and by NWS at Kansas City, MO.

8. Publications:

A short report on lessons learned from AHPS workshops and focus groups will be published on WAS*IS website.

ADVANCED WEATHER (AWIPS) SUPPORT FOR SATELLITE HYDRO-METEOROLOGY (SHYMET) AND VIRTUAL INSTITUTE FOR SATELLITE INTEGRATION TRAINING (VISIT) TRAINING AND EDUCATION

Principal Investigator: Bernie 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: 1) improved forecast training capabilities and NWS compatible VISIT training sessions due to training development on a platform used by NWS; 2) porting of CIRA research products into AWIPS; and 3) evaluation of and input to improvement of AWIPS satellite data utilization and analysis capabilities. To achieve these objectives, multiple NOAAPORT/AWIPS options have been researched, collaborative work with FSL, COMET and CIMSS has been completed, and funds for the NOAAPORT portion of the project have been obtained from NWS, and a proposal for funding of an AWIPS system has been submitted to NESDIS. This proposal provides funding to procure and install a server and high end workstation similar to those used for AWIPS operations at NWSFO's. Once the NOAAPORT data ingest and AWIPS data processing and display system are operational, joint efforts with the NWSFO in Cheyenne, Wyoming, FSL, COMET and CIMSS will continue to facilitate system familiarization, new product evaluation and investigation of product insertion.

2. Research Accomplishments/Highlights:

All software on the AWIPS data server, AWIPS workstation, and WES workstation has been upgraded to the latest field version. In addition, an experimental AWIPS workstation has been procured and configured for use in RAMMB product transition to AWIPS. The AWIPS configuration continues to provide RAMMB/CIRA researchers with real-time NOAAPORT data for analysis and archive. Data archived from the system was used to develop a Coastal Effects WES training course. An additional data server and expanded storage and archive capabilities have been implemented to alleviate bottlenecks in the initial configuration.

RAMMB/CIRA IT staff received product port training from SSEC IT staff, and efforts are underway to implement the RAMMB shortwave albedo product on the experimental AWIPS. Several other target products have been defined, and work is ongoing between RAMMB/CIRA and NWS staff to determine priorities for product transition.

RAMMB/CIRA staff has also met with forecasters and Science and Operations Officers in Cheyenne, WY, to transition the CIRA Wind Regime Cloud Climatology application and database to the AWIPS GFE (Graphical Forecast Editor). Initial problems with netCDF file formats are being addressed.

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

The project goals are to upgrade NOAAPORT/AWIPS and WES hardware and software. WFO collaboration and test product implementation are completed.

4. Leveraging/Payoff:

The current AWIPS configuration used in NWSFO's provides a minimal satellite data set and no advanced analysis capabilities. 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, Communications and Networking:

This project leverages funds obtained from NWS to facilitate data ingest. Collaborators include NWS, COMET, CIMSS, and WDTB. Collaborative projects with the Cheyenne, WY, and Eureka CA, forecast offices are underway.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

AN IMPROVED WIND PROBABILITY ESTIMATION PROGRAM

Principal Investigator: Stan 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:

A Monte Carlo (MC) method was utilized to combine the uncertainty in the track, intensity and wind structure forecasts under Joint Hurricane Testbed (JHT) funding. The project includes three tasks to improve the probability program, as follows.

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 the Naval Research Laboratory 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.

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

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 website, and was developed from data from 1988-1997. In addition to using error distributions that are at least 10 years old, the current version of this product only extends to 72 hr even though the NHC official forecasts were extended to 120 hr in 2003.

2. Research Accomplishments/Highlights:

Progress was made on each of the above three tasks. The MC algorithm was reformulated as a two dimensional problem so that the costliest program components could be eliminated over most of the product domain where they are not needed. The optimized code provided a speed up of about 600%. The new code was delivered to NHC and implemented in time for the 2007 hurricane season.

The MC code was also modified to produce all of the input needed for the wind speed probability table program. Since the MC model already runs to 5 days, there will no longer be a need for a separate program to generate the wind probability table input. Arrangements are being made to modify the real time wind speed probability table web product for the 2008 hurricane season.

The inclusion of GPCE information to modify the track probability distributions has a significant impact on the wind speed probability distribution, illustrated in Fig. 1. Special modifications to the probability distributions accounts for the fact that the GPCE was originally developed to estimate the average of the total track error, which is always positive, but the MC model is formulated in terms of along and cross track error which can be negative or positive and have a mean value near zero. The GPCE version of the MC model will be run in parallel during the main part of the 2008 hurricane season. Following the hurricane season these GPCE-Modified MC wind speed probabilities will be compared to the operational MC wind speed probability output.

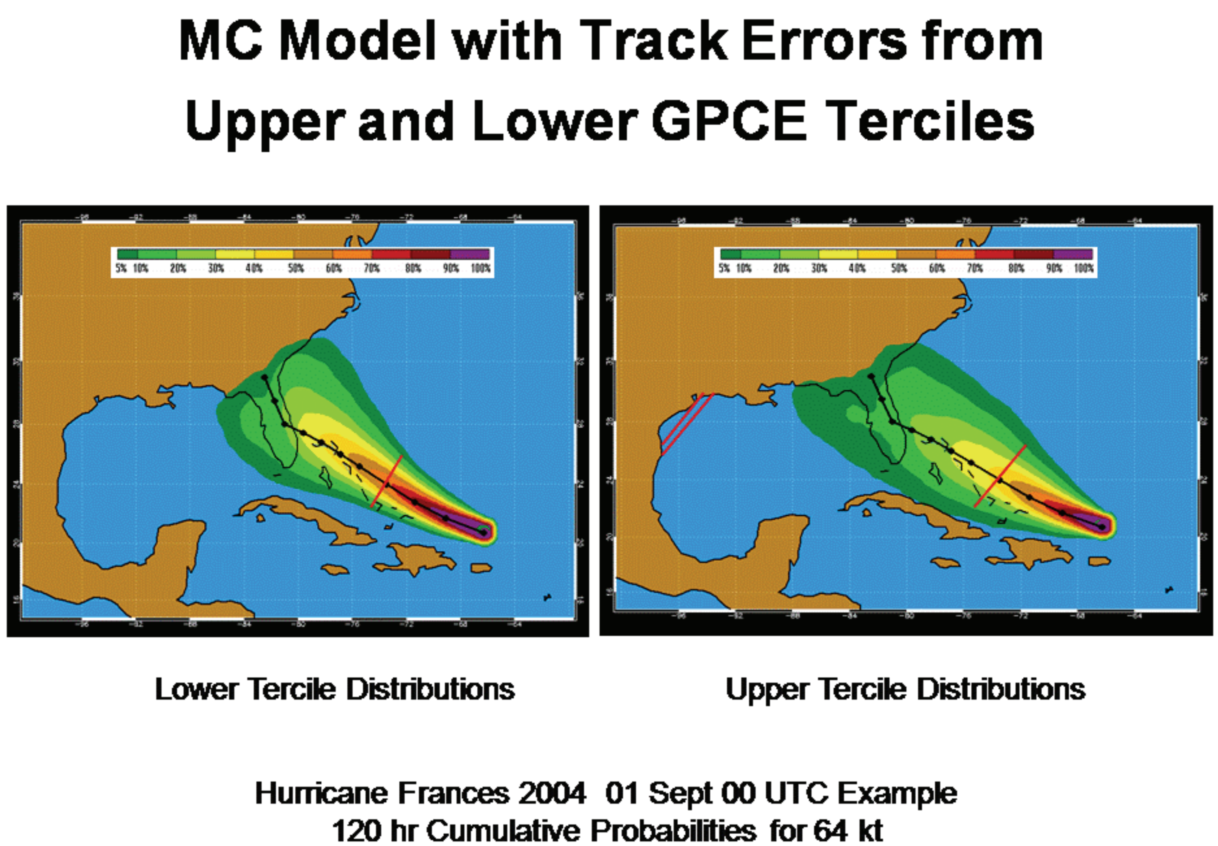


Figure 1. An example of the cumulative 120-h wind speed probability distribution resulting from the GPCE lower tercile and upper tercile for Hurricane Frances 1 September 2004 at 00 UTC.

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 among 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 as yet

7. Outreach:

<u>Presentations</u>

DeMaria, M., S. Kidder, P. Harr, J. Knaff and C. Lauer, 2007: An Improved Wind Probability Program: A Joint Hurricane Testbed Project Update. *62nd Interdepartmental Hurricane Conference*, 3-7 March, Charleston, SC.

8. Publications:

<u>Conference Proceedings</u>

Knabb, R., M. Mainelli, and M. DeMaria, 2008: Operational Tropical Cyclone Wind Speed Probability Products from the National Hurricane Center. *AMS Annual Meeting*, January 2008, New Orleans, LA.

ANALYSES AND DIAGNOSTIC STUDIES FROM SMN RADAR AND RELATED DATA IN SUPPORT OF NAME

Principal Investigator: Timothy J. Lang

NOAA Project Goal: Climate – Climate Observations and Analysis, Climate Predictions and Projections, Climate Forcing

Key Words: Radar Meteorology, North American Monsoon, Rainfall

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

Calibrate and quality control Mexican weather service (SMN) radar-rainfall data obtained during the North American Monsoon Experiment (NAME), which occurred during summer 2004. For this we are intercomparing measurements from the SMN radars with raingauges, the NCAR/NSF S-Pol polarimetric radar, and the TRMM satellite.

Create a merged, quality-controlled reflectivity product from all available radars (SMN and S-Pol) that can be used to develop high temporal resolution (~15 minutes) 2-D rainfall maps. Then post these products on the NAME website and in the JOSS archive for access by all NAME investigators.

Carry out basic diagnostic studies using the merged radar products, emphasizing quantitative rainfall estimation, convective fraction of precipitation, event structure and evolution, convective forcings, mesoscale dynamical organization, and diurnal cycle. These secondary data products will also be shared with the NAME community.

Evaluate biases in satellite rainfall over the NAME region using NAME radar-based rainfall products.

Study the relationships between convective storms, synoptic forcing, and lightning in this region, through intercomparison of the radar-based rainfall products, upper-air data, and cloud-to-ground lightning observations made by the long-range National Lightning Detection Network (NLDN).

2. Research Accomplishments/Highlights:

Version 1 2-D radar composites have been used to analyze the spatial and temporal variability of precipitation in the NAME Tier I domain. Based on the initial findings of this analysis, it is found that terrain played a key role in this variability, as the diurnal cycle was dominated by convective triggering during the afternoon over the peaks and foothills of the Sierra Madre Occidental (SMO) mountain range. Precipitating systems grew upscale and moved WNW toward the Gulf. Distinct precipitation regimes within the monsoon are identified. The first, Regime A, corresponded to enhanced precipitation over the southern portions of the coast and GoC, typically during the overnight and early morning hours. This was due to precipitating systems surviving the westward trip (~7 m s^{-1}; 3-4 m s^{-1} in excess of steering winds) from the SMO after sunset, likely because of enhanced environmental wind shear as diagnosed from local soundings. The second, Regime B, corresponded to significant northward/along-coast movement of systems (~10 m s^{-1}; 4-5 m s^{-1} in excess of steering winds), and often overlapped with Regime A. The weak propagation is explainable by shallow/weak cold pools. Reanalysis data suggest that tropical easterly waves were associated with the occurrence of disturbed regimes. Gulf surges occurred during a small subset of these regimes, so they played a minor role during 2004. Mesoscale convective systems and other organized systems were responsible for most of the rainfall in this region, particularly during the disturbed regimes. This work has been published in the *Journal of Climate*.

We released Version 2 of the NAME radar composites to the NAME community in summer 2006. This dataset, like Version 1, provides rainfall and reflectivity snapshots every 15 minutes over 6 weeks of observations, encompassing the main period of the North American Monsoon (July and August). The dataset features improved beam blockage correction in the S-Pol radar domain, improved rain rate estimates throughout the entire composite domain, and IR brightness temperatures on the same grid as the radar data, for improved identification of sea clutter near Cabo San Lucas. This dataset was used by the students supported on this grant.

We released Version 1 of the 3-D S-Pol radar grids, matched horizontally to the regional multi-radar 2-D grids released earlier. These 3-D grids were used to examine the vertical structure of precipitating systems in the NAME domain.

We have examined selected high-resolution satellite rainfall estimates using the field campaign precipitation observations from NAME. This study forms a major contribution to the Pilot Evaluation of High Resolution Precipitation Products (PEHRPP), which is sponsored by the International Precipitation Working Group. Findings include the following:

--Ground-based precipitation estimates show improved agreement (when using Version 2 NAME radar products compared to gauges relative to Version 1);
--Ground based-products provide evidence that CMORPH and PERSIANN (both microwave-bias corrected) overestimate precipitation along the and west of the SMO.
--However, TRMM, CMORPH, and PERSIANN do a good job at representing the basic diurnal cycle of precipitation, however phase lags of 1-2 hours are common. Microwave estimates tend to peak a few hours later than ground-based products.
--The vertical structure of convection changes over the diurnal cycle and likely impacts the amount and timing of precipitation in the radar and satellite estimates.

Lightning data has been used as a proxy for convective vertical structure/intensity, and in particular, the relative phasing of convective vertical structure with the dynamics of tropical easterly waves (TEWs) as they propagate potential vorticity, vertical wind shear, and moisture westward and northward into Central and North America. To this end, we employ long range NLDN lightning data in the tropical latitudes south of the U.S. as a convective structure proxy. In addition, high space and time resolution precipitation data from the NOAA-CPC CMORPH 3-hr rainfall product, and environmental data from the NCEP North American Regional Reanalysis (NARR) will be examined in the context of easterly wave phase and convective intensity estimates provided by the lightning data during the 2004 warm season to examine precursors of monsoon bursts in the southwest U.S. Findings include:

--Lightning and rainfall are extremely well correlated over Arizona (i.e., rain yield is constant); the correlation decreases toward the south.
--Monsoon onset in NW Mexico and Arizona was punctuated by strong lightning burst and temporarily decreased rain yield over the SMO. Rain yields are lower during the core of the monsoon season than during non-monsoon periods over NW Mexico.
--For the lightning events during 2004, easterly waves, troughs in the westerlies, and gulf surges played a role in generating convection in Arizona; easterly waves are shown to be a key driver in modulating lightning in NW Mexico during the monsoon.
--Coherent moisture buildups along the SMO, advected in southeasterly flow from the Tropics, are identified in the NARR data.

Using the 2-D regional grids, various rain statistics have been computed. These results were qualitatively similar to those from the NAME Event Rain Gauge Network (NERN), but provided more spatial context and resolution compared to that possible from rain gauge data alone. There is a clear diurnal cycle in precipitation, with rain production in the highest terrain band sampled (> 2000 m MSL) leading rain production at lower elevation (1000-2000 m) by about 3 hours. Rain intensities were about a factor of two larger at lower elevation compared to rain rates at the highest elevation band sampled (> 2000 m). A pronounced diurnal cycle in precipitation frequency also was evident, indicating the strong preference for rain in the afternoon and evening hours. Around the afternoon peak, rain was more probable at higher elevation compared to the coastal plain (the latter defined as the 0-1000 m elevation band). Echo-top heights during NAME showed an approximately trimodal structure, a finding similar to the one seen in the TOGA-COARE experiment. There was a low-altitude mode near 2 km MSL, a mid-level mode near 9 km, and an upper-level mode near 13-14 km that was most apparent in the 1000-2000 m elevation band. Past studies have interpreted the low-level mode as due to the commonly observed trade-wind inversion in the tropics, while the mid-level mode corresponded to a congestus phase. The upper mode was associated with deep cumulonimbus convection. This result demonstrates that, despite the strong topographical forcing in the NAME region, convective characteristics may have broad similarities to other tropical locales.

Using the 2-D regional radar composites and synoptic analysis products, we have performed an objective analysis of precipitation features during NAME and their relationship to synoptic regimes. Ninety-nine percent of precipitation is produced by features at least 25 km^2 in size. Most features are convective, small, and unorganized in nature; however, the majority of precipitation (~72%) is produced by MCS-sized features, and these MCS features are generally unorganized as well (57% of rainfall generated from non-linear MCS, 15% from linear MCSs). The diurnal cycle is evident in number of features and rainfall as a function of time of day. Maximum values occur around 6 p.m. local, minimum values occur around 10 a.m. Examination of the thermodynamic and kinematic fields indicate that there were significant fluctuations in shear during the period of our analysis. Low-level shear is very small, and these fluctuations only become evident when shear is computed through a deeper layer (4 or 6 km deep). Overall, 6-km shear seems to be a bit stronger further south in our domain compared to the northern edge of our radar analysis. Thermodynamics fluctuations are also observed, though not with the same periodicity and magnitude as the shear. Moreover, the CAPE values, unlike the shear, are larger further north. We are currently attempting to identify if these changes in mesoscale thermodynamic and kinematic conditions are associated with variations in rainfall and organization structure of features.

We have contributed to an overview journal article on the entire NAME project, which was published in 2006 in the *Bulletin of the American Meteorological Society*.

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

Complete – Data quality control and radar intercomparisons are complete and all dataproducts have been released to the community. No further QC work is planned.

Complete – Version 2 merged radar composites are now available. We have released Version 1 of the 3-D quality-controlled grids from just the S-Pol radar, which are matched to the 2-D regional grids.

Complete – We have published a journal article on the initial findings of these analyses (Lang et al. 2007). The Ph.D. student on this grant has finished his work and will defend soon.

Complete – The M.S. student on this grant defended and has a paper on her work accepted for publication. In addition, another paper on satellite biases, led by Steve Nesbitt of UIUC, was accepted for publication.

Complete – Analysis of the lightning and environmental data taken during NAME has been completed.

4. Leveraging/Payoff:

NAME seeks to determine the underlying sources of predictability of warm season precipitation over North America. To achieve its objectives, NAME employs a multi-scale approach with focused monitoring, diagnostic, and modeling activities in the core monsoon region (Tier I), on the regional scale (Tier II), and on the continental scale (Tier III). The SMN and S-Pol radar observations were made in order to improve our understanding of convective processes within Tier I (northwestern Mexico and the southwestern United States), the central location of the North American Monsoon system. The latent heat release from the convection in this region is a principal driver for the monsoon, which itself is a principal mode of variability for warm season weather in the United States. Thus, in order to improve our understanding and forecasting ability of this weather, we must better understand the large-scale behavior of the monsoon, and for that we must first understand the behavior of convection with its core region. In particular, we need to examine the effects of various atmospheric, oceanic, and land surface characteristics and processes on convective behavior, as well as on precipitation amount and distribution. The NAME radar network is being used to understand these effects.

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

Walt Petersen of University of Alabama-Huntsville – Collaboration on lightning, radar and upper-air analyses

Phil Arkin of University of Maryland – Collaboration on intercomparison with satellite rainfall estimation

David Gochis of NCAR – Collaboration on intercomparison with satellite and gage rainfall estimation

Rit Carbone and Dave Ahijevych of NCAR – Collaboration on collection of the data, quality control of the data, synthesis of the radar composites, merging of radar and raingauge data, and analysis of the data

Vaisala Corporation – Providers of long-range NLDN data

6. Awards/Honors: None as yet

7. Outreach:

L. Gustavo Pereira, Ph.D. candidate
Angela Rowe, M.S. student

8. Publications:

Ahijevych, D. A., R. E. Carbone, T. J. Lang, S. W. Nesbitt, and S. A. Rutledge, 2006: Radar-observed precipitation during NAME 2004. *1st CPPA PIs and 8th NAME Scientific Working Group Meetings*, Tucson, Arizona.

Carbone, R. E., D. Ahijevych, A. Laing, T. Lang, T. D. Keenan, J. Tuttle, and C-C. Wang, 2006: The diurnal cycle of warm season rainfall frequency over continents. *27th Conference on Hurricanes and Tropical Meteorology*, Monterey, California.

Carbone, R. E., T. Lang, D. Ahijevych, S. Nesbitt, D. Gochis, S. Rutledge, and R. Cifelli, 2006: Diurnal and intra-seasonal variability of precipitation in the North American Monsoon region. *Second International Symposium on Quantitative Precipitation Forecasting and Hydrology*, Boulder, Colorado.

Higgins, W., et al., 2006: The North American Monsoon Experiment (NAME) 2004 Field Campaign and Modeling Strategy. *Bulletin of the American Meteorological Society*, 87, 79–94.

Lang, T. J., D. A. Ahijevych, S. W. Nesbitt, R. E. Carbone, S. A. Rutledge. And R. Cifelli, 2007: Radar-observed characteristics of precipitating systems during NAME 2004. *Journal of Climate*, 20, 1713-1733.

Lang, T. J., S. W. Nesbitt, R. Cifelli, D. Ahijevych, R. Carbone, S. A. Rutledge, 2006: The diurnal cycle in NAME. Preprints, *27th Conference on Hurricanes and Tropical Meteorology*, Monterey, CA., Amer. Meteor. Soc.

Lang, T. J., S. W. Nesbitt, R. Cifelli, S. A. Rutledge, D. Lerach, L. Nelson, G. Pereira, A. Rowe, D. A. Ahijevych, and R. E. Carbone, 2006: Continuing research on radar-observed precipitation systems during NAME 2004. *1st CPPA PIs and 8th NAME Scientific Working Group Meetings*, Tucson, Arizona.

Lang, T. J., D. Ahijevych, R. Carbone, R. Cifelli, S.W. Nesbitt, G. Pereira, and S. A. Rutledge, 2005. "Radar Observations During NAME 2004. Part I: Data Products and Quality Control", 32nd Conf. On Radar Meteorology, Albuquerque NM, American Meteorological Society.

Lang, T. J., D. Ahijevych, R. Carbone, R. Cifelli, S.W. Nesbitt, G. Pereira, and S. A. Rutledge, 2005. "Radar Observations During NAME 2004. Part II: Preliminary Results", 32nd Conf. On Radar Meteorology, Albuquerque NM, American Meteorological Society.

Lang, T. J., D. Ahijevych, R. Carbone, R. Cifelli, S.W. Nesbitt, G. Pereira, and S. A. Rutledge, 2005. "Radar Observations During NAME 2004 – Data Products and Initial Results", NOAA Climate Diagnostics and Prediction Workshop, State College, PA, NOAA.

Nesbitt, S. W. and D. Gochis, 2007: The upscale growth of convection along the Sierra Madre Occidental during the North American Monsoon Experiment: Implications for precipitation estimation in complex terrain. *J. Hydromet.*, submitted.

Nesbitt, S. W., D. J. Gochis, and T. J. Lang, 2006: The initiation and upscale growth of convection within the diurnal cycle along the Sierra Madre Occidental. *1st CPPA PIs and 8th NAME Scientific Working Group Meetings*, Tucson, Arizona.

Nesbitt, S. W., T. J. Lang, R. Cifelli, S. A. Rutledge, D. A. Ajijevych, R. Carbone, P. Arkin, and M. Sapiano, 2006: An evaluation of high resolution satellite precipitation products during NAME. Poster, Second International Symposium on Quantitative Precipitation Forecasting and Hydrology, 4-8 June 2006, Boulder, CO, USA.

Nesbitt, S. W., W. A. Petersen, and S. A. Rutledge, 2006: Using lightning, rainfall, and reanalysis to study the intraseasonal variability in the North American Monsoon. Poster, American Geophysical Union Joint Assembly, 23-26 May 2006, Baltimore, MD, USA.

Nesbitt, S. W., D. Gochis, and T. J. Lang, 2008: The upscale growth of convection along the Sierra Madre Occidental during the North American Monsoon Experiment: Implications for precipitation estimation in complex terrain. *Journal of Hydrometeorology*, Accepted.

Pereira, L. G. and S. A. Rutledge, 2006: On the Relationship Between Horizontal Organization of Precipitationg Systems, Easterly Waves and Gulf Surges. Preprints, 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, Amer. Meteor. Soc.

Rowe, A. K., S. A. Rutledge, T. J. Lang, P. E. Ciesielski, and S. M. Saleeby, 2008: Elevation-dependent trends in precipitating features observed by the NAME radar network. *Monthly Weather Review*, Accepted.

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.

The following is an excerpt from our presentation to the Department of Energy for our work in the participation in the ARM (Atmospheric Radiation Measurement) program.

Measures of aerosol-cloud interactions and their uncertainties: A case study from the AMF Pt. Reyes deployment

Allison McComiskey, Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder / NOAA Earth System Research Laboratory
Graham Feingold, NOAA Earth System Research Laboratory, Boulder, CO
Shelby Frisch, Cooperative Institute for Research in the Atmosphere, Colorado State University / NOAA Earth System Research Laboratory, Boulder, CO
Qilong Min, Atmospheric Sciences Research Center, State University of New York, Albany

Introduction:

Measures of aerosol-cloud interactions (ACI), derived from a range of instruments and platforms, vary widely. As these measures are used in GCM parameterizations, understanding the causes and nature of this variability is necessary in understanding and improving resulting uncertainty in calculated radiative forcing. Using data from the AMF Pt. Reyes deployment in 2005, we demonstrate the nature of aerosol-cloud interactions, specifically the first aerosol indirect effect, and variability in ACI measures for marine stratus over the California coast.

Some of the results are shown in Figures 1 and 2. ACI, the aerosol cloud interaction, is defined as:

$$ACI = \frac{1}{3}\frac{d\ln N_d}{d\ln\alpha}$$

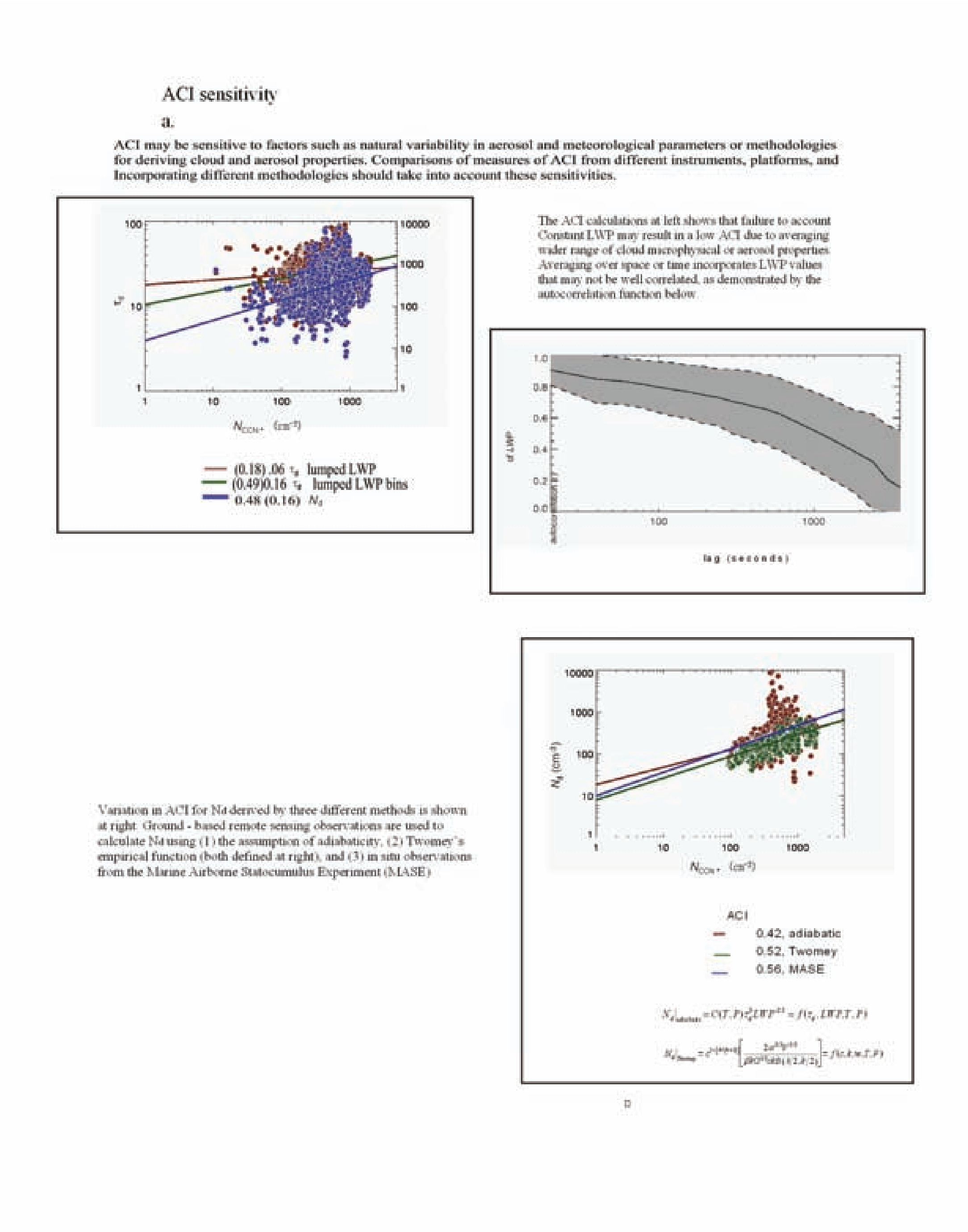


Fig. 1. Aerosol-Cloud Interaction (ACI) sensitivity examples. Effects of LWP and averaging and methods.

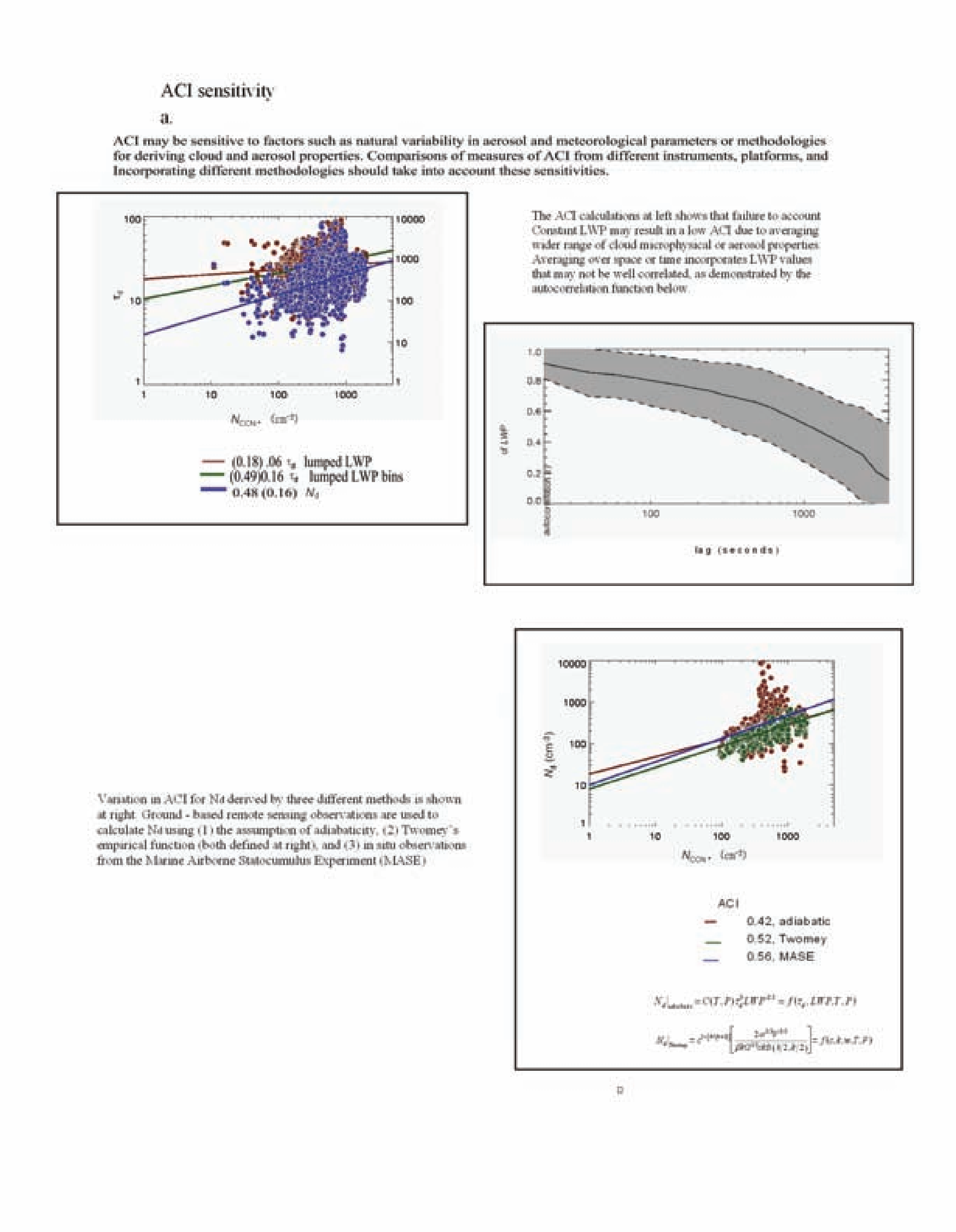


Fig. 2. ACI and Updraft Velocity.

The results are summarized as:

GCMs use ACI to parameterize aerosol-cloud interactions.

Variability in observed ACI is high.

Attribution to physical processes and/or measurement uncertainties is unclear.

Empirical measures of ACI explored for California coastal stratocumulus show:

Consistency among various ACI representations

Ground-based measures consistent with *in situ* airborne measures

Variability in ACI with dependence on (1) assumption of constant *LWP,* (2) methods for retrieving N_d, (3) particle size, and (4) updraft velocity

Variability in ACI is presented in the context of local cloud radiative forcing for California coastal stratocumulus from ~ -3 to -9 W m^{-2} for a range of *LWP* and aerosol concentrations from ~ -3 to -10 W m^{-2} for each 0.05 increment error in ACI.

The Pt. Reyes AMF deployment ran from May through September 2005. Observations used in this analysis from ground-based remote sensing and surface *in situ* monitoring are shown in the report. Measurements of cloud properties are made at a temporal resolution of 20 seconds, aerosol light scattering at one minute, and CCN concentrations at 30 minutes. All observations are interpolated to 20 second temporal resolution. The subset of data used in this analysis includes observations for which all variables are available and *LWP* values fall between 50-300 g m^{-2}.

Statistics for the full deployment, shown in the frequency histograms in the report, provide ample variability for quantification of the first indirect effect.

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:

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

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

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 Accomplishments/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 one hurricane event and for several 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.

For the Hurricane Wilma (October 2005) mesoscale case study, the CSU RAMS model produced an 11 hour forecast for the time period of 18 -19 October 2005. Forecast fields were saved every 5 minutes. Synthetic GOES-R ABI satellite imagery was produced for the ten upper GOES-R ABI channels at 3.9 µm, 6.19µm, 6.95 µm, 7.34 µm, 8.5 µm, 9.61 µm, 10.35 µm, 11.2 µm, 12.3 µm, and 13.3 µm. An example of synthetic GOES-R Hurricane Wilma imagery at the 10 wavelengths for one time step (19 October 2005 at 1705 UTC) is given in Figure 1 below.

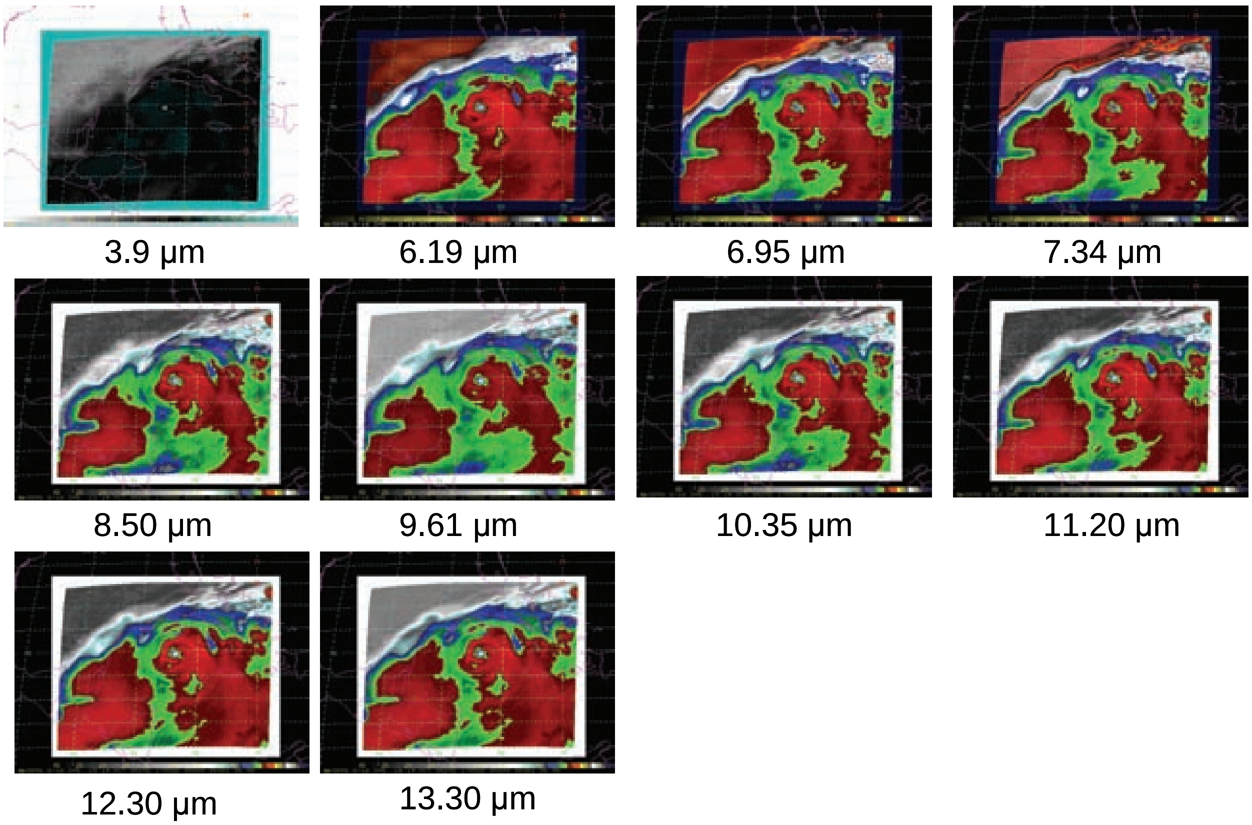


Figure 1. Synthetic GOES-R ABI imagery depicting Hurricane Wilma on 19 October 2005 at 1705 UTC for the ten upper GOES-R ABI channels (band 7 through 16).

Real fire events as well as hypothetical fires were used to produce GOES-R ABI fire proxy datasets for three different ABI wavelengths, 3.9 µm, 10.35 µm, and 11.2 µm. The hypothetical fires were embedded in a severe weather case over Kansas (May 2003). For this case, 135 fires were located on a regularly spaced grid with fire temperature and fire size increasing in linear steps. The simulations generated radiance fields under a variety of conditions: constant fires with no clouds, constant fires with clouds, and flickering fires with no clouds present. Close collaboration with fire experts ensured that the simulated fires resemble realistic situations in fire temperature, size and flickering frequency.

Real fire scenarios were simulated for a case of agricultural fires in Central America (April 2004) and for the Southern California fires which occurred in October 2007. Information regarding the fire location and fire temperature was taken from a CIMSS dataset (ABBA retrieval based on a GOES-12 image). Figure 2 below depicts the Southern California fires from 23 October 2007. On the left is an enhanced true color MODIS image from Aqua at a resolution of 1 km. This is a NASA product with enhanced fire locations. On the right is a CIRA/RAMM Branch product. This is part of the GOES-R AWG proxy dataset which was produced in support of GOES-R ABI algorithm development. For this fire case, a 6-hour RAMS forecast was produced at 400 m spatial resolution and at an interval of every 5 minutes. The ABI-like satellite imagery is then created by applying an ABI wavelength-specific point spread function considering the actual ABI footprint for the area of Southern California.

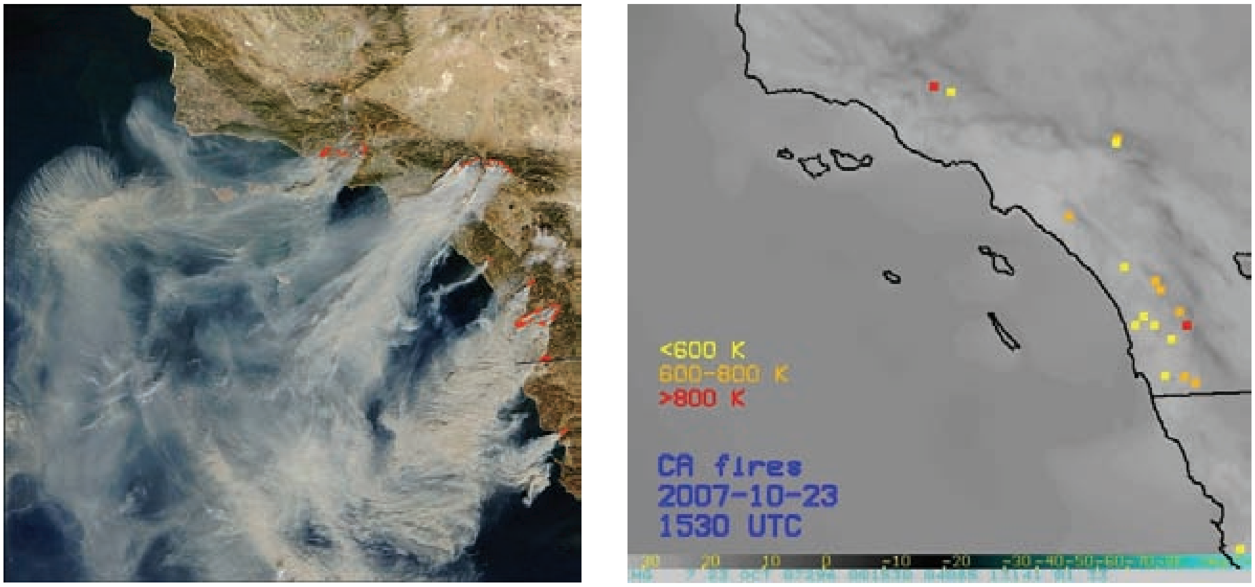


Figure 2. Fires in Southern California on 23 October 2005. The left image is an enhanced MODIS true color image from Aqua (NASA). The right image is a CIRA-produced synthetic GOES-R ABI 3.9 μm image for roughly the same time (2007/10/23 15:30 UTC)

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. All synthetic imagery can be viewed on the RAMMB GOES-R Case Study Database at: http://rammb.cira.colostate.edu/research/goesrstudies/administrative/GOESR_IPO_case_study_database.html

Many more technical details regarding this synthetic imagery can be found in Grasso, et al. 2008.

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, Communications and Networking:

NOAA/NESDIS, CIMSS, NASA/JPL, CICS/ University of Maryland

6. Awards/Honors: None as yet

7. Outreach:

(a) Three undergraduate students are partially supported by this project (Daniel Coleman, Kashia Jekel, Greg DeMaria).

(b) see section 8

(c) none

(d) Louie Grasso spoke to a first grade class at Bauder Elementary.

(e) A website was developed to illustrate the utlility of GOES-R proxy data.

8. Publications:

Refereed Journal Articles

Fromm, M., O. Torres, D. Diner, D.T. Lindsey, B. Vant Hull, R. Servranckx, E. P. Shettle, and Z. Li, 2008: The stratospheric impact of the Chisholm pyrocumulonimbus eruption: Part I, earth-viewing satellite perspective. *Journal of Geophysical Research*

Grasso, L.D., M. Sengupta, J. Dostalek, Renate Brummer, and M. DeMaria, 2008: Synthetic Satellite Imagery for Current and Future Environmental Satellites. *International Journal of Remote Sensing.* (in press)

Hillger, D.W., 2008: GOES-R advanced baseline imager color product development. *Journal of Atmospheric and Oceanic Technolog-A.*

Lindsey, D.T., and L.D. Grasso, 2008: An effective radius retrieval for thick ice clouds using GOES. *Journal of Applied Meteorology and Climatology.*

Rosenfeld, D., W. Woodley, A. Lerner, G. Kelman, and D.T. Lindsey, 2008: Satellite Detection of Severe Convective Storms by their Retrieved Vertical Profiles of Cloud Particle Effective Radius and Thermodynamic Phase. *Journal of Geophysical Research*.

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.*

Setvak, M., D.T. Lindsey, R.M. Rabin, P.K. Wang, and A. Demeterova, 2008: Indication of water vapor transport into the lower stratosphere above midlatitude convective storms: Meteosat Second Generation satellite observations and radiative transfer model simulations. *Atmospheric Research*.

<u>Conference Proceedings</u>

Brummer, R.L., M. DeMaria, J.A. Knaff, B.H. Connell, J.F. Dostalek, D. Zupanski, 2008: GOES-R mesoscale product development. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Brummer, R.L., M. DeMaria, J.A. Knaff, B.H. Connell, J.F. Dostalek, D. Zupanski, 2008: GOES-R mesoscale product development. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Grasso, L.D., M. Sengupta, D.T. Lindsey, 2008: Improved calculations of legendre coefficients for use in generating synthetic 3.9 µm GOES-R ABI imagery. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Grasso, L.D., M. Sengupta, D.T. Lindsey, 2008: Improved calculations of legendre coefficients for use in generating synthetic 3.9 µm GOES-R ABI imagery. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Hillger, D.W., and R.L. Brummer, 2008: Real-time display of experimental GOES-R products. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Lindsey, D.T., D.W. Hillger, L.D. Grasso, 2008: Development of severe weather products for the GOES-R Advanced Baseline Imager. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Lindsey, D.T., 2008: Examining a possible relationship between positive dominated storms and cloud-top ice crystal size. *3rd AMS Conference on Meteorological Applications of Lightning Data*, 21-25 January, New Orleans, LA.

Mostek, A., M. DeMaria, J. Gurka, 2008: Preparing for GOES-R+ user training and education, *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Sengupta, M. L.D. Grasso, D.W. Hillger, R.L. Brummer, M. DeMaria, 2008: Quantifying uncertainties in fire size and temperature measured by GOES-R ABI, *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

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 FY06, CIRA worked with the Naval Research Laboratory in Monterey to assess the impact of the OHC input in the Statistical Typhoon Intensity Prediction Scheme (STIPS) that is run operationally for the Joint Typhoon Warning Center in Honolulu (Knaff et al, 2005). To increase the sample size these forecasts continue to be evaluated in FY07. The project will focus on the Atlantic and eastern North Pacific tropical cyclones in FY07, which are in the area of responsibility of the National Hurricane Center in Miami. NHC runs the operational Statistical Hurricane Intensity Prediction Scheme (SHIPS), which includes OHC input for the Atlantic forecasts (DeMaria et al, 2005; Mainelli et al, 2007). However, the OHC is not included in the eastern Pacific version due to the lack of an OHC climatology. Recently, a global OHC climatology has been developed by the NOAA Atlantic Oceanographic and Meteorology Laboratory. The climatology will be used to determine the impact on SHIPS model intensity forecasts for the eastern Pacific, from Mexico to the dateline. The thermal structure in the eastern Pacific region has some differences from the Atlantic, in that the thermocline is not as deep in the part of the eastern Pacific where most of the tropical cyclones form, but the oceanic stability is greater. Thus, the OHC may impact storms in a different way.

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. Research will be performed 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 is available from the operational version of the GFDL coupled ocean-atmosphere hurricane model. This data will be used in conjunction with the OHC climatology to develop an SST cooling parameterization. This parameterization will be tested in the SHIPS model to determine the impact of including a more physically based relationship with OHC on the intensity predictions.

2. Research Accomplishments/Highlights:

The STIPS intensity model that was run during 2006 and 2007 was developed from data from 1997-2004. The AOML TCHP fields from these years were used to derive a parallel version of STIPS that includes TCHP as an additional predictor. Figure 1 shows the percent improvement of the average intensity forecast error in an independent sample of 661 tropical cyclone cases when TCHP is added as a predictor. These results show that the addition of TCHP as a predictor decreased the mean intensity errors ~1.0 % through 120 hours, with results being statistically significant at 95% level for 24-h through 72-h forecasts.

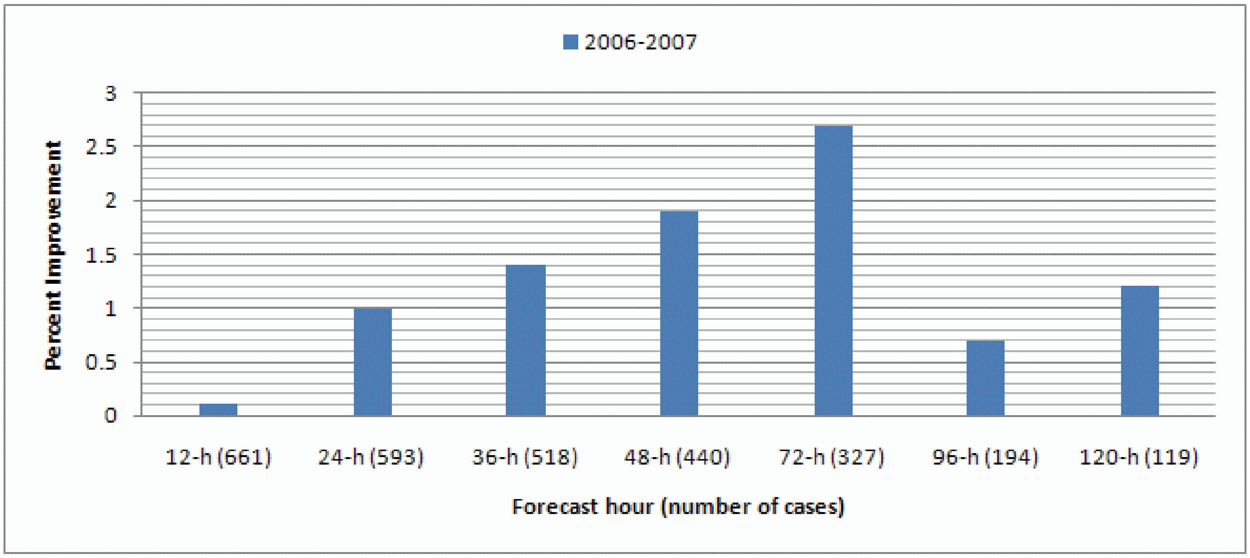


Figure 1. The percent improvement in the dependent version of the STIPS model at each forecast interval (blue bars) when TCHP is added as a predictor. The sample size is 661 STIPS forecasts.

The second task related to this project was to examine the SST cooling under a model storm and develop a mathematical relationship between this cooling and altimetry-derived ocean heat content (OHC). For development purposes, both atmospheric and oceanic outputs were used from reruns of the HWRF ocean-coupled model for all Atlantic basin tropical cyclones from 2004-2006. Storm characteristics such as translational speed (tspd) and intensity (vmax) and ocean characteristics such as ocean heat content (OHC) were computed at each forecast time available for each run (generally 5 times per run at t = 24h, 48h, 72h, 96h, and 120h). Also, at each forecast time and respective storm center location, the SST cooling beneath the TC inner core ($dSST_{ic}$) was computed as $dSST_{ic} = SST_{ic}(t=t') - SST_{ic}(t=0)$, where $SST_{ic}(t)$ is the average temperature of all HWRF SST data points at radius < 60 km from the storm center at time t. A simple multiple regression analysis was then performed to determine the relationship between independent variables vmax, tspd and OHC and $dSST_{ic}$. The resultant regression equation explains 55.3% of the variance of $dSST_{ic}$. Work is underway to test this new regression-based equation for computing $dSST_{ic}$ in the SHIPS model.

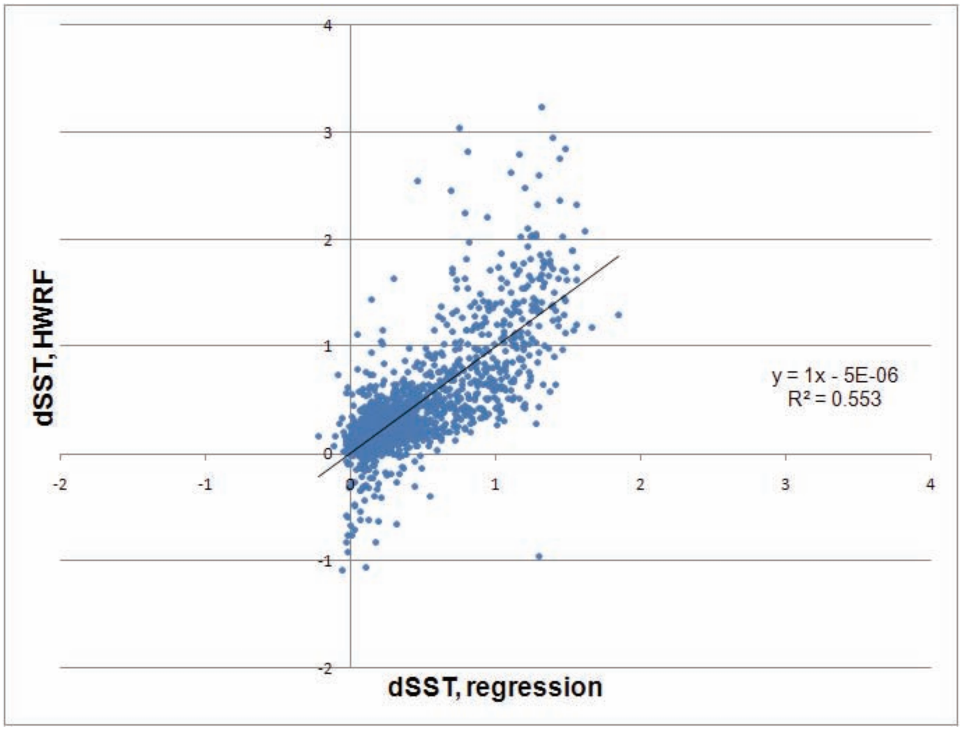


Figure 2. The average SST cooling beneath the TC inner core as predicted by the regression equation vs. that observed in the HWRF reruns, for all Atlantic TC from 2004-2006.

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 TCHP 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, Communications and Networking:

This research is a joint effort between several groups within NOAA, the university community, and the Department of Defense. These include 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, and Colorado State University.

6. Awards/Honors: None as yet

7. Outreach:

Presentations

CIRA/RAMMB Tropical Cyclone Forecast Tools: Planned Operational Transitions and New Initiatives, given at the National Hurricane Center, Miami on 1 November 2007.

A simple parameterization of sea surface cooling beneath a hurricane inner core, 28th Conference on Hurricanes and Tropical Meteorology, 2 May 2008, Orlando, FL., http://ams.confex.com/ams/28Hurricanes/techprogram/paper_137611.htm

8. Publications:

Refereed Journal Articles

Mainelli, M., M. DeMaria, L.K. Shay, and G. Goni, 2007: Application of Oceanic Heat Content Estimation to Operational Forecasting of Recent Atlantic Category 5 Hurricanes. *Wea. Forecasting*, 23, 3-16.

Sampson, C.R., J. L. Franklin, J. A. Knaff, and M. DeMaria, 2008: Experiments with a Simple Tropical Cyclone Intensity Consensus. *Wea. Forecasting*, in press.

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:

A) 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.

B) 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.

C) Study the anomaly product. Currently, it is based on normals from the NASA Water Vapor Product (NVAP) dataset (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 biggest accomplishment is that Objective A (above) has been completed. Both the Blended GPS-AMSU-SSM/I TPW product and the TPW anomaly product are available on the web (http://amsu.cira.colostate.edu/GPSTPW), on a McIDAS Server (ULY/AMSU.27 and 28), and by File Transfer Protocol (FTP; ftp://amsu.cira.colostate.edu/composites/AREA0027 and AREA0028; see Fig. 1). These products are flowing through SPoRT center to the NWS Southern Region, and they are now scheduled for AWIPS Operational Build 9 (see the report for Project 1238).

Sheldon Kusselson (NESDIS Satellite Applications Branch (SAB)) has been a prime user and advocate of the products and has documented many cases where the anomaly product was useful to forecasters and indicative of floods or severe weather.

The scientific research focus (Objective C) is to understand the anomaly product through comparison with other meteorological fields, such as cloud occurrence. A four-month period from January through April, 2007 has been studied over different areas of Earth to understand the relationship of cloud vertical structure to TPW anomaly. The hypothesis that cloud vertical structure is a strong function of TPW is supported by comparisons to CloudSat / CALIPSO data during this period. Figure 2 shows the frequency of occurrence of cloud at different levels from the combined radar/lidar product as a function of TPW anomaly. The low cloud does not strongly change over this ocean region, but deep middle and high clouds become more common as the anomaly increases beyond 120 %. This relationship could have future value in forecasting cloud base and thickness, and as a diagnostic of model performance, since the same statistics could be gathered from a NWP model. The anomaly was created from SSM/I data using a slightly different TPW retrieval algorithm, so the distribution and bias of the anomaly are also subjects of current research.

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

Objective A: Complete

Objective B: In progress

Objective C: In progress

4. Leveraging/Payoff:

Analysis of moisture for forecasters, and representation of moisture in models are both areas where there is much room for improvement. The blended TPW website and anomaly product at http://amsu.cira.colostate.edu/gpstpw is accessed by NWS forecasters on a daily basis to help fill the need for a single integrated view of TPW.

One of the factors controlling hurricane intensity is entrainment of dry air from the environment. The TPW anomaly product has the potential of describing the hurricane environment from a standpoint of moisture and whether dry air is available to weaken a storm. Hurricane intensity prediction is one of the great challenges in atmospheric science, and this product has bearing on that important problem.

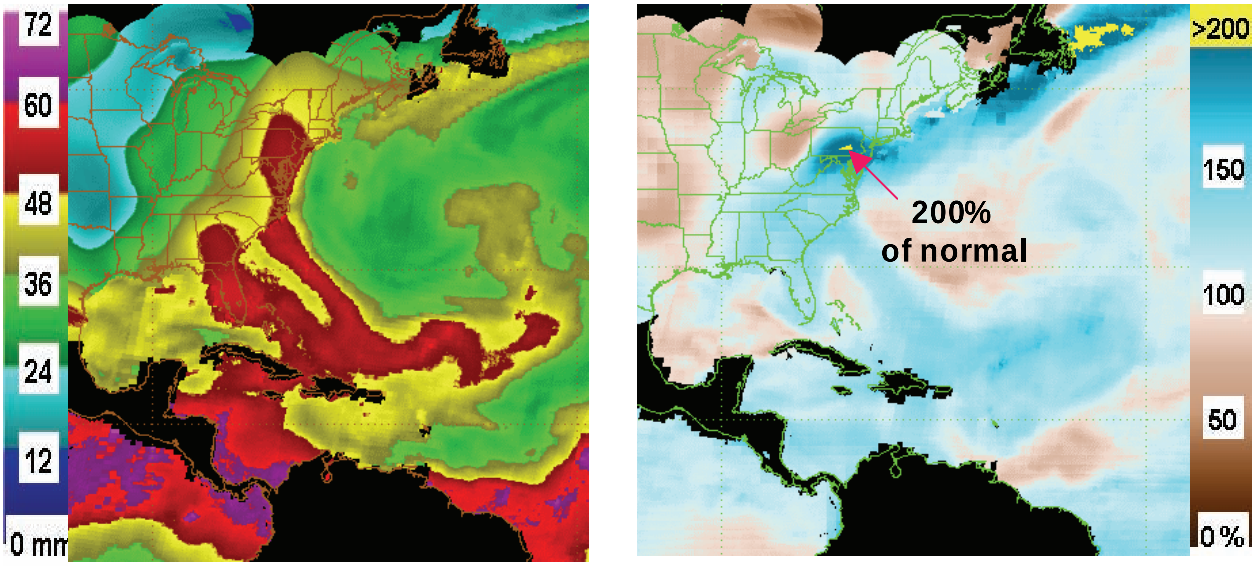


Figure 1**.** Blended TPW (left, TPW in mm) and TPW anomaly (right, percentage of weekly normal) capture moisture fueling record flooding in the Mid-Atlantic states, June 25, 2006.

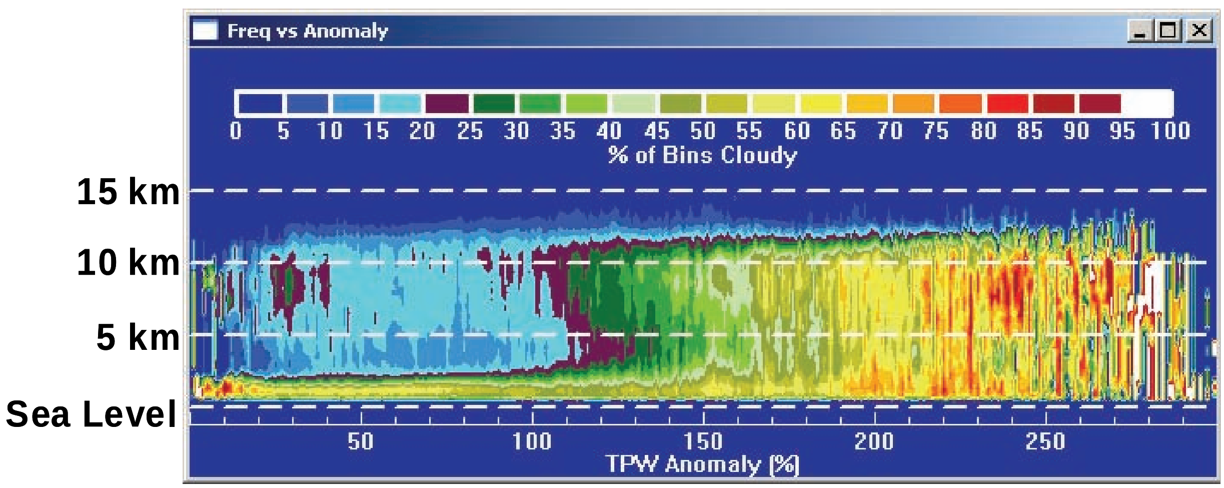


Figure 2**.** Early science result of the frequency of cloud vertical occurrence as a function of TPW anomaly over the northeastern Pacific Ocean for January – April, 2007. The frequency of clouds from the combined CloudSat/CALIPSO cloudmask is shown as a function of TPW anomaly. Note the strong increase in deep cloud as the anomaly exceeds 120%.

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

The TPW anomaly product is not specific to NOAA uses for forecasting extreme precipitation. Our research indicates that it is reflective of the total vertical thickness of clouds, so it appears to have diagnostic ability for cloud thickness and cloud base height, which are perennial needs for Air Force and Navy weather research. It might also be applied to earth imaging sensors which are degraded by water vapor absorption, such as some infrared sensors. Imaging targets could be selected during more pristine viewing conditions.

6. Awards/Honors: None as yet

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: Tom 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 Accomplishments/Highlights:

Project I: Regional Cloud Climatologies

The Cheyenne Regional Cloud Climatology project conducted a planning meeting to discuss incorporating wind regime cloud climatologies into the Cheyenne's National Weather Service (NWS) office forecast process. Science and Operations Officer, Melissa Goering, Information and Technology Officer, Ray Gomez from Cheyenne, and Deb Molenar and Cindy Combs from CIRA attended. A plan was developed to include the cloud climatologies into Cheyenne's Graphical Forecast Editor (GFE) for a first guess in cloud cover forecast. All McIDAS products were translated into netCDF for the Cheyenne office. Products will be tested on CIRA's GFE before they get transferred to Cheyenne.

A work plan was developed with the National Weather Service (NWS) office in Eureka, CA to produce satellite cloud composites every hour during the summer months that are stratified by early morning marine layer depth. Meetings were held with Science and Operation officer Mel Nordquist and interns Becca Mazur and Treena Hartley from

Eureka to discuss cloud composites to investigate marine stratus burn-off rate. It was decided that Eureka will pull stratus layer depths from their GIS system which will then be combined with the pre-processed Eureka sectors from GOES West to produce the climatologies. In addition, preprocessing of GOES west data over the Eureka area has been started. This effort has added May and September 1998-2005 to the already processed set of June-August for this time period. Existing procedures were updated so they can handle newer GOES-11 data. The climatology work also focused on the processing of large sector U.S. climatologies. Products completed include monthly large sector composites for September and October 2007.

Project II: Severe Weather and Mesoscale Studies with GOES

Satellite and model data have been collected from the summers of 2006 and 2007. The data was analyzed and adjustments were made to the algorithm coefficients in order to improve the existing GOES MCS Index. The update allows for NAM data in GRIB2 format to be processed. This is important because the NWS ftp server removed most NAM GRIB1 files in February 2008 and replaced them with GRIB2 files.

The GOES-11 and GOES-12 Storm-Top Effective Radius Retrieval is currently working in real-time. An example of the retrieval from 8 January 2008 is shown in Figure 1 below. In addition, mesoanalysis data has been collected from the summer of 2007 from the Storm Prediction Center. Work began on analyzing the data and on investigating what severe storm factors determine storm-top ice crystal effective radius.

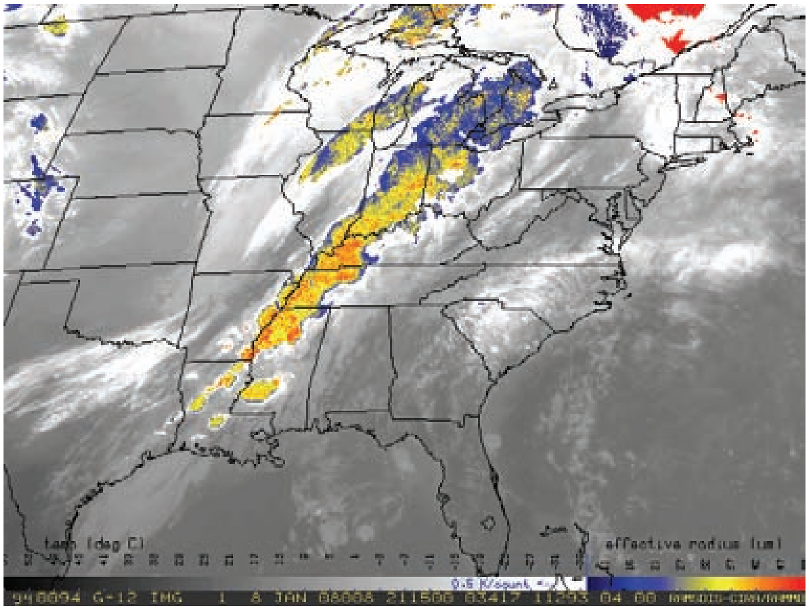


Figure 1. GOES-12 Effective Radius Retrieval from 8 January 2008. Severe storms can be seen in Mississippi, Tennessee, and Kentucky.

GOES-11 data was collected from the summers of 2006 and 2007, as was sounding data from 11 locations in the Central Plains of the U.S. Work has begun to match the satellite data to the raob locations, and compare brightness temperatures (primarily bands 4 and 5) with sounding-derived water vapor profiles. In addition, RUC and NAM data have been collected to supplement the information from GOES. GOES pixels have been matched up with cloud-free raob locations in the central U.S. at 00 UTC, so model and satellite data can now be compared with actual soundings. Work is currently underway to determine what additional information is provided by the satellite data about low-level moisture.

Project III: National and International Training

CIRA continued to contribute to VISIT and SHyMet training as needed. Support was also provided for a VISIT/SHyMet/WMO focus group presentation given by Tony Mostek, NWS Training Division in Boulder, to a group in Cartagena, Colombia in October.

The WMO Virtual Laboratory Task Team conducted 3 monthly English and Spanish weather briefings through VISITview using GOES and POES satellite Imagery from CIRA (http://hadar.cira.colostate.edu/vview/vmrmtcrso.html) and voice via Yahoo Messenger. 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, Trinidad and Tobago, and Venezuela. The participants include researchers and students as well as forecasters. The discussions were well attended with an average of 22 computer connections and multiple participants at many sites. Throughout the sessions, participating countries offer comments on the features of interest for their local weather.

The discussions mentioned above have mainly been coordinated with the RMTC Center of Excellence in Costa Rica. Throughout the fall, Barbados has been conducting weekly briefings for the Eastern Caribbean to stimulate discussion and collaboration for the Hurricane season. CIRA has been assisting with the logistics of the sessions and providing imagery through the hadar server listed above.

An email group was established through Yahoo this past fall (WMOSatMetOMM). To date we have roughly 140 members. The list came in extremely handy this past December to pass along information about the operational status of GOES-12 and GOES-10 when GOES-12 experienced outages.

Project IV: Tropical Cyclone Forecast Product

1982-1994 GOES imagery information has been acquired and the necessary GOES predictors assembled for inclusion in the SHIPS developmental datasets. Data were acquired from J. Kossin (U. Wisc.) In order to eliminate corrections steps in the SHIPS model code, GOES predictors as well as Oceanic Heat Content (OHC) also must exist for the 1982-1994 period. Altimetry data, and thus OHC, exists from 1995 onward, but prior to that time an estimate of OHC is needed. Work began this quarter on a method to estimate OHC from the climatological OHC and the observed sea surface temperature. Once OHC estimates are available 1982-1994, tests will begin on a version of SHIPS without the correction step.

As part of our development of a complex PC method for rapid intensification study, twenty-five extremely rapidly intensifying tropical cyclone cases with IR imagery have been collected 1987-2006. The average starting intensity of these cases is ~60 kt and after 24 hours the final intensity is ~110 kt. Techniques were developed to remap and spatially filter the brightness temperatures to a storm motion relative, cylindrical coordinate system. Complex EOF analysis of these datasets with the azimuthal mean brightness temperature removed reveled 3 CEOF's of interest. The analysis was conducted without removing the azimuthal mean. This analysis provided a clearer picture of possible predictive signals contained in these data. CEOFs 1-5 explain 66.5 percent of the variance. Figure 2 shows the CEOFs along with their suspected physical processes. In Figure 2 amplitudes are given by the shading, phase is given by the contours and the direction of the phasing is given by the wind barbs (note erroneous barbs occur where the phase changes sign).

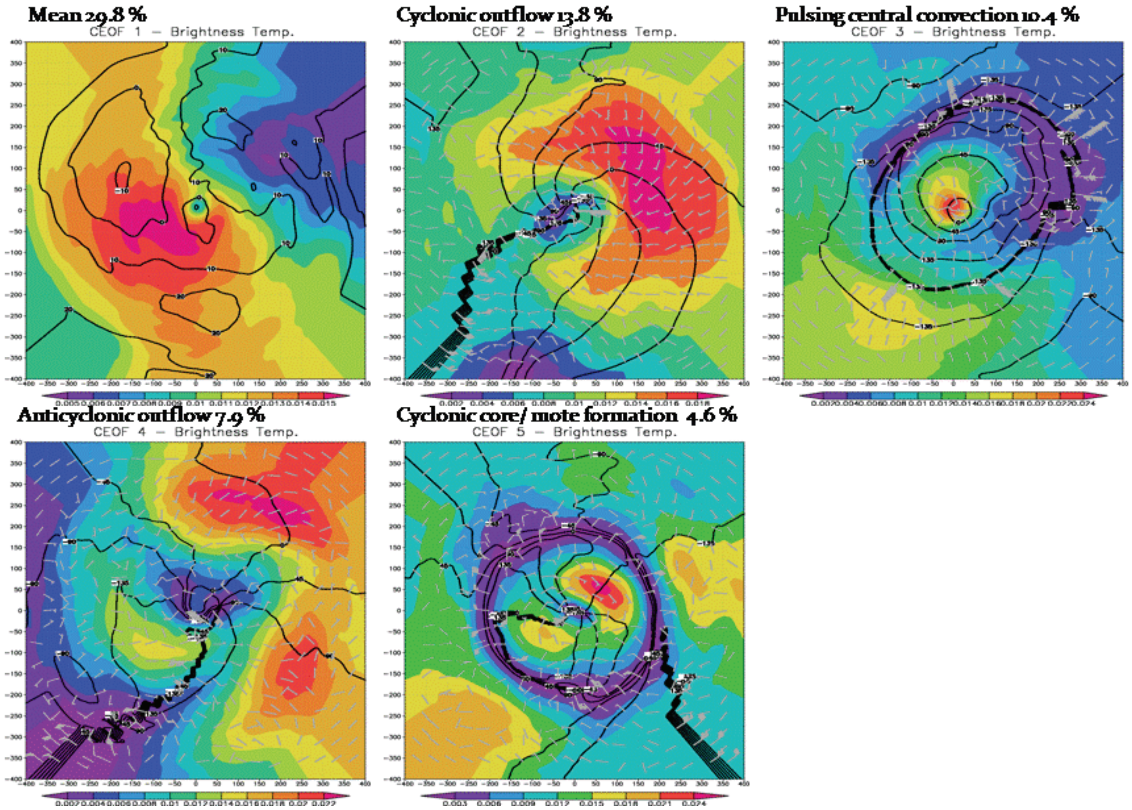


Figure 2. Spatial amplitudes (shaded) temporal phase (contoured), and phase speed/direction (wind barbs) of the first three complex principle components of the azimuthal brightness temperatures found in 25 rapidly transitioning tropical cyclones. A 48-hour period is used for each storm encompassing 24 hours prior and the 24-hour during these rapid transitions. The intensity at the beginning (end) of these rapid transitions was 60 (108) kt.

Composite analysis reveals that some of the CEOF behavior is stochastic and others more systematic. Cyclonic outflow (CEOF 2) increases in amplitude and tends to orientate toward the front of the TC during the 24 h prior to rapid intensification onset. Similarly, the pulsing of convection expands outward to near 200 km near the onset of rapid intensification. The cyclonic core/ mote formation seems more stochastic in nature suggesting that the amplitude of this mode may also be important for better predicting the occurrence of rapid intensification. To examine the predictive nature of these modes, the false alarms cases associated with Kaplan and DeMaria rapid intensification index have just started to be examined.

Annular Hurricane (AH) cases in 2007 were verified. The Annular hurricane index was able to correctly identify Hurricane Flossie as being Annular. Flossie was the only Annular Hurricane in the Central/East Pacific and Atlantic tropical cyclone basins.

Figure 3 shows the 6-hourly time periods when the AH algorithm identified Flossie as being an annular hurricane.

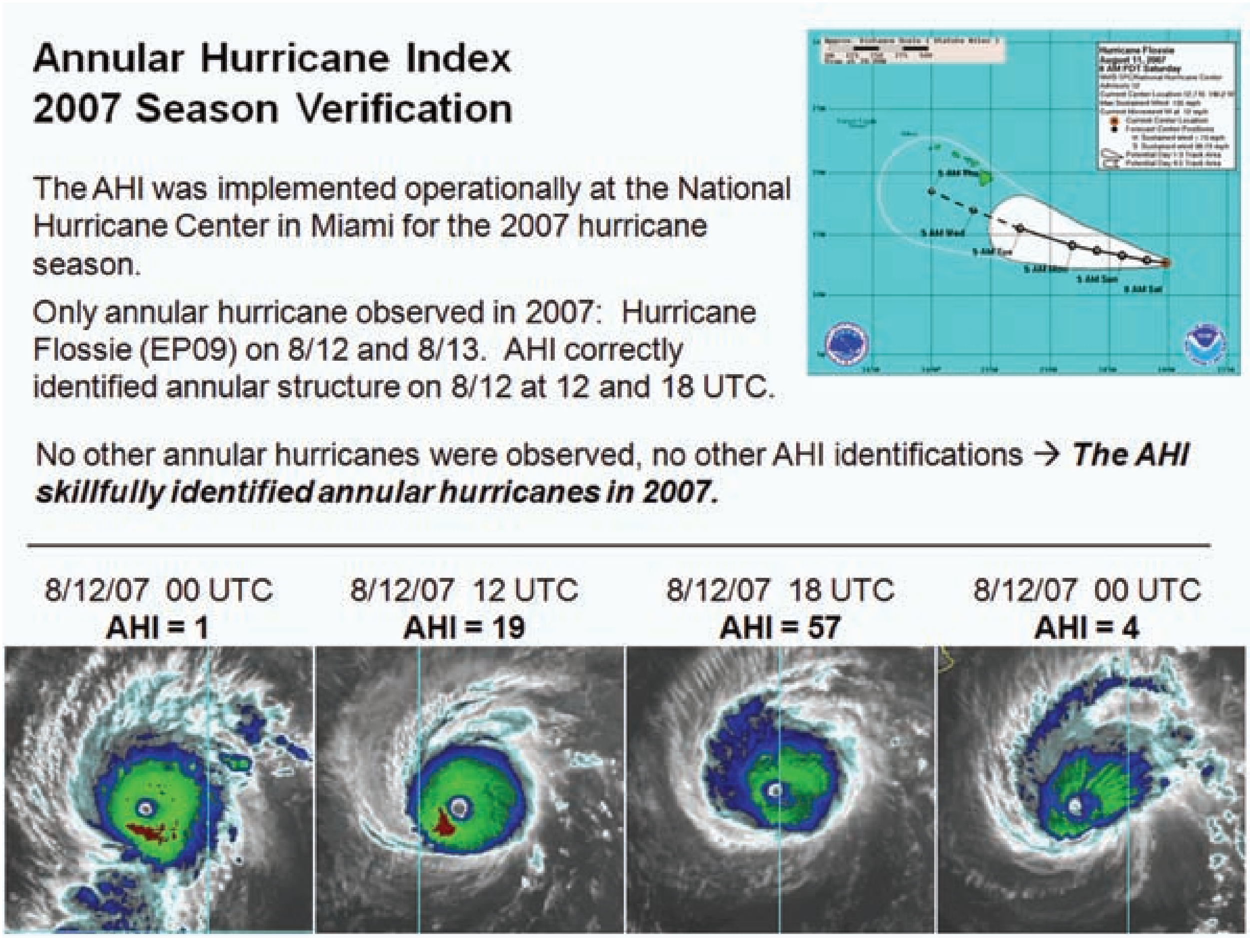


Figure 3. Slide showing the performance of the Annular Hurricane Index (AHI) during Hurricane Flossie (2007). The track of Flossie is shown in the upper right. Individual IR images are shown with the valid time and the AHI value. The AHI can range from 0 (not an annular hurricane) to 100 (the highest probability of being an annular hurricane).

<u>Project V: Winter Weather Studies with GOES.</u>

The Winter Weather Study project has focused on the application of the so-called “Henry’s Rule. Henry’s Rule states that a stationary trough over the southwestern U.S. will begin to lift out when an upstream shortwave travels to 2200 km from the stationary trough. Analysis of nine cases began, not only to assess the usefulness of the water vapor imagery in tracking the position of the upstream shortwave relative to the stationary low, but also to see if the behavior of the stationary low itself, as seen in satellite imagery, gives any indication that it will begin to lift out. Additional cases are being collected as well. An example of Henry’s rule is shown in Figure 4.

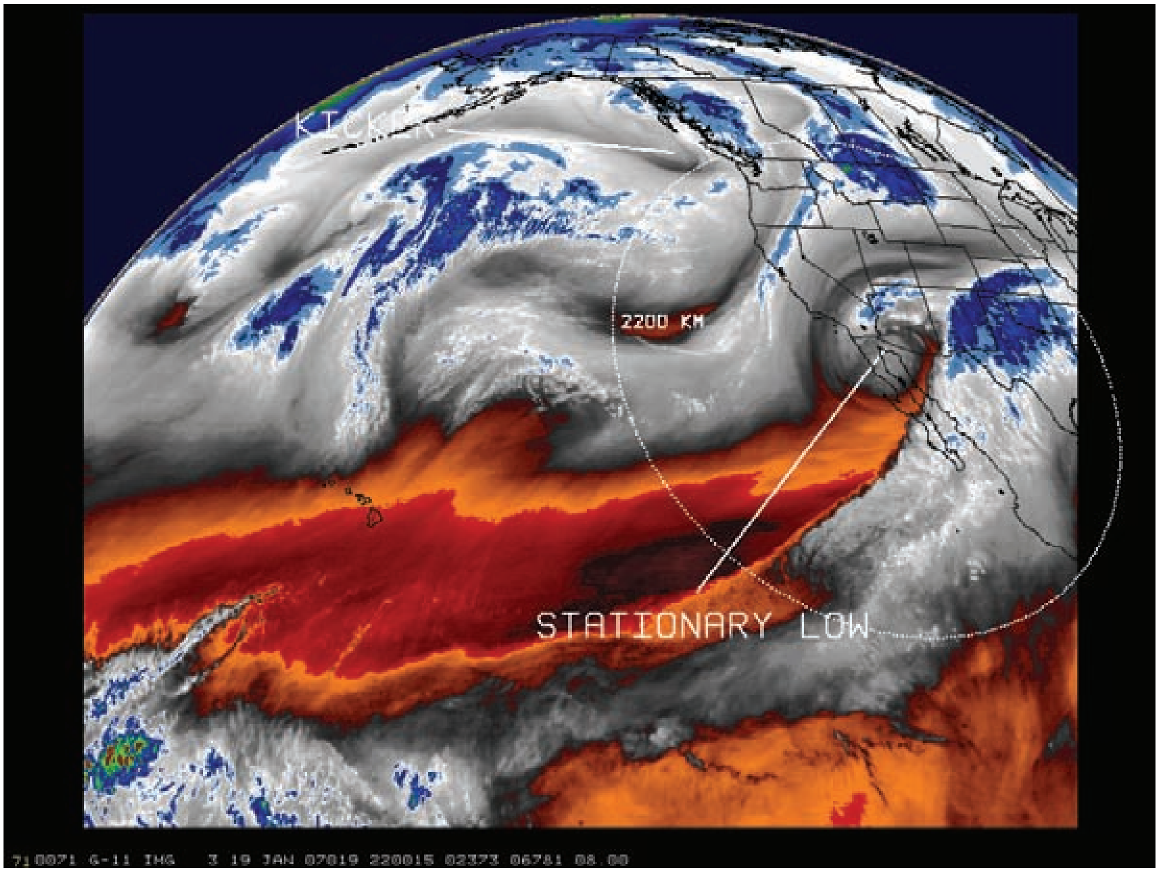


Figure 4. An example of Henry's rule. Water vapor image from 2200 UTC 19 January 2007 just before the stationary low began to lift out. The locations of the stationary low, the "kicker" and the 2200 km radius from the stationary low are depicted.

As part of the project to develop a quantitative measure of central surface pressure of midlatitude cyclones over the eastern Pacific Ocean from satellite imagery, collection of GOES 10.7 μm infrared and 6.7 μm water vapor imagery has been completed for the winter season 2006-2007 and analysis begun. Imagery from the winter season 2007-2008 is currently being collected.

The relationship between cloud morphology as seen in GOES 10.7 μm imagery and snowfall patterns over the central United States is also being investigated. So far three cases have been selected, the data for them obtained, and analysis begun. Additional cases will also be added to the study. An issue arose concerning problems with reading the North American Regional Reanalysis (NARR) files in McIDAS. The McIDAS Users' Group was contacted and a solution was suggested and will be implemented next quarter. The mean sea level pressure from the NARR data is used to track the surface low center of the systems.

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, Communications and Networking:

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

6. Awards/Honors:

2007: DOC/NOAA/NESDIS Bronze Medal Award for the development and operational implementation of the Tropical Cyclone Formation product that quantitatively predicts storm formation probability. (Joint Award, RAMMB recipients: Mark DeMaria, John A. Knaff)

2008: NASA Achievement Award for providing the next generation of advanced weather satellites, a service essential to the Nation. (Group Achievement Award: Donald W. Hillger as part of the GOES-N Series Team)

7. Outreach:

(a) One college undergraduate assisted in the project (Daniel Coleman).
(b) See section 8
(e) The CIRA/RAMMB webpage depicts the results of our GIMPAP research activities.

8. Publications:

<u>Refereed Journal Articles</u>

Knaff, J.A., T.A. Cram, A.B. Schumacher, J.P. Kossin, and M. DeMaria, 2008: Objective Identification of Annular Hurricanes. *Weather and Forecasting,* 23, 17-28.

Mainelli, M., M. DeMaria, L.K. Shay, and G. Goni, 2008: Application of Oceanic Heat Content Estimation to Operational Forecasting of Recent Atlantic Category 5 Hurricanes. *Weather and Forecasting*, 23, 3-16.

Sampson, C.R., J.A. Knaff, and E.M. Fukada, 2007: Operational Evaluation of a Selective Consensus in the Western North Pacific Basin, *Weather and Forecasting,* 22, 671-675.

Conference Proceedings

Connell, B., V. Castro, M. Davison, A. Mostek, B. Fallas, K. Caesar, and T. Whittaker, 2008: International Focus Group– Virtually there with VISITview*, AMS 17th Symposium on Education*, 21-25 January, New Orleans LA.

Lindsey, D.T**.**, 2008: Examining a possible relationship between positive dominated storms and cloud-top ice crystal size. *3rd AMS Conference on Meteorological Applications of Lightning Data,* 21-25 January, New Orleans LA.

Presentations

Knaff, J.A**.,** A. Krautkramer, M. DeMaria**,** and A.B. Schumacher, 2008: New and updated operational tropical cyclone wind products. *62nd Interdepartmental Hurricane Conference*, 3-7 March, Charleston SC. [Available at http://www.ofcm.gov/ihc08/Presentations/Session10/s10-05Jknaff.ppt]

Schumacher, A.B., M. DeMaria, J.A. Knaff**,** and D.P. Brown, 2008: The NESDIS tropical cyclone formation probability product: An overview of past performance and future plans. *62nd Interdepartmental Hurricane Conference*, 3-7 March, Charleston SC.

CLOUD AND MICROWAVE EMISSIVITY VERIFICATION TOOLS FOR USE WITHIN THE CRTM

Principal Investigator: Andy 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 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”. The emissivities are constrained by assumed covariance errors that are incrementally updated as the analysis matured. Objective quality control is made possible by the interactions of the error covariance matrix values and the data innovation vectors. Explicit propagation of the errors is used to derive estimates of quality.

In addition, combinations of unique cloud datasets such as CloudSat with the microwave imagery will enable further quality control improvements.

The project goals are as follows:

--Use new CloudSat/CALIPSO cloud radar and lidar datasets 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) (Jones et al., 2004) to the CRTM.

2. Research Accomplishments/Highlights:

Delivery of the CSU MWLSM v1.0 to the JCSDA for insertion into the operational JCSDA CRTM. This will enable use of the WindSat microwave imager channels over land within NOAA data assimilation systems.

CloudSat datasets have been matched to our WRF-3DVar data assimilation case studies.

WRF-3DVAR use of the microwave emissivities is underway in our first experiment using the observational microwave emissivities. Results indicate brightness temperature improvements on the order of 30K over the deserts of the Middle East (see Figure 1) which represents a substantial improvement over the CRTM estimates.

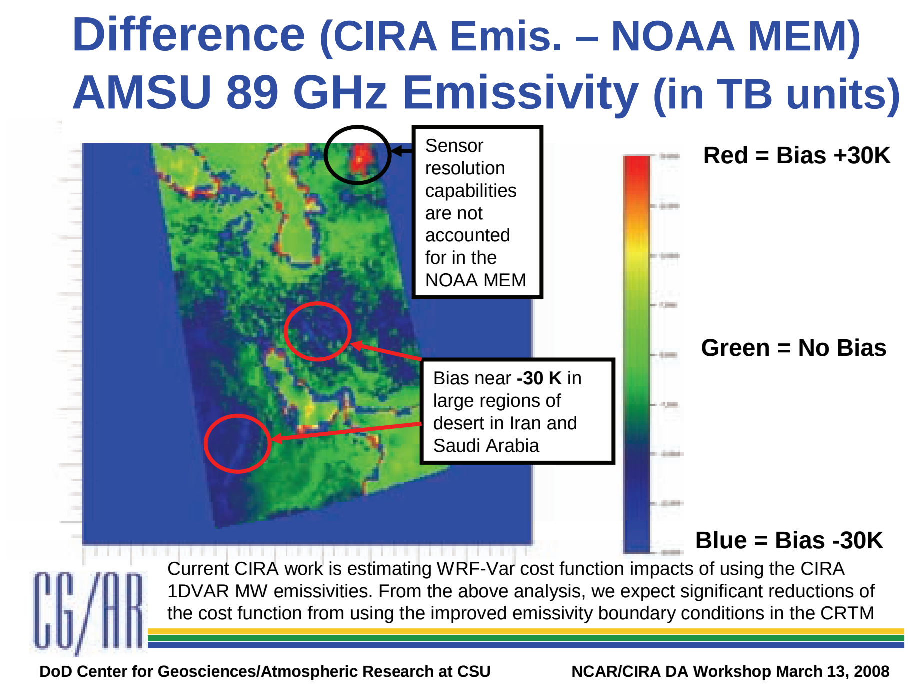


Figure 1. Microwave emissivity difference between the CIRA 1DVAR results and the NOAA-Microwave Emissivity Model (MEM) results for NOAA-16 at 89 GHz for Oct. 1, 2006. The emissivity differences are shown in radiometric brightness temperature units (K). Red, green, and blue denote biases of 30 K, 0 K, -30 K, respectively.

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

All major project deliverable milestones were completed. Our initial WRF-3DVAR studies using the CIRA microwave emissivities are nearly complete, with tests in progress (status as of April 16, 2008).

4. Leveraging/Payoff:

The MWLSM was developed under DoD funding sources and is being provided to NOAA 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.

6. Awards/Honors: None as yet

7. Outreach:

Dr. Jones presented the keynote talk for the AMS Data Assimilation Education Forum at the AMS Annual Meeting in New Orleans, LA, Jan. 21, 2008. The talk was entitled: “What is Data Assimilation? – A tutorial”.

8. Publications: None as yet

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 10th 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 31 states and the District of Columbia. Four more states are in the cue for 2008. Over 5,000 volunteers now report precipitation every day and nearly 5,000 more have participated at least occasionally during the past year. This makes CoCoRaHS one of the largest sources of daily "ground truth" precipitation data in the U.S. With the help of new data export functions and improved mapping and data processing capabilities on the CoCoRaHS website, 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 now 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. In the past year, we have completed our first set of instructional resources for Extension 4-H volunteer leaders that combines CoCoRaHS participation with after-school science enrichment opportunities through 4-H.

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

From the time this project began, we have been holding on tight for a fast ride. In less than 2 years we have accomplished most of our 3-year goals. Nine more states and thousands of additional volunteers have joined the CoCoRaHS team in the past year bringing the total to 31 states. While not specifically planned, the focus of CoCoRaHS expansion in the past year has been the southeastern states including the Carolinas, Florida, Georgia, Alabama and Kentucky. To some extent this may be partially the result of extreme drought conditions in these areas during the past year – greatly increasing public awareness about precipitation. As we approach the 2008 hurricane season, we have close to 1,000 volunteers in place along the Gulf Coast and the southeast Atlantic Coast ready to measure and report precipitation from tropical systems.

We have been able to stay close to on schedule with the development, testing and implementation of instructional materials for 4-H leaders. Approximately 14 lesson plans have been written and tested and are now being readied for promotion outside of Colorado through 4-H programs in other states. Some background work has been initiated, but we are just getting started on the climate and CoCoRaHS resources for Master Gardeners. A "Needs Assessment" has shown that the resources needed by Master Gardeners include 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.

Other education-focused activities are continuing and expanding. Several dozen group training programs were held across the country, some in conjunction with NWS's annual severe weather spotter training activities (SKYWARN). Some states conducted web-based group trainings. Most volunteers continue to use slide show and video instructional materials on the CoCoRaHS website. Participating volunteers then receive bi-weekly newsletters and daily web updates. These contain a steady stream of educational messages.

We are nearing completion on a major web-based survey that will be administered to CoCoRaHS volunteers to determine the extent to which CoCoRaHS participation is contributing towards enhanced climate literacy. This will be conducted in the coming months.

During the past year, CoCoRaHS staff have attended meetings and met personally with NOAA staff and leadership at NWS Headquarters, the NWS Eastern, Southern and Central Region Headquarters, the NOAA Office of Education, the NWS National Operational Hydrologic Remote Sensing Center, and the National Climatic Data Center. These meetings have been invaluable in gaining a better understanding of NOAA needs and NOAA educational resources that can be shared with the public through CoCoRaHS.

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.

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 dataset of good quality, as the observations are taken by trained observers using officially recognized standard 4-inch rain gauges. The dataset of precipitation measurements is of unparalleled density. 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.

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 dataset 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 foster more effective studies of small-scale climatology within a forecast area.

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:

Numerous partnerships and collaborations have taken place through CoCoRaHS. In fact, Collaboration is what the network is all about (and included in its name). Here is a list, although not exhaustive, of other collaborators leveraging NOAA's funding for this project.

National Oceanic and Atmospheric Administration, National Weather Service, 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, 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, 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

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. A highlight of this past year was an invited briefing to the Whitehouse Subcommittee on Water Resources in Washington D.C.
(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.

COLLABORATIVE RESEARCH WITH NIDIS FOR THEIR WEB PORTAL

Principal Investigator: Shripad D. Deo

NOAA Project Goal: Weather and Water (Serve society's needs for weather and water information)

Key Words: Science, Communication, Education

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

The project aimed at suggesting participatory approach to help the National Integrated Drought Information System (NIDIS) to forge new paths in the information society. The common "technical" concept of a web portal reflects how "technical" elements will be put together. It does not pay sufficient attention to the immense possibility of forging an epistemic community where knowledge about droughts is discussed, debated and disseminated using new communication technologies. It makes discussion among practitioners, policy makers and public possible enabling each other to understand the information needs. Social science can facilitate such exchanges of ideas and interests.

2. Research Accomplishments/Highlights:

Through active participation in designing and developing the web portal it was shown that it is important to make it accessible to various stakeholders in understanding droughts, their causes, early signs and consequences.

A demonstration of how text and images (pictures, maps, diagrams, etc) can be used to communicate messages more effectively without compromising scientific integrity. The importance of communication of scientific information to lay, or non-scientific, audiences needs to focus on how the information relates to them was emphasized.

It was also shown that general public, policy-makers or citizens, does not appropriate scientific concepts or information in order to emulate the scientist. They seek information about relevant natural phenomena to make sense of their own lives and livelihoods from within their own cultural framework. An architect cannot design a house according to his or her interests alone. The design needs to respond to the needs of the customer who will be using it. Hence, the structure of the web portal and the information needs to reflect and respond to the needs of different users. It should not become an exclusive playground of climatologists interested in droughts.

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

The project was completed in December 2007. The NIDIS web portal was opened to the public. The initial reviews were favorable. More work is needed to be done to make it truly accessible to different stakeholders. It can be developed into an agora where different interest groups can participate in the discussion across disciplinary boundaries,

4. Leveraging/Payoff:

The work done with the NIDIS web portal can provide a template, from social science perspective, to pursue similar approaches in severe weather, flash flood warnings, and other natural hazards. However, the managers need to recognize how social science collaboration can push the envelope for greater benefit to society that is not measured by strictly economic gains.

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

This project was supported by the National Integrated Drought Information System.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

CONTINUATION OF CIRA RESEARCH COLLABORATION WITH THE NWS METEOROLOGICAL DEVELOPMENT LAB

Principal Investigator: Ken Sperow

NOAA Project Goal: 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, AutoNowcast (ANC), Four-dimensional Stormcell Investigator (FSI), TDWR, AWIPS Data Visualization and Monitoring System for Observational Records (ADVISOR), CWSU, SOA

Since joining CIRA in mid-December 2007, 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 II.

The AutoNowcast (ANC) Prototype Project

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. This year's package was delivered to the WFO for installation in mid-March. Scott O'Donnell played a crucial role in designing and developing the ingest, communication, and conversion software that communicates and sends data to and from the ANC system and AWIPS as well as notifications within the AWIPS system. My role in this first phase was as a consultant and preparer of the installation packages, which required an in-depth understanding of the AWIPS system. The NWS also sent me to the FWD WFO to 1) help troubleshoot a networking issue, outside of our control, that was preventing the system from transferring data; 2) assist in the training of the WFO staff; 3) observe the ANC focal point train other forecaster; and 4) build relations with the WFO staff and NCAR ANC personnel on site.

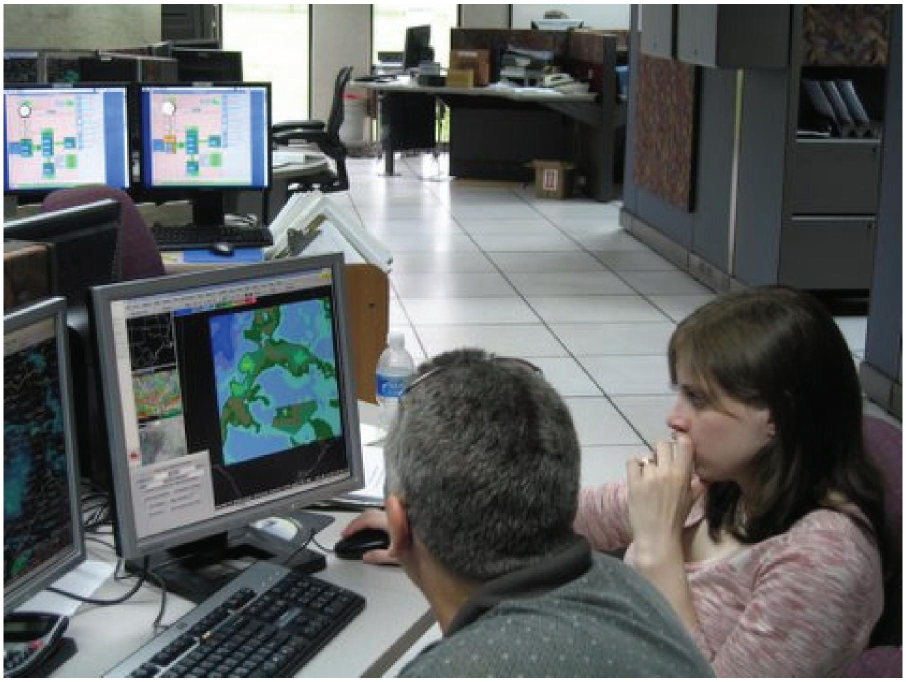


Fig. 1. A FWD meteorologist training NWS forecasters on ANC use.

The NWS asked that I lead 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 are needed to run the system. MDL has four servers and the additional three are on order. In order to minimize the time to get the system up and running, we are using the same datasets and formats that NCAR uses in Boulder to run ANC. We are also installing and setting up the ANC system in phases so that we can make progress while we wait for the remaining hardware. The first phase is to get the data ingest running. The datasets come in via Unidata's LDM and this software has been installed and is running and acquiring the necessary datasets on MDL's ANC cluster. NCAR's ANC team provided the source code and ingest configuration files and the ANC ingest is now running on MDL's ANC cluster. The second phase of this task requires the new hardware to be setup and NCAR to provide the necessary configuration files. It is expected that this phase of the task will be completed by the end of June, at which point we will have a fully running ANC system at MDL.

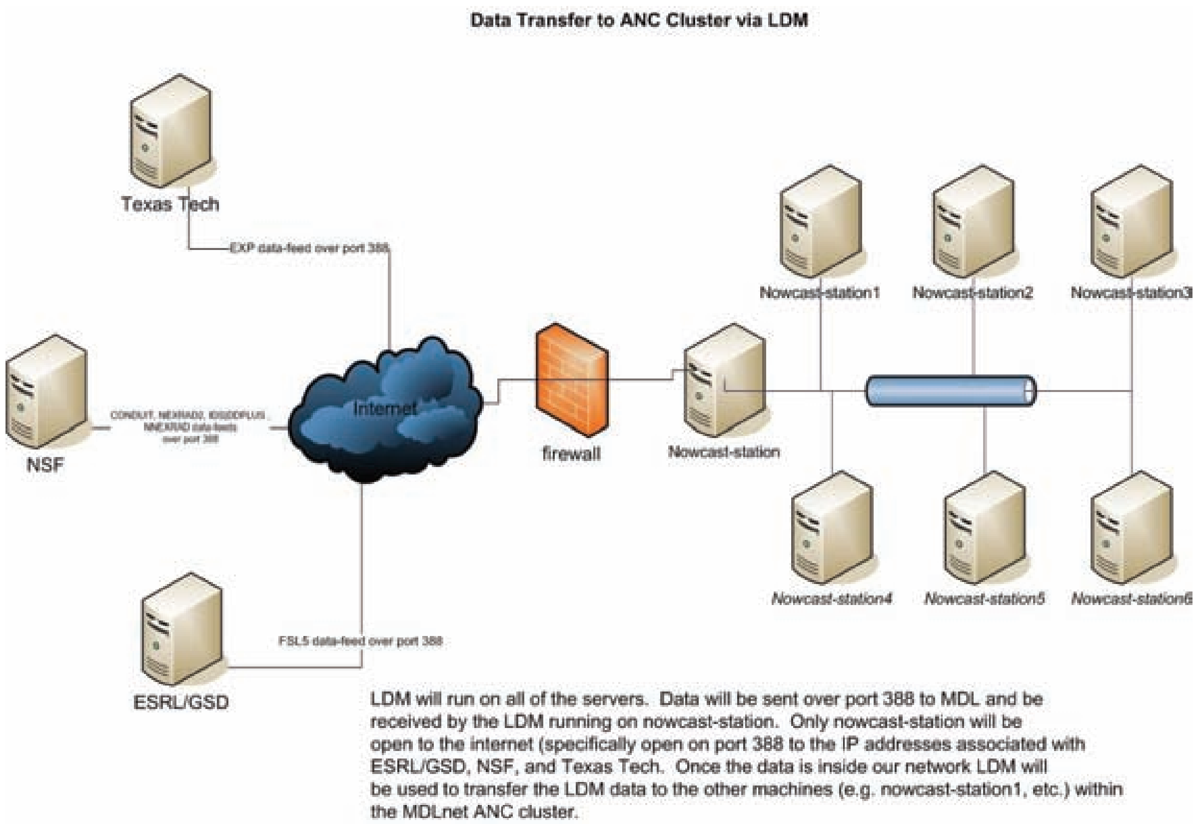


Fig. 2. Diagram showing the ANC cluster at MDL and how data comes into the system for use by ANC.

3. Comparison of Objectives Vs. Actual Accomplishments for 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:

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:

7. Outreach:

8. Publications

AWIPS II

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.

Background
MDL is not directly responsible for the migration of its applications from AWIPS to AWIPS II; this is the responsibility of Raytheon, the prime contractor. However, MDL will be overseeing the migration of its current applications, developing new applications in the new framework, and enhancing existing applications beyond OB9, which falls outside the scope of Raytheon's migration.

AWIPS II uses many technologies (JAVA, Mule, Hibernate, JavaScript, JMS, JMX, etc.) 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:

Since starting with CIRA, I have gone through the AWIPS II training that Raytheon provided and have the AWIPS II environment up and running on a laptop. I have written several documents on how to build and debug the AWIPS II software within Eclipse, which have been distributed to the AWIPS II users. 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.

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

Objectives for the past year were successfully met.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators, Communications 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:

7. Outreach:

8. Publications:

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. This year, I have been leading a project to make Terminal Doppler Weather Radar (TDWR) data available within the FSI. I have conducted both requirement and design approach reviews and am currently in the middle of making the coding changes required so that the TDWR data will be available in build OB9 of AWIPS. I have coordinated with the Melbourne, Florida WFO and will be conducting an alpha test of the software in July of this year at their site.

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

Objectives for the past year were successfully met.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators, Communications 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:

7. Outreach:

8. Publications:

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 in its formative stages. A statement of need has been developed and I created a requirements document for this project. This project will be prototyped in the new AWIPS II framework with the intention of bringing the application into operations after AWIPS II has been deployed to the field.

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

Objectives for the past year were successfully met.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators, Communications 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:

7. Outreach:

8. Publications:

CONTINUED DEVELOPMENT OF TROPICAL CYCLONE WIND PROBABILITY PRODUCTS

Principal Investigator: Stan 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:

This project is to continue the development of the Monte Carlo (MC) wind probability program and assist with the implementation of new products that are derived from the output. A verification system for the probabilities will also be developed. At the request of TPC, a new task involving the evaluation of the probabilities associated with hurricane watches and warnings from the 2004 and 2005 hurricane landfalls was added. Results from this new study were presented at the 2006 IHC. Michelle Mainelli from TPC is extending the work with the probabilities and the watches/warnings.

2. Research Accomplishments/Highlights:

Training assistance and product improvement.

M. DeMaria coordinated with Rick Knabb of TPC to provide feedback on a training session that was developed to help explain the new probabilities to NWS forecasters and other users of the new products. The MC model was run for a number of historical cases for inclusion in the training. In addition, several cases from the 2004-2006 seasons were re-run using the most current version of the program for Pablo Santos from the Miami WFO, for the development of an experimental algorithm that utilizes the probability output.

A feature in the code that assigned the climatological wind radii calculation by basin of origin instead of current location was identified. This problem has been fixed in the current version of the code.

Examining wind probabilities at the watch/warning break points

The wind probabilities associated with U.S. hurricane warnings from the 2004 and 2005 seasons were evaluated. Table 1 lists all the storms that had a warning issued for at least on time period. A program to match the supplemental break points with a hurricane warning with the probability output has also been developed. The probabilities at the break points had slightly negative biases but, nonetheless, were 28% better than the NHC deterministic forecast at determining whether hurricane conditions occurred and were very skillful in discriminating between events and non-events. Results show that for all the coastal points for which a warning was issued for these 14 storms, the average 5-day cumulative probability was 28%, and the probabilities at the ending point of the warning were 9%. This is consistent with previous analysis of the warning regions which suggests that when a warning is issued there is actually only about a 1 in 4 chance of the point experiencing hurricane winds. Another interesting finding was that for this sample, warnings were left up long after the threat was over (i.e., P=0%) in some cases and the warning areas could be reduced if probabilities set to the 10th percent were use as guidance for when to lower warnings. Development of an automated procedure to provide objective guidance for the placement of hurricane watches and warnings for the NHC forecasters is under development.

Table 1. Atlantic Storms with at Least One Hurricane Warning

Storm Name	Year
Alex	2004
Charley	2004
Frances	2004
Gaston	2004
Ivan	2004
Jeanne	2004
Arlene	2005
Cindy	2005
Dennis	2005
Emily	2005
Katrina	2005
Ophelia	2005
Rita	2005
Wilma	2005

Verification code

The primary goal of this project was the development of FORTRAN code to verify the Monte Carlo wind probabilities and compare those forecasts to information contained in the deterministic forecasts issued by TPC and JTWC. The verification code creates statistics that answer specific questions about the MC forecasts. Table 2 shows those statistics and the questions they answer.

The verification consists of the comparison of the six MC grids (i.e., 34, 50, 64, cumulative and incremental) with similar grids populated by ones and zeros that were created from observed (i.e., best track) and deterministic (i.e., OFCL +DRCL wind radii when no OFCL wind radii exist) forecasts. The final output consist of an accumulation of statistics (in three files) shown in Table 2 at each 6-hourly time period. The year-to-year changes in the statistics can be used to gauge deterministic forecast improvements, and improvements/changes in the MC algorithms.

Examples of the reliability diagrams for the 72-hour cumulative probabilities in each of these basins are shown in Figure 1. The statistics (not shown) also indicate the wind probabilities in the Atlantic, East Pacific and Central Pacific are performing well with acceptable initial biases, are able to outperform the deterministic forecasts in detecting winds exceeding the 34-, 50-, and 64-kt thresholds and are very skillful in discriminating events (in a basin wide sense).

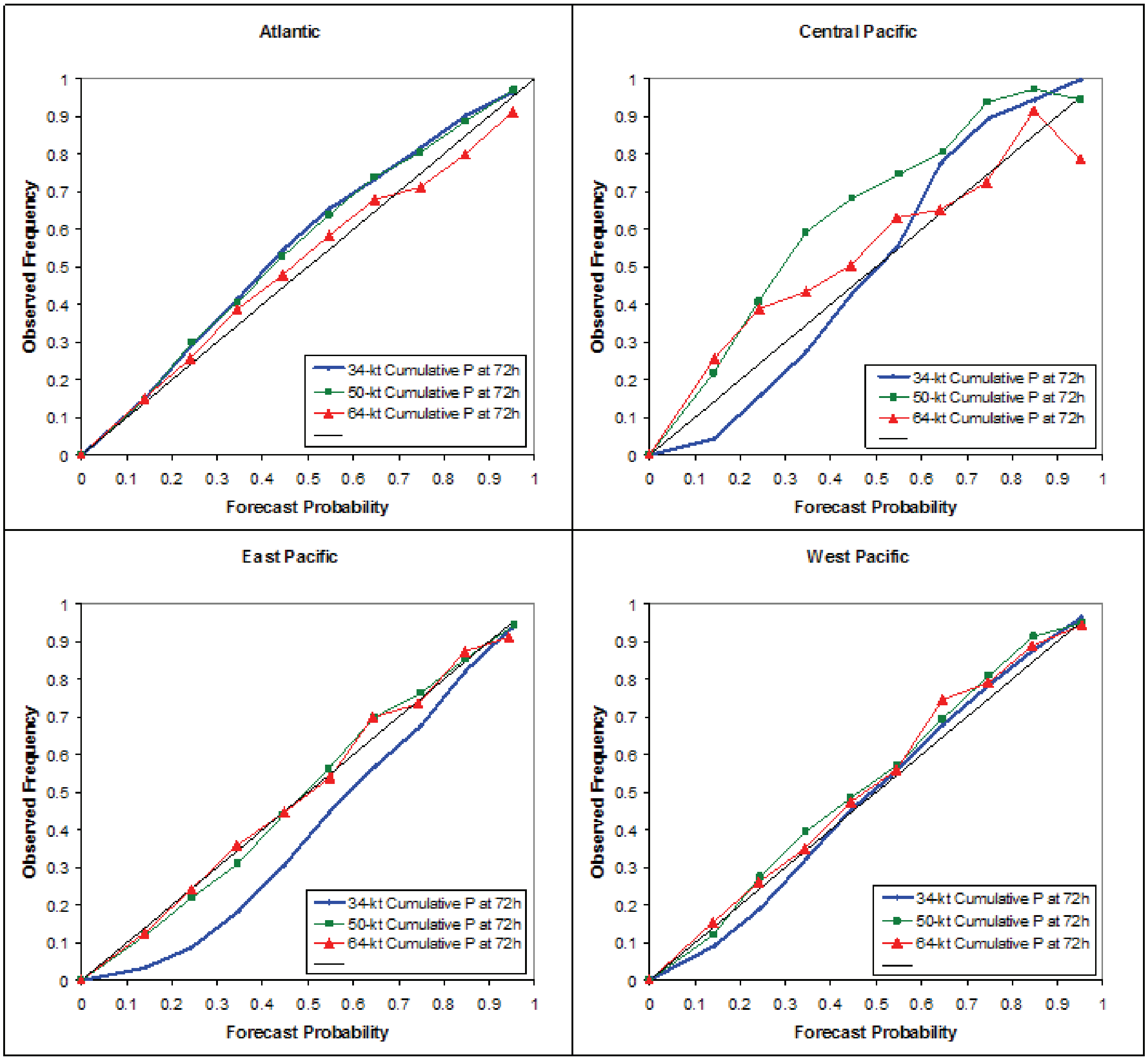


Figure 1. Reliability diagrams for cumulative 72-h tropical cyclone wind probabilities at 34-, 50-, and 64-kt wind thresholds in the Atlantic (110W-1W), Central Pacific (180W-140W), East Pacific (95W-140W), and the West Pacific (100E-180). The latitude domain is 1N to 60N.

The Western North Pacific probabilities on the other hand have larger initial biases and do not outperform the deterministic forecast until beyond 48 hours. We speculate that the problem at the early forecast times is related to the way in which JTWC estimates their wind radii.

Table 2. Statistics associated with the verification of probabilistic forecasts and the questions they are designed to answer.

Statistic	Question answered
Brier Score	*What is the magnitude of the probability forecast errors?*
Brier Skill Score a. climatology reference b. deterministic forecast reference	*What is the relative skill of the probabilistic forecast over that of climatology and the deterministic forecast, in terms of predicting whether or not an event occurred?*
Reliability Diagrams	*How well do the predicted probabilities of an event correspond to their observed frequencies?*
Relative Operating Characteristics	*What is the ability of the forecast to discriminate between events and non-events?*

The verification code has been provided to TPC via C. Lauer and 2001-2006 error distributions were provided to JTWC and TPC/NCEP.

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

All proposed tasks have been accomplished.

4. Leveraging/Payoff:

This project has a direct connection with the public interest. Coastal evacuations and other preparations for tropical cyclones are extremely expensive. Track and intensity forecast improvements should help to narrow down the regions that require coastal evacuations. The new probability program will provide a quantitative measure of the risk of various wind thesholds and will likely lead to a number of new operational products that will be distributed to the public.

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

This research is a joint effort between several groups with 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 as yet

7. Outreach:

<u>Presentations</u>

DeMaria, M., J.A. Knaff, S. Kidder, P. Harr and C. Lauer, 2008: An improved wind probability program. 62nd Interdepartmental Hurricane Conference, March, 2008, Charleston, SC.

Knabb, R., M. Mainelli, and M. DeMaria, 2008: Operational Tropical Cyclone Wind Speed Probability Products from the National Hurricane Center. AMS Annual Meeting, January 2008, New Orleans, LA.

8. Publications:

<u>Refereed Journal Articles</u>

DeMaria, M., J.A. Knaff and C. R. Sampson, 2007: Evaluation of long-term trend in tropical cyclone intensity forecasts. *Meteor. Atmos Phy*., 97, 19-28.

Knaff, J. A., C. R. Sampson, M. DeMaria, T. P. Marchok, J. M. Gross, and C. J. McAdie, 2007: Statistical Tropical Cyclone Wind Radii Prediction Using Climatology and Persistence. *Wea. Forecasting*, 22:4, 781–791.

CONTINUED INVESTIGATION OF THE NORTH AMERICAN MONSOON SENSITIVITY TO BOUNDARY AND REGIONAL FORCING WITH A FOCUS ON LAND-ATMOSPHERE INTERACTION

Principal Investigators: Roger A. Pielke, Sr. and Christopher L. Castro

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

Key Words: North American Monsoon System (NAMS), El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Modeling

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

Warm season precipitation in North America and its variability is strongly influenced by the North American Monsoon System (NAMS). Two hypotheses exist to explain NAMS variability: 1) remote sea surface temperature (SST) forcing, and 2) local surface influence. NAMS onset is influenced by time-evolving Pacific SST teleconnection patterns related to the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), as shown by Castro et al. (2006a,b). Presumably, local surface influences of snow cover, soil moisture, and vegetation become more important as the summer proceeds. The role of soil moisture, particularly in the central U.S., has been investigated using both GCMs and RCMs more unknown is the possible role of vegetation on NAMS variability. NAMS-focused RCM investigations have thus far been limited to diagnostic or sensitivity studies. To systematically test each hypothesis of NAMS variability in a RCM framework, it is desirable to use an ensemble approach in which the RCM experimental design is fixed for a series of summer simulations. The Regional Atmospheric Modeling System (RAMS) is being used to continue the NAMS investigation with a focus on land-surface influence. The first phase of this study will explore the role of antecedent soil moisture on summer teleconnection patterns. During the second phase, a fully coupled atmospheric-biospheric model (GEMRAMS), will be used to assess the impact of dynamic vegetation in the RCM simulations.

2. Research Accomplishments/Highlights:

Dynamically downscaled the NCEP-NCAR global reanalysis for the period 1950-2002 (Castro et al. 2007a). This was follow-on modeling work from the observational study of Castro et al. (2001). The regional climate model (RCM) used in this study was the Regional Atmospheric Modeling System (RAMS) (Pielke et al. 1992; Cotton et al. 2003). The incorporation of a modified Kain-Fritsch cumulus parameterization scheme (Castro et al. 2002, 2007a) was crucial to improve the spatial and temporal distribution of warm season precipitation. This study created the longest RCM summer climatology to date for the contiguous U.S. and Mexico. The comparison between the RCM simulations and the North American Regional Reanalysis demonstrated that the resolution provided by a RCM is essential to capture summer climate variability. The main reason for the improvement above a global reanalysis or general circulation model (GCM) is primarily due to the model representation of the diurnal cycle of convection.

By analysis of the variability in these RCM simulations it was shown that the dominant time-varying SST modes in the Pacific affect the onset of the North American Monsoon System (NAMS) (Castro et al. 2007b). A RCM is again needed because the places with the strongest relationship to Pacific SST remote forcing are the central U.S. and the core monsoon region, and summer precipitation in these locations is dominated by the diurnal cycle Time-evolving teleconnections are maximized in early summer and then wane. The model simulations also suggested that the cause of the observed decrease in summer precipitation in western Mexico is due to a long-term increase in eastern Pacific SST, and this could only be realized within the RCM domain.

Similar RAMS boreal summer experiments dynamically downscaled simulations from the NASA Seasonal-to-Interannual Prediction Project (NSIPP) GCM to establish the physical link to remote SST forcing (Castro et al. 2007b). These simulations showed similar results to the ones mentioned before when the GCM accurately represented the summer teleconnection response. This demonstrated that the RCM can yield predictive skill in a seasonal weather prediction dynamical downscaling mode in which the lateral boundary conditions are derived from a GCM with specified SST conditions.

Current work is evaluating the impact of soil moisture conditions and vegetation dynamics to quantify the role of the land surface on North American summer climate variability in a RCM framework (Castro et al. 2006; Castro et al. 2007c). These simulations use spatially varying soil moisture derived from a long-term North American Land Data Assimilation (NLDAS) product, satellite-derived leaf area index (LAI), and a fully coupled atmospheric-biospheric model GEMRAMS. Preliminary statistical analysis of the significant spatiotemporal modes of soil moisture and vegetation show that they act as integrators of the remote forcing by Pacific SST at the interannual and interdecadal time scales. Significant variability occurs at a timescale of about 7 to 9 years for the land-surface variables. The central U.S. has the highest amplitude response in soil moisture because the relationship between precipitation and Pacific SSTs is consistent throughout the whole year in this region. A paper is in preparation that will document the statistical analysis of soil moisture and vegetation (Castro et al. 2008).

We have processed 21 years of bi-weekly Global Inventory Modeling and Mapping Studies Satellite Drift Corrected and NOAA-16 incorporated Normalized Difference Vegetation Index (GIMMS-NDVI) data and derived LAI and vegetation fraction for June to September from 1982 to 2002 for a North America simulation domain. Bi-monthly maximum value composite of GIMMS-NDVI is available for North America for 8 km × 8 km pixel footprint from July 1981 up to-date. These data will be used in spring-summer simulations in an uncoupled mode (using daily climatological satellite-derived LAI) and in a fully coupled mode (using initial LAI) where LAI is prognosed.

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

Due to the PI move to CU-Boulder and Co-PI move to the University of Arizona last year, we have had some delay in the RCM sensitivity experiments with extreme soil

moisture conditions and incorporation of the satellite-derived leaf area index. Other than that, all of our objectives are being met at the rates indicated in our original proposal.
4. Leveraging/Payoff:

We will evaluate the land-surface influence (i.e., soil moisture and vegetation) apart from and in conjunction with remote Pacific-SST forcing. We anticipate that significant synergistic relationships between antecedent soil moisture, dynamic vegetation and large-scale atmospheric variability may be found that lead to extreme summer climate in North America.

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

Our research findings and papers are posted on our research website at http://cires.colorado.edu/science/groups/pielke/pubs/ to provide prompt and broad dissemination of our current research. Dr. Castro and Dr. Beltrán-Przekurat presented research results at the First CPPA Meeting at Tucson, AZ, in August 2006. Dr. Castro participated in the Monsoon Region Climate Applications Binational Workshop in Guaymas, Sonora, Mexico, May 8-11, 2006 and the 31st Climate Diagnostics and Prediction Workshop in Boulder, CO, Oct. 23-27, 2006. Dr. Castro was appointed as a member of the North American Monsoon Experiment (NAME) Science Working Group (SWG) in 2006. During the reporting period, invited presentations were also given by Dr. Castro at the *Centro de Investigación y Educación Superior de Ensenada* (CICESE), Sep. 29, 2006; National Center for Environmental Prediction (NCEP), Oct. 11, 2005; NASA Goddard, Oct. 10, 2005; Purdue University, Department of Atmospheric Sciences, Oct. 6, 2005; and the University of Arizona, Sep. 8, 2005. Although this contract has ended through Colorado State University, the research is ongoing through the University of Colorado and this will not be the final progress report on this project.

6. Awards/Honors:

Dr. Castro accepted a professorship at the University of Arizona in Tucson and started there effective July 2006. Dr. Adriana Beltrán-Przekurat has begun working on this project through a subcontract to the University of Colorado in addition to Dr. Castro and Dr. Pielke.

7. Outreach:

Conference and Meeting Presentations

Beltrán-Przekurat, A., C.H. Marshall, and R.A. Pielke, Sr., 2006: Numerical Simulations of Recent Warm-Season Weather: Impacts of a Dynamic Vegetation Parameterization. Presented at The First Climate Prediction Program for the Americas (CPPA) PIs Meeting, Tucson, Arizona, August 14-16, 2006.
http:// climatesci.colorado.edu/publications/presentations/PPT-68.pdf

Castro, C.L., R.A. Pielke Sr., and J.O. Adegoke, 2006. Investigation of the Summer Climate of North America: A Regional Atmospheric Modeling Study (Investigación del Clima del Verano en Norteamérica: Un Estudio con un Model Atmoférico Regional). Presented at: 1) Monsoon Region Climate Applications: a Binational Workshop. Instituto Technológico de Sonora (ITSON), Guaymas, Sonora, Mexico, May 8-11, 2006; 2) First Climate Prediction Program for the Americas (CPPA) Principal Investigators Meeting, Tucson, Arizona, August 14-16, 2006; and 3) 31st Climate Diagnostics and Prediction Workshop, Boulder, Colorado, October 23-27, 2006.
http:// climatesci.colorado.edu/publications/presentations/PPT-63.pdf

Castro, C.L., A.B. Beltrán-Przekurat, and R.A. Pielke, Sr., 2006. Statistical Characterization of the Spatiotemporal Variability of Soil Moisture and Vegetation in North America for Regional Climate Model Applications. Presented at: 1) First Climate Prediction Program for the Americas (CPPA) Principal Investigators Meeting, Tucson, Arizona, August 14-16, 2006; and 2) 31st Climate Diagnostics and Prediction Workshop, Boulder, Colorado, October 23-27, 2006.
http://climatesci.colorado.edu/publications/presentations/PPT-67.pdf

Castro, C.L., A.B. Beltran-Przekurat, and R.A. Pielke Sr., 2007c: Spatiotemporal Variability and Covariability of Temperature, Precipitation, Soil Moisture, and Vegetation in North America for Regional Climate Model Applications. Presented at the American Geophysical Union Joint Assembly, Acapulco, Mexico, 22-25 May 2007.
http://climatesci.colorado.edu/publications/presentations/PPT-85.pdf

8. Publications:

Beltrán-Przekurat, A., C.A. Marshall, and R.A. Pielke Sr., 2008: Ensemble re-forecasts of recent warm-season weather: Impacts of a dynamic vegetation parameterization. J. Geophys. Res. - Atmos., accepted with revisions.
http://climatesci.colorado.edu/publications/pdf/R-335.pdf

Castro, C.L., A. Beltrán-Przekurat, and R.A. Pielke Sr., 2008. Long-term spatiotemporal variability of soil moisture and vegetation in North America and its relationship to atmospheric forcing. In prep., J. Hydrometeorology.

Castro, C.L., R.A. Pielke, Sr., and J.O. Adegoke, 2007a. Investigation of the Summer Climate of the Contiguous U.S. and Mexico Using the Regional Atmospheric Modeling System (RAMS). Part I: Model Climatology (1950-2002). *J. Climate*, 20, 3866-3887.
http://climatesci.colorado.edu/publications/pdf/R-306.pdf

Castro, C.L., R.A. Pielke, Sr., J.O. Adegoke, S.D Schubert, and P.J. Pegion, 2007b. Investigation of the Summer Climate of the Contiguous U.S. and Mexico Using the Regional Atmospheric Modeling System (RAMS). Part II: Model Climate Variability. *J. Climate*, 20, 3888-3901.
http://climatesci.colorado.edu/publications/pdf/R-307.pdf

Rockel, B., C.L. Castro, R.A. Pielke Sr., H. von Storch, and G. Leoncini, 2007: Dynamical downscaling: Assessment of model system dependent retained and added variability for two different RCMs. Geophys. Res. Lett., submitted. http://climatesci.colorado.edu/publications/pdf/R-325.pdf

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

Principal Investigator: Lewis Grasso

NOAA Project Goal: Weather and Water

Key Words: Tropical Cyclone, Hurricane, Precipitation, Rainfall, Tropical Cyclone Intensity, Tropical Cyclone Formation

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

This project encompases the development and improvement of three separate operational products including: (1) the development and operational implementation of an Advanced Microwave Sounding Unit (AMSU) –based global tropical cyclone intensity algorithm, (2) the development and operational implementation of an objective satellite-based tropical cyclone formation prediction for the Atlantic, eastern N. Pacific and the western N. Pacific, and (3) improvements of the already operational NOAA/NESDIS Hydroestimator product using cloud resolving numerical modeling.

The long-term goals of this project are as follows:

(1) To develop and operationally implement an AMSU-based tropical cyclone intensity algorithm developed at CIRA. The original algorithm was developed for use in the Atlantic and eastern North Pacific. Using historical global tropical cyclone datasets this algorithm is being generalized for global use. Once generalized it will be produced in real-time in both an experimental and pre-operational manner at CIRA. Working with NOAA/NCEP/TPC personnel, the Algorithm will be made part of set of operational products and will provide routine fixes of tropical cyclone to complement the DVORAK-based tropical cyclone intensity estimates.

(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 SAB website. Finally, the product will be extended to the central and western N. Pacific.

(3) The long-term research objectives are to aid in the improvemnt of the operational hydroestimator in collaboration with Dr. Bob Kuligowski. Specifically, a numerical cloud model is combined with an observational operator—that contains OPTRAN code and

radiational transfer models—to produce synthetic GOES infrared images. These images are used in conjunction with numerical model output to build brightness temperature/rainrate statistics.

2. Research Accomplishments/Highlights:

Products (1) and (3) were reported as completed in the FY06 report.
(2) The pre-operational phase of the new Tropical Cyclone Formation Probability (TCFP) product was successfully completed during this report period. During this phase a new TCFP product with an updated algorithm and an extended domain that covers the Atlantic, eastern N. Pacific and the western N. Pacific was run experimentally at CIRA and displayed in real-time on the experimental website http://rammb.cira.colostate.edu/projects/gparm/index.asp. The new TCFP product was run concurrently with the current operational product, available at http://www.ssd.noaa.gov/PS/TROP/genesis.html.

The product was verified by CIRA scientists over the 2007 hurricane/typhoon season and found to be skillful with respect to a reference forecast based on climatology alone. In addition, the Joint Typhoon Warning Center (JTWC) in Pearl Harbor, HI provided a written evaluation of the product from August – December 2007. This JTWC evaluation indicated that the TCFP was a good product for identifying possible areas of TC formation and suggested that the sub-basin time series products were useful in establishing trends. The evaluation also suggested future additions and improvements that could be made to the product, including the extension of the forecast period beyond 24 hours. Many of the suggested improvements are currently being worked on under other projects, and those that are not will be considered for future modifications to the TCFP product.

With the help of personnel from NOAA/NESDIS/IPB, the new TCFP product is currently in the process of being transitioned to operations and expected to be declared operational on schedule by June 2008.

.

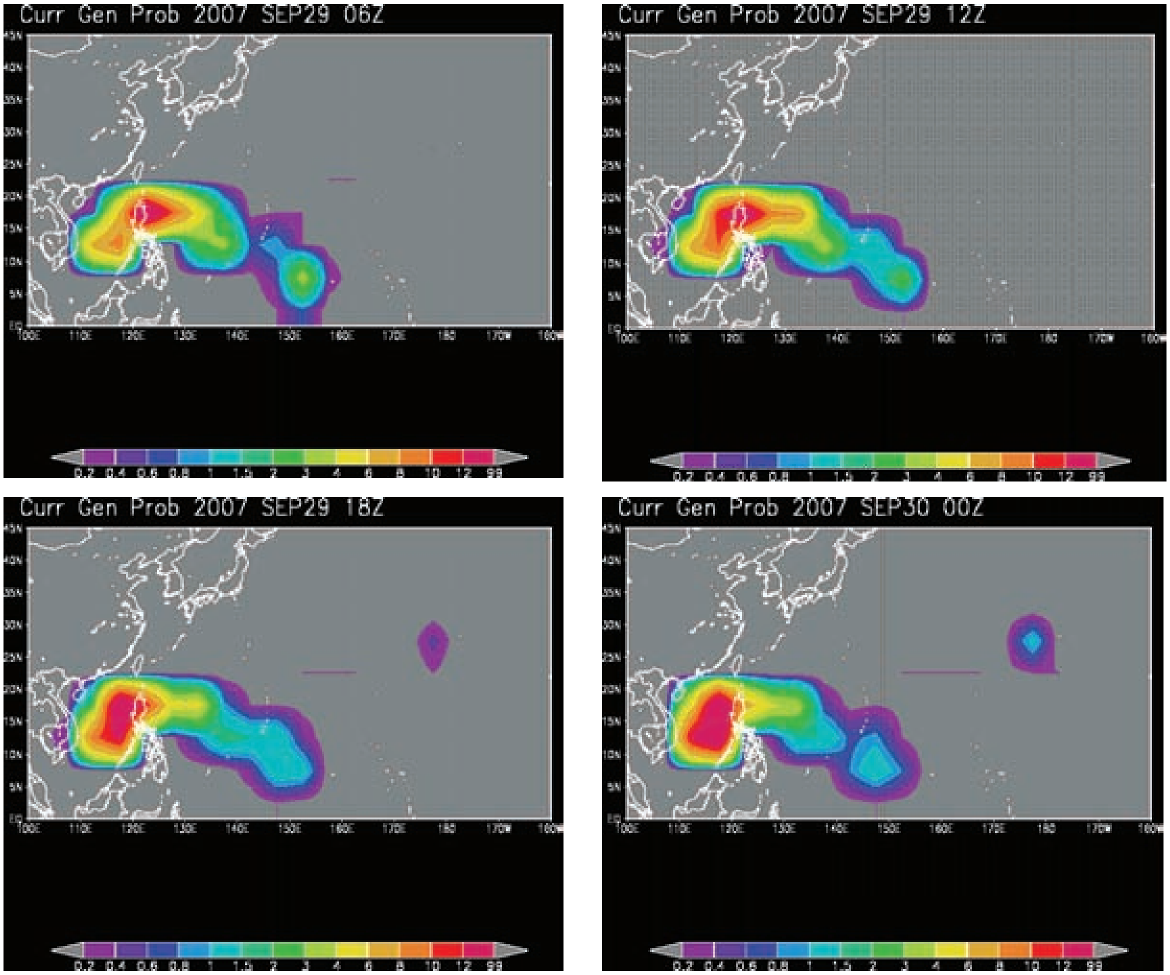


Figure 1. The TCFP predicted probabilities over the western N. Pacific for 9/29/07 6Z (upper left), 12 Z (upper right), 18Z (lower left) and 9/30/07 0Z (lower right), which correspond to the 4 analysis time within 24 hours prior to the formation of WP16 (Typhoon Lekima) at 9/30/07 6Z.

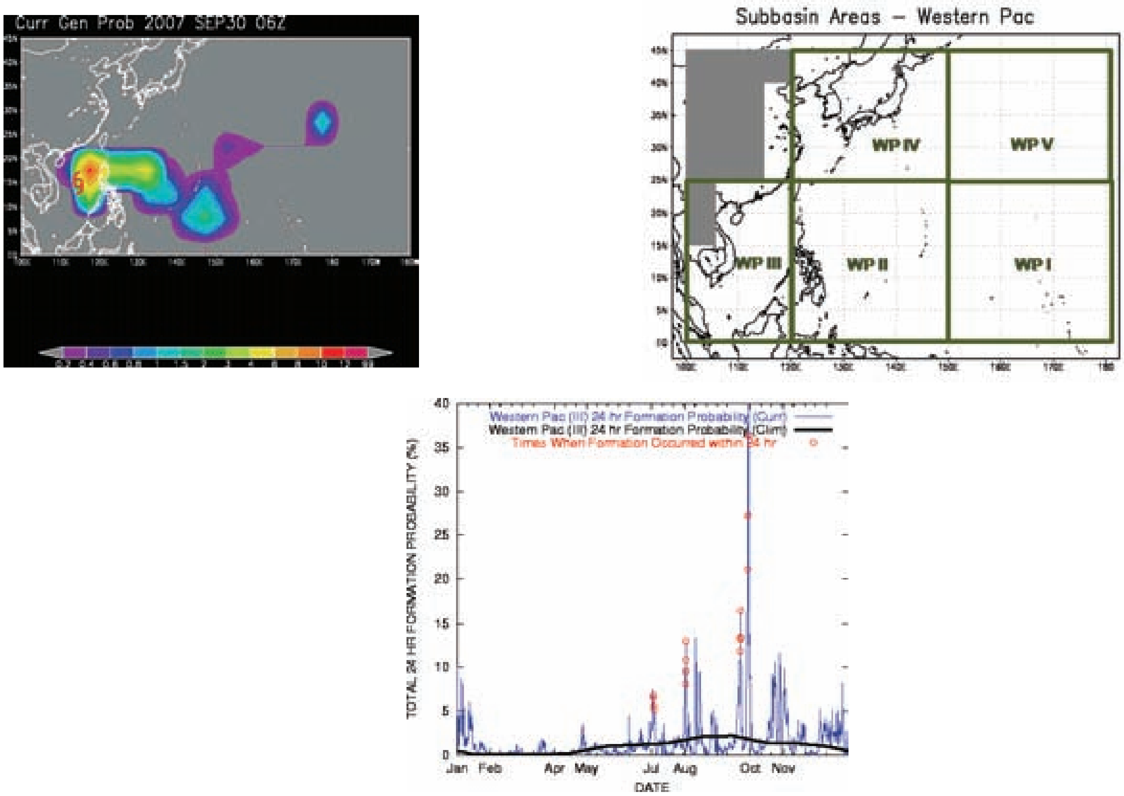


Figure 2. WP16 (Typhoon Lekima) formed at 14.9° N, 114.9° E (top left), which is in western N. Pacific sub-basin WPIII (top right). The time series plot of summed formation probabilities over WPIII (bottom) shows a sharp increase in sub-basin probabilities just prior to the formation of WP16 on 9/30/07 6Z. The red dots indicate the times at 6, 12, 18, and 24 hours prior to formation.

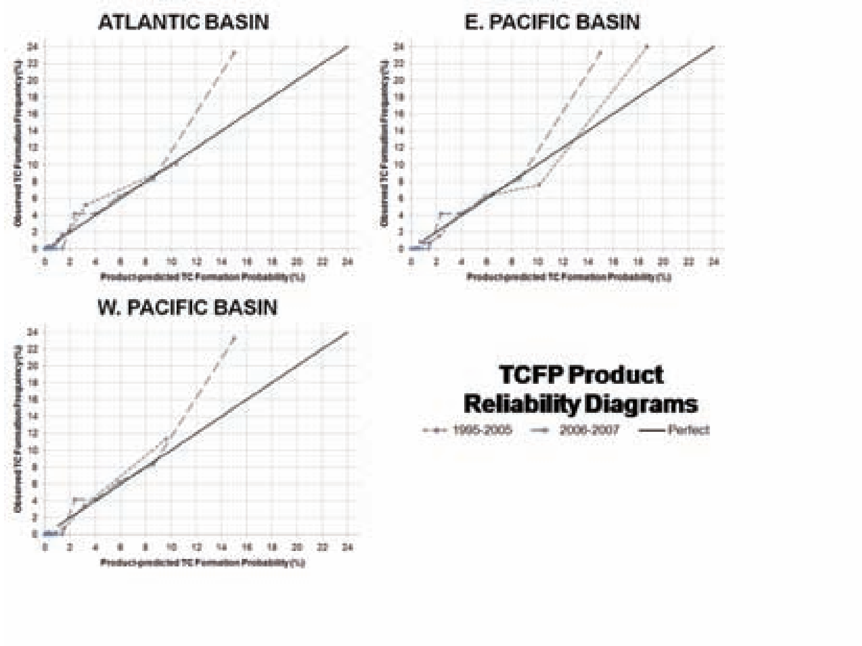


Figure 3. Reliability Diagrams for the Atlantic (top left), E. Pacific (top right) and W. Pacific (bottom left) basins.

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

We have met our objectives for this reporting period. The pre-operational phase, which included the experimental running of the new TCFP product in real-time at CIRA and the evaluation of that product at the end of the 2007 hurricane/typhoon season, is complete. Transfer of the new TCFP, including all fortran code and scripts, to the Satellite Services Division Satellite Analysis Branch is in progress and is expected to be complete by the deadline of June 2008.

4. Leveraging/Payoff:

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.

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

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).
6. Awards/Honors:

NOAA Bronze Medal, Mark DeMaria, Antonio Irving, Nancy Merckle, John A. Knaff: For the development and operational implementation of the Tropical Cyclone Formation product that quantitatively predicts storm formation probability.

7. Outreach:

(a) An undergraduate student at Colorado State University (Greg DeMaria) assisted with the webpage product display for the new experimental TCFP product.

8. Publications:

Refereed Publications

Schumacher, A. B., M. DeMaria, and J.A. Knaff, 2007: Objective Estimation of the 24-Hour Probability of Tropical Cyclone Formation. *Wea. Forecasting*, submitted 12/2007.

Conference Proceedings

Schumacher, A. B., M. DeMaria, J. Knaff, D. Brown, 2008 Oral Presentation: *The NESDIS Tropical Cyclone Formation Probability Product: An Overview of Past Performance and Future Plans*. 62nd Interdepartmental Hurricane Conference, Charleston, SC, available on-line at http://www.ofcm.gov/ihc08/linking_file_ihc08.htm.

DEVELOPMENT OF A MULTI-PLATFORM SATELLITE TROPICAL CYCLONE WIND ANALYSIS SYSTEM

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Weather and Water, Commerce and Transportation

Key Words: Tropical Cyclone, Hurricane, GOES data, Microwave Satellite Data

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

The purpose of this project is to combine measurements from a number of satellite platforms to estimate the surface wind fields of tropical cyclones. There are several methods for estimating subsets of the tropical cyclone wind field from satellite data that are used at operational forecasting centers. However, these methods tend to be used in isolation. For example, the Dvorak classification method has been used for several decades to provide an estimate of the maximum wind of tropical cyclone from either an infrared or visible satellite image. However, it does not directly utilize other information available information such as microwave imagery. In this project, GOES infrared imagery and feature-tracked wind, the Advance Microwave Sounder Unit (AMSU) from the NOAA Polar-orbiting satellites, surface scattermeter winds (currently from QuikSCAT), and passive wind speed estimates from Defense Military Satellite Program (DMSP) microwave data will be combined. The wind information from these various sources will be combined in a specialized varitaional analysis that can include measures such as those from DMSP that only provide a wind speed estimate. The eventual goal of the project is to provide the multi-platform wind tropical cyclone wind analysis system to operational forecast centers.

2. Research Accomplishments/Highlights:

During the first year of the project, a method to estimate the wind field from GOES IR data was developed. The IR wind field estimate is the anchor for the variational analysis because that data is nearly always available in all tropical cyclone basins. The IR wind field estimate can then be refined when other data sources are available. For this part of the study, a dataset of 402 cases from 1995-2003 Atlantic and east Pacific tropical cyclones was constructed for development of the IR wind field algorithm. GOES infrared imagery was obtained for these cases, which also have aircraft reconnaissance data available for groundtruth. The IR wind algorithm uses a parameter wind model and requires an IR image, the storm position, the storm motion vector, and the storm intensity as input.

The variational analysis system was adapted to the problem of using satellite wind observations to estimate a complete surface wind field. The analysis system utilizes a “model fitting” approach where the data on a regular grid that provide the best fit to the observations is determined. A smoothness constraint helps to determine the wind field in data void regions. In the solution for the final wind field, a “cost function” which measures the difference between the observations and the model counterpart of the observations (in this simplest version of the variational analysis used, the model counterpart of the observations is the analysis wind field interpolated to the observations points) is minimized. In this framework, it is straightforward to include observations that only provide an estimate of the wind speed but without a direction. Two important contributions to tropical cyclone wind field outside of the eyewall region of the storm comes from the AMSU instrument and from QuikSCAT. Considerable effort was made to determine the error characteristics of these two wind instruments, and a method was developed to convert the AMSU winds (which are representative of winds above the boundary layer) to the surface. This work was performed by a CIRA visiting scientist from the Japanese Meteorloglical Agency (JMA).

In the second and final year of this project, collection of satellite-derived wind datasets (QuickScat, AMSU, Cloud drift, Water Vapor, SSMI, and IR-based) over all global tropical cyclones has been automated as this project moves toward the goal of a satellite-only tropical cyclone wind field. The collection of these data over a 12-hour period preceding the synoptic time has also been automated to produce a general format for use in variational analysis described above. The production of 6-hourly tropical cyclone wind fields at the surface and at 700 hPa was begun in late summer of 2005. The automation includes a simple gradient suface correction over both land and water. The results are displayed on a webpage for anyone to peruse. Information from the analyses is also being shared with the Joint Typhoon Warning Center for evaluations of their usefullness in operations. Figure 1 shows an example of three surface wind analyses of Typhoon Chanchu (02W 2006) as it makes landfall east of Hong Kong.

The automated output generated during the 2005 Atlantic Hurricane Season was verified against H*wind analysis which include aircraft reconnaissance, ships, bouy, surface station data in addition to scatterometry and cloud drift winds. These results were presented at the AMS satellite conference. Following this verification, the algorithms were modified to correct for problems found during evaluation. The algorithm will be further evaluated following the 2006 Hurricane season.

The longer-term goal is to transition the final process to operations.

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

The project is on schedule. The development of the components of the satellite tropical cyclone wind algorithm are complete. Real-time analyses will be produced for evaluation by operational forecast centers by 1 August.

4. Leveraging/Payoff:

This research should lead to improved methods for estimating the tropical cyclone surface wind field. The improved method will provide more accurate measurements of the radii of critical wind thresholds such as gale, storm and hurricane (34, 50 and 64 kt) that are routinely provided by operational forecast centers. These radii are crucial for determining the timing of coastal evacuations, ship routing, and are used as input for other applications such as wave forecast models, and tropical cyclone track and intensity models. All of these parameters are important for protecting lives and property from the effects of tropical cyclones.

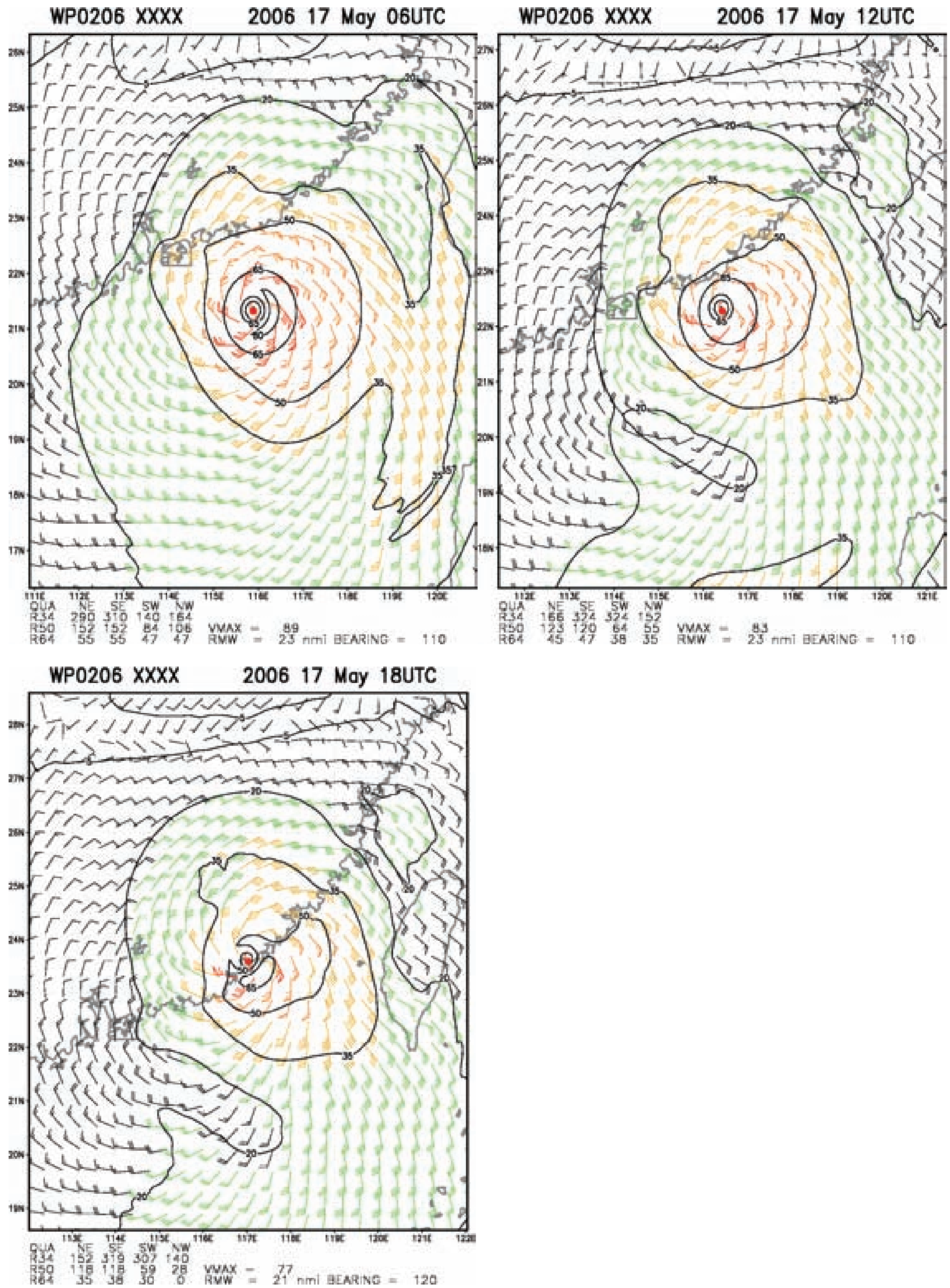


Figure 1. Six-hourly surface wind analyses for Typhoon Chanchu on May 17, 2006 as it makes landfall in China just east of Hong Kong. These were created in real-time and displayed on the web.

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

This work is a collaborative effort between the NOAA/NESDIS Office of Research and Applications, the NOAA/OAR Hurricane Research Division, the NOAA/NCEP Tropical Prediction Center, the Department of Defense Joint Typhoon Warning Center, Colorado State University and the Japenese Meteorological Agency (JMA). It is likely that some aspects of this research will be adapted by JMA, and may lead to new operational forecast products for JTWC and TPC.

6. Awards/Honors: None as yet

7. Outreach:

(a) Two CSU graduate students (both Masters) have contributed to this research. Julie Demuth helped to develop the AMSU tropical cyclone wind analysis system, and Kimberly Mueller is developing the algorithm for the GOES IR wind field.

(d) Information on applications of satellites to hurricane analysis is often included in K-12 presentations.

8. Publications:

<u>Refereed Journal Articles</u>

Bessho, K., M. DeMaria, J.A. Knaff, 2006: Tropical Cyclone Wind Retrievals from the Advanced Microwave Sounder Unit (AMSU): Application to Surface Wind Analysis. *J. of Applied Meteorology.* 45:3, 399 - 415.

Demuth, J.L., M. DeMaria, and J.A. Knaff, 2006: Improvement of advanced microwave sounding unit tropical cyclone intensity and size estimation algorithms. *J. App. Met.*, in press.

Mueller K., M. DeMaria, J.A. Knaff, and T.H. Vonder Haar 2005: Objective Estimation of Tropical Cyclone Wind Structure from Infrared Satellite Data. *Wea. Forecasting*, in press.

<u>Conference Proceedings</u>

Knaff, J.A., and M. DeMaria, 2006: A Multi-platform Satellite Tropical Cyclone Wind Analysis System. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

DEVELOPMENT OF A POLAR SATELLITE PROCESSING SYSTEM FOR RESEARCH AND TRAINING

Principal Investigator: Bernie Connell

NOAA Project Goal: Weather and Water; Commerce and Transportation; Programs: Local Forecasts and Warnings, Hydrology, Aviation Weather, Marine Weather, and Surface Weather

Key Words: Training, Outreach, National and International Cooperation and Collaboration

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

The long term research objective is to perform research to develop products and training for current and future geostationary and polar orbiting satellites. This proposal is to help set up a processing system at CIRA for Met-Op and other polar satellite systems to obtain the data for research purposes. In particular, during this first year, this project will implement a polar satellite data processing system for Met-Op polar orbiting satellite data. Met-Op is operated by the European Space Agency (ESA) and through international agreements; it will provide morning coverage that will complement the afternoon coverage provided by NOAA satellites. The Met-Op satellite contains a number of unique instruments that will be useful for development of products for mesoscale meteorology. These include the hyperspectral IASI sounder, an ocean surface wind instrument (ASCAT), and a five-channel microwave humidity sounder (MHS), which may also be available on future NOAA satellites. In addition, Met-Op includes the AVHRR-3 imager and the Advanced Microwave Sounder Unit. These advanced instruments have numerous applications to tropical cyclone and severe weather analysis and forecast products, and also provide subsets of what will be available on GOES-R and NPOESS.

2. Research Accomplishments/Highlights:

The project will begin in July 2008

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

None as yet

4. Leveraging/Payoff:

NOAA needs to view as tool for justifying public investment in science initiatives). Having data available from the advanced sensors will allow researches to develop products for the forecaster to utilize in severe weather situations. It will also allow for preparation of training materials to train the forecaster to use the products. This will in turn lead to better weather/hazard forecasts for the public.

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

DEVELOPMENT OF AN IMPROVED CLIMATE RAINFALL DATASET FROM SSM/I

Principal Investigators: Christian Kummerow and Wesley Berg

NOAA Project Goal: Climate Observations and Analysis

Key Words: Climate, Rainfall

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

Implement GPROF-2008 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 website (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:

Produced updated and quality controlled archive of SSM/I antenna temperature data in Wentz and TDR formats from DMSP F08, F10, F11, F13, F14, and F15 for the period from July 1987 through the present. We also developed software for the processing of both the Wentz and TDR formats.

Delivered the SSM/I data archive to NCDC for public distribution through their CLASS system

Developed a beta version of an SSM/I specific version of the latest operational GPROF 2008 retrieval algorithm. Initial testing of the algorithm is currently underway.

Developed a technique for intercalibrating the SSM/I brightness temperatures with TRMM TMI in order to produce a consistent climate record. Currently working with the intercalibration working group within the NASA Precipitation Measurement Mission (PMM) science team to refine this approach.

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

--Implement GPROF-2008 for SSM/I: In progress
--Investigate sensitivity of rainfall products: Yet to be started
--Investigate diurnal cycle impacts: In progress
--Produce and distribute SSM/I rainfall products: Yet to be started
--Create composite monthly climate rainfall product: Yet to be started

4. Leveraging/Payoff:

Project goal is to produce improved climate rainfall products from SSM/I for use in merged products such as the Global Precipitation Climatology Project (GPCP) as well as direct distribution of data/plots for public use. Eliminating many of the sources of climate biases is critical for the use of climate rainfall products to investigate climate variability/trends in rainfall.

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

Worked with researchers at NESDIS, CIRA, and NCDC to recover data for long-term SSM/I data archive and subsequently distribute via NCDC's CLASS system.

Leveraging algorithm development efforts funded through NASA to produce long-term rainfall dataset from SSM/I.

6. Awards/Honors:

Certificate of appreciation from the director of NOAA's National Climatic Data Center for providing a comprehensive archive of SSM/I data and associated documentation.

7. Outreach:

Graduate/Undergraduate students:

Eric Stoner, M.S. defense scheduled for August 2008

8. Publications: None as yet

DEVELOPMENT OF THREE-DIMENSIONAL POLAR WIND RETRIEVAL TECHNIQUES USING THE ADVANCED MICROWAVE SOUNDER UNIT

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: POES, AMSU, Satellite-Derived Wind Measurements

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

Satellite-derived wind measurements are most valuable over the oceanic regions where fewer conventional observations exist. This lack of observational data extends over all latitudes, from the tropics to the Polar Regions. Recent results have shown that horizontal winds in Polar Regions estimated from satellites have the capability to increase the accuracy of numerical model forecasts, illustrating the need for improved wind observations in these data sparse regions.

A satellite-based method for estimating the winds in tropical cyclones has been adapted for use at high latitudes. In this method, temperature profiles are calculated from radiances from the Advanced Microwave Sounder Unit (AMSU) which flies aboard NOAA's most recent polar-orbiting satellite series. Using the hydrostatic assumption and a 100-hPa height field from the GFS model as a boundary condition, the temperature profile is used to compute the height field as a function of pressure. A balance equation (geostrophic, linear, or nonlinear) is then solved for the stream function from which the u and v components of the nondivergent wind may be calculated. These retrievals will be referred to as sounder balance winds.

Specifics of the plan to develop this technique include:

Validation of the AMSU temperature retrievals against radiosonde measurements.

Conversion of the balance equation solver from beta-plane geometry on an equidistant latitude/longitude grid to a rotated polar-stereographic coordinate.

Comparison of the sounder balance winds with radiosonde-measured winds as well as with feature-tracked winds from MODIS measurements.

Collection of a larger dataset for validation against radiosondes and comparison to MODIS feature-tracked winds.

2. Research Accomplishments/Highlights:

The research highlights of this year were the comparison among the sounder balance winds, the MODIS feature-tracked winds, and radiosonde winds for the original winter dataset of 2-17 December 2004 as well as for an additional summertime dataset for 13-31 July 2007.

Figure 1 shows the wind speed bias and vector root mean square error (RMSE) of the geostrophic, linear-balance, and nonlinear-balance winds compared to the winds measured by radiosondes. The results are for matches within 1.5 hours and 200 km. These time and distance windows are the same as used by Key et al. (2003). Also shown is the mean radiosonde wind speed as a function of pressure. Plotted on the right-hand side of the figures is the number of matchups at each level. The sounder balance winds perform favorably compared to the MODIS feature-tracked winds. Through the entire atmosphere the wind speed bias of the three balances is between -0.7 and -1.0 m s^{-1}, and the vector RMSE is between 6 and 7 m s^{-1}. Key et al. (2003) report a bias of -0.58 m s^{-1} and an RMSE of 8.11 m s^{-1} for the MODIS feature-tracked winds.

In order to do a more direct comparison between the MODIS feature-tracked winds and the sounder balance winds, a three-way comparison among the two satellite-based techniques and radiosonde launches was performed. As with the AMSU and radiosonde matchups, the time and distance windows were 1.5 hours and 200 km, respectively. All vertical levels were considered together, as the number of matches for each individual level could be rather small. The results for the 120 three-way matches of the winter 2004 dataset are given in Table 1a, and the results for the 188 matchups of the summer 2007 dataset are given in Table 1b. The results are consistent for both the winter and summer datasets. The MODIS feature-tracked winds show a smaller bias (magnitude) than the sounder balance winds, but the balance winds typically have a smaller vector RMSE than the MODIS feature-tracked winds. Only the geostrophic balance for the winter dataset had a greater RMSE than the MODIS feature-tracked winds.

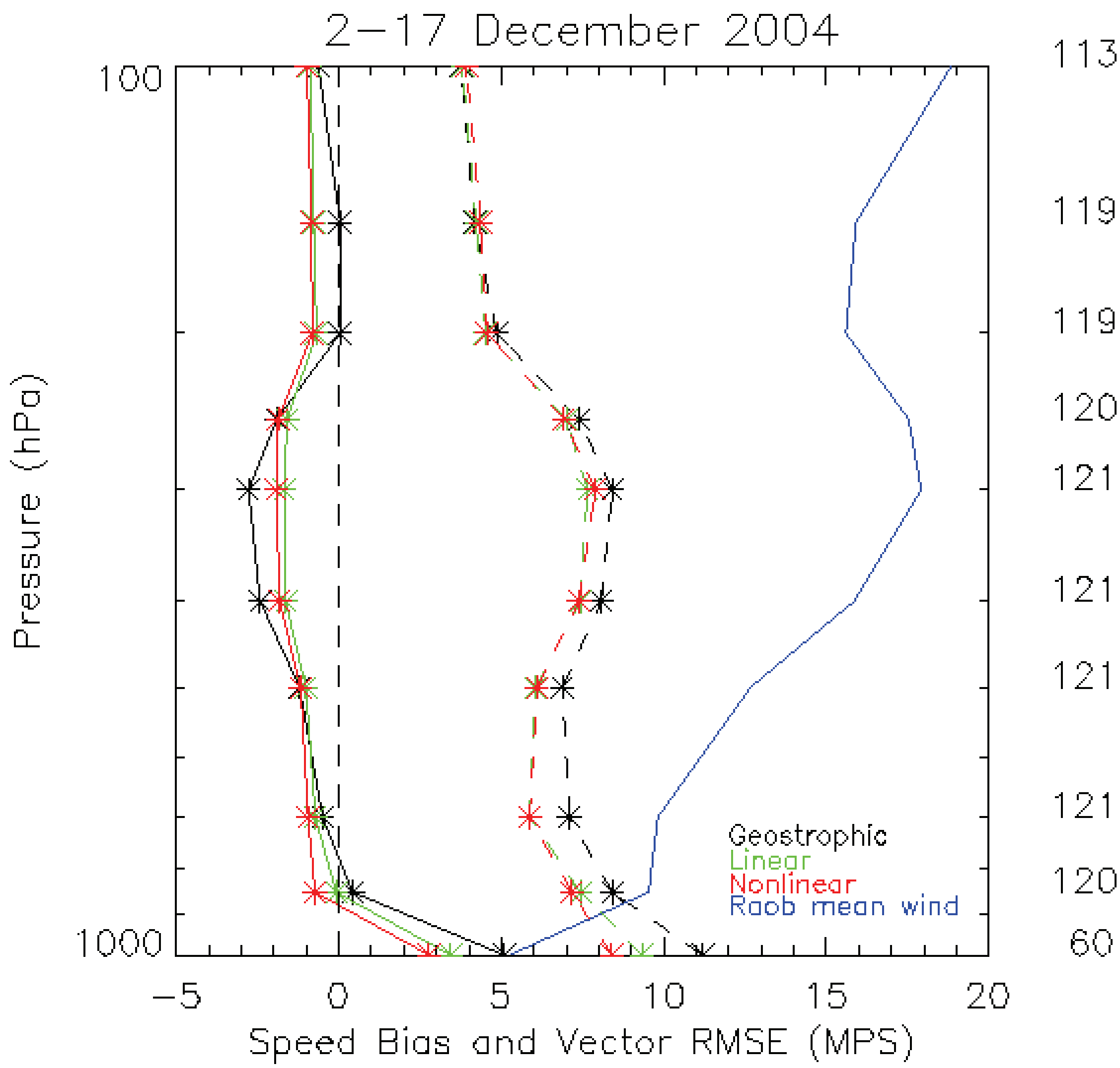


Fig. 1a. Wind speed bias and vector RMSE between the sounder balance winds and collocated radiosondes for the winter 2004 dataset. Solid lines are the bias and dashed lines are the RMSE, with the exception of the solid blue line, which is the mean radisonde-derived wind speed. The colors correspond to the different balance approximations. The number of comparisons at each level is given on the right-hand side of the figure.

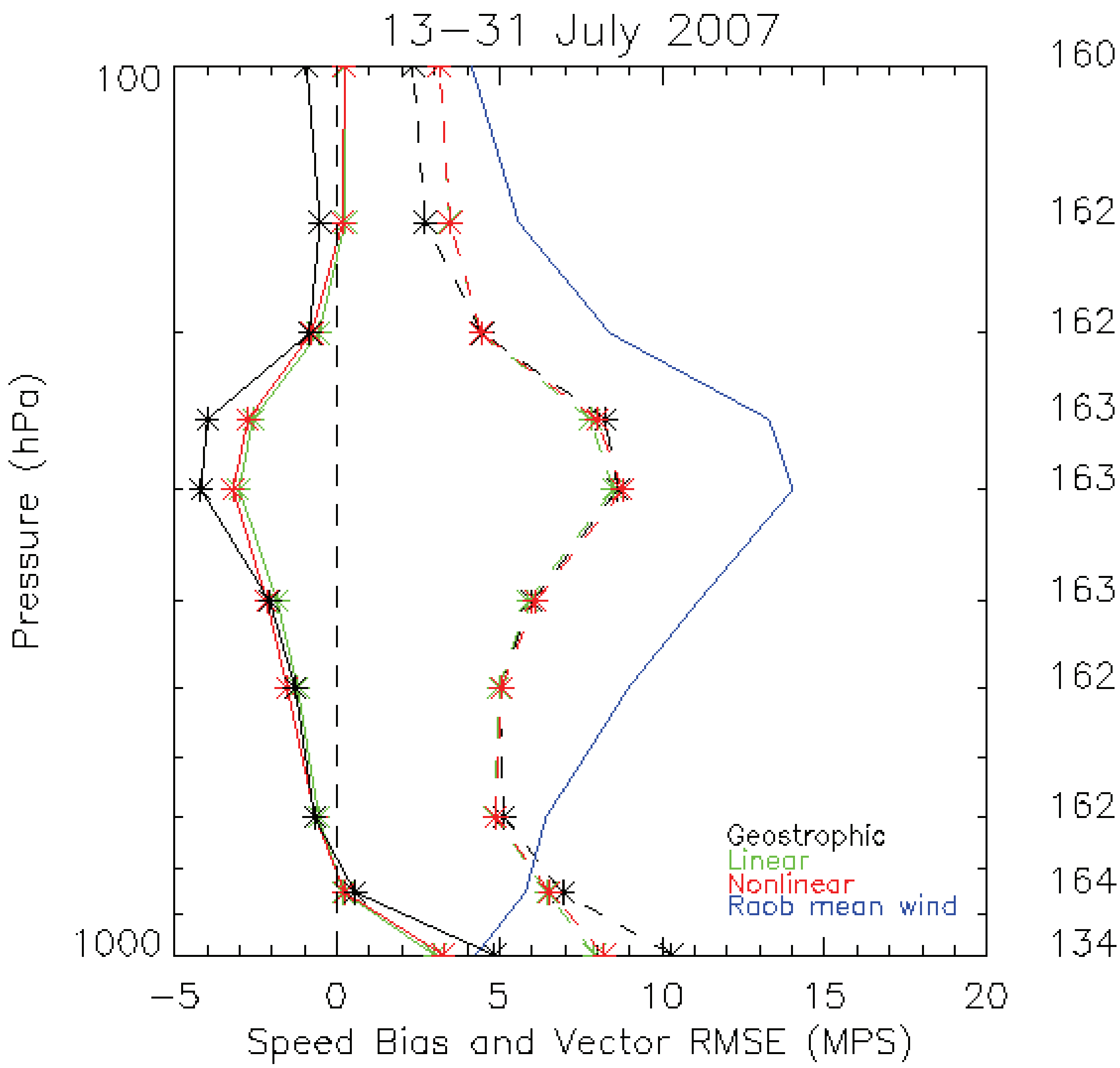


Fig. 1b. Same as Fig. 1a, but for the summer 2007 dataset.

	Speed Bias (m s^{-1})	Vector RMSE (m s^{-1})
MODIS	0.19	8.02
Geostrophic Balance	-2.40	8.18
Linear Balance	-1.60	7.26
Nonlinear Balance	-1.85	7.37

Table 1a. Results of the three-way matchups among the radiosonde winds, MODIS feature-tracked winds, and the sounder balance winds for the 120 matchups of the winter 2004 dataset.

	Speed Bias (m s^{-1})	Vector RMSE (m s^{-1})
MODIS	-0.35	7.11
Geostrophic Balance	-3.00	6.87
Linear Balance	-2.49	6.35
Nonlinear Balance	-2.71	6.61

Table 1b. Same as Table 1a, only for the 188 matchups of the summer 2007 dataset.

Reference Used:

Key, J. R., D. Santek, C. S. Velden, N. Bormann, J. N. Thépaut, L. P. Riishhojgaard, Y. Zhu, and W. P. Menzel, 2003: Cloud-drift and water vapor winds in the polar regions from MODIS. *IEEE Trans. Geosci. Remote Sens.,* 41(2), 482-492.

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

This study is a three-year effort. In the first year, the first two items in section 1 were completed. During the second year, work on the third item began. In the third and final year, the third and fourth items were completed.

4. Leveraging/Payoff:

The development of a satellite-based wind retrieval technique for use over the polar regions will provide wind measurements in an area which is currently sparsely sampled. The inclusion of these wind measurements into numerical models can improve forecasts to the general benefit of the public.

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

The polar winds project involves collaborations with other agencies including the National Environmental Satellite, Data, and Information Service's Office of Research and Applications and CIMSS located at the University of Wisconsin – Madison.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

ENVIRONMENTAL APPLICATIONS RESEARCH

Principal Investigator: T.H. Vonder Haar

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 Prive'

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 Aerial Systems (UAS), Climate, Observations, Arctic

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.

2. Research Accomplishments/Highlights:

Code for the generation of synthetic UAS observations were debugged and ported to the wjet computer system. Access to the NCEP supercomputer was obtained and an account for the GSI data assimilation package has been set up. A method of converting the synthetic UAS observations into BUFR format for ingestion into the GSI was developed and testing of the assimilation of the synthetic data into the GSI is currently underway. Initial testing of the OSSE system is confined to the NCEP supercomputer at the moment due to unavailability of software (GFS/GSI) on wjet. Error characteristics for the synthetic observations have not been included in initial testing of the OSSE system, and are expected to be addressed during the next stage of OSSE development (calibration).

Evaluation of the Nature Run for the Pacific UAS testbed OSSE (Rossby waves) and Arctic Testbed OSSE were performed. The Rossby wave dynamics in the Nature Run were compared with wave behavior in the ECMWF and NCEP reanalysis; Arctic lows were similarly investigated. The boundary layer physics and vertical profile of the Arctic were also compared with observations from sondes, surface data, and upper air observations.

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 was completed. Diagnostic evaluation of the Nature Run is ongoing.

--Objective: Support for the development of an Arctic UAS testbed.

Status: On-going. A panel of UAS testbed leads has been formed and awaiting their determination of further projects for support of the three proposed testbeds in the Arctic, Pacific, and Gulf regions.

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, Communications and Networking:

6. Awards/Honors:

7. Outreach:

8. Publications:

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 and 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 websites for display of those graphics, and creation and management of graphics for hallway public displays, including software for automatic real-time updates.

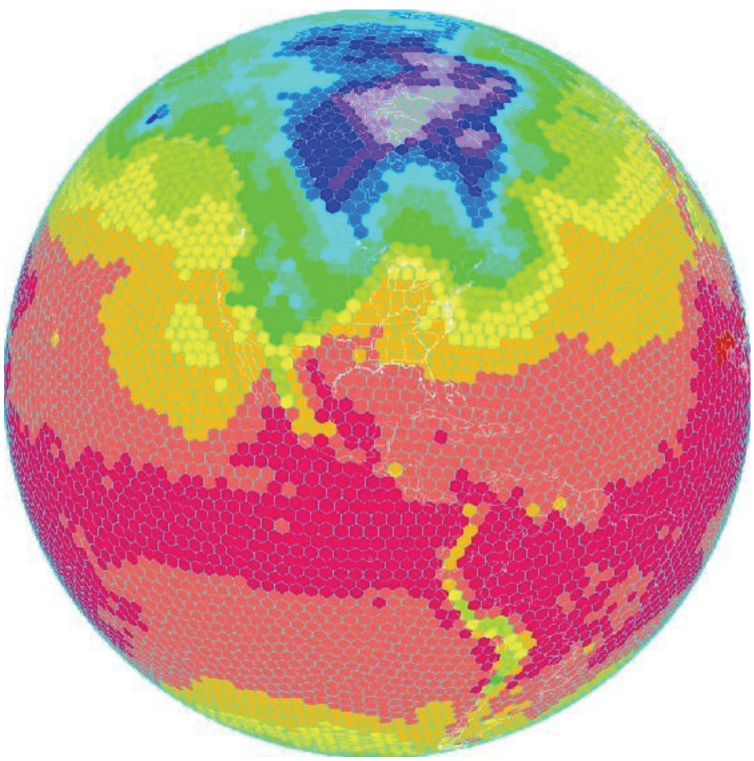


Fig. 1. An example of the icosahedral grid, with FIM model temperature plotted (provided by Ning Wang).

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 and can be compared with other global models such as the Global Forecast System (GFS) model. Currently, a cylindrical equidistant projection is used (Fig. 2); however, other projections are being investigated.

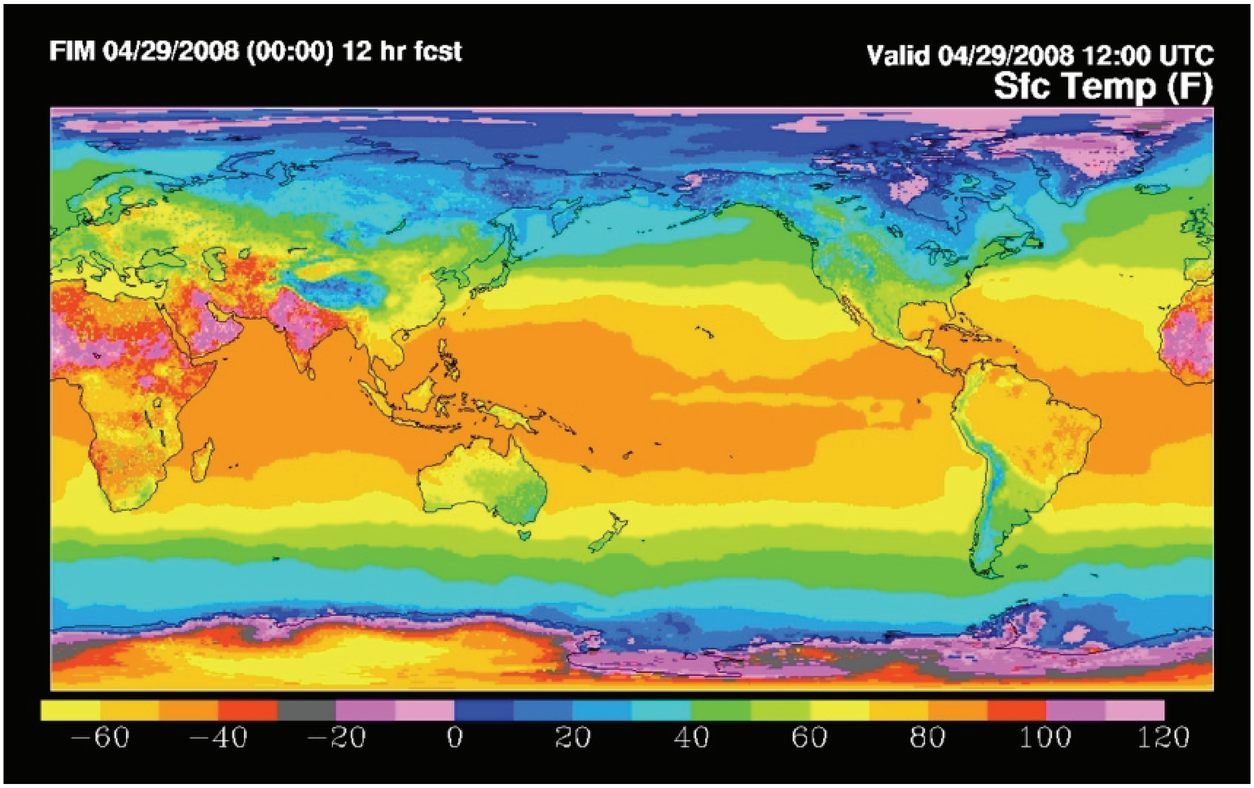


Fig. 2. A cylindrical equidistant plot of surface "skin" temperature from a 12-hour FIM forecast interpolated to a 0.5 degree latitude-longitude grid.

A website for display of FIM model output has been created and has some preliminary products available for perusal with 3-hourly forecasts going out to 7 days (http://fim.noaa.gov/fimgfs). The website is currently being enhanced to include more output products, GFS model output, and FIM-GFS difference fields.

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

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:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Project Title: T-REX (Terrain-induced Rotor EXperiment)

Participating CIRA Researcher: Brian Jamison

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

Key Words: T-REX, Terrain-induced Rotor EXperiment, Wind Flow in Complex Terrain

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

The T-REX project is a testbed for high-resolution, nonhydrostatic weather models in order to provide accurate guidance in complex environments. The test area for T-REX is in the vicinity of the Sierra Nevada mountain range, the location of some of the highest terrain in the coterminus U.S. Tasks for this project include: display of several model variables on a number of isobaric and height levels, display of model and diagnostic parameters through defined cross sections, and development of interactive webpages to facilitate analysis.

2. Research Accomplishments/Highlights:

Scripts were written to display the model and diagnostic variables including: potential temperature, relative humidity, dewpoint, wind, and vertical velocity for five pressure levels; wind, omega, potential temperature, and relative humidity for six height levels; and wind, omega, turbulent kinetic energy (TKE), Richardson number, Scorer parameter, Na/U and Nh/U (which describe the atmospheric response to orographic gravity waves) for vertical cross sections. Some additional plots are also generated for accumulated precipitation, mean sea level pressure, terrain, and skew-T charts for two locations. These scripts were implemented into a master script to automatically generate these graphic products following runs of two separate Weather Research and Forecasting (WRF) models: Advanced Research WRF (ARW) and National Mesoscale Model (NMM). Both of these models used a 2 km X 2 km domain with 50 vertical levels. The products are made available for viewing and comparison on a webpage (http://www-frd.fsl.noaa.gov/mab/trex/).

Adjustments were made to the aforementioned webpage and scripts. The webpage was modified to accept 27 different runs of the two WRF based models. This was designed to allow easy comparison of the output of the models following particular model parameter adjustments. Some other plots were added, including actual terrain along the cross section paths and four-panel plots which feature a top-down view of each relevant flight segment, the "crosstrack" plot (i.e. an aircraft track plotted on a vertical cross section), the comparison plot of aircraft observed theta and vertical velocity against the model data, and a model terrain plot along the aircraft path (Fig. 1).

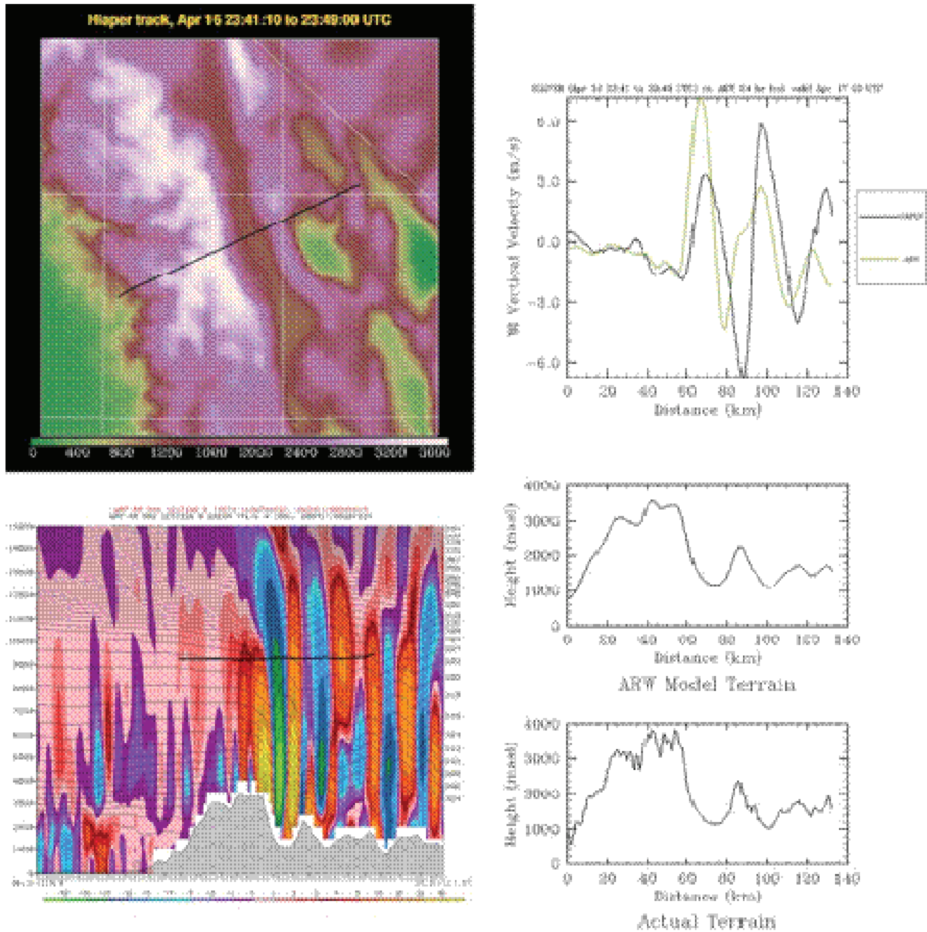


Fig. 1. An example of a 4-panel plot, showing the plan view aircraft track, the "crosstrack" plot of the aircraft track on a vertical cross section, a comparison plot of aircraft and WRF-ARW vertical velocity, and plots of model and actual terrain.

Jim Doyle of the Naval Research Laboratory organized a T-REX model intercomparison study using 2-dimensional model runs with common initial conditions. From the WRF-ARW output, several products were generated including cross section plots of potential temperature, wind components, vertical velocity, turbulent kinetic energy, and eddy diffusivity. In all, five different simulations were performed, three using a simulated "Witch of Agnesi" mountain (Fig. 2), and the other two using actual terrain. Two of the simulation runs revealed some strange results, particularly in the plots of TKE. Further investigation revealed a "bug" in the WRF-ARW code, that when corrected, produced much more reasonable results. Using the corrected version of the model, the plots for all the simulations were redone. An internal webpage was created to allow easier analysis of both the "new" and "old" plots, which currently resides at http://www-frd.fsl.noaa.gov/mab/trex/2dsims.

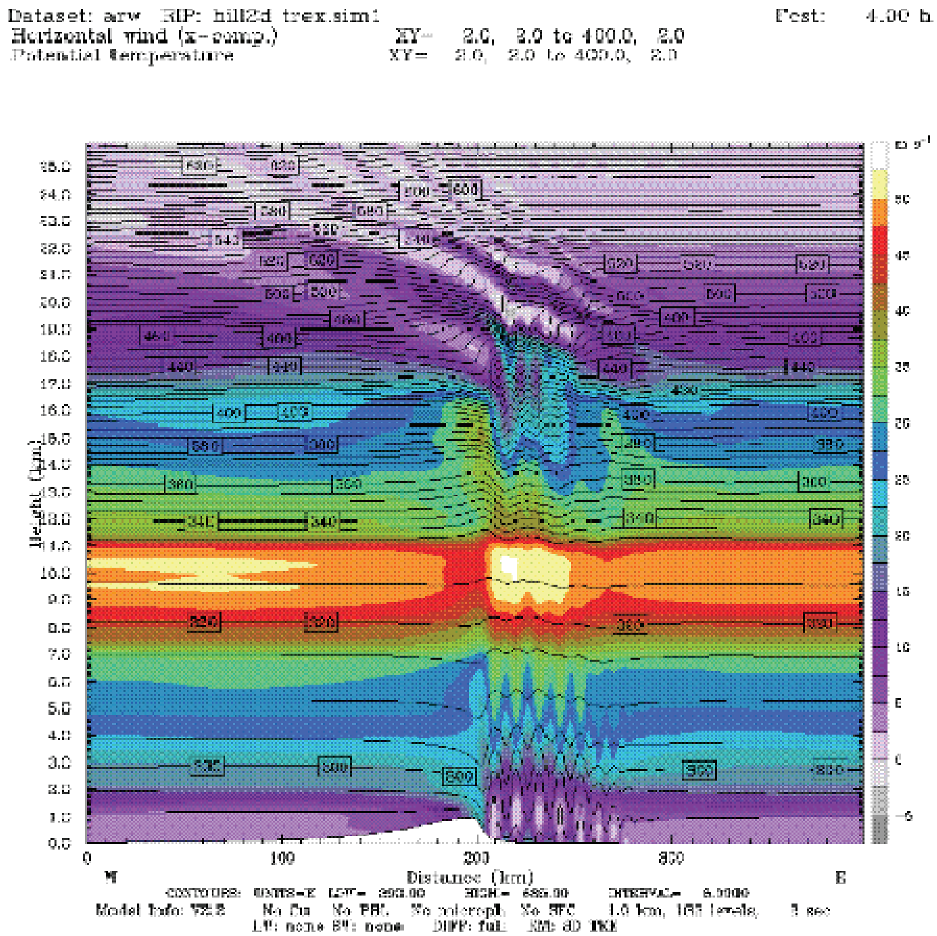


Fig. 2. A 4-hour forecast of the east-west wind component for a 2D WRF-ARW simulation using a "Witch of Agnesi" mountain with a height of 1 kilometer. The color scale is wind magnitude in m/s and black contours are potential temperature.

3. Comparison of Objectives vs Actual Accomplishments for the Report 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:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

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 seven research efforts. All seven 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, 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 approximately every two 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 also continue to develop and improve the WRF Portal—the graphical front end to the WRF NMM and ARW model. Specifically, they will generalize WRF Portal's work flow management to support a wider variety of WRF tasks including the WRF Pre-processor System (WPS), and support additional HPC systems including ejet and wjet. They will also assist in expanding the use of WRF Portal to support other models including FIM, GFS, and GSI.

c) CIRA researchers will continue developing the computer science aspects of the Flow-following, Finite-volume Icosahedral Model (FIM). As FIM becomes more mature, emphasis will shift from development to optimization (both scalar and parallel) and testing.

d) CIRA researchers will continue their collaborations on the development of computer software for the parallelization of atmospheric and oceanic weather and climate models. Collectively, this software suite is known as the Scalable Modeling System (SMS).

CIRA researchers will collaborate on adding SMS debugging capabilities to the WRF code.

e) CIRA researchers will also complete the development of Domain Wizard, a Java-based tool that replaces the existing WRFSI GUI (written in Perl). Domain Wizard enables users to graphically select and localize a domain for WRF ARW and NMM. CIRA researchers will continue to collaborate with developers of WPS at NCAR to ensure that the tool will be compatible with the newest version of WRF.

f) 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. They will also assist in the research and development of web services that are expected to be used to locate and retrieve model data within GSD.

g) Finally, CIRA researchers will continue teaching Java courses to staff at ESRL as needed to support project development activities within the laboratory.

2. Research Accomplishments/Highlights:

Objective A:

The GSI code uses MPI2 I/O to enable multiple processors to write simultaneously to a single file. CIRA researchers investigated how this use of MPI2 I/O impacts the wjet file system and concluded that the wjet file system cannot support this I/O method when more than about 50 processors are used. Consequently, the wjet system managers came up with RAM disk as a method to support MPI2 I/O. So far, RAM disk has shown great promise for running GSI on large numbers of processors. CIRA researchers continue to fix bugs in GSI and help meteorologists who encountered problems with GSI.

Objective B:

In April 2008, CIRA researchers released a beta version of a Java application called WRF Portal that is a graphical user interface (GUI) to WRF-NMM and WRF-ARW and runs on most computer systems. WRF Portal also supports 2D visualization and it includes WRF Domain Wizard as a built-in software component. CIRA researchers created the wrfportal.org website, presented a paper at AMS, co-authored another paper at AMS, and gave presentations at the 2008 Winter WRF-NMM tutorial and plan on presenting a paper at the 9th Annual WRF Users Workshop in June 2008.

Objective C:

CIRA researchers have been an integral part of the team that has brought the FIM code to the current level of maturity where FIM produces daily weather forecasts. Specifically, CIRA researchers have created a complete system where one make command builds the pre-processing software, the FIM model, and the post processing software, and one qsub command runs the pre-processing, FIM and post-processing. CIRA researchers continue to improve and optimize FIM. Specifically, CIRA researchers are investigating the cache coherence of the unstructured grid and the advantages and disadvantages of traversing the globe using the Hilbert space-filling curve versus traversing the globe using Cartesian coordinates. In addition, CIRA researchers have improved the software engineering processes used during FIM development by creating source code repositories, developing an automated test suite for FIM, and implementing a lightweight software engineering process tailored to FIM requirements. The repositories are hosted by GSD's GForge-based Subversion server. CIRA researchers taught an introductory course covering fundamentals of software revision control using Subversion and initially assisted FIM scientists and developers in its day-to-day use. With the new process, test suite, and repositories in place, FIM software engineering practices are now on a par with other major production NWP and climate codes such as CCSM and WRF. CIRA researchers refactored upper levels of FIM software to allow interoperability with NCEP's NEMS architecture implemented via the ESMF. This effort included detailed collaboration with Tom Black at NCEP to generalize the NEMS ESMF approach so it meets requirements of NCEP models (GFS, NMMB) as well as FIM. CIRA researchers have created a prototype FIM ESMF component and are implementing the functional details to permit coupling of FIM physics and dynamics within the NEMS architecture. CIRA researchers also assisted GSD scientists to incorporate aspects of WRF-CHEM into FIM. This new feature now works correctly for serial execution, and distributed-memory parallel capability is under development.

In the grid generation package, CIRA researchers continue their work to improve the efficiency and flexibility of the software. The program that generates the grid mesh and cell boundaries is improved so that it will be able to accommodate different numerical schemes. The utilities for the package now include more tools to help trace and debug computations on the grid.

The post-processing package has been running in real-time for more than 3 months. Its output has been used to create display products for Fx-net, ALPS, and the SOS system. In March, these displays have been used to successfully demonstrate the FIM model to a high level delegation from NOAA headquarters.

Objective D:

CIRA researchers continue to improve SMS and to assist SMS users with SMS. SMS support for unstructured grids, newly developed last year by CIRA researchers in support of the FIM model, continues to be enhanced and optimized.

Objective E:

On April 17, 2008, CIRA researchers released version 1.10 of WRF Domain Wizard—the GUI for the new WRF Preprocessing System (WPS) and a component of WRF Portal. The new version supports editing namelist.input: the namelist file used to configure running real.exe and wrf.exe. WRF Domain Wizard enables users to choose a region of the Earth to be their domain, re-project that region in a variety of map projections, create nests using the nest editor, and run the three WPS programs. CIRA researchers are exploring the possibility of adapting this software to work with LEAD (Linked Environments for Atmospheric Discovery), a NSF-funded project.

Objective F:

CIRA researchers continue to help users parallelize and debug their codes on the jet computer systems, help ITS debug wjet, and improve the FIM part of the jet benchmarking suite. CIRA researchers have developed an OGC-compliant Data Locator web service (and website) for searching and viewing meteorological datasets here at GSD/ESRL. Utilizing a MySQL database and written primarily in Java, this website won a web award for 2007. CIRA researchers have also attended preliminary meetings on the probabilistic forecasting software project.

Objective G:

No Java classes have been taught since the summer of 2007.

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

Objective A—Successful in diagnosing the I/O problem and support is in progress

Objective B—Successful

Objective C—Successful in bringing FIM to the level of producing daily forecasts. Ongoing improvements are in progress

Objective D—In Progress

Objective E—Successful

Objective F—Successful

Objective G—N/A

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

Jeff Smith received the 2007 GSD Web Award for "Best New Site" for Data Locator

Jacques Middlecoff, Tom Henderson and Ning Wang each received a NOAA Certificate of Appreciation for preparing FIM for display on Science On a Sphere.

7. Outreach:

8. Publications:

B. Aviation Systems—Development and Deployment

Project Title: Federal Aviation Administration (FAA) Prototyping and Aviation Collaboration (PACE) Effort—Traffic Management Unit (TMU) Project

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 datasets 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 TMU project is currently using convective weather products to address the weather information needs of the TMU relating to weather-related hazards impacting air traffic; this phase will be followed by icing, turbulence, and ceiling/visibility. Each phase will address the tactical (0-1 hour) and the strategic (2-6 hour) application of the above products to help the TMU decision maker in directing air traffic into and out of the ARTCC airspace. All phases will be subjected to the iterative process of defining, developing, demonstrating, and evaluating the weather related hazard graphic and its presentation to the Traffic Manager.

The FX-Collaborate (FXC) software, developed at NOAA's Earth System Research Lab 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 datasets 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 datasets 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 website.

A major advancement in the design evolution of the TMU Project took place in the 2.2a release of the software in June 2007. This was the first release of an end-to-end application that allows CWSU forecasters and traffic managers to plan for the safest and most efficient use of ARTCC, TRACON, and terminal airspace for all types of weather impacts. It was an integration of a Decision Aids Database, the Web-Based content, FXC, and AWIPS. 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 datasets that would then be stored in the database and server side processing and generation of the web content generation.

A goal of the TMU website is to consolidate all tactical aviation weather hazards information into a suite of products for presentation to TMU decision-makers in an easily understood format (A, GO-NO-GO, approach to air traffic route and flow information). What is important to understand about the Weather Information Decision Aids (WIDA) web content page is that it is a complete end-to-end system, not just a simple web display that provides useful information assisting in tactical and strategic decision making. It is an extremely complex suit of systems that involves AWIPS, FXC, content generation for the web, and a database backend. This is an end-to-end decision aid tool centered on the forecaster in the loop concept for helping to keep and create a more consistent, relevant, and accurate Weather Information Decision Aid (WIDA) product available for TMU managers. The consistency and power comes from the fact that all these systems are now tied and share the same data source.

The following images highlight the concept of “forecaster overrides” in the 2.2a release of the TMU Project software. The following sequence of images will show North, South, East, West, ZFW TRACON Departure Gates Impact Information based on NCWF2 and then Forecaster Edited Override information.

Images 1, 2 and 3 show current impact with no Forecaster Edits. ZFW TRACON departure gates are displaying green (no impact) and yellow (partial impact). Images 4, 5, and 6 show the result of a forecaster overriding the impact information by editing all Departure Gates RED and how such a change in FXC is propagated back for display in the WIDA Webpage used by the TMU Traffic Managers.

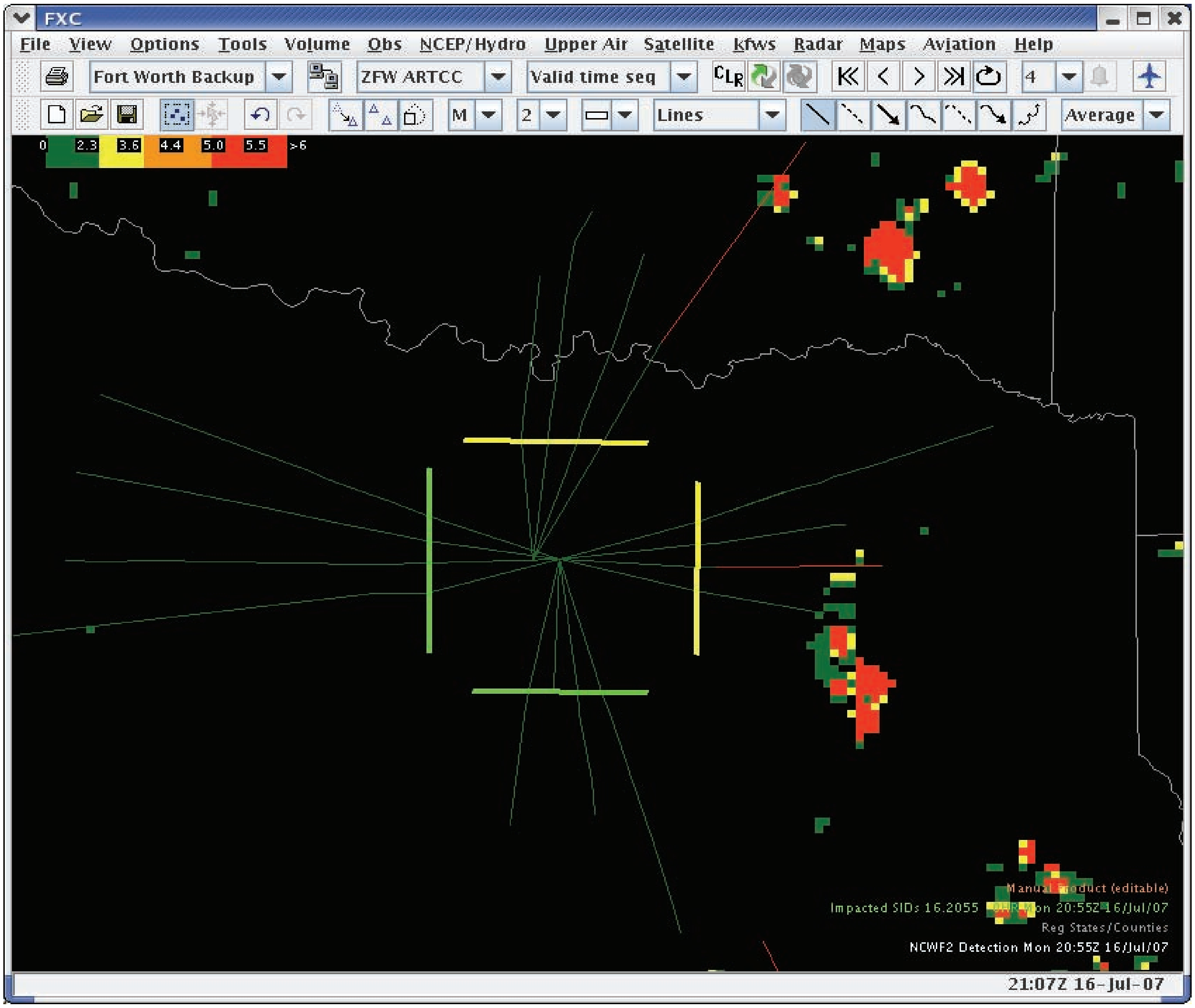


Fig. 1. Forecaster FXC tool showing current ZFW TRACON Departure Gate impacts with NCWF2.

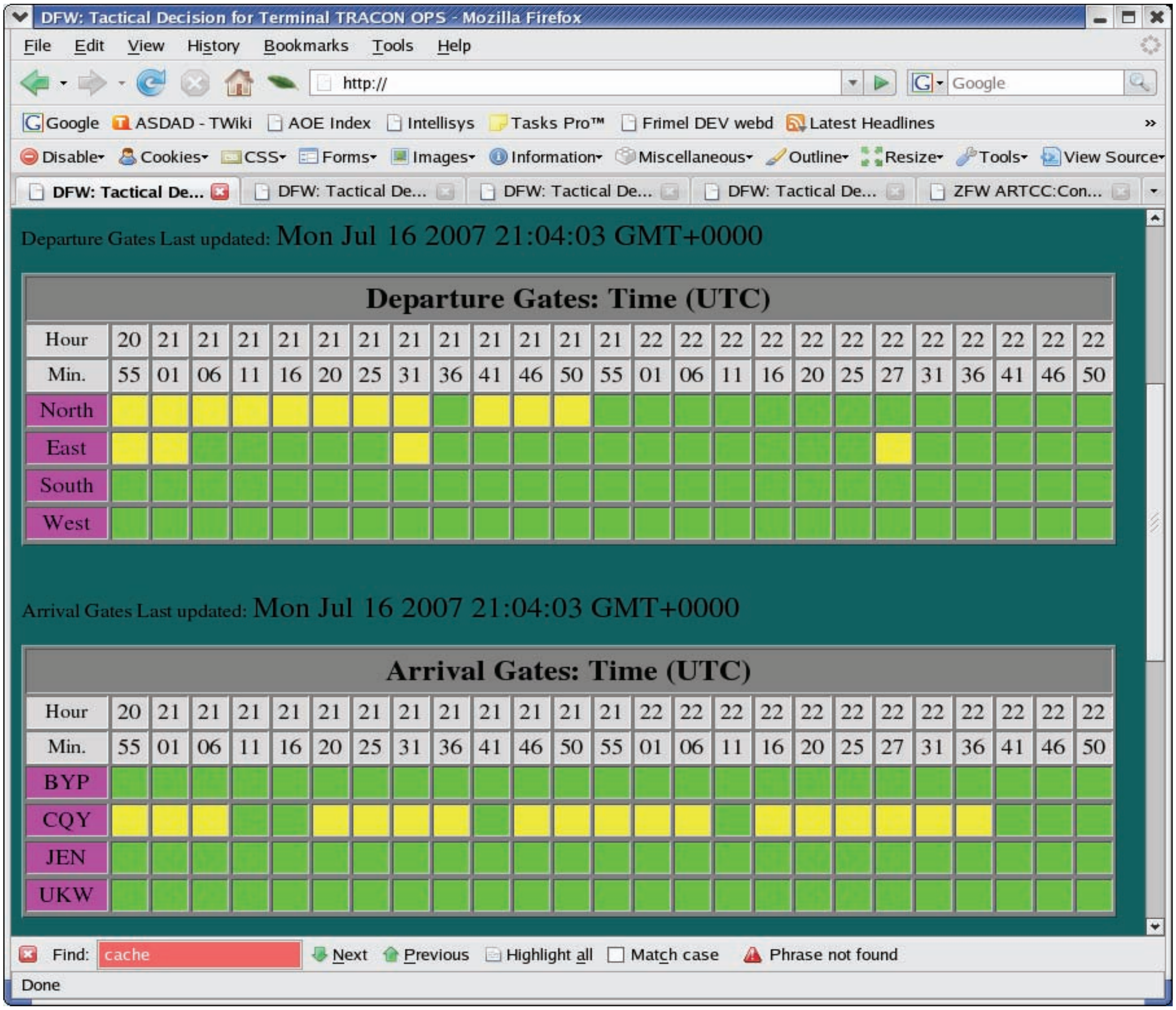


Fig. 2. Traffic Manager (WIDA) Web Display showing concurrent Red-light/Green-light Departure Gate Impact information.

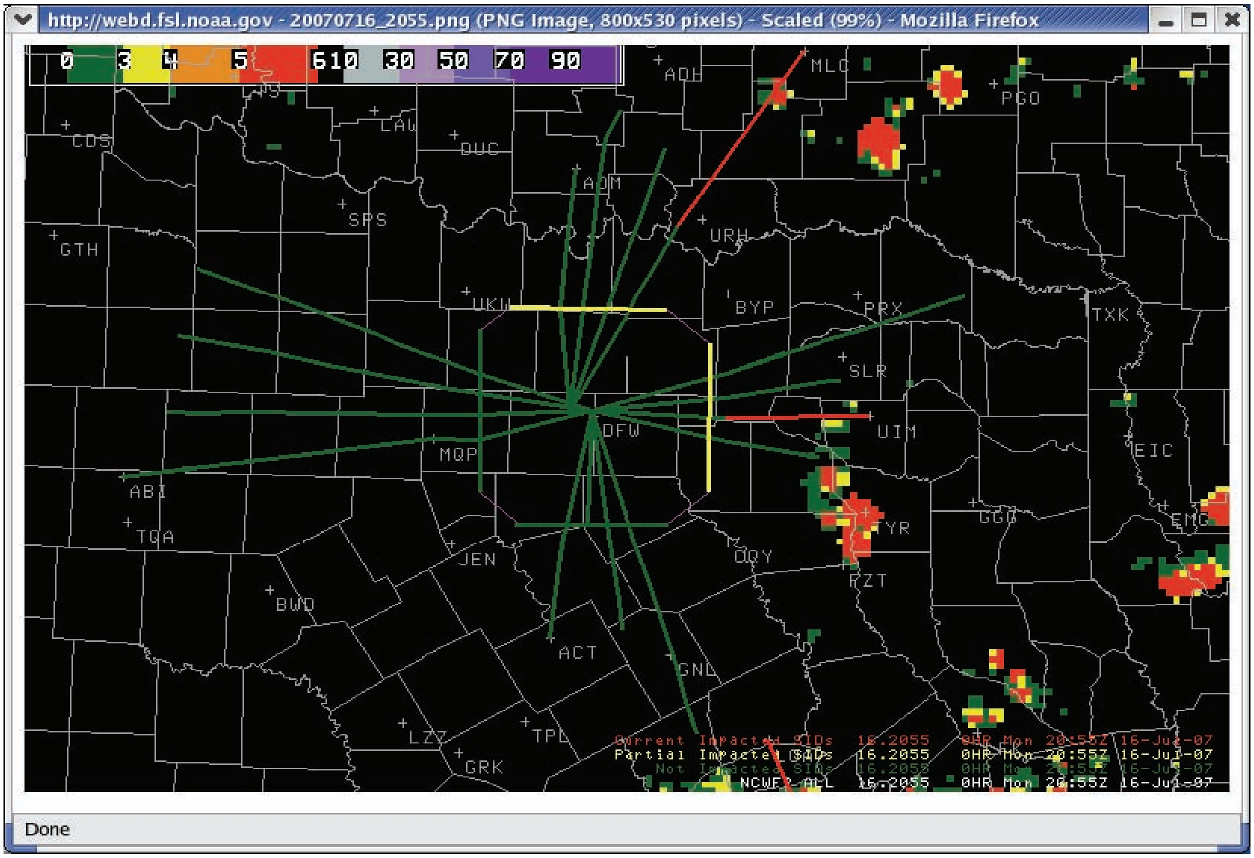


Fig. 3. Traffic Manager (WIDA) Web Display showing concurrent Drill Down image Departure Gate Impact Information (Drill Down image is available by selecting any desired route/time cell within the webpage).

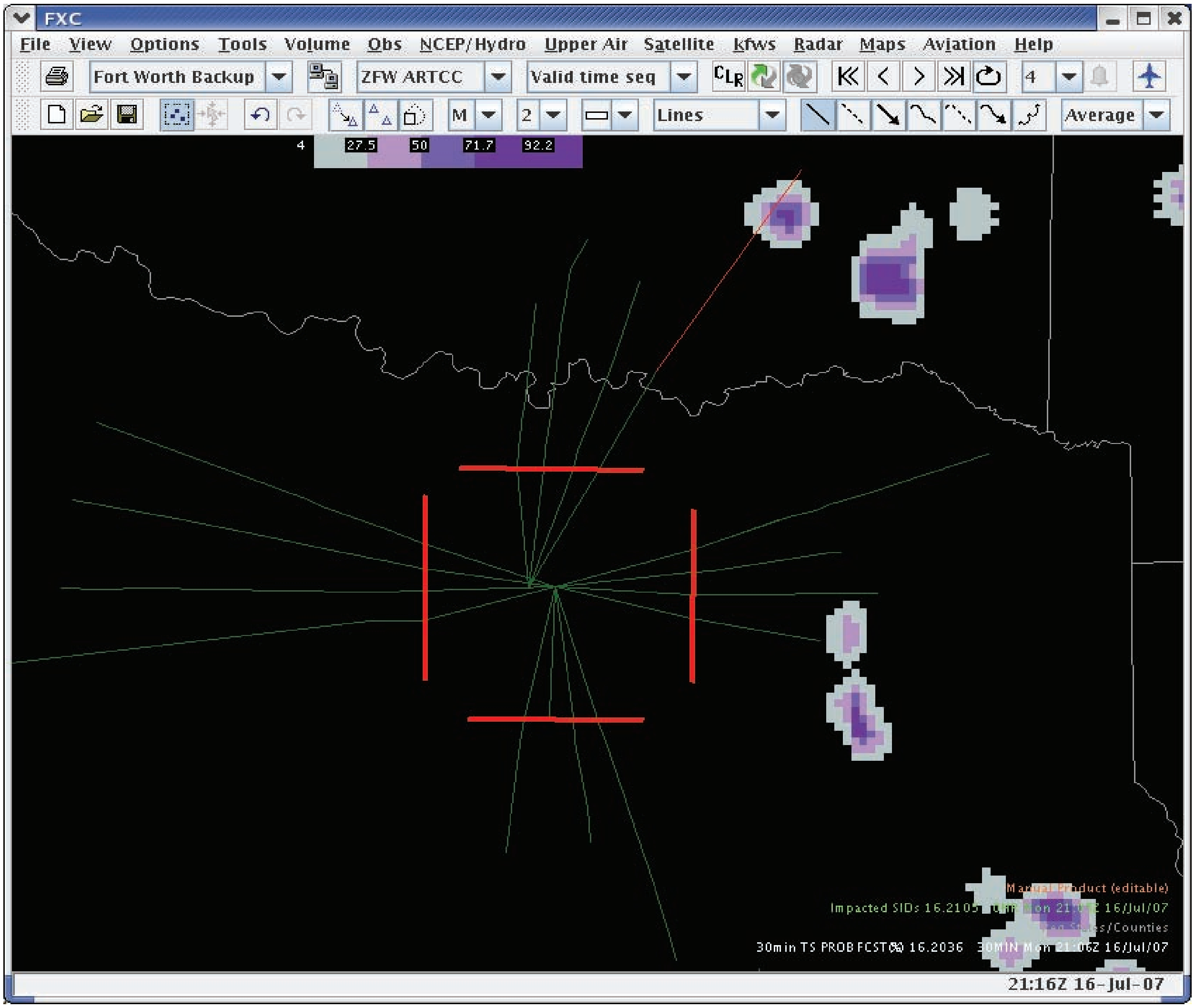


Fig. 4. FXC tool showing FORECASTER EDITS and OVERIDE to all RED of the ZFW TRACON Departure Gate impacts with NCWF2.

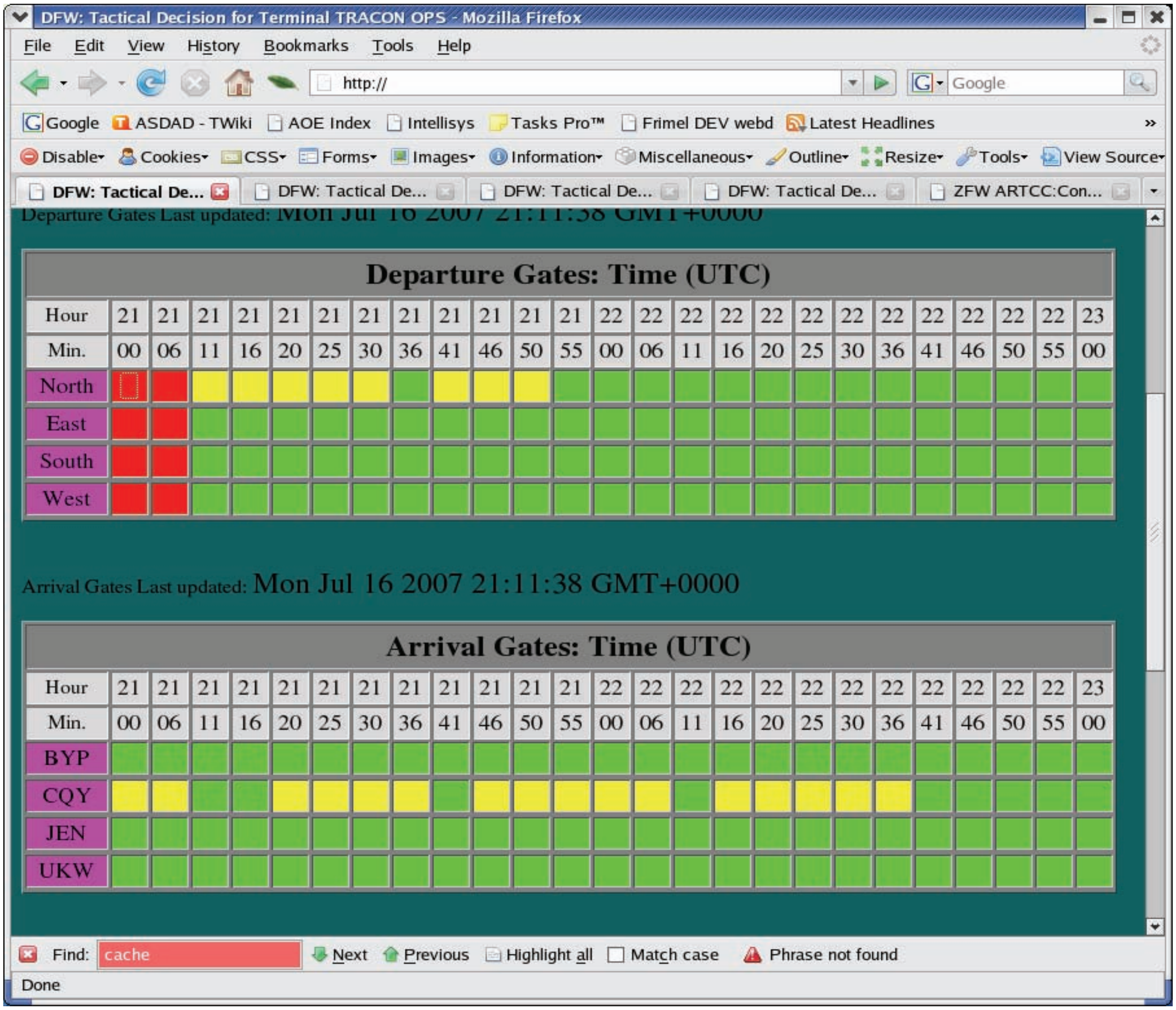


Fig. 5. Traffic Manager (WIDA) Web Display showing updated RED OVERIDE Red-light/Green-light Departure Gate Impact information.

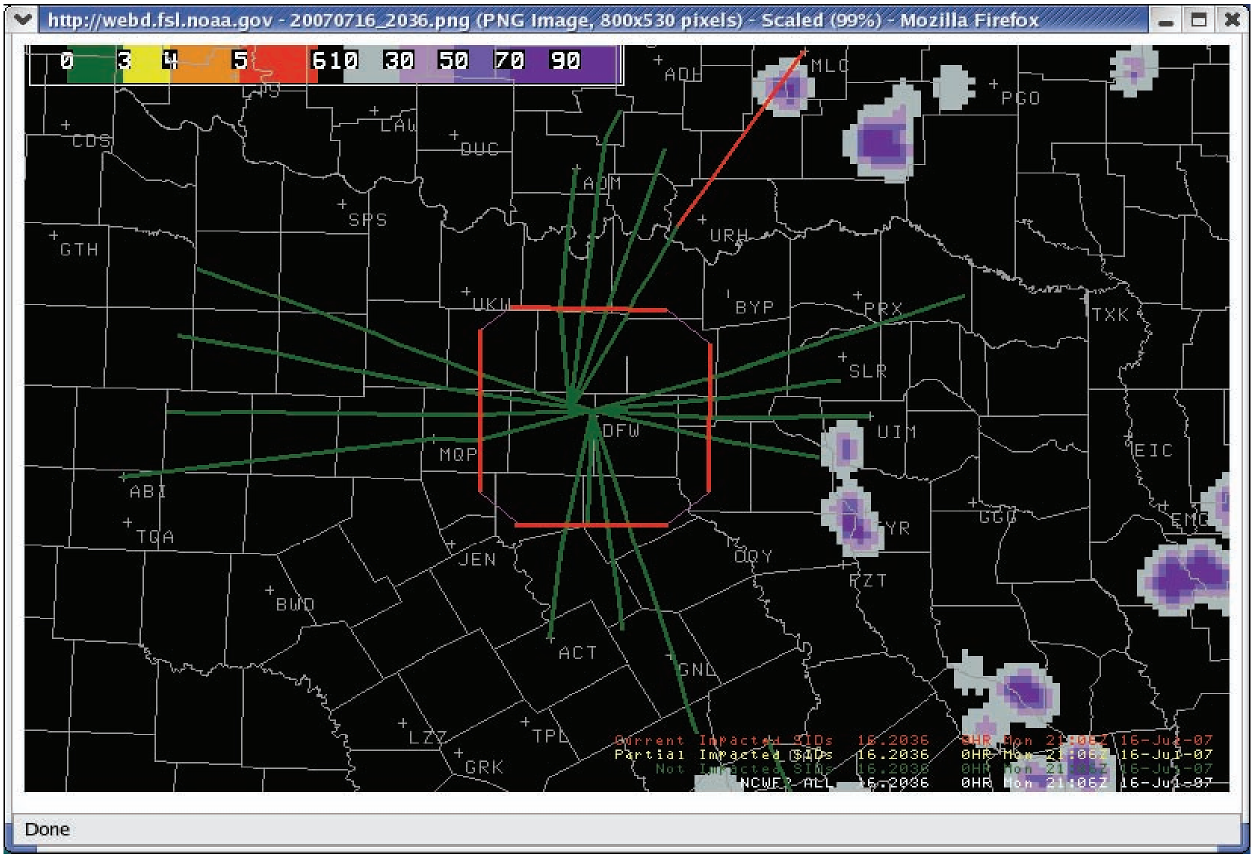


Fig. 6. Traffic Manager (WIDA) Web Display showing updated RED OVERRIDE Drill Down image Departure Gate Impact Information (Drill Down image is available by selecting any desired route/time cell within the webpage).

2. Research Accomplishments/Highlights:

At the end of the previous research year, the TMU Project team was notified of a budget and funding shortfall. This unfortunately resulted in a June 30, 2007 layoff of CIRA engineers and federal contractors working on the project. 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.

Continued funding for this project was from base allocations and is being maintained by a skeleton team. The decision to keep the project afloat was based on the high value and the potential for resurrecting this project in the future. Throughout the year, continued effort by the Federal Manager was placed on securing funding for the project's revival. This effort was augmented by the systems support and software changes made throughout the year.

A March 10, 2008 email was circulated indicating that NWS Southern Region had approved the transition of the experimental “Tactical Convective Hazard Product (TCHP)” to operational effective immediately. This is good news. It is a positive reflection of the project work but only indicates that TCHP as a concept has been accepted as a baseline product in CWSU operations and does not indicate any definitive funding.

During the 2007/2008 research year, CIRA staff at NOAA's Earth System Research Lab in the Global Systems Division’s Aviation Branch concentrated its efforts on the follow up and downsizing of the TMU Project 2.2a release of system in June 2007.

July through September 2007 priorities focused on configuring the Minimum Environment Development Framework that would reduce overhead but still allow for project maintenance, support, development, and testing. During the middle of July, a patched version of the TMU system was delivered along with training in Ft. Worth demonstrating the ability of forecaster overrides and the decision aids database.

September through October 2007, priorities focused on preparation for an FAA meeting in Washington DC demonstrating the system’s current capabilities, the decision aids website database, and FXC Override capability. This exercise required the creation, development and testing of running the systems, the override capability and the database from an archived data case in an offline mode. In November, we continued and propagated the Aviation Decision Aids and AWIPS Database rebuild and maintenance on all our remaining operational systems in the minimum environment topology.

January through May 2008, priorities focused on a Final TMU delivery with the latest systems build. Software changes included fixes to AIRMETs, SIGMETs, and Aircraft Situation ingest, CCFP web image content, scale changes, and map background updates. Additionally, enhancements were made to the TCHP Website to incorporate the decision aids impact data for STARs, SIDs, and High Use Airways. Also, all web content for both the Aviation Decision Aids (ADA) and the TCHP products were now being generated from a single content generator.

Over the past year, the TMU Project has had the following highlights in GSD headlines.
http://www.fsl.noaa.gov/media/hotitems/2007/07Oct30-2.html

Aviation Technology Successfully Transferred; excerpt from link above.

Aviation technology developed by ESRL's Global Systems Division has been successfully transferred to Raytheon. Aviation-specific enhancements made to the Advanced Weather Information Processing System (AWIPS) regarding icing, turbulence, convection, ceiling, and visibility are now integrated into the OB8.2 and OB8.3 versions of AWIPS, being prepared for field deployment in 2008. For the first time, the National Weather Service's (NWS) Center Weather Service Units can use the AWIPS Remote Display (ARD) to view aviation weather products and map backgrounds for use in their aviation forecasting and briefings to the Federal Aviation Administration's (FAA) Traffic Management Units (TMU). These products give visual references to affected airspace that words alone sometimes do not capture. This is a major step at ensuring that future aviation research and development efforts will transition into aviation operational forecasting systems quickly and efficiently and that NWS' role in aviation forecasting for the FAA is strengthened.

Customer feedback from Tom Amis, Fort Worth CWSU MIC

ATC Daily report for July 31 2007:
Another success story for PACE Convective Tactical Decision Aid. We started the day off at 1000z with a small area of convection near our BYP arrival gate, RUC model data was indicating the potential for growth and in like manner, both the NCWF2/6 were both keyed in on the areas. By 1015z, we were talking with ZFW TMU to develop a SWAP for East departures and the BYP2 playbook through 15z.

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:

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

6. Awards/Honors:

7. Outreach:

8. Publications:

Project Title: FXC AI (Aviation Initiative) 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, 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 ESRL technologies and services being developed by CIRA engineers at the Prototyping Aviation Collaborative Effort (PACE) facility at the Fort Worth ARTCC. For a description of PACE and related FXC Development, refer to the FXC TMU project description above. The FX-Collaborate (FXC) software, developed at NOAA's ESRL was the major software system used in the Aviation Initiative Demonstration. The FXC Aviation Initiative offers on-demand services, remote briefing capabilities, new graphical products, and tactical decision aids.

2. Research Accomplishments/Highlights:

Over the past year, no new research or development was directly applied to any AI Project work. However, enhancements to the FXC software from development for the TMU and FXC VACT projects will directly benefit and translate to the AI system since it is based on the same core software. 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 is being used at the Leesburg, Virginia Center Weather Service Unit (CWSU) for its daily weather briefings to the Traffic Managers.

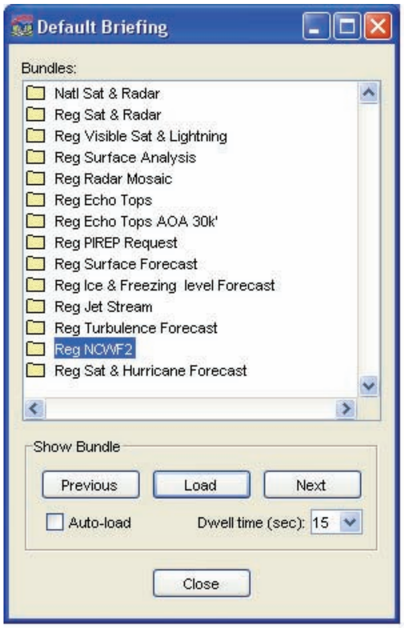


Fig. 1. View of the remote briefing play list.

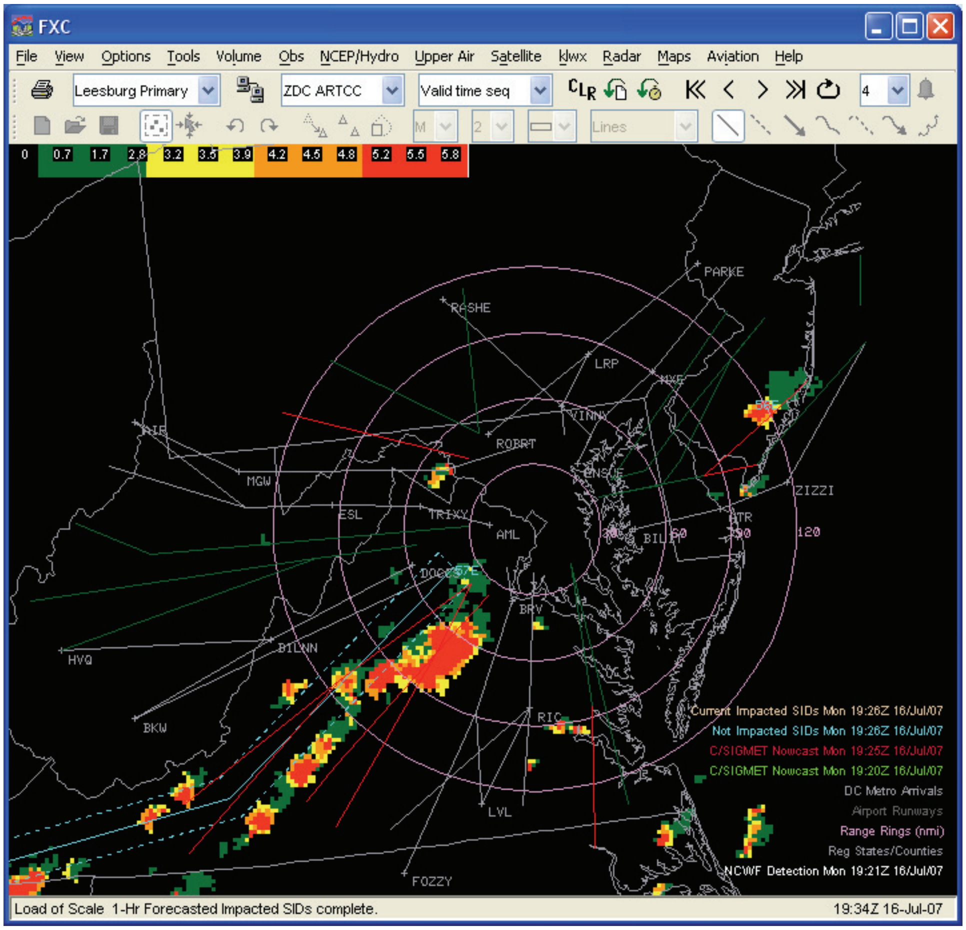


Fig. 2. View of the FXC AI BriefEE display with map enhancements and impacted DC Metro departure routes.

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 timeframe set to end in September 2006, requirements, plans, and goals were subject to adjustment in order to meet the timeline without interfering with the overall objectives. The demonstration was completed and the objectives were met.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

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 datasets 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 datasets 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 datasets (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 datasets 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 the previous research year, the FXC VACT Project team was notified of a budget and funding shortfall. This unfortunately resulted in a June 30, 2007 layoff of CIRA engineers and federal contractors working on the project. 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.

Continued funding for this project was from base allocations and is being maintained by a skeleton team. The decision to keep the project afloat was based on the high value and the potential for resurrecting this project in the future. Throughout the year continued effort by the Federal Manager was placed on securing funding for the projects revival. This effort was augmented by the systems support and software changes made throughout the year.

During the 2007/2008 research year, CIRA staff at NOAA's Earth System Research Lab in the Global Systems Division's Aviation Branch concentrated its efforts on the follow up and downsizing of the FXC VACT Project in June 2007.

July through September 2007 priorities focused on configuring the Minimum Environment Development Framework that would reduce overhead but still allow for project maintenance, support, development, and testing.

September through December 2007, the FXC VACT work focused on preparation for a January 07 delivery that had been reprioritized back in June 06 by the NWS funding source in favor of the FXC AI Demonstration. This delivery included fixing software defects, making enhancements, and system testing. Fixes related to the Puff Interface were implemented in addition to a punch list of item related to data, menus, and radar.

In January, the FXC VACT 2.2a release was installed in Anchorage, Alaska at three NWS sites and at the AVO USGS site. Training was performed on many of the new capabilities in the system that supported and streamlined the dissemination of products to the FAA regarding a volcanic ash threat to their airspace. This included:

--Enhancements and fixes to procedures
--MIS Text
--Layer order, colors, bundles, slide show, loop, zoom
--Auto update
--JPG resolutions and saving images collaboratively
--More Data Models
--Volcano Cameras added to the menus

January through May 2008, priorities focused on a Final VACT delivery for May 2008 with the latest systems build. Software changes were based on feedback from the January delivery which included Full Resolution Alaska Satellite fixes, data fixes, enhancements to the scales, and maps.

Also demonstrated was FXC's send to web capabilities for creating and delivering enhanced web products for Volcanic Ash SIGMETS and Volcanic Ash Advisory products. A webpage accessible on the VACT website was created showing sample graphics generated in FXC (http://vact.noaa.gov). This demonstrates the capability of FXC to generate and deliver enhanced graphical products that are currently being distributed by the NWS Alaska Aviation Weather Unit.

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:

5. Research Linkages/Partnerships/Collaborators:

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

6. Awards/Honors:

7. Outreach:

8. Publications:

C. Forecast Verification

Project Title: Real-Time Verification System (RTVS)

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

RTVS Background:

Over the past several years, the FAA's Aviation Weather Research Program (AWRP) has funded the NOAA Earth System Research Laboratory's Global Systems Division (ESRL/GSD) (formerly Forecast Systems Laboratory) and its collaborators to evaluate experimental meteorological forecast and diagnostic products for use in operations, and to develop the Real-Time Verification System (RTVS). This system, currently operated at GSD, provides statistics and verification displays in near real-time for operational aviation forecast products. It also generates statistics supporting comparisons between similar forecasts (e.g., convective forecast products) which allows study of the performance of the products for use in air traffic operational planning. RTVS makes all of this real-time and historical information available to operational and research communities through the Internet.

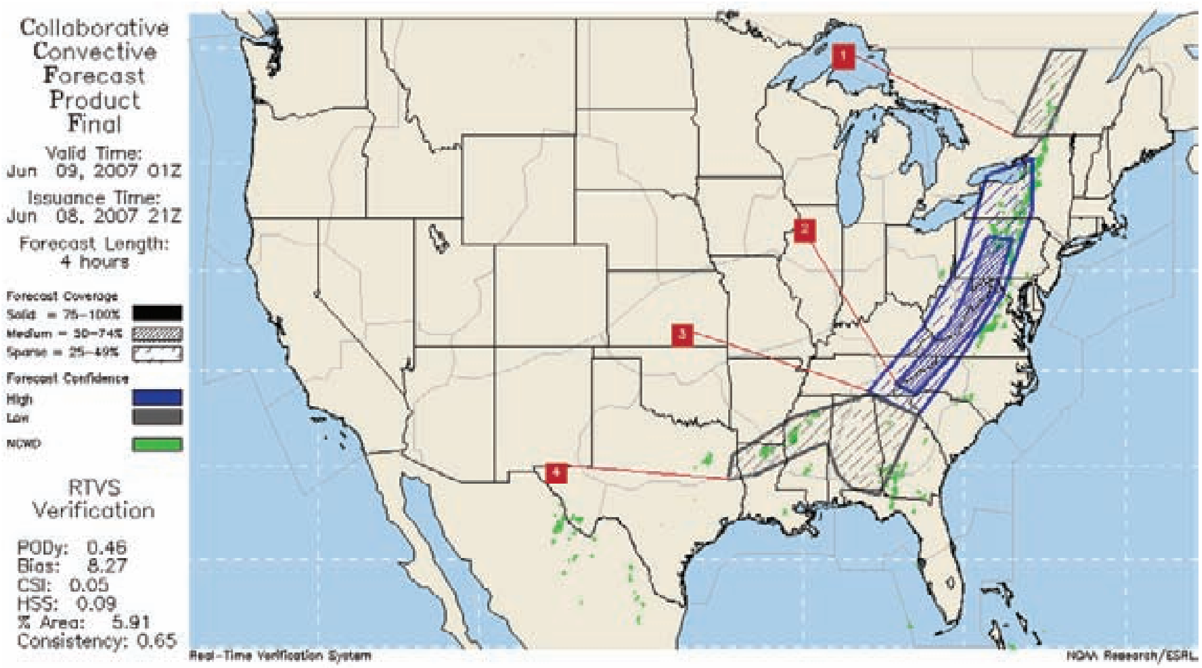


Fig. 1. Example of RTVS verification of the Collaborative Convective Forecast Product (CCFP), a human-generated forecast issued by the NWS/AWC. This is just one of many forecast and analysis products evaluated by RTVS.

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.

--Research to Operation (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 as 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.

--Transition of the Real-Time Verification System to the NWS Telecommunications Operations Center (TOC).

2. Research Accomplishments/Highlights:

a) Formal Assessment of the Forecast Icing Potential Product

In support of the operational transition of the Forecast Icing Potential (FIP) product, which was developed by the FAA's Icing Research Team, CIRA researchers provided a formal assessment to the Aviation Weather Technology Transfer (AWTT) Technical Review Committee (TRC).

Attributes of the forecast that were evaluated include icing probability, icing severity, and supercooled large drops (SLD). The FAA has designated that FIP, when certified for operational use, will be used as a supplemental product, which requires it to be used for flight planning purposes only in conjunction with the operational icing Airmen's Meteorological Information (AIRMET) issuances.

The main objective of the report was to understand the value of FIP as a supplement to the icing AIRMET. Agreement between the two forecasts was measured. Then, the skill of the supplemental product was examined in two ways: constraining the grid to within the boundaries of AIRMET polygons and constraining the grid to outside of the boundaries of the polygons. The performance of FIP was also assessed during the summer season, a time when icing AIRMET issuances substantially decrease. Finally, FIP was considered as an independent product and a reasonable attempt was made to directly compare its skill with that of the icing AIRMET.

Findings indicated that FIP showed significant value as a supplement to the AIRMET, which, qualitatively, can be seen in Fig. 2. Primarily basing their decision on the study, the TRC formally approved the use of FIP in FAA operations.

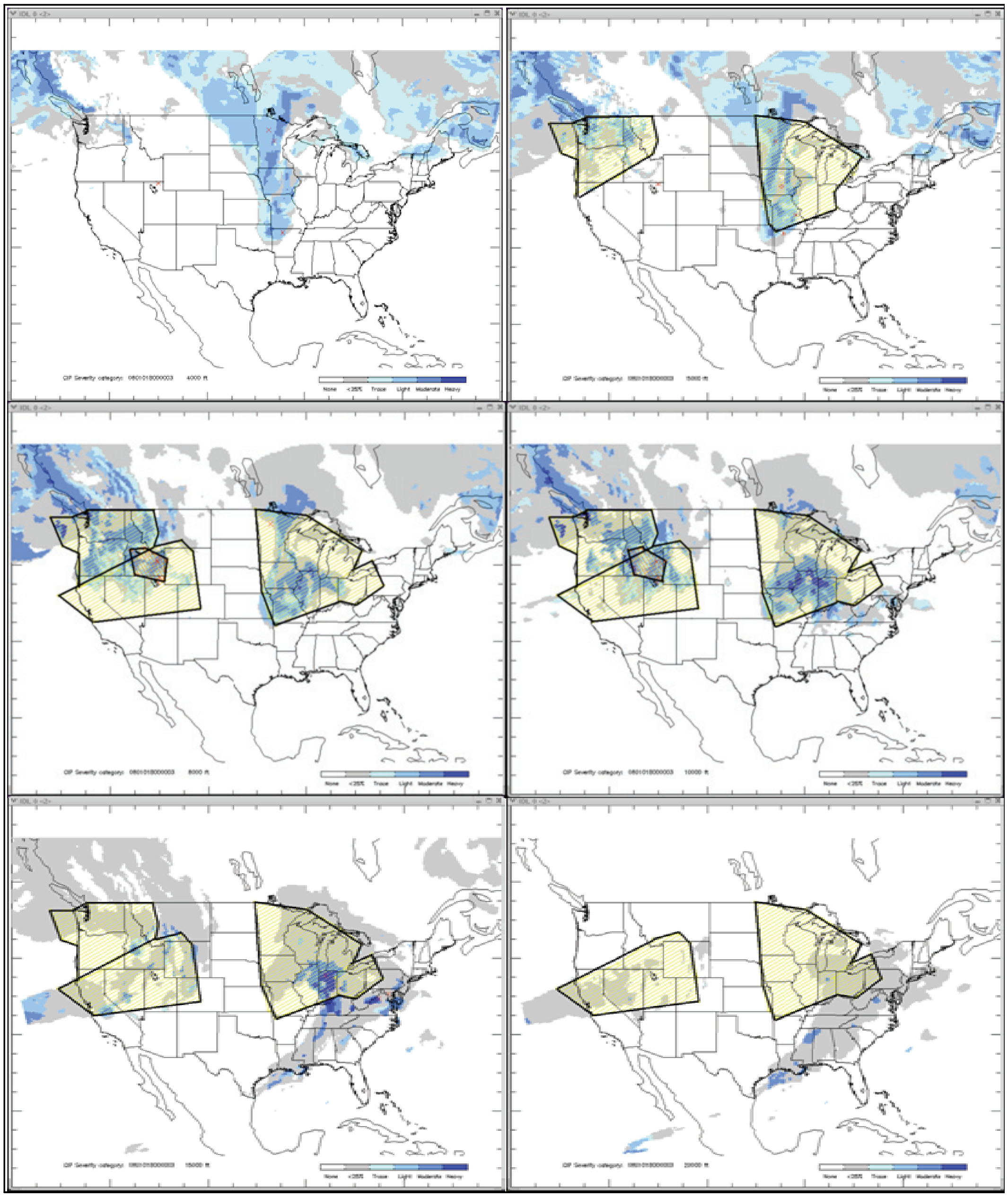


Fig. 2. A case study of the FIP icing severity (blue shading) overlaid with AIRMET boundary (stippled yellow at different altitudes from 1 January 2008 (3-h lead time valid at 2100UTC). Top left, 4000 ft AGL; top right, 5000 ft AGL; middle left, 8000 ft AGL; middle right, 10000ft AGL; bottom left, 15000ft AGL; bottom right, 20000ft AGL.

b) Convective Season (2007) Forecast Evaluation

The goal of the scientific evaluation was to assess the performance of several convective forecasts with respect to their application to operational air traffic flow planning. Five forecasts, including CCFP Preliminary and Final, RUC Convective Probability Forecast (RCPF), RUC Reflectivity, and the NAM Reflectivity were evaluated using the National Convective Weather Diagnostic (NCWD) product from 11 June – 31 August 2007. This Executive Summary highlights the main aspects of the scientific evaluation, but further detail and analyses are summarized in a comprehensive report.

The main verification approach applied in the study was used to inter-compare the forecast quality of the five products at strategic flight planning time periods and within impacted sectors (Fig. 3). This unique measure of forecast quality was linked directly to the application of the convective forecasts to the operational flight planning process.

Relevant results from the study indicated:

1) Nearly identical forecast performance from the CCFP Preliminary and the CCFP Final.

2) The CCFP and RCPF performed similarly for nearly all time periods, except at the 2-h outlook period where CCFP performed slightly better.

3) At early valid times and for shorter outlook periods, CCFP performed slightly better than RCPF.

4) At later valid times and longer output periods (i.e., when convective weather has the potential to severely impact air traffic), the RCPF performed as well as the CCFP.

5) Analysis of the top ten high impact air traffic days indicated that the performance of the RCPF at the 8-h outlook period for the afternoon shows some promise for planning purposes.

6) On high coverage, high impact days, neither CCFP nor RCPF performed significantly different from the other.

7) The CCFP, for every valid time of interest, better identified the sectors that were impacted by convection than did the RCPF.

8) The reflectivity products (NAM and RUC) showed virtually no skill at forecasting hazardous convection, but did provide some guidance at long lead periods for areas of concern.

9) The probabilistic aspects of CCFP and the RCPF exhibited low reliability.

Recommendations that were identified from the results include:

--Meteorologically, the forecast skill of the CCFP Final and Preliminary perform similarly, thus we recommend that the meteorological collaboration and its relationship to the planning process be further evaluated before possible elimination.

--In the near term, RCPF should be used as input to the CCFP generation process.

--In the longer term, we recommend adoption of a gridded probabilistic forecast as meteorological input to the traffic planning process. Since the radar reflectivity products have in some cases alerted planners to areas of hazardous weather 8-24 hrs in advance, we recommend further resources be devoted to the development of these products to improve their ability to better forecast convective intensity and structure. This may also benefit other automated convective forecasts.

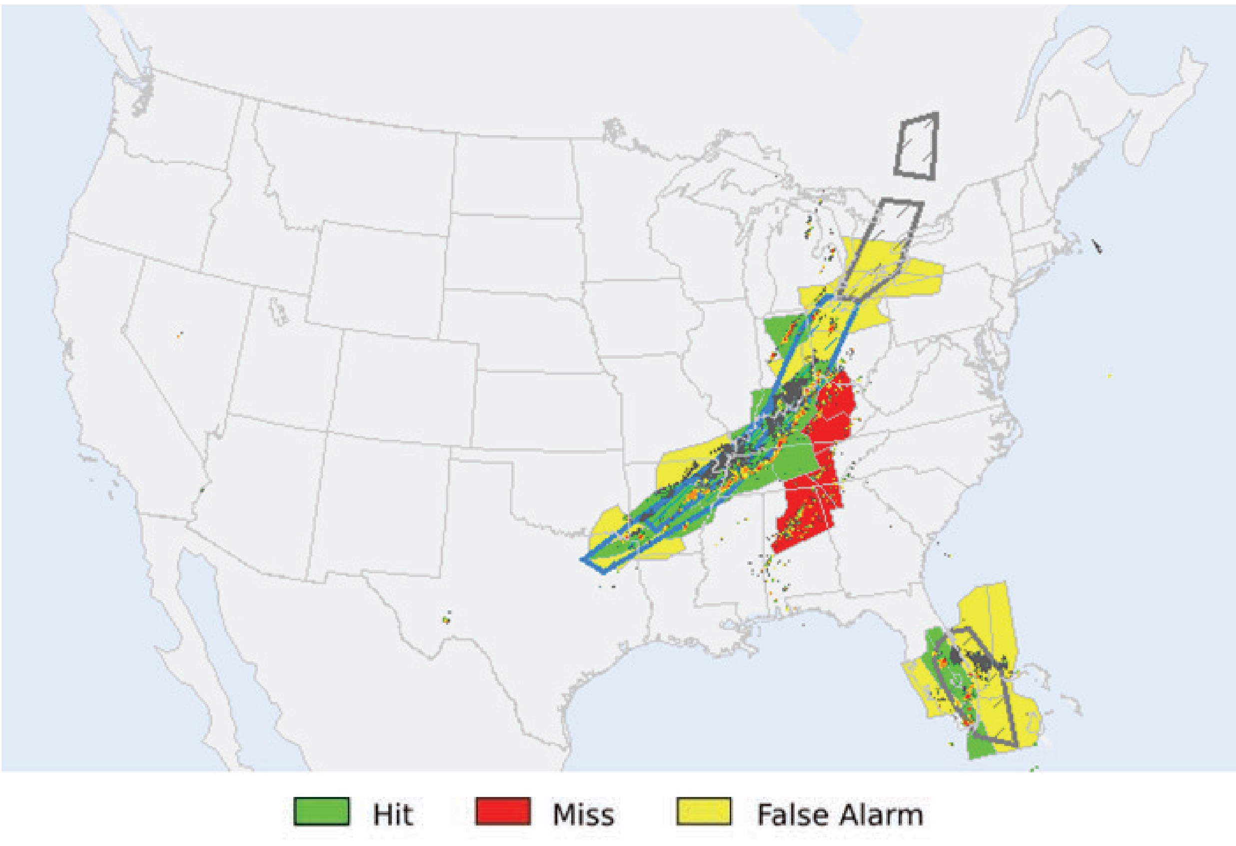


Fig. 3. Sector-based verification of the 2-h CCFP Final forecast from 8 June 2007 issued at 1500 UTC, with NCWD observations shown as well. Impacted sectors are color-coded to depict the verification results.

c) Development of a Lead Time Metric for the Terminal Aerodrome Forecast (TAF)

In order to minimize costly weather-related delays, aviation planners require accurate, precise, and timely information regarding hazardous conditions (Instrument Flight Rules) in terminal areas. Performance metrics for the Terminal Aerodrome Forecast (TAF), a critical product for air traffic planning, currently include Probability of Detection (POD) and False Alarm Ratio (FAR), which provide measures of accuracy and precision. In response to the need for a performance measure related to the timeliness of terminal forecasts, CIRA researchers continued to collaborate with NOAA to develop a lead-time metric for the ceiling and visibility attribute of the Terminal Aerodrome Forecast (TAF). In addition, diagnostic web-based tools were developed and made available to operational forecasters for evaluation (Fig. 4).

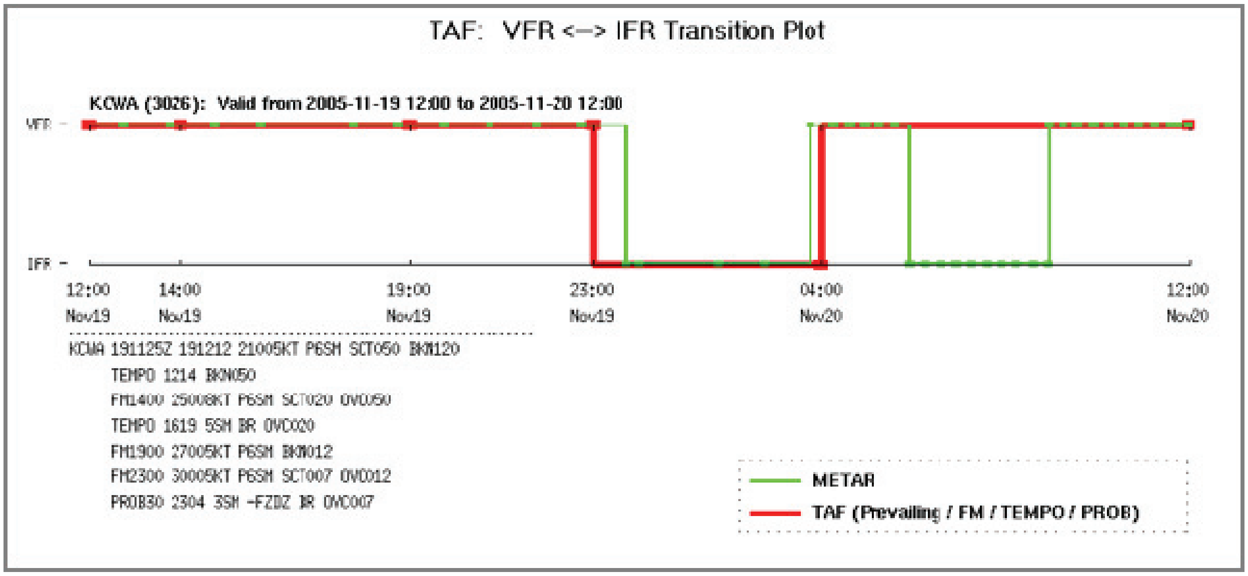


Fig. 4. Output from the diagnostic event viewer tool, depicting observed IFR events (green) overlaid by the forecast IFR event (red) for the TAF issued at Charleston, WV.

d) Development of a Verification Framework for the NextGen

The CIRA team has collaborated with the RTVS group to create and demonstrate a verification framework to support processing of meteorological quality information within NextGen. Critical to the effort is the ability to effectively integrate information from the air traffic planning process. CIRA researchers have successfully implemented a proof-of-concept to evaluate and demonstrate the new ideas. This approach proved valuable to the operational community; as a result, work continues on enhancing the capability and integrating the system into the NextGen development.

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

--Objective: Analysis and creation of an overall system architecture that will support RTVS processing needs

Status: In Progress. CIRA researchers have created a proof-of-concept demonstrating the feasibility of the new framework. Work continues to enhance the capability and integrate the system into the NextGen development.

--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: Research of strategies for data management of geophysical observations, diagnostics and forecast products

Status: In Progress. The CIRA team continues to study concepts, such as resampling approaches in statistical significance testing, in an attempt to uncover approaches that would better support the engineering needs of the NextGen verification system.

--Objective: Analysis and creation of a lead-time metric for the NWS's Terminal Aerodrome Forecast (TAF)

Status: In Progress. CIRA researchers have guided the development of a new lead-time metric. With significant input from the sponsors and operational forecasters, the technique has been substantially refined. A website now makes evaluation by the field users feasible. Also, diagnostic tools, most importantly the event viewer, have been made available.

--Objective: Research of operationally relevant verification measures that incorporate ASD data

Status: In progress. As part of the study of convective forecast performance during the 2007 season, the CIRA team utilized an implementation of the Weather Impacted Traffic Index (WITI) to provide better assessment information to the operational community. Work continues to better incorporate enroute impact as well as impact of weather on terminal efficiency.

--Objective: Support for operational adaptation of RTVS for deployment

Status: In progress. The CIRA team has utilized an operationally available data interface for RTVS that will enable the transfer of technology to NWS operations in the near future.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

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:

7. Outreach:

8. Publications:

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, BobLipschutz, Glen Pankow, Richard Ryan, 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

Background:

Cooperative Institute for Research in the Atmosphere (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. The services provided by ODS are illustrated in Figure 1. These services include data ingest, data transformation, data distribution, system and data monitoring, data saving, compute services, and on-line storage.

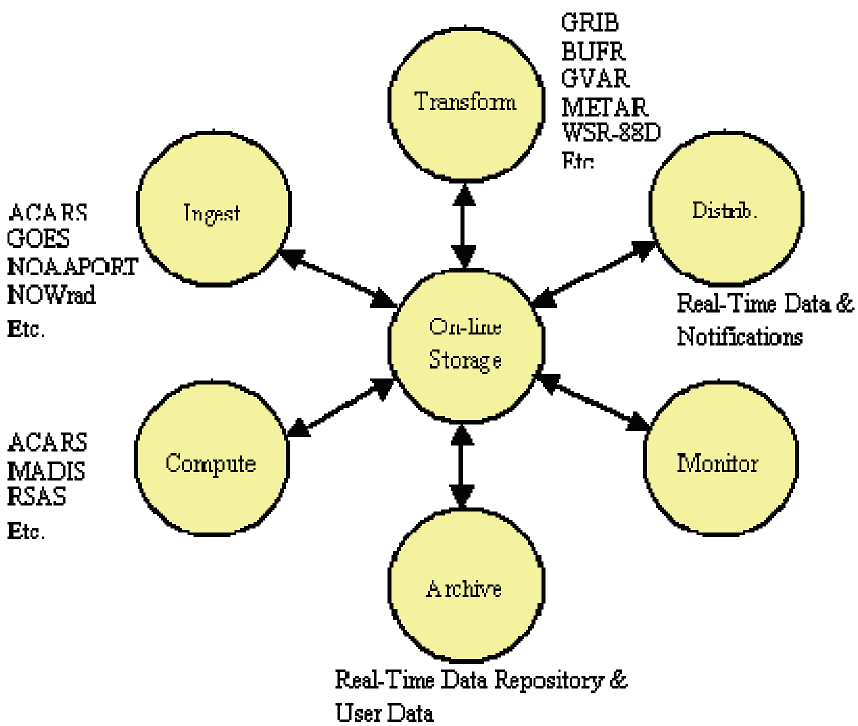


Fig. 1. Central Facility services provided by ODS

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

Design and development for new and modified datasets 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 datasets 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 datasets.

2. Research Accomplishments/Highlights:

DSG's highlights of the past year include:

--Data transformation
    --Developed ODS Maritime data decoder to replace legacy software
    --Developed a HDF4-to-NetCDF3 conversion application

- --Updated GRIB decoding software for edition 2, including developing software for table discovery and a template refactoring to allow for the introduction of new templates without the need for additional software development
- --Updated RAOB decoder
- --Updated METAR decoder
- --Updated PIREP decoder
- --Updated POES BUFR handling
- --Updated ACARS decoder to account for a new formula for en(de)coding the water vapor mixing ratio

--NEXRAD decoding software packaged for distribution with GSD's Local Analysis and Prediction System (LAPS) project

--Set up, tested, and debugged a new Facility Data Repository (FDR) server to save all gridded data files to the Mass Store System, and put it into production

--Installed and configured collaborative development applications

- --TWiki, an open-source collaborative knowledge management tool. This allows both the Systems Support Group (SSG) and DSG to edit and track changes to the FICS documentation
- --Bugzilla, an open-source issue tracking system for Central Facility services
- --Ruby on Rails, an open-source web framework that will support the development of new monitoring capabilities

--Developed and put into production a new point data processing system, enabling the re-purposing of the legacy hardware

--Developed software for the real-time generation of KML files to enable GoogleEarth display of global satellite images and LAPS datasets

--Real-Time Verification System (RTVS)

- --Started working with the RTVS group on a proof-of-concept tool that will lead to a new verification framework
- --Acquired several new weather data products from Aviation Weather Center (AWC), National Center for Atmospheric Research (NCAR), and the Air Force Weather Agency (AFWA)

--Science On a Sphere® (SOS)

- --Configured local GOES systems to generate full-disk products for GOES-11 and GOES-12
- --Configured McIDAS image remapping for a global water vapor product from AWC
- --Implemented new methods and hardware for distributing SOS data to its many Installations

--Meteorological Assimilation Data Ingest System (MADIS)/ RUC Surface Analysis System (RSAS)

- --Participating on the transition team for the transition of MADIS to NWS operations
- --Added UrbaNet

    - --UrbaNet is a surface research network involving NOAA's Air Resources Laboratory (ARL) and the private sector, which is designed to explore the use of using integrated commercial and government meteorological data in forecasting within the complex topology of the urban environment
    - --MADIS has been established as the mechanism to ingest, integrate, quality control and distribute the UrbaNet mesonet observations in support of homeland security, emergency management, dispersion modeling, and general forecasting applications
- --Implemented a method to monitor the Cooperative Agency Profiler Dialer systems
- --Added new Mesonet datasets
    - --Maryland Department of Transportation
    - --Maine Department of Transportation
    - --Ft. Collins, Colorado Utilities
    - --Alaska Mesonet
    - --New Hampshire Department of Transportation
    - --White Sands Missile Range
    - --Colorado Avalanche Information Center
    - --Bridger Teton National Forest Avalanche Center
    - --New Jersey Weather and Climate Network
    - --National Estuarine Research Reserve System

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

--Goal: Acquisition of Meteorological Data

Continue acquisition of a large variety and volume of conventional (operational) and advanced (experimental) meteorological observations in real-time. The ingested data, which are used by CIRA and GSD researchers on a wide variety of projects, encompass almost all available meteorological observations along the Front Range of Colorado and much of the available data in the entire United States including data from Canada, Mexico, and many observations from around the world. The richness of this meteorological database is illustrated by such diverse datasets as advanced automated aircraft, wind and temperature profiler, satellite imagery and soundings, Global Positioning System (GPS) moisture, Doppler radar measurements, and hourly surface observations.

Status: This work is in progress.

--Goal: 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.

--Goal: ODS Improvements/Upgrades

Design and development for new and modified datasets 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.

--Goal: Metadata Handling

Metadata handling techniques for use with all datasets 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 multithreaded 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.

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

6. Awards/Honors:

Patrick Hildreth - GSD Best Product/Internal Use Web Award for FICS Docs (FIDO)

7. Outreach:

8. Publications:

IV. Research Collaborations with the GSD Forecast Applications Branch

A. 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 #1, 2, 3, 5, 6, 7, 8, 9, and 10)
--Coasts, Estuaries, and Oceans (for activity #10)
--Hydrology (for activities #3 and 9)

Key Words: Local Analysis and Prediction, High Resolution Modeling

LAPS / WRF Improvements

Participating CIRA Scientists: Steve Albers, Chris Anderson, and 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 weather 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. 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 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 continue 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:

LAPS Observational Datasets

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

Surface observation ingest quality control was improved. Duplicate station checks were made more versatile and otherwise streamlined. Default memory allocation was increased so more observations can be accommodated.

Upper Air Observations

The dropsonde ingest should now support the NIMBUS NetCDF format. This opens the way to do research on the usefulness of special sondes dropped into Pacific atmospheric rivers or Atlantic hurricanes to name two examples. Dropsonde support was also added to our case data retrieval script. Aircraft observation quality control was improved.

For cloud-drift winds, traditional IR data plus newer datasets for visible, water vapor, and sounder instruments/channels are being included. Support was added for the ASCII format we see with newer satellites such as GOES11 (and GOES12), as well as support for water vapor (WV) based measurements. The default list of satellites was also changed to GOES 10 and 11.

Surface Analysis

The handling of observation error was streamlined in the software. Temperature QC thresholds are now applied independently over land and water areas to help in the global analysis of sea surface or "ground" temperature. Surface verification bias statistics are now included in the data summary "what-got-in" log file.

Radar Processing

We have worked towards more efficiency and other functional improvements for radar remapping and mosaicing. We now handle either /public or NCDC formats for archived wideband radar data. Error checking and debugging info was added for remap lookup table generation. The radar mosaicing program has improved warning messages about parameter consistency.

Wind/Temperature Analyses

A new 1-D weighting array was added to improve looping efficiency with a 20% overall speedup noted in the wind analysis. A new K looping strategy was implemented that further speeds up the wind analysis somewhat. The maximum number of wind observations can now be set dynamically as a runtime parameter for better flexibility with machines of different memory capacity. Some other wind analysis mods were made to optimize the use of memory on the IBM. This helped pave the way to increase the vertical resolution of our operational runs.

The vertical radius of influence for surface wind observations was reduced to half that of other observations to help improve wind analysis accuracy in the boundary layer. Data structures were updated (for consistency with the wind analysis) in support of specifying temperature observation locations in between vertical grid levels.

Cloud/Precipitation Analyses

For the cloud omega field, the single namelist parameter now switches all of CWB collaborator Adan Teng's changes in both the radar omega and the cloud omega routines. Therefore, we would run without Dr. Teng's flag for HMT (stratiform cases) and perhaps with the flag for convective or tropical storm cases. There may be ways to make the cloud omega code adjust in a more dynamic fashion between these regimes. In brief, perhaps the parabolic profile could be set to extend about halfway above the convective portion of a cloud into the overlying stratiform region.

Improvements were made to cloud analysis handling of radar echoes and cloud bases as a result of evaluating LAPS reruns for the Greensburg, KS tornado case day. Furthermore, the use of surface derived lifted condensation level (LCL) information is being considered as an aid in the decision tree to find cloud base height in the vicinity of radar echoes.

Ed Szoke collaborated with us to obtain cloud analysis output to perform comparisons with CloudSat cross-sections. These were presented at the CIRA Coffee Confab in November, 2007.

The precipitation analysis has a new gauge of only 1-hour precipitation analysis that is substituted for incremental precipitation areas where the radar analysis is missing. The background (e.g. GFS) precipitation is used as a first guess if it is available. This is being tested in real-time on the global LAPS run.

General Software Improvements & Portability

LAPS documentation, process logging, and CDL descriptions were improved. Software was streamlined and made more consistent helping to make it more understandable. Software was made more portable to different platforms and quality control checks were improved. LAPS was made more portable to work with the Intel 'ifort' compiler. LAPS build and ingest driver scripts were updated and improved. Scripts that report what data get into the analyses were improved. The scheduling script can now accept a command line argument that selects from a variety of combinations of runtime executables depending on the application.

Archive case rerunning scripts accessing mass store data were refined. The scripts for accessing archived observations for retrospective LAPS runs can now automatically untar the data files. Data purging scripts were improved.

LAPS Implementation

We continue to run an hourly global LAPS analysis (GLAPS) on a 21km resolution domain. Real-time data and graphics are available on the LAPS website, an ESRL-wide web database, as well as Science On a Sphere (SOS). Improvements were made in the geometric re-projection of wind barbs when displaying GLAPS on SOS. The SOS display resolution was recently increased. Color tables and color bars were improved as well. GLAPS was featured in a recent town hall meeting given by the ESRL Director.

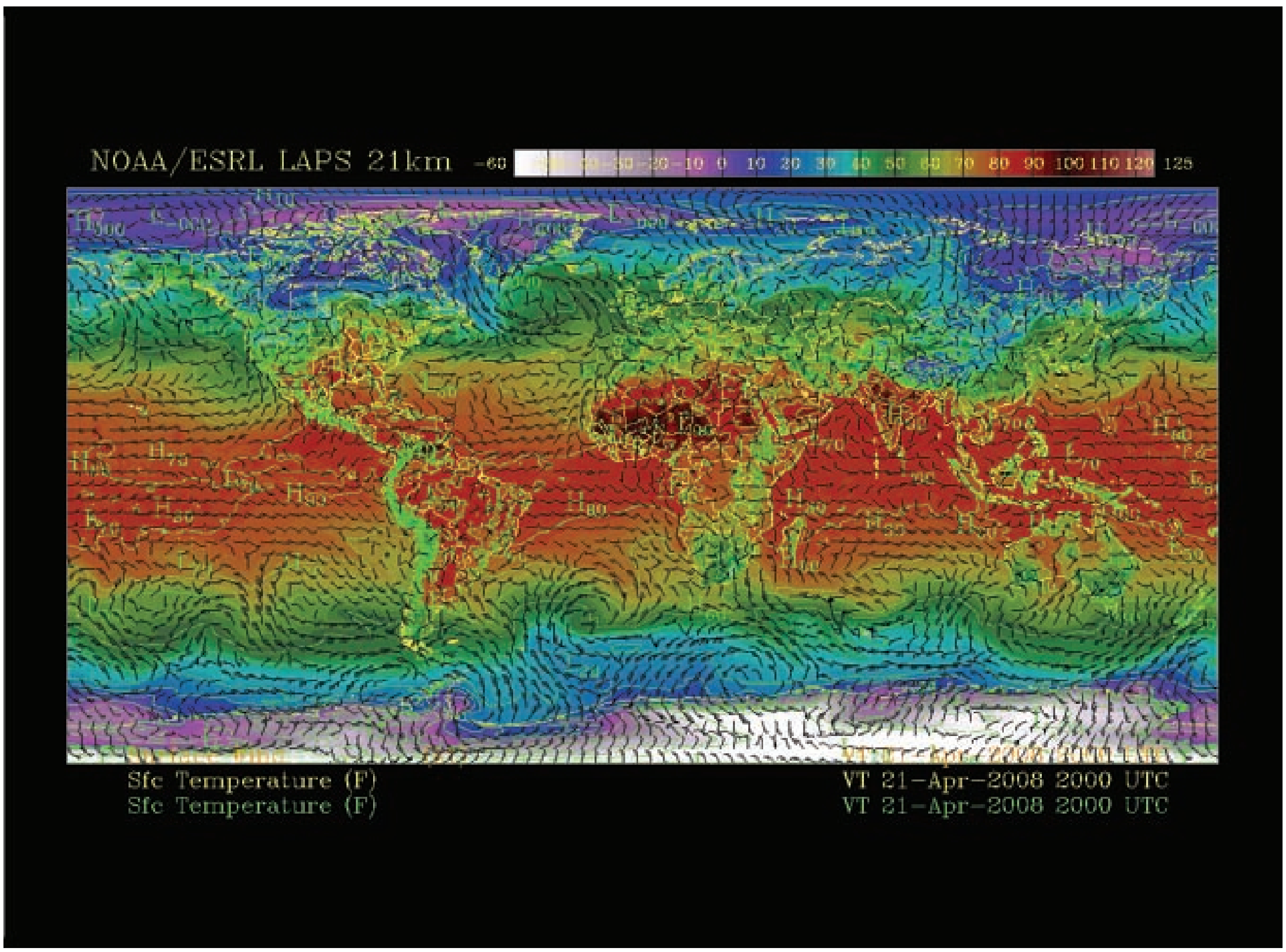


Fig. 1. Analyzed surface temperature and wind on the GLAPS 21-km global domain

A LAPS software build was set up on our newest supercomputer (wjet) for the purpose of testing and integrating STMAS 3-D software. For surface STMAS, MADIS QC flags were added for pressure variables (MSLP, altimeter, and station pressure). A QC check was also added for the MADIS subjective station reject list. In collaboration with NOAA colleagues, a journal article is being submitted.

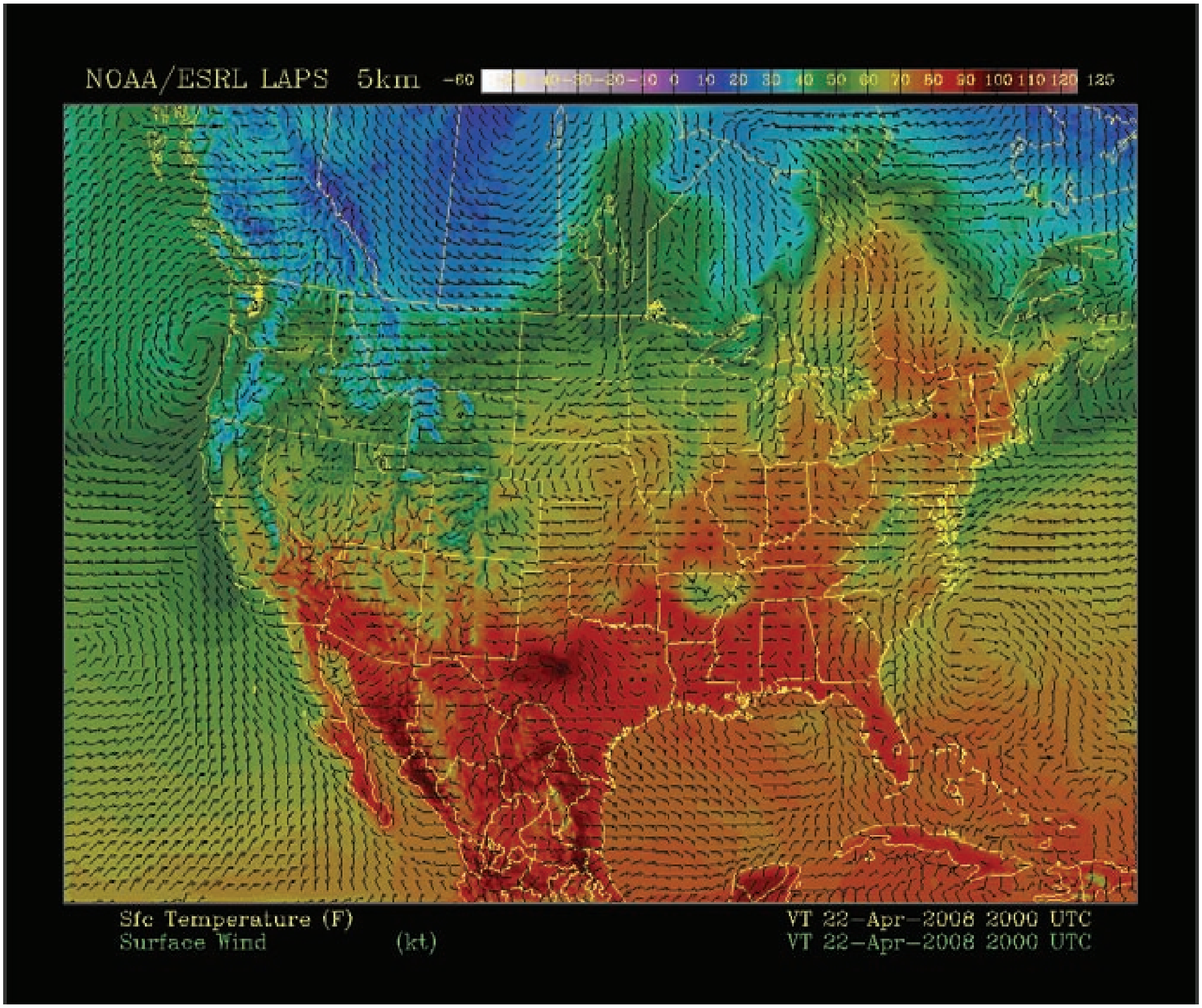


Fig. 2. STMAS surface temperature and wind on the 5-km CONUS domain

The LAPS software distribution and the associated website continue to be maintained.

WWW LAPS Interface

A lag time parameter was added that will allow reading data up to 3 hours old without specifying a time when using the "on-the-fly" webpage. A test for missing model RH data was included to help get the best humidity field when plotting model forecasts. Image support was added for balanced divergence. Place holders were added for future high-resolution coastline (RANGS) data use.

The color scheme for surface observation plots now reflects the vertical location of the observations. Color tables were improved for Theta (e-sat) cross-sections and for precipitable water providing better global moisture depiction. Color bars were improved for high resolution plots. Wind barb density was increased for zoomed in upper air plots while satellite image plots now have improved zooming functionality. Changes were made so labels can be displayed with zoomed in fields.

Cloud and precipitation type cross-sections were optimized to work with the new high-resolution display strategy. Full station names can now be plotted for stations up to five characters. Updates from the "on-the-fly" page have been added to the LAPS software release.

Mesoscale NWP Model Initialization and Evaluation

Regarding software improvements to the WRF numerical model, Schultz microphysics has been added to the microphysical suite in the latest version 3 of WRF-ARW code.

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

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Range Standardization and Automation (RSA) Project

Participating CIRA Scientists: Chris Anderson and Steve Albers

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 U.S. Space Launch facilities (ranges) located at Vandenberg AFB, California and Cape Canaveral Air Force Station, Florida. In collaboration 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 continued.

2. Research Accomplishments/Highlights:

We continue to maintain LAPS analysis shadow runs on the GSD cluster in support of the on-site LAPS/MM5 runs for range safety operations at Kennedy Space Center and Vandenberg Air Force Base. The system was modified over the previous year to include initialization from real-time SST analysis that is received in the data feed to the US Space Launch facilities.

Software logging information was improved to assist the selection of the level used in the surface reduced pressure analysis. Guidance and software assistance to the Western Range was provided to get Level-II and Level-III radar ingest working again. Tower data declarations were fixed for the newer RSA Met Tower routines we are using on the GSD shadow run. We also helped verify that LAPS running at the ranges is satisfying the requirement agreements for data ingest and analysis.

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

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships:

6. Awards/Honors:

7. Outreach:

8. Publications

Model Ensembles and Ensemble Post Processing

Participating CIRA Scientists: Chris Anderson and Isidora Jankov

Ensemble forecast system testing and implementation continued in support of the Hydrometeorological Testbed. Recently, the forecast length of the system was extended from 24 to 72 hours. Testing of the system included using the ensemble output to drive stream-flow models to provide ensemble river stage forecasts and designing alternative domain configurations to accommodate a wider user base. Ensemble work is described more extensively in connection with the HMT project below.

Wind PADS (Precision Airdrop)

NOAA/CIRA funding was unavailable for work during this period.

Taiwan Central Weather Bureau (CWB)

Participating CIRA Scientists: Steve Albers and Chris Anderson

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

See LAPS/WRF Improvements under section 1.

2. Research Accomplishments/Highlights:

Several LAPS analysis runs for Taiwan domains both at GSD and at the CWB continue to be maintained. One of our runs on EJET is being evaluated and compared with the GSI run. Some improvements to the radar remapping code lookup tables were made so they work properly on EJET. Our ACARS ingest was improved so it can bring in the aircraft observations for our CWB runs.

We worked with the CWB towards the goal of improving the velocity dealiasing software they are contributing to LAPS. We worked to reestablish the tropical cyclone bogusing data feed from their new server for our GSD runs.

Collaborating with others in FAB, we coordinated the preparation of our LAPS/WRF Ensemble modeling software on a DVD for delivery to the CWB.

A README file was started to help in understanding and documenting how the new STMAS-3D software operates.

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

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

NWS Interaction

Participating CIRA Researchers: Ed Szoke, Steve Albers, Chris Anderson, and Isidora Jankov

a) AWIPS and AWIPS/LAPS

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 am in GSD. Several CIRA researchers also take part in presenting and producing weather briefings.

Regional Climate Studies

Participating CIRA Scientist: Chris Anderson

(Additional NOAA Mission Goal to Understand climate variability and change to enhance society's ability to plan and respond / Climate predictions and projections)

A modeling system was developed based on WRF that can be used to perform seasonal to decadal regional simulations of climate. The system will be used to test the utility of downscaling seasonal forecasts from the Climate Forecast System for use in western water management decisions.

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.

LAPS III (Ensemble-based LAPS)

Participating CIRA Scientists: Chris Anderson and Randy Collander

Ensemble work is described briefly in the previous “Model Ensemble & Ensemble Post Processing” Section and more extensively in connection with the HMT project in the section below.

Hydrometeorological Testbed (HMT)

Participating CIRA Scientists: Steve Albers, Chris Anderson, Ed Szoke, and Isidora Jankov

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 stream flow. Three large field campaigns were held in December through March of the past three winter seasons in the American River Basin (ARB) of the Central Sierra Mountains (Fig. 1). CIRA researchers 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.

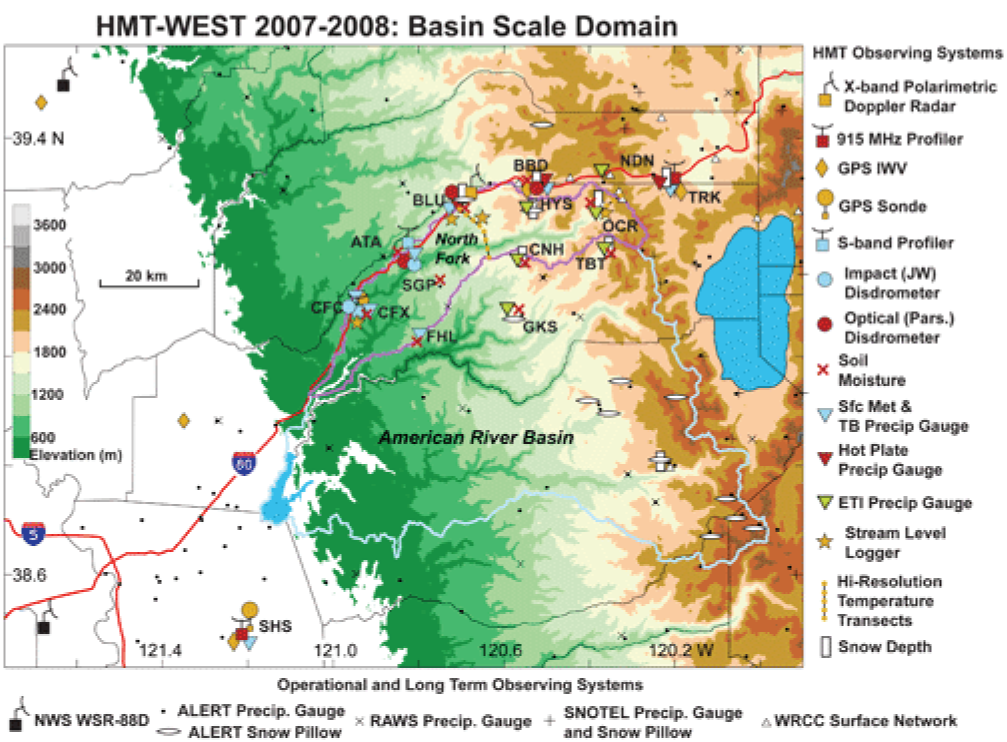


Fig 1. Basin-scale map of the third full-scale deployment of HMT-West; successfully conducted December, 2007 - March, 2008

2. Research Accomplishments/Highlights:

LAPS Analysis

The HMT/LAPS analyses (laps.noaa.gov) are used to create web graphics for nowcasting, and they provide gridded initial conditions for experimental numerical weather prediction models being run in support of NWS weather forecast office and river forecast center operations. The analysis software assimilates a wide variety of in-situ and remotely sensed data including GOES satellite and full volume reflectivity and velocity scans from nine WSR-88D radars. Some experimental observation systems are assimilated as well, e.g., the 915 MHz profilers deployed in the HMT domain by ESRL/PSD. We set up and made improvements to our real-time hourly analysis run over the American River Basin running at 3km resolution. The surface relative humidity and wind fields show a wealth of detail related to the topography and larger scale weather systems (Fig. 2). Fig. 3 shows where the precipitation (both liquid equivalent and snowfall) has accumulated over the past day in the HMT domain, as well as the current location and type of precipitation. Cross-sections (Fig. 4) also help show how the three dimensional wind and precipitation fields interact with the terrain. This information is useful for a forecaster who may want to anticipate the evolution of precipitation over the ARB, located in the center of the domain.

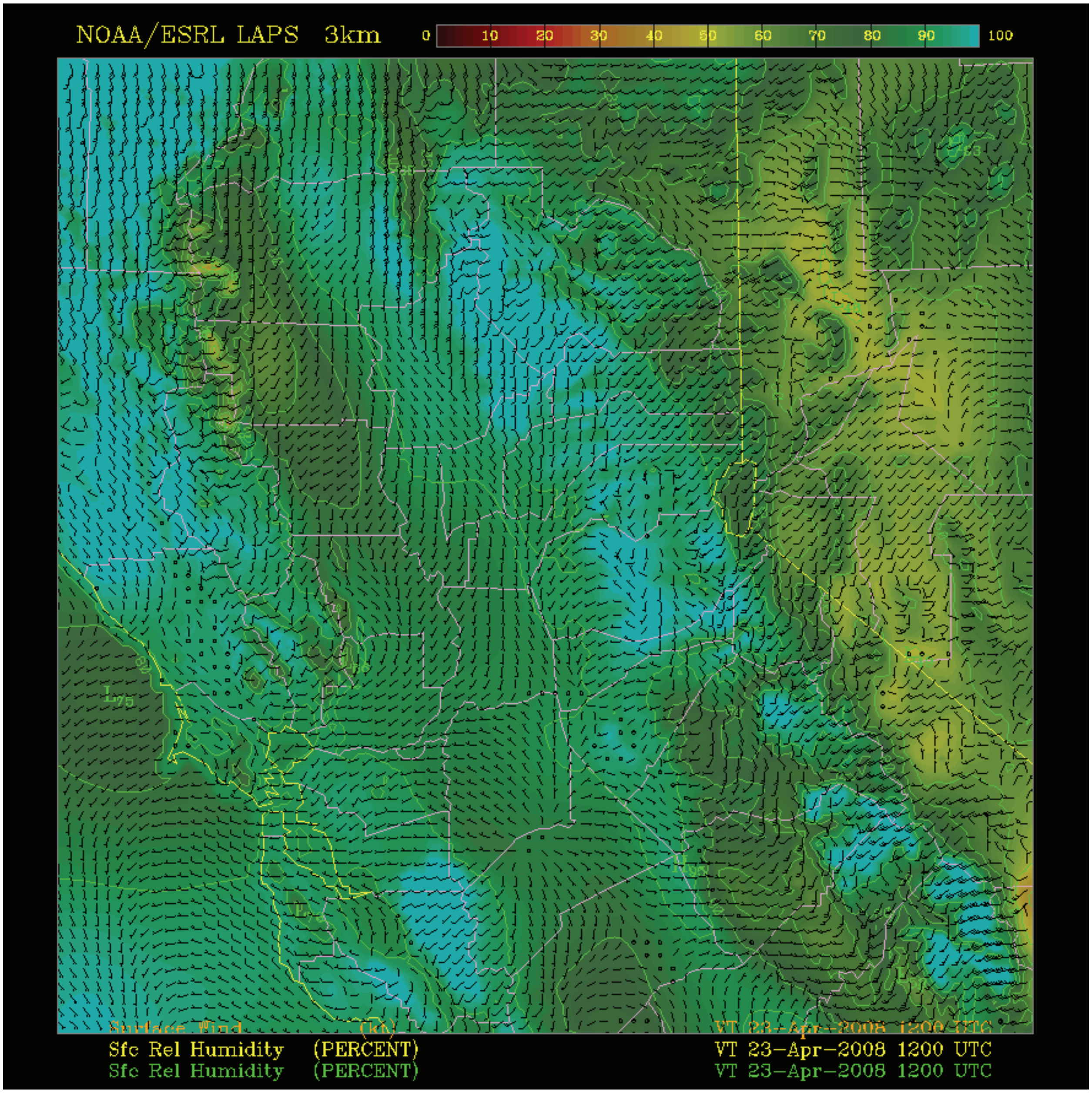


Fig 2. LAPS hourly analysis of surface RH and wind for the HMT domain

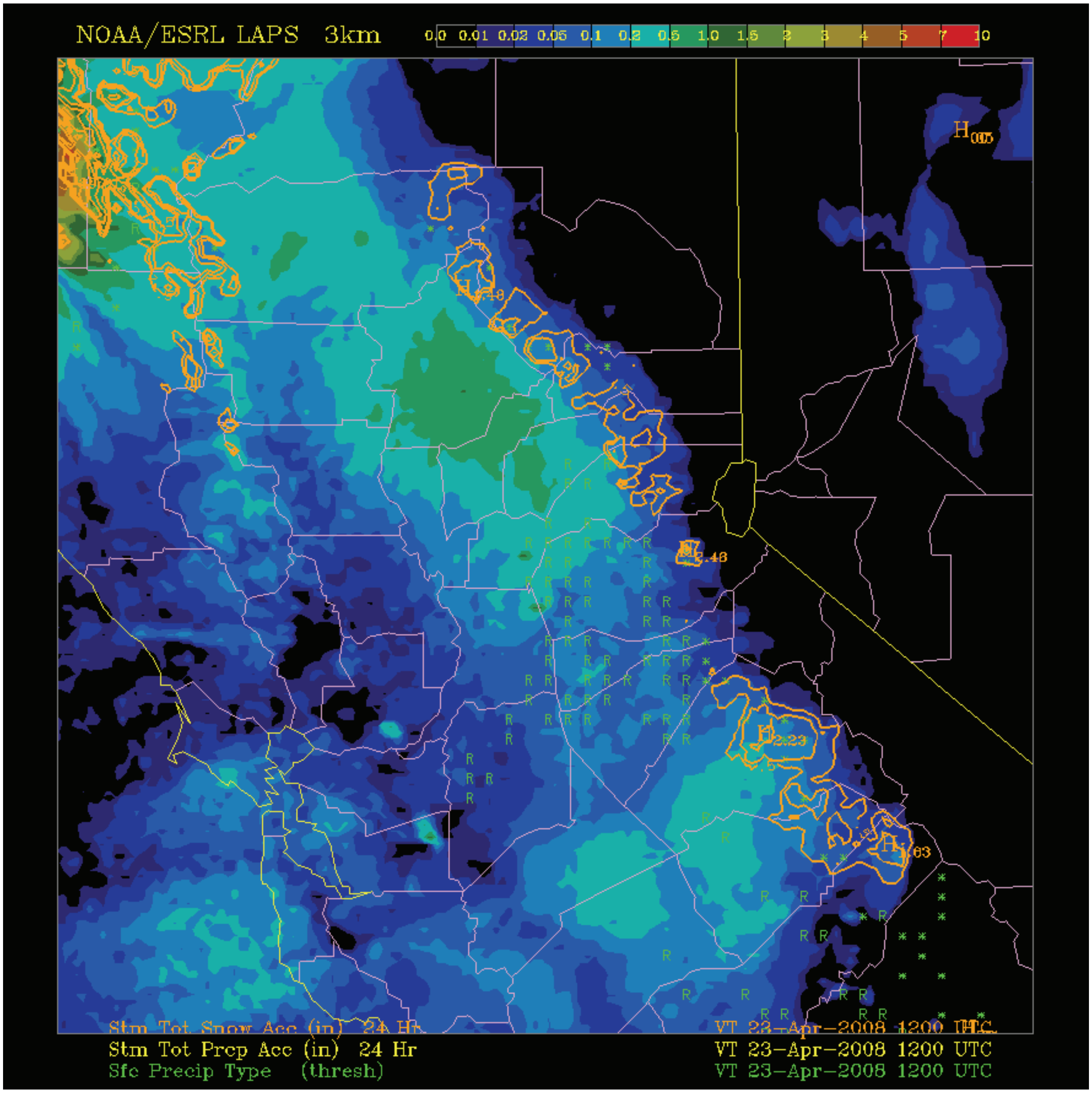


Fig 3. LAPS analysis of 24-hr accumulated precipitation (shaded colors), current surface precipitation type (green icons), and 24-hr snow accumulation (orange contours).

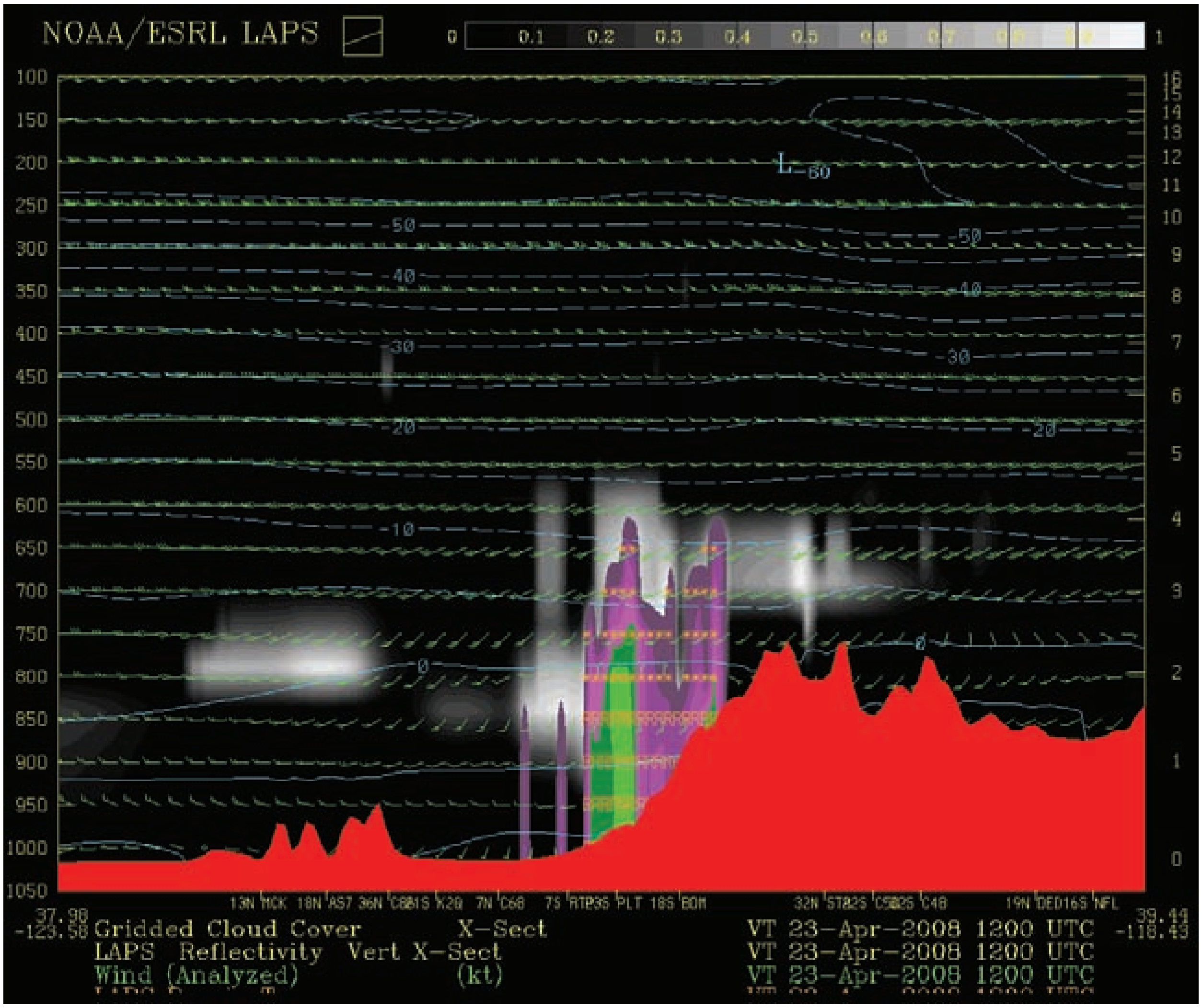


Fig 4. LAPS cross-section of clouds, radar reflectivity and precipitation type showing clouds moving over the California coastal range (left), and precipitation over the Sierra Nevada mountain range (right). The section is oriented perpendicular to the Sierras.

Model Forecasts

Forecasts from NWP models are a primary source of guidance to forecasters at forecast lead teams beyond 6 to 12 hours. NWP efforts for HMT are focused on improving precipitation forecasts in order to improve the timeliness of flash flood warnings and the accuracy of stream and river flow predictions.

During the 2007-2008 winter field campaign, we responded to forecaster input by producing ensemble forecasts out to a 72 hour lead time. We added a few diagnostic variables and participated in system testing to improve the timeliness of model output display on ALPS machines installed during the field campaign.

The project is now moving into an intense developmental phase in which a new forecast domain will be designed, perhaps new ensemble strategies explored, and computing resources determined to install the new ensemble system with the support of California Department of Water funding at the California-Nevada River Forecast Office in 3-4 years.

Daily Forecast Support

For the third year in a row, CIRA researchers provided real-time support to the field experiment in the form of detailed daily discussions of the precipitation forecast over the testbed. This included participation in the daily (7 days a week) conference call and posting text forecasts to the HMT website.

An important part of the HMT program, as outlined at http://www.esrl.noaa.gov/psd/programs/2007/hmt/, is to assess various instrumentation, including new radar technologies, designed to better measure precipitation and determine precipitation type. The ultimate goal is to arrive at more accurate quantitative precipitation estimates (QPE) which, coupled with the advances in high resolution numerical modeling, can lead to improved hydrologic forecasts and warnings. Additional observations during events include special radiosonde launches at frequent intervals to document the characteristics of each storm. All of these special observations require scientists to be on station for each event, but events might be widely spaced in time, so the strategy has been to make a forecast of each event and then staff accordingly, with some of the required staff having to fly in from Boulder as well as Norman, Oklahoma.

The general forecast goals are to give as much advance warning of a potential event (an "Intensive Operational Period" or IOP) as possible, with a go/no go decision needed usually no less than 24 to 48 hours in advance. The ultimate decision to call an IOP rests with the Project Director (this position rotating among several scientists within NOAA), but is of course highly influenced by the forecasters and their confidence in a potential IOP. A conference call among HMT participants occurs every day during the program at 12:30 local mountain time, with the initial business a forecast discussion, followed by further discussion and interpretation leading to a decision on a potential IOP. A written forecast and forecast discussion is also done and posted to the project webpage (http://www.esrl.noaa.gov/psd/programs/2007/hmt/) near or shortly after the conference call. A preliminary version of the forecast discussion is sent to the project directors at least an hour or so ahead of the conference call for planning purposes.

CIRA staff have been an integral part of a larger forecasting cadre that represents a cooperative effort between the National Weather Service (NWS) Weather Forecast Offices (WFO) in the HMT area, which are the Sacramento and Monterey WFOs in California and the Reno WFO in Nevada, the NOAA California-Nevada River Forecast

Center in Sacramento, and the NOAA National Centers for Environmental Prediction (NCEP) Heavy Precipitation Branch. During the HMT exercise, the Boulder forecasters were responsible for the written discussion posted to the website and leading the forecast part of the daily conference call. Typically, the forecast discussion involves input from the other participants, particularly when the weather prediction becomes less certain. A prototype AWIPS workstation was installed at the participating WFOs to allow the forecasters there to examine the output from the special model forecasts being run at GSD for the project. There was also occasional participation by two NOAA forecasters from ESRL's Physical Sciences Division, who provide occasional longer range (2 to 3 week) guidance based on their analyses and interpretation of model forecasts.

CIRA and other forecasters in Boulder use a variety of information and model forecasts to make the HMT daily forecast. The standard operational models are found on AWIPS, but the web offers a look at many other models as well as ensemble model forecasts from the NCEP Global Forecast System (GFS), as well as a set of ensemble forecasts from Environment Canada. Analyses of water vapor and other parameters are available from a number of other sites, with one of the favorites out of the University of Hawaii. A set of the most often used sites has been compiled onto a webpage for the project at http://laps.fsl.noaa.gov/szoke/DWB/Hydromet_Test_Bed_fcsthomepage.html. In the shorter range, of course, the forecasters utilize the various 3 km and ensemble runs initialized with LAPS and run locally at GSD that are described in this article.

Post-Season Analysis and Research

In terms of research activities, there are several ongoing HMT projects in collaboration with PSD and CIRES scientists. Initially, a study by Jankov et al (*J. Hydrometeor.*, 2007) evaluated the impact that various microphysical schemes, planetary boundary layer (PBL) schemes, and initial conditions had on Quantitative Precipitation Forecast (QPF) over the HMT area and for events characterized by atmospheric river settings. It was found that for this type of event and for this location, variations in microphysics resulted in a statistically significant impact on simulated precipitation amounts. Several ongoing studies build on this finding and focus on various ways to evaluate performance of the high-resolution numerical model with various microphysics and possibly finding a way to improve QPF in the case of significant precipitation events during the winter in California.

An ongoing study in collaboration with several scientists from NOAA/PSD (Jian-Wen Bao, Paul Neiman and Allen White) and CIRES (Huiling Yuan) focuses on a detailed analysis of a high-resolution numerical model with various microphysics and its performance in cases of atmospheric river events. For this purpose, simulations of the representative events have been performed by utilizing the WRF-ARW numerical model with four different microphysics (Lin, Thompson, WSM6 and Schultz). 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.

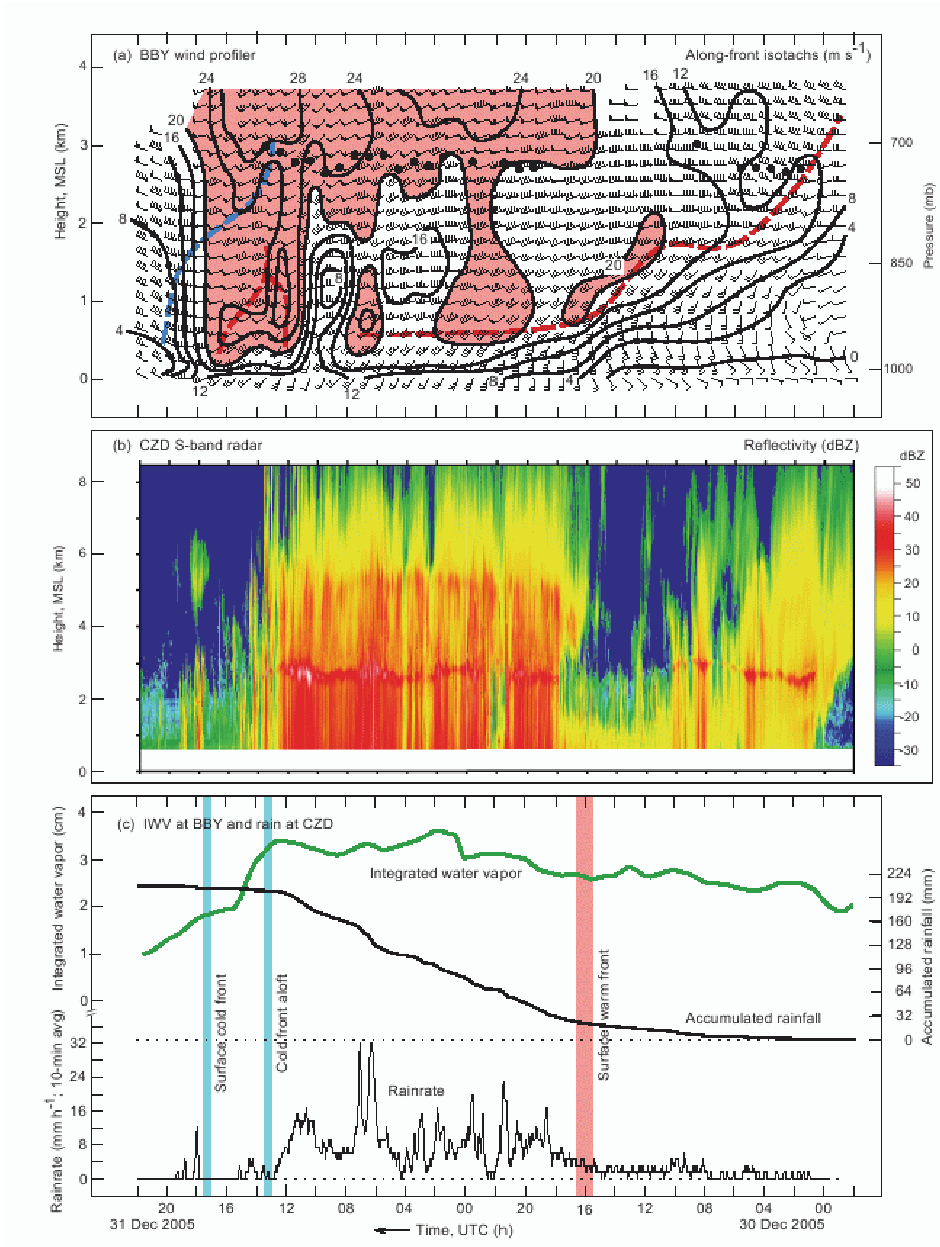


Fig 5. Time series of observations from BBY and CZD between 22 UTC 29 December and 22 UTC 31 December 2005. (a) Time-height section of hourly-averaged wind profiles (wind flags 25 m s-1; barbs = 5 m s-1; half-barbs = 2.5 m s-1), along-front isotachs (directed from 230 degrees; red shading >20 m s-1), bright band melting-level height (bold black dots), and axes of maximum thermal wind-derived warm and cold advection (red and blue dashed lines, respectively), from the wind profiler at BBY. (b) Time-height section of ~1.5-min radar reflectivity (dBZ) from the S-band radar at CZD. (c) Time-series traces of 30-min IWV (cm; green) from the GPS sensor at BBY and 2-min rain accumulation (mm) and rain rate (RR = mm h-1; 10-min averaging period) data recorded at the rain gauge at CZD. The red- and blue- shaded bars in the bottom panel denote warm- and cold-frontal transitions, respectively.

The finding about the WRF-ARW model tendency to overestimate the intensity and duration of the upslope wind component has served as a motivation for a study to quantify the impact that various microphysical schemes and intensity of upslope wind component as well as the interaction between the two have on simulated orographically induced rainfall. For this purpose, 12-hour high resolution WRF-ARW model simulations of a typical atmospheric river event will be used. The simulations will include variations in microphysical schemes and wind initial conditions. The initial wind perturbations will be generated by Monte Carlo sampling from Gaussian distribution using analysis based covariance estimate. The impact of microphysics and wind variations on the simulated rainfall will be quantified by using the factor separation methodology. This method measures absolute, relative and synergistic contribution of each variation to the simulated rainfall.

Further evaluation of the WRF-ARW model with various microphysics performances will be assessed by producing synthetic satellite imagery and using an objective measure of difference in various microphysics compared to observations. This research will be performed in collaboration with CIRA scientists Louie Grasso and Manajit Sengupta. To make this research possible, a production of observational operators for WRF-ARW model has been developed as a part of collaborative work with a group of CIRA scientists (Renate Brummer, Louie Grasso, Manajit Sengupta, Dusanka and Milija Zupanski) on a WRF/RAMS Synthetic Imagery Project. An example of a synthetic satellite image (brightness temperature) from a WRF-ARW model simulation using Schultz microphysics over the HMT domain is presented in Fig. 6

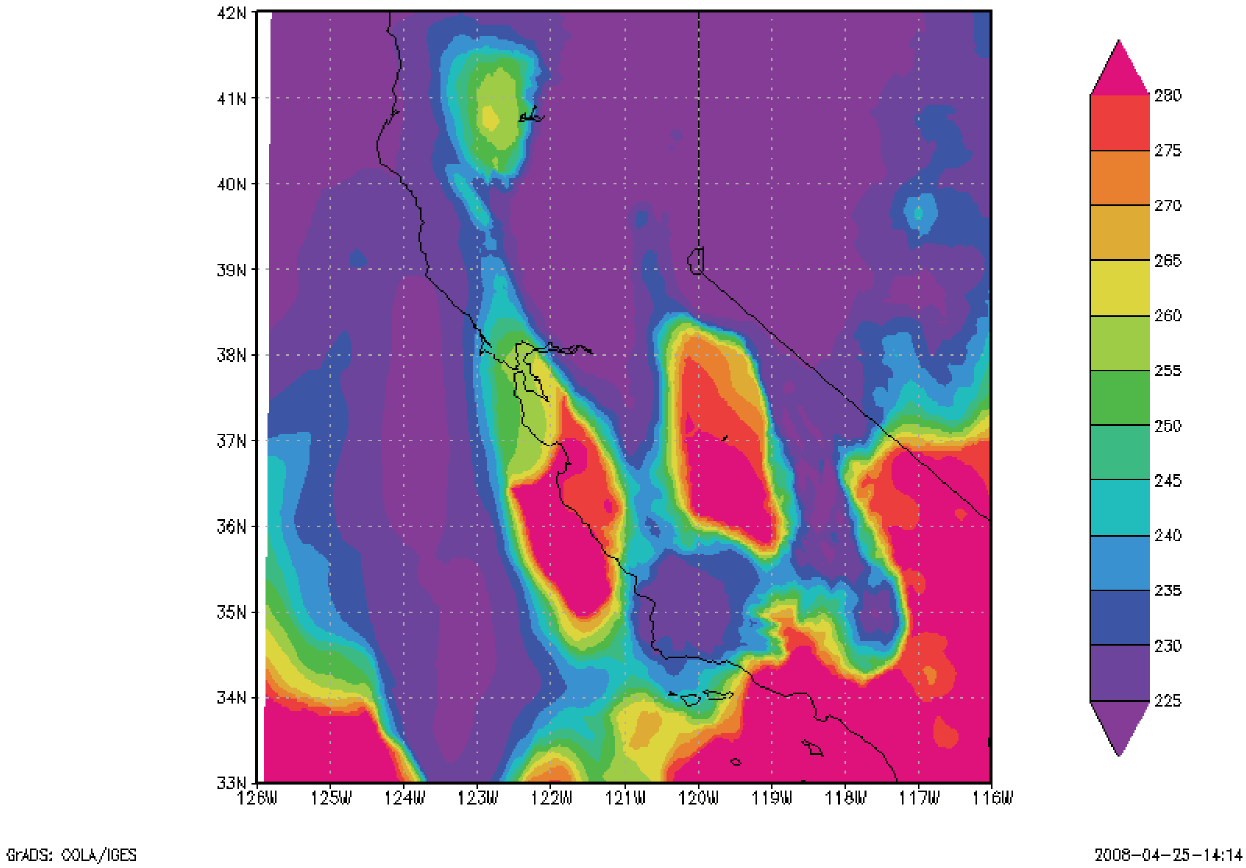


Fig. 6. Synthetic brightness temperature calculated from WRF-ARW model output using WSM6 microphysics valid at 06 UTC 30 december 2005.

An NSF proposal in collaboration with CIRES scientist Tomislava Vukicevic for work which will focus on improving nonconvective precipitation accuracy by objectively estimating the individual contributions of parameterized processes representing generation and depletion of the various hydrometeors has been recently granted. The new method will be developed and tested using the Weather Research and Forecasting (WRF) model and this model's 4-dimensional variational (4DVAR) data assimilation system. In this study, once again, the focus will be on modeling and prediction of precipitation associated with strong synoptic scale forcing mechanisms and topography.

One of the current ongoing activities is built on a theoretical study performed in collaboration with CIRES scientist Tomislava Vukicevic and FAB scientist John McGinley (Vukicevic et al., 2008). The main focus of this study was a development of a technique that unifies evaluation of the forecast uncertainties produced either by initial conditions or different model versions, or both. 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. The current activity consists of applying the theoretical approach on "real" data. For this purpose, simulations of atmospheric river events performed by using WRF-ARW model with mixed physics and mixed initial conditions are used.

CIRA researchers actively participated in a Quantitative Precipitation Evaluation (QPE) project funded by the GSD Office of the Director and led by Steven Mullen from Arizona State University. The main goal of this study was to evaluate a possibility of producing a better precipitation analysis by using an ensemble of WRF model forecasts to recover a background error covariance. Preliminary results were presented in a recent seminar and first draft of an official journal publication has been made. CIRA researchers will take part in an extension of this study which will involve an implementation of the experimental radar data available for the HMT 30-31 December 2005 IOP. The experimental x-band radar data have been obtained from PSD scientist David Kingsmill.

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 (Dan Gottas, Sara Michelson, Jian-Wen Bao, Paul Neiman, Allen White, Seth Gutman, Marty Ralph, Dave Kingsmill and Tim Schneider) 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.

Working with the California Dept. of Water Resources, we coordinated the HMT datasets that were presented using Science On a Sphere at the California State Fair in late summer 2007. We also gave a number of on-site SOS demos with these and other datasets at the fair. We also helped with the preparation of graphics being shown with Science On a Sphere for an interview of HMT participants by a National Geographic film crew.

3. Comparison of Objectives vs Actual Accomplishments for Report Period:

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Jankov, I., P. J. Schultz, C. J. Anderson, and S. E. Koch, 2007: The impact of different physical parameterizations and their interactions on cold season QPF. *J. Hydrometeor.* 8, 1141-1151.

Jankov, I., W. A. Gallus, Jr., M. Segal, and S. E. Koch, 2007: Influence of initial conditions on the WRF-ARW model QPF response to physical parameterizations changes. *Wea. Forecasting* 22, 501-519.

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

Schultz, P., S. C. Albers, C. J. Anderson, D. Birkenheuer, I. Jankov, and J. McGinley, 2008: A computationally efficient method for initializing numerical weather models with explicit representation of moist convection. Submitted to *Wea. Forecasting.*

Vukicevic, T., I. Jankov, and J. McGinley, 2008: Diagnosis and optimization of ensemble forecasts. *Mon. Wea. Rev.*, 136, pp. 1054-1074.

Yuan, H., J. A. McGinley, P. J. Schultz, C. J. Anderson, and C. Lu, 2008: Short-range precipitation forecasts from time-lagged multimodel ensembles during the HMT-West-2006 campaign. Accepted by *J. Hydrometeor.*

Yuan, H., C. Lu, J. McGinley, P. Schultz, B. Jamison, L. Wharton, and C. Anderson, 2008: Short-range precipitation forecasts using time-lagged multimodel ensembles. Submitted to *Wea. Forecasting*

LAPS/WRF Modeling Activities

Participating CIRA Scientists: Steve Albers, Chris Anderson, and Isidora Jankov

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

2. Research Accomplishments/Highlights:

Fire Weather

We continue to support a web interface recently developed that allows an end user (e.g. Redzone Inc.) to automatically move a fire analysis/forecast domain so that we can quickly respond to evolving fire situations. 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.

A LAPS case study was performed of fire weather for recent Southern California fires that was presented to NWS personnel in the Los Angeles area.

Department of Homeland Security (DHS)

A presentation on LAPS analyses was provided to Dr. Starnes Walker from NOAA and DHS in the hopes of setting up additional projects related to disaster preparedness.

We maintained 4.5km and 1.5km LAPS analysis runs for domains over the Washington D.C. area, including the use of Level-II Doppler radars. Assistance was provided with the development of an observation converter from LAPS format to WRF format that can be used in DHS WRF runs.

Some changes were made to the wind analysis towards the goal of improving the boundary layer winds. This entails allowing the vertical radius of influence to be adjustable based on observation type. The vertical radius of influence for surface wind observations was reduced to half that of other observations for evaluation of the anticipated improvements.

ATMET/AFTAC

We are working with ATMET to make a version of LAPS that can be built as a single executable with other changes allowing incorporation as the analysis step of the RAMS model. Recent discussions were held with both ATMET and AFTAC center on the best plan to continue the configuration of a single executable version of LAPS, including what software conventions should be used.

Global parameter names were changed by stripping off the "_cmn" or "_common" suffix to improve interfacing with ATMET's single executable version of LAPS. Modifications in various LAPS FORTRAN routines and scripts were made to accommodate this. Variable declarations are being changed from "real*4" to "real" and "integer*4" to "integer" to make the GSD and ATMET versions of LAPS more compatible. This should also make LAPS more robust when compiled on 64-bit platforms. A new global parameter was added to help control the writing of output from individual routines for ATMET purposes.

FORTRAN 90 modules that will be used by the single executable driver routines are now being compiled into LAPS, including modules used for namelist parameter definition and access. LAPS libraries—global, ingest and wind parameters—and wind analysis drivers were made more compatible with the F90 single executable ATMET

LAPS realization. LAPS configuration is now set up to use C preprocessor directives to compile LAPS in either the single or multiple executable mode. Different wind driver code is specified by these directives based on the configuration.

The wind analysis modules are now better organized according to their function; this helps in setting up the desired ATMET configuration. The wind analysis has been updated to handle the passage of input and output arrays (as well as parameters) in a way that is compatible with the ATMET single executable version and keeps memory usage to a minimum. More of the global arrays are passed down from the main wind driver.

Finnish Meteorological Institute (FMI)

We advised FMI on LAPS software including topics such as graphics plotting, web displays, and software portability. We are troubleshooting the radar remapping with some of their case data. We have a hypothesis that explains the presence of ring shaped artifacts and are advising FMI on ways to address them.

Hazardous Weather Testbed (HWT)

Collaboration between the Hazardous Weather Testbed and Hydrometeorological Testbed has been established. Chris Anderson traveled with a group of managers to an initial brainstorming session to determine how the two testbeds can work together to accomplish common goals. A primary developmental priority that was identified was the need to advance the use of high-resolution forecasts so that they could be used in an adaptable manner. A pilot test is underway in which a mesoscale model ensemble forecast designed by Dave Stensrud and Mike Coniglio is being used to provide initial and boundary conditions to produce a cloud-scale model ensemble forecast. Also, Isidora Jankov has been recently invited by the Spring Experiment organization committee to actively participate as a researcher in this year's experiment which takes place in Norman, Oklahoma.

Atlantic Oceanographic and Meteorological Laboratory (AOML)

We collaborated with AOML to run a LAPS analysis for Hurricane Dennis from 2005, including the use of special derived radar observations. This is a proof of concept for using LAPS to initialize the WRF model with current tropical cyclone information to help improve forecasts. The planned WRF experiments are in collaboration with a PhD student Jin-Young Kim coming to us from Korea. Our web interface was improved to be able to plot the densely packed special observations that support the analysis of tropical storms, along with flexibility in wind barb colors.

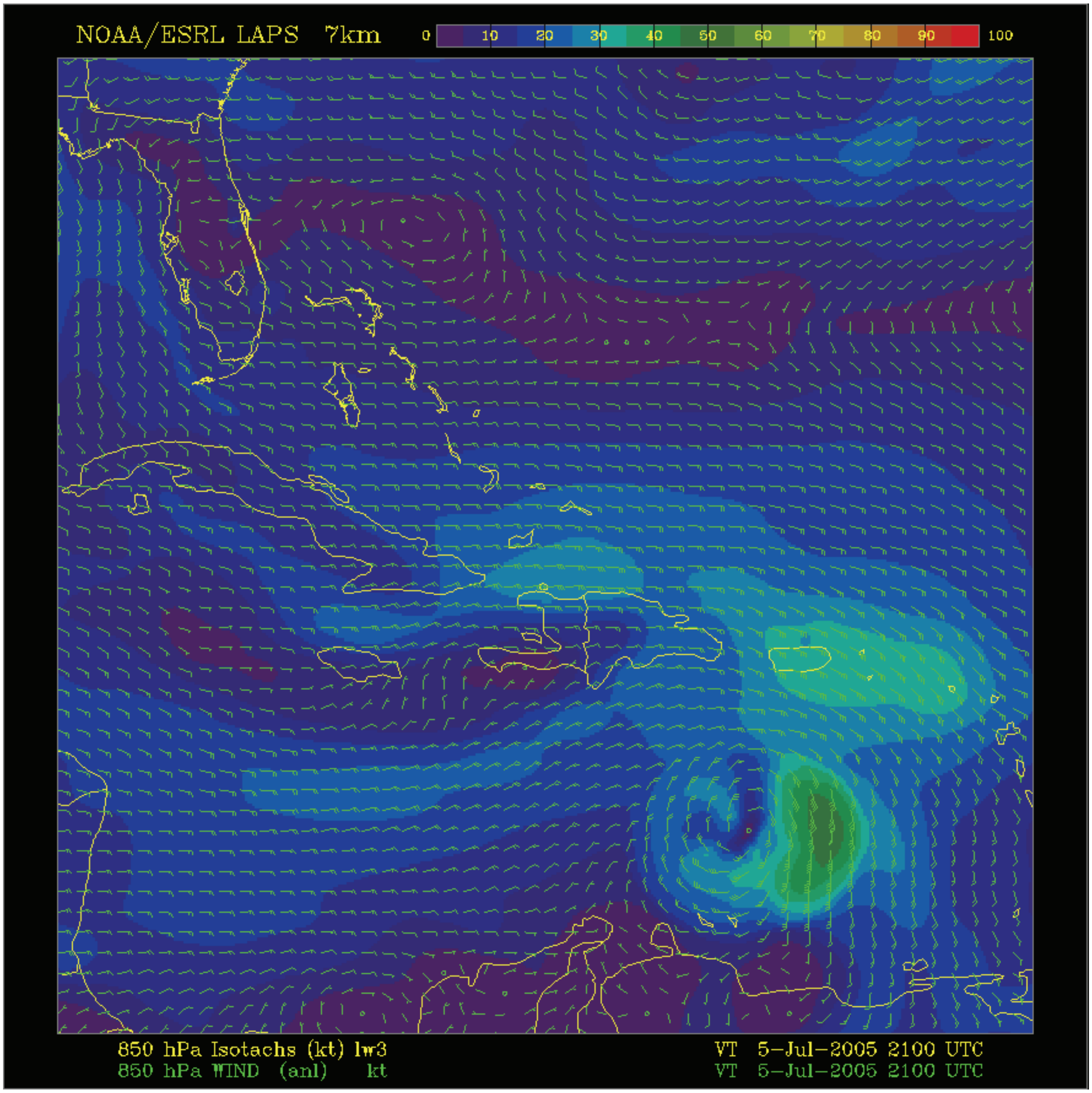


Fig. 1. Developing Hurricane Dennis 850mb winds as analyzed by LAPS with supplemental airborne radar information from AOML

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

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

Project Title: Non-LAPS Activities

Science On a Sphere (SOS)

Participating CIRA Researcher: Steve Albers

FIM and GFS global model forecast displays were updated with additional fields and improved color tables. For example, a display that overlays precipitable water with surface pressure is useful for tracking tropical cyclones. These displays are now utilizing the higher resolution 0.5 degree gridded data. This was the centerpiece of a "high-level" presentation to NOAA administrators. IDL display procedures were generalized to make it easier to switch models and modify color tables & color bars. GLAPS analysis displays were also updated with improved color tables and wind barb depiction.

Efforts were restarted to combine or "unrender" various SOS datasets so they can be used with a more generalized projector configuration.

The dataset for Mercury was updated based on recent data from the MESSENGER spacecraft as well as Earth-based radar information (Fig. 1). A new map of Io from the USGS is now available for SOS. We worked to construct updated planetary satellite maps for several of Saturn's moons, including Dione, Tethys, Enceladus, and Iapetus. An improved map of Ariel we've been working on is part of a collaboration mentioned in a poster at a NASA planetary science conference.

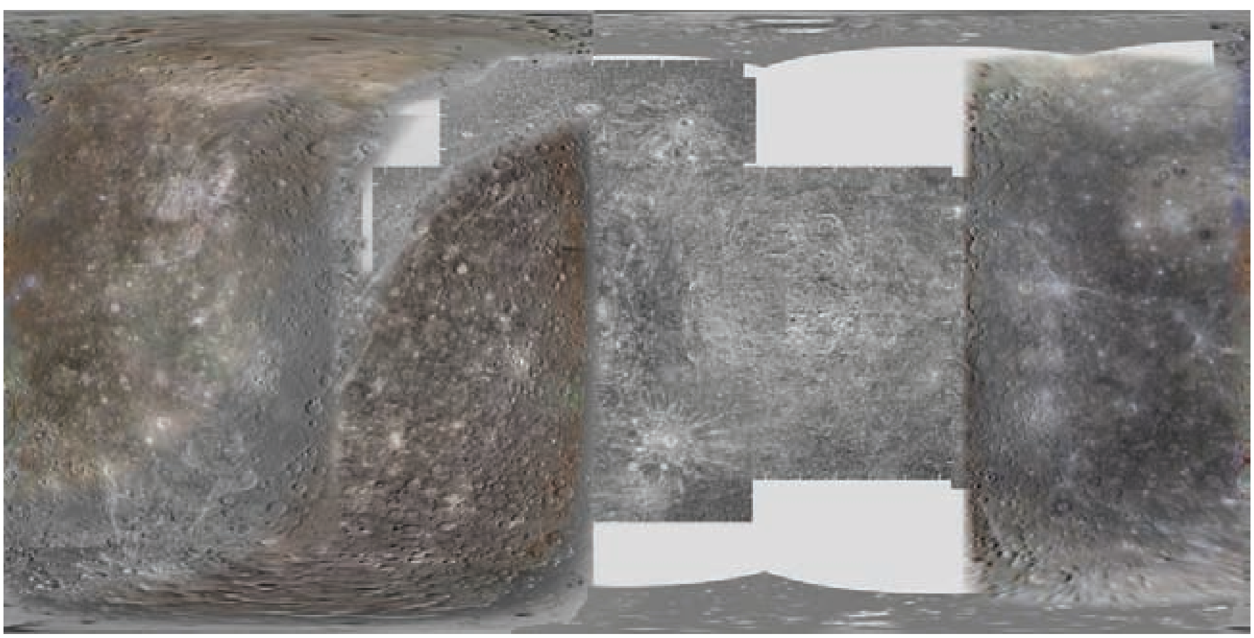


Fig. 1. Updated SOS dataset of the planet Mercury using recent spacecraft and Earth-based radar data

Several SOS demos were presented to groups visiting the Space Weather Prediction Center. In August, we attended a NASA workshop on Outer Planet Satellites held in Boulder. As part of that meeting, an SOS presentation was provided at ESRL of the related Solar System datasets that are being working on. Consultation also occurred with the Smithsonian Museum of Natural History about an SOS exhibit they are developing showing oceans and the early Earth.

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 dataset 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:

In FY08, close collaboration with the EMC yielded criteria refinement and successful software test runs were completed and the software was introduced into NCEP daily operations for model precipitation verification. The refined criteria were applied to individual observations and daily totals as well as subjective evaluation of station performance during the preceding 30-day period. Listings of stations that passed or failed the criteria were used in the Real Time Verification System (RTVS) of GSD's Aviation Branch. Several case studies for the Hydrometerological Testbed project study of extreme rainfall were completed and the results used to identify weaknesses in the quality control scheme that led to discussion of criteria refinement (as well as proposed additional tests). The examination includes station reliability (observations received on a regular basis), anomalous observations (excessive hourly values or daily sums), stuck gages (reporting the same value for multiple consecutive hours or pattern of hours) and a neighbor check (comparison to values reported by nearby stations).

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

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

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 ™ 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 ™ 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 ™ 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 FY08, a team of NOAA/ ESRL scientists from the Global Monitoring Division (GMD) and the Global Systems Division (GSD) completed another successful stratospheric balloon flight, testing the AirCore ™ atmospheric gas concentration profile sampler. The flight was 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 balloon was launched and cut down by radio command from the EOSS ground station at Windsor, CO with the payload landing over 7,030 miles away adjacent to Interstate 76. The AirCore ™ was 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. ESRL has submitted a patent application for the AirCore™ because of its enormous potential to obtain numerous profiles of trace gases on a global scale. The AirCore™ could feasibly collect 1,000 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.

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

Our accomplishments for this project compare favorably with the goals projected in the statement of work.

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:

In FY08, design reviews were held between NOAA and CIRA personnel and Applied Research Associates, the developer of the ultra-light dropsonde. Size, shape and weight of the dropsonde were discussed, modifications suggested and incorporated into the prototype dropsonde to be delivered for testing in late FY08 or early FY09.

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.

<u>Development of a Multi-Vehicle Atmospheric Trajectory Prediction System</u>

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 superpressure 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:

NOAA/CIRA funding was unavailable for this project during this period.

TAMDAR Assessment

Participating CIRA Researcher: Ed Szoke

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

The TAMDAR (Tropospheric AMDAR (Aircraft Meteorological Data Relay)) program underwent a big milestone when the National Weather Service (NWS) agreed to purchase the TAMDAR data from the Midwest and mid-CONUS that had been part of the TAMDAR Great Lakes Field Experiment. The objective and subjective evaluation efforts by GSD and some NWS WFOs (particularly WFO Green Bay, Wisconsin) were crucial to establishing the usefulness and reliability of the data input that went into the NWS decision.

2. Research Accomplishments/Highlights:

In the past year, we continued to evaluate the TAMDAR data, including examination of new fleets that have come online with TAMDAR in Alaska. The evaluations include the impact on forecasts from the Rapid Update Cycle (RUC) model, utilizing both objective scoring and subjective case studies. Both objective and subjective evaluation of the model output has shown that TAMDAR does indeed have a positive impact on RUC forecasts of wind, temperature, humidity, and precipitation. Demonstration of the utility of the TAMDAR soundings for forecasting convection and other weather problems has also continued. A number of conference papers have been presented during the past year.

3. Comparison of Objectives Vs. Actual Accomplishments:

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outrech:

8. Publications:

A CIRA-FAB 2007-2008 publications list is available on-line at this URL:
http://laps.noaa.gov/cira/annual_report/2007-2008/pubs/all.html

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 Conference on Aviation, Range, and Aerospace Meteorology*, 20-24 January 2008, New Orleans, LA, AMS, Paper P2.20.

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, 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, Paper 6.4.

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. Accepted by *Mon. Wea. Rev.*

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

Keywords: 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, support of the RUC development continued, both at NCEP and at GSD. Extensive documentation on the RUC13, including significant differences from the RUC20, is available at http://ruc.fsl.noaa.gov/ruc13_docs/RUC13ppt.htm.

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.

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

RUC13 updates at NCEP are a successful technology transfer. 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:

6. Awards/Honors

7. Outreach:

8. Publications:

Smith, T.L., S.G. Benjamin, S.I. Gutman, and S. Sahm, 2007: Short-range forecast impact from assimilation of GPS-IPW observations into the Rapid Update Cycle. *Mon. Wea. Rev.*, 135, 2914-2930.

Project Title: <u>TAMDAR (Troposheric Airborne Meteorological Data 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 weather 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. At GSD, one of the major efforts in the evaluation of TAMDAR has been to determine its impact on forecasts from numerical weather prediction models. Using the Rapid Update Cycle (RUC) model, the long-term evaluation of TAMDAR impact continued using identical versions of the RUC model run with and without TAMDAR. Both objective and subjective evaluation of the model output has shown that TAMDAR does indeed have a positive impact on RUC forecasts of wind, temperature, humidity, and precipitation. Demonstration of the utility of the TAMDAR soundings for forecasting convection and other weather problems has also continued. Tasks during the past year primarily involved examining the data for quality, and investigating the impact of the data on weather model forecasts.

2. Research Accomplishments/Highlights:

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 November 26 to December 5, 2006 were necessary in order to determine the effect of adjustments to the model and/or the input data. Continuing with runs performed during fiscal year 2006-2007, additional runs for this period include:

a) a run with all profiler data removed.

b) a run with the radar Velocity Azimuth Display (VAD) data removed.

c) a run with all radiosonde observation (RAOB) data removed.

d) a run with all mesonet data removed.

e) a run with all surface data (mesonet and METAR) data removed.

f) a run where a routine is removed that creates pseudo boundary layer observations.

g) two runs where the background moisture error was lowered to 10 g/kg and 5 g/kg.

h) a run with cloud drift wind data removed.

i) a run accounting for the drift of the radiosonde balloons.

j) three runs where the height of profiler data were limited to 4 km, 8 km, and 12 km.

k) a run with changes to the background error limits for winds.

Another retrospective period was selected (August 15-25, 2007) to examine the data denial effects for summertime. This time period was selected primarily due to its substantial convective activity. Runs are ongoing, and a number of them have been completed. These include:

a) a baseline run using all data with no alterations in parameters, for which successive runs will be compared to determine impacts

b) a run with all TAMDAR data removed.

c) a run with all aircraft (AMDAR) data removed.

d) a run with all profiler data removed.

e) a run with all VAD data removed.

f) a run with all RAOB data removed.

A number of conference papers have been presented during the past year.

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:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

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 IOAS-AOLS*, 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, 2008: New TAMDAR fleets and their impact on Rapid Update Cycle (RUC) forecasts. *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.

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.

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. McGinley, P. Schultz, B. Jamison, L. Wharton, and C. Anderson, 2008: Short-range precipitation forecasts using time-lagged multi-model ensembles. *Wea. Forecasting* (submitted).

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: 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 Cycle model 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 current HRRR domain extends from northern Minnesota to northern Oklahoma, and includes most of the northern East Coast. Tasks for this project include: generating graphics of output fields, creation and management of websites for display of those graphics, and creation and management of graphics for hallway public displays, including software for automatic real-time updates.

2. Research Accomplishments/Highlights:

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 website was also created for display of these images (http://www-frd.fsl.noaa.gov/mab/hrrr3). This website also offers the option to display an alternate version of the HRRR which does not include upgrades developed at GSD.

In addition, similar graphics and a website (http://rapidrefresh.noaa.gov) were generated for the Rapid Refresh (RR) model, which is an upgrade to the RUC model that includes assimilation of radar reflectivity, TAMDAR observations, enhanced convection and enhanced land-surface radiation. The RR remains at 13 km resolution; however the domain covers all of North America rather than just the continental U.S. (Fig. 1).

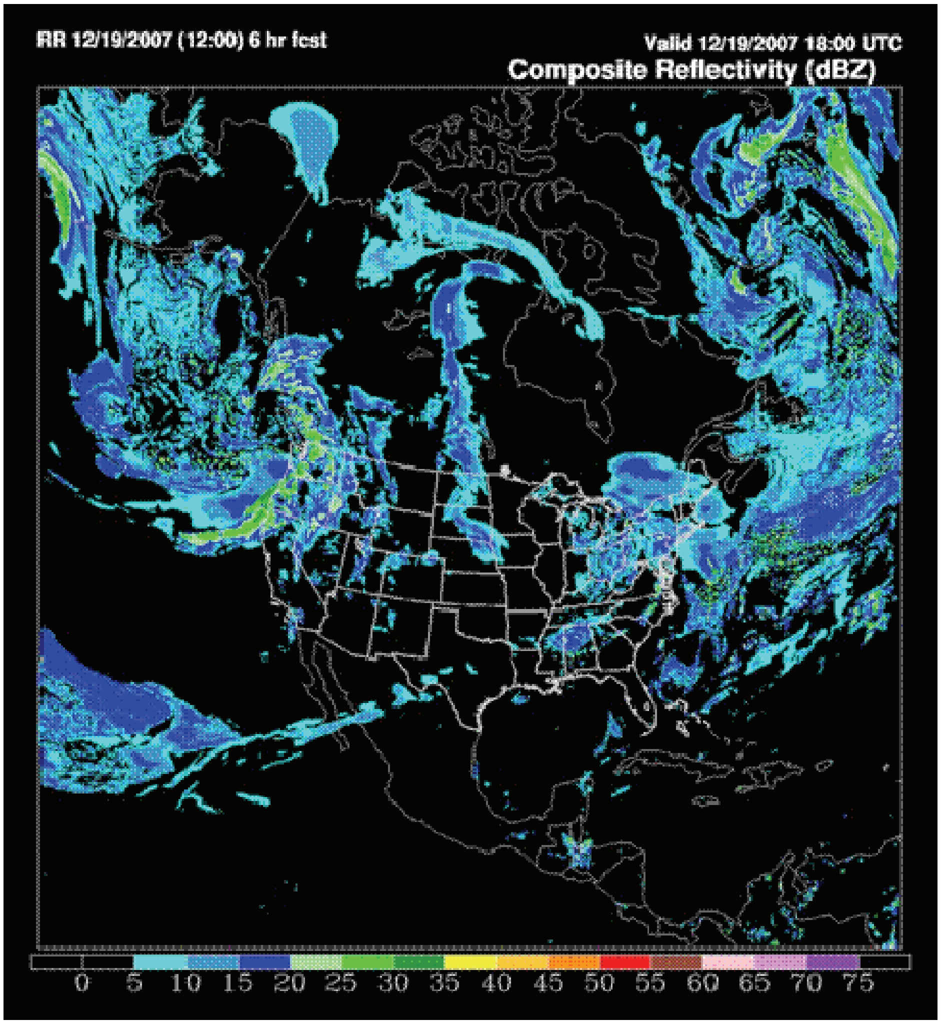


Fig. 1. An example of a large domain Rapid Refresh image. A six-hour forecast of composite reflectivity from the Rapid Refresh non-cycled cold start model.

RR products for the Alaska region and the continental U.S. (CONUS) were also created and are available from the website.

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 displayed and updated regularly.

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:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Project Title: **Study of gravity waves and turbulence interaction in the upper troposphere**

Principal Scientist: 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 transferred an algorithm for unbalanced flow diagnostics in the upper troposphere to the Federal Aviation Administration two years ago. A series of papers have been published in journals 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. This research is still in progress, and the on-going research effort will be carried over to the next few years.

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

This research is in progress and collaboration with NOAA/ESRL/GSD will continue in the coming year. 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.

4. Leveraging/Payoff:

In leveraging current NOAA/OAR 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.

5. Research Linkages/Partnerships/Collaborators/Outreach:

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 on a series of research projects. (This CIRA scientist was invited to spend a short visit in Beijing, China.). A German professor from University of Frankfurt, Dr. Ulrich Achatz, paid a visit to our group in Boulder, Colorado. We also discussed future collaboration in this area. It has also been proposed that a post doctorate fellow from the China Ocean University will conduct research on gravity waves during the coming year. This research collaboration is supported by the Chinese National Nature Science Foundation.

6. Awards/Honors:

7. Outreach:

8. Publications:

This research has generated several publications during the past year.

Koch, S. and C. Lu, 2007: Turbulence and gravity waves in a dynamically unbalanced upper-level jet-frontal system. *16th Conference on Atmospheric and Oceanic Fluid Dynamics*, 25-29 June 2007, Sante Fe, NM. AMS

Lu, C. and S. Koch, 2007: Interaction of upper-tropospheric turbulence and gravity waves as observed from spectral and structure function analysis. *J. Atmos. Sci.,* in press.

Lu, C. and S. Koch, 2008: Gravity waves and turbulence in spectral, structure functional, and multifractal spaces. *First US-China Symposium in Mesoscale Meteorology*, Norman, OK.

Wang, N. and C. Lu, 2008: A two-dimensional continuous wavelet algorithm and its application to meteorological data analysis. *Mon. Wea. Rev*., submitted.

Project Title: Hydrometeorology, QPE and QPF, and data assimilation and ensemble forecasting

Principal Scientist: 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, multimodel ensemble systems and ensemble-based data assimilation systems, and applied these systems to various projects and experiments. We have 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 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.

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

Project is in progress.

4. Leveraging/Payoff:

Based upon NOAA’s support, we have developed several NSF, DoD, and NASA proposals. We anticipate some of this funding will foster and enhance our research over the next few years.

5. Research Linkages/Partnerships/Collaborators/Outreach:

Last year, we hosted two postdoctoral fellows—one funded by the National Research Council and the other jointly supported by CIRA 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. Our CIRA scientist 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. Our CIRA scientist 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 plan 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 High Education Committee.

6. Awards/Honors:

7. Outreach: See above

8. Publications:

Kim, O., C. Lu, J. McGinley, and J. Oh, 2008: Recovery of mesoscale background error covariance using time-lagged ensembles. *Mon. Wea. Rev.*, in preparation for submission.

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. *1st China-US international Symposium on Mesoscale Meteorology and Data Assimilation*, Norman, OK.

Lu, C., H. Yuan,, B. Schwartz, and S. Benjamin, 2007: Short-range forecast using time-lagged ensembles. *Wea. and Forecasting*, 22, 580-595.

Lu, C., H. Yuan, S. Koch, E. Tollerud, N. Wang, J. McGinley, and P.Schultz, 2007:Towards understanding of uncertainties of global QPF and QPE from satellite and NWP model fields. *Mon. Wea. Rev,* in revision.

Xu, X., C. Lu, X. Shi, and S. Gao , 2008: The world water tower: An atmospheric perspective. *Geophys. Res. Lett*., in review.

Xu, X., R. Zhang, T. Koike, C. Lu, X. Shi, P. Li, S. Zhang, X. Cheng, L. Bian, and G. Ding, 2007: A new integrated observational system over the Tibetan Plateau (NIOST) for weather/climate monitoring and forecasting. *Bull. Amer. Meteor. Soc.,* accepted.

Yuan, H., C. Lu, J. McGinley, P. Schultz, L. Wharton, and B Jamison, 2007: Short-range quantitative precipitation forecast (QPF) and probabilistic QPF using time-phased multi-model ensembles. *Wea. and Forecasting,* conditionally accepted.

Yuan, H., J. McGinley, P. Schultz, C. Anderson, and C. Lu, 2007: Evaluation and calibration of short-range PQPFs from time-phased and multi-model ensembles during the HMT-West-2006 campaign. *J. Hydrometeorology,* in press.

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 aerosols which are the key components of smog and are especially harmful to human health. Currently, a 3DVAR system (Gridpoint Statistical Interpolation) is being developed, but plans are made and funding being secured for a 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.

Recently, an initiative was taken to improve WRF-Chem forecasts with data assimilation using the Gridpoint Statistical Interpolation (GSI, Purser et al., 2003a and b). The subject of this report is to present accomplishments achieved during the past year. This effort concentrated on the development of background error covariances for ozone and its implementation in the GSI. Also, the assimilation cycle has been implemented for WRF-Chem (NMM version). Thus far, funding has been available for the NMM version of WRF-Chem, which is currently somewhat deficient in performance compared to the ARW version of WRF-Chem; funding for data assimilation in the ARW version of WRF-Chem is forthcoming. The results of data assimilation of surface ozone observations with WRF-Chem NMM and GSI have been evaluated over a period of three weeks in August 2006 and are presented below.

To calculate background error covariances and the characteristic length scales, the NMC method (Parish and Derber,1992) was used with WRF-Chem ozone forecasts from August 2004 at 12 km resolution. Modeling domain is shown in Fig. 1.

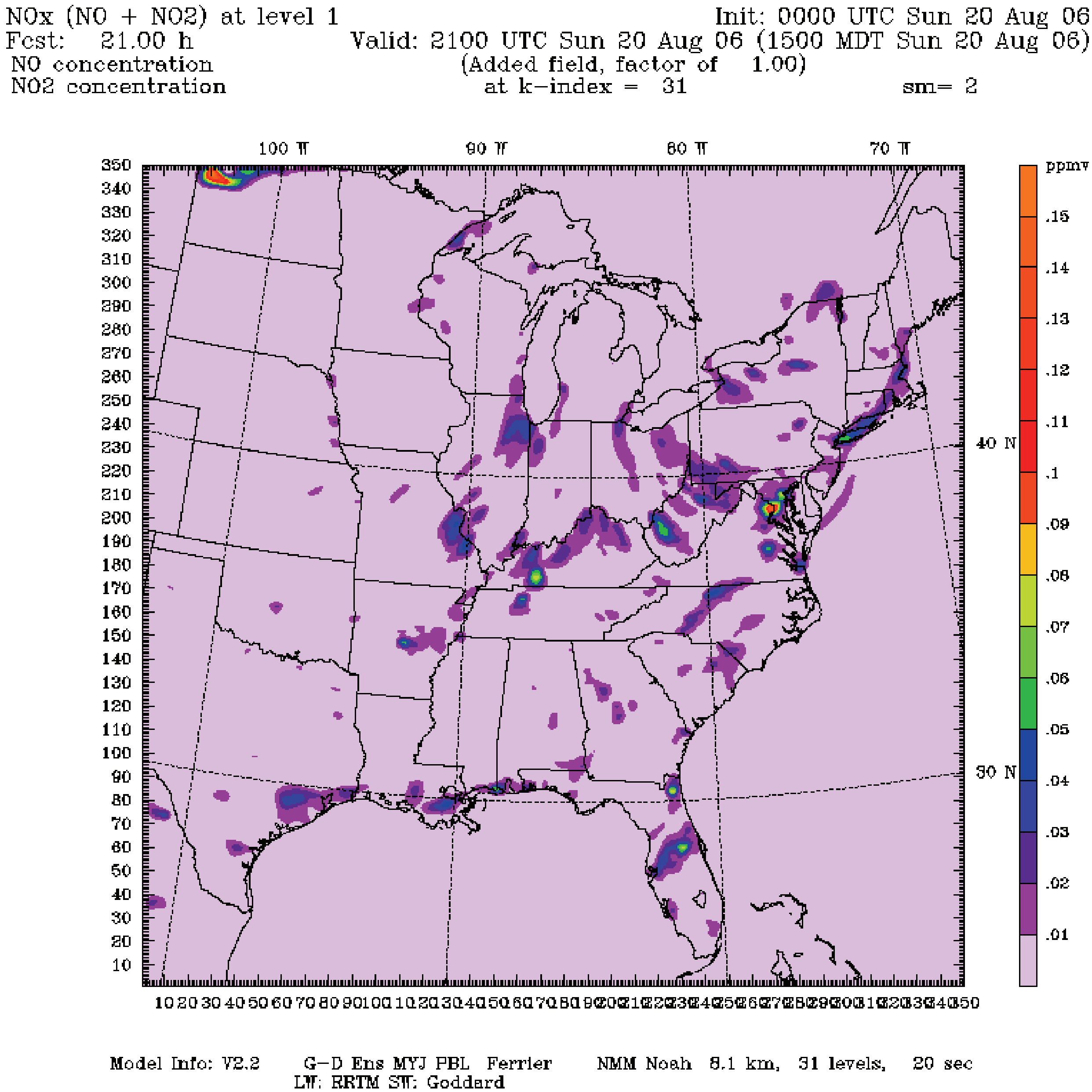


Fig. 1. Modeling domain

Background error covariances were calculated from the differences between 48h and 24h forecasts and were used to calculate correlation length scales for different model levels by fitting Gaussian curves. The distance-correlation dependence for different vertical models levels is shown in Fig. 2.

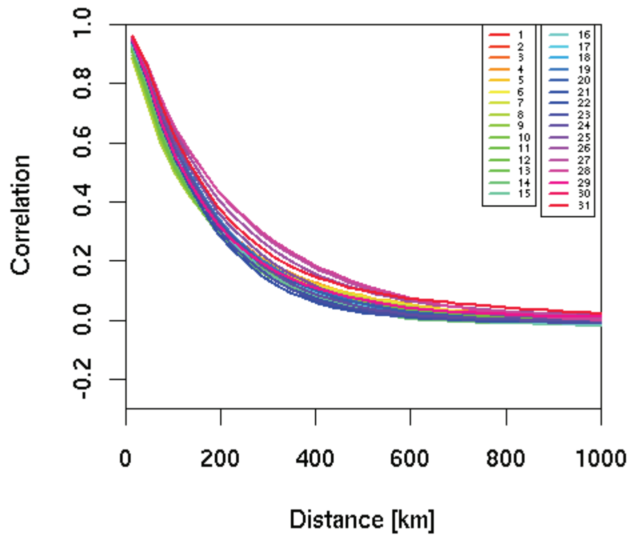


Fig. 2. Horizontal distance-correlation relation for ozone at different model levels

In a similar manner, vertical correlation length scales were obtained. They are shown in Fig. 3.

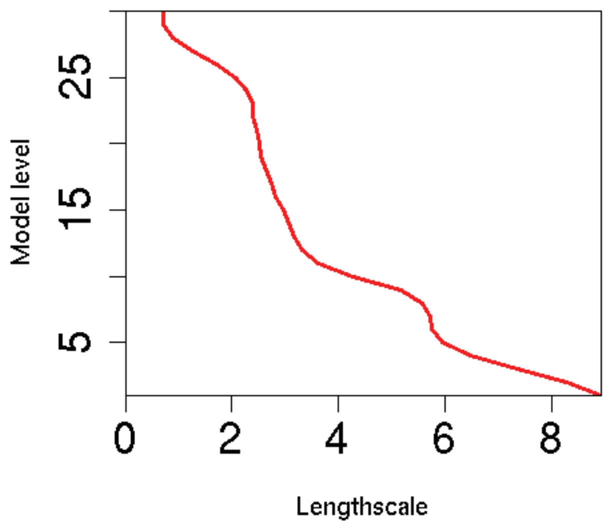


Fig. 3. Variability of the vertical correlation lengthscales at different model levels for ozone

Map with measurement network of surface ozone concentrations that was used in the data assimilation experiment is shown in Fig. 4.

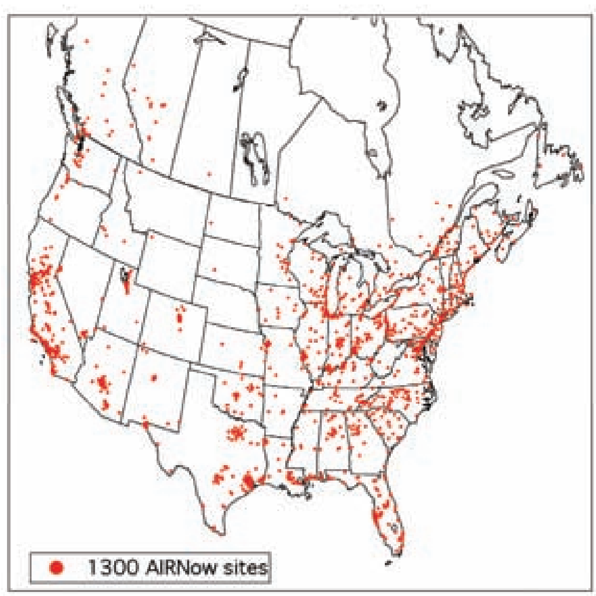


Fig. 4. Map of real-time ozone measurement stations that constitutes AIRNow network

Performance metrics (correlation, bias, and root-mean square errors) of the data assimilation experiment with cycle implemented at 24 hour intervals at 0000 UTC are shown in Fig. 5 for the next day maximum daily 8-hr ozone concentrations. Corresponding results without data assimilation are shown in Fig. 6.

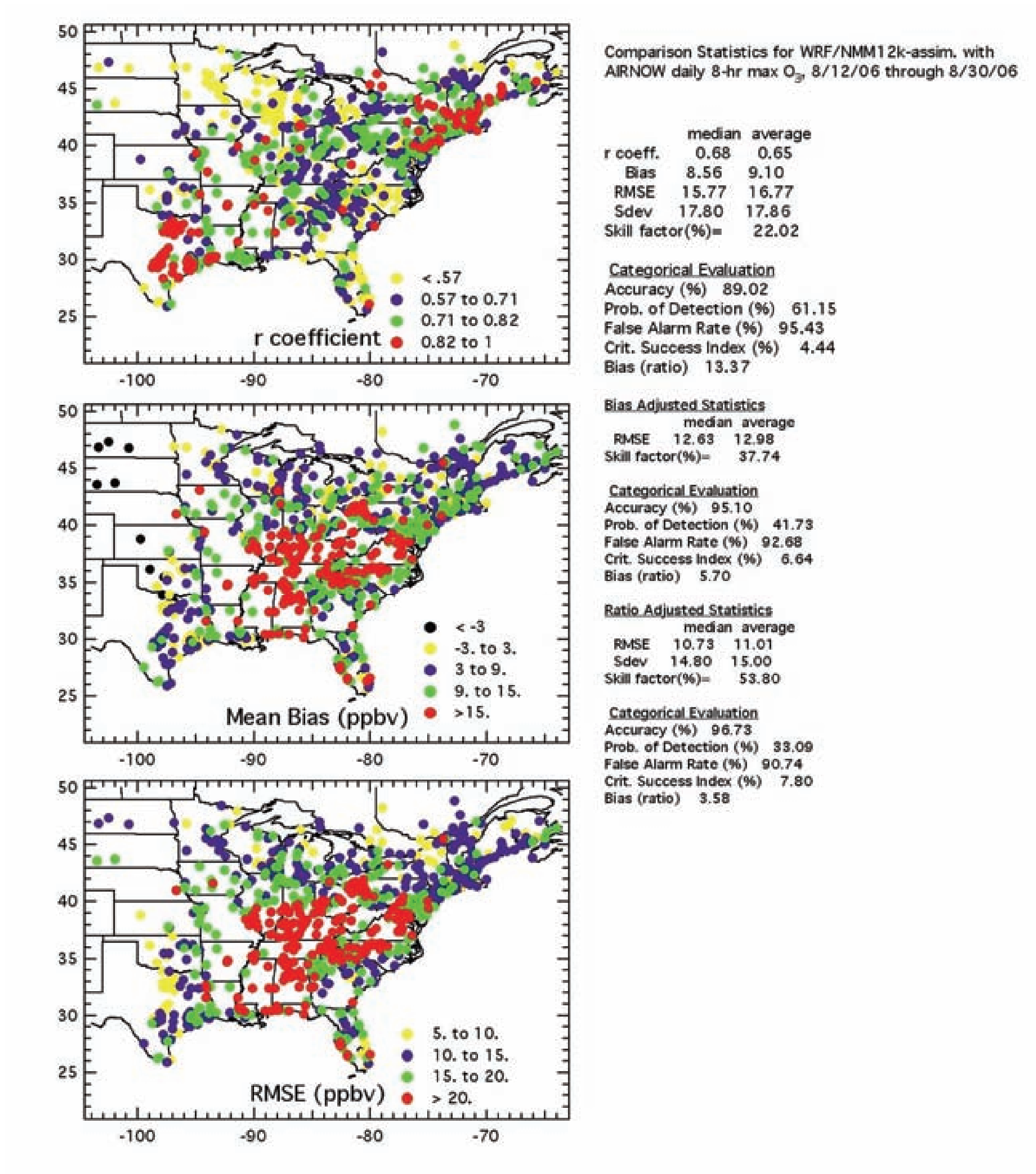


Fig. 5. Correlation, bias, and RMSE for data assimilation experiment

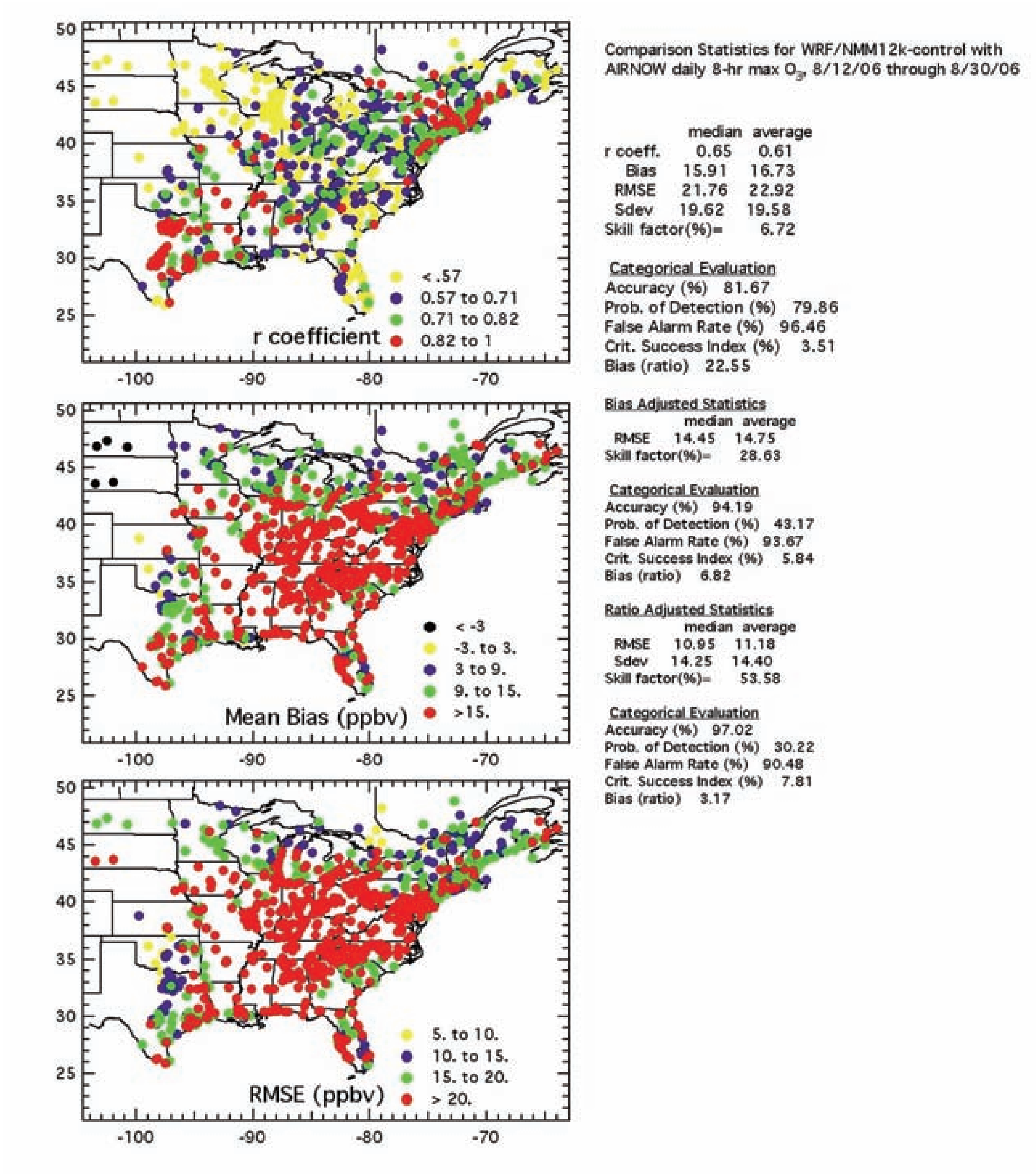


Fig. 6. Correlation, bias, and RMSE for the control simulations data assimilation experiment

It can be noted that the positive effect of the assimilation of surface ozone observations is largely limited to bias an RMSE reduction and has smaller effect on improvement of correlation. This less than fully satisfactory result is affected by poor properties of the numerical schemes in WRF-Chem NMM with respect of mass conservation. This is a known problem in WRF NMM that is currently being addressed.

More objective results of data assimilation on quality of ozone forecasts will become available with the ARW version of WRF-Chem. These experiments will begin shortly.

Future plans with data assimilation of chemical species include:

a) assimilation of vertical profiles and aircraft data for ozone
b) assimilation of surface aerosol measurements
c) assimilation of satellite ozone and aerosols
d) chemical OSSEs
e) development of adjoints for chemical reactions for gaseous species and aerosols
f) development of 4DVAR data assimilation system for WRF-Chem

Full description of the project is given in Pagowski et al. (2007).

References Used:

Pagowski, M., G.A. Grell, D. Devenyi, S.E Peckham, and S. McKeen, 2007: Chemical data assimilation: Initial results using the NMM-WRF/Chem and the Gridpoint Statistical Interpolation (GSI) Analysis System. *NOAA/ESRL/GSD Report.*

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: See above

4. Leveraging/Payoff:

5. Research Linkages:

6. Honors/Awards:

7. Outreach:

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.

Gultepe, I., R. Tardif, S. Michaelides, J. Cermak, A. Bott, J. Bendix, M. Muller, M. Pagowski, B. Hansen, G. Ellrod, W. Jacobs, G. Toth, and S.G. Cober: 2007: Achievements and future perspectives of fog research: A review. *Fog Observations and Its Modelling*, 2007, Birkhauser Verlag, I. Gultepe, Ed., AG, Basel, Switzerland, 310 pp.

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.

VI. Research Collaborations with the GSD Technology Outreach Branch

Project Title: 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). FX-Net is a cross-cutting solution provided to all these program elements.

Key Words: PC workstation, Fire Weather, Air Quality, Compression Algorithm

Background on FX-Net for Fire Weather/All Hazards

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 dataset 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 capabilities to the AWIPS II architecture. The AWIPS II system is scheduled to begin operational testing in FY09. The FX-Net team is researching the technologies used in the AWIPS II architecture and documenting FX-Net performance parameters 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 datasets 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 websites, Java web groups, external training and interaction with local web developers at UCAR and NOAA.

Future research will include evaluating new data distribution, data basing and display technologies to meet the goals of the ultimate system. In the next year, new technologies to be evaluated include UCAR's Unidata IDV data distribution and display system, the commercial IBL system, distributed data base systems utilizing Service Oriented Architecture (SOA), and extended Java applications. Research is continuing to focus on the many open source programs available to develop an SOA system that provides the same capability and performance as the current FX-Net system while adding developmental and operational flexibility.

The Wavelet Compression (refer to the Gridded FX-Net Project described below) research for the FX-Net project continues to concentrate on code optimization, improved compression ratios for image data, and extended precision control capabilities.

2. Research Accomplishments/Highlights:

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 a hybrid version of AWIPS OB6 and OB8. The intention in FY07-08 was to use AWIPS OB8 for the new version of the system. However, this version was not stable at the time the development servers were built, so a hybrid version was implemented to assure the new datasets and server features of OB8 were available to FX-Net users, while preserving reliability and availability.

The new version of the FX-Net Client (v.5.1) (see Figs. 1 - 4) is scheduled for release at the end of May 2008. This version of the client includes the addition of significant new data analysis and display tools. A significant retooling of the FX-Net Java Client included the following:

-- Use of Java SE 6 (JAXB) architecture for XML binding to provide XML Procedures.
-- Used open source (OCG) GeoTools to retool display to allow Shape file import.
-- Decoupled display engine to render layers individually. This allows the future use of external sources of geospatial data such as OGC Web Mapping and Web Feature Services. This architecture is being used by the AWIPS II development contractor.

Based on an analysis of the requirements received from the IMETS and NIFC fire weather forecasters, the new FX-Net 5.1 display and analysis tools are as follows:

--Image on Image (Fig. 1) - This tool allows the user to selectively load a satellite, radar or model image in combination with any other image. Controls were developed to adjust the brightness for each individual image, which gives the user the ability to control the visualization of the image combination.

--Shape File Import (Figs. 2 and 3) - During fire incidents the fire perimeter is redrawn every 6 to 12 hours. These files are created in a Shape file format. FX-Net's AWIPS servers do not accept Shape files as a part of the displayable data base. In order to serve the fire weather community, FX-Net developers re-tooled the Java display code to allow other data types to be imported directly from the FX-Net client and to be stored locally on the user's PC. The shape file in Fig. 2 depicts the perimeters of all the fires that burned in Oregon in 2007. The display also shows a radar image overlay. Fig. 3 shows the user-selectable data record associated with each shape. The data records can be sorted by date or location.

--Markers (Fig. 4) - The Markers tool provides a persisted, user-defined, and uniquely labeled Geospatial point. They are managed via the toolboxes show in Fig. 4.

--Compression Improved - Additional memory and code optimizations were added to v. 5.1. See Wavelet Compression under the Gridded FX-Net Forecaster Workstation Project.

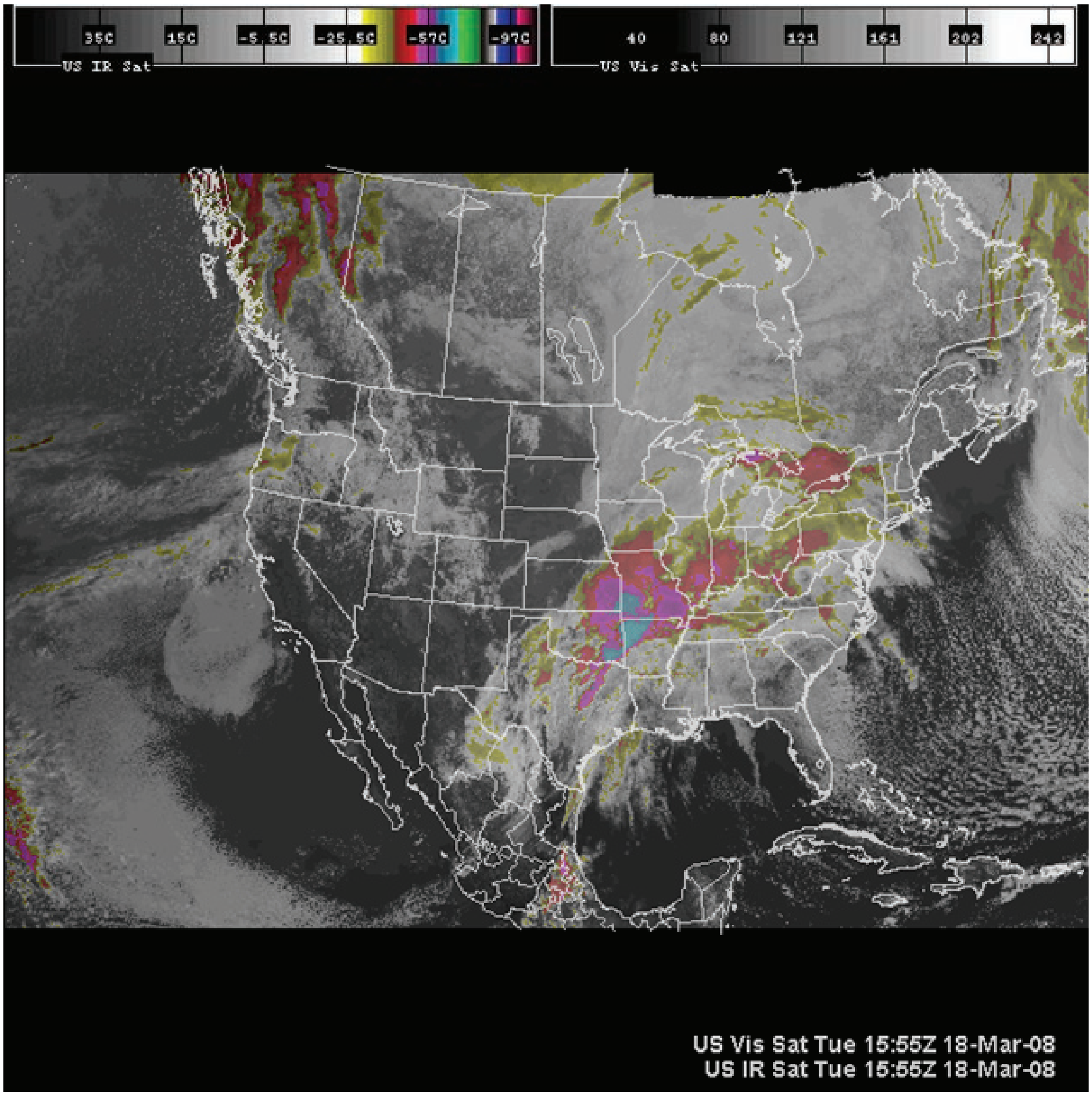


Fig. 1. FX-Net v. 5.1 Client display showing new Image on Image display

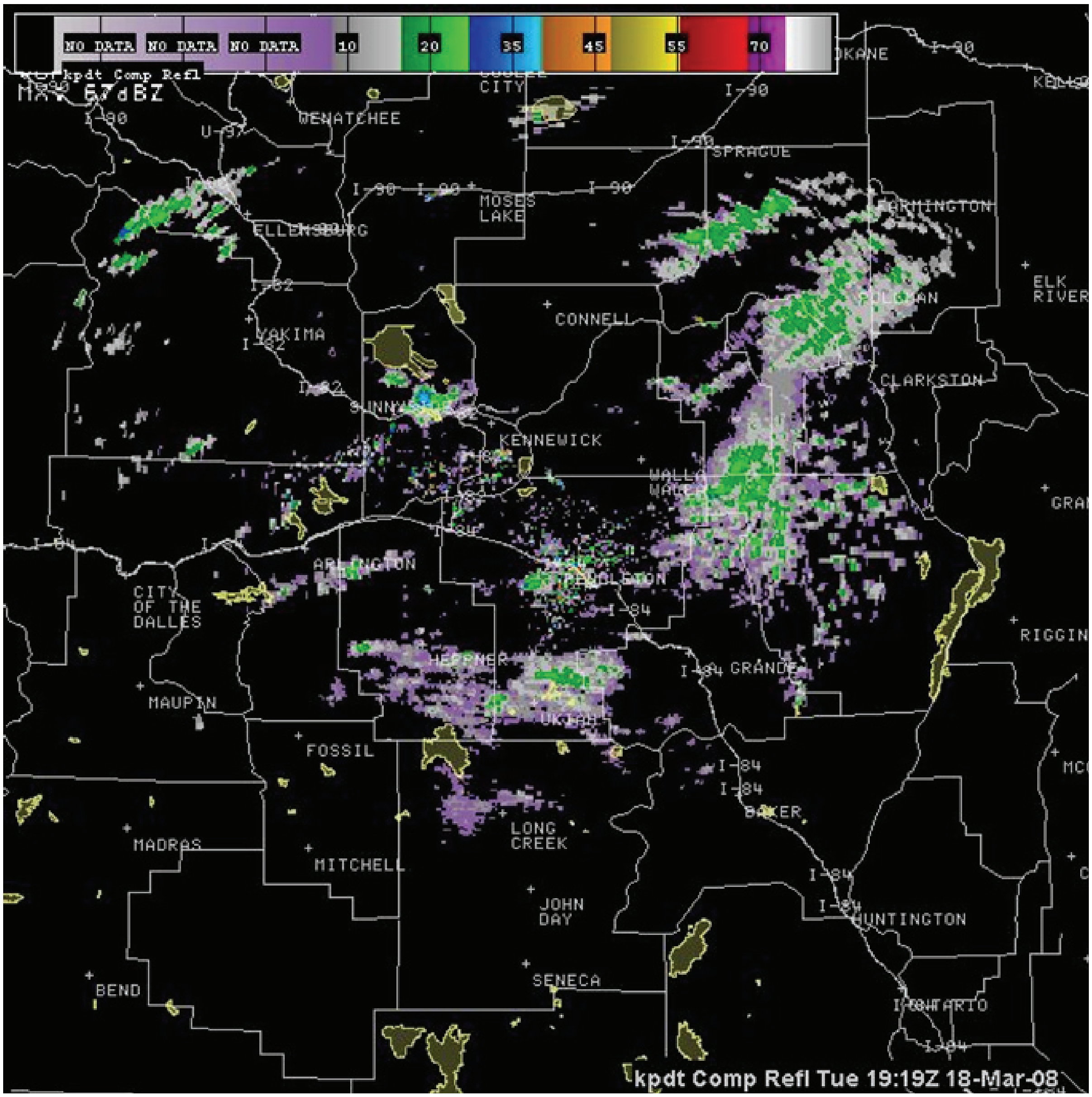


Fig. 2. Shape file import and radar data display

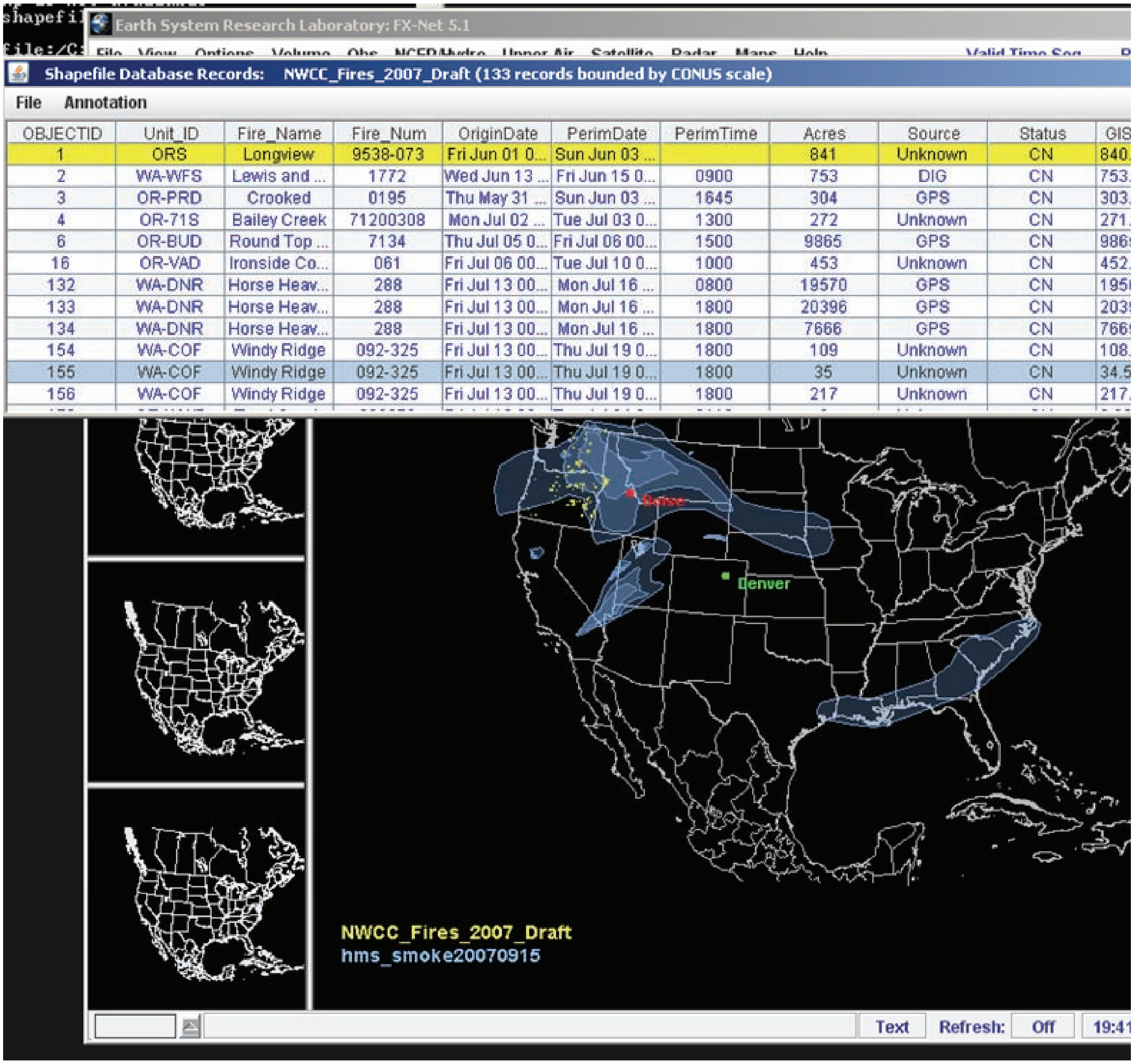


Fig. 3. Shape file display with data records associated with individual shape

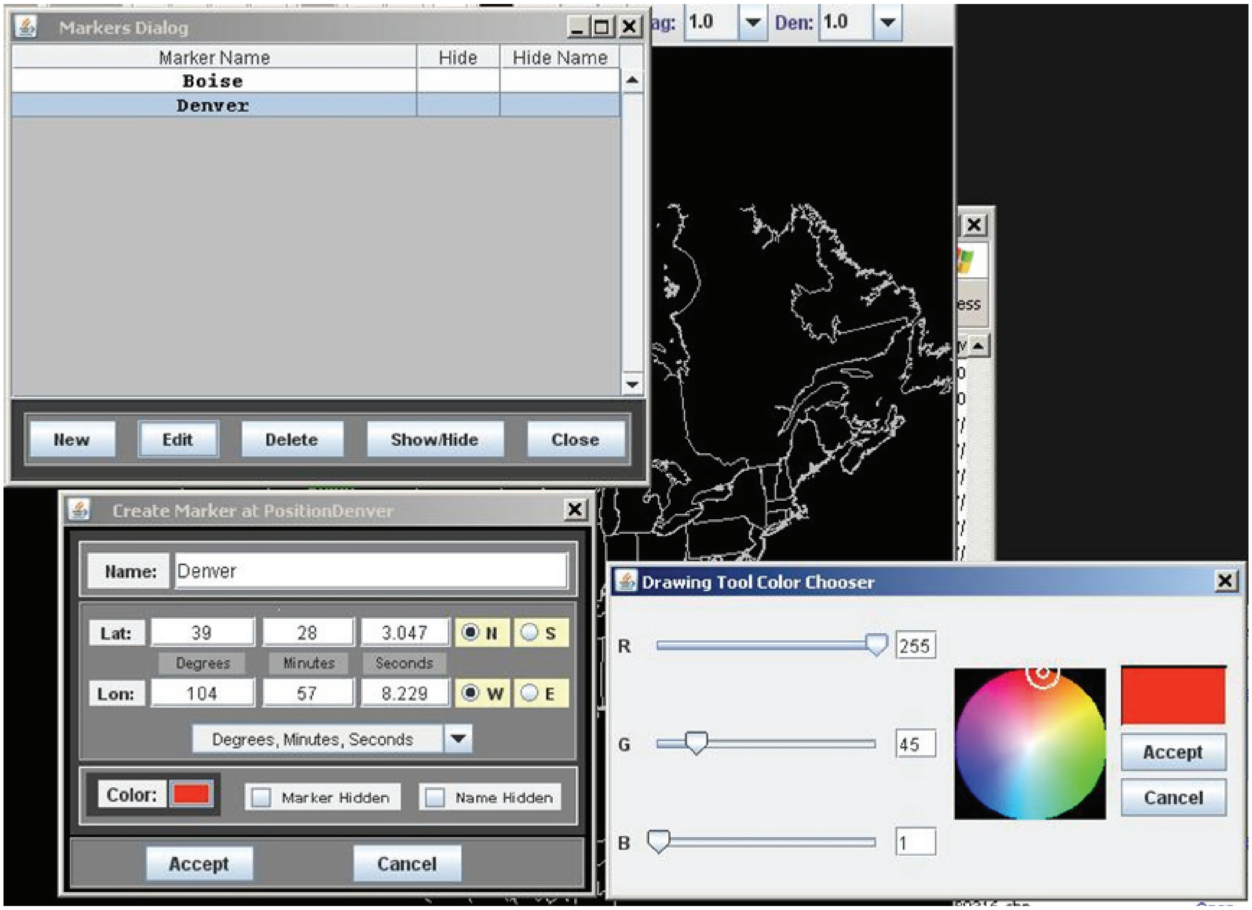


Fig. 4. Dialogue boxes used to create and manage geospatial markers

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 (Benefits to the Public):

The FX-Net system is highly leveraged in terms of program funding and technology. The project is funded by the National Weather Service, the U.S. 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/Collaborators/Technology Transfer:

<u>FX-Net at the National Interagency Fire Center (NIFC)</u>

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 FY07-08, 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 websites 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.

<u>FX-Net and the EPA Air Quality Pilot Project</u>

The EPA did not renew the Pilot Project funding for FY07-08. In order to provide continued service for the state and local air quality forecasters, ESRL transferred a version of the FX-Net technology to a private sector company (ENSCO) who is offering the client and data services for a modest monthly subscription fee.

FX-Net in Atmospheric and Air Quality Research

The FX-Net system continues to be used by Plymouth State University. Other universities using the system in the classroom and the field include the University of Northern Iowa, Florida State University and the University of Northern Florida. In FY05-06, an updated version of the FX-Net client (v. 5.0) was delivered to the university community. The system continues to be used in the classroom.

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.

A brief FX-Net training session was held at Andrews AFB for Air Force One forecasters in May, 2008. Forecasters for Air Force One use FX-Net to view high resolution cross sections along the flight path to forecast turbulence and icing conditions.

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. Awards/Honors:

7. Outreach:

- 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 Adm. Lautenbaucher and other visitors to the exhibits at the Annual AMS Conference and Exhibit in New Orleans, January 2008, to attendees at the Planned and Inadvertent Weather Modification Conference in Westminster, CO, April, 2008 and to the NOAA External Fire Weather Science Advisory Board in Silver Spring, MD, September, 2007.

- FX-Net training was held at the Annual Incident Meteorologist's (IMETS) training meeting in March 2008 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.

8. Publications:

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: PC Workstation, Fire Weather Services Improvement, Incident Meteorologist, All-Hazards system, Air Quality Services, Compression Algorithms

Background on Gridded FX-Net for Fire Weather

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 FY07-08 Gridded FX-Net project goals were to upgrade and build on the Phase III Gridded FX-Net system demonstrating the ability to:

a) Distribute additional observational, gridded and image data to multiple, remote D2D users from one AWIPS server;

b) Improve the gridded data compression to maintain the NWS-approved maximum error while improving compression ratios and memory usage;

c) Add more remote clients and measure data distribution performance; and

d) Improve the robustness of the data distribution system.

2. Research Accomplishments/Highlights:

Server software:

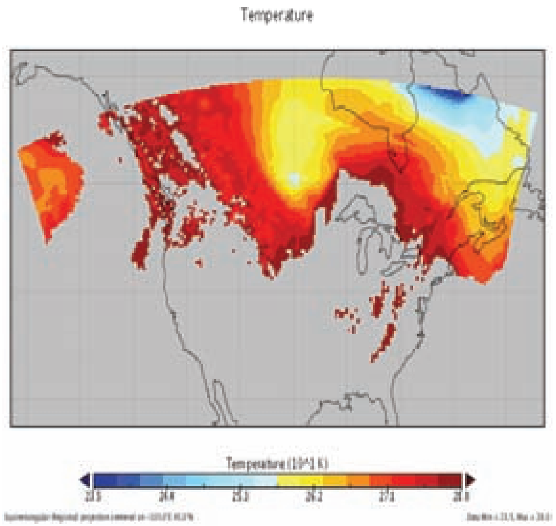
a) Added data ‘Pull’ capability to the Compression Relay Management System (CRMS) to allow users to individually retrieve products and observations that are not automatically distributed via the CRMS LDM data distribution.

b) Upgraded AWIPS software to a hybrid OB6 – OB8 version.

c) Applied all required security and software patches to Linux OS.

Wavelet Compression:

a) A new capability has been added to the grid data codec to compress grid datasets with irregular boundaries, such as Theta fields. The newly designed algorithm and implemented encoding/decoding software provide good compression performance at the expense of minimum extra computation. Fig. 1 shows the original temperature field and the compressed and reconstructed field at a constant theta level, with a 20:1 compression ratio.



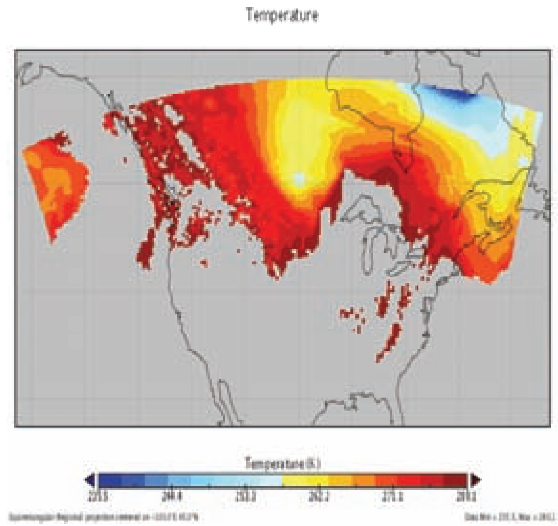


Fig. 1. Original (left) and reconstructed (right) temperature field at a constant theta level with maximum error of < 0.125 deg

b) Additional optimizations of the compression software have been accomplished for the Gridded FX-Net data server. The new implementation reduced memory usage by 56%. Furthermore, a new feature has been added to the compression software to facilitate compression of super high resolution grid data files.

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.

Plans for FY 2008-2009 include:

a) Evaluate new technologies that improve the abilities to distribute large volumes of datasets to multiple remote users.

b) Continue to add Service Oriented Architecture capabilities to the FX-Net Java Client, including extending the expansion of data display type to include XML, Web Mapping and Web Feature Services.

c) Install a preliminary version of the AWIPS II software to familiarize developers with the architecture.

d) Prototype a fire weather services Web Mapping Service to support fire weather modeling activities within NOAA OAR.

e) Design and develop a new all purpose grid data compression package that can compress most currently available grid dataset.

f) Porting and consolidating FX-Net and Gridded FX-Net data compression software into one unified framework.

g) Continue to investigate the viability of a lossless wavelet compression code.

4. Leveraging/Payoff/Benefits to the Public:

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/Collaborators/Technology Transfer:

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 and Honors:

In July 2007, a member of the FX-Net development team won the CIRA Research Initiative award for his work on the Compression and Relay Management System.

7. Outreach/Education:

Numerous demonstrations of this system have been given to public agencies and the private sector.

8: Publications:

Project Title: <u>Science on a Sphere (SOS) Development</u>

Principal Researcher: Michael Biere
CIRA Team Members: Steve Albers

NOAA Project Goal: The Science on a Sphere^{TM} Development project addresses NOAA's cross-cutting priority of promoting environmental literacy.

Key Words: Dataset Display and Animation, Spherical Visualization

The NOAA Science on a Sphere^{TM} (SOS) project displays and animates global datasets 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 datasets.

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

--Display of MPEG-4 encoded files was highly optimized, allowing routine high-resolution 2048x1024 pixel imagery to animate at 30 frames per second.

--The picture-in-a-picture (PIP) capability was enhanced, allowing MPEG-4 display in addition to the previous still imagery.

--A background image underlay capability was developed, allowing flexible and space-efficient display of datasets with transparent background over static global imagery.

--SOS was installed at four new permanent public venues— NOAA's National Severe Storms Laboratory, Norman, OK; Ocean Explorium, New Bedford, MA; Clark Planetarium, Salt Lake City, UT; and Lawrence Hall of Science, Berkeley, CA.

--Model output data from the FIM global meteorological model were rendered for display on SOS. Existing GFS model output was visually enhanced and new and improved planetary datasets were developed.

2. Research Accomplishments/Highlights**:**

Objective: CIRA proposed to continue the development of new capabilities and datasets for the Science On a Sphere (SOS) global visualization system. With 12 installations of SOS currently, support of user sites is expected to take more time than previously, and more sites will come on line this year as well. There are also a number of software enhancements we expect for the system.

Status: As of April 2008, there were a total of 20 sites where SOS is in operational use. The SOS systems have proven to be quite stable thus far, so support of site operations has been relatively easy. Most of our support has been related to data or software enhancement requests by sites.

Display of MPEG-4 encoded files was optimized, resulting in a doubling of our display frame rate. We can now support global high-resolution 2048 by 1024 pixel imagery at 30 frames per second.

A picture-in-a-picture (PIP) capability was enhanced, allowing MPEG-4 display of movies in a window visually over the underlying sphere dataset. Previously, only still imagery could be displayed with the PIP capability.

A background image underlay was added to SOS, allowing a static background for space-efficient display of some datasets, such as seasonal sea ice. In the case of sea ice display, the overlaid data can be efficiently stored as an overlay with transparent background. This also allows more editorial license in choosing the background to display such data over.

The above enhancements were released to the existing SOS installed base as a software upgrade, in addition to being provided to the newly installed sites this year.

Objective: CIRA staff will continue to develop and enhance near real-time global datasets for SOS museum sites. The current global IR satellite composite product will be improved if additional satellite data feeds continue to be acquired at ESRL. Our collection of planetary imagery will continue to be enhanced as higher resolution data becomes available.

Status: FIM and GFS global model forecast displays were updated with additional fields and improved color tables. For example, a display that overlays precipitable water with surface pressure is useful for tracking tropical cyclones. These displays are now utilizing the higher resolution 0.5 degree gridded data. This was the centerpiece of a "high-level" presentation to NOAA administrators. IDL display procedures were generalized to make it easier to switch models and modify color tables & color bars. GLAPS analysis displays were also updated with improved color tables and wind barb depiction.

Efforts were restarted to combine or "unrender" various SOS datasets so they can be used with a more generalized projector configuration.

The dataset for Mercury was updated based on recent data from the MESSENGER spacecraft as well as Earth-based radar information. A new map of Io from the USGS is now available for SOS. We worked to construct updated planetary satellite maps for several of Saturn's moons, including Dione, Tethys, Enceladus, and Iapetus. An improved map of Ariel we've been working on is part of a collaboration mentioned in a poster at a NASA planetary science conference.

Objective: Additional SOS sites are expected to be awarded by the NOAA Environmental Literacy Grant program in FY 2008. CIRA researchers will be providing technical support for SOS installation at any additional new sites that may arise, either within or outside this program.

Status: SOS was installed at four new permanent public venues this year, including the NOAA Environmental Literacy Grant sites and others—NOAA's National Severe Storms Laboratory, Norman, OK; Ocean Explorium, New Bedford, MA; Clark Planetarium, Salt Lake City, UT; and Lawrence Hall of Science, Berkeley, CA.

Objective: CIRA plans to continue support of the SOS museum sites with our on-line Web Forum, and CIRA researchers will participate in the enhancement of the board content and software.

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.

Objective: Possible software upgrades to SOS this year include further additions to the control protocol, improved notification to the user of error conditions, and the addition of multiple interactive layers of annotations and graphics. The retrieval of real-time data from web-based services is also being considered as a possible new area of development.

Status: In addition to the software enhancements already discussed in the first objective above, a sample application for retrieving data from web-based services was developed as a working demonstration of this web-based capability. It was released to sites interested in exploring this capability, but will require some refinement to be truly useful to most of our sites. The sample application is functional, but requires knowledge of the web protocols and data sites to be useful.

The display software of SOS was rearranged somewhat into a more object-oriented display class hierarchy to support general layering capabilities. The background image underlay and PIP overlays (discussed earlier) are the first uses of this new software design.

Additions to the external control protocol of SOS were made to allow external control of the new PIP and background layer capabilities.

VII. <u>Research Collaborations with the GSD Information Systems Branch</u>

Project Title: <u>AWIPS Evolution: Web Services Development</u>

Participating CIRA Researchers: MarySue Schultz, Tom Kent, and 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: Service Oriented Architecture, SOA, Distributed Database, Web Services Development, Visualization, Advanced Meteorological Workstation Development, Hydrometeorological Testbed, HMT

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

The focus of the Web Services Development project is the exploration of new technology that will support a more integrated approach to accessing, viewing and manipulating the wide variety of datasets that are becoming available from organizations around the world. 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, display and manipulation of global datasets.

2. Research Accomplishments/Highlights:

a) Development of prototype software for the distributed retrieval and processing of ensemble model data

b) Development of prototype web service software using OGC standards

c) Development of modules for the Earth Information Services prototype: data retrieval from new sensors, analysis module, work-flow module.

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

Objective: Advanced Linux Prototype System (ALPS)

Developing a new data distribution paradigm: selective pull of data from a remote server instead of non-selective push.

Status: In progress.

Accomplishments: The ALPS project is composed of risk-reduction activities that feed into future development of the Advanced Weather Interactive Processing System (AWIPS). AWIPS is the system used by NWS forecasters for issuing weather forecasts, watches and warnings. NOAA's Hydrometeorological Testbed (HMT) project used ALPS in their 2008 field demonstration (HMT West 2008). The HMT project is experimenting with ways of moving new technology, models and scientific findings from the research environment to operations. HMT West 2008 was one of several experiments that took place in the American River Basin in California. The emphasis was on multi-sensor estimations of precipitation and on ensemble forecasting of precipitation elements. Forecasters were provided with data from a number of experimental instruments for the multi-sensor exercise and with output from multiple runs of the Weather Research and Forecasting (WRF) model, each using a different microphysics package for the ensemble forecasting exercise. The WRF output was stored on a GSD test system in Colorado and was remotely accessed by the HMT test sites. CIRA software engineers developed an experimental web-based data access capability on ALPS that enabled the test sites to download only the hydrological parameters from each WRF dataset instead of downloading the entire model run. The speed of the downloads was a concern since the volume of data was large enough to overload the networks and data servers at the test sites. Using the new data access capability, the workstations were able to display approximately one frame per second, which was acceptable and allowed the ensemble forecasting exercise to be successful.

CIRA staff were also involved in the evaluation of the data usage patterns during the HMT exercise. The NWS will use the evaluation results to make decisions regarding whether the data from the experimental instruments are useful in predicting hydrological events.

Objective: NOAA-wide Information System

Exploring new technologies to address the need for a more integrated method of accessing, displaying and manipulating the growing number of environmental datasets available from scientific organizations around the world.

Status: In progress.

Accomplishments:

CIRA and the Information Systems Branch are investigating Service Oriented Architecture (SOA) concepts. CIRA software engineers are involved in two related efforts in this area:

a) OGC Web Services Testbed. The Open Geospatial Consortium (OGC) is currently in the process of defining standards for web access to geospatial data. The idea is to make it easy for users to locate and download data from any OGC-compliant website. The goal of the Web Services Testbed project was to develop expertise in OGC standards within CIRA and GSD by implementing an experimental OGC-compliant web service. CIRA software engineers and other project team members investigated OGC standards, designed and implemented a prototype web service that provided access to GSD data, and presented the results of the exercise to ESRL staff through demonstrations and a seminar. Results: Because the experimental service adhered to OGC standards, a number of existing systems were able to use the service easily: Science on a Sphere, FX-net and FX-Connect (systems that have been developed within GSD), Google Earth, and any web browser. Also, once the service for accessing GSD data was developed, data from any OGC server around the world became available to the client systems with no extra work. Although complying with OGC standards had benefits, the team recommended that other standards such as the Joint METOC Broker Language (JMBL) be investigated in the future. This project has been completed. There may be some follow-on work, but this hasn't been defined.

b) EIS/ISET. CIRA is collaborating with ISB on the Earth Information Services (EIS) project. The project goal is to investigate the web technologies needed to build a framework into which users can plug in a variety of web services to access, display and manipulate data and to produce predictions and probabilistic forecasts. To further this research, during 2006-2007, the EIS team established a collaboration with the University of Alaska through the Interdisciplinary Scientific and Environmental Technologies (ISET) program. ISET is a cooperative research program between ESRL and eight universities, with the goal of introducing underrepresented students to NOAA research. During 2007-2008, two additional universities joined the EIS effort: North Carolina Agricultural and Technical State University (NCAT), and the University of Minnesota (U of M). In cooperation with CIRA and ISB software engineers, students from these schools are developing experimental web services that can be plugged into the framework: 1) a work-flow service, which provides users with a tool for combining services to produce customized research systems; 2) a data retrieval service to access NCAT sensor data; and 3) an analysis service that creates a time series of temperature data. The next step will be to integrate the data retrieval and analysis services with the work-flow technology to create an end-to-end system. This work will validate the EIS concept, as well as produce useful web services.

4. Leveraging/Payoff:

CIRA's research in the areas of web service development, distributed databases, and OGC standards has benefits in many areas. If web technologies can be integrated with the AWIPS systems at the weather forecast offices, NWS weather forecasters will be able to collaborate more easily with NOAA research organizations, resulting in better forecast services for the public. Improved web services will also provide the public with easier access to NWS forecasts and information, and will enable forecasters to have a more interactive relationship with the public. Web services will benefit NOAA researchers, allowing them to more easily share both data and analysis tools. The current research promotes web services expertise within CIRA and ISB. This knowledge will be used in determining the role of web services in future AWIPS development, and will support a more global approach to research and forecasting.

Distributed database technology will enable both NWS forecast offices and NOAA research organizations to access the wide variety and large volumes of data needed for global forecasting and research, since local storage of data will not be necessary. If standards are adopted and adhered to, it will be easier to access data from all over the world, and to provide data to others as well. Distributed data sharing will have the added benefit of reducing the load on data delivery networks and servers.

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

CIRA software engineers collaborated with ISB, the National Weather Service, GSD's Forecast Applications Branch, and the Physical Sciences Division of ESRL to achieve the goals of HMT West 2008. CIRA, ISB, the Forecast Applications Branch, ESRL's Information and Technology Services group, and GSD's Aviation Branch cooperated on the OGC Web Services Testbed. CIRA, ISB, UAS, NCAT and the U of M are cooperating on the Earth Information Services project.

6. Awards/Honors:

7. Outreach:

Hosted students from NCAT and UAS for several days.

8. Publications:

Yaohang L., A. Esterline, C. Baber, K. Fuller, M. Burns, V. Freeh, T. Hansen, T. LeFebvre, M. Schultz, M. Govett, P. Hamer, and A. Mysore, 2008: A sensor information framework for integrating and orchestrating distributed sensor services. *6th Annual NOAA-CREST Symposium*, Mayaguez, Puerto Rico, Feb 20-22, 2008.

Project Title: AWIPS and AWIPS II

Principal Researcher: Joanne Edwards
CIRA Team Members: Leigh Cheatwood-Harris, MarySue Schultz, 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

Keywords: 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, etc. 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 5, 6 and 8
b) Completed collection of baseline metrics for AWIPS II
c) Began training on SOA technology
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 provide metrics for the new AWIPS which will serve as a benchmark for evaluating the performance of AWIPS II.

Status: The first part of the objective is in progress. The second part of the objective has been completed.

Accomplishments: 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 2007, we completed the Independent Validation and Verification of Task Orders 5 and 6, and began writing test plans for TO8. 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 metrics on the current AWIPS that will be used for evaluating the performance of the new AWIPS. CIRA researchers completed the development of baseline metrics for AWIPS II and provided them to the NWS. This effort focused on performance, since AWIPS II must perform at either the same level of AWIPS I or better.

Objective: Begin developing an in-depth knowledge of AWIPS II for future enhancements to AWIPS II.

Status: This objective is in progress.

Accomplishments: CIRA researchers began training on the SOA infrastructure and the AWIPS II ADE in particular. The training consists of on-line courses, books, and tutorials. This task was begun late in 2007 and will be completed December 31, 2008. In-house training in Java was completed in May, 2007. This training has been of great benefit since most of the AWIPS II code has been written in Java.

Objective: Continue support of AWIPS I development to support on-going weather forecast field operations.

Status: This objective is in progress.

Accomplishments: CIRA researchers completed the ingest and display of two highly anticipated radar products: the Super-res products, which are ¼ km resolution and ½ deg in azimuth, and the Dual Polarization products. With dual polarization, the antenna sends both horizontal and the vertical pulses, enabling detection of the shapes of objects, and reducing the effects of ground clutter effect.

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.

With the transfer of AWIPS functionality to Raytheon as part of the maintenance contract, GSD and CIRA researchers can focus on researching new capabilities for AWIPS, respond faster to new AWIPS requirements, and begin research into converting current AWIPS applications to the new AWIPS II architecture. By shifting our focus back to research and development, and risk reduction activities, we can better serve society's needs for enhanced weather forecasting, both nationally and internationally.

The new dual polarization data has the potential for improvements in the following areas:

a) Improved estimation of rain and snow rates.
b) Discrimination of hail from rain and possibly gauging hail size
c) Identification of precipitation type in winter storms
d) Identification of electrically active storms
e) Identification of aircraft icing

In addition to the above benefits, dual polarization data will help forecasters detect non-meteorological objects such as birds.

5. Research Linkages/Partnerships/Collaborators:

CIRA, ISB, NWS and Raytheon collaborated on the research required for the evaluation of AWIPS II.

6. Awards/Honors:

7. Outreach:

8. Publications:

VIII. Research Collaborations with the GSD Information Systems Branch (ISB) / Information Presentation Section

Project Title: AWIPS I and II Display Development and Support

Principal Researchers: Jim Ramer, Jim Fluke, and U. Herb Grote

NOAA Project Goal/Program: Weather and Water--Serve society's needs for weather and water information / Local forecasts and warning.

Keywords: AWIPS, ALPS, Meteorological Data Visualization

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

The research objective is the continued collaboration to investigate, design, develop and test advanced meteorological workstation display software. The emphasis within ISB/IPS is on the exploratory development of new user interface and data rendering aspects of meteorological workstations.

The D2D display software and associated data storage software is the central visualization component of the NWS AWIPS system. CIRA, in collaboration with ISB, will continue to augment this software base with novel data sources and visualization approaches. Furthermore, since the NWS is developing a new SOA (Service Oriented Architecture) based AWIPS II that will replace the current AWIPS system, CIRA will be working to familiarize itself with the new architecture and provide enhancements to this new system.

2. Research Accomplishments/Highlights:

The ability to view dual polarized radar data on the workstation is a powerful new capability. Dual polarized radar data provides significant additional information for estimating the amount of precipitation present in a radar echo. It provides information on the aspect ratio of the moisture droplets and therefore can identify the presence of hail in an echo, and also discern ground clutter from real meteorological data. A number of changes were made to the AWIPS workstation in anticipation of forecast offices having access to this data. The basic radar tilts can be viewed from the radar menu and CAPPIs (Constant Altitude PPI) and cross-sections have been added to the volume browser menu. In addition to constant altitude displays, forecaster can also view the data on isosurfaces such as temperature and pressure.

The ALPS (Advanced Linux Prototype System) provides an ideal platform for prototyping new capabilities. Many new features have been demonstrated and tested using the ALPS system. Among these is the ability to create graphics in KMZ format and display them on GoogleEarth (TM). Also, the FIM (Finite-volume Icosahedral Model) was integrated and displayed for the entire globe on the ALPS “movable” scale (see Fig. 1). This same data can be exported and displayed on SOS (Science on a Sphere).

A “gridded data server” was implemented to improve the speed with which an ALPS workstation user can view remotely located forecast model grids. This made it possible for selected west coast offices participating in the HMT (Hydrometeorological Testbed) to access very high resolution model data generated at GSD in Boulder in real-time.

CIRA continues to perform software CM (configuration management) for local developers working on AWIPS I. The CM support includes: keeping the local GSD AWIPS I baselines synchronized with the official baseline maintained by Raytheon; creating new local baselines when needed for AWIPS I and ALPS; and keeping these baselines up to date by merging appropriate AWIPS I changes into them. This year, support activities were expanded to include installation of new AWIPS II software with each TO (Task Order) deliverable, assisting other users in installing the software, exploring AWIPS II code, and learning to extend the system through “plugins.”

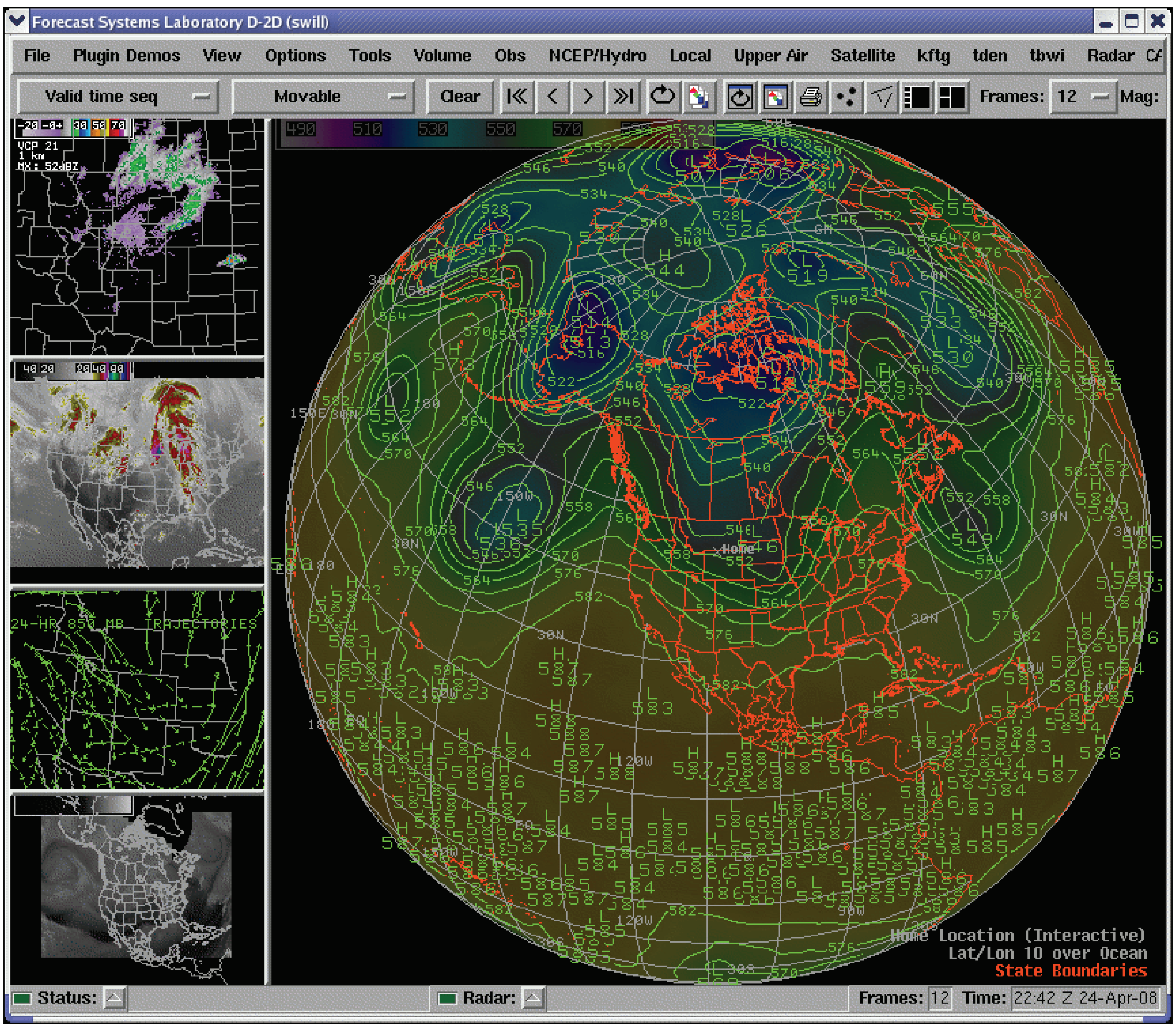


Fig 1. The movable scale on ALPS workstation displaying the FIM

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

The team successfully supported the ALPS HMT development and deployment of the workstation to several NWS offices. CIRA provided support for AWIPS I Operational Builds (OB) with features such as the dual polarization data display.

4. Leveraging/Payoff:

The Central Weather Bureau in Taiwan is interested in making the ALPS system its new operational forecast system. The HMT experiment promises to help improve hydrometeorological forecasts.

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

CIRA staff presented a paper at the 2007 Annual Meeting of the American Meteorological Society on the strengths and weaknesses of various graphic meta file formats for graphical data representation.

8. Publications:

Project Title: <u>Collaborative Forecast Workstation Development</u>

Principal Researcher: U. Herb Grote

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

Key Words: Forecaster Collaboration, Graphical Product Generation, FXC

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

The objective is to develop an interactive display system that allows forecasters/users at different locations to collaborate in real-time on a forecast for a particular weather or weather-dependent event.

In order for several forecasters 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 datasets 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 particulates such as volcanic ash, smoke, or toxic chemicals, and provide an alert capability using "reverse 911" vendors.

FXC is currently being enhanced and evaluated by several outside projects and organizations. The most significant are the following:

Geo-targeted Alerting System (GTAS)

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

The objective of the GTAS project is to develop a prototype public notification system to be used by NOAA and the DHS operations centers in the event of a biological, chemical or radiological release in the National Capital Region.

The key system components of the GTAS system are FXC (FX-Collaborate) and the HySPLIT dispersion model developed by ARL. Users execute the HySPLIT model from FXC and then collaborate to create the alert message to be sent to selected commercial vendors who then notify the public.

2. Research Accomplishments/Highlights:

Much of this year's work consisted of coordinating with NOAA HQ and DHS staff on defining the future expansion of GTAS. Several demonstrations of the system were given to DHS staff in Washington and to other visitors in Boulder. CIRA started coordination with Lawrence Livermore National Laboratory, developers of the NRAC dispersion model, to define the interface between GTAS and NRAC. NRAC is currently being used by DHS and several other government agencies.

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

The basic objective of GTAS continues to be met. However, the emphasis this year changed from building and installing prototype systems to developing a deployment strategy.

4. Leveraging/Payoff:

GTAS development leverages the development done by GSD on FXC and AWIPS, and by ARL on the dispersion model. Features developed specifically for GTAS are found to be useful to other projects using FXC as their base platform.

5. Research Linkages/Partnerships/Collaborators:

The GTAS work is done in collaboration with NOAA/ARL, the developers of the HySPLIT model. ARL personnel are working with CIRA and GSD staff to assure that the model will work appropriately in the GTAS environment.

6. Awards/Honors:

7. Outreach:

The NOAA GTAS project leader presented a paper on GTAS at the 2007 Annual Meeting of the American Meteorological Society.

8. Publications:

Graphical Forecast Preparation

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

Government agencies at various levels need to be able to communicate important weather information to the public in many different ways. FXC 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.crh.noaa.gov/lbf/?n=crwebgraphics). These graphical products are posted to the web for public use, included in presentations, and used in briefings to various end users. The objective 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**:**

CIRA, with support from a NOAA contractor, added further enhancements to the software to improve the ability to read and display geographical information. FXC users require easy access to and flexibility in viewing various GIS information. In addition to shapefiles, FXC users can now also display high resolution mapped (i.e. geo-referenced) images that have been exported from ArcMap (TM) (see Fig. 2). To assist users in installing and customizing FXC to their needs, the FXC installation and management script was also enhanced to provide greater support for importing maps and color tables. Coordination continues with CWB (Central Weather Bureau) in Taiwan to assist them in making FXC their primary system for preparing graphical forecast products.

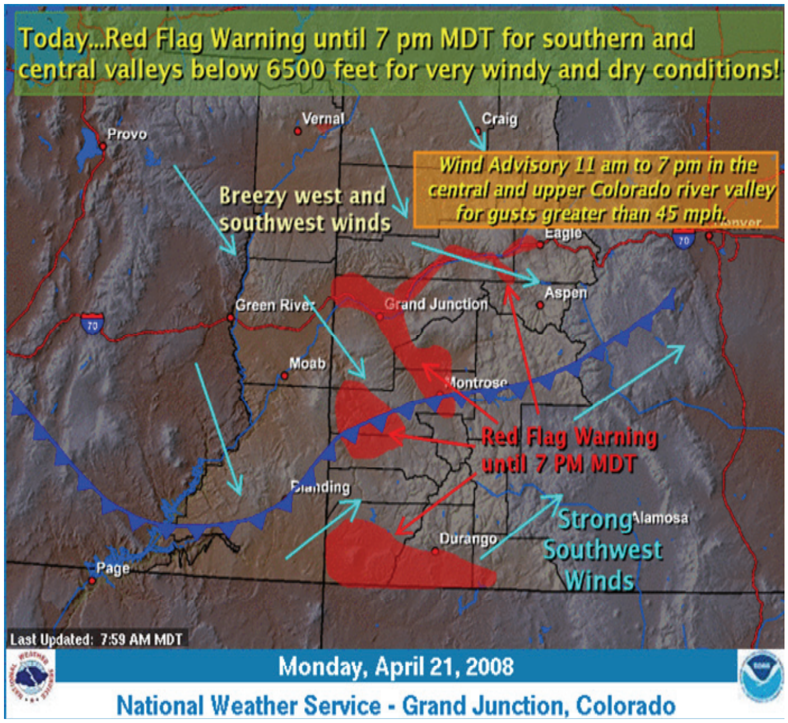


Fig. 2 Graphical Forecast for the Web created with FXC

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

CIRA released FXC Version 4.4.2 to NWS forecasters, which provides additional features for preparing graphical products for the Web. The same software was also released to CWB staff for tailoring to their special needs.

4. Leveraging/Payoff:

FXC leverages the development done for AWIPS I and uses other software developed in the public domain. FXC uses GeoTools to read ESRI shapefiles and other Java software packages to support features such as animated GIFs. Several projects within GSD are tailoring FXC for their particular customer's needs.

5. Research Linkages:

The FXC staff coordinates primarily with other branches within GSD. Current activities include investigation of JavaScript and AJAX as possible technologies to replace the current 100% Java based system.

6. Awards/Honors:

7. Outreach:

FXC provides a website (http://fxc.noaa.gov) 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:

EVALUATION OF GOES-13 IMAGER AND SOUNDER DURING NOAA'S SCIENCE TEST: COLLECTION AND ANALYSIS OF DATA

Principal Investigators: Bernie Connell, in partnership with Donald Hillger and Mark DeMaria

NOAA Project Goal: Weather and Water

Key Words: GOES, Post Launch Testing, Science Test, Calibration/Validation

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

In this CIRA project research methods are applied to the analysis of the quality of GOES-N/O/P series Imager and Sounder data as secured during the NOAA Science Tests. During GOES Pre-operational Science Tests, the instruments are run in both special and operational schedules to provide radiance measurements to be validated as well as to generate image products from the radiances. In particular, the Science Test for GOES-13 lasted 3 weeks, following other Post Launch Tests (PLT) during which most of the engineering and control of GOES were being tested and evaluated, followed by the transition of GOES-13 into storage. GOES-13 Science Test data have been collected, analyzed, and reported with few exceptions. This leaves the preparations for the next Science Test that for GOES-O as the main focus of current work.

2. Research Accomplishments/Highlights:

GOES-N/O/P data are unique. Although the last three of the current Geostationary Operational Environmental Satellites (GOES) to be launched have instruments similar to the previous GOES-8/12 instruments, they are on a different spacecraft bus. The new bus allows improvements both to image navigation and registration as well as image quality. For example, by supplying data through the eclipse, the GOES-N/O/P system addresses one of the major current Imager limitations which are eclipse and related outages. Outages due to Keep Out Zones (KOZ) are greatly minimized. In addition, there have been radiometric improvements. Science Test analysis indicates that the GOES-13 instruments (Imager and Sounder) have proven to be less noisy than previous GOES. On the other hand, the potential reduction in striping to be achieved through increasing the Imager scan-mirror dwell time on the blackbody from 0.2 sec to 2 sec has not been realized. Finally, there have been improvements in both the navigation and registration of GOES-13 imagery. Frame-to-frame registration of the imagery appears to be improved as well. All these enhancements were monitored during the NOAA Post-launch Science Test by the use of special data collection schedules.

There are several main goals for the GOES-N/O/P Science Tests. First, the quality of the raw GOES data are to be investigated. This is accomplished by comparison to other satellite measurements or by calculating the signal-to-noise ratio compared to specifications. The second goal is to generate products from the GOES-N/O/P data stream and compare to those produced from other satellites. These may include several Imager and Sounder products currently used in operations. In addition, rapid-scan imagery of both severe and winter weather cases were collected at temporal resolutions as little as every 30 seconds. Details of the GOES-13 Science Test and results of analyses are available on the GOES-13 Science Test webpage at http://rammb.cira.colostate.edu/projects/goes_n/.

The analyses results are available on the webpage noted above and were also compiled in a *NOAA Technical Report*, which was distributed within NOAA and made available to anyone on CD at their request. The report is a reference for future users of GOES-13 information that may be useful when questions arise as to the quality of the data and products that will become operational when GOES-13 is again brought out of storage.

This project is in coordination with GOES-13 work proposed as part of the CIRA GIMPAP project. In that project the emphasis is on mesoscale product development and enhancement with the new GOES-13 capabilities. In this project, the emphasis is on data collection, calibration, validation, documentation, and dissemination that is of interest to the wider GOES-13 user community.

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

We have met our objectives for this reporting period. The primary goal in this fiscal year was to turn over experimental algorithms to operational forecast centers and to consult on their implementation.

4. Leveraging/Payoff:

These post-launch check-out periods are essential to the subsequent operational use of the satellite assets.

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

A number of groups within NOAA/NESDIS and its Cooperative Institutes take part in the Science Test,

6. Awards/Honors: None as yet

7. Outreach: See section 8

8. Publications:

Refereed Journal Articles

Hillger, D.W., and T.J. Schmit, 2008: The GOES-13 Science Test: A Synopsis. *Bull. Amer. Meteor. Soc.,* accepted for publication.

Conference Proceedings

Hillger, D.W., and T.J. Schmit, 2007: An overview of the GOES-13 Science Test, *Third Symposium on Future National Operational Environmental Satellites,* AMS, 14-18 January, San Antonio TX, 17-p.

Other articles

Hillger, D.W., and T.J. Schmit, 2007: The GOES-13 Science Test, *NOAA Tech. Rep., NESDIS 125*, (September), 88 p.

Hillger, D., 2007: GOES-13 Science Test, *CIRA Newsletter*, 27, Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins CO, (Spring), 23-25.

EXPANSION OF CIRA RESEARCH COLLABORATION WITH THE NWS METEOROLOGICAL DEVELOPMENT LAB

Principal Investigator: Scott O'Donnell

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

Key Words: NWS, MDL, NCAR, AWIPS, AutoNowcaster, FFMP, GIS

Work was primarily on two research projects during the past year. The project requiring the greatest amount of time was the prototype of NCAR's AutoNowcaster (AN) Convective Weather Forecasting tool to AWIPS' NWS short-term weather forecaster workstation. On this project, I completed the 'end-to-end' testing and implementation, with the installation at the Fort Worth/Dallas WFO.

The second project was working on database access improvements to the datasets embedded in GIS shapefiles for MDL's Flash Flood Monitoring Program (FFMP).

A third project, the Southern California Debris Flow Project, is worked on as time allows.

The 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 installed and has tested an AutoNowcast display system (CIDD) at the Fort Worth-Dallas WFO. The NCAR CIDD is installed 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 datasets 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

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.

The display of decoded and stored data is provided on the AWIPS workstation (Data Display). Many of the forecaster interactions were delivered in previous releases. This year, NCAR has elected to integrate the AWIPS available for well over a year allowing a complete 'end-to-end' implementation and test.

This year's accomplishments have greatly improved each of the following areas:

Data Management

During this year, the AWIPS AutoNowcast system adopted the role of 'data manager' from NCAR. This requires AWIPS to keep an accounting of all 'active' boundaries and polygons within the system as well as sending forecaster selected weather regimes (synoptic 'forcing' scenarios, such as a dry line, or a cold front, etc.), which are menu-driven to direct the AutoNowcast modeling.

In our initial designed implementation, data were exchanged in generally an asynchronous manner. Data sent or received were done without any attempt at handshaking or acknowledgement. NCAR determined that the updates they received needed to be provided at a known frequency specified by their receipt of radar data. To meet this additional requirement, NCAR now makes data 'requests'. The 'requested' products are acknowledged by the return of the requested data, as in a typical Client-Server relationship.

Data Interactions

Few new user interactions are provided.

In the previous release, the Boundary Editor functions were enhanced to allow the AWIPS forecaster to specify a motion vector to a previously defined stationary, initiation boundary.   Additionally, boundary motion adjustments are made to a selected boundary by dragging the boundary to its preferred location or to speed-up or slow a moving boundary by a percentage of its velocity vector. If the boundary's shape needs to be modified, each vertex can be dragged to a new location and/or additional vertexes are added (or removed) where necessary. Fig. 1 shows a forecaster entered initiation boundary anticipating a line of the highest potential for convection initiation in the initiation field.

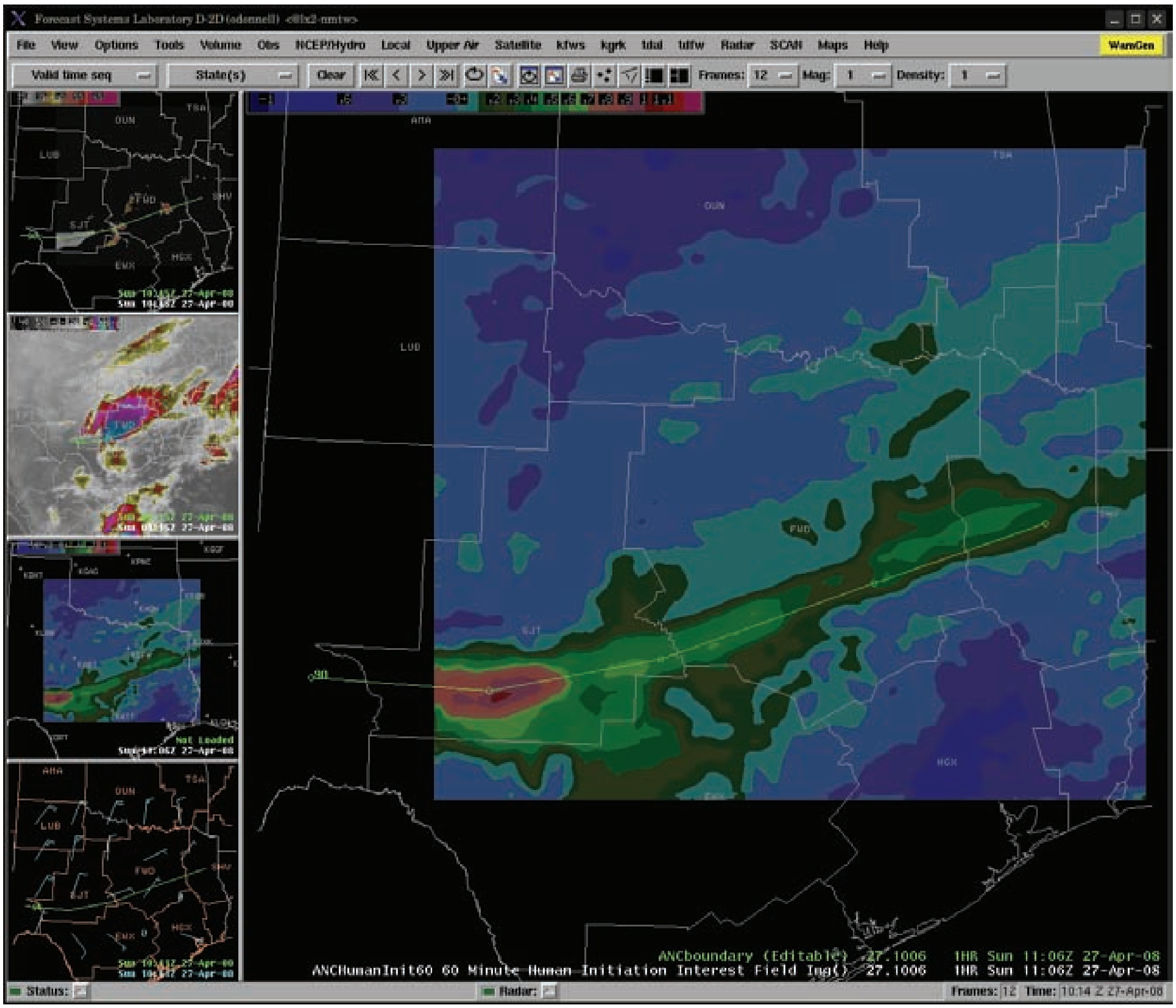


Fig. 1. Example of Initiation Boundary overlaid on the Convection Initiation field. Good correlation exists between Initiation Boundary and the predictor field.

Also last year, a Polygon Editor was added to the suite of AWIPS AutoNowcast interactive tools. This tool allows the forecaster to enhance or reduce the weight of the predictor fields. See Fig. 2 for an example of the effect of this operation on the initiation predictor field. Late in the most recent development cycle, NCAR provided the algorithms they used to apply a forecaster's area weighting adjustments to the convective initiation predictor field. Assumptions made in the prior implementation were rewritten to correct the application.

Polygon Convection Initiation Enhancement

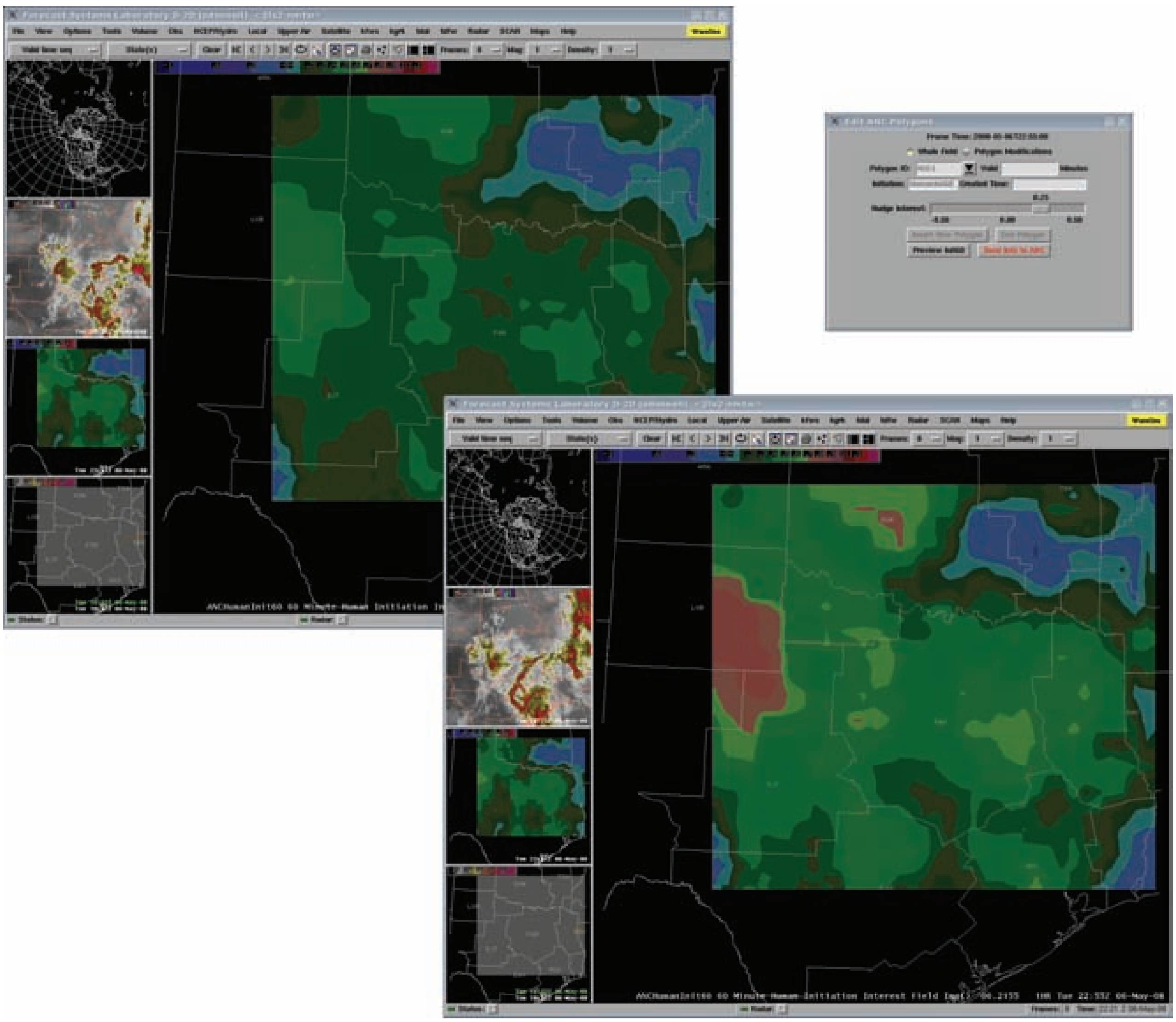


Fig. 2. Example of Polygon Convection Initiation Enhancement. The right foreground image shows the Convection Initiation field after a 25% enhancement of the left background image.

Data Display

As forecasters change the weight of the initiation predictor field, local data products are provided within seconds, rather than requiring the forecaster to wait minutes for these products to be processed and returned from NCAR.

Data Dissemination

All data returned to NCAR from AWIPS is now formatted in XML. XML is a platform-independent ASCII format in which the data are 'tagged' in a specific manner making the parsing task much simpler than using unlabeled data fields. XML also removes the sometimes difficult problems caused by minor formatting errors between the client and its server.

The problematic network security problems overcome last year between NCAR and AWIPS returned after yet another modification by Southern Region NWS Headquarters. Fortunately, unlike previous years, this was eventually corrected within the SR network without requiring modification of the data exchange software.

Operational Testing

Prior to release, some testing was conducted by MDL development staff and interested volunteers. Adjustments were made based on the findings of the tests.

An operationally ready software distribution was delivered to FWD WFO in April 2008 for installation, forecaster training, and operational use during the remaining 2008 severe weather season. Preliminary results are very positive and we await a thorough evaluation of this NWS operational test.

NCAR AutoNowcaster software installed at MDL

In an effort to optimize the NCAR AutoNowcaster product generation for AWIPS, the AutoNowcaster software has been installed at MDL on hardware dedicated to this purpose. In the initial installation, a full NCAR emulation including ingesting NWS data from external sources is complete to evaluate the entire system. As we learn more about the system, perhaps 'natuve' NWS data sources can replace the external sources.

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

All planned objectives of this project for this year were met when the software was installed operationally and NCAR reconfigured their operational software to use the AWIPS forecaster input data (boundaries, polygons, regime changes).

The significance of this achievement goes beyond providing improved severe weather situational awareness, in that, NCAR provides the FAA Central Weather Service Unit (CWSU) at Fort Worth (ZFW) with operational products to assist in regional air traffic control.

These data are now being served using input data provided by NWS forecasters using AWIPS!

Potential areas for additional research:

The next stages of development focus less on forecaster operational needs and more on the migration of NCAR AutoNowcast modeling to the NWS and the expansion of the forecast domain to regional scales. This work will address the issues involved in scaling a local-scale, short-term model to a regional scale model.

The FAA needs a larger domain to allow the forecasters to 'see' farther upstream. This requires doubling the number of radars included in the AutoNowcaster domain. Also, a larger RUC model area, satellite imagery areas, and more mesonet and surface observations will need to be processed to generate the grids for the larger domain. Available processing power is a significant constraint, as well as timely delivery of the additional datasets. Evaluation of needs and levels of effort will be addressed with this activity.

The larger domain leads to consideration of even longer-term goals allowing multiple forecasters from different WFOs to begin to introduce their individual boundaries and polygon areas. The issues of 'conflict' resolution arise in those areas where jurisdictions overlap.

Ultimately, the entire CONUS will be served by several regional AutoNowcast servers. Input resolution will need to be applied to those areas of adjacent regions and possibly multiple user inputs.

Also, study needs to be applied to determine the level of effort required to migrate AutoNowcaster systems to areas where that have significantly different weather forcing systems. The AutoNowcaster has been successfully applied to several areas in the West and Midwest. The topics that need to be studied include what’s required to successfully move the AutoNowcaster to other areas with very different weather regimes such as sub-tropical Florida or the maritime Northeast coast.

FFMP GIS Database Access Improvements

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

Although WFO Service Hydrologists have few rainfall-runoff tools available to them, they are responsible for reliably issuing flash flood forecasts in their forecast area. FFMP attempts to alert forecasters to those areas that have a high flash flood potential.

To do this, the CONUS has been discretized into 2-10 km^2 watersheds, provided to the WFO as sets of ESRI formatted 'Shapefiles'. This GIS dataset 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 point, etc. The 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.

FFMP runs in the background, monitoring in real-time many input datasets. For each 2-10 km^2 watershed in the FFMP domain, it monitors precipitation accumulation from each input data type, such as radar estimates or QPF (forecast rainfall) at several durations, while comparing each to the available excess rainfall guidance values. When a watershed's rainfall accumulation reaches a predefined threshold (forecasters define them for all watersheds) 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. Fig. 3 provides a graphical example of the watersheds FFMP monitors in which the instantaneous rain rate is greater than 0.1 in./hr.

FFMP Instantaneous Rainfall Rate

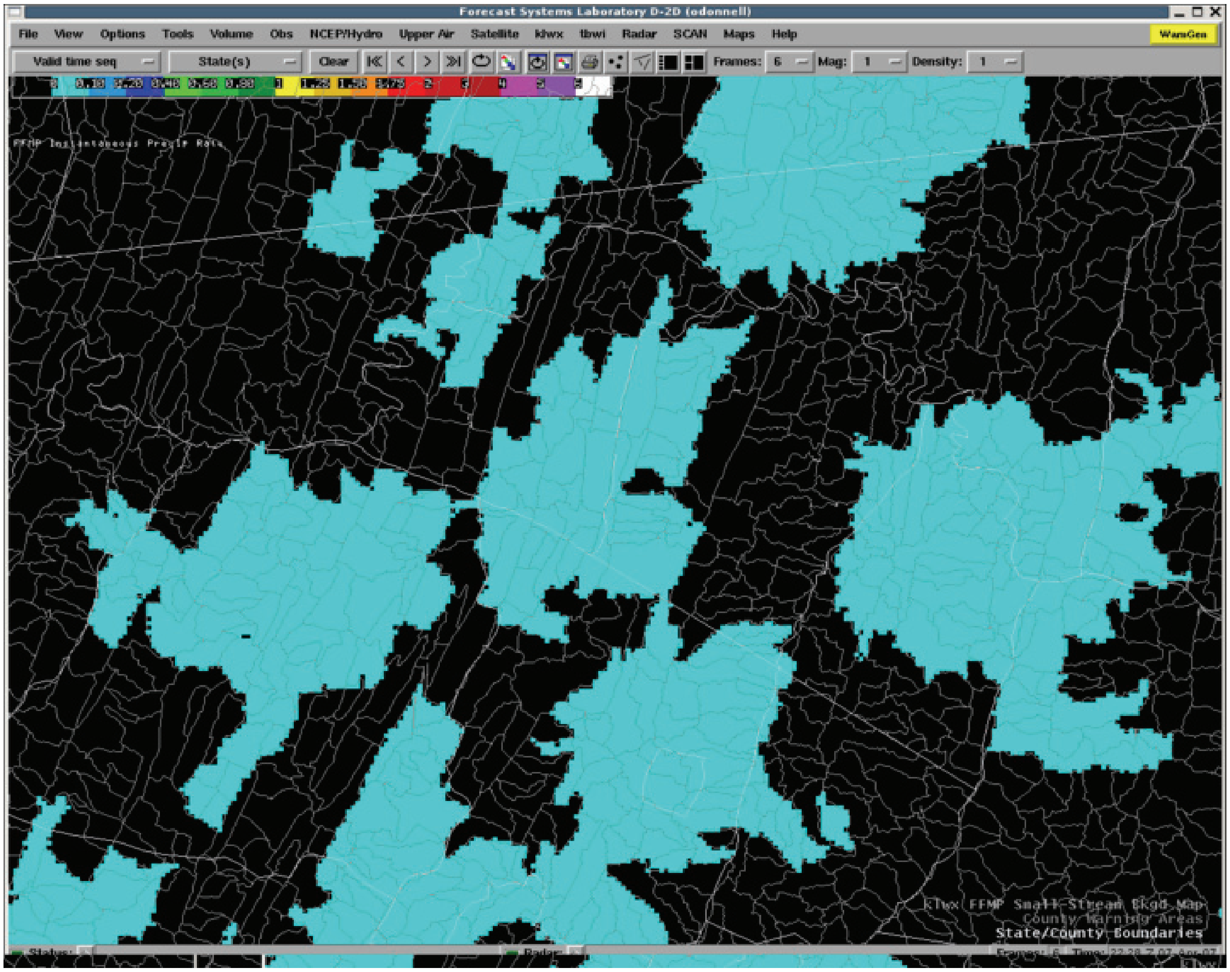


Fig. 3. Example of Instantaneous Rainfall Rate in FFMP. The light blue areas indicate instantaneous rainfall rates in individual watersheds of less than 0.1 in./hr. The dark areas indicate no rainfall.

In the past year, FFMP has undergone a major revision in the way it accesses and presents data to the forecaster. This more general approach is designed to improve FFMP's ability to use new datasets, such as, QPF, QPE, or MPE precipitation forecasts or estimates. Also, precipitation guidance data may come from additional sources rather than exclusively from a River Forecast Center (RFC). Debris Flow Guidance from the USGS Geological Hazards Team is an example of a new type of flash flood guidance.

2. Research Accomplishments/Highlights:

The much larger forecast area required a significantly larger GIS area to be used for FFMP's initialization. This, in turn, required the database retrieval methods to be improved. Previously, the relatively small GIS datasets performed acceptably using a sequential search method. This fit in well with the data organization and structures built into the database, “dbf”, files.

The larger domains required these methods to be converted to random access retrievals to improve the retrieval time. Because the “dbf” files do not implicitly support random access, entirely new access and retrieval methods were required, designed, and implemented. All the database retrieval methods were converted to use the new methods and organizational tables which allow random access to the sequential data. These new methods allow larger data retrievals to be performed in less time than the previous methods retrieving smaller datasets.

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.

Debris Flow Support in FFMP

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

The USGS has a mandate to issue for Debris Flow watches and warnings but no infrastructure to provide this service. This requirement became acute after the devastating wind-swept fires in populous Southern California.

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 to cooperate to provide Debris Flow watches and warnings using a prototype application based on the well-established FFMP application. Because FFMP monitors precipitation and because excess rainfall is the cause of Debris Flows, FFMP is well suited to provide a Decision Support System for Debris Flow watches and warnings in Southern California.

The USGS has provided the NWS with background GIS maps and also provides Debris Flow precipitation guidance values as conditions change. Fig. 1 shows several Debris Flow monitoring areas (green map polygons) with their contained watersheds (light gray) which are continuously monitored for potential Debris Flows.

Prototype Debris Flow Basins

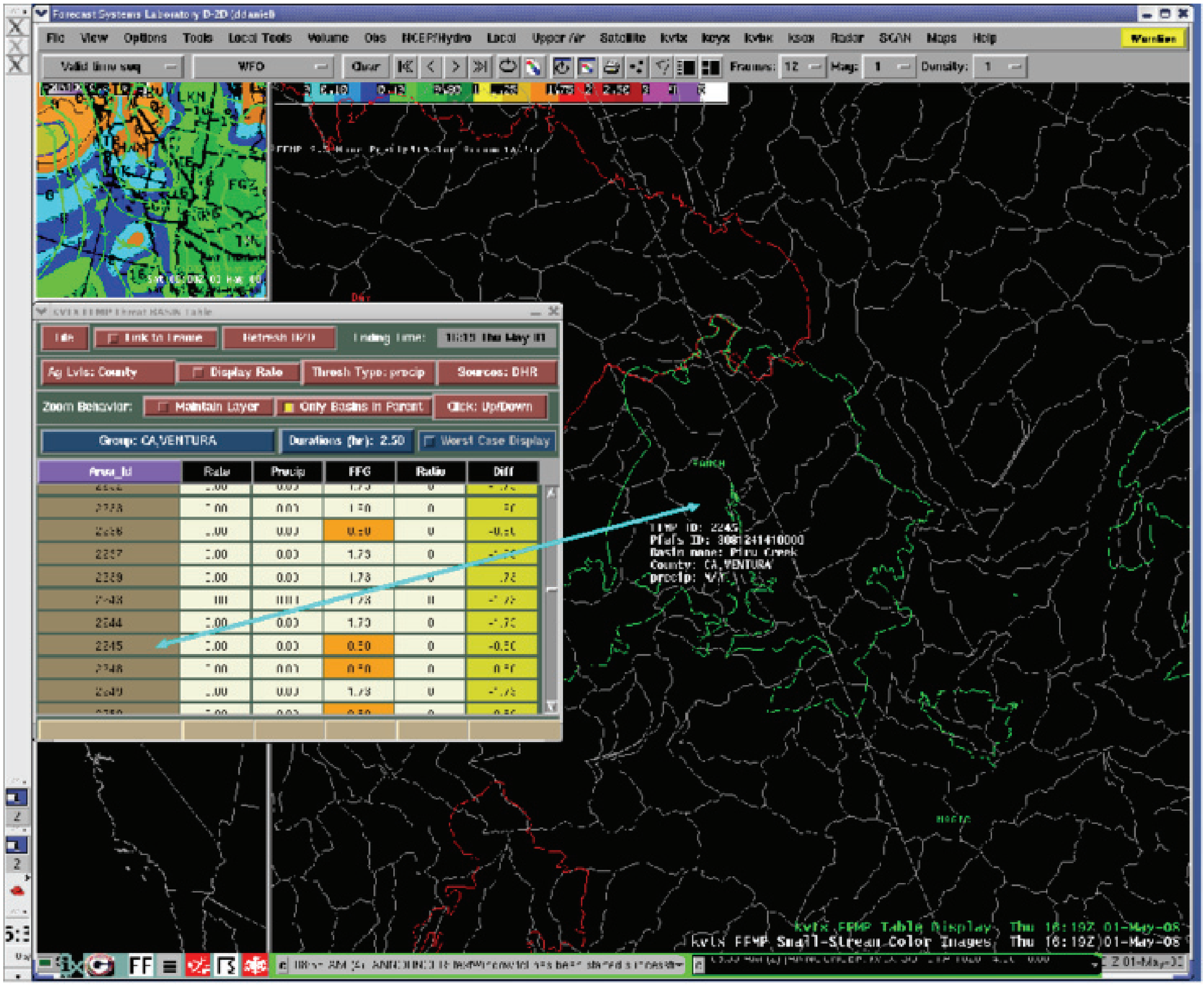


Fig. 1. Example of Debris Flow Forecast area data retrieval on AWIPS.

2. Research Accomplishments/Highlights:

As the liaison for MDL, my task is to provide NWS support to the USGS. Because the USGS does not have a real-time data collection network necessary to provide frequent Debris Flow updates, the initial USGS request is to provide local, real-time rainfall data that are available within each WFO. This work has started and is expected to be completed before the end of the summer for integration into the USGS models in preparation for the next rainy season.

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:

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

The NWS's 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, Project Lead) w/ NWS/DAB.

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

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

6. Awards/Honors:

7. Outreach:

8. Publications:

FUNDS FOR THE COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE, TASK 1

Principal Investigator: T. Vonder Haar

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

July 10, 2007, N. Prive. Towards an Observing System Simulation Experiment (OSSE) for Atmospheric Measurements from Unmanned Aircraft Systems (UAS).

July 20, 2007, P. Stephens. New Developments in Monte Carlo Model as Applied to OCO Spectroscopy.

July 25, 2007, M. Pagowski (ESRL/GSD). Behaviour of the Weather Research and Forecasting (WRF) Model Boundary Layer and Surface Parameterizations in One-Dimensional Simulations during the BAMEX Field Campaign.

August 13, 2007, S.Y. Hong (Yonsei University, Korea). The Yonsei University Research Model System (YOURS).

August 16, 2007, E. Gerber (Columbia University). Timescales of the NAO and Annular Modes: Tropospheric Feedbacks and Stratospheric Coupling.

August 23, 2007, M. Sapiano (CICS). A New Global Analysis of Precipitation.

August 30, 2007, A. Butler, L. Ciasto, T. Ellis, L. Van Roekel and T. Ito (CSU ATS). Understanding Ocean General Circulation using the CSU Spin Tank.

September 13, 2007, W. Schubert (CSU ATS). Some Aspects of the Inner Core Structure of Hurricanes.

September 20, 2007, T. Chase (CU). Modeling and Predicting Three Asian Monsoon Systems.

September 25, 2007, G. Liston. International Polar Year (IPY): Barrenlands Snow-Measurement Expedition.

September 26, 2007, S. Bony-Lena (LMD/IPSL, Paris). Cloud Radiative Feedbacks and Their Role in the Climate System: Progress, Questions and Prospects.

October 4, 2007, B. Cotton (CSU ATS). Aerosol Influences on Clouds and Precipitation.

October 8, 2007, L. Illari (MIT). Weather in a Tank.

October 10, 2007, R. Klein (Potsdam Institute). Multiple Scales in the Atmosphere: Anelastic Approximation for Dry and Moist Flows.

October 10, 2007, G. Holland (NCAR). A Revised Hurricane Pressure-Wind Model.

October 16, 2007, P. McMurry (University of Minnesota). New Particle Formation and Growth Rates in the Atmosphere.

October 17, 2007, J. Shukla (George Mason University). Dynamical Seasonal Prediction: Model Fidelity vs. Predictability.

October 25, 2007, B. Medeiros (UCLA). Can Aquaplanets Predict a GCM's Climate Sensitivity?

November 1, 2007, N. Lovenduski (CSU ATS). Enhanced CO2 Outgassing in the Southern Ocean from a Positive Phase of the Southern Annular Mode.

November 8, 2007, K. Steffen (CIRES). Changes in the Arctic Ice Cover: Greenland Ice Sheet and Surrounding Oceans.

November 14, 2007, T. Schneider (NOAA ESRL). An Overview of the NOAA Hydrometeorological Testbed (HMT).

November 15, 2007, J. Randerson (UC Irvine). Contrasting Climate Effects of Fire in Boreal and Tropical Regions.

November 28, 2007, C. MacDermaid, J. Smith and P. Hamer (ESRL/GSD). Use of Google Earth at ESRL/GSD.

November 29, 2007, C. Boxe (JPL). Surface Chemistry and Physics: Implications for Terrestrial Polar Science and Planetary Science.

December 3, 2007, J. Yano (Paris). Large-Scale Tropical Atmospheric Dynamics: Waves or Balance?

December 6, 2007, M. DeMaria (NOAA). Dynamic and Thermodynamic Controls on Tropical Cyclone Intensity Change.

December 11, 2007, C. Wieninmyer (NCAR). Estimating Emissions from Vegetation for Air Quality Modeling: Methods and Challenges.

January 16, 2008, H. Brix (IGPP UCLA). Seasonal, Interannual and Decadal Variability in the Biogeochemistry of Mode Waters.

January 31, 2008, J. Snider (University of Wyoming). Clouds: Their Effect on Aerosol and Vice-Versa.

February 7, 2008, D. Neelin (UCLA). Rethinking Convective Quasi-Equilibrium.

February 14, 2008, T. Li (NASA NPL). Lidar Observed Interannual Variability in the Middle Atmospheric Temperature

February 22, 2008, C. Holloway (UCLA). Constraints on Tropical Convection: What Can We Learn from Vertical Temperature and Moisture Structures?

February 25, 2008, H. Okamoto (CAOS). Study of Ice Cloud Microphysics using Radar and Lidar Observations.

February 26, 2008, S. Shimizu (NIED, Japan). Structure and Formation Mechanism on 24 May 2000 Supercell-like Storm Developing in a Moist Environment over the Kanto Plain in Japan.

February 28, 2008, M. Betsill (CSU). An Overview of the Policy Landscape for Dealing with Climate Change.

March 6, 2008, S. Denning (CSU ATS). A Stool with Three Legs: Sources of Uncertainty in the Climate of the 21st Century.

March 11, 2008, E. Raschke (University of Hamburg, Germany). Effects of Ancillary Data on Cloud and Radiation Products in the ISCCP and SRB Projects.

March 13, 2008, G. Bryan (NCAR MMM). Gravity Currents in a Deep Anelastic Atmosphere.

March 24, 2008, S. Van Den Heever (CSU ATS). The Impacts of the Cold Pool and Gust Front on Convective Storms.

March 27, 2008, D. Chelton (Oregon State University). Observations and Modeling of Sea Surface Temperature Influence on Surface Winds and the Troposphere.

March 27, 2008, V. Grubisic (Desert Research Institute). Terrain-Induced Rotor Experiment: New Insights into Lee Waves and Atmospheric Rotors.

April 1, 2008, B. Fox-Kemp (CIRES). Submesoscales and Mixed Layer Eddies.

April 3, 2008, D. Gochis (NCAR). Multiscale Observations and Modeling of Land-Atmosphere Interactions.

April 10, 2008, S. Madronich (NCAR ACD). Atmospheric Chemistry In and Near a Megacity: The 2006 Mexico City MILAGRO Field Campaigns.

April 15, 2008, A. Sorooshian (CA Institute of Technology). Aerosol Composition and Hygroscopicity Studies: Instrument Development/Characterization, Ambient and Laboratory Measurements, and Modeling.

April 17, 2008, P. Sellers (NASA). What It's Like to go Into Space.

April 28, 2008, K. Barsanti (NCAR ASP). Representing Secondary Organic Aerosols: From New Particle Formation to Absorptive Partitioning.

May 1, 2008, H. Miura (JAMSTEC). A Study on the Madden-Julian Oscillation Using a Global Cloud-Resolving Model.

May 9, 2008, E. Gruntfest (University of Colorado, Colorado Springs). Weather and Society * Integrated Studies (WAS*IS).

May 19, 2008, H. Cochrane. The Regional Economic Impact of Disaster: A Rapid Assessment Tool.

June 13, 2008, S. Vutukuru (University of California, Irvine). Secondary Aerosol Formation in the Atmosphere: Model Development and Applications.

June 20, 2008, C. Zhang (University of Miami). Bimodal Variability of Tropical Diabatic Heating.

June 27, 2008. G. Liston (CSU/CIRA). International Polar Year, South Pole/Antarctica Research Expedition.

June 27, 2008. Y. Zhang (North Carolina State University). Development and Application of the Weather Research and Forecasting Model with Chemistry (WRF/Chem): From Urban Pollution to Regional/Global Climate Change.

Post Doctoral Program

David Baker – CIRA Post Doc (Partial Year)

Project Title: Atmospheric Modeling, Assimilation, and Source-Sink Estimation for the Carbon Cycle

Principal Investigator: Denis O'Brien

Keywords: Orbital Carbon Observatory (OCO), CO2 Fluxes, Sources and Sinks of CO2, Atmospheric Transport model, Variational Data Assimilation, 4Dvar

New Post Doc as of April 2008. Nothing to report as of this time.

Isidora Jankov – CIRA Post Doc (Partial Year)

Dr. Jankov was promoted to a Research Scientist during the last fiscal year Her work performed as a CIRA Post Doc was carried forward to her new position. Research updates can be found under the Environmental Applications Section, GSD/FAB, with Steve Albers.

Tarendra Lakhankar – CIRA Post Doc (Partial Year)

Project Title: Soil Moisture Estimation from Microwave Remote Sensing Data

Principal Investigator: Tarendra Lakhankar

NOAA Project Goal: Weather and Water (Hydrology)

Key Words: Soil Moisture, Neural Network, Variogram, Kriging, 4D Var

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

In a limited water environment and scarcity of natural resources, the data of accurate soil moisture (soil water content) retrieval from remote sensing satellite data is a great way to look at the sustainability of agriculture, and climate and weather prediction. Beside this, the soil moisture content also provides information of area specific land-cover/land-use changes which are a serious concern for biodiversity and ecosystem structure and function in the US economy. We use very advance technique such as Artificial Neural Networks (ANN) and Variational Data Assimilation (DA) techniques for retrieving the data from space to retrieve the very precise and accurate soil moisture on earth surface. The benefits of accurate soil moisture retrieval are:

Economical and water conservation benefits through precision farming via rational irrigation scheduling based on soil moisture information (Save ~200 million dollars annual in 2 states of Great Plains: as per NOAA's 5 year plan).

Flood forecasting and risk assessment can be advanced up before disaster due accurate information on runoff and infiltration.

In nontraditional combat zone mobility and trafficability of armed vehicles planning can saves of thousands of soldiers' lives and bringing global peace.

2. Research Accomplishments/Highlights:

The research is divided in two categories:

High resolution soil moisture retrieval from active microwave remote sensing data:

The soil moisture retrieval from active microwave remote sensing has shown great potential based on the large contrast between the dielectric properties of wet and dry soil. However, the retrieval is affected by the variation in soil surface roughness and vegetation characteristics. Further, soil surface temperature (ST) is a function of the thermal inertia of the soil and is strongly dependent on soil moisture. Therefore, soil surface temperature and vegetation characteristics such as Normalized Difference Vegetation Index (NDVI), vegetation optical depth (VOD), and Leaf Area Index (LAI) derived from VIS/IR sensors (GOES/AVHRR) can be used as complementary high resolution data from Radarsat satellite.

The intent of this research focuses on using active microwave data from Radarsat and soil temperature and vegetation indices as input nodes to a neural network to produce improved soil moisture mapping capabilities. The spatial resolution of the Radarsat data (e.g., 25 m) will be aggregated to the resolution of the soil temperature and vegetation indices (1 km) for training the neural network. The relationship between soil temperature and soil moisture in the presence of vegetation and soil texture will also be evaluated. This research will be coordinated and reported to the Army Corps of Engineers (Dr. Mason) and the Army Research Laboratory (Mr. McWilliams and Dr. Mungiole).

A proposal has been approved by National Aeronautics and Space Administration (NASA) to provide the very high resolution (25 m) active microwave remote sensing RADARSAT data.

Spatial variability analysis of low resolution soil moisture data:

The spatial pattern of soil moisture varies at different scales due to evapo-transpiration and precipitation which are transformed by topography, soil texture, and vegetation. The mapping of soil moisture by remote sensing has several advantages over conventional field measurement techniques especially in the case of heterogeneous landscapes. However, validation of a soil moisture product such as those from the AMSR, WindSAT and SSM/I at larger footprints is difficult using only field point measurements. One validation approach is to use existing soil moisture measurement networks and scale these point observations up to the resolution of remote sensing footprints. This is possible by characterizing the variability of soil moisture data using a geostatistical approach. The prediction of a point soil moisture value has higher uncertainty due to its stochastic sampling nature. Therefore, it is interesting to relate point-based field measurements with averaged pixel measurements from satellite remote sensing by using block kriging for interpolation between scales.

The aim of this study is twofold. First, the characteristics of the in-situ OK Mesonet data variogram are compared to AGRMET (Agricultural Meteorology model) and WindSAT soil moisture and precipitation data using Bias, RMSE, and variance ratio. Second, the kriging prediction is cross-validated at sampling locations not used in kriging analysis. This study aims to use 100+ Oklahoma Mesonet field soil moisture data points to compare to the AGRMET and WindSAT soil moisture products. AGRMET is a near real-time global land surface analysis model generate soil moisture at 47 km spatial resolution based on NOAH community land-surface soil hydrology module operated by the U.S. Air Force. WindSAT is the first spaceborne high-precision passive microwave imager measures partially polarized energy emitted, scattered, and reflected form the earth’s atmosphere and surfaces. The soil moisture values from WindSAT microwave brightness temperature were retrieved using Microwave Land Surface Model. The spatial distribution of the above datasets is suitable for this type of kriging analysis. The variogram analysis indicates that the de-correlation length is higher for AGRMET compared to the OK Mesonet data. This could be due to a smoothing effect in soil moisture estimation using the AGRMET model, as higher smoothing leads to larger de-correlation length. We also found that the effect of precipitation via change in soil moisture on de-correlation length at higher average soil moisture leads to lower de-correlation length for both AGRMET and OK Mesonet data. The variance of the variogram (sill) is higher at wet soil moisture conditions. The average RMSE value of estimated soil moisture at 11 sampling locations not used in the kriging analysis is found to be 3.5% of the soil moisture value. Variances of OK Mesonet soil moisture values are low during the dry season and high during the wet season.

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

4. Leveraging/Payoff:

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

ARL collaborators are Mr. Gary McWilliams and Dr. Michael Mungiole (Adelphi, MD). Dr. George Mason is our ERDC collaborator from the US Army Corps of Engineers (Vicksburg, MS).

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

<u>Journal Papers</u>

Arevalo, Ghedira H, J.C., Azar A.E., Lakhankar T., Khanbilvardi R., and R. Blake, 2007 Capabilities and limitations of neural networks in snow cover mapping from SSM/I images, Submitted to *Journal of Applied Remote Sensing*.

Lakhankar, T., A. S. Jones, et al, 2007: Analysis of large scale spatial variability of soil moisture data using a geostatistical method, In-preparation to be submitted to *Journal of Hydrometeorology*.

Lakhankar T., Ghedira H, Khanbilvardi R., and R. Blake, 2007: Non-parametric Classifiers for Soil Moisture Retrieval from Active Microwave Data, Submitted to *Journal of the American Water Resources Association*.

<u>Technical Reports and Conference Papers</u>

Combs, C. L., T. Lakhankar, D. Rapp, A. S. Jones, G. Mason, M. Mungiole, G. McWilliams, 2007: *Comparison of AGRMET model results with in situ soil moisture data,* CG/AR Tech. Report, April 2007, 43 pp., in preparation.

Jones, A. S., C. L. Combs, S. Longmore, T. Lakhankar, G. Mason, G. McWilliams, M. Mungiole, D. Rapp, T. H. Vonder Haar, and T. Vukicevic, 2007: NPOESS soil moisture satellite data assimilation research using WindSat data, *Third Symposium on Future National Operational Environmental Satellite Systems—Strengthening Our Understanding of Weather and Climate,* January 16-17, San Antonio, TX, P2.17.

Jones, A. S., G. McWilliams, C. L. Combs, T. Lakhankar, S. Longmore, G. Mason, M. Mungiole, D. Rapp, and T. H. Vonder Haar, 2007: NPOESS soil moisture satellite data assimilation using WindSat data, *27th AGU Hydrology Days,* March 19-21, 2007, Fort Collins, CO.

Lakhankar, T., A. Jones, C. Combs, D. Rapp, and T. H. Vonder Haar, 2007: Geostatistics of Large Scale In Situ and Satellite Derived Soil Moisture Data, *CG/AR Annual Review,* Fort Collins, CO, Apr. 17-19 (poster).

Lakhankar, T., A. S. Jones, and H. Ghedira, 2007: High resolution soil moisture retrieval from active microwave remote sensing data, *27th AGU Hydrology Days,* March 19-21, 2007, Fort Collins, CO.

Lakhankar, T., A. S. Jones, C. Combs, D. Rapp, and T. H. Vonder Haar, 2007: Geostatistics of large scale in-situ and satellite derived soil moisture data, *27th AGU Hydrology Days,* March 19-21, 2007, Fort Collins, CO.

McWilliams, G., A. S. Jones, C. L. Combs, T. Lakhankar, S. Longmore, G. Mason, M. Mungiole, D. Rapp, and T. H. Vonder Haar, 2007: NPOESS soil moisture satellite data assimilation: Progress using WindSat data, *IGARSS 2007,* July 23–27, Barcelona, Spain.

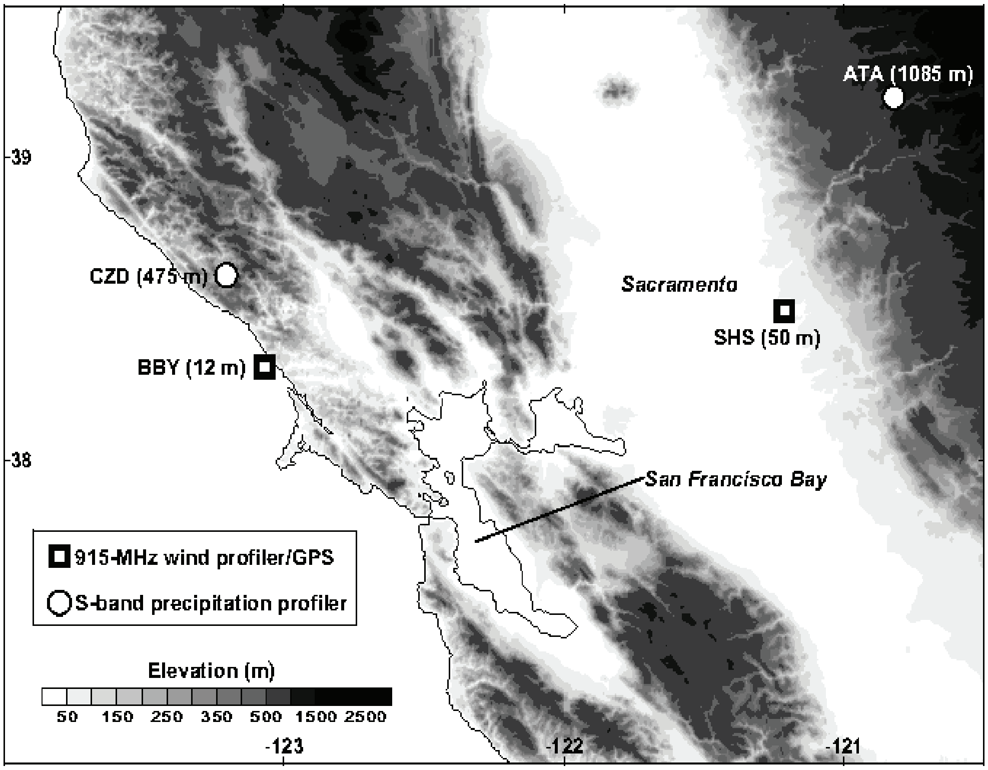


Fig. 1. Terrain base map of California, with the wind profiler sites shown at Bodega Bay (BBY) and Sloughhouse (SHS), and the S-band radar sites shown at Cazadero (CZD) and Alta (ATA).

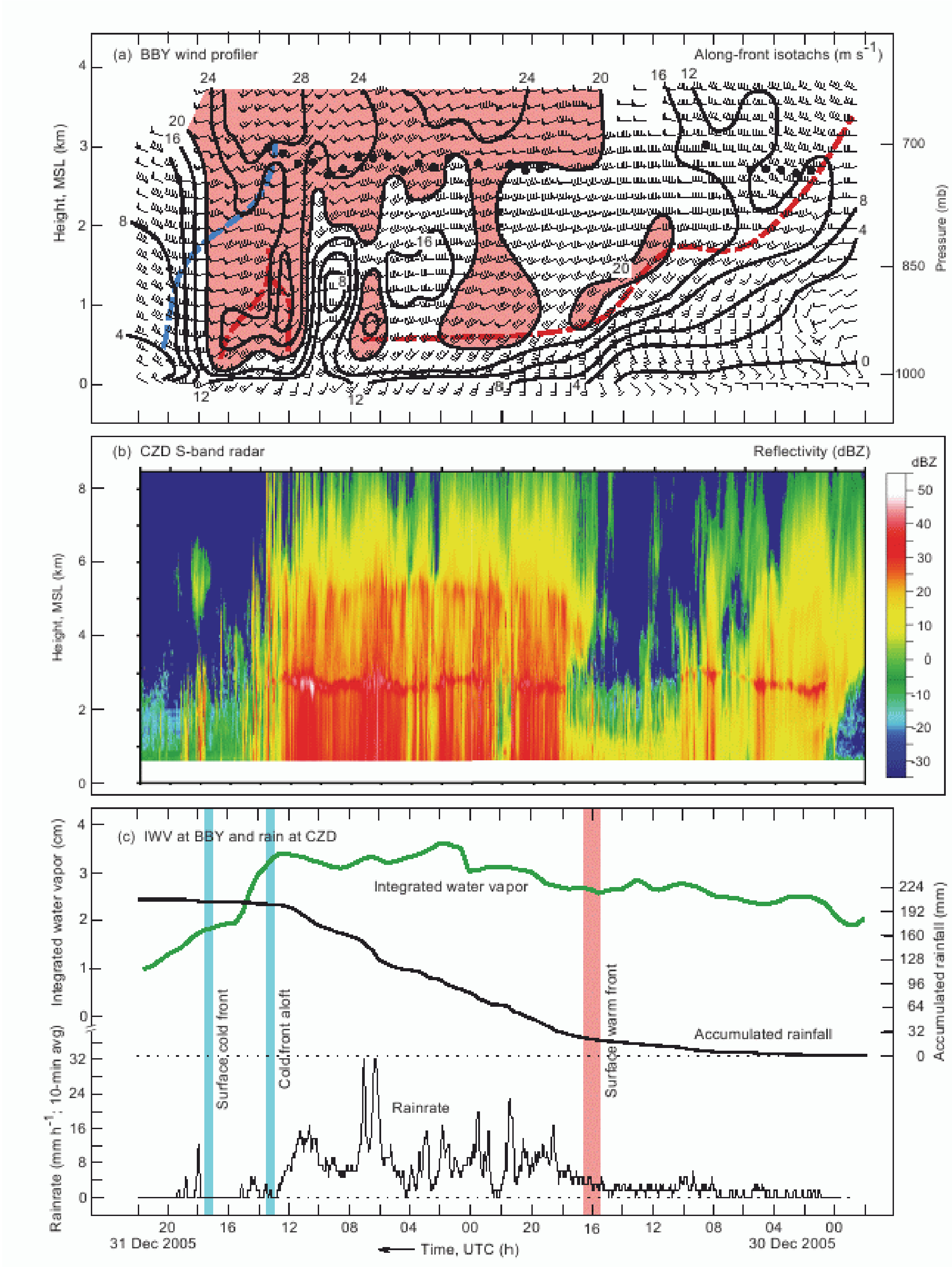


Fig. 2. 3-panel wind profiler/S-band radar/GPS/rainfall figure from BBY and CZD for the period 22 UTC 29 December to 22 UTC 31 December 2005.

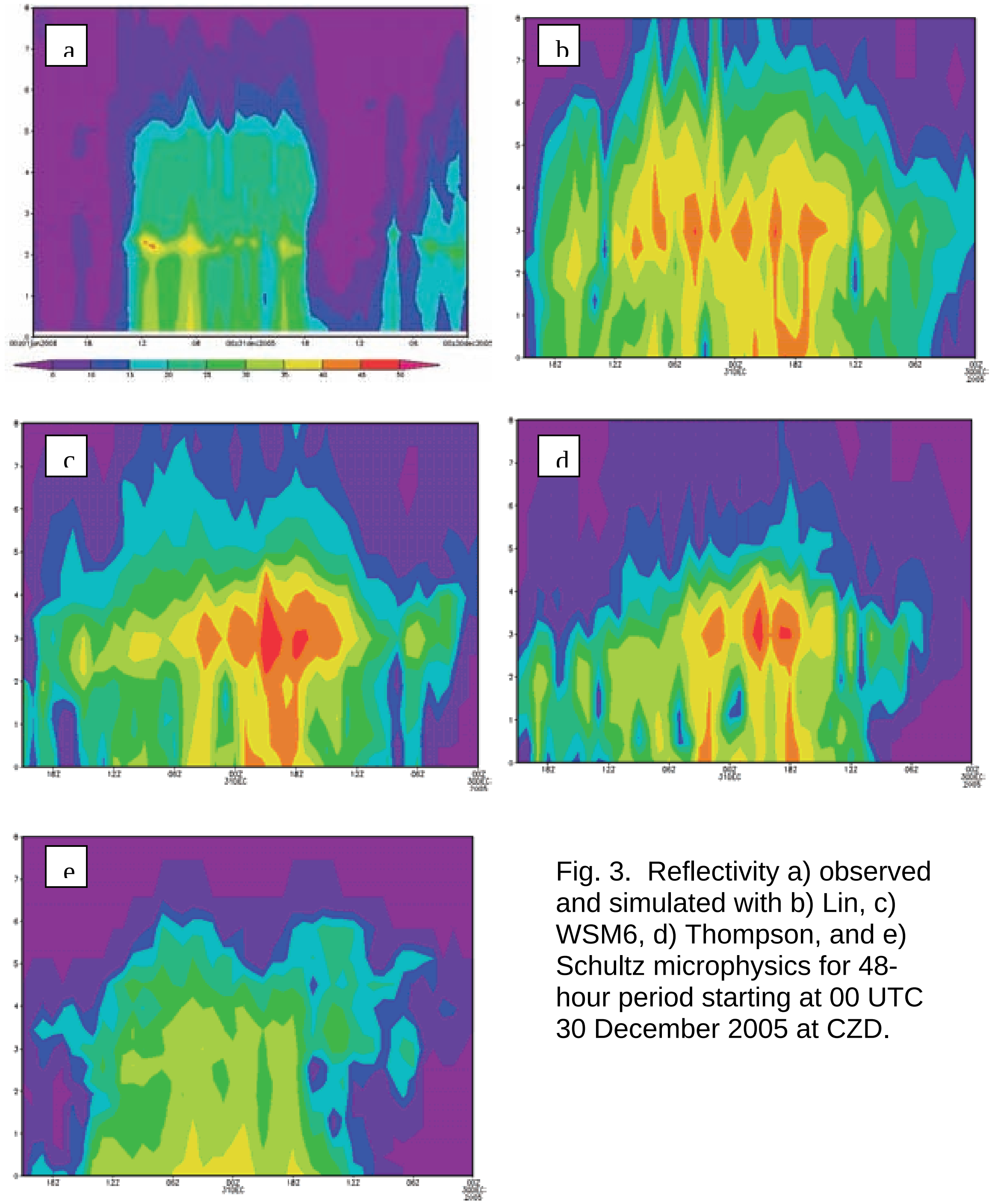


Fig. 3. Reflectivity a) observed and simulated with b) Lin, c) WSM6, d) Thompson, and e) Schultz microphysics for 48-hour period starting at 00 UTC 30 December 2005 at CZD.

<u>Yoo-Jeong Noh – CIRA Post Doc </u>(Partial Year)

Project Title : Development of a Snowfall Retrieval Algorithm Over Land Using Satellite and Aircraft Observations

Principal Investigator: Tom Vonder Haar

NOAA Project Goal : Weather and Water (weather water science and technology)

Key Words: Microwave, Satellite, Radar, Snowfall Retrieval, Surface Emissivity, AMSU-B, CloudSat

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

Develop a Bayesian snowfall retrieval algorithm over land utilizing high-frequency satellite microwave measurements and various observational data

--Analyze aircraft measurements of snowfall cases during the C3VP/CLEX10 field experiment.

--Build the a-priori database of snow clouds for a Bayesian snowfall retrieval algorithm over the Great Lakes region by radiative transfer modeling using various observations as input.

2. Research Accomplishments/Highlights:

--Collect and process datasets to construct the a-priori database of snowfall and brightness temperatures that is a key component of the Bayesian algorithm. Try to include various measurements--as many as possible such as AMSU A/B, AGRMET, CloudSat 2B products (V4), and C3VP/CLEX10 aircraft/sonde data.

> --Process NEXRAD Level II data using two NCAR radar programs (Sprint and Cedric) to obtain snowfall rates for selected stations in The Great Lakes region. A Ze-S relationship of Super and Holroyd (1998) was adopted to convert radar reflectivity to snowfall rate.
>
> --Updated using the latest version of the CloudSat 2B-CWC product.

--WRF simulations were done for a total of twelve cases using GFS data as initial/boundary data and mainly Thompson's cloud microphysics scheme and narrowed down to eight by considering CloudSat passages. The results give the additional atmospheric sounding inputs to the radiative transfer model.

--Completed a histogram analysis of averaging AMSU-B for four months to find background brightness temperatures at each frequency. Found a possibility to more clearly detect scattering signatures over the complex surfaces.

--Build the first version of the a-priori database by using a radiative transfer model (Liu, JAS 2004) that includes various observations as input and also employs microwave land surface emissivity from the NOAA Microwave Land Emissivity Model (MEM) using AGRMET and AMSU-A.

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

--Presented the preliminary results using the first version of the a-priori database in the 2007 EUMETSAT/AMS joint meteorological satellite conference

--Updating the a-priori database for a Bayesian retrieval algorithm is in progress since the second version of C3VP/CLEX10 data and improved CloudSat liquid water products were newly released during this period.

--Snowfall retrievals for real cases will continue using the updated database.

4. Leveraging/Payoff:

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

For the C3VP/CLEX10 data process, we are collaborating with David Hudak and Peter Rodriguez (Environment Canada).

6. Awards/Honors:

7. Outreach: Seminar presentation as follows.

Noh, Y. J., S. Q. Kidder, T. H. Vonder Haar, and J. A. Kankiewicz, 2007: Analysis of wintertime mixed-phase clouds using satellite and aircraft measurements, The 4th Workshop of the Canadian CloudSat/CALIPSO validation project, 27-28 November 2007, St. Hubert, Quebec, Canada.

8. Publications:

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, Symposium on Recent Developments in Atmospheric Applications of Radar and Lidar/88th AMS Annual Meeting, 20 January 2008 - 24 January 2008, New Orleans, LA, USA.

Noh, Y. J., A. S. Jones, and T. H. Vonder Haar, 2007: Snowfall retrievals over land using high frequency microwave satellite data, 2007 EUMETSAT Meteorological Satellite Conference and the 15th AMS Satellite Meteorology and Oceanography Conference, 24-28 September 2007, Amsterdam, The Netherlands.

Noh, Y. J., 2007: Observational Analysis and Retrieval of Falling Snow using Satellite Data at High Microwave Frequencies. ISBN:978-3-8364-2425-7, VDM Verlag Dr. Müller, Saarbrücken, Germany, 104 pp.

8. Funds for CIRA General Publications:

Vonder Haar, T.H., 2008. Annual Report on the Cooperative Institute for Research in the Atmosphere 01 July 2007 – 30 June 2008, Cooperative Institute for Research in the Atmosphere, Colorado State University, Ft. Collins, CO.

GETTING READY FOR NOAA'S ADVANCED REMOTE SENSING PROGRAMS A SATELLITE HYDRO-METEOROLOGY (SHYMET) TRAINING AND EDUCATION PROPOSAL

Principal Investigator: Bernie 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:

Maintain and make small incremental changes to the SHyMet Intern Course http://rammb.cira.colostate.edu/training/shymet/intern_intro.asp .

Provide a summary of 2006 SHyMet topics survey. Based on feedback from the topics survey, select and organize the content for the next SHyMet Course.

Coordinate with NWS personnel in Boulder to include a hydrology module in the next SHyMet course.

Coordinate with the VISIT team on porting the existing and new course materials, questions, and surveys for SHyMet into the new NOAA LMS system.

Update the CIRA SHyMet webpage to reflect new/revised course offerings.

Advertise and make SHyMet course materials available nationally and internationally to individuals outside NOAA/NWS.

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 Accomplishments/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 April 2007 – March 2008 (compared to entire period April 2006 – March 2008)

37 new NOAA/NWS employees/participants have registered at CIRA
(144 total for period April 2006 – March 2008)

7 of the new NOAA/NWS individuals have completed SHyMet Intern Course
(60 total for period April 2006 – March 2008)

8 non-NOAA participants have registered at CIRA (National Environmental Satellite, Data, and Information Service / Satellite Applications Branch (NESDIS/SAB) contractors, and Korean Meteorological Service)
(22 total for period April 2006 – March 2008)

1 non-NOAA individual has completed the SHyMet Intern Course.
(9 total for period April 2006 – March 2008)

Registrations through LMS tracking indicate that an additional 74 individuals not registered at CIRA have taken various SHyMet modules this year. This is a conservative estimate. The NWS changed LMS vendor this past year.

May 1, 2007 marked the end of the original LMS hosted by GeoLearning and the beginning of the new LMS hosted by Learn.com. Course materials, questions, and surveys were ported from the old LMS (prior to May 1) and into the new LMS. Access to the new LMS system began in June. Accessibility and functionality of the new system has not been as smooth as expected and transitioning work continues into March 2008.

SHyMet training session	Registrations
Orientation	258
GOES Imaging and Sounding Area Coverage	235
GOES Channel Selection	233
Introduction to POES	217
GOES Sounder Data and Products	157
GOES High Density Winds	157
Cyclogenesis	155
Introduction to Satellite Severe Weather	173
Tropical Cyclones	241
SHyMet teletraining sessions (April-June 2006)	Registrations
GOES Sounder Data and Products	53
GOES High Density Winds	48
Cyclogenesis	54
Introduction to Satellite Severe Weather	52

Table 1. Number of students registered via the LMS for SHyMet web-based training sessions between April 1, 2006 and March 31, 2008 followed by number of teletraining sessions for April – June 2006.

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 helped to form the basis for selection of topics for the next version of the SHyMet course.

The SHyMet and VISIT members met at CIMSS in Madison, WI in early November 2007 to discuss the topics survey, select topics, and plan the direction of the next version of the SHyMet course.

The following topics were selected for the next 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 (include section on hyperspectral soundings) (CIRA)

Cloud climatology (CIRA)

Water vapor channels (CIMSS)

Aviation hazards (CIRA)

Hazard detection (Fog, fire, volcanic ash, dust, aerosols) (CIRA)

There is a 1-2 year timeframe to have the new course ready

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting 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, Communications 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 the Regional 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://hadar.cira.colostate.edu/vview/vmrmtcrsogrp.html ,

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 as yet

7. Outreach:

B. Connell 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 both the Fall 2007 and Spring 2008.

CIRA has participated in monthly VISITview weather briefings using GOES satellite imagery (http://hadar.cira.colostate.edu/vview/vmrmtcrsogrp.html) 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.

Training

CIRA gave input to and provided support for VISIT/SHyMET/WMO focus group presentations to the following:

August 22, 2007: The International Workshop of Meteorological Satellites for South American Users, Maceio, Brazil given by Tony Mostek, NWS Training Division in Boulder

October 2 and 9, 2007: Workshop on Meteorological Satellites, Cartagena, Colombia presentation given by Vilma Castro, University of Costa Rica. Weather briefing

8. Publications:

Newsletters
Article published in the fall 2007 CIRA Newsletter: “International Activities: Weather Briefings and Training via the Internet” by B. Connell, M. DeMaria, and J. Purdom pages. 4- 7 http://www.cira.colostate.edu/publications/newsletter/fall2007.pdf

Professional Meetings
A conference paper and poster were prepared for the AMS 17th Symposium on Education to be held in New Orleans in January 2008. “International Focus Group– Virtually there with VISITview” by B. Connell, V. Castro, M. Davison, A. Mostek, B. Fallas, K. Caesar, and T. Whittaker
http://ams.confex.com/ams/88Annual/techprogram/paper_134924.htm

Conference

Dr. Vilma Castro, a collaborator from The University of Costa Rica, gave a presentation to the seventh Computer Aided Learning in Meteorology (CALMet VII) conference held in Beijing, China 2-7 July 2007. The presentation titled “International Satellite Weather Briefings via the Internet” detailed the work being done with the Focus Group activities in Central and South America and the Caribbean. The authors included V. Castro & B. Fallas, UCR Costa Rica, B. Connell, CIRA, A. Mostek & M. Davison, NWS USA,; KA Caesar, CIMH Barbados.

GOES-WEST ISCCP SECTOR PROCESSING CENTER

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Climate. Program: Climate Observation and Analysis

Key Words: GOES, ISCCP, Data Collection, Product Generation, Data Stewardship, CloudSat, CALIPSO

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

Data Collection

Since 1983 CIRA has collected and processed GOES data (especially, but not exclusively, GOES-West data) for ISCCP. The data are collected and inspected for noise and missing data. Alternated times or replacement data are prepared as needed. Currently, the list of data processed includes:

3 hourly GOES West 8 km sampled 10 bit data to IAC.

3 hourly GOES West 32 km sampled 10 bit data to GPC.

Calibration sectors for GOES 10 and 12 to Calibration Center.

Continued back up data collection for GOES East and calibration sectors.

GOES 10 data collection over South America.

Data Stewardship

In addition to collecting the data for ISCCP, we try to be good stewards of the data by investigating the data quality. This year, we are focusing on comparing data from the recently-launched CloudSat and CALIPSO satellites with ISCCP products.

2. Research Accomplishments/Highlights:

We have begun to match CloudSat and CALIPSO data with MODIS data from the Aqua satellite to investigate how well the channels on which ISCCP cloud retrievals sense clouds and cloud layers. Figure 1 shows an 11 µm MODIS image of a cloud band in the South Pacific. Less than two minutes later, CloudSat and CALIPSO sliced through the cloud from A to B (Fig. 2). Figure 3 shows the Geoprof-Lidar Cloud Layer Product (red and blue), which combines CloudSat and CALIPSO data to retrieve up to five layers of clouds, giving the top and bottom heights for each layer (Mace & Zhang 2007; http://www.cloudsat.cira.colostate.edu/icd_pdf.php?avid=33&pvids=210). Also in Fig. 3 are the 11 µm MODIS brightness temperature (white line) and the cloud phase, derived from the VIIRS Cloud Phase algorithm. We believe that the CloudSat and CALIPSO data offer unprecedented opportunities for improvement of the ISCCP dataset.

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

Objective A: In progress

Objective B: In progress

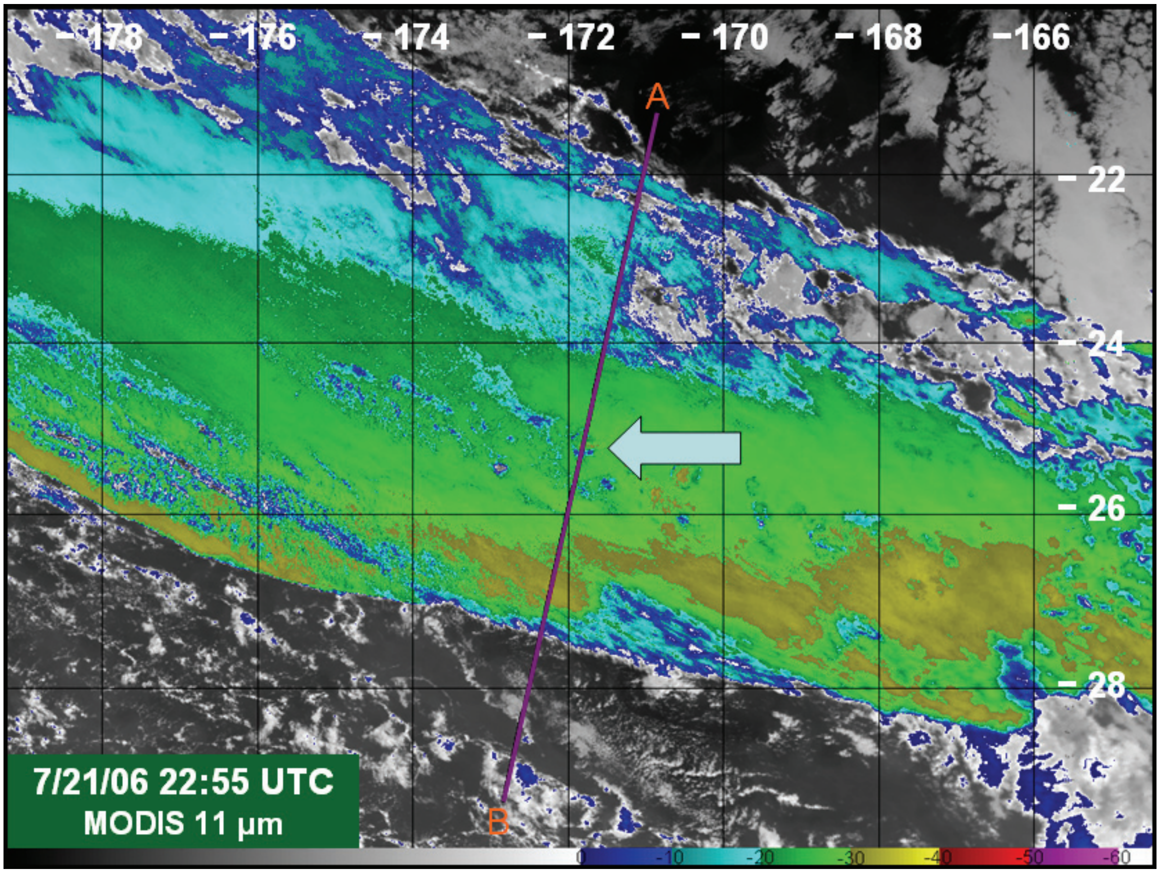


Figure 1. An 11 µm MODIS image of a mid-level cloud band. (Note difficult to detect convective element at the location of the arrow.) [From Kidder et al. (2007)]

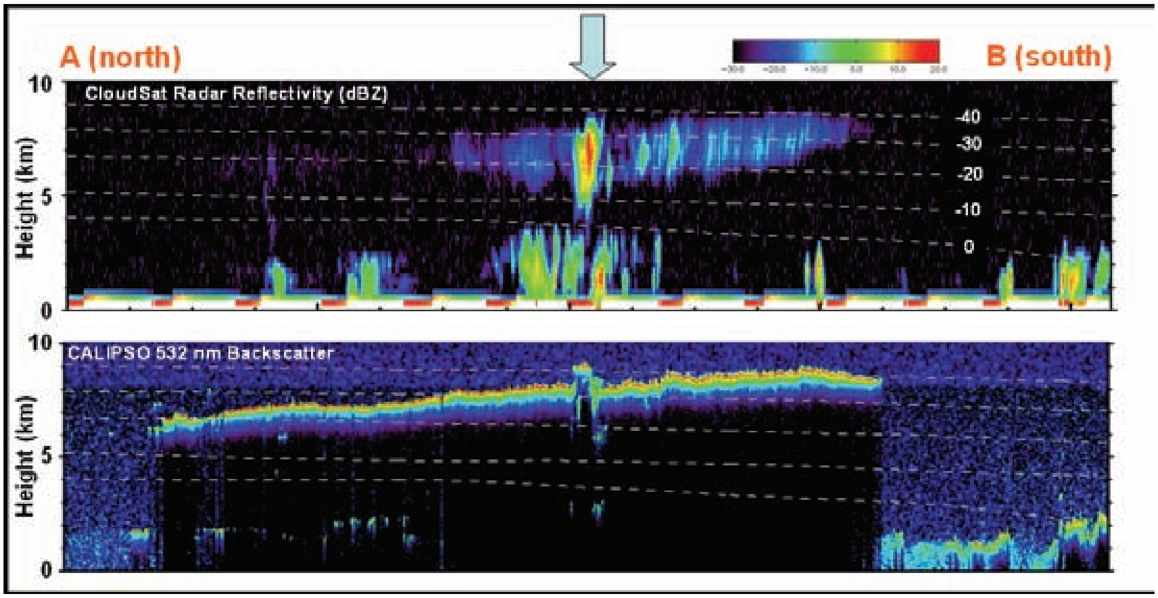


Figure 2. CloudSat and CALIPSO “slices” through the cloud on the line from A to B in Fig. 1. (Note convective element at the location of the arrow.) [From Kidder et al. (2007)]

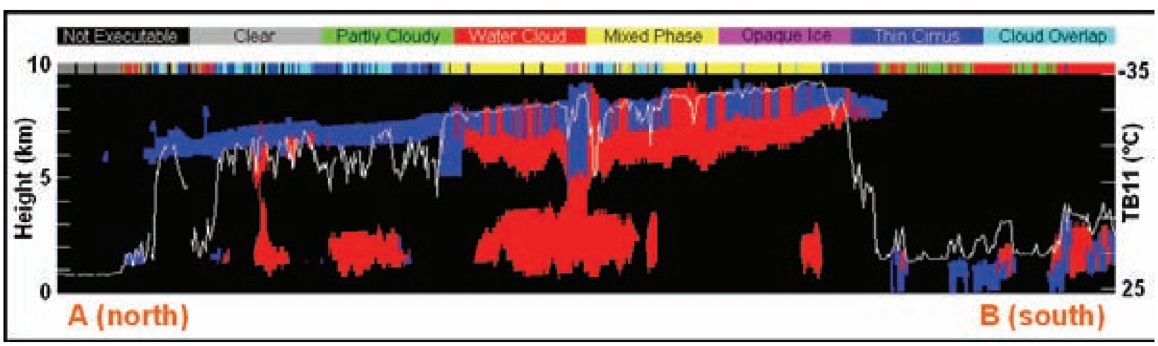


Figure 3. CloudSat/CALIPSO Geoprof-Lidar Cloud Layers overlaid with the MODIS 11 μm brightness temperature (white line) and with the VIIRS Cloud Phase (colored band at the top of the image). [From Kidder et al. (2007)]

4. Leveraging/Payoff:

ISCCP is the premier cloud climatology in the world and is essential for understanding climate change.

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

We closely collaborate with NASA/GISS on this project.

6. Awards/Honors: None as yet

7. Outreach:

See our Website: http://isccp2.cira.colostate.edu.

8. Publications:

Kidder, S. Q., J. A. Kankiewicz, and T. H. Vonder Haar, 2007: The A-Train: How formation flying is transforming remote sensing, The Joint 2007 EUMETSAT Meteorological Satellite Conference and the 15th American Meteorological Society Satellite Meteorology and Oceanography Conference, Amsterdam, The Netherlands, 24-28 September. [http://amsu.cira.colostate.edu/kidder/Amsterdam_paper.pdf]

IMPACT OF FUNDAMENTAL ASSUMPTIONS OF PROBABILISTIC DATA ASSIMILATION/ENSEMBLE FORECASTING: CONDITIONAL MODE VS. CONDITIONAL MEAN

Principal Investigator: Milija Zupanski

NOAA Project Goal: Weather and Water

Key Words: Probabilistic Assimilation/Prediction, Ensemble, Maximum Likelihood Ensemble Filter, Global Forecasting System

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

Long-term objective of this research is to explore the possibility for NOAA operational use of ensemble assimilation/prediction system. This implies the assimilation of NCEP operational observations (including satellite radiances), and the use of NCEP Global Forecasting System (GFS) spectral model, at resolution T126. The NCEP operational observations are accessed using NCEP infrastructure, i.e. using the forward component of the operational Grid-point Statistical Interpolation (GSI) system.

Since this project is currently under no-cost extension during last year, our work focuses on developing an ensemble data assimilation prototype system in collaboration with scientists from NOAA/NCEP (Zoltan Toth, Yucheng Song, Mozheng Wei), University of Maryland (Istvan Szunyogh, Eugenia Kalnay), NOAA/ESRL (Jeff Whitaker, Tom Hamill), NRL Monterey (Craig Bishop), and others. The NOAA Earth Systems Research Laboratory (ESRL) scientists are leading the effort.

The results of this research are directly related to the NOAA goals and plans through the THORPEX Research Program. The work is conducted on the NOAA/NCEP computers (Haze currently, Vapor in near future), employing directly operational codes, thus making the results of this research easily transferable to NOAA/NCEP operations.

2. Research Accomplishments/Highlights:

Major achievements during last year are:

The prototype ensemble data assimilation (EnsDA) system has been developed and tested

The EnsDA system generally outperforms the operational GSI (3d-Var) system

In terms of the root-mean-squared errors, the results are especially improved at upper levels of the troposphere

The Maximum Likelihood Ensemble Filter (MLEF), developed at CSU/CIRA, is also available for use on the NCEP computers, but continued development will require additional funding.

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

4. Leveraging/Payoff:

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

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

Carrio, G.G., W.R. Cotton, D. Zupanski, and M. Zupanski, 2008: Development of an aerosol retrieval method: Description and preliminary tests. *J. Appl. Meteor. Climate*., (*in press*).

Fletcher, S. J., and M. Zupanski, 2008: Implications and Impacts of Transforming Lognormal Variables into Normal Variables in VAR. *Met. Zeit.*, 16, 755-765.

Fletcher, S.J., and M. Zupanski, 2008: A study of ensemble size and shallow water dynamics with the Maximum Likelihood Ensemble Filter. *Tellus*, 60A, 348-360.

Fletcher, S. J., and M. Zupanski, 2006: A Hybrid Normal and Lognormal Distribution for Data Assimilation. *Atmos. Sci. Lett.,* 7, 43-46.

Fletcher, S. J., and M. Zupanski, 2006: A Data Assimilation Method for Log-normally Distributed Observational Errors. *Q. J. Roy. Meteorol. Soc.*, 132, 2505-2519.

Lokupitiya, R.S., D. Zupanski, A.S. Denning, S.R. Kawa, K.R. Gurney, M. Zupanski, W. Peters, 2008: Estimation of global CO_2 fluxes at regional scale using the maximum likelihood ensemble filter. *J. Geophys. Res.* (*submitted*).

Uzunoglu, B., S.J. Fletcher, I. M. Navon, and M. Zupanski, 2007: Adaptive Ensemble Size Reduction and Inflation. *Q. J. R. Meteorol. Soc.,*133, 1281-1294.

Zupanski, D., A.Y. Hou, S.Q. Zhang, M. Zupanski, C.D. Kummerow, and S. H. Cheung, 2007: Application of information theory in ensemble data assimilation. *Q. J. R. Meteorol. Soc*., 133, 1533-1545.

Zupanski, D., A. S. Denning, M. Uliasz, M. Zupanski, A. E. Schuh, P. J. Rayner, W. Peters and K. D. Corbin, 2007: Carbon flux bias estimation employing Maximum Likelihood Ensemble Filter (MLEF). *J. Geophys. Res*., 112, D17107, doi:10.1029/2006JK008371.

Zupanski, D. and M. Zupanski, 2006: Model Error Estimation Employing Ensemble Data Assimilation Approach. *Mon. Wea. Rev*., 134, 1337-1354.

Zupanski, M., D. Zupanski, S. J. Fletcher, M. DeMaria, T. Vonder Haar, and B. Dumais, 2008: Ensemble data assimilation with the Weather Research and Forecasting model: The hurricane Katrina case. *J. Geophys. Res*., (*submitted*).

Zupanski, M., I. M. Navon, and D. Zupanski, 2008: The Maximum Likelihood Ensemble Filteras a non-differentiable minimization algorithm. *Q. J. R. Meteorol. Soc*., (*in press*).

Zupanski, M., and I.M. Navon, 2007: Predictability, Observations, and Uncertainties in Geosciences. *Bull. Amer. Meteor. Soc.*, 88, 1431-1433.

Zupanski, M., S.J. Fletcher, I.M. Navon, B. Uzunoglu, R.P. Heikes, D.A. Randall, T.D. Ringler, and D. Daescu, 2006: Initiation of Ensemble Data Assimilation. *Tellus*, 58A, 159-170.

Zupanski, M., 2005: Maximum Likelihood Ensemble Filter: Theoretical Aspects. *Mon. Wea. Rev*., 133, 1710–1726.

<u>Book Chapters</u>

Zupanski D., 2008: Information Measures in Ensemble Data Assimilation. Chapter in the book titled "*Data Assimilation for Atmospheric, Oceanic, and Hydrologic Applications*", S. K. Park, Editor, (*submitted*).

Zupanski, M., 2008: 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, Editor, (*submitted*).

INVESTIGATION OF SMOKE AEROSOL-CLOUD-RADIATION AND SURFACE INTERACTIONS USING LARGE EDDY SIMULATIONS

Principal Investigator: Hongli Jiang

NOAA Project Goal: 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 examine aerosol-cloud interactions between clouds, aerosols, radiation, surface fluxes and boundary layer processes in warm convective clouds in the Houston area. In analysis of the GoMACCS data, we will identify cases represented under a wide range of atmospheric conditions and perform model simulations to compare with observational data. We will focus on a statistical comparison between the simulated and observed data.

To explore the Arctic boundary layer clouds in preparation for the International Polar Year (IPY) field experiments.

2. Research Accomplishments/Highlights:

We have performed comparisons of the statistical properties of Large Eddy Simulations (LES) with aircraft observations of non-precipitating, warm cumulus clouds observed in the vicinity of Houston, TX during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS). Statistical comparisons have focused on the properties of a set of dynamical and thermodynamical variables. For all variables, good agreement between the simulated and observed clouds is achieved. These comparisons, together with the excellent agreement between observed and simulated cloud size distributions, suggest that the LES is able to successfully generate the cumulus cloud populations that were present during GoMACCS.

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

A paper reporting the study in the Houston area is accepted and will appear soon in the Journal of Geophysical Research. A separate paper (in preparation led by S. Schmidt, at CU) will examine comparisons of observed radiative fluxes and fluxes simulated based on the model output.

The study to explore the Arctic stratiform clouds is under way. We have tested the model with previous field experiment data, and are currently waiting for the new data to come in.

Additionally, I have been in collaboration and co-author with A. Hill and G. Feingold to work on the impact of entrainment and turbulent mixing on marine stratocumulus clouds

4. Leveraging/Payoff:

The concept of statistical comparisons between models and observations was the goal of the study. This is a new approach to evaluating models that has paid great dividends. 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. This provides us with confidence that we are capturing aerosol-cloud interactions in a realistic way. Our current work which looks at the radiative flux response will be an even more rigorous evaluation of our model.

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

Research was conducted in collaboration with:

Feingold, G: NOAA/ESRL

Hill, A: NOAA/ESRL

Seinfeld, J, Flagan, R: California Institute of Technology, Pasadena, CA

Jonsson, Haflidi: Center for Interdisciplinary Remotely-Piloted Aircraft Studies, Naval Postgraduate School, Monterey, CA.

Chuang, P. Y.: University of California, Santa Cruz, CA

Schmidt, S. and Pilewskie, P: University of Colorado, Boulder, CO

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Hill, A., G. Feingold, and H. Jiang, 2008: The influence of mixing on the climate forcing of non-precipitating marine stratocumulus", *JAS* (in revision).

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). To appear in *J. Geophysical Res.*

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.

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.

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 as yet

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 as yet

MONSOON FLOW AND ITS VARIABILITY DURING NAME: OBSERVATIONS AND MODELS

Principal Investigator: Richard Johnson

NOAA Project Goal: Climate – Climate Predictions and Projections

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:

Insight into the dynamics of Gulf of California surges has come about as a result of NAME. The most prominent surge (13-14 July 2004) was found to consist of two stages: a shallow, bore-like disturbance that traveled rapidly (20-25 m s^{-1}) up the Gulf, followed by a Kelvin wave-like disturbance characterized by a deeper layer of sharp cooling and strong moisture transport.

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.

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

The proposed research on monsoon surges and the surface flows during NAME has been completed. Work is underway on upper-level troughs, the diurnal cycle of convection, and low-level jets.

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, has been used by the Tucson and Phoenix NWS offices for forecasting monsoon surges and associated rainfall.

5. Research Linkages/Partnerships/Collaborators, Communications 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).

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

7. Outreach:

Peter Rogers (M.S. 2005)
Elinor Martin (M.S. 2007)
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*, in press.

Martin, E. R., and R. H. Johnson, 2008: An observational and modeling study of an atmospheric internal bore during NAME 2004. *Mon. Wea. Rev*., in press.

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)

Yong Chen – NESDIS Post Doc

Project Title: Develop and Evaluate Community Radiative Transfer Model (CRTM) for Uses in Numerical Weather Prediction Models. CRTM Impacts in Global Forest Model (GFS), Especially for Hyperspectral Infrared Satellite Data Assimilation

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Weather and Water, Local Forecasts and Warnings, Hydrology

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:

Generating the new transmittance coefficients for historical sensors (TIROS-N to NOAA-12 AVHRR, HIRS and SSU, GOES-8 to GOES-10 Image channels and sounder channel 8-13) in OPTRAN for supporting the EMC data reanalysis.

Implementation of an algorithm to address the CRTM top-layer Jacobian issue. The implementation does not change the user interface. Expecting that the forward calculations will be more accurate for high peak channels if the user profiles do not reach the level significant for the calculations.

Submitted a paper titled “Validation of the Community Radiative Transfer Model (CRTM) by Using CloudSat Data” by Yong Chen, Fuzhong Weng, Yong Han, Quanhua Liu to the Journal of Geophysical Research. The work summarized in the paper validates the capabilities of the CRTM to simulate cloudy radiances and quantifies the model errors. The achievement is a significant step forward towards cloudy radiance data assimilations.

Training the transmittance coefficients for IASI in OPTRAN, and preparing for IASI assimilation in GSI system.

Applied a Planck-weighted transmittance method in which CRTM regression predicts convolved transmittances that are weighted by the Planck function. The method can significantly reduce the bias and standard deviation for very broad band satellite sensor channel (e.g., METEOSAT SEVIRI 3.8 micro channel) to an acceptable value.

Comparison of the microwave line-by-line models (MonoRTM, Liebe MPM-89/92 model, and Rosenkranz 2003 model) for NOAA-18 AMSUA channels.

ECMWF high resolution infrared sounders (AIRS, IASI) cloud detection algorithm has been tested into GSI. Comparisons have been made between the current GSI cloud detection Algorithm and ECMWFs.

Generating the new MSU transmittance coefficients for corrected frequencies, msu_n06, msu_n07, msu_n08, msu_n09, msu_n10, msu_n11, msu_n12, msu_n14, and msu_tirosn.

Generating the transmittance coefficients for IR sensors on FY3A: iras_fy3a, virr_fy3a, mersiD**_fy3a (** from 01-40), and mersi_fy3a.

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

Validate the CRTM for infrared, and microwave under various atmospheric (clear, and cloudy sky) and surface conditions has been completed (12/2007).

Improvement of the transmittance algorithm in CRTM. Based on our experiences on compact-OPRTAN, OPTRAN-v7, SARTA, RTTOV, OSS and PC-RTM, we believe that we can improve the gas absorption model in CRTM. (11/007-01/2008, 50% work of transmittance algorithm and training software for generating transmittance coefficients has been finished. Since then I have change my primary task to test CRTM in GSI).

Developments of assimilation experiments of IASI and transition into operations are in progress.

4. Leveraging/Payoff:

Validation of CRTM under cloudy condition is directed towards use of satellite radiances affected by cloud and rain.

Identifying clear channels from IASI and AIRS to a high degree of accuracy and yielding significantly more clear data (in the mid to upper troposphere and lower stratosphere) is very important to improve temperature, water vapor profiles in NWP models

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Chen, Y., F. Weng, Y. Han, and Q. Liu (2008), Validation of the Community Radiative Transfer Model (CRTM) by Using CloudSat Data, J. Geophys. Res., doi:10.1029/2007JD009561, in press.

Prasanjit Dash – NESDIS Post Doc

Project Title: An improved SST Product from AVHRR/3 sensor flown onboard MetOp-A

Background: With the advent of newer satellites and satellite based Sea Surface Temperature (SST) Products, the need for quality control and assurance (QC/QA), constant monitoring of SST products, and validate them routinely, is also increased. The post-doctoral research/development contributions towards this end have been focused mainly on developing and automating a comprehensive Global QC/QA Tool (GQT) for the SST products from many different platforms. Along with a sound understanding of the Radiative Transfer Modeling (RTM), also robust statistical methods and their implementation as a comprehensive tool are crucial for this study.

Along with monitoring MetOp-A SST products, the approach is also implemented on products from other platforms and can be adapted to any newer platforms.

Principal Investigator:
Postdoctoral Scientist: Prasanjit Dash
Supervisor : Tom Vonder Haar, CIRA
Principal Technical Advisor: Alexander Ignatov, NESDIS/STAR
Team Members: John Sapper (NESDIS/OSDPD); Xingming Liang, Dilkushi DeAlwis; Feng Xu (postdoc); Y. Kihai; N. Shabanov; B. Petrensko; D. Frey; J. Stroup (contractors); Andy Heidinger (NOAA/Wisconsin)

NOAA Project Goal: Climate; Long-term Environmental Data Record (EDR), primarily Sea Surface Temperature (SST), will be derived, archived, and used for climatic studies, with a proper QC/QA of the products and an objective measurement on a routine basis.

Key Words: Sea Surface Temperature (SST), NOAA/MetOp Satellites, AVHRR, Radiative Transfer Modeling (RTM), Validation and Bias Analysis of RTM, Cloud Detection, Global QC/QA Tool (GQT) for SST, Split Window Technique (SWT)

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

Firmly establish a comprehensive, near real-time QC/QA tool for constant monitoring of SST products from multiple satellites.

Plans:

a. Automate the web-publishing of GQT results for MUT (heritage SST processor) and ACSPO (SST processor).

b. Inter-compare and publish results of satellite SST products against major available global SST. This reference field may be a climatological dataset or it can be a global analysis field derived by assimilating SSTs from various sources, on a uniform grid. The reference blended-analysis SSTs are: weekly Reynolds-Smith OI.v2 SST (Reynolds et al., 2002), two daily Reynolds-Smith OI SSTs (Reynolds et al., 2007), Real Time Global (RTG) low resolution SST (Thiébaux et al., 2003), RTG high resolution SST (Gemmill, Katz, and Li, 2007), Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) SST (Stark et al., 2007), and Ocean Data Analysis System for Mersea (ODYSSEA) SST (Autret and Piollé, 2007), and one climatological reference SST field is Bauer-Robinson 1985 SST. A possible outcome of this work is also to select the most appropriate reference SST and inter-compare the various satellite SSTs (will be considered in future).

Related References

Autret, E., and Piollé, J.-F. (Oct. 2007), ODYSSEA Global SST Analysis - User manual, MERSEA-WP02-IFR-STR-001-1A, CERSAT, IFREMER.

Bauer, R. A. and Robinson, M. K., 1985: Description of the Bauer-Robinson Numerical Atlas. Compass Systems, Inc., 4640 Jewell St., #204, San Diego, CA 92109, 13 pp.

Gemmill, W., Katz, B., and Li, X. (2007). Daily real-time, global sea surface temperature- high-resolution analysis: RTG_SST_HR, NOAA/NCEP. NOAA / NWS / NCEP / MMAB Office Note Nr. 260, 39 pp (available at: http://polar.ncep.noaa.gov/sst/)

Reynolds, R. W., Smith, Liu, Chunying, Chelton, D. B., Casey, K. S., and Schlax, M. G. (2007). Daily high-resolution-blended analyses for sea surface temperature. Journal of Climate, 20, 5473-5496.

Reynolds, R. W., Rayner, N. A., Smith, T. M., Stokes, D. C., and Wang, W. (2002). An improved in situ and satellite SST analysis for climate. Journal of Climate, 15, 1609-1625.

Stark, J. D., Donlon, C. J., Martin, M. J., and McCulloch, M. E. (2007), Oceans '07 IEEE Aberdeen, Marine challenges: coastline to deep sea. 18-22 June, 2007, Aberdeen, Scotland.

Thiébaux, J., Rogers, E., Wang, W., and Katz, B. (2003). A New High-Resolution Blended Real-Time Global Sea Surface Temperature Analysis. Bulletin of the American Meteorological Society, 84, 645-656.

c. Peer-reviewed publication of the same (split into separate parts)

2. Research Accomplishments/Highlights:

a. Completed radiative transfer modeling and Validation of MODTRAN4.2 and established an objective way which can be followed for validating any other RTM

Extensive validation of the MODTRAN4.2 RTM was performed for 3 AVHRR channels onboard five platforms (NOAA-15 through 18 and MetOp-A).
This work sets a major “approach” of validating any RTM, even if the MODTRAN4.2 was chosen for this particular study. It also shows the importance of characterizing the

bias as a function of geophysical variables before an RTM is used for SST purposes. The work includes an "unprecedented" amount of RT Modeling and inter-compared biases for FIVE platforms and THREE channels on a global scale.

b. Global Quality control quality assurance (QC/QA) Tool for SST (GQTv.1)
A robust, flexible, and automated Global QC/QA Tool (GQT) based on statistics was developed in IDL for SST products. It takes input via configuration files UNIX scripts are used for operational purposes (cron jobs).

- GQT is an effective tool for objective monitoring of improvements in newer processor. The tool was also used to extensively compare SST products from newer ACSPO processor and the heritage MUT processors. The analysis results were distributed as an internal document.

Attached is a copy of the Power Point file "ACSPOvsMUT_SST_Comparison". The results show the comparisons of heritage (MUT) vs. newer (ACSPO) SST products, in anomaly space (= satellite SST – weekly Reynolds SST). It includes, histograms, trend-plots (anomaly vs. zenith angle), and animated global anomaly maps for 4 platforms and are separated by day and night.

Results are planned to be automatically published at:
http://www.star.nesdis.noaa.gov/sod/sst/gqt/

Currently, its access has been limited as the website is yet to be stable. (Access can be arranged by writing an email.) Once it's gets stable, we will make it open to www.

Distribution Software is under preparation

c. Comparison of heritage MUT SST products against 8 global reference fields, employing the GQT.

In this work, global reference fields were archived and were appended to multiple years of NESDIS Heritage SST from 4 platforms. After appending of these SSTs, the products were statistically analyzed and were inter-compared.

This is an interesting work for the whole SST community, and an objective measure of the comparisons will prove to be helpful for a number of purposes including monitoring and algorithm development.

Please see the attached "MUTvs8GlobalSST_PDash.doc" document for a sample of results. Figure 1 in this document compares the MUT SST from MetOp-A Platform vs. OSTIA SST (Stark et al., 2007).

The outliers are excluded using a robust standard deviation approach. The robustness of the approach is shown in Figure 2.

The comparison for one week of nighttime satellite SST data against 8 reference fields is shown in Figure 3.

The results are being documented for a peer-reviewed publications (splitted into different parts as there are too many results to be documented in one paper).

3. Comparison of Objectives Vs. Actual Accomplishments:

a. Radiative Transfer Modeling and Validation

Completed validation of MODTRAN4.2 and published in RSE (pdf attached)

b. Quality Control / Quality Assurance Tools

Completed the GQT-v1 and fully automated for heritage MUT system including web-publishing/updating.

c. Analyze products from current MUT system for time-series

Completed analyses of 4 years of data and results are being documented in a GQT papers (splitted to more than one).

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.

5. Research linkages/Partnerships/Collaborators:

Collaborations: CIRA
Partnership: None
Linkages, Communication, Networking: EUMETSAT, some European professional relations for exchange of views and thoughts, extensive discussions with experts from different groups within NOAA (mainly for sensor calibration issues). Referee for few journals (review papers upon invitation).

6. Awards/Honors:

Not during the reporting period

7. Outreach:

Not during the reporting period

8. Publications:

<u>Journal</u>

Dash, Prasanjit and Alexader Ignatov, 2008. Validation of Clear-Sky Radiances over Oceans Simulated with MODTRAN4.2 and Global NCEP GDAS Fields against nighttime NOAA15-18 and MetOp-A AVHRRs. Remote Sensing of Environment , 112 (6) pp. 3012-3029

Conference

Dash, Prasanjit, Alexander Ignatov, John Sapper, Yury Kihai, Alexander Frolov, and Dilkushi de Alwis. Development of a global QC/QA processor for operational NOAA 16-18 and Metop AVHRR SST products. Joint EUMETSAT/AMS Met. Sat. Conf., 23.-28. September, 2007, Amsterdam,. Poster (PDF, 171KB), Extended abstract (PDF, 500KB)

Near-future: GQT-related papers split into parts.

Attachment 1 (Power Point Presentation)

Comparison of ACSPO SST vs. MUT SST

(Please ensure, this document is for internal communication & limited distribution only, as we are still improving on our capabilities and analyses, and only a stable version will be released for public)

Comparisons in anomaly space (satellite SST – Weekly Reynolds SST)

Global Quality Control/Quality Assurance Tool (GQT) Analyses

Prasanjit Dash, Mar-31-2008

Contributions: Dash, Ignatov, Kihai, Sapper
Thanks: XingMing Liang

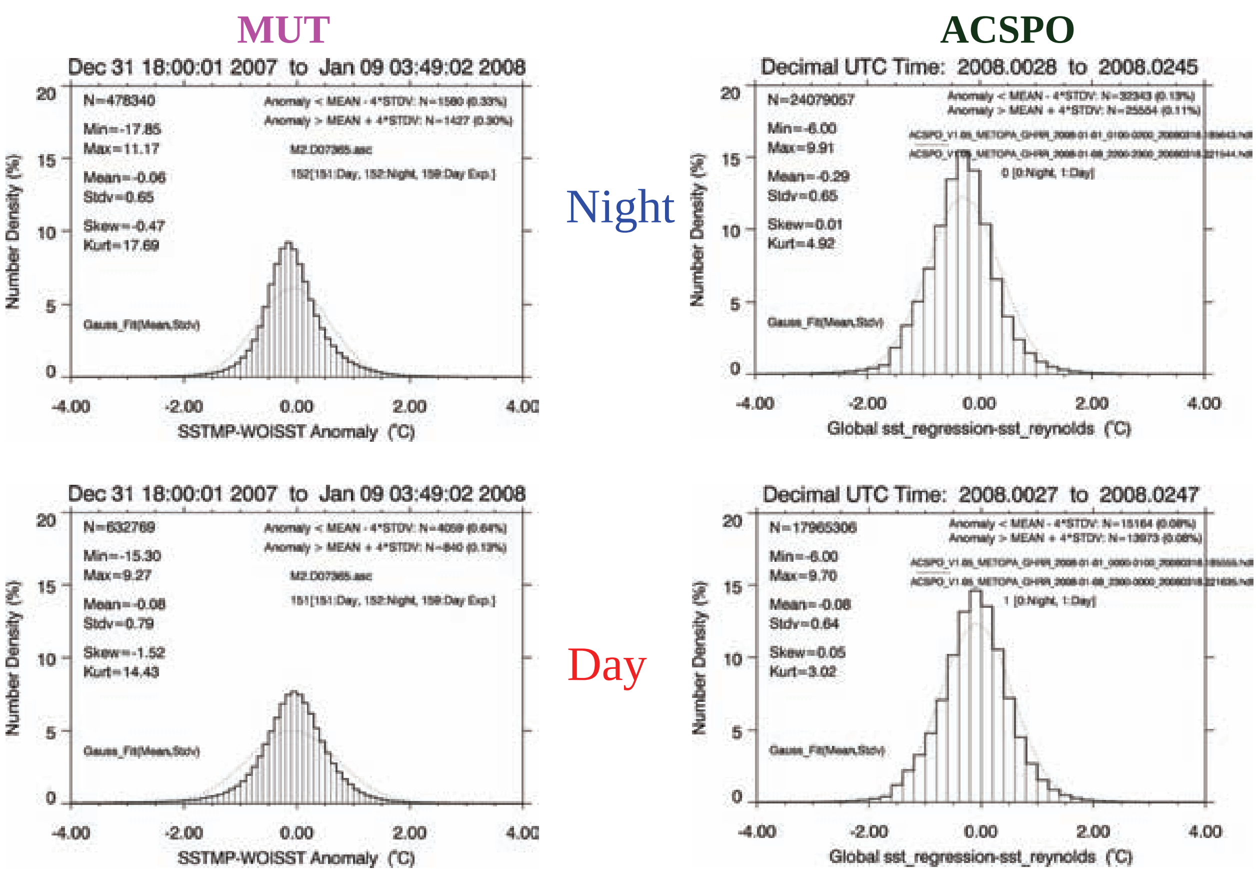
ACSPO SST vs. MUT SST

Comparisons at "Native Resolution: MUT ~8 km, ACSPO ~4 km"

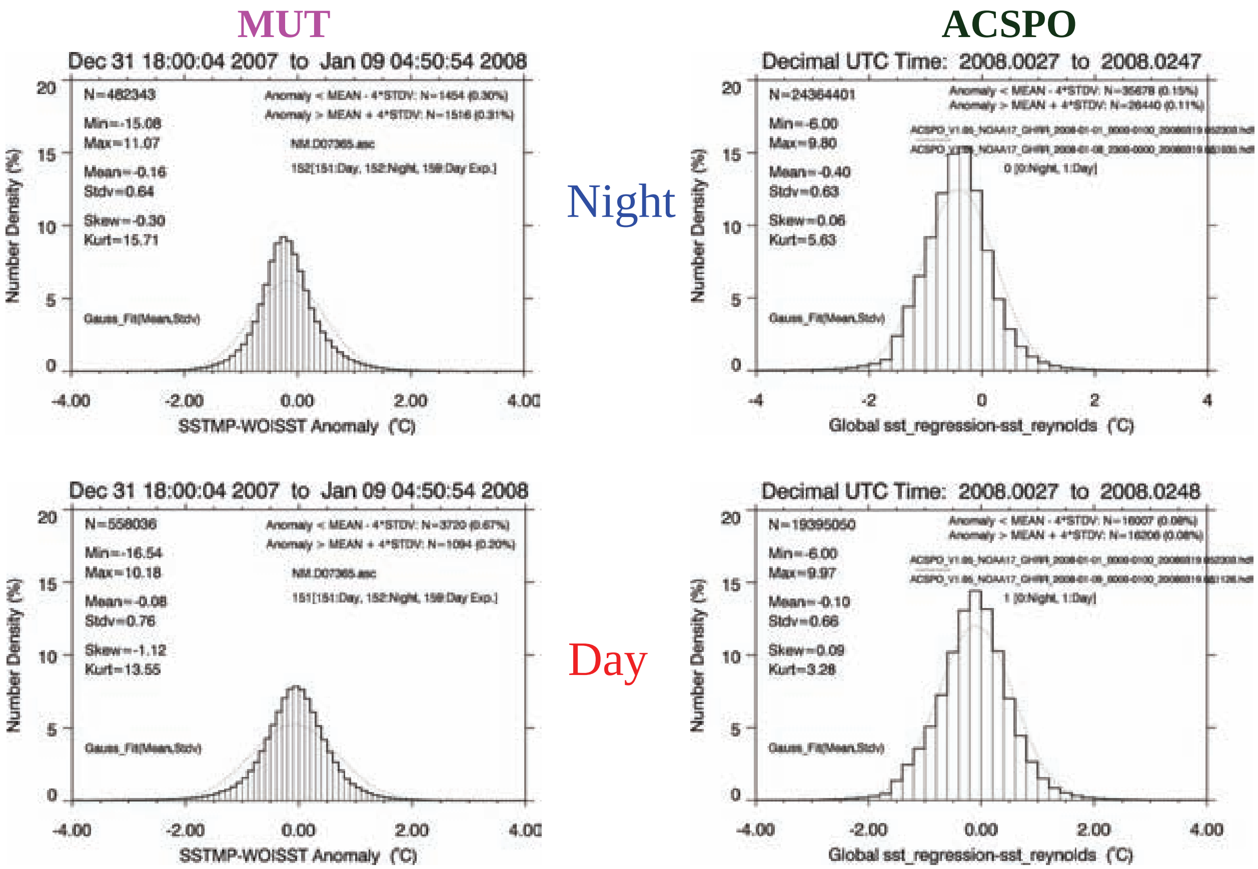
Abbreviations:

SSTMP = SST from heritage MUT system
SST_regression = SST from newer ACSPO processor
WOISST = Weekly Reynold's SST

Anomalies in: Heritage SST vs. ACSPO, MetOp-A



Anomalies in: Heritage SST vs. ACSPO, NOAA-17



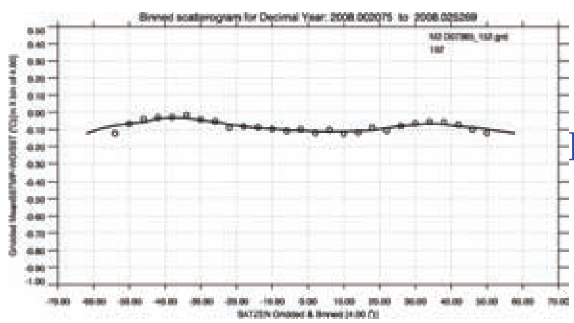
ACSPO SST vs. MUT SST

Comparisons with “Gridded Data: 1 lat x 1

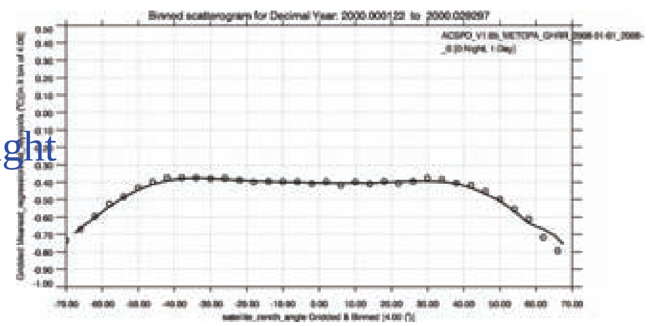
Anomaly as a function of Zenith Angle, MetOp-A

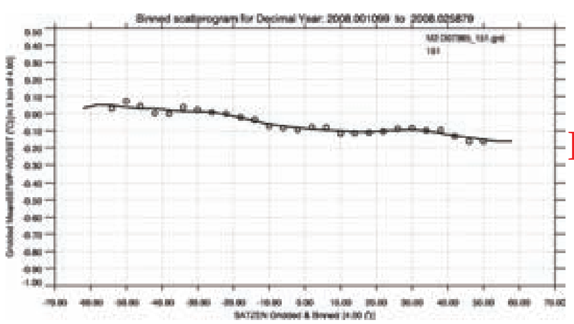
Y-axis: SST anomaly (SST-weekly Reynolds) 0.5 to -1.0 K ; X-axis: Satellite Zenith Angle -70 to 70

MUT **ACSPO**

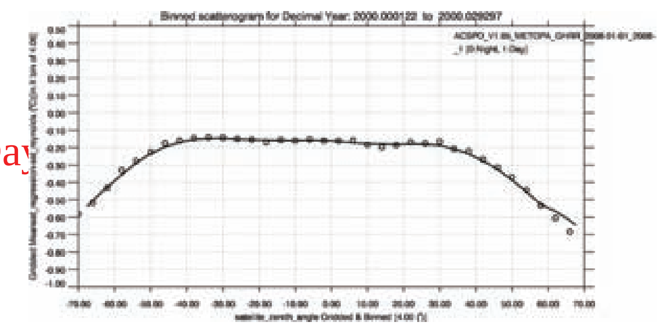


Night



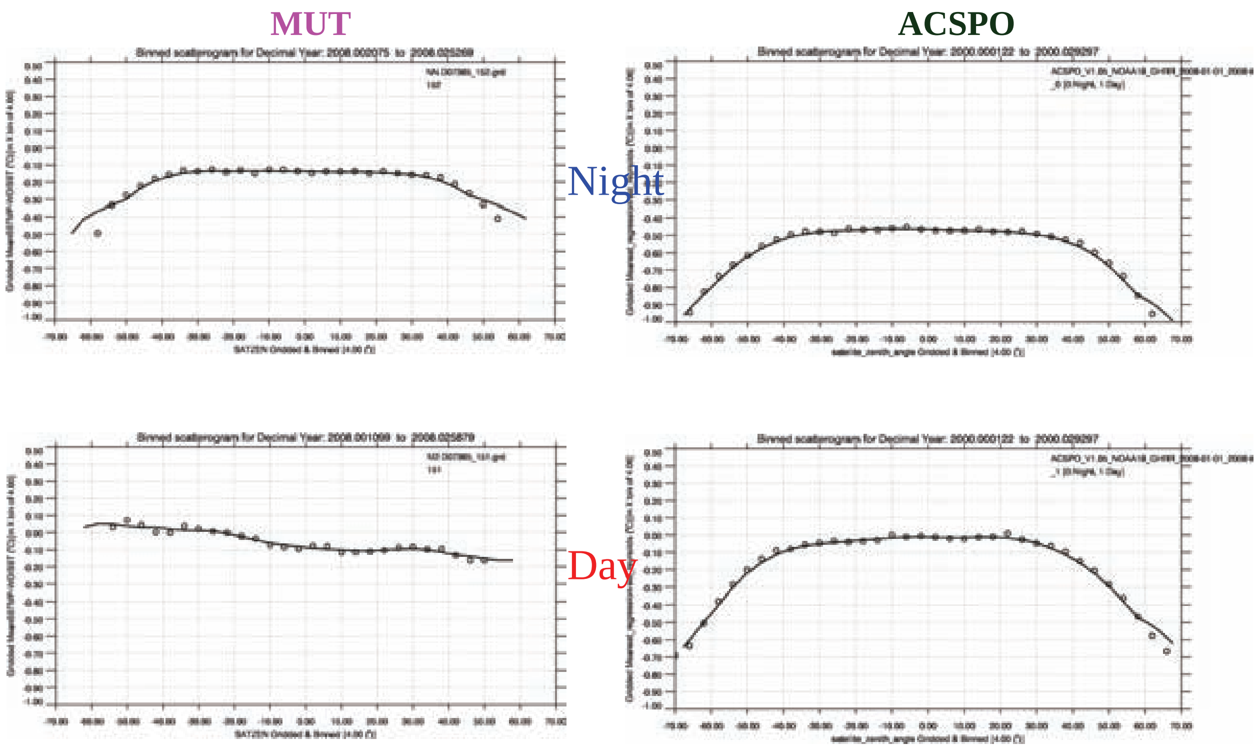


Day



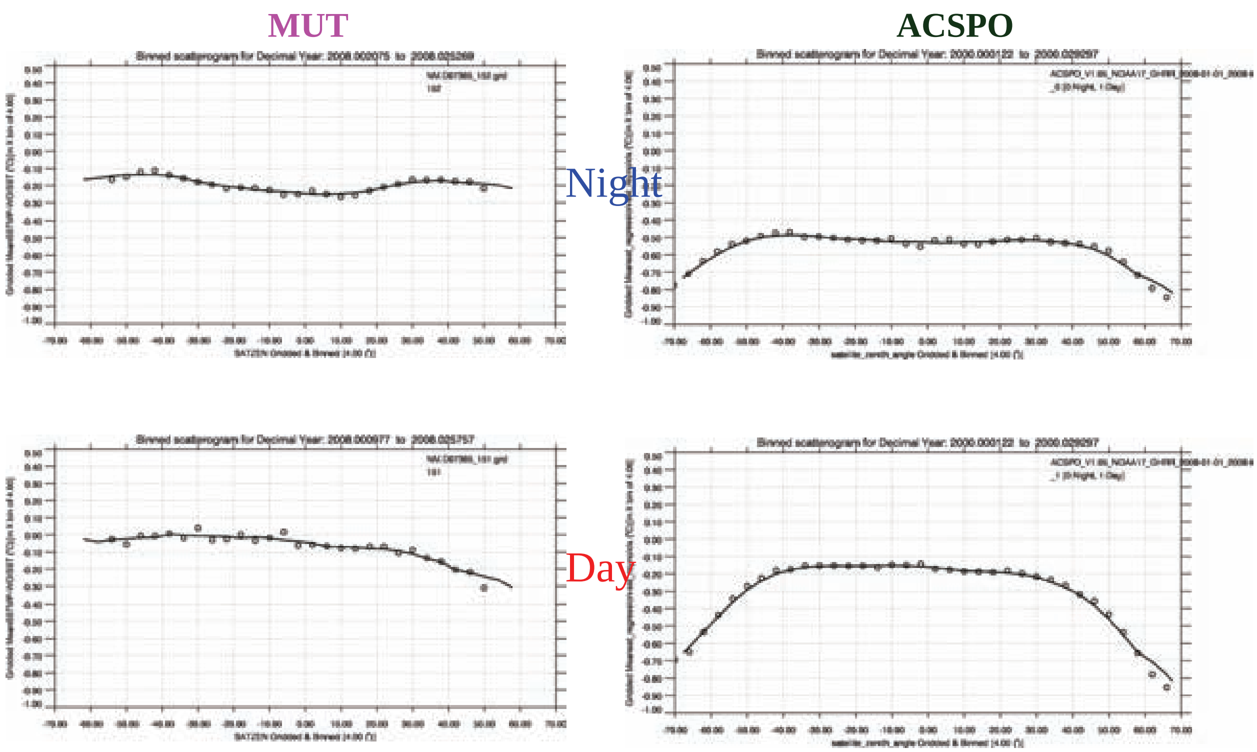
Anomaly as a function of Zenith Angle, NOAA-18

Y-axis: SST anomaly (SST-weekly Reynolds) 0.5 to -1.0 K ; X-axis: Satellite Zenith Angle -70 to 70



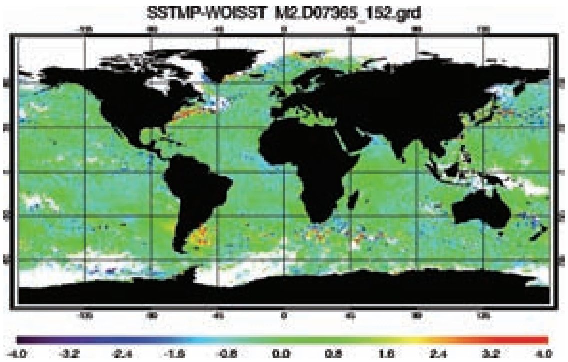
Anomaly as a function of Zenith Angle, NOAA-17

Y-axis: SST anomaly (SST-weekly Reynolds) 0.5 to -1.0 K ; X-axis: Satellite Zenith Angle -70 to 70

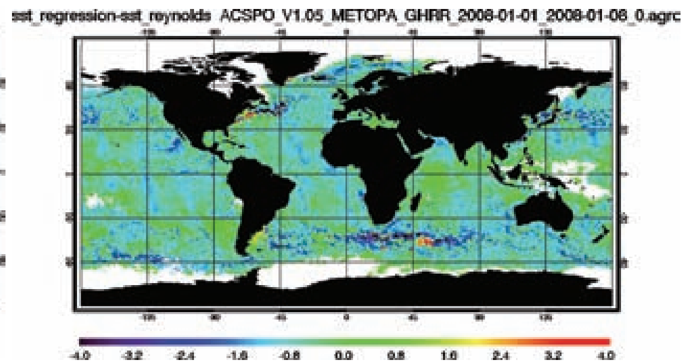


Anomaly Maps, MetOp-A, Night

MUT 8 Days

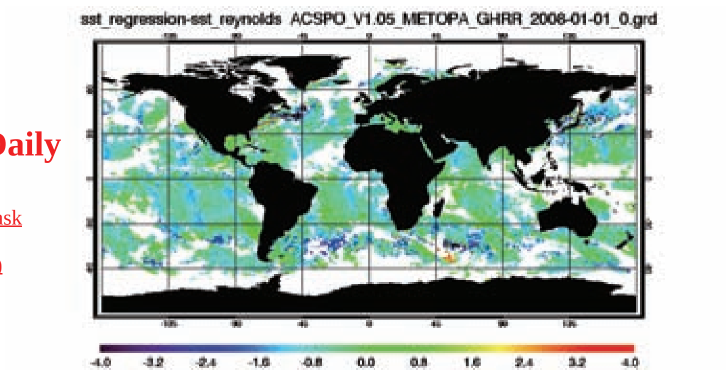


ACSPO 8 Days



ACSPO Daily

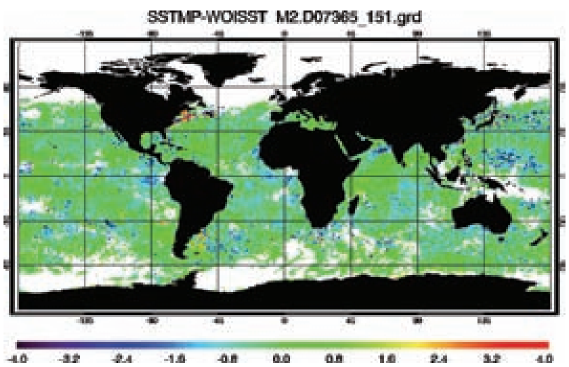
After diagnostics, cloud-mask has been subsequently improved (Boris Petrensko)

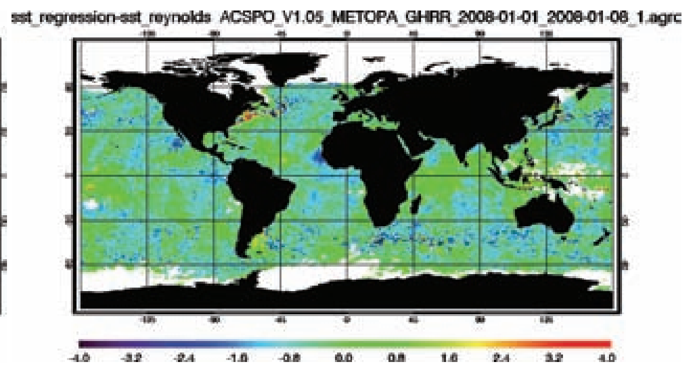


Anomaly Maps, MetOp-A, Day

MUT 8 Days

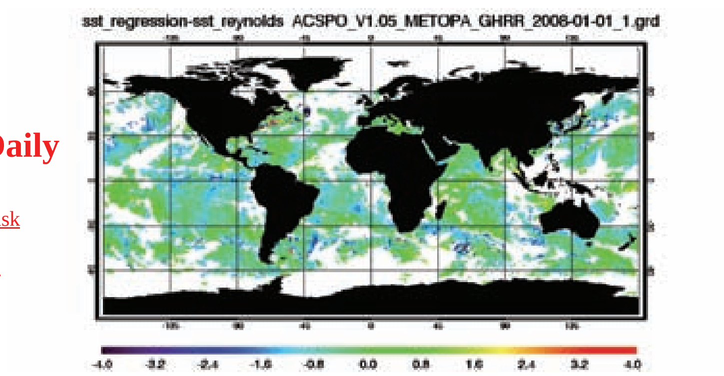
ACSPO 8 Days





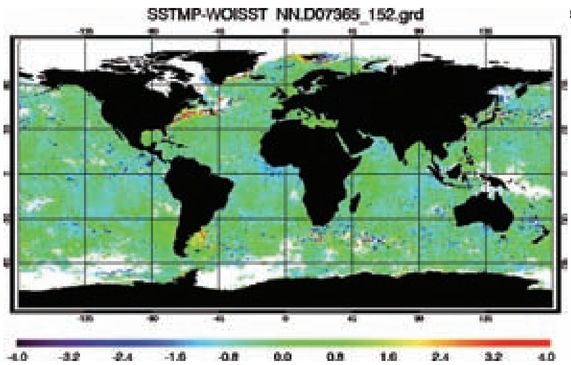
ACSPO Daily

After diagnostics, cloud-mask has been subsequently improved (Boris Petrensko)

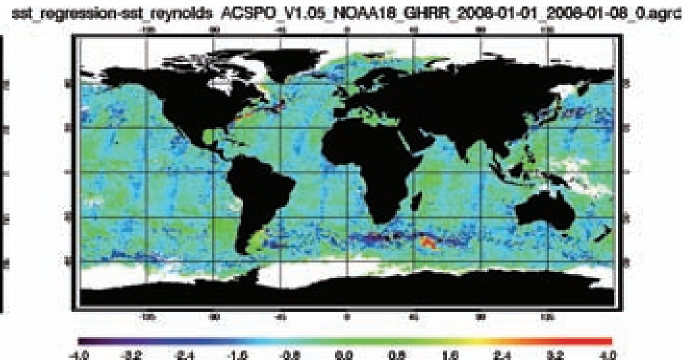


Anomaly Maps, NOAA-18, Night

MUT 8 Days

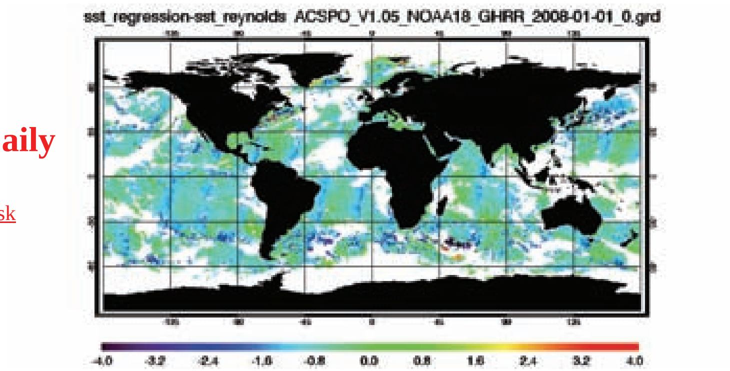


ACSPO 8 Days



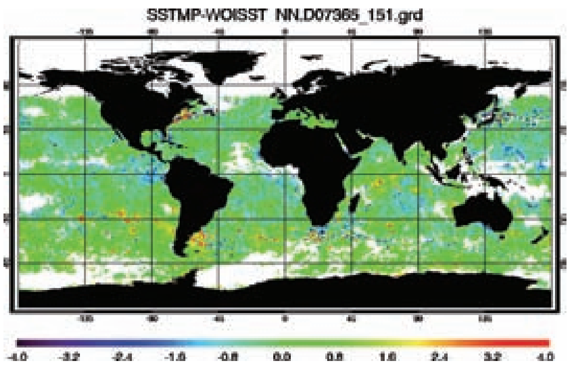
ACSPO Daily

After diagnostics, cloud-mask has been subsequently improved (Boris Petrensko)

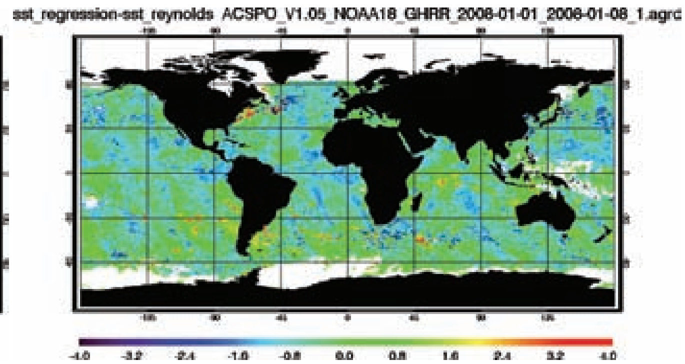


Anomaly Maps, NOAA-18, Day

MUT 8 Days

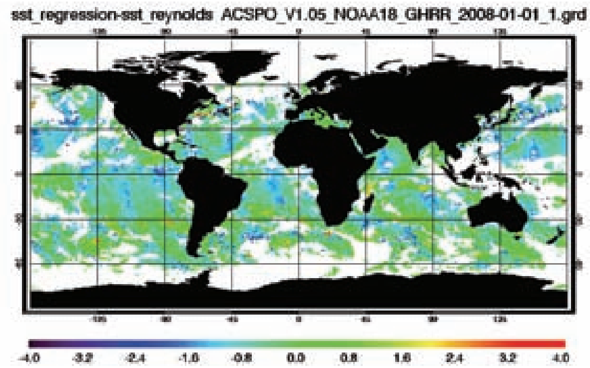


ACSPO 8 Days



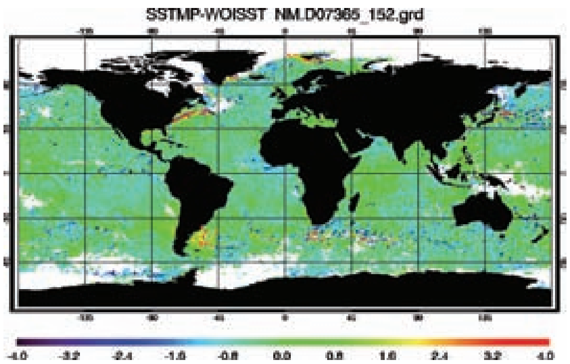
ACSPO Daily

After diagnostics, cloud-mask has been subsequently improved (Boris Petrensko)

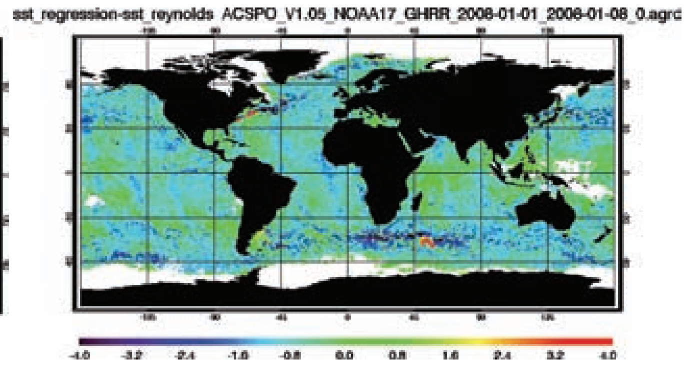


Anomaly Maps, NOAA-17, Night

MUT 8 Days

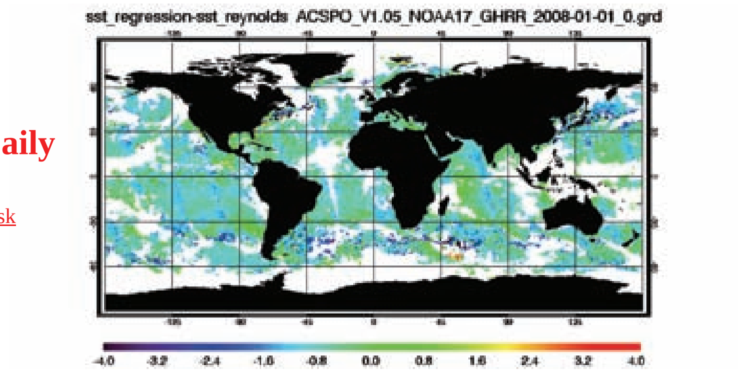


ACSPO 8 Days



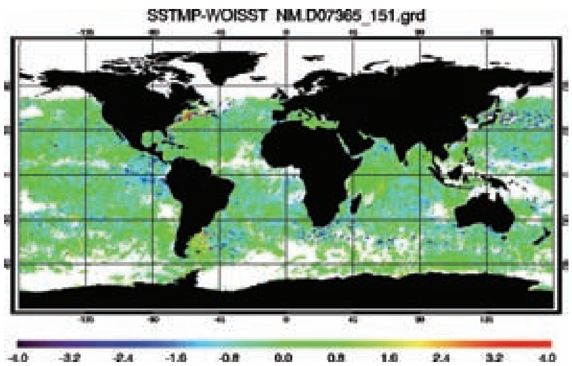
ACSPO Daily

After diagnostics, cloud-mask has been subsequently improved (Boris Petrensko)

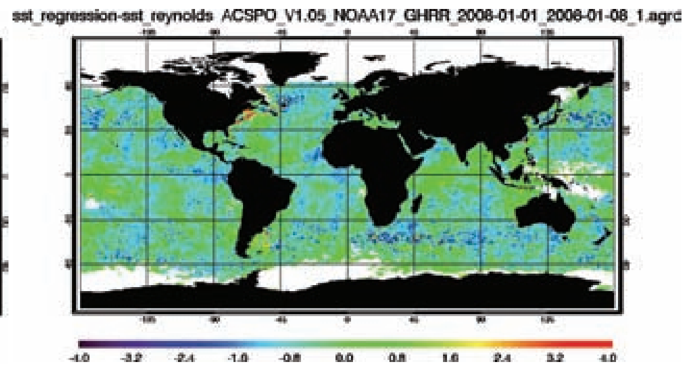


Anomaly Maps, NOAA-17, Day

MUT 8 Days

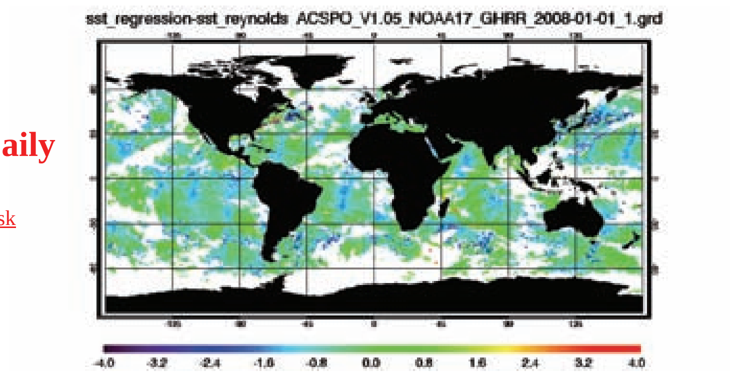


ACSPO 8 Days



ACSPO Daily

After diagnostics, cloud-mask has been subsequently improved (Boris Petrensko)



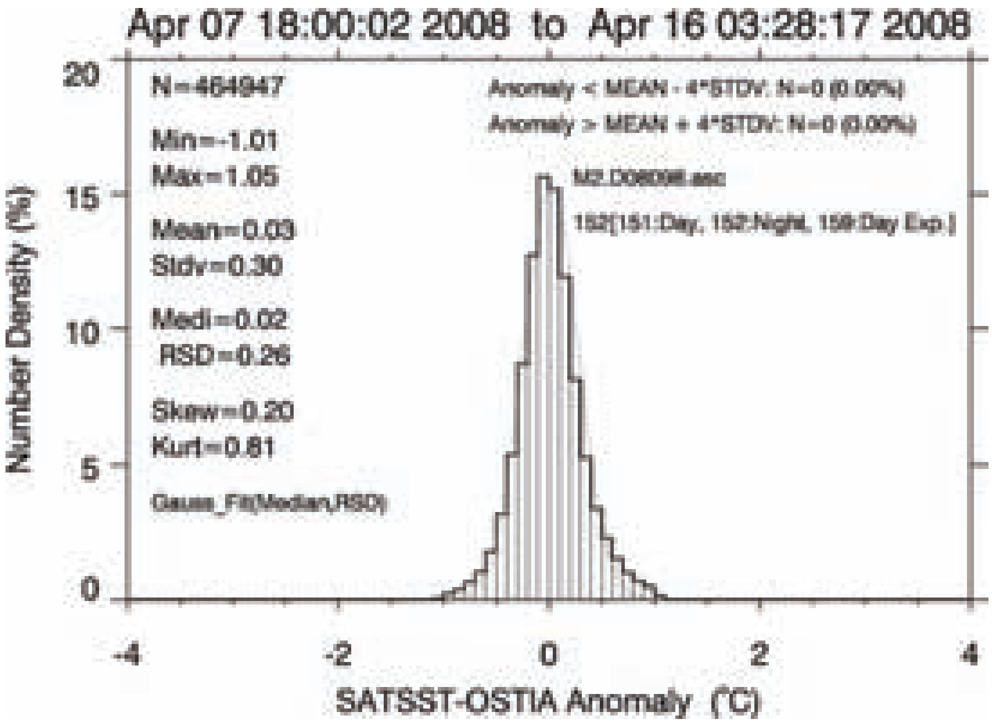
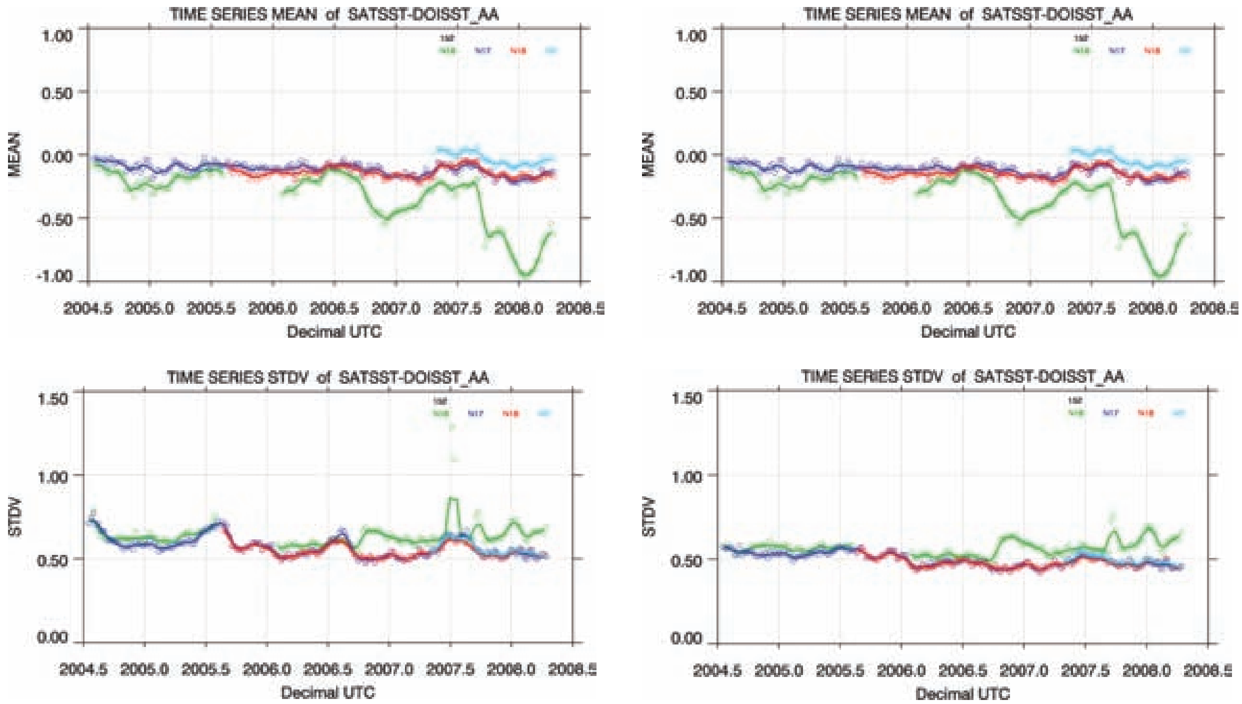


Figure 1. Global anomaly statistics for MetOp-A AVHRR nighttime SST against OSTIA foundation SST. The number of observations (N), minimum anomaly (Min), maximum anomaly (Max), mean of anomaly (Mean), median of anomaly (Medi), standard deviation of anomaly (Stdv), a robust standard deviation of anomaly (RSD), skewness of anomaly (Skew), and kurtosis of anomaly (Kurt) are annotated on the left side of the histogram. An ideal Gaussian fit using median and RSD is over-plotted on the histogram (dotted gray line). The numbers of retrievals beyond ‘Mean 4 Stdv’ are shown on top-right. The name of the SSTOBS file processed is annotated (M2.D08098.asc) which contains platform information (M2 implies MetOp-A and second part is the start day-of-year of 8 day SSTOBS data). Below filename is shown the type (day or night or experimental). The MUT generates SST products for 3 types: day (151), night (152), and an additional experimental (159) type with relaxed cloud-tests. The SSTOBS files contain 8-days’ data and the start and end times are shown on the top of the viewgraph.

The “suspected outliers” are removed using a robust statistics. Note that removing only 8948 observations from a total of 473,895 (~1.9%), reduces the standard deviation by 0.08. Also, the skewness and kurtosis values get closer to an ideal Gaussian distribution. An important observation here is the insensitivity of the robust standard deviation (RSD) to the presence or absence of outliers. More independent analysis showed that the RSD varies to only within a few hundredths of a Kelvin for all the dataset used in this study.

Before removing outliers **After removing outliers**

Conventional central moments (mean and standard deviation)



Robust statistics (median and robust standard deviation)

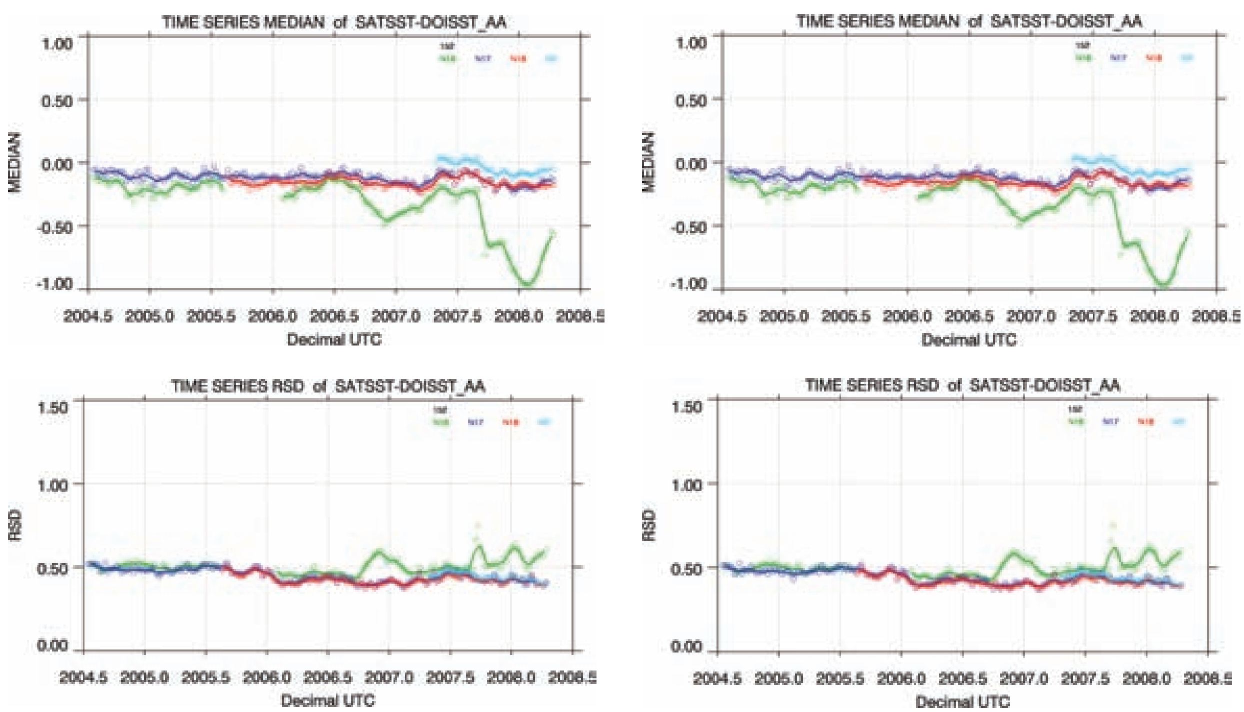


Figure 2. Time-series of daytime SST anomaly mean (first row), standard deviation (second row), median (third row), and robust standard deviation RSD (fourth row), for 4 platforms (NOAA-16: green, …color names), against optimally interpolated SST (Reynolds et al., 2007) based on AVHRR and AMSR. Left panel: outlier removal, Right panel: after outlier removal. Note the insensitivity of RSD to the outliers.

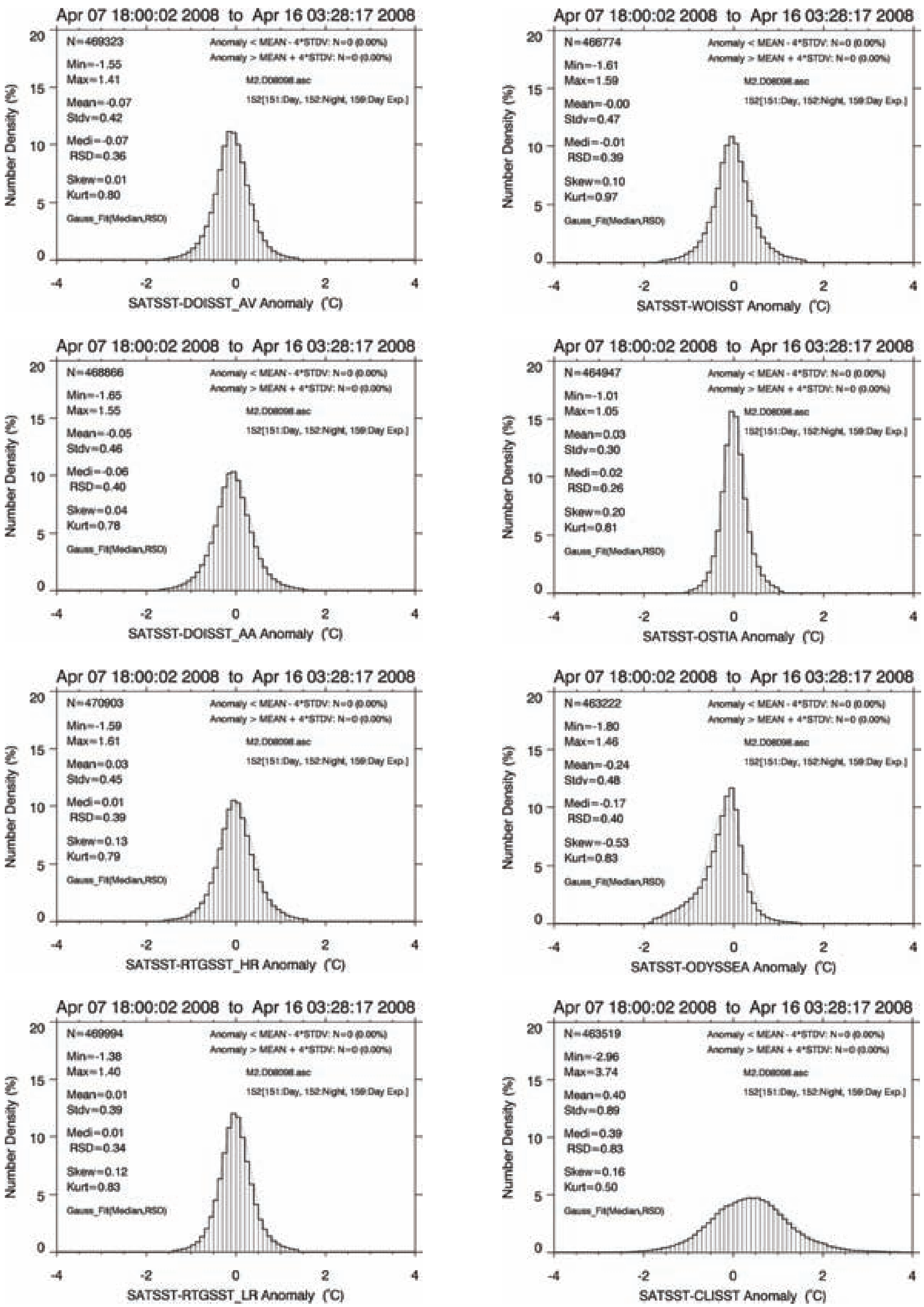


Figure 3. Nighttime global anomaly histograms for MetOp-A AVHRR SST against eight reference states. The statistical parameters described in Figure 1 are annotated after removal of the suspected outliers.

Min-Jeong Kim – NESDIS Post Doc

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 title (2): 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 Objectives and Specific Plans to Achieve Them:

Long-term Objectives:

--Generation of the 2nd version of GOES-R ABI proxy dataset applicable for all sky conditions using the Community Radiative Transfer Model (CRTM)

--Continue to run the GOES-R proxy data management systems

--Developing 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 Objective 1:

--Computing of ABI radiances using mesoscale model and global forecasting model simulations using the latest version of CRTM

--Finding the correlations between SEVIRI and ABI measurements

--Generating the ABI proxy dataset from SEVIRI observations

To accomplish Objective 2:

--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 Objective 3:

--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 Objective 4:

--Employing the AMSU-A and SSMIS in the OSSE tests

--Assessments the impacts of cloudy microwave radiance assimilation

To accomplish Objective 5:

--Employing the ABI proxy datasets in the OSSE tests

--Assessments of GOES-R impacts

2. Research Accomplishments/highlights:

The beta version of GOES-R proxy data has been produced. By employing the CRTM, radiances have been simulated for thermal ABI channels and MSG SEVIRI channels in cloudy atmosphere. Conversion coefficients from SEVIRI data to ABI channels have been calculated and provided to GOES-R proxy data application teams.

I set up and updated the monthly report template in Microsoft Word format and the project progress sheet in Microsoft Excel format which were requested by the GOES-R Program Office. I have been updating the status of project progress using these forms and send them to the GOES-R program office.

Although numerical model forecasts are often sensitive to initial conditions in regions with cloud and precipitation occurrence, NCEP has been assimilating only cloud cleared radiances in GSI analysis system. I have been building cloudy radiance assimilation components in GSI system.

1) I set up the codes to add cloud water mixing ratio as the additional analysis variables in the GSI.

2) I set up to compute cloudy radiances and Jacobians with CRTM in GSI.

3) I built the tangent linear models for cloudy radiances assimilations in the GSI.

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

Objective 1: Generation of the GOES-R ABI proxy dataset applicable for all sky conditions using the Community Radiative Transfer Model (CRTM)

In progress (Completed for ABI thermal channels. Under quality control for ABI solar channels.)

Objective 2: Set up the GOES-R proxy data management systems

Completed

Objective 3: Developing the cloudy radiance data assimilation system for NOAA operational forecasting models

In progress

Objective 4: Impact assessments for microwave cloudy radiance assimilation in NCEP GDAS

In progress

Objective 5: 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:

Oral presentation entitled “The Inclusion of Cloudy Radiance Assimilation in NCEP GDAS” at the 16th International TOVS Study Conference (ITSC)

8. Publications:

Kim, Min-Jeong , J.A. Weinman, W. Olson, D. Chang, G. Skofronick-Jackson, and J.R. Wang), 2008: A physical model to estimate snowfall over land using AMSU-B observations. *J. Geophy. Res.* 113, D09201, doi:10.1029/2007JD008589, 2008

Skofronick-Jacson, G., A. Heymsfield, E. Holthaus, Cerese Albers, and Min-Jeong Kim, 2008: Nonspherical and spherical characterization of ice in Hurricane Erin for wideband passive microwave comparisons, *J. Geophy. Res.* 113, D06201, doi:10.1029/2007JD008866, 2008

XingMing Liang – NESDIS Post Doc

Project Title: Physical SST Retrieval for NOAA/AVHRR, GOES-R/ABI

Principal Investigator: Alexander Ignatov

NOAA Project Goal: Climate; Long-term Environmental Data Record (EDR)-primarily Sea Surface Temperature (SST) will be derived, archived, and used for climate studies

Key Words: Sea Surface Temperature (SST), GOES-R, ABI, AVHRR, Radiative Transfer Model (RTM), Cloud Mask (CM), QC/QA Tools for SST, Physical SST Retrieval.

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.

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

Physical SST retrieval is used to retrieve SST using inverse method based on radiative transfer model (RTM). It can be used to more intuitively evaluate SST performance with respect to geophysical and environment parameters than the regression SST technique. Physical SST technique also has been discussed and studied in many previous works. However, it is well known that regression SST retrieval (SWT) has been operational as a NOAA SST robust product from 1970, while physical SST retrieval still lacks in research and operational implementations. It is due to complicated nature and ineffective implementation speed of RTMs. With the advent of more accurate and effective RTMs, such as Community Radiative Transfer Model (CRTM), RTTOV and so on, developing robust, high effective and accurate global physical SST product will become possible and crucial.

On physical SST retrieval, validation of Top of Atmosphere (TOA) clear-sky Brightness Temperature (BT) between the RTM simulated (so-called, forward RTM) and observation is a key requirement. It comprises of 1) validation of key parameters influence on ‘Model minus Observation’ (M-O) bias, 2) clear-sky condition, 3) input data quality control and 4) sea surface emissivity model assumption. In our plan, clear-sky check is made using the ACSPO cloud-detection algorithms which is based on the

Clouds from AVHRR Extended (CLAVR-x). We firstly emphasize evaluation of the bias and anomaly for forward RTM and concentrate on validation of key parameters for physical SST retrieval, such as sensor view angle, column water vapor, sea surface temperature, latitude dependence of (M-O) bias. Global climate data input, such as NCEP (National Centers for Environmental Prediction) -GFS (Global Forecast System), ECMWF (European Center for Medium range Weather Forecasting), NCEP ANALYSIS and so on, with different format and spatial resolution, should be carefully selected and quality-controlled to avoid high anomaly in forward RTM. Sea surface emissivity model has been discussed for several decades in previous works, but using the Fresnel's model and flat surface assumption only generated 0.1K bias, as discussed by Watts (1996), provides confidence to use a simply emissivity model.

When a robust, accurate and highly-effective forward RTM is obtained, physical SST retrieval will be implemented and extended to other sensors.

Objective:

Develop Physical SST retrieval product and extend them to other IR sensor.

Plan:

Select a highly accurate and effective radiative transfer model (RTM) for physical SST retrieval, such as MODTRAN, CRTM, RTTOV and so on. Develop effective Quality Control/Quality Assurance tools for evaluation of RTM performance.

Incorporate RTM into AVHRR (Advanced Very High Resolution Radiometer) Clear-Sky Processor for Oceans (ACSPO). Validate clear sky RTM brightness temperature against AVHRR with respect to key parameters for physical SST retrieval, such as sensor view angle, column water vapor, sea surface temperature, latitude, and evaluate RTM performance and sensor behaviors.

Control data quality of air and sea surface temperature inputs to reduce anomaly of RTM BT. Consider different data on forward RTM, such as NCEP-GFS, ECMWF, NCEP-ANALYSIS data and so on.

Validate sea surface emissivity model on forward RTM. Evaluate band-integrated emissivities against the "exact" solution of the radiative transfer equation.

Compare different forward RTM against AVHRR to make sure the selected RTM effective and accurate.

Complete testing and document for CRTM/AVHRR validation on ACSPO.

Update and test new ACSPO version toward improvement of ACSPO clear-sky mask and CRTM clear-sky radiance, and computational efficiency for ACSPO.

Develop a website of near real-time processing, to monitor the long-time performance of ACSPO.

Develop Initial physical SST retrieval product. Make physical SST retrieval from all individual bands.

Validate single-channel SST retrievals against Regression-SST, REYNOLD-SST and so on.

Enhance robustness and accuracy of physical SST retrieval product. Explore blending of physical and regression algorithms for improved SST performance.

Extend physical SST retrieval for ABI/GOES-R, SEVIRI/MSG or other IR sensors.

Current project:

Document peer-publication of validation CRTM/AVHRR on ACSPO. (in progress)

Develop a website of real-time processing for ACSPO. (in progress)

Update current ACSPO version to: 1) speed up CRTM running time, 2) integrate the newest CRTM (V1.1) into ACSPO, 3) provide accurate Jacobian parameter from CRTM for clear-sky mask, and 4) replace Weekly-SST with Daily-SST as input to CRTM in ACSPO. (yet to be started)

2. Research Accomplishments/Highlights:

Update ACSPO beta version 1.0 to 1.02, to replace NCEP SST with weekly Reynolds SST as CRTM input (Figure 1), and replace radiative transfer equation with Taylor expansion to interpolate the simulated brightness temperature from 1º (1º latitude x 1º longitude) to 1 pixel. (Developed by FORTRAN9-9.5, Compilers are INTER FORTRAN) (complete)

Participated AMS meeting 2008 in New Orleans, and submitted the extend abstract of the paper about CRTM/AVHRR validation. (complete)

Created an initial web page (http://www.orbit.nesdis.noaa.gov/sod/sst/xliang/) to show time series dependence of M-O bias with respect to column water vapor, view zenith angle, wind speed, SST, sea-air temperature difference and latitude. (Developed by Dreamwaver 8.0 and Javascript) (complete)

Tested out every ACSPO beta versions (Ver0.75 to Ver1.06, Figure 2, 3) using the QA/QC tools, which was described at last annual report. (Developed by IDL6.4) (complete)

Worked towards finishing peer-reviewed publication on CRTM/AVHRR implementation and validation (Title: Validation of the Community Radiative Transfer Model (CRTM) against AVHRR Clear-Sky Processor for Oceans (ACSPO) Nighttime Radiances for Improved Cloud Detection, Monitoring Clear-sky Radiances and Physical SST retrievals) (in progress)

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

None as yet

4. Leveraging/Payoff:

None as yet

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Conference/Symposium

Ignatov, Alexander, Prasanjit Dash and XingMing Liang, "Validation of Clear-Sky Radiances over Oceans for SST and Aerosol retrievals", Annual GOES-R AWG Conference, 14-16 May, 2007.

Liang, XingMing, Alexander Ignatov, Yury Kihai, Andrew Heidinger, Yong Han, Yong Chen, "Validation of the Community Radiative Transfer Model (CRTM) against AVHRR Clear-Sky Processor for Oceans (ACSPO) Nighttime Radiances for Improved Cloud Detection and Physical SST Retrievals", 5th GOES Users' Conference, 88th AMS Annual Meeting (http://ams.confex.com/ams/88Annual/techprogram/paper_128705.htm). 20-24 January, 2008.

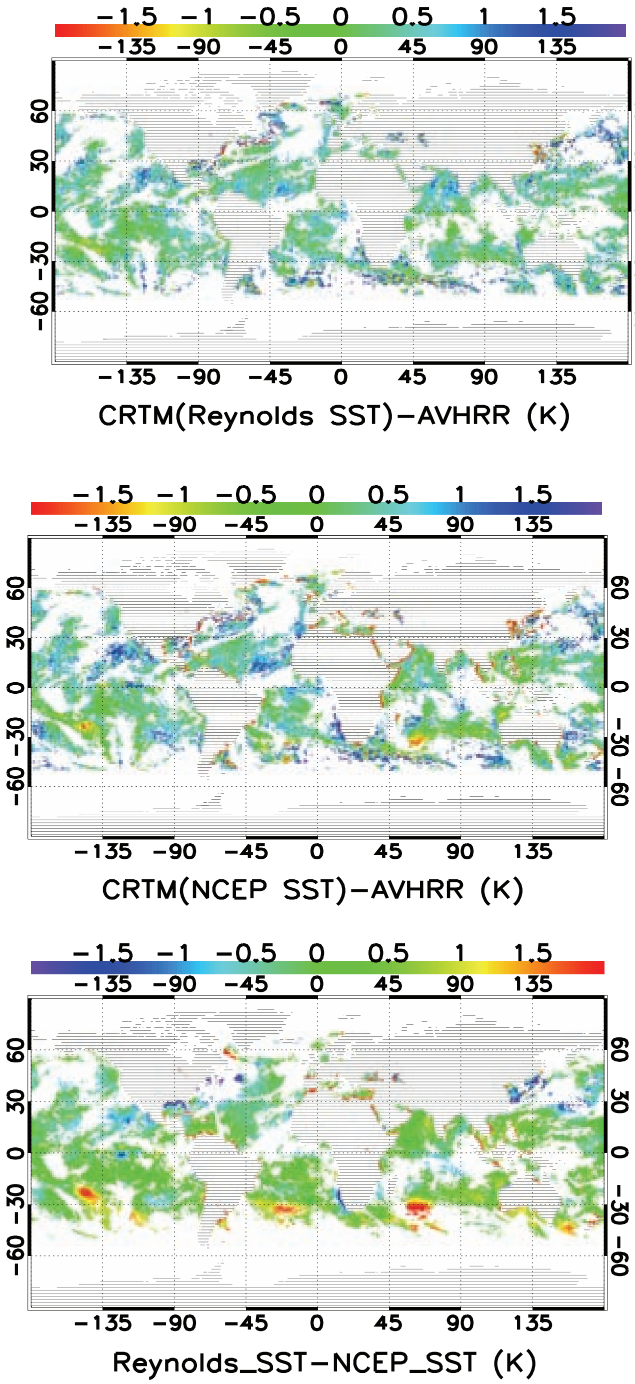


Figure 1. Global distribution of the M-O bias in NOAA18-Ch3B, and corresponding SST differences for one day of 18 February 2007. (Top) Reynolds-SST; (Middle) NCEP-SST used as input to CRTM; (Bottom) corresponding Reynolds and NCEP SST differences. Note read contouring around the continental coastal lines in the middle and down panels.

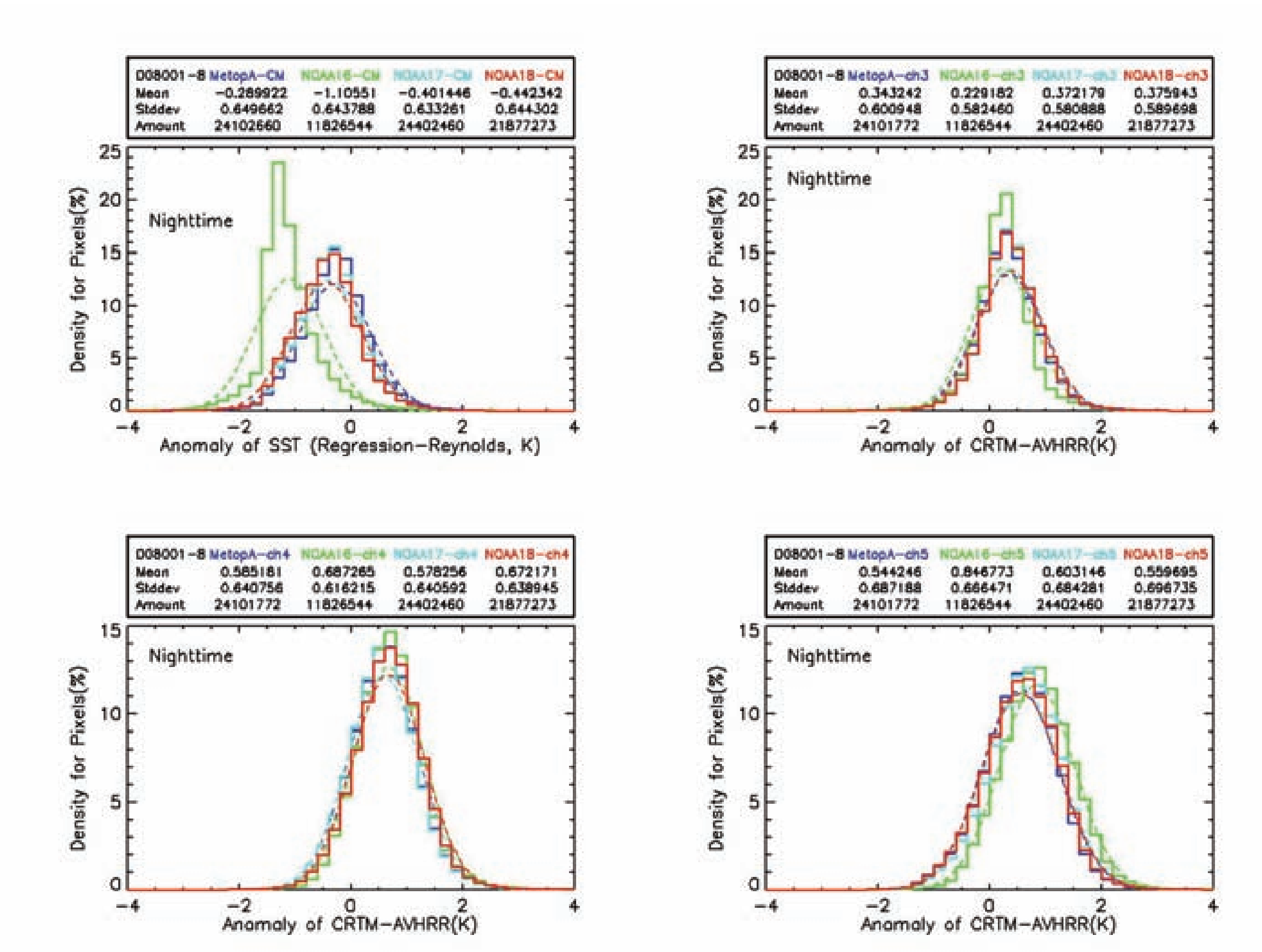


Figure 2. Global histograms of the M-O bias for the Week of 1-8 January 2008 using ACSPO beta ver 1.06

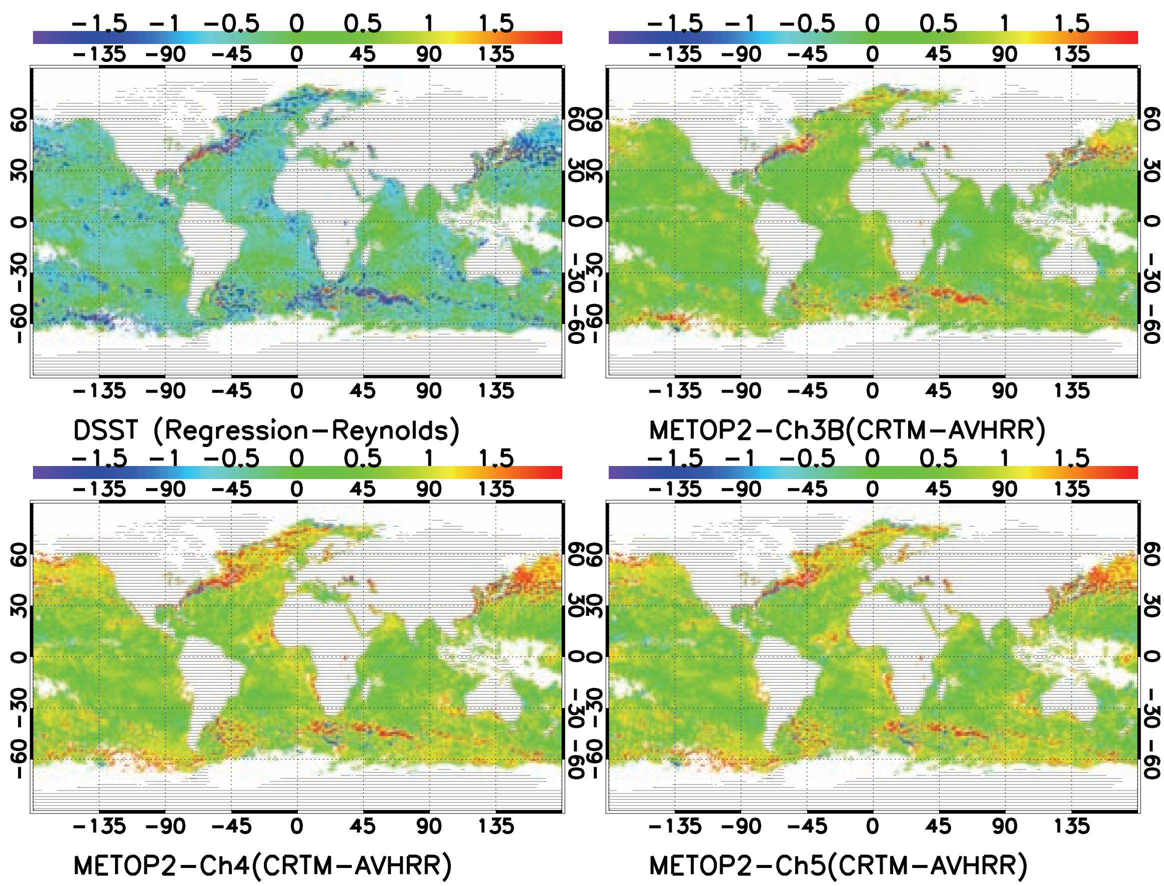


Figure 3. Global distribution of the M-O bias for MetopA, corresponding to Figure 1

Dilkushi de Alwis Pitts – NESDIS Post Doc

Project Title: Improve the Climate Observations and Analysis by Enhancing the Accuracy of the Calibration/Validation System with Scientifically Grounded Quality Control Criteria

Principal Investigator/s:
Postdoctoral Scientist Dr. Dilkushi de Alwis, (NESDIS/CIRA)
Supervisor Prof. Steven D. Miller, (CIRA)
Principal Technical Advisor Dr. Alexander Ignatov, (NESDIS/STAR)
Team Members Mr. John Sapper (NESDIS/OSDPD); Dr. Bill Pichel (NESDIS); Mr. Yury Kihai (QSS contractors); Dr. Prasanjit Dash (NESDIS/CIRA); Dr. Nikolay Shabanov (QSS contractors); Dr. Xingming Liang (NESDIS/CIRA); Dr. Boris Petrenko (QSS contractors); Dr. Feng Xu (NESDIS/CIRA)

NOAA Project Goal: Climate - Analysis of outlier removal approaches for quality control of AVHRR sea surface temperature global matchup datasets for a better Calibration/Validation system

Key Words: Sea Surface Temperature (SST), MetOp, AVHRR, Calibration/Validation of SST Products, QC/QA tools for SST, Outlier Analysis, SEVIRI

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

Objective 1: Understand, document and replicate the heritage Cal/Val system

Plans:
Publication

Objective 2: Design a Cal/Val system to be executed in an operational mode to run in parallel to the heritage system

Plans:
a. After thorough evaluation of the pre-operational mode algorithm and presentation of the results at the quarterly Cal/Val meetings, promote the research mode code to operational mode.

b. Integrate an automated outlier mapping tool

Objective 3: Obtain global statistics pertaining to spatial/temporal variability

Plans:
Evaluate spatial and temporal statistics pertaining to satellite, *in situ* and ancillary parameters.

Objective 4: Screen *in situ* data at global scale to identify malfunctioning buoys prior to the integration of the system

Plans:
a. Create spatiotemporal matchup files
b. Explore global QC/QA analyses of *in situ* data and implement into regular processing stream
c. Publish on web in an automated way

Objective 5: Calculate satellite coefficients for the newly launched MetOp satellite

Plans:
Use matchup data to obtain the operational coefficients

Objective 6: Calculate satellite coefficients for SEVIRI

Plans:
Use matchup data to obtain the operational coefficients

Objective 7: Calculate satellite coefficients for MetOp processed through the ACSPO system

Objective 8: Use eigenvector decomposition to replace the regression method to obtain day- and nighttime SST coefficients.

Objective 9: Matchup daily Reynolds data with the heritage binary matchup files.

Objective 10: Conduct quarterly Cal/Val meetings

Plans:
Organize quarterly meetings and brain storming sessions. Present and discuss results.

Objective 11: Calculate Calibration and Validation statistics for the ACSPO system

2. Research Accomplishments/Highlights:

a. Designing a fully automated system for Cal/Val.
A fully automated system for Cal/Val was designed to run in parallel to the heritage system. Outlier maps and monthly histograms and animations were added as a part of the output system.

b. Quality controlling the *in situ* data using reference fields namely, low and high resolution RTGs, weekly & daily Reynolds, OSTIA (Operational Sea Surface Temperature and Sea Ice Analysis) and ODYSSEA.

The work conducted so far has suggested that the *in situ* data contain most of the contamination that has impacted the overall validation statistics. Hence screening *in* *situ* data at a global scale to identify malfunctioning buoys prior to the integration of the system is advantageous. In order to screen the data, seven types of reference analysis daily/weekly SST fields (namely low and high resolution RTG, Weekly Reynolds, Daily Reynolds -AVHRR, Daily Reynolds-AMSER, OSTIA and ODYSEA) were matched spatiotemporally to the 12 hr *in situ* data fields. The reference data were at different spatial and temporal resolution, which made the spatiotemporal matching challenging. Shown in Figures 1 and 2 are the anomaly statistics of the *in situ* temperature - Daily Reynolds AVHRR SST and OSTIA analysis SST. The screened in situ data will be integrated to the ACSPO system.

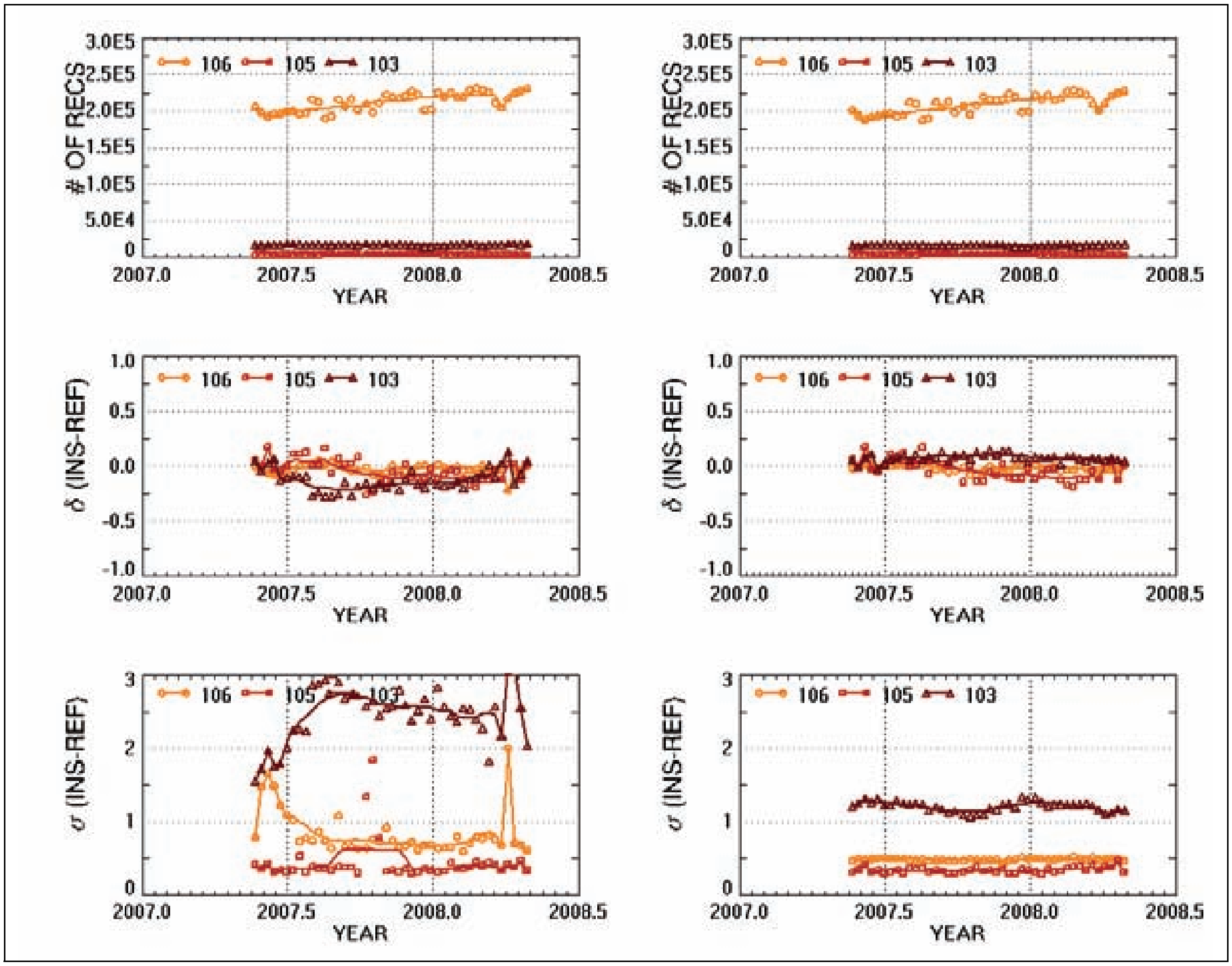


Figure 1: Number of Records, Mean and RMSD of the time series of *in situ* temperature –daily Reynolds AVHRR SST anomaly of drifters, moored buoys and ships (denoted by orange (106), red (105) and brown (103)). The left panel shows all data before any quality control steps and the right panel shows the statistics after outlier removal. Each point on the graph represents an 8-day average.

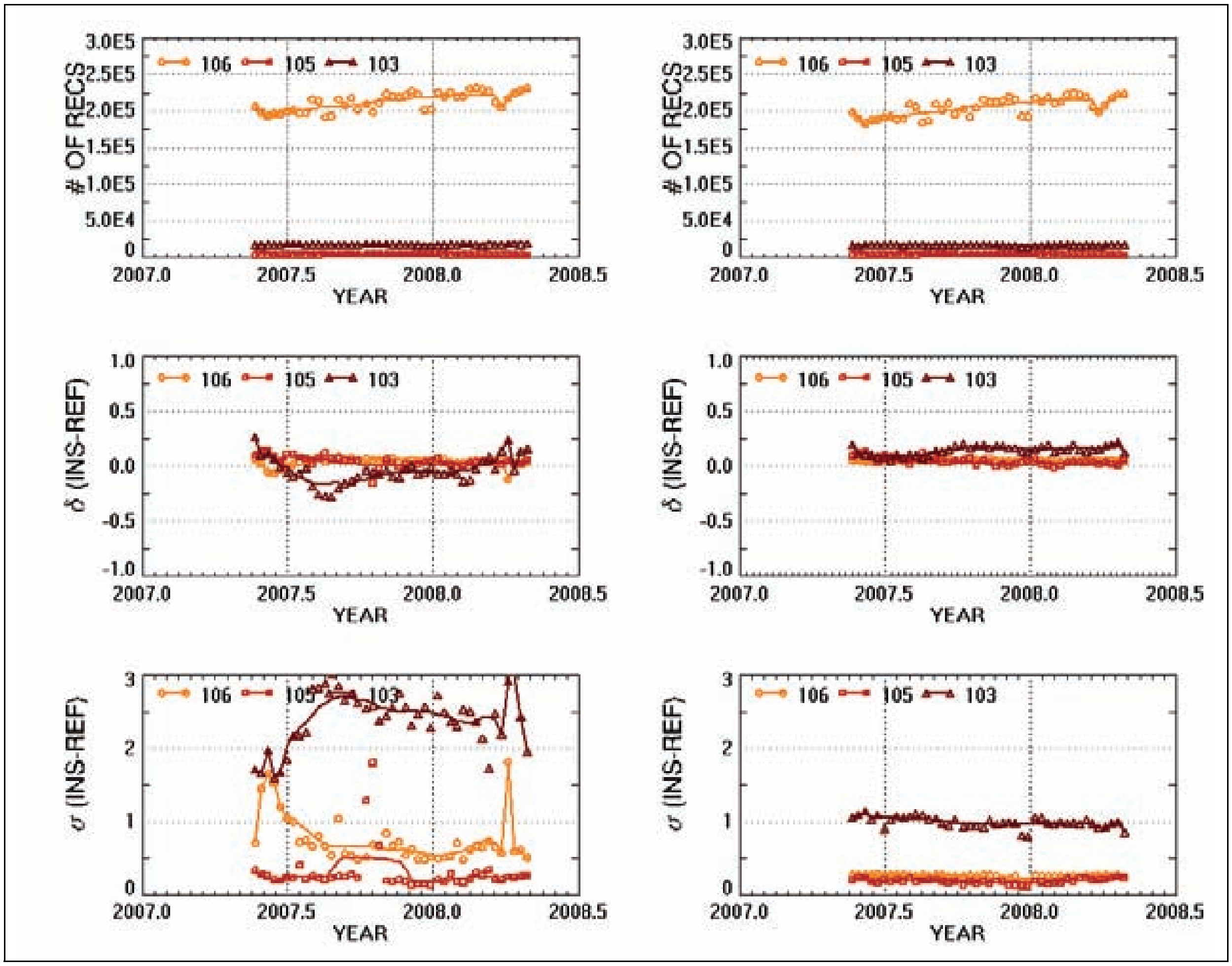


Figure 2: Number of Records, Mean and RMSD of time series of in situ temperature – daily OSTIA analysis SST anomaly of drifters, moored buoys and ships (denoted by orange (106), red (105) and brown (103)). The left panel shows all data before any quality control steps and the right panel shows the statistics after outlier removal. Each point on the graph represents an 8-day average.

c. Calculation of day- and nighttime SST coefficients for the newly launched MetOp-A satellite.

The satellite was launched in 2007.

Day NLSST Split

Day NLSST Split: A1*T4 + A2*Tsfc*(T4-T5) + A3*(T4-T5)*(sec( )-1)+A4

Coefficients:

A1= 0.945995

A2= 0.0839104

A3= 1.01458

A4= -256.746

MCSST Triple
Night MCSST triple window A1*T4+A2*T3+A3*T5+A4*(T3-T5)*(sec( )-1)+A5*(sec( )-1)+A6
Coefficients:
A1= 0.297975
A2= 1.21294
A3= -0.505499
A4= 0.108667
A5= 1.52873
A6= -273.205

Where T3, T4 and T5 are the equivalent blackbody temperatures in Kelvin for the AVHRR 3, 4 and 5 channels (3.7, 11 and 12 µm), respectively, T_{sfc} is the SST derived from the closest NESDIS global field analyzed 100km SST. Field value is in degrees Celsius; is the satellite zenith angle; the calculated SST is in degrees Celsius; only T_{sfc} pertaining to values less than 28 C is considered.

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

Objective 1: Understand, document and replicate the heritage Cal/Val system

Currently editing of the first draft of the peer reviewed publication is in progress. Overview of the NESDIS heritage AVHRR Sea Surface Temperature Calibration/Validation system. Dilkushi de Alwis, Alexander Ignatov, John Sapper, William Pichel, Prasanjit Dash, Yury Kihai, Xiaofeng Li

Objective 2: Design a Cal/Val system to be executed in an operational mode to run in parallel to the heritage system

Completed.

At present quality controlling of the *in situ* data are added to the system.

Objective 3: Obtain global statistics pertaining to spatial/temporal variability

Not yet started

Objective 4: Screen *in situ* data at global scale to identify malfunctioning buoys prior to the integration of the system

70% complete. Need to integrate it to the system and publish the results on the web.

Objective 5: Calculate satellite coefficients for the newly launched MetOp satellite

Completed

Objective 6: Calculate satellite coefficients for SEVIRI

Several sets of coefficients were calculated using different cloud masks. An iterative approach is being explored.

Objective 7: Calculate satellite coefficients for MetOp processed through the ACSPO system

Not yet started.

Objective 8: The use of eigenvector decomposition to replace the regression method to obtain day and night time SST coefficients.

Data from the SEVIRI sensor were used to build some case studies to explore the possibility of eigenvector decomposition to calculate the SST coefficients. Work in progress

Objective 9: Matchup daily Reynolds data with the heritage binary matchup files.

Daily Reynolds Analysis SST are being added to the heritage binary matchup files to be used for quality control of the heritage Cal/Val system. 30% of the work is complete.

Objective 10: Conduct quarterly Cal/Val meetings

One cal/val quarterly meeting/brain storming session was organized.

4. Leveraging/Payoff:

To understand the global temperature patterns, predict changes in the pattern and quantify their effects, conserve and manage marine resources by providing proper input to global and local models.

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Conference/Symposium

Dash, Prasanjit, Alexander Ignatov, John Sapper, Yury Kihai, Alexander Frolov, and Dilkushi de Alwis. Development of a global QC/QA processor for operational NOAA 16-18 and Metop AVHRR SST products. Amsterdam,. Joint EUMETSAT/AMS Met. Sat. Conf., 23.-28. September, 2007.

de Alwis, Dilkushi, Alexander Ignatov, John Sapper, Prasanjit Dash, William Pichel, Yury Kihai and Xiaofeng Li. Overview of the NESDIS heritage AVHRR Sea Surface Temperature Calibration/Validation system. [AMS Conference, New Orleans, 20-24 January 2008. Fifth GOES users' conference]

Journal

Planned Titles:

Analysis of outlier removal approaches for quality control of AVHRR sea surface temperature global matchup datasets. Dilkushi de Alwis, Prasanjit Dash, Alexander Ignatov [*Journal undecided, MS sent to the technical advisor for reviewing (4:11:2008).*]

Overview of the NESDIS heritage AVHRR Sea Surface Temperature Calibration/Validation system. Dilkushi de Alwis, Alexander Ignatov, John Sapper, William Pichel, Prasanjit Dash, Yury Kihai, Xiaofeng Li [*Journal undecided, First draft submitted to the technical advisor and I am working on the edits.*]

NESDIS Post Doc Wei Shi

Project Title: Ocean Color Algorithm Development and Application.

Principal Investigator: 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:

The SWIR atmospheric correction algorithm developed by Wang and Shi for ocean color remote sensing has extensive application in the coastal regions and inland waters. This algorithm has been demonstrated to be able to derive an accurate coastal bio-optical product; and it greatly enhances our ability to monitor the physical, geochemical and biological processes in the coastal region

3. Comparison of Objectives Vs. Actual Accomplishments:

4. Leveraging/Payoff:

The algorithm developed by Wang and Shi has extensive application in monitoring the coastal and inland water ecosystem; a specific example is demonstrated in an *EOS* feature article published on May 27, 2008 (see publication list).

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications (2007-Present)

Liu, X., M. Wang and W. Shi, A Study of a Hurricane Katrina-Induced Phytoplankton Bloom Using Satellite Observations and Model Simulations, Journal of Geophysical Research, (in review).

Shi W. and M. Wang, Three dimensional observation of Cyclone Nargis-induced sediment re-suspension with MODIS and CALIPSO, (in review).

Shi W. and M. Wang, An Assessment of the Ocean Black Pixel Assumption for the MODIS SWIR Bands, Appl. Opt. (in review).

Shi W. and M. Wang, Observations of Hurricane Katrina-Induced Phytoplankton Bloom in the Gulf of Mexico, Geophysical Research Letter, V. 34, L11607, doi: 10.1029/2007GL029724, 2007.

Shi, W. and Wang, M., Detecting turbid waters and absorbing aerosols for the MODIS Ocean Color Data Processing in the Coastal Regions, Remote Sensing of Environment, 110, 149-162, doi: 10.1016/j.rse.2007.02.013, 2007.

Wang, M. and W. Shi, Satellite observed blue-green algae blooms in China's Lake Taihu, EOS, Transaction, AGU, 2008.

Wang, M. and W. Shi, The NIR-SWIR combined atmospheric correction approach for MODIS ocean color data processing, Optics Express, V. 15, Issue 24, 15722 – 15733, 2007.

Wang, M., S. Son and W. Shi, A Validation Study for the SWIR and NIR-SWIR Atmospheric Correction Algorithm Using SeaBASS Data, Remote Sensing of Environment (in review).

Wang, M, J. Tang and W. Shi, Ocean color Products in the China East Coast Regions Derived From MODIS Measurements, Geophysical Research Letter, V. 34, L06611, doi:10.1029/2006GL028599, 2007.

Feng Xu – NESDIS Post Doc

Project Title: GOES-R

Principal Investigator: Alexander Ignatov

NOAA Project Goal: Geostationary Satellite Acquisition

Key Words: Sea Surface Temperature, Error Characterization, Skin/Bulk

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

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)

Optimized regression SST in ACSPO

Objective: Improved, more accurate regression SST in ACSPO

Plan: Fit Reynolds SST with NLSST/MCSST equations, compare with heritage calibration; Stratify regression by retrieval space (angle, water vapor, ambient cloud); Fit analytical curves to coefficients as a function of angle, water vapor; Inspect Day/Time continuity

Skin/Bulk SST

Objective: Two SST Products in ACSPO: Skin and Bulk

Plan: Begin with simpler nighttime case where Skin/Bulk difference = f (wind speed); Move on to more complex cases (low winds at night; using NCEP fluxes during day)

2. Research Accomplishments/Highlights:

Began employment on February 11, 2008. Have been working on SST error characterization. SST error behaviors have been under observation and patterns of SST bias-mean vs. retrieval conditions were concluded. Analytic formulas are used to describe SST bias varying along retrieval parameters.

A simplified statistic model is constructed to describe the problem of SST error characterization. Methods are devised in order to automatically and accurately analyze the complicated error behaviors in the multi-dimensional retrieval space.

Couplings between different factors (dimensions-of-retrieval-space) are automatically identified via the Fisher-Test of the goodness-of-fit of two fit functions with different degrees of freedom. Another iterative method is used to fit error-characteristics surface in 2D coupled retrieval space.

So far, analyses have been performed on ACSPO product of 3 platforms, i.e. MetOp-A, NOAA-17, NOAA-18, during three different one-week time periods, but in the tropic zone only, due to the different characteristics of different zones. It is found that different platforms have different error characteristics, but they seem stable in different time periods.

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

SST error characterization is in progress and will be extended to global scope and full analysis (including 2nd-3rd moment statistics and the distribution of SST error).

Optimized SST is yet to be started after finish error characterization.

Reading of Skin/Bulk literatures is in progress. Skin/Bulk modeling is not yet started.

4. Leveraging/Payoff:

SST error characterization is useful in 5 aspects which all lead to improvement of accuracy and quality of SST product. All SST data users would be benefited:

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)

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

NESDIS Post Doc Hao Zhang

Project Title: Evaluating Sun-glitter Models Using MODIS Imageries

Principal Investigator: Dr. Menghua Wang (CIRA technical advisor)

NOAA Project Goal:

Key Words: Satellite Remote Sensing, Ocean Color, Sun Glint

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

For ocean color sensors that do not have a glitter-tilting functionality such as MODIS Aqua, sun glint contaminated area would significantly effect ocean products retrievals. In past years the ocean color community has been using the Cox-Munk model without wind direction dependence as the glint masking criteria. Our goal is to first evaluate the performances of different sun-glint models and then replace the current model with the one having better performance, if any, and perform atmospheric corrections over the newly-masked the region and evaluate the results.

2. Research Accomplishments/Highlights:

By comparing MODIS measurements with different sun-glitter models we have found that the Cox-Munk models with a wind direction dependence (anisotropic models) has higher correlations with the Cox-Munk model that does not have a wind direction dependence (isotropic model). Now we are in the process of replacing the isotropic model with the anisotropic ones in glint-contaminated region masking in atmospheric corrections.

3. Comparison of Objectives Vs. Actual Accomplishments:

Work in progress, manuscript to be submitted to refereed journal (Applied Optics).

4. Leveraging/Payoff:

Once completed, this aerosol retrieval algorithm may be implemented to operational ocean color products retrieval.

5. Research Linkages/Partnerships/Collaborators: N/A

6. Awards/Honors: None

7. Outreach: None

8. Publications: In preparation.

NPOESS APPLICATIONS TO TROPICAL CYCLONE ANALYSIS AND FORECASTING

Principal Investigator: Renate Brummer

NOAA Project Goal: Weather and Water

Key Words: NPOESS, VIIRS, ATMS, CrIS

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

The long term research objectives of this project are to assess the utility of NPOESS instruments for tropical cyclone applications. Proxy data from currently available satellites and synthetic data from mesoscale and radiative transfer models are being used for this purpose. The primary emphasis is to develop tropical cyclone applications for the imager (VIIRS), and sounders (ATMS and CrIS).

2. Research Accomplishments/Highlights:

The NPOESS Applications to Tropical Cyclone Analysis and Forecasting reseach can be split into three categories: A) Proxy Datasets, B) Impact of VIIRS on the Dvorak intensity estimation algorithm, and C) Hurricane Analysis from ATMS/CrIS retrievals. Accomplishments in each of these areas are listed below. A manuscript is in preparation describing the results from this project.

(A) Proxy Datasets

Two large NPOESS proxy datasets have been created as part of this project, as described below.

AIRS/AMSU retrievals (proxy for ATMS/CrIS) from the AIRS Science Team were collected in the environment of 11 tropical cyclones for which in situ soundings from the NOAA Gulfstream Jet were also available for ground truth. Table 1 summarizes this dataset.

Table 1. Number of cases with matching AIRS and NOAA Gulfstream Jet soundings

Storm Name	Year	No. of Matching Sounding
Lili	2002	158
Fabian	2003	24
Isabel	2003	94
Ivan	2004	145
Emily	2005	43
Irene	2005	37
Katrina	2005	138
Ophelia	2005	81
Rita	2005	52
Wilma	2005	88
Total	02-05	860

Figure 1 depicts an example of NOAA aircraft mission dropsonde data collected during a mission flown in the area of tropical cyclone Ophelia on September 10, 2005 (1800 UTC) and the matching AIRS data granule (Surface Skin and 700mb Temperature).
.

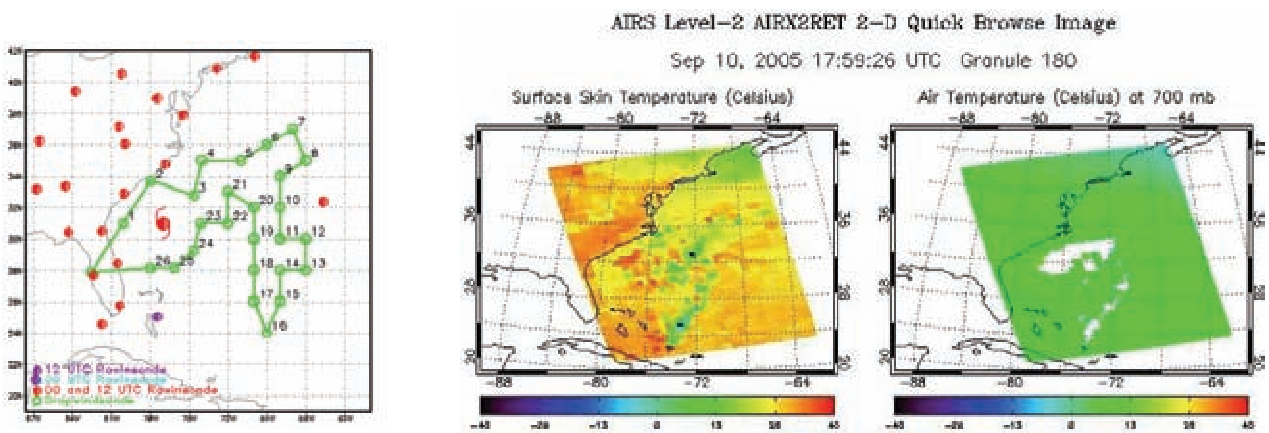


Figure 1. Ophelia 09/10/05 1800 UTC: Dropsonde location and AIRS Surface Skin and 700mb Temperature

This NPOESS proxy dataset is being used to evaluate potential improvements to the analysis of the storm environment and its relationship to forecasting tropical cyclone intensity changes using ATMS/CrIS. Soundings in hurricane eyes are also being used to test a potential new method for estimating tropical cyclone intensity.

Full resolution MODIS and AVHRR window channel imagery (proxy for VIIRS) were collected for about 400 cases. The dataset can be seen at http://rammb.cira.colostate.edu/projects/awg/data.html.

(B) Impact of VIIRS on the Dvorak Intensity Estimation Algorithm

The VIIRS proxy dataset described above was used in a study of the impact of resolution on the Dvorak intensity estimation technique. The resolution of the 1 km data was degraded to that of GOES (4 km) and next generation GOES (2 km) for comparison. Results show that the impact of resolution is small in most cases, but can be large for storms with small eyes and where the scene type in the Dvorak method is ambiguous.

(C) Hurricane Analysis from ATMS/CrIS retrievals

A method to estimate tropical cyclone wind structure from temperature and moisture retrievals was evaluated using AMSU temperature retrievals as a proxy for ATMS/CrIS. The basic idea is that the temperature and moisture soundings can be used as input to the hydrostatic equation and then vertically integrated to provide the geopotential height field on a constant pressure surface. Then the nonlinear balance equation can be used to estimate the winds. For the hurricane applications, the satellite soundings are integrated downward to 850 hPa and the wind field is derived. Surface winds are estimated by a surface reduction technique, based on statistical properties from the NOAA GPS wind soundings near tropical cyclones.

This algorithm is now being run in real time using AMSU temperature retrievals for all tropical cyclones around the globe. These are being made available to forecasters at the National Hurricane Center in Miami and the Joint Typhoon Warning Center in Honolulu via a CIRA webpage (see http://rammb.cira.colostate.edu/products/tc_realtime/). Work has begun to generalize this method to include retrievals from AMSU/IASI and MetOp.

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

All primary objectives of this research have been accomplished.

4. Leveraging/Payoff:

What NPOESS will receive for resources invested is:

Advanced product development,

Extended operational use of the satellite

Greater utilization of NPOESS data for tropical cyclone analysis

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

Our research linkages include:

Coordinating with CIMSS on the development of proxy datasets and the NCEP Tropical Prediction Center on possible operational applications

6. Awards/Honors: None as yet

7. Outreach:

(a) One college undergraduate and two graduate students were supported by this project (Greg DeMaria, Rebecca Mazur, Robert DeMaria).
(b) See section 8
(c) None
(d) None
(e) A website was developed to illustrate the utility of NPOESS with proxy data

8. Publications:

<u>Conference Proceedings /Presentations</u>

M. DeMaria, R. DeMaria, D. Hillger and R. Mazur, 2008: Tropical Cyclone Applications of NPOESS Soundings, *4th Annual Symposium on Future National Operational Environmental Satellite Systems*, 22-24 January 2008, New Orleans, Louisiana.

POES-GOES BLENDED HYDROMETEOROLOGICAL PRODUCTS

Principal Investigator: Stanley Q. Kidder

NOAA Project Goal: Weather and Water

Key Words: AMSU, SSM/I, GPS, GOES, Total Precipitable Water (TPW), Blended Product

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. Currently, a global blended TPW product is created at CIRA hourly from AMSU and SSM/I, and a 6-hourly product using inputs from GPS and GOES Sounder is created to show the moisture field over land. The product has received great support from NOAA forecasters and is particularly useful for model verification, flood forecasting, and tracking tropical waves. This work will move the processing from CIRA to the NOAA NSOF facility to become an operational product. An experimental TPW anomaly product is also created to highlight exceptionally moist and dry regions, and this product will be made operational as well.

Specific objectives are:

(A) Mar 08: Static test data file provided to NWS/AWIPS (OB9.x)

(B) Jun 08: Preliminary Design Review

(C) Sep 08: Critical Design Review

(D) Oct 08: Code is prepared for implementation

(E) Jan 09: Code transitions to operations; all documentation is complete

(F) Jan 09: Brief SPSRB that capability is ready to be operational

2. Research Accomplishments/Highlights:

The merged TPW and accompanying TPW anomaly product developed at CIRA currently uses 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 websites http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw are routinely accessed by NWS forecasters and demand to make these products fully operational have spurred this technology transition effort. 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.

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

Complete: Objective A (above).

Complete: Demonstration at CIRA and automatic generation of products with update of websites.

Complete: CIRA newsletter article (Spring 2008) on the products and their uses.

In Progress: Objectives B−F (above).

In Progress: Delivery of new Data Processing and Error Analysis System (DPEAS) build to NOAA, containing updates of satellite inputs (NOAA-18 and MetOp), and codes to merge in the GPS and GOES Sounder data and compute the TPW anomaly. New merged system expected to be running at CIRA by June 2008, with code delivery shortly afterwards. The GPS domain has been updated, and the operational GOES Sounder TPW product from NESDIS is now flowing into the system.

In Progress: Journal paper on forecaster applications with Sheldon Kusselson (NESDIS SAB) in initial stages. Many figures gathered, will expand upon conference paper.

Tech Transferred: McIDAS files are currently being delivered to NOAA SAB, where they are then routed through NCEP and make their way to the National Hurricane Center. The successful completion of this work will result in all of the software and dataflows generating the products to move to NESDIS, and the products will be available to all NOAA forecast offices via AWIPS Operational Build 9.

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. This site is also available to the public to show a view of atmospheric moisture unavailable elsewhere.

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

By definition in the PSDI project, we have NOAA Collaborators. Principal among these are Sheldon Kusselson, Ralph Ferraro, Limin Zhao, and John Paquette. In addition, we collaborate with NWS personnel.

6. Awards/Honors: None as yet

7. Outreach:

The websites http://amsu.cira.colostate.edu and http://amsu.cira.colostate.edu/gpstpw are routinely accessed by NWS personnel and people worldwide.

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 newsletter article (Spring 2008 issue).

Forsythe, J. M., S. Q. Kidder, A. S. Jones, and T. H. Vonder Haar, 2007: Moisture profile retrievals from satellite microwave sounders for weather analysis over land and ocean. 15th AMS Conference on Satellite Meteorology and Oceanography, Amsterdam, The Netherlands.

Kusselson, S. J. S. Q. Kidder, 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.

PROCESSING OF ORGANIC AEROSOLS BY HETEROGENEOUS AND MULTIPHASE PROCESSES

Principal Investigator: Barbara Ervens and Sonia M. Kreidenweis

NOAA Project Goal: Climate, *Programs*: Climate Observations and Analysis; Climate Forcing; Climate Predictions and Projections

Key Words: Aerosols, Carbonaceous Aerosols, Indirect Aerosol Climate Effects, Direct Aerosol Climate Effects, Secondary Organic Aerosol (SOA), Tropospheric Chemistry

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

Uncertainties in estimating the effects of aerosols arise due to the complexity of aerosol properties and the diversity in their (chemical and physical) source and sink processes. Particulate organic carbon has been shown to be an important component of the global aerosol system, and yet its physical and chemical sources are poorly understood. Our long-term objective is to contribute towards improvements in the representation of properties and formation processes of organic aerosols in chemical and climate models, including their role in aerosol indirect forcing. We plan to accomplish this through collaboration with colleagues who perform laboratory and field studies and provide their data as input to our model applications.

Specific plans include the following: We keep collaborating with colleagues who provide most recent laboratory results on organic aqueous phase chemistry. Our efforts in (i) building a detailed state-of-the-art aqueous phase mechanism and (ii) subsequent parameterization for the application in larger scale models will be extended to a wider variety of conditions (cloud types, chemical precursors, …). The model will be applied in order to interpret field measurements that were performed during the 'Cumulus Humilis Aerosol Processing Study (CHAPS) in the frame of our newly funded project by the Atmospheric Science Program (Department of Energy).

In addition, we will extend our studies in order to explain measured number concentrations of cloud condensation nuclei (CCN) and to identify aerosol properties that are most crucial in order to obtain CCN closure in a variety of scenarios, locations, aerosol sources and compositions.

2. Research Accomplishments/Highlights:

We continued our CCN studies in collaboration with colleagues at CU Boulder and NOAA/GMD. In addition to previously available datasets (Chebogue Point, Ervens et al., 2007; Riverside, CA, Cubison et al., 2008), we considered a wider variety of datasets (Pt. Reyes, CA; Holme Moss, UK) in order to give a more general and comprehensive view on the importance of chemical composition and mixing state vs. physical parameters such as size distributions. In addition, we are in contact with other colleagues who performed CCN measurements in order to acquire an even wider variety of datasets.

Our collaborative work on aqueous phase modeling of SOA formation has resulted in a collaborative paper (Ervens et al., 2008). Our modeling studies have shown that SOA yields from isoprene (i) depend strongly on the initial volatile organic carbon (VOC)/NO_x ratio resulting in 42% > Y_c > 0.4% over the atmospherically-relevant range of 0.25 < VOC/NO_x < 100; (ii) increase with increasing cloud-contact time (iii) are less affected by cloud liquid water content, pH, and droplet number. (iv) The uncertainty associated with gas/particle-partitioning of semivolatile organics introduces a relative error of -50% ≤ Y_c < +100 %. The reported yields can be applied to air quality and climate models as is done with SOA formed on/in concentrated aerosol particles (SOA_{aer}).

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

We have completed all project objectives, including publications.

4. Leveraging/Payoff:

The results of this work will be applicable to reducing the current large uncertainty in estimates of radiative forcing of climate by (organic) aerosols.

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

We are collaborating with Dr. Graham Feingold, NOAA/ESRL, on this project. Dr. J. Jimenez, Dr. M. Cubison (University of Colorado), Dr. E. Andrews and Dr. J. Ogren (NOAA/GMD), provided the datasets for CCN closure acquired at Pt. Reyes, CA; Dr. J. Allan, and Dr. H. Coe (University of Manchester, UK) shared their CCN data acquired at Holme Moss, UK.

6. Awards/Honors:

The paper by Ervens et al., (2008) has been selected as ‘Editor’s Highlight’ by the editor of Geophysical Research Letters. In addition it has been mentioned on ‘Science Daily’ (“Cloud Chemistry Concocts Aerosols”).

7. Outreach:

We have reported results from our work at the following conferences during 2007/8:

- DOE ASP Science Team Meeting, Annapolis, 2008
- AGU Fall Meeting, San Francisco, CA, 2007.
- 26th AAAR Annual Conference, Reno, 2007.

8. Publications:

Journal Articles

Carlton, A. G., B. J. Turpin, K. E. Altieri, A. Reff, S. Seitzinger, H. Lim, and B. Ervens, Atmospheric oxalic acid and SOA production from glyoxal: Results of aqueous photooxidation experiments, *Atmos. Environ.* 41*,* 7588-7602, 2007.

Cubison, M. J., D. T. Topping, G. McFiggans, H. Coe, B. Ervens, and G. Feingold, Unresolved particle mixing state and its influence on cloud activation properties, *Geophys. Res. Lett., submitted*.

Cubison, M. J., B. Ervens, G. Feingold, K. S. Docherty, I. M. Ulbrich, L. Shields, K. Prather, S. Hering, and J. L. Jimenez, The influence of chemical composition and mixing state of Los Angeles urban aerosol on CCN number and cloud properties, *Atmos. Chem. Phys. Discuss.*, 8, 5629-5681, 2008.

Ervens, B., A. G. Carlton, B. J. Turpin, K. E. Altieri, S. M. Kreidenweis, and G. Feingold, Secondary organic aerosol yields from cloud-processing of isoprene oxidation products, *Geophys. Res. Lett.*, 35, L02816, doi: 2007GL031828, 2008.

Petters, M.D. and S. M. Kreidenweis, A single parameter representation of hygroscopic growth and cloud condensation nucleus activity – Part 2: Including solubility, *Atmos. Chem. Phys. Discuss*., 8, 5939–5955, 2008

Invited Talks

Ervens, B.: Chemical processes in cloud droplets as a source of secondary organic aerosol, International Aerosol Modeling Algorithms (IAMA) Conference, Davis, CA, USA, 2007.

Ervens, B: Secondary organic aerosol formation in clouds, Analytical, Environmental and Atmospheric Seminar Series, University of Colorado, Boulder, CO, 2007.

Conference Contributions

Cubison, M., B. Ervens, E. Andrews, G. Feingold, J. A. Ogren, J. L. Jimenez, P. DeCarlo, A. Nenes, H. Coe, J. Allan, K. Docherty, I. Ulbrich, K. Denkenberger, K. Prather, D. Snyder, J. J. Schauer, CCN studies at different locations: Relative importance of aerosol composition, hygroscopicity and mixing state, AGU Fall Meeting, San Francisco, CA, 2007.

Ervens, B., and G. Feingold, A study of cloud processing of organic aerosols using models and CHAPS data, DOE ASP Science Team Meeting, Annapolis, 2008.

Ervens, B., A. G. Carlton, B. J. Turpin, K. E. Altieri, S. M. Kreidenweis, and G. Feingold, SOA formation by chemical processes in cloud droplets, AGU Fall Meeting, San Francisco, CA, 2007.

Sorooshian, A., F. J. Brechtel, M. Lu, G. Feingold, B. Ervens, H. Jonsson, R. C. Flagan, J. H. Seinfeld, Secondary organic aerosol formation in clouds: A synthesis of data from four field campaigns, AGU Fall Meeting, San Francisco, CA, 2007.

Ulbrich, I., K. Docherty, J. L. Jimenez, M. Cubison, B. Ervens, E. Andrews, G. Feingold, J. Ogren, K. Denkenberger, K. Prather, D. Snyder, J. Schauer, A. Nenes, Modeling cloud condensation nuclei activation at urban and background locations: The influence of composition and mixing state, 26th AAAR Annual Conference, Reno, 2007.

PROPOSAL ON EFFICIENT ALL-WEATHER (CLOUDY AND CLEAR) OBSERVATIONAL OPERATOR FOR SATELLITE RADIANCE DATA ASSIMILATION

Principal Investigator: Manajit Sengupta

NOAA Project Goal: Weather and Water: Weather Water Science Technology and Infusion

Key Words: Radiative Transfer, Data Assimilation

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

The goal of this project is to develop capabilities within the Community Radiative Transfer Model (CRTM) for assimilation of satellite visible radiance in both clear and cloudy atmospheres. To achieve this capability, a radiative transfer algorithm capable of dealing with multiple scattering in clouds along with its adjoint needed to be developed. The plan was to develop such an algorithm and deliver it to the Joint Center for Satellite Data Assimilation (JCSDA) for incorporation in the CRTM. In addition, some components will be tested to see the impacts on satellite data assimilation.

2. Research Accomplishments/Highlights:

COMPLETE: A visible radiative transfer model and its adjoint were developed. This model is called the Spherical Harmonics Discrete Ordinate Method Plane Parallel for Data Assimilation (SHDOMPPDA). This model has been tested and compared with the Discrete Ordinate Radiative Transfer (DISORT) model and has been found to be 5 times faster. A newer version of the CRTM was incorporated into the CIRA 4-D Variational data assimilation system called Regional Modeling and Data Assimilation System (RAMDAS). This new version has the capability to use GOES sounder data. Building on previous GOES imager radiance assimilation work, radiances from some of the GOES sounder channels have been assimilated.

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

The main objective of this proposal has been previously met and the code has been transferred to the JCSDA. The work done this year to assimilate GOES sounder radiances using the RAMDAS system is in support of the goals of the JCSDA to show the impact of data assimilation on cloud prediction. It was shown that assimilation of sounder radiance for 2 channels significantly improves cloud prediction when compared with observations.

4. Leveraging/Payoff:

The ability to assimilate visible radiances into cloudy atmospheres has not been previously available. As visible radiances provide information about cloud optical properties not available at other wavelengths, this model provides NOAA with the ability to improve cloud prediction. This model will help NOAA assimilate GOES visible radiances in weather forecasting models. With GOES-R containing 6 visible and near-infrared bands, SHDOMPPDA will play an important role in satellite data assimilation in the future. The RAMDAS system was built primarily with non-NOAA funding. The use of this system for data-assimilation related to NOAA/JCSDA provides a definite benefit to NOAA at no immediate additional cost.

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

This model was developed in partnership with Dr. Frank Evans of The University of Colorado whose expertise has been helpful in the JCSDA fulfilling its goals.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Evans, K. F., 2007: SHDOMPPDA: A radiative transfer model for cloudy sky data assimilation. *J. Atmos. Sci.*, 64, 3858–3868.

REGIONAL TRANSPORT ANALYSIS FOR CARBON CYCLE INVERSIONS

Co-Principal Investigators: A. Scott Denning

NOAA Project Goal: Climate

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

Report was unavailable from PI at this time. It will be submitted as an addendum.

RESEARCH & DEVELOPMENT FOR GOES-R RISK REDUCTION

Principal Investigator: Tom Vonder Haar

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 achive 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 Accomplishments/Highlights:

Our 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). The impact of covariance localization (based on employing local sub domains) on the information measures was examined. As expected, the covariance localization resulted in increasing the total number of degrees of freedom in the data assimilation system and, consequently, in improving the data assimilation results (Fig. 1).

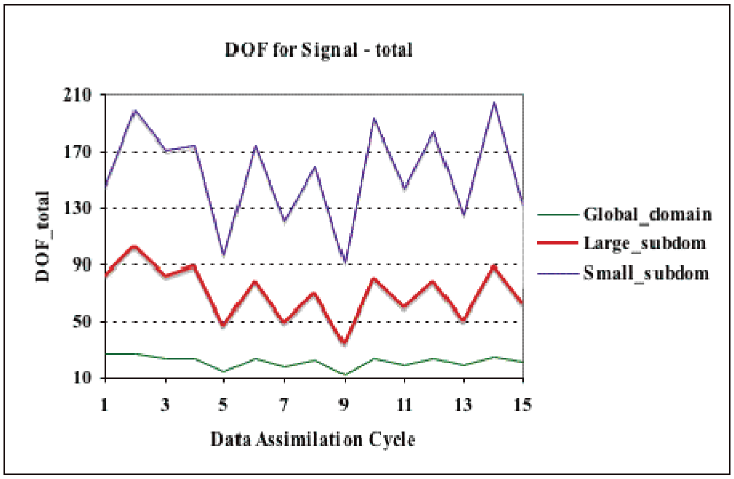


Figure 1. Total number of Degrees of Freedom (DOF) for signal obtained in different data assimilation experiments using the WRF model and conventional (SYNOP and radiosonde) observations. DOF for signal is shown as a function of data assimilation cycles. Green line corresponds to the experiment without covariance localization (no sub domains are used). Red and purple lines correspond to the experiments with covariance localization employing larger and smaller local domains, respectively. Note significant increase in DOF for signal due to covariance localization. The zig-zag behavior of the lines indicates larger amount of information at the synoptic times (00z and 12z) compared to the asynoptic times (06z and 18z). Data assimilation interval was 6h.

In addition, the radiative transfer observation operators were interfaced with the MLEF algorithm and the Schultz micro-physical scheme was included in our version of the WRF model. The Schultz scheme, developed at NOAA/ESRL, is computationally efficient and suitable for assimilation of the MSG data. The algorithms were also successfully prepared for assimilation of conventional observations from NCEP.

Project II: Hazards Studies with GOES-R Advanced Baseline Imager (ABI)

A simulated GOES-R Product Web using ABI-equivalent MSG data was developed (see http://rammb.cira.colostate.edu/products/goes-r/). Currently the page shows experimental products developed for fog/stratus discrimination and for blowing dust, as well as a GOES-11 blowing dust product using the same split-window difference that still is available with GOES-West. Explanations of how the products are generated are available on the webpage below each image, as well as explanations of how to interpret the products. Both latest images and image loops are available for each product.

An image product for detection of blowing dust was generated from GOES-11 (GOES-West) imagery. The product is a variant of the longwave split-window difference image product, but with a color table designed to emphasize areas of increasing likelihood of blowing dust in orange and red colors. A cloud mask is also applied based on the visible albedo, with cloudy areas blanked out as white. Other than blowing dust, which is a common feature over the high plains, areas of false dust signal often occur over the southwestern U.S. due to surface radiative characteristics that look similar to dust in this product. Surface winds are plotted over the blowing dust product image as partial confirmation of the dust outbreaks, which are usually associated with high winds and the passage of low pressure troughs. Image loops help discriminate between blowing dust and other false dust signals in the product. The product was made available in real time at http://rammb.cira.colostate.edu/ramsdis/online/goes-r.asp .

A single-frame example of the blowing dust image product for 1830 UTC on 24 March 2008 is given in Figure 2. In this example a cold front moved down from Canada into Montana. After the dry frontal passage, strong winds at the surface kicked up dust from Montana and into North Dakota. Areas of white are masked out based on clouds in the visible albedo product. Strong surface winds help confirm the blowing dust signal, even though no surface weather stations specifically reported the blowing dust.

Synthetic imagery of different fire scenarios were produced. Research focused on how GOES-R ABI will sample the data. Several idealized fire “hotspots” were added into the 8 May 2003 severe weather case. The Fire Radiative Power (FRP) parameter was added to all fire datasets.

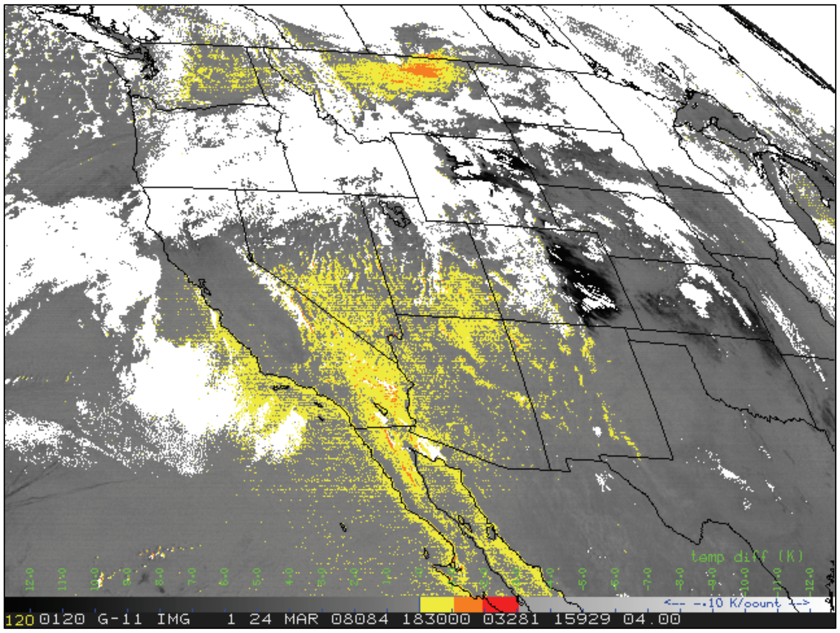


Figure 2. Blowing dust image product for a case over Montana and North Dakota at 1830 UTC on 24 March 2008. See accompanying text for details.

Project III: <u>Severe Weather</u>

GOES data was collected from the summer 2007, along with mesoanalysis data from the Storm Prediction Center, in order to seek a statistical relationship between thunderstorm-top effective radius and severe weather. The goal is to develop a severe weather product which can be greatly improved with the additional spectral bands on the GOES-R Advanced Baseline Imager.

American Regional Reanalysis and GOES-12 data for a Mesoscale Convective System (MCS) that occurred on 3-4 April 2007 was collected as part of the “Application to MCS” task. The simulation run for this case is in progress.

Work continued on the development of other GOES-R ABI severe weather products, including the retrieval of boundary layer moisture. A simulated domain is created in which temperature and moisture profiles can be varied spatially. Next, an observational operator is used to create synthetic GOES-R imagery for several different bands. Principle component (PC) analysis was then be used to determine the relative importance of the different bands on the boundary layer moisture.

Project IV: Training

Two presentations were given on National and International Training Activities: The first was given to Brigitte Horner, NESDIS/OSD August 8, and the second was given to a satellite meteorology workshop held in Algoas, Brazil on August 22. Both were given virtually using two different collaboration software packages: Gotomeeting and Visitview. The presentations highlighted the development of NWS training activities and tools and how they have been extended to other audiences, particularly the international community. GOES-R training activities are being built on the NWS training structure.

Training experiences with Meteosat, which has similar channel capabilities as the future GOES-R, were discussed with Jochen Kerkmann, a training expert from EUMETSAT . We participated in monthly conference calls for the NWS Satellite Requirements and Solutions Steering Team (SRSST) to improve communications on training issues and, in particular, to participate in discussions on GOES-R requirements.

The overall GOES-R training approach was discussed with Jim Gurka (NESDIS/OSD/GOES-R), staff at COMET (Abshire, Dills, Weingroff, Parrish, Mostek, Lamos) and NRL (Lee). This interaction continued 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.

Information passed on at the GOES-R Users Conference at the AMS Annual Meeting in New Orleans (January 2008) led to useful links particularly for Space Weather Instruments and the Lightning Mapper. The development of an outline and content for the GOES-R module began.

Project V: GOES-R Applications to Tropical Cyclone Analysis and Forecasting

A new dataset was obtained as a proxy for the GOES-R lightning mapper. The World-Wide Lightning Location Network (WWLLN) data is from a ground-based system that provides times and locations of most strong global cloud-to-ground lightning strikes. Data is provided over tropical oceans and will be used for tropical cyclone genesis and intensity forecast algorithms. The lightning data over the eastern tropical Atlantic will be analyzed in conjunction with the MSG imagery, which is a proxy for the ABI. The WWLLN database has also been made available on a local Linux system, and software to access the data for the SHIPS cases is being developed. In addition, the proxy database was extended by adding the data for 2007 from the World Wide Lightning Locator Network (WWLLN). Figure 3 below shows the daily strike locations from 4 September 2007 when Hurricane Felix was in the western Caribbean.

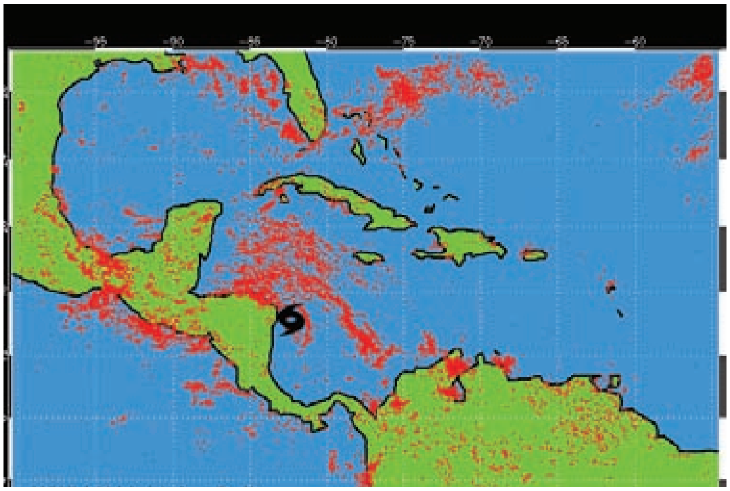


Figure 3. Lightning strikes from 4 September 2007 from the ground-based WWLLN. The center of Hurricane Felix is indicated by the tropical cyclone symbol in the western Caribbean.

The development of the GOES-R proxy tropical cyclone database for Dvorak intensity estimation studies was completed. About 400 IR images from AVHRR and MODIS were collected from 11 tropical cyclones from 2002-2005 at 1 km resolution. These were remapped to 2 and 4 km resolution and companion GOES imagery was obtained. This data will be used to develop new tropical cyclone intensity algorithms for GOES-R as part of the Algorithm Working Group project.

A real-time source of simulated Advanced Baseline Imager (ABI) infrared channels has been developed using an algorithm obtained from the GOES-R Algorithm Working Group (AWG). The ABI infrared channels are approximated using Meteosat Second Generation (MSG) data obtained from the NESDIS server. The Simulated ABI data, Channels 7 – 16, are then made available via a MCIDAS server that facilitates the development of case studies; allowing the researcher to obtain the data in smaller areas over long periods of time as interesting events occur. These algorithms also can be applied to the MSG datasets collected over the tropical Atlantic during the 2005, 2006 and 2007 hurricane seasons.

A GPS dropwindsonde AIRS sounding match-up database was completed. The AIRS soundings were compared to those dropwindsonds and statistics of the comparison were created. In addition, statistics evaluating the utility of AIRS soundings relative to the GFS model first guess were compiled.

Simulated ABI 6.95 um water vapor channel (i.e., Channel 9) was collected in a region that overlaps with the GOES-East satellite coverage to be used for the TC genesis parameter for GOES-R satellite inputs. Software is being developed to extract storm-relative lightning strikes in a cylindrical coordinate system for testing in the SHIPS model and the related Rapid Intensity Index.

Project VI: Winter Weather Studies with GOES-R

The goal of this project is to collect geostationary and COSMIC data for a mid-latitude cyclone case study and to develop the PV/Ozone technique. Total ozone from the current GOES sounder or Meteosat will be used. Information was gathered on uses of ozone observations from satellite. A Colorado snowstorm case which occurred on 20-21 December 2006 was chosen for code development. COSMIC data was collected for this case. Figure 4 shows the time of the COSMIC soundings for 20 December over the United States and surrounding areas.

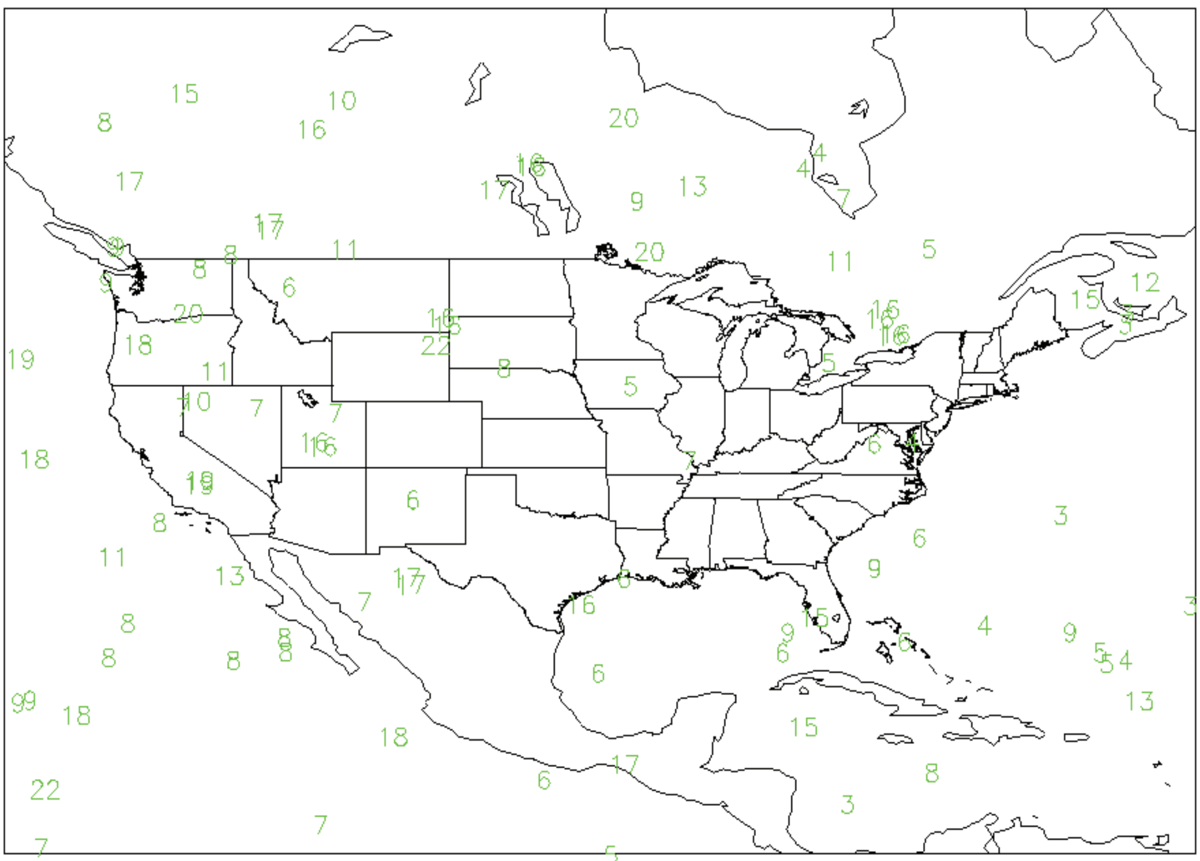


Figure 4. Time (hours, UTC) of the COSMIC soundings for 20 December 2006.

For more information visit our website. (http://rammb.cira.colostate.edu/projects/goes_r)

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

This project is on schedule and milestones have been reached.

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, Communications 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 as yet

7. Outreach:

(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) see section 8
(c) none
(d) Louie Grasso spoke to a first grade class at Bauder Elementary.
(e) A website was developed to illustrate the utlility of GOES-R research.

8. Publications:

<u>Refereed Journal Articles</u>

Fromm, M., O. Torres, D. Diner, D.T. Lindsey, B. Vant Hull, R. Servranckx, E. P. Shettle, and Z. Li, 2008: The stratospheric impact of the Chisholm pyrocumulonimbus eruption: Part I, earth-viewing satellite perspective. *Journal of Geophysical Research*.

Grasso, L.D., M. Sengupta, J. Dostalek, Renate Brummer, and M. DeMaria, 2008: Synthetic Satellite Imagery for Current and Future Environmental Satellites. *International Journal of Remote Sensing* (in press).

Hillger, D.W., 2008: GOES-R Advanced Baseline Imager Color Product Development, *J. Atmos. Ocean. Technol. - Atmospheres,* 25(6), (June), 853–872.

Lindsey, D.T., and L.D. Grasso, 2008: An effective radius retrieval for thick ice clouds using GOES. *Journal of Applied Meteorology and Climatology.*

Rosenfeld, D., W. Woodley, A. Lerner, G. Kelman, and D.T. Lindsey, 2008: Satellite Detection of Severe Convective Storms by their Retrieved Vertical Profiles of Cloud Particle Effective Radius and Thermodynamic Phase. *Journal of Geophysical Research*.

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.*

Setvak, M., D.T. Lindsey, R.M. Rabin, P.K. Wang, and A. Demeterova, 2008: Indication of water vapor transport into the lower stratosphere above midlatitude convective storms: Meteosat Second Generation satellite observations and radiative transfer model simulations. *Atmospheric Research*.

<u>Conference Proceedings</u>

Brummer, R.L., M. DeMaria, J.A. Knaff, B.H. Connell, J.F. Dostalek, D. Zupanski, 2008: GOES-R mesoscale product development. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Brummer, R.L., M. DeMaria, J.A. Knaff, B.H. Connell, J.F. Dostalek, D. Zupanski, 2008: GOES-R mesoscale product development. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Grasso, L.D., M. Sengupta, D.T. Lindsey, 2008: Improved calculations of legendre coefficients for use in generating synthetic 3.9 µm GOES-R ABI imagery. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Grasso, L.D., M. Sengupta, D.T. Lindsey, 2008: Improved calculations of legendre coefficients for use in generating synthetic 3.9 µm GOES-R ABI imagery. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Hillger, D.W., and R.L. Brummer, 2008: Real-time display of experimental GOES-R products. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Lindsey, D.T., D.W. Hillger, L.D. Grasso, 2008: Development of severe weather products for the GOES-R Advanced Baseline Imager. *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Lindsey, D.T., 2008: Examining a possible relationship between positive dominated storms and cloud-top ice crystal size. *3rd AMS Conference on Meteorological Applications of Lightning Data*, 21-25 January, New Orleans, LA.

Mostek, A., M. DeMaria, J. Gurka, 2008: Preparing for GOES-R+ user training and education, *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Sengupta, M. L.D. Grasso, D.W. Hillger, R.L. Brummer, M. DeMaria, 2008: Quantifying uncertainties in fire size and temperature measured by GOES-R ABI, *5th AMS GOES Users' Conference*, 21-25 January, New Orleans, LA.

Presentations

DeMaria, M., J.A. Knaff, S. Kidder, P. Harr and C. Lauer, 2008: An improved wind probability program. *62nd Interdepartmental Hurricane Conference*, March, 2008, Charleston, SC.

Hillger, D.W., and T.J. Schmit, 2007: Results of the GOES-13 (NOAA) Science Test: December 2006. *Joint 2007 EUMETSAT Meteorological Satellite Conference* and the *15th American Meteorological Society (AMS) Satellite Meteorology & Oceanography Conference*, 24-28 September, Amsterdam, the Netherlands.

Hillger, D.W., and M. DeMaria, 2007: GOES-R Advanced Baseline Imager (ABI) Color Product Development. *Joint 2007 EUMETSAT Meteorological Satellite Conference* and the *15th American Meteorological Society (AMS) Satellite Meteorology & Oceanography Conference*, 24-28 September, Amsterdam, the Netherlands.

Knabb, R., M. Mainelli, and M. DeMaria, 2008: Operational Tropical Cyclone Wind Speed Probability Products from the National Hurricane Center. *AMS Annual Meeting*, January 2008, New Orleans, LA.

Knaff, J.A., A. Krautkramer, M. DeMaria, A.B. Schumacher, 2008: New and updated operational tropical cyclone wind products. *62nd Interdepartmental Hurricane Conference*, 3-7 March, Charleston, SC.

Lindsey D.T., and L.D. Grasso, 2007: Exploring the relationship between satellite-retrieved ice crystal size and thunderstorm intensity. *4th European Conference on Severe Storms*, 10-14 September, Trieste, Italy.

Lindsey, D.T., and L.D. Grasso, 2007: Numerical simulation of the effects of CCN on thunderstorm intensity and evolution. *EUMETSAT Training Workshop on Interpretation of Satellite Images/ Products of Convective Storms*, 5-7 September, Trieste, Italy.

Schumacher, A.B., M. DeMaria, J.A. Knaff, D.P. Brown, 2008: The NESDIS tropical cyclone formation probability product: An overview of past performance and future plans. *62nd Interdepartmental Hurricane Conference*, 3-7 March, Charleston, SC.

Setvak, M., P. Novak, D.T. Lindsey, R.M. Rabin, P.K. Wang, and M. Radova, 2007: Central European convective storms penetrating deep into the lower stratosphere - MSG IR and radar observations and radiative transfer modeling. *4th European Conference on Severe Storms,* 10-14 September, Trieste, Italy.

SENSITIVITY OF THE NORTH AMERICAN MONSOON TO SOIL MOISTURE AND VEGETATION, AND ITS TELECOMMUNICATION MECHANISMS INTO THE U.S.: A MODELING AND OBSERVATIONAL STUDY

Principal Investigator: William R. Cotton

NOAA Project Goal – Climate; Climate Forcing and Climate Predictions and Projections

Key Words - Climate; Climate Forcing and Climate Predictions and Projections

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

Examine positive potential vorticity anomalies generated by monsoon convection as a telecommunication mechanism between convection over Northern Mexico during monsoon surges and convection/mesoscale convective systems over the central U.S.

Examine the relative influence and dynamics of LLJs and the monsoon boundary layer on the evolution of precipitating systems associated with the North American Monsoon (NAM).

Examine the sensitivity of the NAM to soil moisture and SST using RAMS 30km grid spacing simulations for several full North American warm seasons. Also run higher resolution tests at 7km grid spacing over the core monsoon region for specific monsoon surge episodes.

Plans have been to perform regional simulations of the evolution of the NAM for selected years using RAMS and to perform sensitivity studies with the model.

2. Research Accomplishments/Highlights:

Impacts of variable SST and soil moisture model initialization on moisture surge events in the Gulf of California during the North American Monsoon season.

A series of model simulations of the July 11-16, 2004 Gulf of California moisture surge event were performed using the Regional Atmospheric Modeling System (RAMS). These simulations were run with 7km grid spacing over the Gulf of California (GoC), Baja Peninsula, and western coastal Mexico, while encompassing much of the Sierra Madre Mountain range. The emphasis was to examine the variability in modeled surge events due to variations the initial sea surface temperature and soil moisture fields. The question to address is: Do changes in the land surface state control or alter the dynamics and thermodynamics of Gulf Surge episodes; and, if so, how does the modeled Gulf Surge vary due to use of various initial SST and soil moisture datasets?

The SSTs used in this study come from climatology, Reynold’s 1.0 degree weekly average, AVHRR 18km weekly average, and MODIS 4.63km weekly average Terra nighttime datasets. The soil moisture fields come from the NCEP reanalysis 2.5 degree data, North American Regional Reanalysis, GFS-FNL 1 degree data, and use of a homogeneous initialization. These specific datasets have been developed for use in the RAMS model, and these modules are available to RAMS users for further study. Figure 1 displays the initial soil moisture field obtained from the available datasets, and figure 2 displays the associated difference fields. Figure 3 displays similar difference fields in the SSTs among the chosen datasets for the period of the Gulf Surge event from July 11-16, 2004. Note that there is a wide range of initial states among the SST and soil moisture data sources.

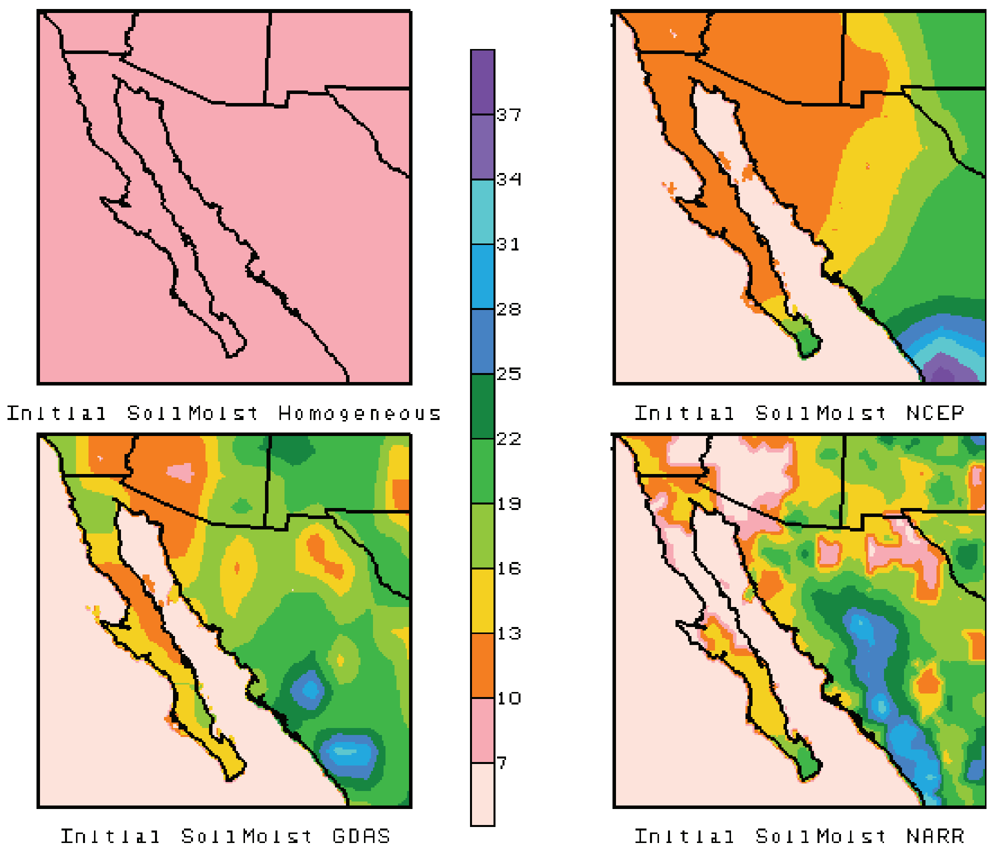


Figure 1. Initial July 11, 2004 volumetric soil moisture fraction (m^3/m^3 x 100) from the following data sources: (top, left) homogeneous, (top, right) NCEP reanalysis, (bottom, left) FNL-GDAS, and (bottom, right) NARR.

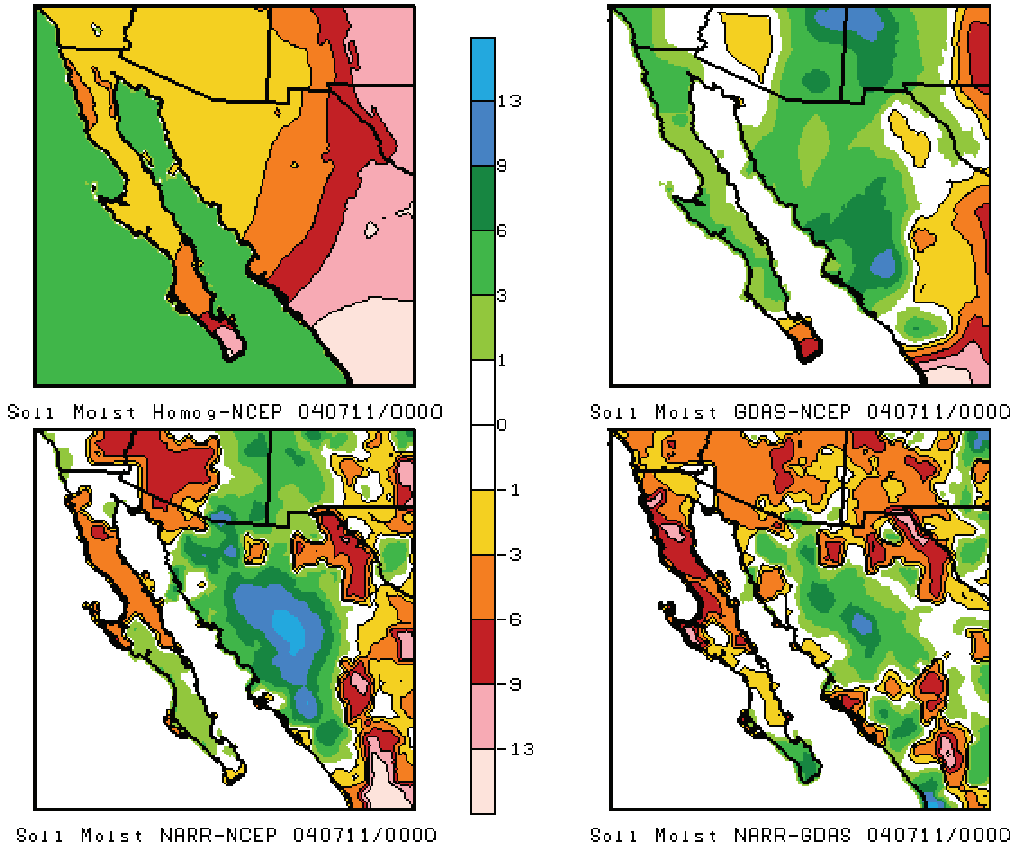


Figure 2. Initial July 11, 2004 volumetric soil moisture fraction difference (m^3/m^3 x 100) between the following data sources: (top, left) homogeneous-NCEP, (top, right) GDAS-NCEP, (bottom, left) NARR-NCEP, and (bottom, right) NARR-GDAS.

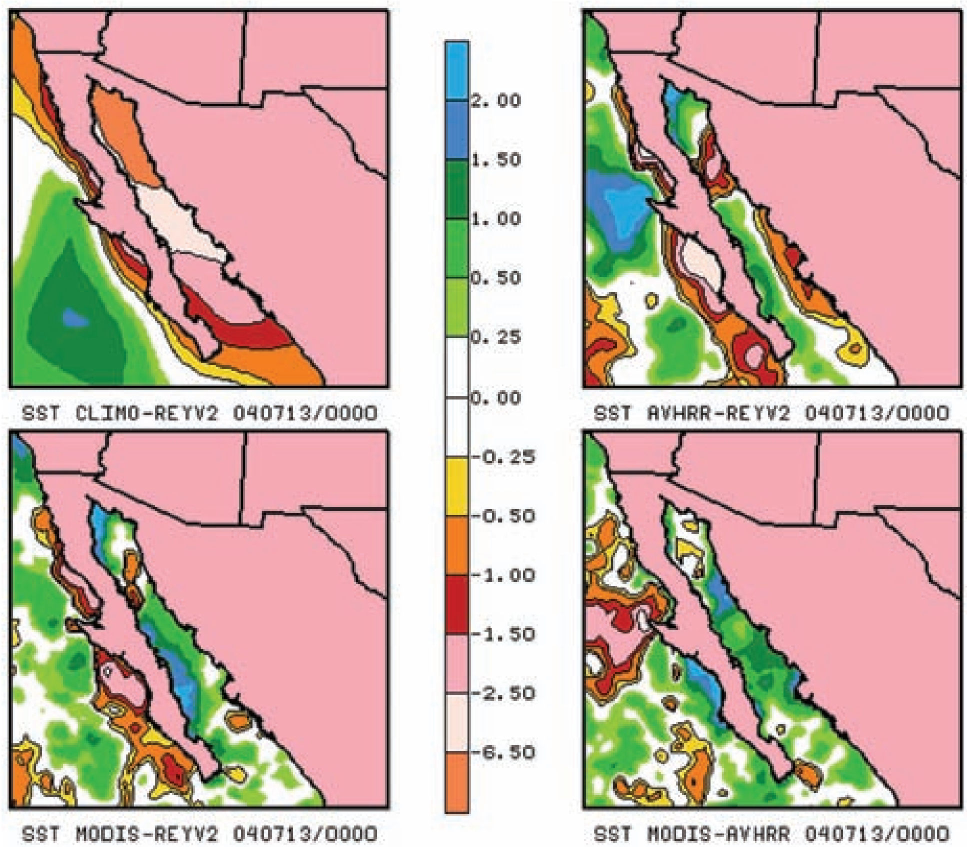


Figure 3. Mid-surge July 13, 2004 sea surface temperature differences (°C) over the Gulf of California region between the following data sources: (top, left) climatology-Reynolds, (top, right) AVHRR-Reynolds, (bottom, left) MODIS-Reynolds, and (bottom, right) MODIS-AVHRR.

a. Impacts on surge events from varying the initial soil moisture field

Aside from impacting precipitation, the initial soil moisture field contributes to formation of initial surface temperature and moisture gradients. This can then impact surface flows associated with gulf surge events. Given that surge events often appear as density currents, the land-sea temperature and moisture contrasts may impact the leading edge of the surge and/or the strength of the surge event. Figure 4 displays a vertical cross-section (and location) of mixing ratio and temperature for the beginning (July11) and mature (July 13) stages of the surge event for the simulations that were initialized with NCEP and NARR soil moisture. The surge event is quite dominant regardless of the soil moisture characteristics. The leading edge of the surge is present in the southern portion of the cross-section on July 11. It is identified as a deeper layer of cool, moist air up to about 1500m AGL with sharp temperature and moisture gradients at the leading edge. Areas ahead of the surge are very warm and the moist layer is shallow (below 500m AGL).

The primary difference between the NCEP and NARR simulations on July 11 is the strength of the gradients at the leading edge of the surge. The gradients are stronger in the NCEP simulation. Near the southern end of the cross-section the NCEP soil moisture is much drier than the NARR and there is a significant along-coast soil moisture gradient. The NARR data exhibits wetter soils along the SMO down toward the coast with a much less substantial along-coast gradient near the surge source region. (Wetter soils would be expected by mid-July during a monsoon season.) The NARR data appears more realistic and the NCEP data certainly cannot resolve the finer features at 2.5° grid spacing.

As the surge propagates northward in the mature stage on July 13, the deep cool and moist layer is quite prevalent in both simulations. The NARR simulation exhibits a sharper leading edge, warmer temperature in advance of the surge, and slight cooler temperatures associated with the surge. It is worth noting that the initial soil moisture gradient is greater in the NARR than in the NCEP data over the northern coastal region of Mexico. One could speculate that strong, along-coast soil moisture gradient may contribute to stronger moisture and temperature gradients at the leading edge of the surge.

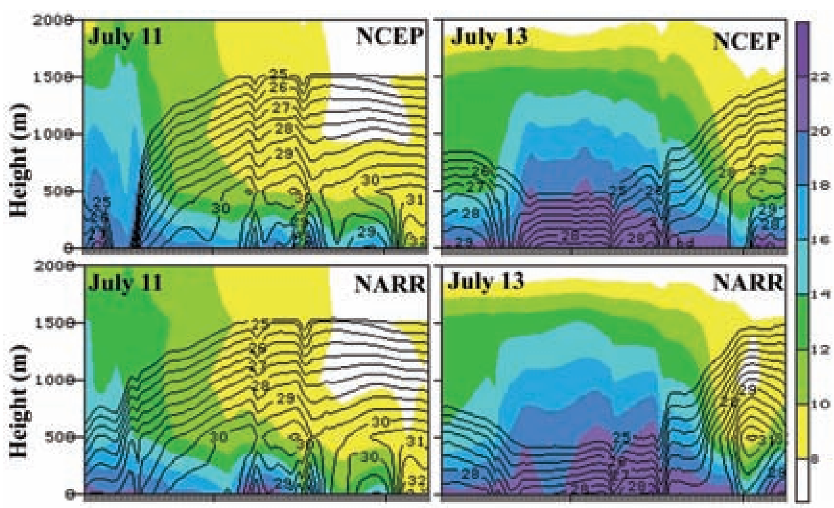


Figure 4. South to north Gulf of California cross-section of mixing ratio (shaded, g/kg) and temperature (contours, °C) during the gulf surge event from July 11-15, 2004. Panels are labeled with the date, and the NCEP (NARR) label denotes the data source for soil moisture initialization.

b. Impacts on surge events from varying the initial sea surface temperature

Vertical cross-sections examined along the GoC during the surge episode revealed variations in the moisture and temperature structure of the surge (see Figure 5). The substantially cooler SSTs in the climatological dataset produced the greatest variability compared to the other datasets. The surge produced from climatology SSTs was nearly 5g/kg drier and up to 4°C cooler compared to surges influenced by the other SST datasets.

The Reynold's 1deg, AVHRR 18km, and MODIS 4.63km weekly averaged data provide great improvements over the climatology when representing SSTs and their impact on monsoon surges in the narrow channel of the Gulf of California. In examining these three data sources, we note that the granularity of the Reynold's data is still too coarse to truly represent some of the small scale warm eddies in the Gulf waters. The differences fields of SST in figure 3 show that the AVHRR and MODIS have greater SST in the northernmost portion of the Gulf by up to 2°C. Furthermore the MODIS appears to be warmer over the central Gulf; this is either an artifact of the differences in remote sensors or the improved resolution of MODIS.

Comparison of the surge thermodynamics in figure 5 from simulations using the non-climatology data reveal rather different results. The difference between use of AVHRR and Reynold's SSTs produce a drier and warmer surge event over the central and southern Gulf where the AVHRR SSTs are slightly cooler along the western coast of Mexico; furthermore, the surge is slightly wetter near the northernmost point in the Gulf where the AVHRR can better resolve the high SST values often observed in this region. The comparison between MODIS and AVHRR reveals a moister surge event, which is consistent with warmer MODIS SSTs that lead to greater evaporation from the ocean into the surge layer.

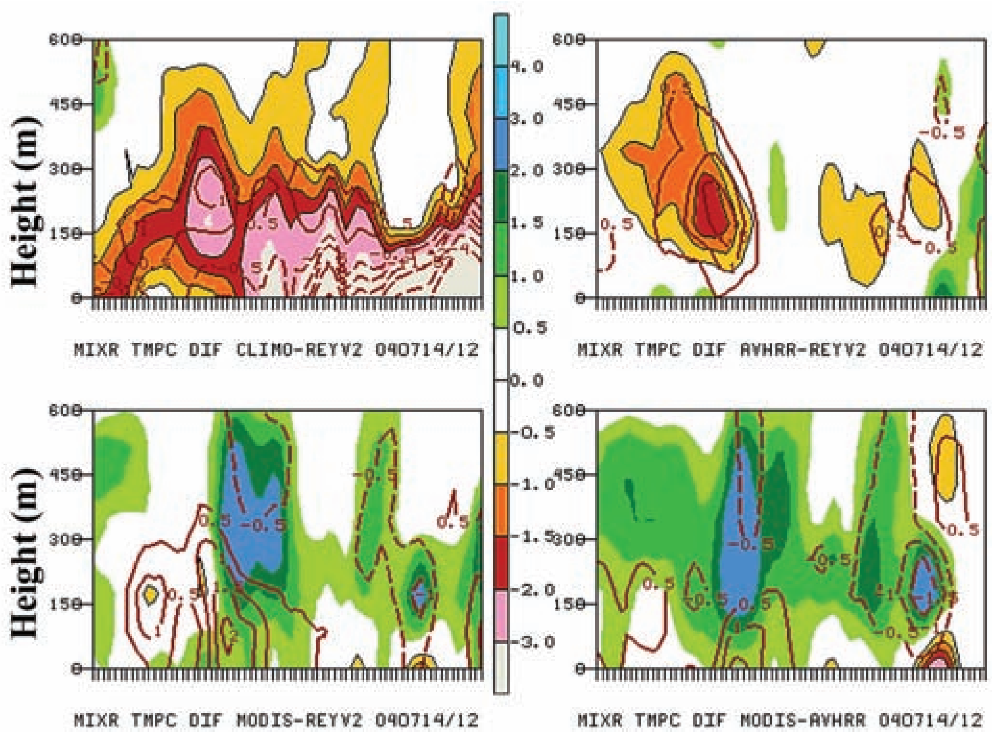


Figure 5. South to north Gulf of California cross-section (see Fig 4) of difference fields of mixing ratio (shaded, g/kg) and temperature (contours, °C) during the gulf surge event on July 14, 2004. Labels display the SST data used in the simulations: CLIMO (climatology), AVHRR (18km data), REYV2 (Reynold's 1 degree data), and MODIS (4.63km Terra nighttime data product).

c. Conclusion

Despite the variability in surge thermodynamics due to variations in local soil moisture or SSTs, these surface modifications and resulting surface flux changes do not appear to alter the overall northward propagation of the surge. The dynamics appear firmly entrenched, while changes in surface characteristics can modify the boundary layer thermodynamics and alter the local precipitation distribution.

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

Our research accomplishments this year have focused on examining sensitivity of North American warm season precipitation to variations in SST and soil moisture as well as impacts on individual monsoon surge episodes.

4. Leveraging/Payoff:

Use of improved datasets of surface characteristics in numerical models may provide better forecasts of local precipitation in the very dry monsoon region of northwest Mexico and the southwest U.S. Given that summer monsoon rainfall provides up to 65% of the yearly water supply over these desert regions, improved forecast models and initialization data may provide better predictions useful for allocation of water resources.

5. Research Linkages/Partnerships/Collaborators, Communications and Networking:
None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Saleeby, S.M., and W.R. Cotton, 2008: Impact of soil moisture initialization on monsoon-related warm season precipitation at multiple spatial and temporal scales. *Geo. Phys. Lett.*, (In preparation).

Saleeby, S.M., and W.R. Cotton, 2008: Impact of sea surface temperature initialization on monsoon-related warm season precipitation at multiple spatial and temporal scales. *Geo. Phys. Lett.*, (In preparation).

SHIP-BASED OBSERVATIONS OF PRECIPITATING CONVECTION AND ENVIRONMENTAL CONDITIONS IN SUPPORT OF NAME-2004

Principal Investigator: Steven A. Rutledge

NOAA Project Goal: Weather and Water

Key Words: Monsoon, Weather Prediction, Mesoscale, Radar

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

The long-term, overarching research objective of this work is to understand the organizational characteristics of convection in the Gulf of California/western coastal plain region of Mexico and the relationship between convection in this area and the onset of the North American Monsoon, in particular, Gulf Surges. Gulf Surges are important for establishing monsoonal conditions in the southwestern portion of the U.S. This proposed effort intended to conduct shipboard radar, profiler and thermodynamic measurements at the mouth of the Gulf of California in support of the NAME field campaign in summer 2004. The NAME project was unable to fund deployment of a shipboard Doppler radar, therefore the proposed effort was seriously compromised because of this observational limitation.

2. Research Accomplishments/Highlights:

Following the observational component of NAME, our efforts have focused on QC of the shipboard sounding and 915 MHZ profiler data, and reshaping the goals of this proposed work given the notable absence of the Doppler weather radar. We have had several meetings with Dr. Chris Fairall and Dr. Christopher Williams to discuss use of the 915 MHz profiler and flux instrumentation collected on the Mexican Naval Ship Altair. Here we are using the profiler data to characterize vertical motions in relation to convection that passed over the ship. This is one component of a project that was led by M.S. student David Lerach, focusing on the land-based profiler observations acquired by NOAA. His M.S. thesis incorporated data from the shipborne profiler. Furthermore, the diurnal cycle of sensible and latent heat fluxes measured on the Altair have been related to convective events. Thermodynamic sounding data acquired from the Altair were used to identify synoptic flow patterns and Gulf Surges. These data were incorporated into the Ph.D. study of Luis Gustavo Pereira who is developing a detailed climatology of convection in NAME. We have completed an analysis of easterly wave passages during NAME 2004 and also completed a preliminary analysis of the structure and organization characteristics of convective systems within the context of the easterly wave passages.

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

The specific objectives of this supported research are: *Detect and track sea-breezes and Gulf Surges with the shipboard instrumentation*; this work is underway but is obviously compromised because of the absence of the ship radar. Rather, sounding and profiler data are being used to identify these periods; *Identify the horizontal and vertical structure of precipitating systems and use these to validate cloud-resolving model simulations of same*; this work is moving ahead very well using the S-pol and SMN radar observations. An intense QC effort of the radar data has been completed in the Radar Meteorology Group, led by Dr. Timothy Lang. Analyses of this dataset are described above.

4. Leveraging/Payoff:

This work has direct relevance to improving the numerical forecasts of the North America monsoon, the major warm-season precipitation source for a large region of the southwestern U.S. The ability of forecast models to simulate convective rainfall and moisture transport are expected to be improved by the NAME project. Radar and thermodynamic analyses planned as part of this work are central to achieving these improvements.

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

This work is linked to support provided by NSF for NAME analyses: In particular, analysis of the NCAR S-pol data. We have also formed research collaborations with the following NAME investigators: Dr. Phil Arkin in the area of satellite-radar precipitation algorithms; Dr. David Gochis in the area of radar-rain gauge rainfall products, with particular attention to studying rainfall behavior as a function of topography on the SMO; Dr. Mitch Moncrieff, in the area of validating mesoscale and cloud-resolving model simulations of NAME convection against radar observations; Dr. Walt Petersen relating easterly wave passages to convective structures and associated modulation in lightning frequency.

6. Awards/Honors: None as yet

7. Outreach:

(a) David Lerach, M.S. – Fall 2006, Vertical Structure and Kinematics of Tropical Monsoon Precipitation Observed From A 2875-MHZ Profiler During NAME; Angela Rowe, M.S. – Fall 2007, Analysis of Convection in NAME.

8. Publications:

Higgins, W., et al., 2004: The North American Monsoon Experiment (NAME). Field Campaign and Modeling Study. *Bull. Amer. Meteor. Soc.,* 87**,** 79-94.

Lang, T.J., R. Cifelli, L. Nelson, S.W. Nesbitt, G. Pereira, and S. A. Rutledge, 2005: Radar Observations During NAME 2004 Part I: Data Products and Quality Control. 32nd Conference on Radar Meteorology, Albuquerque, NM, 24-29.

Lang, T.J., R. Cifelli, D. Lerach, L. Nelson, S.W. Nesbitt, G. Pereira, and S.A. Rutledge, 2005: Radar Observations During NAME 2004 Part II: Preliminary Results. 32nd Conference on Radar Meteorology, Albuquerque, NM, 24-29.

Lang, T.J., A. Ahijevych, S.W. Nesbitt, R.E. Carbone, S.A. Rutledge, and R. Cifelli: Radar-Observed Characteristics of Precipitating systems during NAME 2004, *Journal of Climate,* 20(9), 1713-1733.

Pereira, L.G., and S.A. Rutledge: Diurnal Cycle of Shallow and Deep Convection for a Tropical Land and an Ocean Environment and its Relationship to Synoptic Wind Regimes, *Monthly Weather Review,* 134**,** 2688-2701.

Rowe, A.K., S.A. Rutledge, T.J. Lang, P.E. Ciesielski, and S.M. Saleeby, 2008: Elevation-dependant trends in precipitation observed during NAME. *Monthly Weather Review,* submitted.

SIMULATION AND ANALYSIS OF THE INTERACTION BETWEEN AEROSOLS AND CLOUDS, PRECIPITATION AND THE RADIATION BUDGET OVER THE GULF OF MEXICO AND HOUSTON

Principal Investigators: William R. Cotton, Gustavo Carrió, and William Y.Y. Cheng

NOAA Project Goal: 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:

Simulation of the mesoscale evolution excluding Houston urban land use but using clean background CCN and GCCN concentrations for the Gulf and urban-free countryside, and no direct aerosol radiative heating. We expect that the pure sea-breeze circulation will be the main driving force.

Simulation of the mesoscale evolution including Houston urban land use but using clean background CCN and GCCN concentrations and no direct aerosol radiative heating.

Simulation of the mesoscale evolution excluding Houston urban land use, excluding urban enhancement of CCN and GCCN, but including direct aerosol radiative heating.

Simulation of the mesoscale evolution excluding Houston urban land use, excluding aerosol direct radiative heating, but with urban enhancement of CCN and GCCN and control aerosols in the surrounding countryside and over the Gulf.

Simulation of the mesoscale evolution including Houston urban land use and including aerosol direct radiative heating, but excluding urban enhancement of CCN and GCCN concentrations.

Simulation of the mesoscale evolution including Houston urban land use, including aerosol direct radiative heating, and including urban enhancement of CCN, but excluding urban enhancement of GCCN.

Simulation of the mesoscale evolution including Houston urban land use, including aerosol direct radiative heating, including urban enhancement of GCCN but excluding urban enhancement of CCN.

Simulation of the mesoscale evolution including Houston urban land use, including aerosol direct radiative heating, and including urban enhancement of GCCN and CCN concentrations.

Factor separation analysis (Stein and Alpert 1993) will then be performed to determine which factors have the greatest influence and how they affect clouds and storms in the area. Differences in cloud cover, precipitation, cloud albedo, and top of the atmosphere shortwave and longwave radiation budgets will be calculated as part of the factor separation analysis. In addition, the simulated data for each ensemble member will be compared with available observations in the area including surface observations, satellite, aircraft, and WSR 88D radar data to assess the overall accuracy of the simulations.

2. Research Accomplishments/Highlights:

Processing of Landsat Land Use Data: We have processed the Landsat Thematic Mapper ™ National Land Cover Data (NLCD) for the Houston area, available at a pixel size of ~30 m (Fig. 1). This dataset will be very useful for initializing the finest nested grid of the numerical simulations as the land surface heterogeneities will be much better represented. This is better than the default RAMS land use dataset with a pixel size of 1 km (Fig. 2). The RAMS code has also been modified to ingest the NLCD dataset. Note the details of the urban features such as highways radiating away from the center of Houston which are missing from the default RAMS land use dataset.

Computer subroutines were also written to map the NLCD land use categories into the RAMS land use categories as well as to map the NLCD coordinates into the RAMS spatial coordinates.

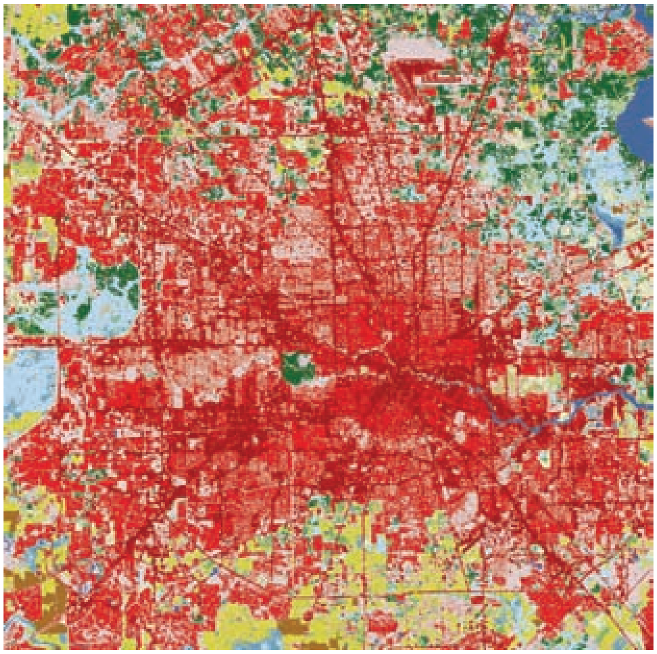


Figure 1. Land use data from NCLD Landsat data for Houston.

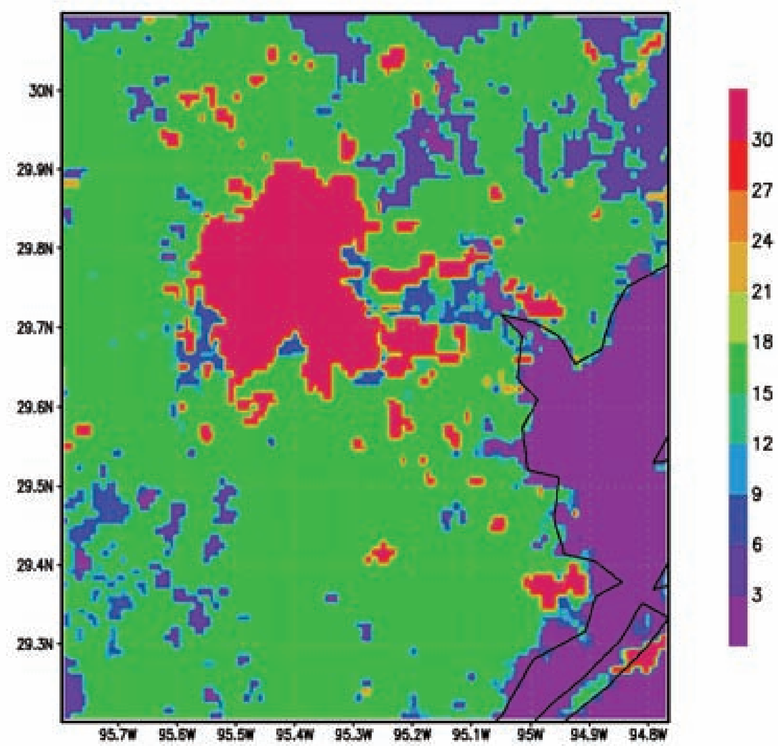


Figure 2. Default RAMS land use data for pixel size of 1 km in the vicinity of Houston.

Processing of aerosol data: Two aerosol datasets documented during TexAQS-GoMACCS were analyzed: i) CCN measurements on the CIRPAS Twin Otter and ii) NOAA P-3 along with other data collected by the research vessel, Ronald H. Brown, for Houston and various locations of the Gulf area. These 1-min time series of CN concentrations, CCN/CN ratios, and the corresponding supersaturations were processed for the entire period to make the concentrations consistent with what "CCN" means for the activation routine in RAMS (i.e., the maximum concentration of cloud droplet that could be activated). In order to avoid the uncertainty introduced by a varying sensor-source distance, we used only the data collected by Ron H. Brown near Houston (and airborne data) for identifying cases representative of a highly polluted day. Peak CCN concentrations exceeded 30000 cm^{-3}, however, we evaluated hourly and daily averages of these time series to characterize the most polluted run for the proposed sensitivity studies.

Selection of case studies: We have selected 4-5 potential cases that could be used for case studies in the sensitivity experiments.

Setting up Linux cluster: We have completed setting up the Linux cluster that will be used to run the RAMS simulations.

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

Processing of Landsat Land Use Data: complete.

TEB Urban Model in RAMS: in progress.

The Town Energy Budget (TEB) urban model was originally coupled to an older version of RAMS. Since then, we have made improvements in RAMS such as i) better representation of the small cloud droplets (cloud1) and large cloud droplets (cloud2) and their interactions, ii) bin emulation approach to riming, and iii) the addition of dust into the RAMS microphysics. TEB is currently being extracted from the older version of RAMS and being transplanted into the newer, improved version.

TEB was originally hardwired for the St. Louis case, so we are currently making the necessary modifications so that TEB will work for any general configuration. In addition, the original TEB in RAMS was designed to work in sequential run only. Work is in progress to make TEB run in parallel so as to maximize the full potential of our computing resources.

Processing of aerosol data: complete.

We processed the TexAQS/ GoMACCS 2006 field campaign data to obtain the aerosol measurements for ingestion into the RAMS model.

Selection of case studies: complete.

We have selected 4-5 potential cases that could be used for case studies in the sensitivity experiments.

Sensitivity experiments: in progress.

We are currently performing a series of mesoscale sensitivity experiments for the Houston area with RAMS@CSU linked to TEB. The model is configured to use three two-way interactive nested model grids with horizontal grid spacings of 37.5, 7.5, and 1.5 km centered over Houston. Grid 1 (50 X 50 grid points) and grid 2 (92 X 92 grid points) are used to simulate the synoptic and mesoscale environments, respectively. The spatial resolution of the finest grid (102X102 grid points) is sufficient to resolve deep convection. Forty vertical levels with variable grid spacing are used, and the model top extended to approximately 22 km above ground level (AGL). Eight of the vertical levels fall within the first 1 km AGL. These numerical experiments are initialized with the aerosol concentration vertical profiles corresponding to the clean and polluted cases, as well as 25, 50 and 75% of the latter.

Additional series numerical experiments will be performed by only perturbing the land use input data as well as varying both aerosol concentration and land use. We will run sensitivity experiments with older NCLD land use data (1992) and compare those with the more recent NCLD land use data to ascertain how changes in land use affects the meteorology in the Houston area. These comparisons will be used as benchmarks for the experimental design of the land use sensitivity experiments

Setting up Linux cluster: complete.

We received the funding in August 2007, so the progress so far is within our expectations.

4. Leveraging/Payoff: None as yet

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

None as yet

6. Awards/Honors: None as yet

7. Outreach:

(a) Jeremy Orban, B.S. (graduates 05/2008)
(b) AT 712: Storm and Cloud Dynamics

8. Publications: None as yet

SOCIAL VERIFICATION OF TORNADO WARNINGS; HOW CAN WE IMPROVE RESPONSE TO WARNINGS?

Principal Investigator: Shripad D. Deo

NOAA Project Goal: Weather and Water (Serve society's needs for weather and water information)

Key Words: Science, Communication, Education

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

It is a common experience that the tornado warnings issued by the National Weather Service (NWS) do not always elicit prompt and desired responses. The responses from the public and emergency management community are not always congruent with the urgency communicated in these messages. The emergency managers often delay activation of warnings for different reasons. As a result, the advantages gained from increased or improved lead-time may be nullified.

This research aims to find out what it is that the emergency managers look for in the warnings before deciding to act. By knowing what it is that they look for and how they understand the urgency of the threat communicated through tornado warnings, we plan to change the way in which tornado warnings are worded and structured. This would improve the chances of prompt response and effective mitigation of damage and destruction.

2. Research Accomplishments/Highlights:

A different approach, using scenario-based questions, to elicit responses from emergency managers.

A demonstration that the criteria for what constitutes a "good forecast" needs to have its relevance to society's needs at the top. The criteria were developed with what would be acceptable to other meteorologists (or hydrologists or climatologists). This was fostered because of insufficient understanding of the relationship between science and society. Most people do not appropriate scientific concepts or information in order to emulate the scientist. They seek information about relevant natural phenomena to make sense of their own lives and livelihoods from within their own cultural framework.

Develop an awareness that it is not sufficient to keep producing what worked before. To develop socially robust knowledge it is necessary to embrace the process of contextualization. The resulting socially robust knowledge has three aspects:

It is valid not only *inside* but also *outside* the laboratory or a scientific organization.

This validity is achieved by involving an extended group of experts, including lay *experts*.

Because ‘society’ has participated in its genesis, such knowledge is less likely to be contested than that which is merely *reliable*.

What *works* has now acquired a further dimension that can be described as a shift from *reliable knowledge* to *socially robust* knowledge.

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

The project is still in progress. The surveys were conducted at three NWS field offices. Analysis of one set is complete. The other set is now being analyzed. The third office lost its completed questionnaires and has agreed to redo the survey. The results from the initial analysis are encouraging. It shows that the emergency managers respond promptly if they understand the nature of potential threat and damage from a tornado. They also respond quickly if the warnings are devoid of jargon.

4. Leveraging/Payoff:

The work done with tornado warnings has provided a template from the social science perspective to pursue a similar approach in flash flood warnings.

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

This project is supported by the Cooperative Program for Operational Meteorology, Education and Training (COMET) of the University Corporation for Atmospheric Research (UCAR) and the National Weather Service (NWS).

6. Awards/Honors: None as yet

7. Outreach:

(e) Public awareness. The approaches and experiences gained from AHPS projects were presented to the workshop organized by the NWS at Kansas City, MO.

8. Publications:

A short report on lessons learned from this study will be published on WAS*IS website to enable others to pursue similar research approach.

STUDY OF THE DIRECT AND INDIRECT EFFECTS OF AEROSOL ON CLIMATE

Principal Investigator: Graeme Stephens

NOAA Project Goal: Climate

Key Words: Weather, Aerosols, Modeling

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

The key goal of the research reported here is to evaluate direct and indirect effects of aerosols on climate in a way that consistently utilizes local-scale measurements along with satellite observations and large-scale modeling. The principal efforts are in three main areas:

(i) Combining aerosol aircraft profile measurements, surface measurements and satellite optical property measurements to arrive at estimates of aerosol radiative forcing. In this way, the research proposes to upscale the more local-scale measurements to global scale forcing.

(ii) Incorporating these aerosol forcings into global climate models. The forcing estimates derived from (i) will be developed using a radiation model already developed by the PI and currently in use in climate models. In this way, the research proposed under (i) will flow directly to the climate model user community.

(iii) Examining the influence of aerosol on cloud and precipitation and thus provide preliminary estimates of the aerosol indirect effect. This component of the research revolves mostly around the use of a cloud resolving model run both in a large scale mode and coupled to a climate model.

2. Research Accomplishments/Highlights:

The current year's activities have made progress on A-Train (MODIS and CALIPSO) aerosol retrievals, begun application of two-moment microphysics in cloud-resolving model simulations needed to assess indirect effects, extended initial small-domain studies of cloud radiative effects to large 3D domains, and begun observational analyses that will enable the assessment of cloud radiative forcing due to anthropogenic aerosols.

Details of the progress to date during the third year of this research project are provided below, followed by related publications and activities planned for the next year.

3. Comparison of Objectives Vs. Actual Accomplishments:

Aerosol Direct Effects - Proposed for Year 3

We plan to develop further the analysis of the A-train observations applying the analysis methods to many cases of matched MODIS-CALIPSO observations. We also plan extending the results of extinction to aerosol direct forcing by feeding the retrieved information into the BUGSRad radiation scheme.

Progress for Year 3

Two student research activities are directed under this award. Both focus on use of the A-Train data to estimate direct aerosol forcing.

a) Critical reflectance approach (Well, PhD; expected completion fall 2008):

This effort focuses on developing and refining the concept of the critical reflectance technique using MODIS imagery combining the data with coincident lidar profiles from CALIPSO. The critical reflectance idea is extended to determine how it might provide some estimate of single scatter albedo. Efforts on modeling the critical reflectance for different aerosol types have been explored in an effort to construct a look-up table to convert critical reflectance to single-scattering albedo. Ancillary datasets from DeepBlue retrievals, NAMMA flight data, AERONET retrievals, and data from the mobile ARM station deployed in Niger in 2006 have been used in this exercise.

MODIS critical reflectance estimates have been developed using MODIS data. Results are for a case from 5 September 2006 over North Africa, a day on which an over-land flight profile was performed during the NAMMA campaign. The DeepBlue retrieved AOD at 550 nm is shown for this day in Figure 1, along with the retrieval for 21 September 2006 (the day used for comparison to do the critical reflectance estimate). The corresponding CALIPSO track is shown in the dashed black line, and the flight track is shown as the black line extending from -23° to -10° W.

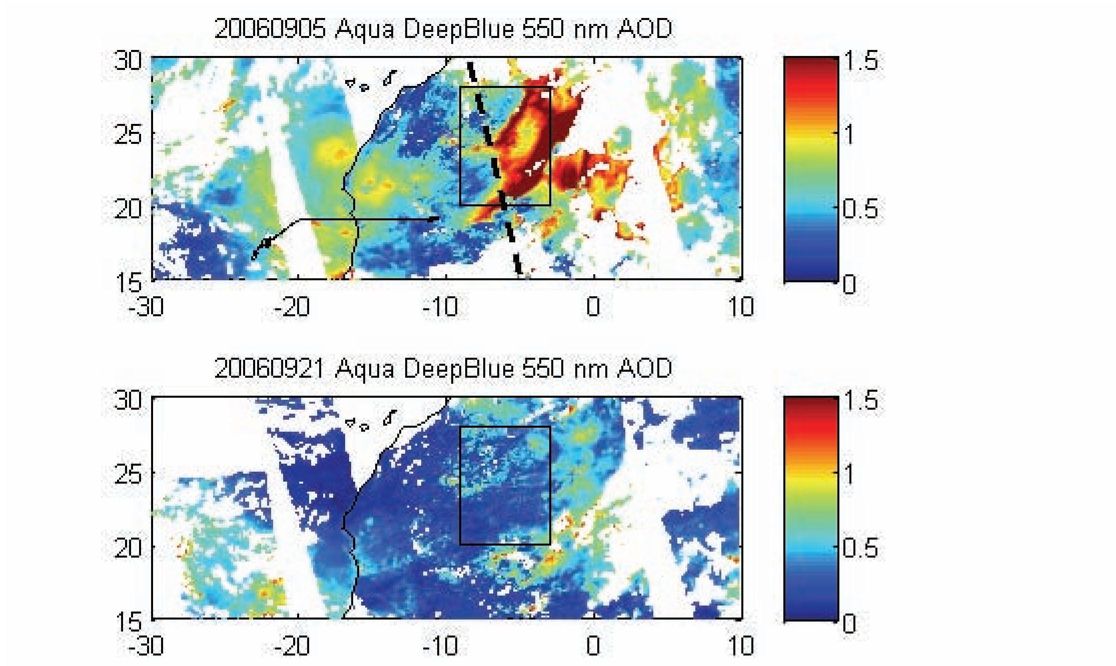


Figure 1. DeepBlue retrieved 550 nm AOD for 5 September (upper) and 21 September (lower) 2006. Critical reflectance results will be shown for the smaller box outlined in black.

Critical Reflectance Results for 5 September 2006

The aerosol critical reflectance and path radiance difference obtained by comparing the two days above are shown in Figure 2, for a swath located in the box outlined on the map. The blue line is the CALIPSO track for this time. The results are at 15-km resolution, and the corresponding uncertainties based on the fitting routine are also shown. For this plume, critical reflectance lies in the 0.3-0.4 range with uncertainties on the order of 10%. Path radiance in the plume ranges from 0.1-0.3, with similar magnitude uncertainties. These uncertainties are obtained from the fitting routine used. I have not really explored ways in which the uncertainty can be reduced by shifting the origin through which the fit is calculated (Vanderlei and I discussed this at one point). This is something I should do.

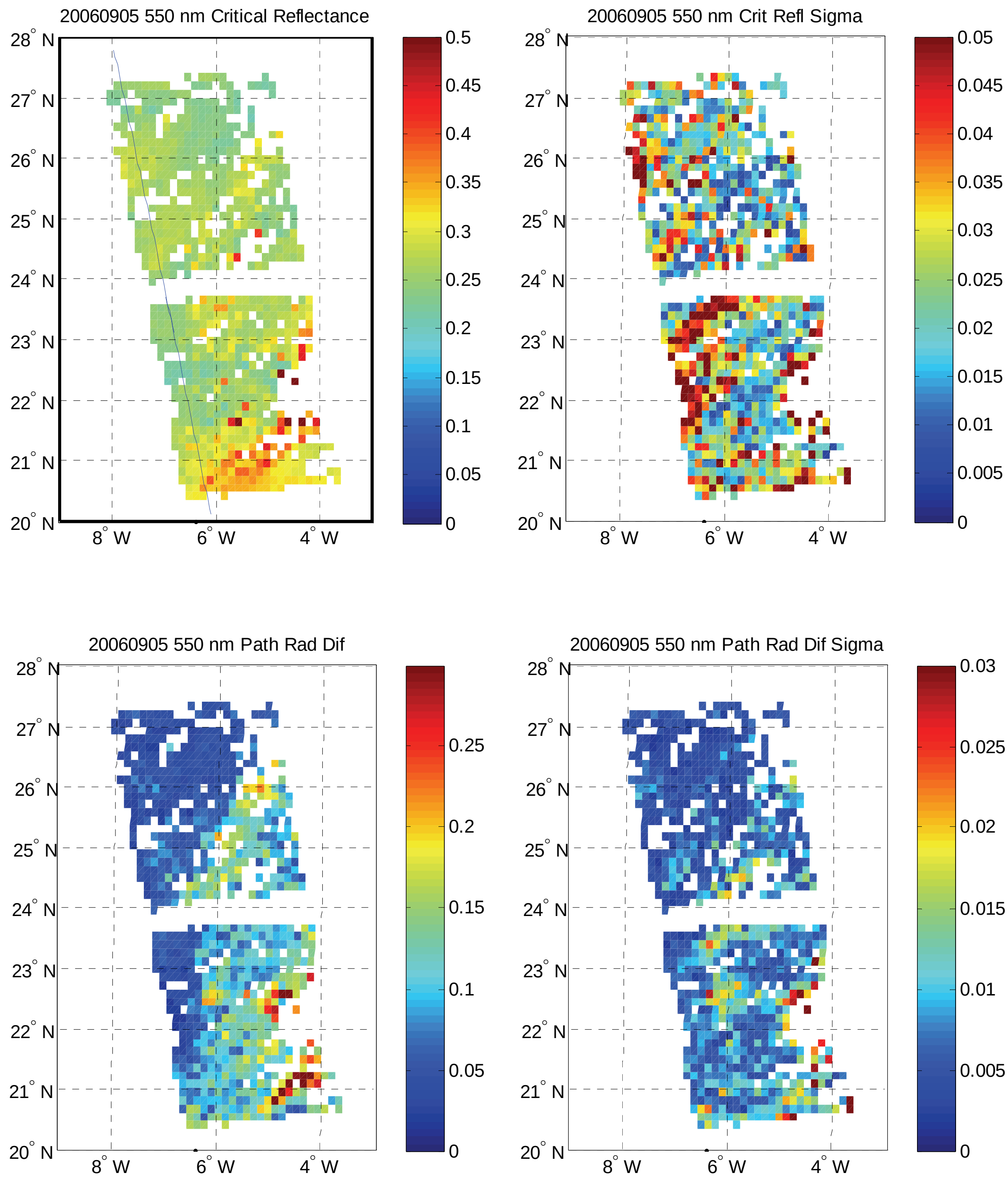


Figure 2. Critical reflectance and path radiance difference at 550 nm obtained by comparing reflectances on 5 September 2006 to those on 21 September 2006 (left panels) and associated uncertainties (right panels). Blue line in the upper-left panel corresponds to the CALIPSO track for 5 September.

The path radiance difference between 5 and 21 September and the corresponding MODIS DeepBlue retrieved AOD at 550 nm (to 0.3 degree resolution) and compared them—results are shown in Figure 3. They seem to compare well…

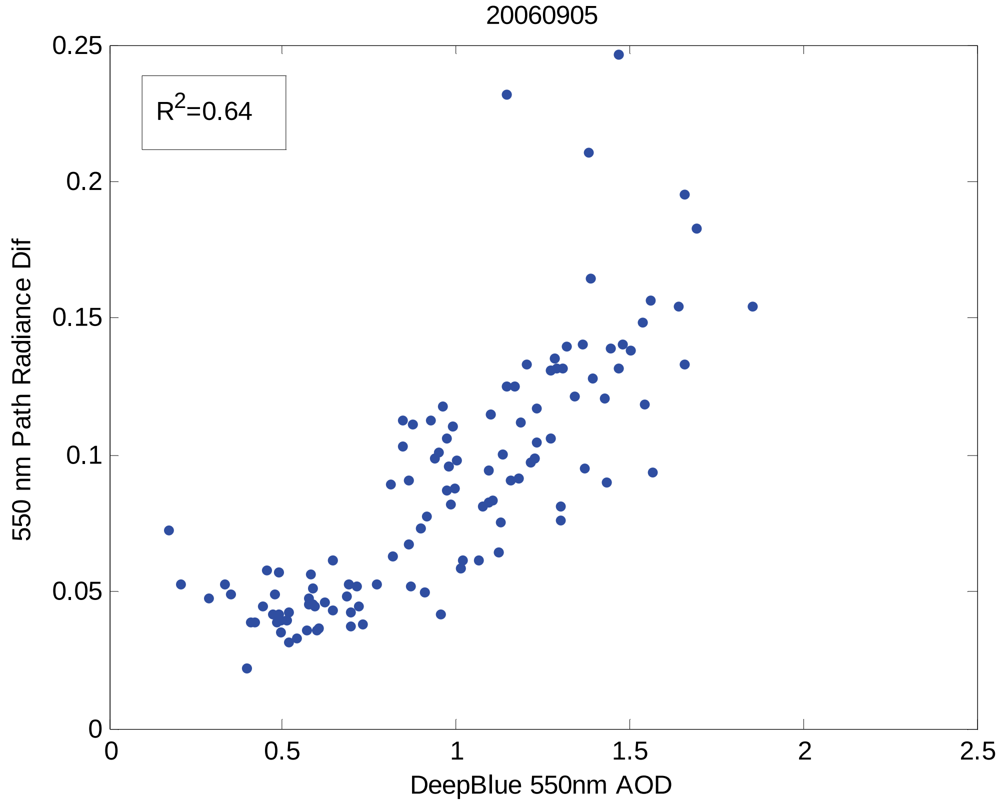


Figure 3. 550 nm path radiance difference versus DeepBlue 550 nm AOD for results shown above.

Critical Reflectance to SSA: DISORT-type code results

A DISORT-type radiative transfer code is used to model the critical reflectance and characterize it as a function of aerosol model type and related single scatter properties. Example results for two different aerosol models at 550 nm are shown in Figure 4. Error bars represent the standard deviation of the surface reflectance at which lines of constant AOD intersect. This information will be used to map the critical reflectance to single-scattering albedo in some sort of best-fit to a set of aerosol models.

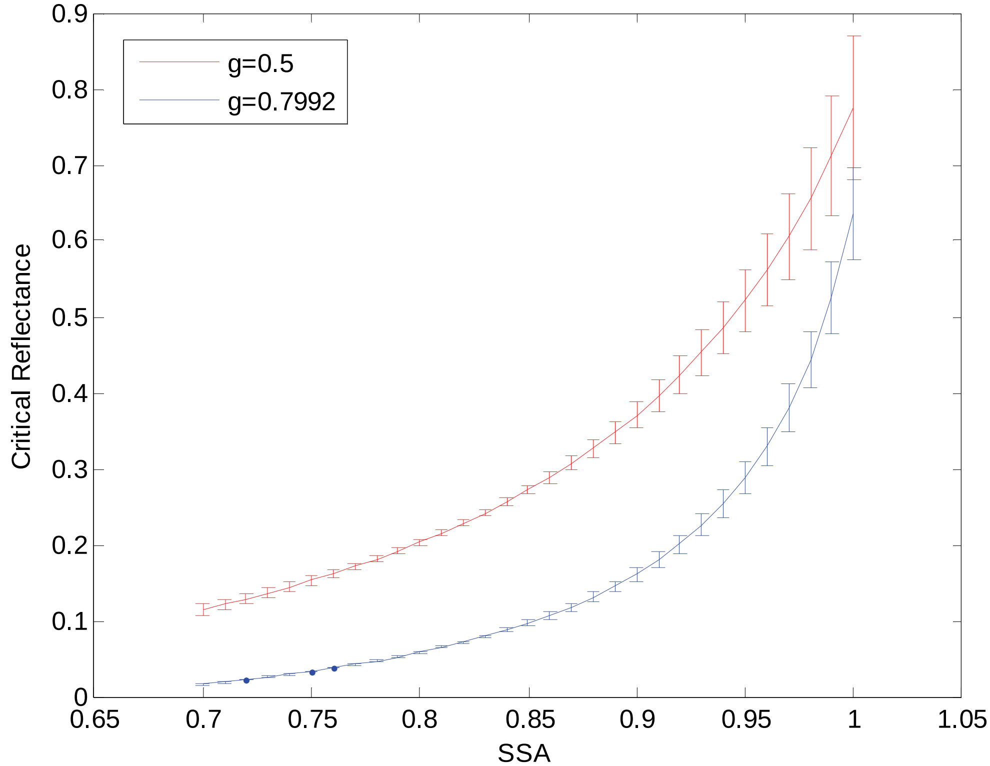


Figure 4. Modeled critical reflectance versus SSA for two aerosol models (g = 0.5 and g = 0.7992). Wavelength is 550 nm.

An example of the approach is presented for the 5 September test case involving a dust outbreak. Results are shown in Figure 5. Assuming the aerosol model to be representative of the actual aerosol, the uncertainties in retrieved SSA at 550 nm using the critical reflectance technique are about ±0.01 to 0.15. $SSA_{550\ nm}$ retrieved in the plume ranges from approximately 0.94 to 0.97. For comparison, data obtained during the NAMMA flight on this day just outside the above swath (19 N, -11 W) indicates a 532 nm SSA in the lowest 5000 ft of the column of 0.99.

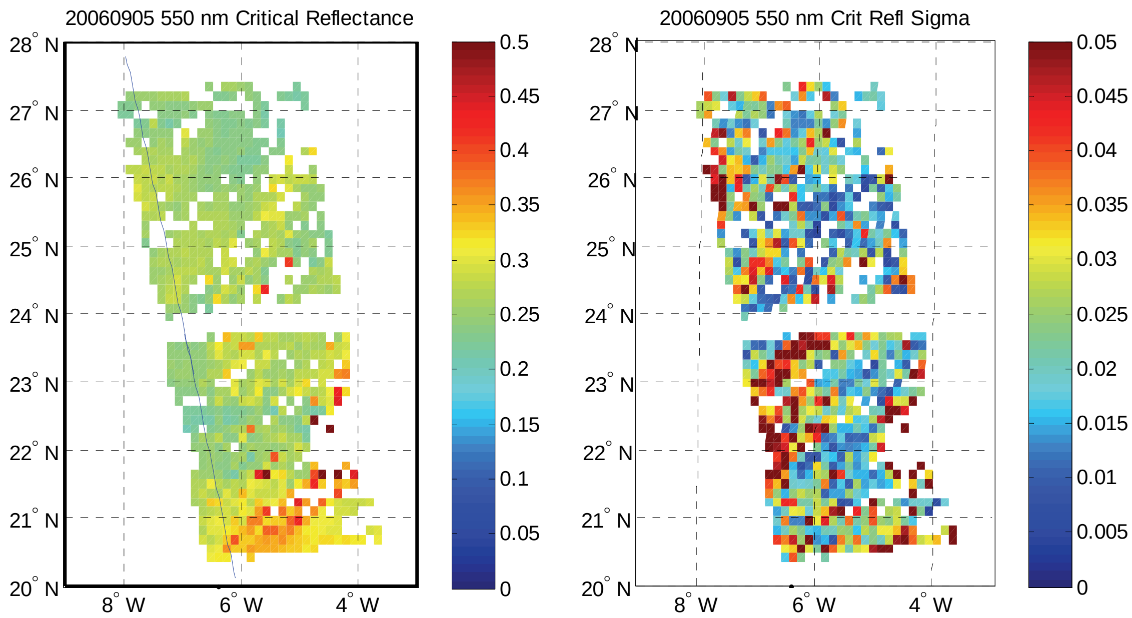


Figure 5. SSA retrieved at 550 nm assuming dust-like aerosol model (upper left) and associated uncertainty (upper right). Critical reflectance (lower panels) is also shown again for comparison.

Work on combining the critical reflectance data with coincident backscatter profiles from CALIPSO. Figure 6 contains CALIPSO 532 backscatter coefficient for the 5 September 2006 case (broken into two panels for the two swaths shown) and corresponding aerosol 550 nm SSA derived from the critical reflectance (determined using nearest neighbor interpolation). The higher SSAs correspond to regions of higher backscatter coefficient for the case.

Future Directions

Comparisons to ground and space-based flux measurements to determine what the combined critical reflectance- vertical profile information contains about aerosol direct radiative forcing.

Modeling direct forcing using critical reflectance and comparing to measurements.

Determining how uncertainty in critical reflectance/SSA translates to uncertainty in direct aerosol forcing.

Characterizing spatial variability in the optical properties of dust and biomass burning aerosol over North Africa with respect to the locations of AERONET stations and ARM mobile site.

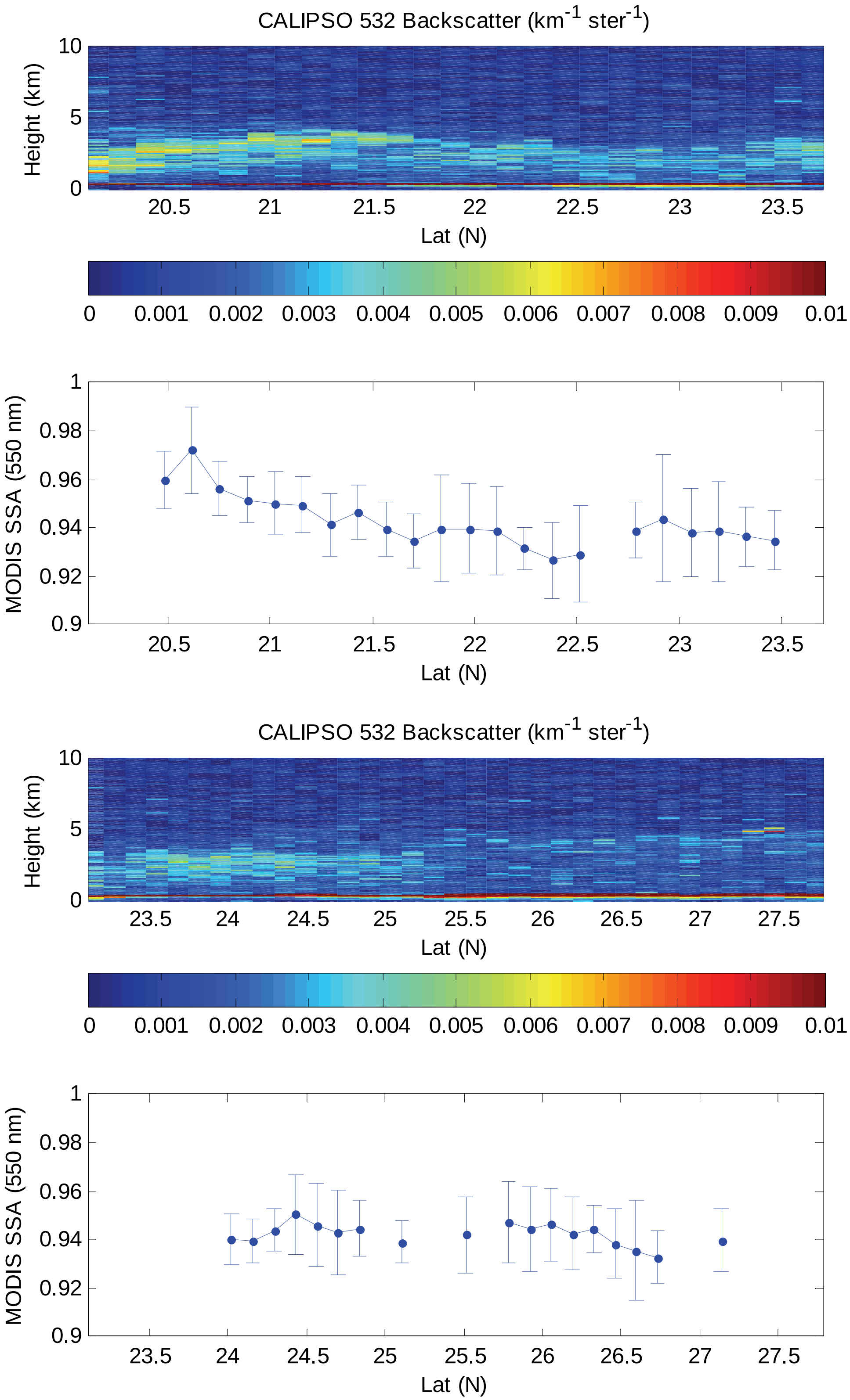


Figure 6. CALIPSO 532 backscatter coefficient and corresponding critical-reflectance derived 550 nm SSA, assuming a dust-like aerosol model.

b) Spectroscopic measures of aerosol (PhD McGarragh, expected completion fall 2009)

This portion of the research seeks to develop a novel satellite remote sensing technique for measuring aerosol parameters from space, including absorption properties that are required to estimate aerosol DRF on a global scale. This technique will then be used to gain a better understanding of the concentration and distribution of absorbing aerosols in the Earth's atmosphere and to study the contribution of aerosol absorption to aerosol DRF on the Earth's radiation budget.

This research has just commenced and seeks to exploit the new OCO observations expected in early 2009. Specifically the research objectives are to:

(i) Develop a technique for the remote sensing of the aerosol parameters, including absorption properties, from space using multispectral and multiangle measurements of intensity and polarization, O2 A-band spectrometer measurements, and lidar-derived aerosol extinction profiles. The retrieval technique will be developed with the A-train instruments POLDER, OCO and CALIPSO in mind.

(ii) Apply the retrieval to at least two seasons' worth of global observations. Comparison with ground-based retrievals will validate the retrieval technique while comparison with existing model and/or satellite-derived aerosol products will assess any improvement that this retrieval provides in the determination of aerosol parameters, particularly that of absorption.

(iii) Use the aerosol retrieval to gain a better understanding of the concentration and distribution of absorbing aerosols in the Earth's atmosphere.

(iv) Use the aerosol retrieval along with ancillary meteorological, cloud, and surface datasets to estimate aerosol DRF on a global scale. Comparison with existing model and/or satellite derived DRF estimates will assess the impact/improvement that the retrieval of aerosol absorption has on the estimation of the DRF.

(v) Use the aerosol retrieval and DRF estimation to study the contribution of aerosol absorption to the DRF of the Earth's radiation budget.

It is anticipated that the proposed retrieval will represent an improvement to existing satellite-based techniques by including aerosol absorption as a retrieved parameter which is typically left out in current methods. This improvement will then lead to a better understanding of the aerosol DRF and will provide valuable insight in to the development and validation of climate models.

Aerosol Indirect Effects - Modeling

Proposed: Our studies of the indirect aerosol effect have thus far focused on the impacts of CCN. The literature, however, indicates that variations in ice nuclei (IN) concentrations may have a significant impact on cloud radiative and microphysical properties, even in tropical convection, although few simulations have been reported in the literature. The focus of this work for the next (and last year) of this project will be on the impacts of IN on the organization, microphysical and radiative properties of tropical convection. Our plan is to complete our CCN analysis, submit the related papers, and then conduct simulations very similar to those described above for CCN for variations in ice nuclei concentrations.

Progress for Year 3

Progress occurred on two fronts: the first concerned the examination of aerosol influences on convection based on large domain cloud model simulations. The second activity combined A-Train observations with a global aerosol cloud model to evaluate the credibility of the aerosol effects on clouds as represented in that model.

Aerosol and convection*:* The impacts of varying concentrations of cloud condensation nuclei (CCN) on the precipitation, microphysical and dynamical properties of tropical convection have been investigated using cloud-resolving model (CRM) simulations within a radiative convective equilibrium (RCE) framework. The tropical atmosphere is never far from a state of RCE, and equilibrium experiments such as these allow for the examination of the feedbacks between radiation, clouds, water vapor and convection, and the impacts that external forcing such as variations in aerosol concentrations may have on these aspects of tropical convection. Two-dimensional numerical simulations were conducted using the Regional Atmospheric Modeling System (RAMS). These simulations were conducted using a single model grid with grid spacing of 2 km, 4000 points in the zonal direction and a stretched grid of 38 levels in the vertical. Two-moment microphysics, in which both the mixing ration and number concentrations of all the hydrometeors are prognosed, was utilized. The model was initialized with the 00 GMT 5 December 1992 TOGA COARE sounding, and convection was initiated using random perturbations to the potential temperature field across the domain. A fixed and uniform ocean surface with a temperature of 300K was employed at the lower boundary, and the lateral boundaries were periodic. A fixed solar zenith angle was used. In the RAMS microphysics module, the maximum concentrations of aerosol particles that can potentially serve as CCN are initialized at the first timestep. These aerosol particles are then only activated as a function of vertical velocity, temperature, supersaturation and the number of CCN present. CCN are also advected, have sources and sinks, and may be considered as a prognostic variable in RAMS.

A series of sensitivity experiments were conducted. In the control simulation, a background concentration of available CCN of 25 cc^{-1} was utilized. This simulation was run for 100 days, with radiative convective equilibrium being achieved at approximately 50 days. Sensitivity tests were then conducted by restarting the control simulation at 50 days and incorporating a level of enhanced CCN concentrations between 2 and 4 km AGL being representative, for example, of the scenario of the advection of Saharan dust over the Atlantic Ocean. The CCN concentrations used within this layer were doubled for each successive test, and included 50, 100, 200, 400, 800 and 1600 cc^{-1}. These sensitivity tests were then run for another 50 days. The control simulation and these six sensitivity experiments were then compared 5 days after the addition of this aerosol layer (days 55-60) and then toward the end of the simulation (days 85-90). The variations in CCN concentrations were found to have numerous effects on various aspects of tropical convection, including the self-aggregation of convection, the trimodal distribution of convection and on precipitation rates. Perhaps the most significant finding of this research is that the influence of enhanced CCN concentrations on surface precipitation varies depending on which convective regime was being considered. Increased CCN concentrations were found to reduce the precipitation from shallow convection in keeping with second indirect aerosol effect. However, precipitation rates from deep convection were enhanced. This was found to occur through an aerosol-dynamic response in which updrafts were stronger in the more polluted cases as a result of larger amounts of cloud water being available for transport to higher regions of the cloud, where freezing and the release of greater amounts of latent heat go to enhance the updrafts. Cumulus congestus represents the transitional regime in that the frequency of occurrence of weaker precipitation rates is reduced, while the frequency of greater precipitation rates was increased as a result of enhanced collection efficiencies once precipitation begins. The results of this analysis have been written up in a manuscript (van den Heever and Stephens, 2008). Similar simulations investigating the impacts of varying ice nuclei have also been conducted. These are currently being analyzed and will be included in a future paper.

Aerosol effects in a global cloud model: The second modeling study (Suzuki et al., 2008) brings the satellite observations and the global cloud resolving (NICAM) models together. In this study the interactions of aerosols with liquid clouds is simulated using a global cloud-system-resolving model implemented with an aerosol transport model. The global model with horizontal resolution of 7km represents the convective cloud growth processes and their interactions with aerosols, and thus provides the first opportunity to investigate the aerosol effects on the resolved liquid convective clouds on a global scale that have been otherwise difficult with traditional climate models. The results include simulations of detailed spatial structures of cloud particle effective radii especially over tropics, global correlation statistics of cloud properties with aerosols for different warm cloud types and vertical growth patterns of liquid droplets influenced by aerosols, similar to those obtained from satellite observations. These results demonstrate the advantage of this model over traditional climate models to simulate the aerosol interactions with liquid convective clouds and, furthermore, how model and satellite observations can be used to address the topic of aerosol effects.

Aerosol Indirect Effects - Observational Studies

Proposed: For this phase of the work we will further exploit A-Train observations to examine aerosol indirect effects. Specifically this activity includes:

Distinguishing the effects of aerosols from those of the thermodynamic environment using either CWV or a combination of CWV and LTSS as an indicator of atmospheric stability.

Determine if certain thermodynamic conditions are more favorable for the enhancement of liquid water path by aerosol.

Determine if clouds in high aerosol environments are less likely to precipitate than those in pristine environments by using the CloudSat rainflag and AMSR-E derived rain rates.

Quantify the total albedo enhancement of cloud due to aerosols including the effects of cloud droplet size, liquid water path, and cloud fraction and use this estimate to estimate the total radiative forcing due to the indirect effects of anthropogenic aerosols.

Progress: Research on this topic is ongoing. We have developed novel ways of studying the transition from cloud to warm rain (Stephens and Haynes, 2007: Near Global Observations of the Warm Rain Auto-conversion Process. *Geophys. Res. Lett*., 34, L20805, doi:10.1029/2007GL030259 and Suzuki and Stephens, 2008b; Global identification of warm cloud microphysical processes with combined use of A-Train observations, Geophys. Res Lett, 35, L08805, doi: 10.1029/ 2008GL033590.) using A-Train observations and we are in the process of applying these tools to observations of clouds in different air mass and related aerosol conditions. This work will be completed in the coming months.

4. Leveraging/Payoff:

5. Research Linkages:

6. Honors/Awards:

7. Outreach:

McGarragh, Ph.D research - Satellite Estimation of Aerosol Absorption and Application to Global Estimates of Aerosol Direct Radiative Forcing

Wells, K. C., 2007: PhD research.

8. Publications and presentations

Berg, W., T. L'Ecuyer, and S.C. van den Heever, 2007: Evidence for the impact of aerosols on the onset and microphysical properties of rainfall from a combination of active and passive satellite sensors. To appear in JGR.

Lebsock, M. D., T. S. L'Ecuyer, and G. L. Stephens, 2007: Information content of near-infrared spaceborne multi-angular polarization measurements for aerosol retrievals. J. Geophys. Res., 112, D14206, doi: 10.1029/2007JD008535

Stephens, G.L, S. van den Heever and L.A. Pakula, 2008; Cloud-radiative feedbacks in idealized radiative convective equilibrium, to appear in *J. Atmos. Sci*.

Suzuki, K., T. Nakajima, M. Satoh,, H. Tomita,T. Takemura, T. Y. Nakajima, and G. L. Stephens, 2008;Global cloud-system-resolving simulation of aerosol effect on warm clouds : accepted for *GRL*

van den Heever, S.C., and G.L. Stephens, 2007: Indirect Aerosol Forcing on Tropical Convection in a Radiative Convective Equilibrium Framework. In preparation for submission to J. Atmos. Sci.

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 teletraining modules developed at CIRA and delivered to NWS forecasters.

This objective is achieved by the development and delivery of new satellite-based training sessions at CIRA. New topics for teletraining 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 six sessions created by VISIT collaborators. As training needs develop for new research and products, VISIT personnel will address those needs by building new teletraining sessions. For more information on the VISIT program, see http://rammb.cira.colostate.edu/visit .

2. Research Accomplishments/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 covering a wide variety of topics. To date, over 18,000 training certificates have been awarded (Fig. 1), and most student feedback suggests a direct applicability to current forecast problems. Most NWS forecast offices have participated in VISIT teletraining since October 1, 2004 (Fig. 2). The VISIT program also recognizes the need for flexibility in offering training courses to the busy forecaster. Most of the teletraining sessions have web versions with embedded instructor notes and recorded audio versions that can be viewed at any time. VISIT teletraining 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.

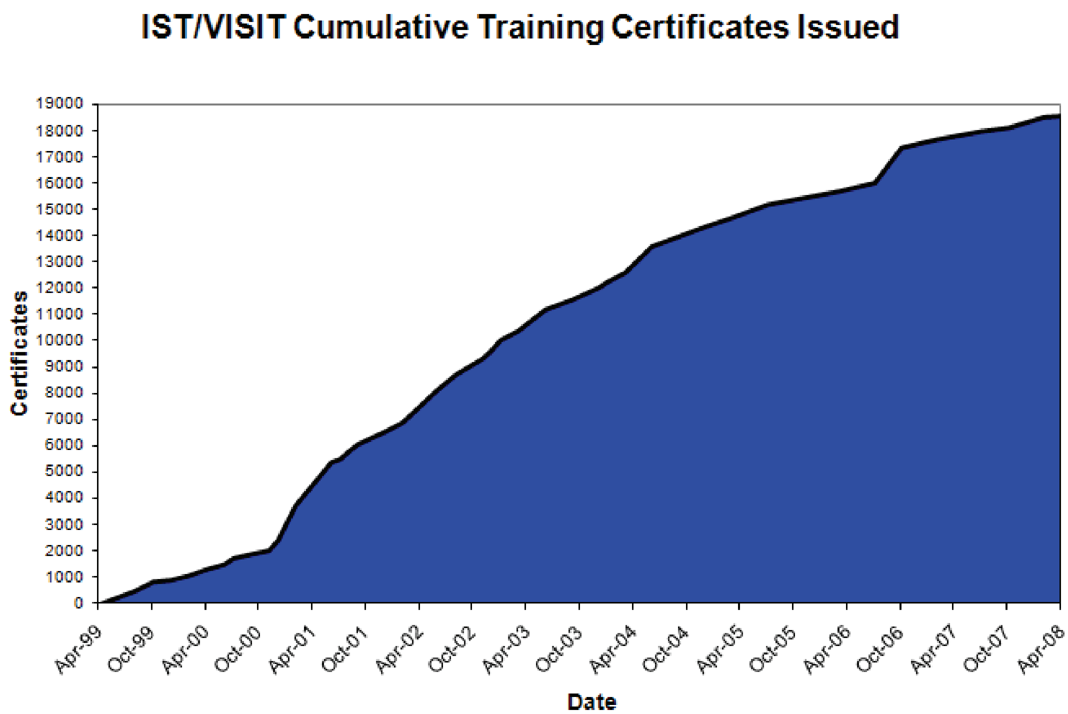


Figure 1. IST/VISIT Cumulative Training Certificates Issued.

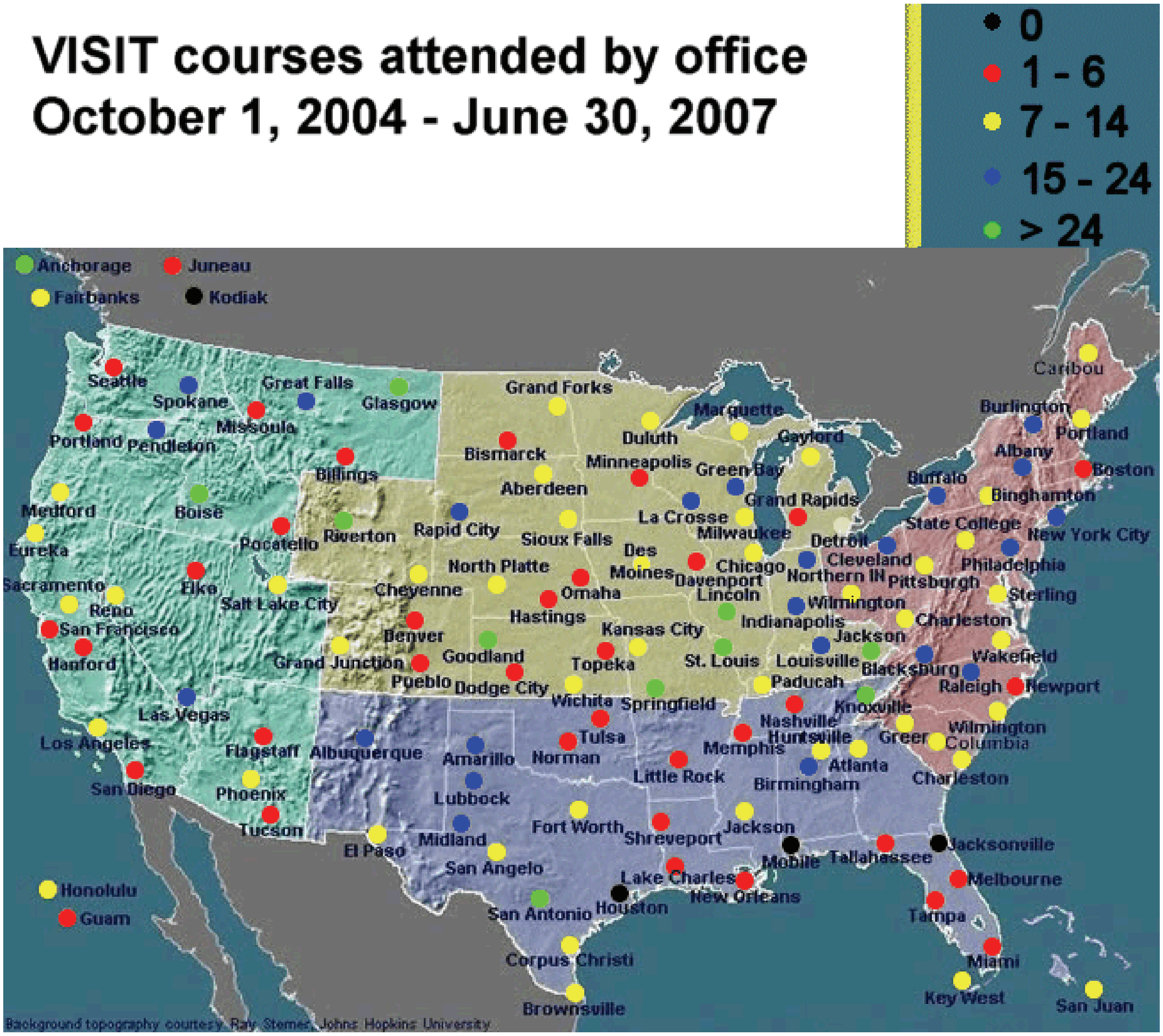


Figure 2. Map showing the NWS forecast offices that have taken VISIT teletraining session(s) since October 2004, number of sessions attended given by the color.

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 requests made by NWS forecasters for training in these topic areas:

“Satellite Interpretation for various Coastal Effects”.

“Utility of GOES Satellite Imagery in Forecasting/Nowcasting Severe Weather”. This includes a post-training WES case exercise so that students may reinforce learning objectives by practicing the techniques on an actual event. This is the first time that a WES simulation exercise has been included in VISIT training, again at the request of forecasters to include a simulation exercise as part of the training.

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 available satellite products. 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 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. When 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 March 28, 2008 there have been 783 completions of VISIT training in this format.

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 training facilitators, webpage maintenance, 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 helped to form the basis for selection of topics for the next version of the SHyMet course.
The SHyMet and VISIT members met at CIMSS (Madison, WI) in early November 2007 to discuss the topics survey, select topics, and plan the direction of 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:
1) monthly international weather briefings,
2) presentations on VISITview and training efforts where appropriate, and contributions to international training materials

6. Awards/Honors: None as yet

7. Outreach:

(a) Two college undergraduate students (Daniel Coleman and Kashia Jekel) are supported by this project.

(b) D.E. Bikos, and J. Braun July 1, 2007 – April 16, 2008: 131 VISIT teletraining sessions delivered to NWS offices, and others (909 participants). CIRA, Fort Collins, CO.

B. H. Connell, July 2007 through March 2008: Collaboration with and participation in monthly international weather briefings (in English and Spanish) conducted by the WMO Virtual Laboratory Task Team using VISITview software (http://hadar.cira.colostate.edu/vview/vmrmtcrso.html). There were participants from the U.S and WMO designated RA III and RA IV countries. The participants include researchers, forecasters, and graduate/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.

B. Connell, April 23, 2008 and November 12, 2007: GOES and the characteristics of its channels. Remote Sensing class at the Metropolitan State College of Denver, CO.

(c) None

(d) J.F. Braun, March 2007: Basic Meteorology for Intro to Physics, Chemistry, and Environmental Science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, October 2007: Basic Meteorology in Relation to Ecosystems for first year Biology, Rocky Mountain High School, Fort Collins, CO.

J.F. Braun, November 2007: Basic Meteorology for Intro to Physics, Chemistry, and Environmental Science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, November 2007: Science fair judge, Boltz junior high school, Fort Collins, CO.

J.F. Braun, February 2008: Basic Meteorology for Intro to Physics, Chemistry, and Environmental Science, Boltz junior high school, Fort Collins, CO.

(e) VISIT training material is available to the public via the Internet.

8. Publications:

<u>Newsletters</u>
Article published in the fall 2007 CIRA Newsletter: "International Activities: Weather Briefings and Training via the Internet" by B. Connell, M. DeMaria, and J. Purdom pages 4-7 http://www.cira.colostate.edu/publications/newsletter/fall2007.pdf

<u>Presentations</u>

D. Bikos and J. Braun, June 2007: Invited lecturers at the COMET Mesoscale Analysis and Prediction (COMAP) course, Boulder, CO.

CIRA gave input to and provided support for VISIT/SHyMET/WMO focus group presentations to the following:

August 22, 2007: The International Workshop of Meteorological Satellites for South-American Users, Maceio, Brazil given by Tony Mostek, NWS Training Division in Boulder

October 2 and 9, 2007: Workshop on Meteorological Satellites, Cartagena, Colombia presentation given by Vilma Castro, University of Costa Rica. Weather briefing

Professional Meetings
A conference paper and poster were prepared for the AMS 17th Symposium on Education held in New Orleans in January 2008. "International Focus Group– Virtually there with VISITview" by B. Connell, V. Castro, M. Davison, A. Mostek, B. Fallas, K. Caesar, and T. Whittaker
http://ams.confex.com/ams/88Annual/techprogram/paper_134924.htm

Conference
Dr. Vilma Castro, a collaborator from The University of Costa Rica, gave a presentation to the seventh Computer Aided Learning in Meteorology (CALMet VII) conference held in Beijing, China 2-7 July 2007. The presentation titled "International Satellite Weather Briefings via the Internet" detailed the work being done with the Focus Group activities in Central and South America and the Caribbean. The Focus Group activities rely heavily on the VISITview software. The authors included V. Castro & B. Fallas, UCR Costa Rica, B. Connell, CIRA, A. Mostek & M. Davison, NWS USA,; KA Caesar, CIMH Barbados

THE ROLE OF AFRICA IN TERRESTRIAL CARBON EXCHANGE AND ATMOSPHERIC CO2: REDUCING REGIONAL AND GLOBAL CARBON CYCLE UNCERTAINTY

(NOTE: Funds were spent past the project end date and, thus, a recap report for the project is included)

Principal Investigator: Niall Hanan, Natural Resource Ecology Laboratory, CSU

Investigators:
Joseph Berry, Carnegie Institution of Washington
A. Scott Denning, Department of Atmospheric Sciences, CSU
Jason Neff, University of Colorado
Robert J. Scholes, Centre for Scientific & Industrial Research, South Africa
Jeffrey Privette, NASA-Goddard Space Flight Center

Senior Personnel:
Christopher A. Williams, Natural Resource Ecology Laboratory, CSU
Neil Suits, Department of Atmospheric Sciences, CSU

NOAA Project Goal: Climate

NOAA Programs: Climate and ecosystems; Climate observations and analysis

Key Words: Carbon Cycle, Africa, Ecosystems, Variability

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

Much uncertainty remains in our understanding of the ways in which atmospheric, terrestrial and oceanic carbon reservoirs interact, and the controls, magnitude and location of fluxes that determine atmospheric CO_2 mixing ratio and terrestrial and oceanic sequestration. Analysis of the rate of increase of atmospheric [CO_2] suggests that carbon uptake by terrestrial ecosystems offsets fossil fuel emissions by 1.5-2.0 Gt per year. Several studies suggest that a significant proportion of that sink lies in northern deciduous and boreal ecosystems, but the range of estimates by different techniques is large and research also indicates a strong tropical sink. Furthermore, inverse estimates of the role of tropical regions in global carbon exchange may be underestimated because of the paucity of real data and because deep convection in the tropics may mask the tropical signal in the existing network of [CO_2] measurements. With expanded research in neo-tropical regions during the last few years, the weakest link in our current understanding of the global carbon cycle, and concomitant potential for greatest return on research effort, is in the old-world tropics, particularly in Africa. With joint funding from the US National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) this project is addressing some of these shortcomings in our understanding of the temporal and spatial dynamics of carbon exchange in Africa. The project includes both biogeochemical forward modeling, using remote sensing data and land surface models, and atmospheric inverse modeling of carbon dynamics across the African continent. Field measurements in support of the modeling activities are being carried out in

Southern Africa (Kruger National Park, South Africa) and West Africa (the Gourma region of northern Mali). The field component is a directed effort to obtain vital new data and process understanding to constrain and parameterize models for regional and continental carbon cycle assessments. We are planning an additional field site in under-represented Central Africa for the coming year, with possible site locations in Zambia or Congo-Brazzaville.

The project will provide more tightly constrained estimates of the spatial and temporal variation in carbon uptake and release from Africa. Satellite data from the AVHRR series and from MODIS and other *Terra* satellite instruments, and assimilated climate data, are being used to parameterize a land surface model (SiB3) to estimate the historical and contemporary variation in vegetation activity across the continent and predict spatially and temporally continuous fields of net carbon, water and stable isotope exchange. In parallel with this “forward modeling” of African carbon dynamics, we are preparing both regional and global inverse analyses of atmospheric [CO_2] and stable isotope concentrations. These analyses will use the existing flask measurement network augmented by new high precision [CO_2] measurements in Africa. We expect that the novel combination of forward and inverse estimates of African carbon exchange will lead to model enhancements and reductions in uncertainty, lead to improved estimates of the spatial and temporal dynamics of carbon and water exchange in Africa, and lead to an improved understanding of the impacts of climate, climate variability and land use in regional carbon dynamics and the contributions of Africa to the global carbon cycle.

Year 2 activities included deployment of continuous precision CO_2 and 13C flask measurement systems in South Africa and West Africa, intensive measurements at a savanna site in southern Africa to examine soil respiration and 13C dynamics in mixed C4-C3 ecosystems, preparation of a manuscript reviewing current knowledge of the African carbon cycle (in review), preparation of datasets and initial simulations of historical carbon cycle dynamics across the continent using the historical AVHRR data archive (1982-2002) and a land surface model, and preparation of regional datasets and atmospheric transport models for new and enhanced atmospheric inversion studies. These activities are described in more detail below.

Year 3 Work Plan

--Run long-term (1982-2002) simulations of the historical carbon cycle in Africa at high temporal and spatial resolution. Analyze resulting data fields for patterns and processes relating to the spatial and temporal variations in carbon, water and energy fluxes (April-August 2006)

--Retrieve and compile MODIS data fields for Africa for 2000-2005 period, including Vegetation Index, f_{PAR}, LAI, land use and fire (burn scar) information (April-September 2006)

--Run MODIS-based simulations of cotemporary carbon cycle in Africa (August-December)

--Install field CO_2 and flask instruments in third ACE study location (Zambia or Congo) (August-September 2006)

--Develop soil respiration and 13C fractionation model for inclusion in land surface models.

--Begin analysis of data on near surface atmospheric CO_2 concentration and flask measurements of d13C. (August 2006)

--Compare simulations using the SiB3 land surface model and site measurements of CO_2 and $^{13}C/^{18}O$ from the Kruger Park and Gourma sites (late 2006)

--Commence inverse analyses using global flask network with additional data from 2 or 3 new African field sites (early 2006)

2. Research Accomplishment/Highlights:

Major Accomplishments in Year 2

1) The African Carbon Cycle

An early activity of this project has been the compilation of a review article summarizing the current state of knowledge of carbon cycle dynamics in Africa using inventory methods, forward models (including climate and satellite-driven approaches), atmospheric inversions and land-use and biomass inventories (Williams et al., 2006, in review).

With low fossil emissions (0.2 Pg C yr^{-1}) and productivity that largely compensates respiration (each ~ 10 Pg C yr^{-1}), land use (0.4 Pg C yr^{-1}) is Africa's primary net carbon release, much of it through burning of forests (Figure 1). Savanna fire emissions, though large (1.5 Pg C yr^{-1}), primarily represent a short-term dry season source rapidly offset by ensuing regrowth. Nonetheless, climate-induced variability in productivity and savanna fire emissions contribute to Africa being a major source of inter-annual variability in global atmospheric carbon dioxide. The sparse observation network in and around the African continent means that Africa is one of the weakest links in our understanding of the global carbon cycle and the location of the so called “missing sink” (Figure 2). Continent-wide observations of carbon stocks, fluxes, and atmospheric concentrations are key priorities to improve our understanding of the carbon dynamics of Africa and the world. For this reason, the field components of the ACE project are intended to provide new data-streams that will reduce uncertainty in atmospheric inversions and improve our mechanistic understanding CO2 dynamics in African ecosystems, and how the mixed C3 and C4 savannas imprint on the stable isotopic signature of CO_2 sources and sinks in the continent.

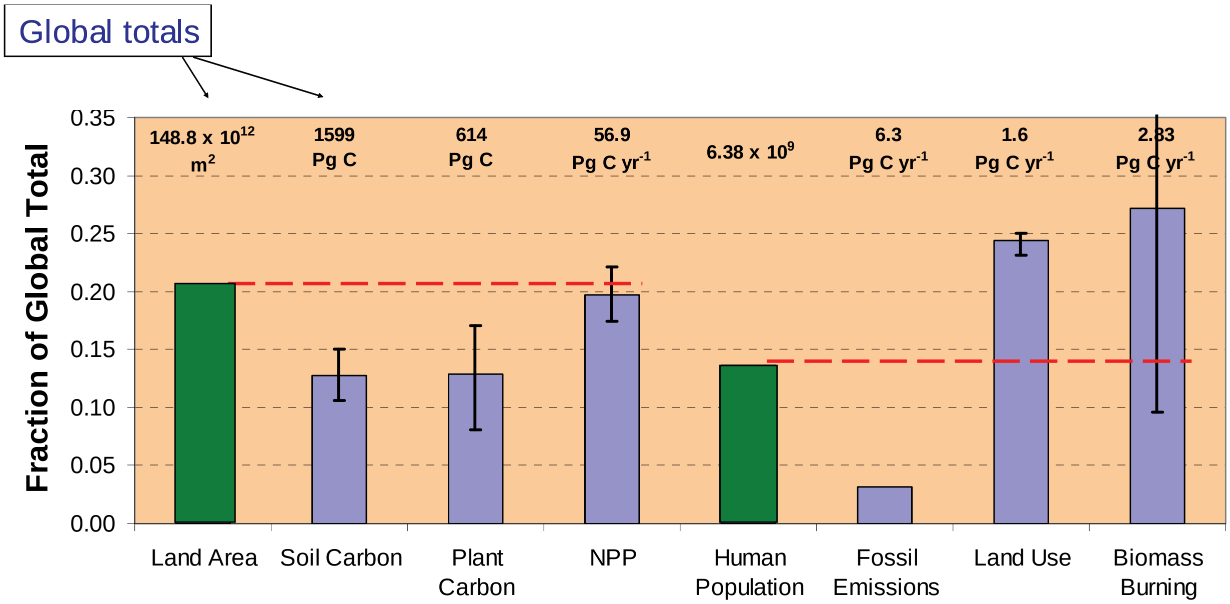


Figure 1. Carbon statistics for Africa expressed as fraction of global totals ('error bars' show range of published estimates). Land area and human population are shown as reference for Africa's fractional contribution to global carbon stocks and fluxes.

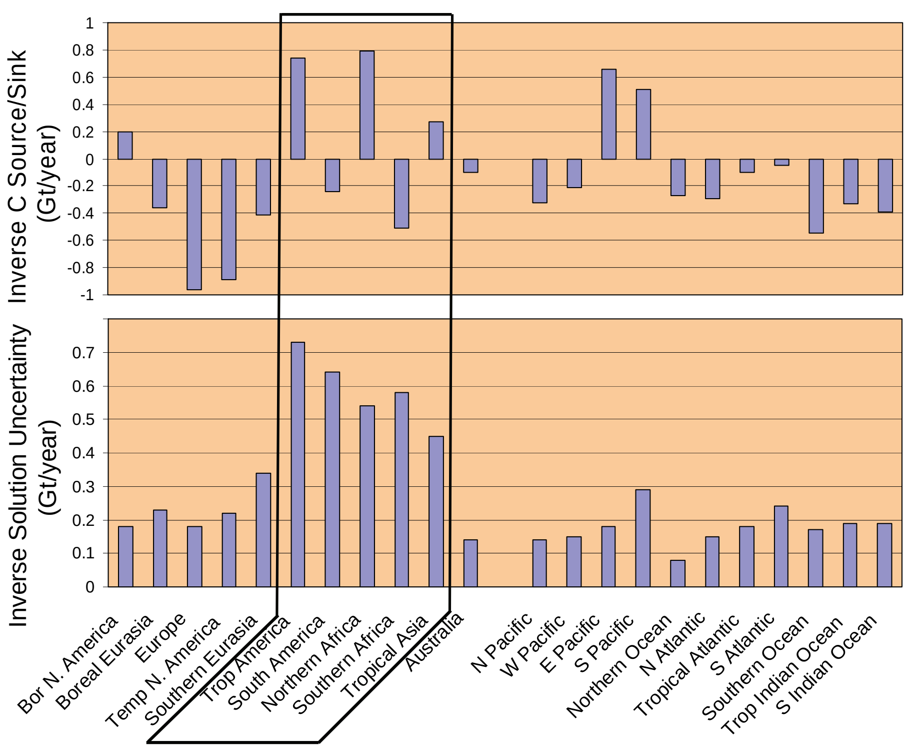


Figure 2. Inverse analysis results showing high levels of uncertainty for Africa and tropical terrestrial regions. (Data from TRANSCOM-2; Gurney et al., 2004).

2) CO_2 dynamics in tropical savannas

The intensive field site in the Kruger National Park, South Africa, was established in 2000 with initial funding from NASA Terrestrial Ecology and EOS Validation Program as a validation site with emphasis on carbon and water fluxes in tropical savannas. The site has become a primary research site for the ACE project because of the challenges savanna systems, with mixed tree-grass vegetation, present to biogeochemical models and remote sensing of vegetation function. The long-term flux measurements at the site will contribute to testing and improvement of land surface models in savannas through better understanding of the partitioning of energy and water between the tree and grass strata, the response of these water-limited systems to rainfall, particularly rainfall pulses, and functional differences between two of the most important savanna types of southern Africa. With the new funding under ACE the site is also contributing new very precise CO2 concentration ([CO_2]) measurements for atmospheric inversions, and measurements of atmospheric and soil 13C and soil respiration processes to better understand ^{13}C fractionation during photosynthetic uptake and respiratory release of CO_2 to the atmosphere.

Savanna systems are water limited systems and thus pulse-driven systems (because rainfall events are always discrete events, with most annual rainfall falling during only a few hours of the year). These pulse events excite physical, physiological, phenological responses in the vegetation and soil that can be complex in terms of the response time, lag dynamics, and decay characteristics (Figure 3). These pulse responses can be extremely important to the carbon and water dynamics of the system, but are often poorly represented (or not represented) by biogeochemical and biophysical models of ecosystem processes. The study of the long-term and pulse response patterns of carbon and water dynamics in these tropical savannas provides important background understanding for modeling these ecosystems that, in their different forms, occupy more than 50% of the African land surface.

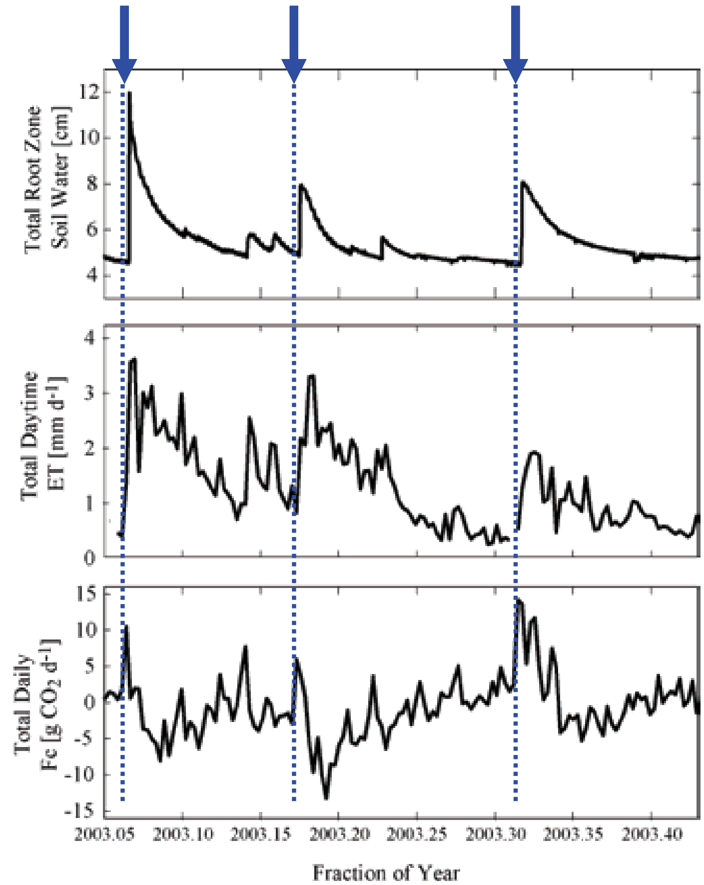


Figure 3. Pulse dynamics in tropical savannas. Measurements at the Kruger Park intensive research site during 2003 show the complex and non-linear response of savanna vegetation to rainfall events that depend not only on soil moisture, but also on phenological status and structural characteristics of the vegetation that impose lags and changing sensitivity to rainfall events through the growing season.

3) Modeling African Carbon Dynamics using Satellite Data

We plan analysis of both historical and contemporary carbon cycle dynamics across the continent using the long-term AVHRR dataset and more recent MODIS data. A study of the historical carbon dynamics of the continent has been initiated using the AVHRR archive and climate re-analyses to parameterize and run the land surface model SiB3 (Simple Biosphere Model, version 3; Figure 4-5. We are examining the spatial and temporal variability of net carbon exchange over the past 2 decades to analyze the impacts of climate variability, drought and land use on the NPP and vegetation activity in the region. In preparing the historical simulations using AVHRR datasets we have found that the seasonality of the moist tropics appears to be exaggerated (see, for example, simulations for a Congo basin site in Figure 4). Using temporally corresponding data on aerosol optical depth from MODIS, we determined that the AVHRR NDVI seasonality is negatively correlated with optical depth, with optical depth over the equator peaking during the dry seasons savanna fires to the north (December) and south (July) of the equator (Figure 6). We anticipate needing to correct the AVHRR record for the moist tropics to reduce the aerosol effect whilst retaining real inter-annual variability that may occur in the region relating to variable rainfall.

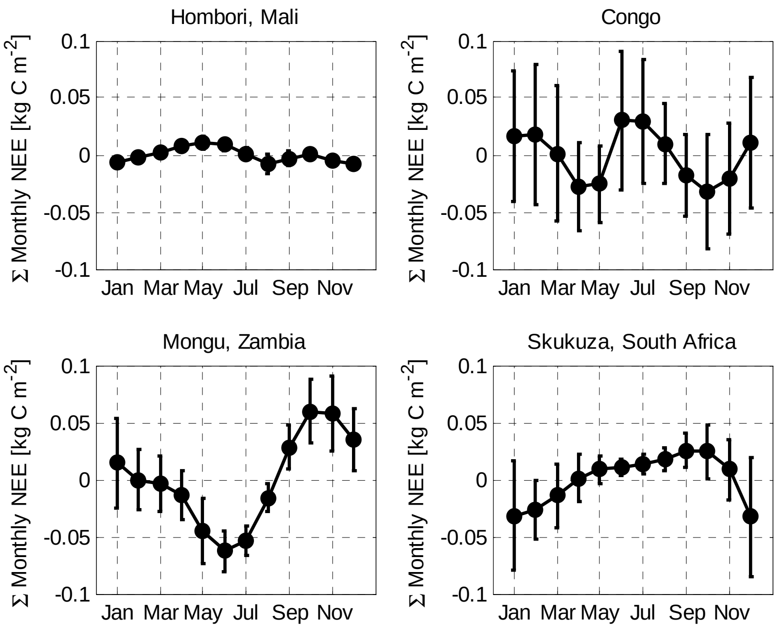


Figure 4. Monthly net ecosystem exchange (NEE) for 4 sample sites in Africa estimated using the Simple Biosphere Model (SiB3) and the long-term (1983-2000) AVHRR dataset. Climate data for the period were obtained from NCEP climate re-analysis fields. Hombori and Skukuza are active ACE field sites for measurement of ecosystem fluxes by eddy covariance and atmospheric CO_2 using the ACE Precision CO_2 and flask sampling system. A third measurement site is planned for either Mongu or a moist tropical (Congo basin) site to be established in the near future by Afriflux collaborators.

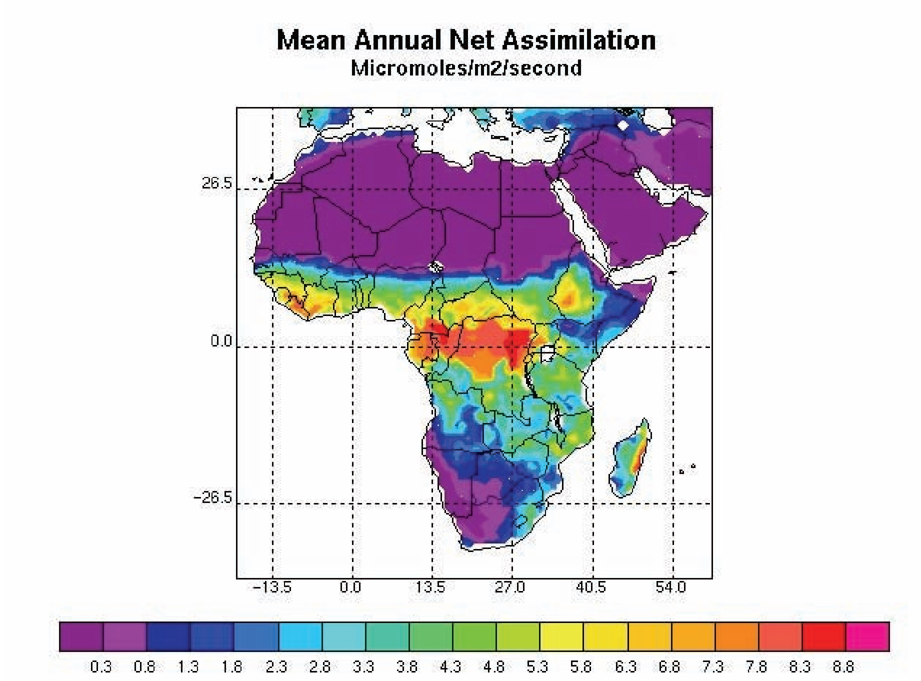


Figure 5. Annual average net assimilation rate (1983-2000) estimated using the SiB3 model, NCEP climate re-analyses and the long-term AVHRR dataset.

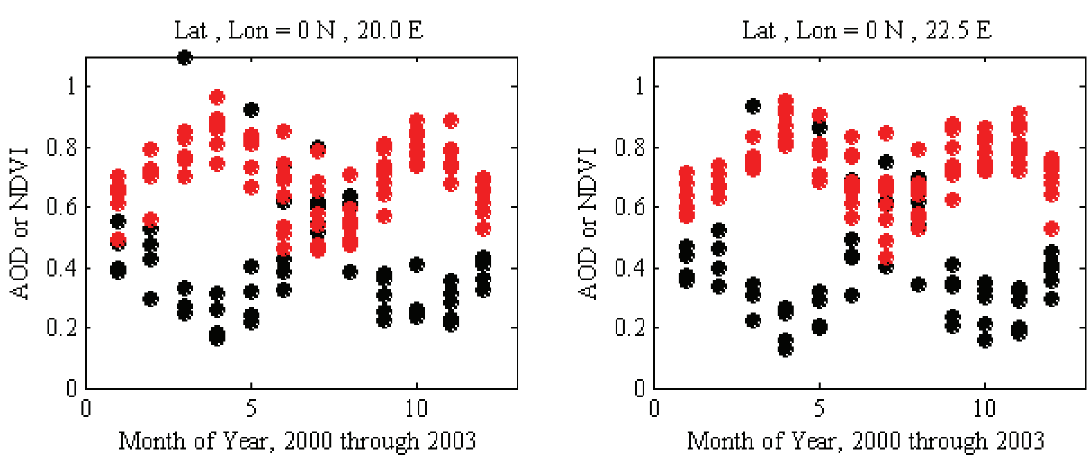
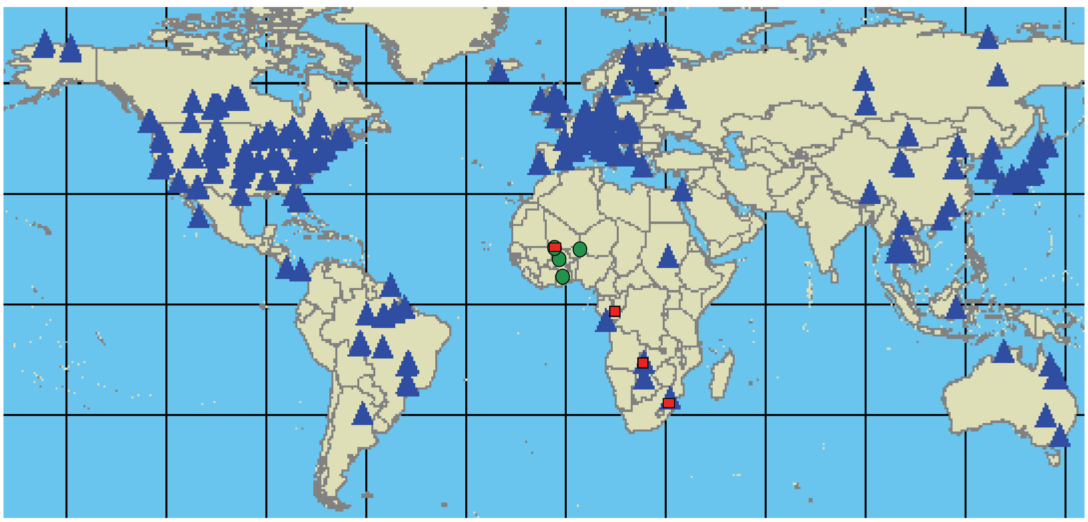


Figure 6. Monthly average AVHRR NDVI (red) and MODIS aerosol optical depth (black) in the moist tropics of Africa. Data are shown for two sites on the equator and for years with overlapping AVHRR and MODIS data availability (2000-2003). Note the strong seasonality in AVHRR NDVI that is negatively correlated with aerosol optical depth.

4) Precision CO_2 for Atmospheric Inversions

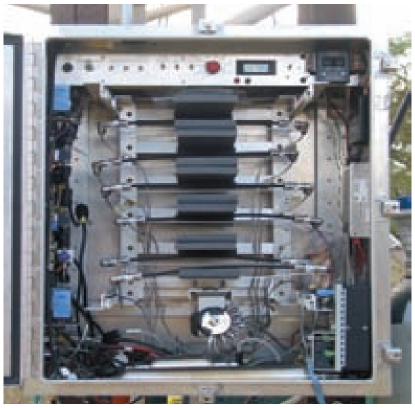
Precision CO_2 systems will provide continuous very precise measurements of atmospheric carbon dioxide concentration ([CO_2]) that will be used to infer CO_2 drawdown in both regional and global atmospheric inversions. The systems are designed to measure [CO_2] with a precision of 0.2 ppm, and with continuous (48 averages per day) and long-term data collection. The system includes a gas-analyzer with a pump and valve system to draw air from above the canopy for sample measurements and automatic zero and span calibration at 2-4 hour intervals. For instrument stability and precision the systems are thermally insulated and the sample air is dried prior to measurements. Two systems have been installed alongside eddy flux



Global distribution of existing Fluxnet sites (▲)
New continuous precision CO_2 measurements (■) in South Africa and Mali supported by ACE.
New and planned African sites (●), including sites in Mali, Ghana, Burkina Faso, and Niger.

Figure 7. Representation of Africa in the global network of eddy flux sites, and continuous precision CO_2 measurements and flask sampling sites installed (South Africa and Mali) and planned (Zambia and/or Congo-Brazzaville) under the ACE project.

measurement systems in Africa. The first at our research site in South Africa (Kruger National Park) and the second at a new eddy covariance site in the Gourma region of northern Mali (Figure 7-8). Measurements in West Africa have been made possible through a developing collaboration between the ACE project and the African Monsoon Multidisciplinary Analysis (AMMA) and in particular with collaborators Eric Mougin (CESBIO, Toulouse, France) and Colin Lloyd (CEH, Wallingord, UK). We are currently constructing a third instrument system for deployment at an eddy flux site operated by collaborators in Zambia and/or Congo (Figure 7).



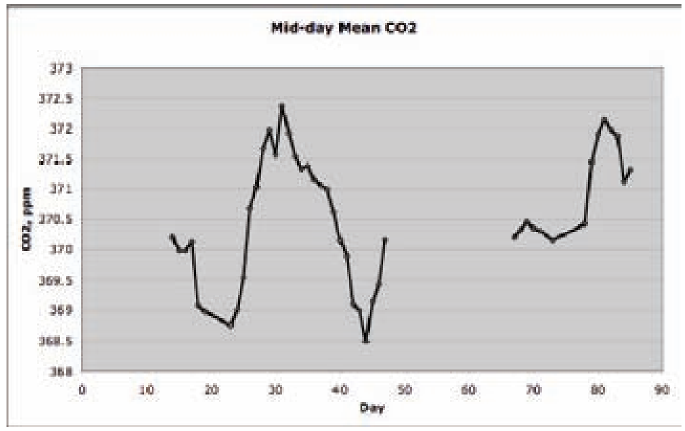


Figure 8. Precision carbon dioxide and flask sampling system (left) and midday atmospheric CO_2 concentration measurements (right) at the Skukuza eddy flux site in the Kruger National Park, South Africa. The system uses automatic calibration with WMO-traceable standards and a temperature controlled infrared gas analyzer to measure CO_2 concentration to an absolute precision of ~0.2 ppm.

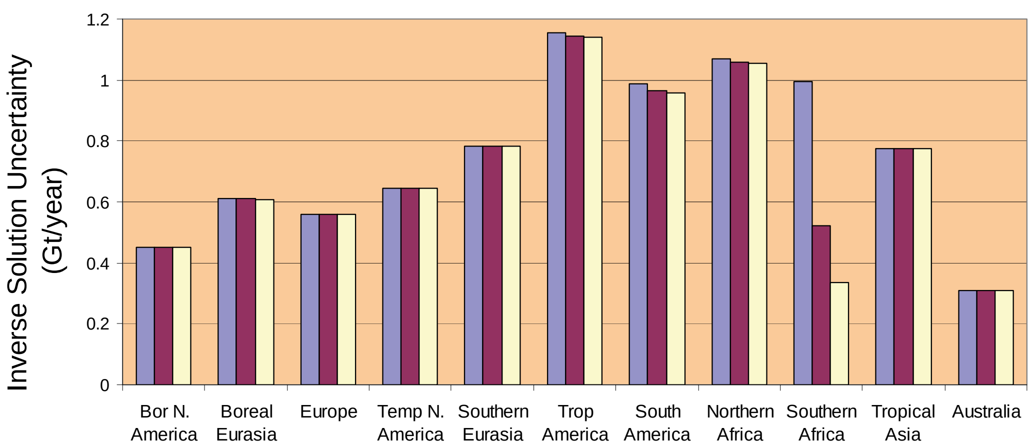


Figure 9. Effect of precision CO_2 sites in Southern Africa on atmospheric inversion uncertainty for Africa and other terrestrial regions (Blue: using existing flask network; Maroon: anticipated effect of adding a precision CO2 site in South Africa; white: adding a precision CO2 site in Zambia). Atmospheric inversion uncertainty arises from lack of CO2 observations and uncertainty in simulated atmospheric transport: the response of African inversions to additional sites indicates that inversions for Africa are especially data-limited, with relatively low transport uncertainty.

5) Global atmospheric inversions

The impact of the new CO_2 data-streams for atmospheric inversions for Africa can be estimated in advance using the existing flask network measurements and atmospheric transport model, and synthetic CO_2 data from each prospective site. For the two southern Africa sites (Skukuza and Mongu) the impact on inversions for the southern Africa region is dramatic (Figure 9). The southern Africa stations have little impact on northern Africa inversions, but inversions for northern Africa will be improved through input of data from the Mali site. We have also developed new bioclimate-based inversion basis regions for Africa (Figure 10). These regions are being used in new simulations of atmospheric transport using the PCTM atmospheric tracer transport model to derive new transport vectors for atmospheric inversions. The new transport vectors and basis regions will facilitate more spatially resolved inversions for regions that are internally self-consistent (unlike previous inversions that separate Africa into two climatically and biologically diverse regions at the equator). With new CO_2 data-streams from northern and southern Africa and from a third site in (or near) the Congo basin, we anticipate dramatic improvements in future atmospheric inversion results.

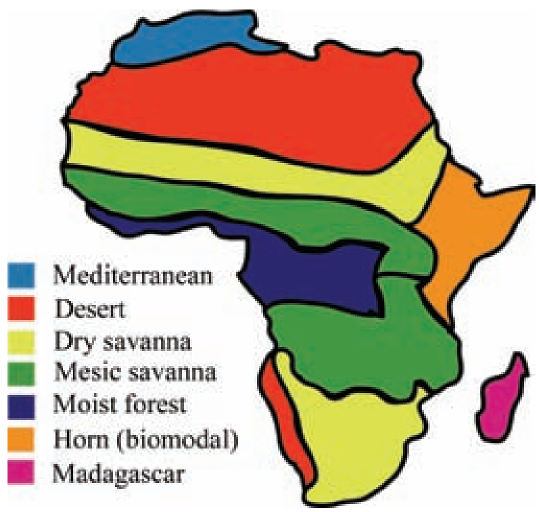


Figure 10. Bioclimate defined basis regions for new atmospheric inversion studies in Africa.

6) Regional Inversions

Terrestrial CO2 measurements respond to local and regional vegetation activity and carry the imprint of carbon fluxes occurring in regions on the order of 10^4 km^2 or more. Several methods have been examined to use the diurnal and seasonal changes in near-surface CO2 concentration to infer regional growth and respiration signals. One of the most promising involves soling the mass budget of the planetary boundary layer using estimates of the degree of mixing between the PBL and free troposphere. In this project we are using the atmospheric tracer transport model to define the PBL turnover time which will allow us to use our precision CO2 measurements to estimate regional fluxes. Initial investigations of this method (prior to availability of sufficient CO2 measurements) have focused on the utility of the transport model (PCTM) to estimate PBL turnover times and net fluxes for the region (Figure 11). As longer time-series of measurements become available from our African precision CO2 sites, regional inversions will provide an independent assessment of terrestrial exchange rates at intermediate scales that can be compared to the global inversions and the forward model estimates based on MODIS vegetation measurements.

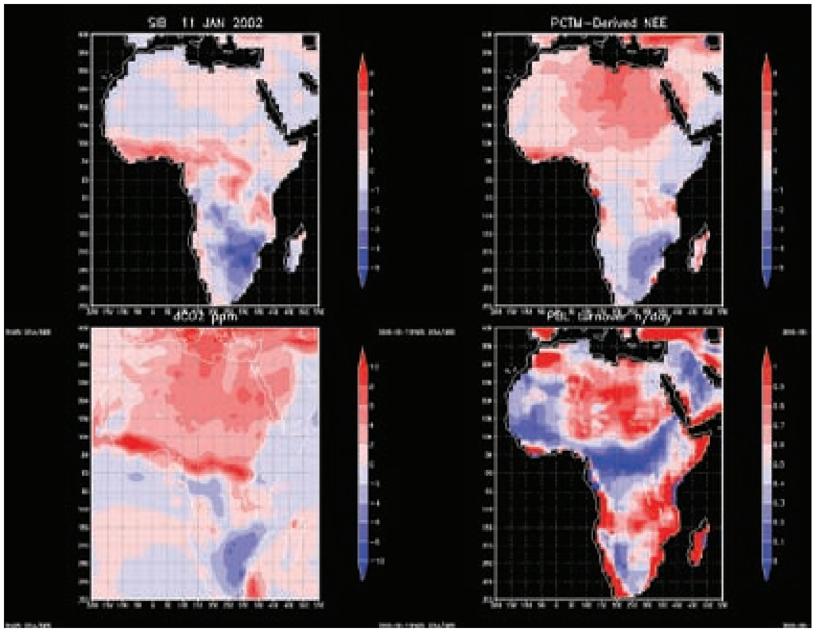


Figure 11. Regional Carbon Flux Estimation using a PBL-budget approach with near-surface [CO2] and atmospheric transport. This figure shows a snapshot (11 January 2002) of an annual simulation. The regional inversion method was described by investigator Berry and collaborators (Betts, Helliker, and Berry, 2004, Coupling between CO2, water vapor, temperature and radon and their fluxes in an idealized equilibrium boundary layer over land. JGR, 109, D18103).

7) Respiration and ^{13}C Dynamics in Savannas

Tropical savannas are unique in the mixture of plant functional types (trees and grasses) that utilize contrasting photosynthetic pathways (C3 and C4, respectively). In many African savannas, the C4 grasses dominate net primary production, but the relative productivity of the trees and grasses depends largely on tree cover. The fractionation of ^{13}C in savanna productivity reflects the relative importance of trees and grasses, but the temporal and spatial dynamics of $d^{13}C$ in photosynthetic and respiratory fluxes is complex. To improve our ability to simulate ^{13}C dynamics in forward models, and our understanding of ^{13}C variability for atmospheric inversions, we have deployed instruments and sampling systems at our intensive savanna research site in South Africa to explore patterns of $d^{13}C$ in soil carbon and respiration.

One of the main goals of the soil and respiration measurements is to narrow uncertainty in the isotopic signal associated with biosphere/atmosphere exchange in Africa. We are focusing efforts in Kruger National Park because it is representative of the savanna biome. Because of the mix between C3 and C4 species in savannas across Africa, it is currently difficult to predict or model temporal or spatial variation in biosphere/atmosphere $d^{13}C$ exchange. Soils in particular represent an important area of uncertainty because of uneven mixing of C3 and C4 biomass spatially across savannas and because of temporal lags between carbon input from litter fall and decomposition from soils. The problem is compounded further by vertical variation in soil ^{13}C associated with root inputs, progressive enrichment during decomposition and the Suess effect.

Our initial results illustrate two key points. First, vegetation cover (interspace vs. canopy samples) results in only a two per mill difference in the $d^{13}C$ signal in soil respiration. Second, the subsurface profiles of $d^{13}C$ suggest that roots from C3 vegetation may be exploiting interspace zones given the increase in C3 SOM signal at 20-25 cm and this use of the interspaces by tree species may help explain some of the similarity in fluxes from these two settings. There are some significant differences between d13C of soil surface fluxes with respect to season (Figure 12), with a strongly enriched signal from the interspace locations immediately following the onset of October rains. This pulse of enriched $d^{13}C$ may result from decomposition of surface soils that are dominated by a C4 signal.

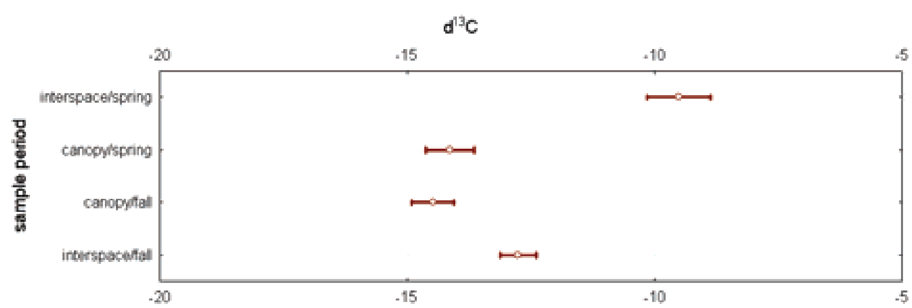


Figure 12. $d^{13}C$ of soil CO_2 flux by season and sampling location for 2006

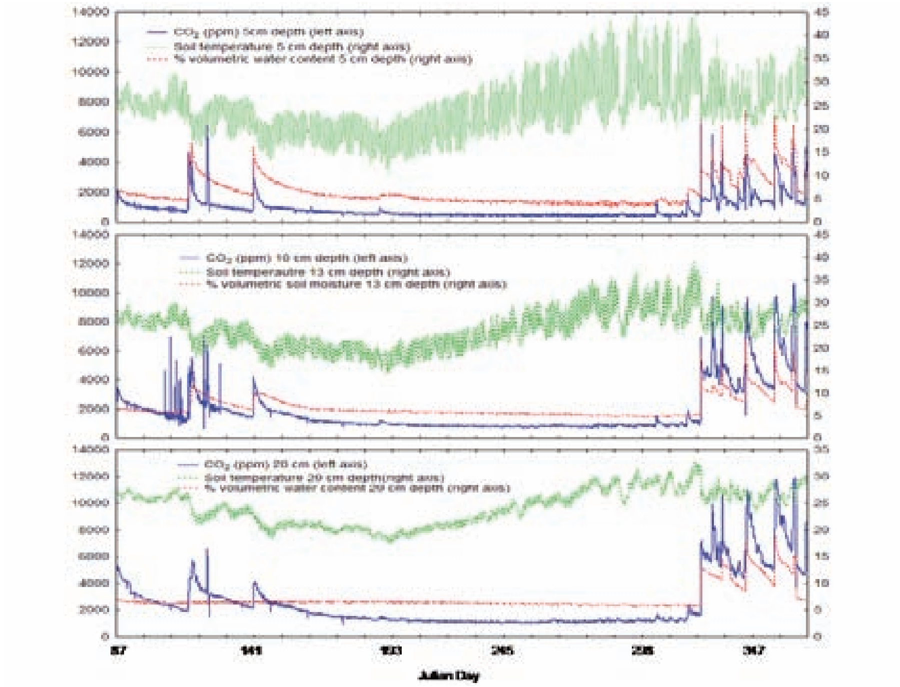


Figure 13. Soil CO_2 concentrations, water content and temperature during 2006 for an undercanopy sampling location. Note the close correspondence between soil CO_2 and water content through the year.

Soil CO_2 probes (Vaisala Instruments) have been in place in an under-canopy site in the Kruger National Park since March 2005. The resulting record shows a period of elevated soil CO_2 concentrations at the end of the wet season in March, very little soil CO_2 production through the dry season and then a large spike in activity with the onset of rains in October of 2006 (Figure 13). Across the seasons, soils also appear to respond very quickly to rain events with CO_2 concentrations peaking just hours after the input of water to the soil. Interestingly we find that soil CO_2 concentrations increase following rains even at depths below the level of water infiltration. We do not yet know the cause of these deeper pulses of CO_2 following rain but are investigating the possibility of root respiration (plant responses to rain) and physical mechanisms including a temporary barrier to CO_2 flux related to the infiltrating water. Our fall installation of a soil CO_2 concentration profile in an interspace site should help address this question because of phenological differences between grasses and trees.

7. Outreach:

The Kruger Park Times, March 23, 2005. *What is a flux tower?* Publication in a popular South African bi-weekly newspaper for the Kruger Park area describing for the general public the local and continental aims of ACE in understanding regional and global carbon dynamics.

8. Presentations and Publications:

Hanan, N. P., Williams, C. A, Scholes, R. J, Denning, A. S, Berry, J. A, Neff, J, Privette, J., 2005 (In and) Out of Africa: estimating the carbon exchange of a continent, Seventh International Carbon Dioxide Conference (ICDC7), Broomfield, CO, September 26-30, 2005. (Invited Presentation)

Hanan, N., 2004, *Afriflux: promoting research on ecosystem function and land-atmosphere interactions in Africa*, Fluxnet Open Science Meeting, December 13-15, 2004, Florence, Italy. (Invited oral presentation)

Hanan, N., Bob Scholes, Werner Kutsch, Ian McHugh, Walter Kubheka, 2004, *Water and productivity in semi-arid savannas: examining the water-limited paradigm using whole-ecosystem flux measurements,* Kruger National Park Science Network Meeting, Skukuza, South Africa, March 29-April 2, 2004. (Oral presentation)

Hanan, N. P., Scholes, R. J., Williams, C. A. and Kutsch, W., 200x Coupled carbon, water and energy fluxes in contrasting fine- and broad-lead savannas of southern Africa. In preparation for *Journal of Arid Environments*

Kutsch, W. L., Hanan, N. P., Scholes, R. J., McHugh, I., Khubeka, W., Eckhardt, H., Williams C. A., 200x, Response of carbon fluxes to water relations in a savanna ecosystem. In preparation for *Journal of Arid Lands*

Kutsch, W., Niall Hanan, Robert Scholes, Ian McHugh, Walter Kubheka, Holger Eckhardt, 2005, *Savanna carbon and water fluxes*, Kruger National Park Annual Science Networking Meeting, Skukuza, South Africa, April 4-8, 2005 (Oral presentation).

Williams, C.A., Hanan, N.P., Scholes, R.J., 2005, Seasonal Controls on Water and Carbon Fluxes Responding to Pulse Precipitation Events in Dryland Systems: Examples from Southern African Savannas, American Geophysical Union Fall Meeting, San Francisco, December 5-9, 2005. (Oral Presentation)

Williams, C.A., Niall Hanan, Joe Berry, Robert Scholes, A. Scott Denning, Jason Neff, Jeffrey Privette, 2005, *Africa and the global carbon cycle: field networks and model studies of African carbon exchange*, Kruger National Park Annual Science Networking Meeting, Skukuza, South Africa, April 4-8, 2005 (Oral presentation).

Williams, C.A., Niall Hanan, Joseph Berry, Robert Scholes, A. Scott Denning, Jason Neff, Jeffrey Privette, 2005, *Africa and the global carbon cycle: field networks and model studies of African carbon exchange*, National Science Foundation US-Africa Workshop: Enhancing Collaborative Research on the Environment in Sub-Saharan Africa, Arlington, VA, January 24-26, 2005 (Poster presentation).

Williams, C. A., Hanan, N. P., Neff, J., Scholes, R. J., Berry, J. A., Denning, A. S., Baker, D., 2006, Africa and the Global Carbon Cycle, (submitted to *Global Change Biology*).

Williams, C.A., Hanan, N. P. and Scholes, R.J. Seasonal variation in environmental controls on water and carbon fluxes in savannas. In preparation for *Agricultural and Forest Meteorology*

ULTRASONIC DEPTH SENSORS FOR NATIONAL WEATHER SERVICE SNOW MEASUREMENTS IN THE UNITED STATES: EVALUATION OF OPERATIONAL READINESS

Principal Investigator: Nolan Doesken

NOAA Project Goal: Climate: Climate observations and analysis

Key Words: Ultrasonic Sensor, Snowfall Algorithm, Snow Depth, Snowfall

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

Year 1 Objectives:

Objective 1: Review Canadian depth sensor testing and snowfall algorithm development to better utilize and incorporate prior snow measurement experience. Travel to Environment Canada and collaborate with their personnel.

Objective 2: Evaluate instrument siting, exposure, installation and system engineering specifications prior to the 2006-2007 winter season. Recommend a standardized station configuration. Meet with the NWS forecast office data acquisition program leaders from each site where instrumentation will be tested to refine these plans prior to implementation.

Objective 3: Improve and test algorithms for estimating snowfall from continuous observations of total snow depth and improve the treatment of snow compaction (settling). Continue to refine current snowfall algorithm using the more standardized snow depth data from the 2006-07 winter season.

Objective 4: Technology review for automated measurement of snow accumulation. Continue to research other possible methods, sensors and studies.

Objective 5: Establish snow measurement intercomparisons from climatically diverse regions of the country for the 2006-07 winter season. Establish guidelines, confirm participation of WFOs, work with NWS regional headquarters to expand network, fully equip and train each test site, revamp website for data ingest and manual observations, collect both automated and manual data beginning November 2006, create and maintain complete database.

Objective 6: Evaluate snowfall measurement uncertainty. Assess in quantitative terms the uncertainty of both manual and automated observations. Describe and explain the sources for the uncertainty and approximate magnitudes to help users assess the confidence, accuracy and resolution of each type of observation.

Year Two Objectives:

Objective 7: Complete 2006-2007 field data collection. Continue data collection during the 2007-2008 winter season.

Objective 8: Using the snowfall estimation algorithm developed during the first year, use a time-series plot of USDS data from the 2006-2007 winter to compute 6-hour and 24-hour snow amounts for each station. Compare these estimates to the manual observations acquired. Compute comparability statistics for each station including snowfall amounts, frequencies, correlations, probability of detection and false alarm rates. This will be done for several snow measurement increments of 0.1 inch up to 1.0 inch.

Objective 9: Complete a system performance evaluation of USDS determining all critical aspects of sensor and system operations, frequency of failure, causes of failure, maintenance requirements, cost of operation, life expectancy, etc. Identify any unsolved problems so that NWS is aware of potential future issues.

Objective 10: Complete the evaluation of snowfall measurement uncertainty and prepare manuscript for presentation at one or more scientific conferences.

Objective 11: Reinstall or re-site as needed locations from the 2006-2007 season deemed necessary for project success.

Objective 12: Transition a few sites to solar power and use of remote communications, as per future need requirements for the HCN-M program.

Objective 13: Acquire and compare the new SR-50A to the network current sensor--the SR-50.

2. Research Accomplishments/Highlights:

This past year has been a continuation of a 2-year project. Snow project data collection successfully continued for the 2007-2008 snow season at all locations. Two sites tested solar power and it was found to be an acceptable alternative for power in remote locations. Several sites installed a newer sensor version (the SR50A) into the network and its performance has been found to be comparable to the original test sensor (SR50). The bulk of work has been spent on snowfall algorithm development which is currently still being investigated, however favorable results are being obtained at many locations, including wind blown environments where precipitation gauge readings are being used to augment the capability of the algorithm under adverse conditions. Error analyses and errors of omission/commission are currently being generated. The algorithm uses single sensors as well as all combinations of the three sensors installed at each site to evaluate what skill is gained in determining snowfall using one sensor, two sensors and three sensors (i.e. consensus approach). The algorithm is also altered to test its efficiency at several reporting resolutions from a tenth up to the whole inch.

The manual snowfall measurement uncertainty test is still a work in progress as we finish up the algorithm development for delivery to NWS in the form of our final report.

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

All objectives have been met or are currently in progress except for Objective 10. Signal processing was to be part of this year's goals; however, that effort was abandoned due to the lack of funds.

4. Leveraging/Payoff:

The measurement and timely reporting of snow accumulation in the U.S. is a public expectation and highly valued for applications in transportation, recreation, commerce and public safety. Traditionally handled by human observation, cost-effective automation of this valued data source is now being explored. Ultrasonic depth sensors have the potential for reporting standard snow observations in the U.S. in real time for climatological purposes, weather forecasting verification, radar verification, and public information. The potential to produce consistent long-term data for an element that has always been difficult to observe and report uniformly makes this project especially timely.

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

Environment Canada, National Weather Service, USDS website at http://snowstudy.coorahs.org

6. Awards/Honors: None as yet

7. Outreach:

Conference and meeting presentations:

Ryan, W.A. and Doesken, N.J. 2008. Evaluation of the Campbell SR-50 sensor in Triplicate for Automation of U.S. Snowfall and Snow Depth Measurements and Work Towards Operational Status. *12th Conference on IOAS-AOLS and 88th American Meteorological Society Annual Meeting*, New Orleans, LA.

Ryan, W.A., Doesken, N.J. and Fassnacht, S.R. 2007. Preliminary Results of Ultrasonic Snow Depth Sensor Testing for National Weather Service (NWS) Snow Measurements in the U.S. and Work toward Operational Readiness. *CMO-CGU-AMS Congress/Eastern Snow Conference*, St. John's, Newfoundland, Canada.

Ryan, W.A. and Doesken, N.J. 2007. Ultrasonic Snow Depth Sensors for National Weather Service (NWS) Snow Measurements in the U.S.: Evaluation of Operational Readiness. *14th Symposium on Meteorological Observation and Instrumentation and 87th American Meteorological Society Annual Meeting*, San Antonio, TX.

8. Publications:

Ryan, W.A, Doesken, N.J, and Fassnacht, S.R. 2008. Preliminary Results of Ultrasonic Snow Depth Sensor Testing for National Weather Service (NWS) Snow Measurements in the U.S. *Hydrological Processes* (Accepted).

Ryan, W.A., Doesken, N.J. and Fassnacht, S.R. 2008. Evaluation of Ultrasonic Snow Depth Sensors for U.S. Snow Measurements. *Journal of Atmospheric and Oceanic Technology*. Vol. 25 (5).

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: N/A

4. Leveraging/Payoff:

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

6. Awards/Honors:

7. Outreach:

8. Publications:

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.

<u>Computer Resources</u>

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: $110k/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 archive contains over 150TB of meteorological data going 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 data processing computer infrastructure. This infrastructure contains 45 individual workstations and 15 terabyte RAID storage systems. The CloudSat data processing system was designed using small footprint PC's as these systems have proven successful in other CIRA projects. These systems consume less power, generate less heat, and are less than half the price of 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 small form factor network attached storage devices were deployed this year. These new units are providing 4TB of RAID5 storage for under $2000.00 each.

The CloudSat data processing center continues to perform above design specifications. Additional ancillary datasets are being processed and stored. NASA and JPL awarded the team with excellence for the second year in a row.

Archive

CIRA has about 1000 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 hourly support, the tapes are being converted to DVD. The group hopes to have converted all the tapes by the end of this year.

Additionally, because of the physical space savings gained by DVD's, the archive room has been split in two. One half is being renovated into a temperature-controlled computer room for the Linux cluster.

Technology

Over the last few years, several technology advancements have been studied for computational effectiveness and environmental load. Computer rooms designed to power and cool 19" rack systems are very expensive. Also, 19" rack systems generate significant audible noise and need to be located away from work areas. Alternative PC form factors have been is use at CIRA for the last 6 years. Intel quad-core systems which do not require a special computer room are successfully running several key services. These systems, in combination with the latest 64-bit Windows operating systems, provide leading performance with significant cost savings. This year, CIRA built the OCO computer cluster using this technology. The OCO group reports that this cluster has exceeded the performance of any previous design for less money. Reliability has been excellent.

Earthstation

GOES-O: Hardware and software development continues this year. This satellite is the latest GVAR imager which continues to provide core satellite coverage over North America. The satellite is expected to launch this year.

Web

The CIRA website is undergoing significant improvements and fundamental design changes. The results from this effort are expected to go online this year. Improvements include dynamic content, better reference to themes and research, and searchable databases.

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.

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

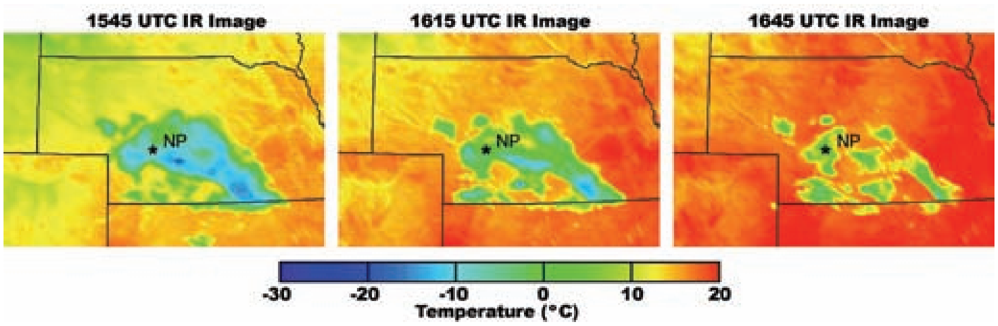
The leveraged payoff on these DoD-funded projects has had significant impacts on CIRA's NOAA research. Specifically the data assimilation work funded by CG/AR was well ahead of NOAA's interest in this area. The skills and infrastructure developed in this area have allowed CIRA to address the NOAA assimilation 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.

Dust Transport and Aerosol Data

A small study of sulfate aerosol simulations vs. IMPROVE observations across U.S. (possibly Europe as well) will be conducted. Initial comparisons (by K. Johnson-Wells) showed some apparent biases in total S (emissions inventory and/or scavenging schemes) and in SO2 converted to sulfate aerosol. We will submit a short report to NRL including COAMPS simulations of clouds with icing potential. We have simulated mixed-phase mid-level layer clouds to better understand the microphysics of mixed-phase mid-level clouds; we simulate two-layer clouds observed during CLEX-9.



Recent Results in 4D Data Assimilation: Assimilation of GOES Sounder Radiances

Objectives:

Develop 4 dimensional variational (4DVAR) cloud data assimilation system for direct assimilation of satellite radiances.

Improve nowcasting of clouds using 4DVAR.

Study the impact of information from multiple satellite channels on cloud analysis.

Assess the impact of time resolution of satellite observations on cloud data assimilation.

Test advanced methods for continuing transfer to the WRF assimilation system.

Assimilate high spectral but low temporal resolution satellite data and study the impact on cloud analysis.

Experiment design:

Use same design as used for GOES imager experiment.

Assimilate 15 GOES sounder channels with data available every hour.

GOES sounder channels have water vapor and temperature profile information not available from GOES imager channels.

Results:

Assimilating 2 channels significantly improves cloud analyses over 1 channel assimilation.

15 channels are available for tying down the analysis. Therefore a better cloud analysis is expected.

Currently system biases, cloud decorrelation lengths and boundary effects are not adjusted and accounted for. Results still show improvement in cloud analysis.

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.

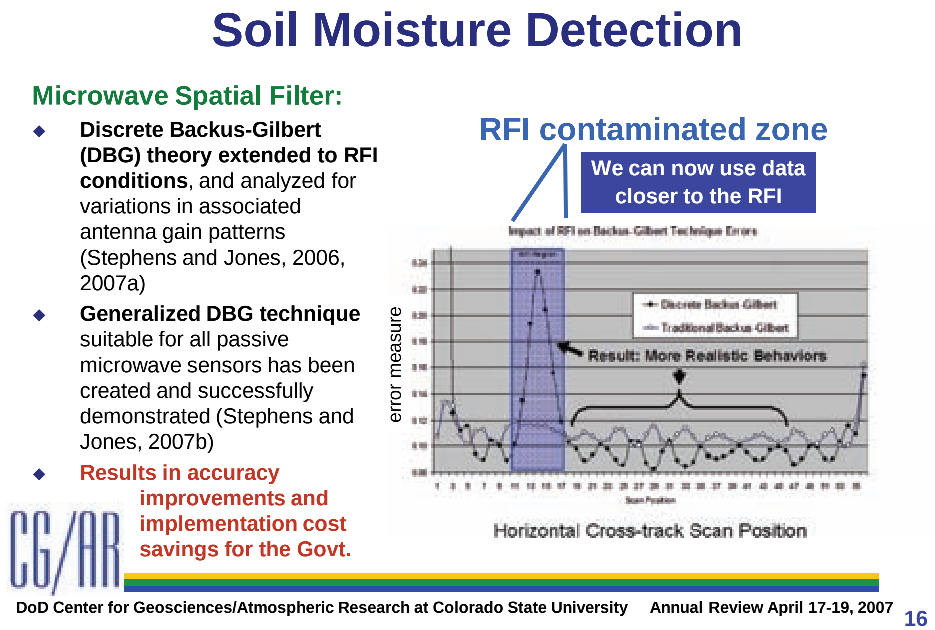
Soil Moisture Detection

Microwave spatial filter techniques (for data resolution enhancement) in adverse Radio Frequency Interference (RFI) conditions

Passive microwave sensitivity studies of physical masking phenomenologies (e.g., vegetation and other surface conditions that obscure the soil moisture data signal)

Observational in situ data use for

- Soil moisture detection validation
- Statistical characterization of the a priori background
- "How good is the background soil moisture state information?"
- "How much should the DA system rely upon the a priori estimates?"



WindSat RTM Intercomparisons:

Microwave Land Surface Model (MWLSM/CSU) compared to Conical Microwave Imager Sounder Model (CM/AER).

The study found that the MWLSM is a generalized research version of the NPOESS CM model code.

Results are very similar between systems if MWLSM parameters are adjusted to match the CM parameter assumptions (details are found in Rapp et al., 2006)

Absolute brightness temperature differences < 3K.

Normalized sensitivities < 0.5 K.

Forward RTM models are in good agreement, primary focus should be observational validation of the underlying RTM theory using WindSat data (part of Rapp MS Thesis topic).

The MWLSM gives physically expected results

Most sensitive to soil moisture.

Sensitive to vegetation and roughness effects.

Soil moisture ranges are similar to expected soil moisture ranges.

Found optimized parameter values for western Oklahoma:

Veg. water content values from 0.5 to 1 kg m^{-2}.

Microwave surface roughness values from 0.5 to 1.

Soil moisture signal is apparent at all four sites of interest.

Passive microwave soil moisture measurement is feasible.

RFI problematic over much of Oklahoma in the C band.

MWLSM sensitivity comparison studies demonstrate these results are applicable to future NPOESS soil moisture retrievals.

Physical Basis of the Indirect 4DVAR Approach:

The challenge: 6 GHz only penetrates the top ~1 cm of soil.

Soil Moisture is a temporally variable field with a significant delay during drying which is dependent on the depth of the underlying soil moisture.

Thus, wet events that are shallow tend to dry quickly.

Wet events that are deep dry more slowly as their soil moisture levels are maintained by deeper soil moisture moving toward the surface to maintain energy and water balances within the soil column.

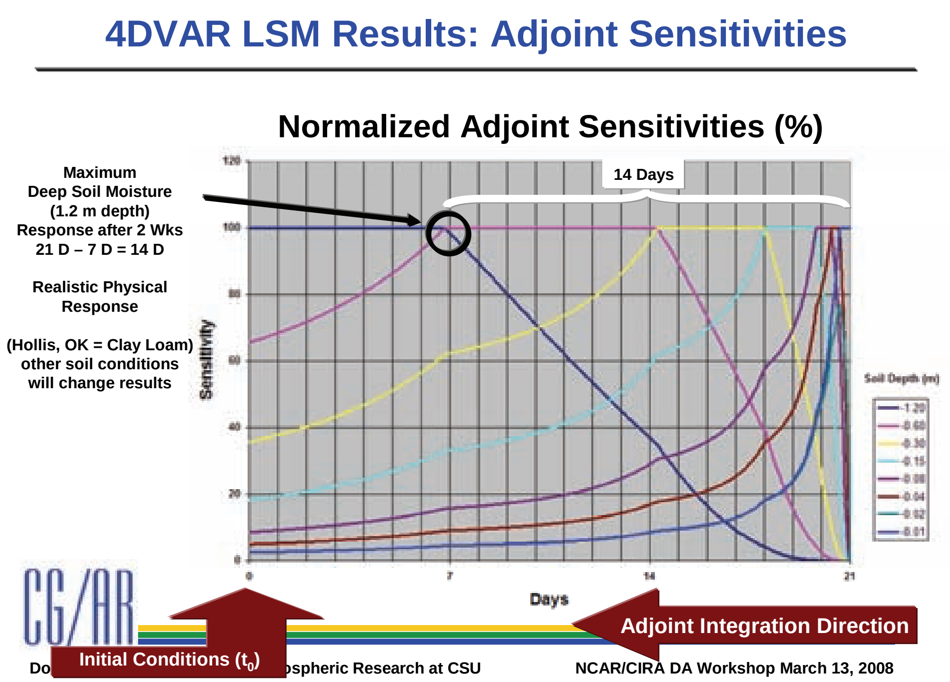
This temporal dependence is used in conjunction with physical model constraints (both the radiometric model and the land surface model) and is mathematically optimized by temporal data assimilation techniques (e.g., 4DVAR).

Extension of the method to higher resolution IR datasets

MW datasets provide the strongest physical soil moisture signal, especially low frequency MW data.

IR datasets provide good spatial resolution and precision, but poor accuracy.
A MW+IR 4DVAR method would be more ideal. This would allow the IR spatial resolution to improve the MW spatial limitations.

Without the MW data however, IR techniques will generate less accurate soil moisture estimates.



WindSat 4DVAR Soil Moisture Experiment Progress - Oklahoma Sep. 17-19, 2003
Status: Completed

RAMDAS model first guess.

All satellite and model data analysis.

Stand-alone Observational Operator (OO) tests (sensitivity and initial parameter optimizations).

WindSat retrievals successfully demonstrated (includes addressing the RFI and veg. factors).

Integrated 4DVAR OO tests completed at single site demonstrates significant sensitivity to soil moisture at depths >1m.

Towards Improving the Satellite Remote Sensing of Mixed Phase Cloud: A Study on its Microphysical and Optical Properties

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).

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:

8. Publications:

Belcher, L. R., L. D. Carey, J. M. Davis, J.A. Kankiewicz, and T.H. Vonder Haar, 2003: MM-wave radar structure and microphysical characteristics of mixed phase altocumulus clouds. Preprints, 31st Radar Conference, American Meteorological Society, Seattle, WA, August 6-12.

Bucholtz, A., J.H. Bowles, K. Carrico, W. Chen, D. Collins, C.O. Davis, J. Eilers, P. Flatau, H. Jonsson, D. Korwan, S.M. Kreidenweis, J.M. Livingston, M. Montes, B. Provencal, E. Reid, J.S. Reid, J. Redemann, B. Schmid, W. Snyder, A. Strawa, A.L. Walker, D.L. Westphal and M. Witek, 2003: Properties and effects of Asian aerosols over the central California coast during the ADAM-2003 (Asian Dust Above Monterey-2003) field study. Proceedings, 22nd Annual American Association for Aerosol Research Conference, October 20-24, Anaheim, California.

Carey, L.D., L.R. Belcher, J.A. Kankiewicz, and T.H. Vonder Haar, 2005: MM-wave radar structure and microphysical characteristics of a mixed phase altocumulus cloud on 2 November, 2001. Preprint CD-ROM, 32nd Radar Conference, American Meteorological Society, October 24-29, Albuquerque, NM.

Carey, L.D., L.R. Belcher, J.A. Kankiewicz, and T.H. Vonder Haar, 2005: MM-wave radar structure and microphysical characteristics of a mixed phase altocumulus cloud on 2 November, 2001. Preprint CD-ROM, American Geophysical Union Annual Fall Meeting, December 5-9, San Francisco, CA.

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.*, (accepted pending revisions).

Castro, C.L., R.A. Pielke Sr., and G. Leoncini, 2005: Dynamical downscaling: Assessment of value retained and added using the Regional Atmospheric Modeling System (RAMS). *J. Geophys. Res. - Atmospheres*, 110, No. D5, D05108, doi:10.1029/2004JD004721.

Chai, T., C.L. Lin, and R.K. Newsom, 2004: Retrieval of microscale flow structures from high resolution Doppler lidar using an adjoint model. *J. Atmos. Sci.*, 61, 1500-1520.

Chibe, R.J, W.R. Cotton, 2003: Numerical forecasting of fog with the RAMS@CSU cloud-resolving mesoscale forecast model (poster). On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Combs, C.L., and T.H. Vonder Haar, 2003: Smart climatology: wind-stratified cloud products from combined satellite cloud observations and model output wind fields (oral). On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Combs, C.L., D. Rapp, A.S. Jones, and G. Mason, 2007: Comparison of AGRMET model results with *in situ* soil moisture data. Pre-print CD-ROM, 21st Conference on Hydrology, January 14-18, San Antonio, TX (AMS).

Cotton, W.R., E. Zarovy, G. Carrio, S. Saleeby, H. Jiang, D. Stokowski, and S. van den Heever, 2004: Mesoscale numerical prediction of aerosols and dust. Extended Abstract, AHPCRC Workshop, May 24-26, Jackson, MS.

Donofrio, K.M., 2007: A 1DVAR optimal estimation retrieval of water vapor profiles over the global oceans using spectral microwave radiances. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 165 pp.

Drobinski, P., P. Carlotti, R. Newsom, R. Foster, R. Banta, and J. Redelsperger, 2004: The structure of the near-neutral atmospheric surface layer. *J. Atmos. Sci.*, 61, 699-714.

Falcone, A.K., 2005: Canonical coordinate feature extraction for cloud classification and analysis. Masters thesis, Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado, 168 pp.

Falcone, A.K., M.R. Azimi-Sadjadi, A. Pezeshki, J.A. Kankiewicz, and D.L. Reinke, 2004: Coherent-based feature extraction for cloud analysis using satellite imagery data. Proceedings, Asilomar Conference on Signals, Systems, and Computers, November 7-10, Pacific Grove, CA, p. 1695-1699.

Falcone, A.K., M.R. Azimi-Sadjadi, 2005: Multi-satellite cloud product generation over land and ocean using canonical coordinate features. 2005 MTS/IEEE Oceans Conference, September 18-23, Washington, DC.

Falcone, A.K., M.R. Azimi, and J.A. Kankiewicz, 2007: Dual-satellite cloud product generation using temporally updated canonical coordinate features. *IEEE Trans. Geosci. Remote Sens.,* 45 (4), 1046-1060 (April).

Falk, M.J. and V.E. Larson, 2006: A simulation of partial cloudiness in multilayered altocumuli. Preprint CD-ROM, Twelfth Conference on Cloud Physics, July 10-14, Madison, WI (AMS).

Falk, M.J. and V.E. Larson, 2007: What causes partial cloudiness to form in multilayered midlevel clouds? A simulated case study. *J. Geophys. Res.* 112, D12206,doi:10.1029/2006JD007666.

Fletcher, S.J. and M. Zupanski, 2006: Implications and impact of transforming lognormal variables into normal variables in VAR. 7th International Workshop on Adjoint Application in Dynamic Meteorology, October 8-13, Innsbruck, Austria.

Fletcher, S.J. and M. Zupanski, 2006: Lognormal data assimilation: theory and applications. Preprint CD-ROM, AGU Fall Meeting, December 11-15, San Francisco, CA.

Fletcher, S.J. and M. Zupanski, 2007: An alternative to bias correction in retrievals and direct radiances assimilation. 11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), January 13-19, San Antonio, TX (AMS).

Fletcher, S.J., M. Zupanski, and T.H. Vonder Haar, 2007: Lognormal Data Assimilation: Theory and Applications. Proceedings CD, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2007, November 6-8, Chestnut Hill, MA. Oral presentation, Session 2: Data Assimilation and Numerical Modeling.

Fletcher, S.J., and M. Zupanski, 2007: Implications and impacts of transforming lognormal variables into normal variables in VAR. *Meteorolgische Zeitschrift*, 16, 755-765.

Fletcher, S.J., and M. Zupanski, 2008: A study of ensemble size and shallow water dynamics with the Maximum Likelihood Ensemble Filter. *Tellus,* 60A, 348-360.

Forsythe, J.M., A.S. Jones, and T.H. Vonder Haar, 2004: Development of a global microwave land surface emissivity retrieval. Proceedings, SPIE Annual Meeting 2004, Denver, CO, August 2.

Forsythe, J.M., A.S. Jones, and T.H. Vonder Haar, 2004: Water vapor profile retrievals from satellite microwave sounding instruments. Preprint CD-ROM, Thirteenth Conference on Satellite Meteorology and Oceanography, September 20-24, Norfolk, VA (AMS).

Forsythe, J.M., M.J. Nielsen, A.S. Jones, R.W. Kessler, K. Donofrio, and T.H. Vonder Haar, 2005: Water vapor and temperature profile retrievals from satellite microwave sounding instruments over land and ocean. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Forsythe, J.M., K.M. Donofrio, R.W. Kessler, A.S. Jones, and T.H. Vonder Haar, 2006: Atmospheric profiles over land and ocean from AMSU. Preprint CD-ROM, Fourteenth Conference on Satellite Meteorology and Oceanography, January 29-February 2, Atlanta, GA (AMS).

Forsythe, J.M., S.Q. Kidder, K.M. Donofrio, A.S. Jones, and T.H. Vonder Haar, 2007: Extending satellite microwave humidity profiles from ocean to land. Pre-print CD-ROM, 11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, January 14-18, San Antonio, TX (AMS).

Forsythe, J.M., S.Q. Kidder, A.S. Jones, and T.H. Vonder Haar, 2007: Moisture profile retrievals from satellite microwave sounders for weather analysis over land and ocean. Proceedings (CD-ROM), The Joint 2007 EUMETSAT Meteorological Satellite Conference and the 15th American Meteorological Society (AMS) Satellite Meteorology and Oceanography Conference, September 24-28, Amsterdam, The Netherlands.

Fowler, L.D. and T.H. Vonder Haar, 2006: Implementation of the RAMS cloud microphysics parameterization in WRF-ARW. On website, Seventh Annual WRF Users' Workshop, June 19-22, Boulder, CO.

Gaiser, P., A. Jones, L. Li, G. Mason, G. McWilliams, M. Mungiole, 2007: Improving the effectiveness of determining soil moisture using passive microwave satellite imagery. Whitepaper to the National Polar-orbiting Operational Environmental Satellite Systems (NPOESS) Integrated Program Office (IPO), 14 pp.

Golaz, J.-C., V.E. Larson, J.A. Hansen, D.P. Schanen, B.M. Griffin, 2006: Elucidating model inadequacies in a cloud parameterization by use of an ensemble-based calibration framework. *Mon. Wea. Rev.,* (in review).

Greenwald, T.J., T. Vukicevic, and L.D. Grasso, and T.H. Vonder Haar, 2004: Adjoint sensitivity analysis of an observational operator for cloudy visible and infrared radiance assimilation. *Quarterly Jou. Royal Meteor. Soc.,* January, B, 685-705.

Johnson, K., 2006: A comparison of the Navy Aerosol Analysis and Prediction System to in-situ aerosol measurements in the continental U.S.: transport vs. local production of soil dust aerosol. Masters Thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 142 pp.

Johnson, K., S.M. Kreidenweis, M. Witek, D.L. Westphal, P. Flatau, 2006: A comparison of the Navy Aerosol Analysis and Prediction System (NAAPS) to in-situ aerosol measurements in the continental U.S.: transport vs. local production of soil dust aerosol. Seventh American Association for Aerosol Research International Aerosol Conference, September 10-15, St. Paul, MN.

Jones, A.S., T. Vukicevic, G.L. Stephens and T.H. Vonder Haar, 2003: Low frequency passive microwave satellite data assimilation research for retrieving deep (10-100 cm) soil moisture information. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Jones, A.S., J.M. Forsythe, S.Q. Kidder, and T.H. Vonder Haar, 2003: Extension of a 1DVAR passive microwave algorithm for near-real time atmospheric profiles and emissivity over land. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Jones, A.S., T. Vukicevic, and T.H. Vonder Haar, 2004: A microwave satellite observational operator for variational data assimilation of soil moisture. *J. Hydrometeorology,* 5, 213-229.

Jones, A.S., J.M. Forsythe, and T.H. Vonder Haar, 2004: Retrieval of global microwave surface emissivity over land. Preprint CD-ROM, Thirteenth Conference on Satellite Meteorology and Oceanography, September 20-24, Norfolk, VA (AMS).

Jones, A.S., J.M. Forsythe, C.L. Combs and T.H. Vonder Haar, 2005: Characterization of global microwave surface emissivity over land. Preprint CD-ROM, Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (9IOASAOLS). January 9-13, San Diego, CA (AMS).

Jones, A.S., G. McWilliams, M. Mungiole, G. Mason, C.L. Combs, D. Rapp, P.J. Stephens, P.C. Shott, T. Vukicevic, B. McKeown, and T.H. Vonder Haar, 2005: Applications of windsat for soil moisture satellite data assimilation and DoD impact studies. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Jones, A.S., P.C. Shott, J.M. Forsythe, C.L. Combs, R.W. Kessler, M.J. Nielsen, P.J. Stephens, and T.H. Vonder Haar, 2005: Global microwave surface emissivity error analysis. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Jones, A.S., D. Rapp, G. McWilliams, M. Mungiole, G. Mason, N.S. Chauhan, C.L. Combs, S. Longmore, B. McKeown, T. Vukicevic, and T.H. Vonder Haar, 2006: NPOESS soil moisture satellite data assimilation and RFI mitigation: Use of WindSat data and a Discrete Backus-Gilbert technique. Proceedings, International Geoscience and Remote Sensing Symposium (IGARSS) 2006, July 31-August 4, Denver, CO.

Jones, A.S., C.L. Combs, S. Longmore, T. Lakhankar, G. Mason, G. McWilliams, M. Mungiole, D. Rapp, T.H. Vonder Haar, and T. Vukicevic, 2007: NPOESS soil moisture satellite data assimilation research using WindSat data. Pre-print CD-ROM, Third Symposium on Future National Operational Environmental Satellite Systems—Strengthening Our Understanding of Weather and Climate, January 16-17, San Antonio, TX (AMS).

Jones, A. S., G. McWilliams, M. Mungiole, and G. Mason, 2007: Applications of WindSat for Soil Moisture Satellite Data Assimilation and DoD Impact Studies: 15 July 2004 – 31 December 2006. Final report to the NPOESS Integrated Projects Office, 20 pp.

Jones, A.S., T. Lakhankar, C.L. Combs, S. Longmore, G. Mason, G. McWilliams, M. Mungiole, M. Sengupta, and T.H. Vonder Haar, 2007: NPOESS soil moisture satellite data assimilation using WindSat data and the 4DVAR method. Proceedings CD, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2007, November 6-8, Chestnut Hill, MA. Oral presentation, Session 2: Data Assimilation and Numerical Modeling.

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, J.C., 2003: Cloud top heights of mid-level, mixed-phase clouds from CLEX-9. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Kang, D.H., 2005: Distributed snowmelt modeling with GIS and CASC2D at California Gulch, Colorado. Masters thesis, Department of Civil Engineering, Colorado State University, Fort Collins, Colorado, 195 pp.

Kankiewicz, J.A., J.M. Forsythe, D.L. Reinke, K.E. Eis, T.H. Vonder Haar, 2003: Comparison between the new CDFS II WWMCA product and the CHANCES-RP and MODIS cloud masks (poster). On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Kankiewicz, J.A., T.H. Vonder Haar, and L. Carey, 2005: An overview of the next cloud layered experiment (CLEX-10). On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Kankiewicz, J.A., D.G. Reinke, D.L. Reinke, and T.H. Vonder Haar, 2006: Quick look cloud data products and their use in facilitating A-Train research. Preprint CD-ROM, AGU Fall Meeting, December 11-15, San Francisco, CA.

Kankiewicz, J.A., S.Q. Kidder, C.J. Seaman, T.H. Vonder Haar, and L.D. Carey, 2007: Mixed phase clouds and aircraft icing conditions observed during the Canadian CloudSat/ CALIPSO Validation Project. Meeting website (poster), BACIMO 2007, November 6-8, Chestnut Hill, MA.

Kidder, S.Q., J.A. Kankiewicz, and K.E. Eis, 2005: Meteosat second generation cloud algorithms for use at AFWA (poster). On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Kidder, S.Q., J.A. Kankiewicz, and T.H. Vonder Haar, 2006: A first look at mid-level clouds using CloudSat, CALIPSO, and MODIS data. Preprint CD-ROM, AGU Fall Meeting, December 11-15, San Francisco, CA.

Kidder, S.Q., and A.S. Jones, 2006: A blended satellite total precipitable water product for operational forecasting. *J. Atmos. and Oceanic Technol.,* 24, 74-81.

Kidder, S.Q., J.A. Kankiewicz, and T.H. Vonder Haar, 2007: The A-Train: How formation flying is transforming remote sensing. Proceedings (CD-ROM), The Joint 2007 EUMETSAT Meteorological Satellite Conference and the 15th American Meteorological Society (AMS) Satellite Meteorology and Oceanography Conference, September 24-28, Amsterdam, The Netherlands.

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).

Kotenberg, K.E., N.B. Wood, and V.E. Larson, 2006: Derivation and tests of the GCSS analytic longwave radiation formula. Preprint CD-ROM, Joint Twelfth Conference on Cloud Physics and Atmospheric Radiation, July 10-14, Madison, WI (AMS).

Koyama, T., T. Vukicevic, A.S. Jones, M. Sengupta, and T.H. Vonder Haar, 2005: Information content of the GOES sounder IR measurements in the presence of clouds. Preprint CD-ROM, Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (9IOASAOLS), January 9-13, San Diego, CA (AMS).

Koyama, T., T. Vukicevic, M. Sengupta, T.H. Vonder Haar, and A.S. Jones, 2006: Analysis of information content of IR sounding radiances in cloudy conditions. *Mon. Wea. Rev.,* 134, 3657-3667.

Larson, V.E., 2004: Prognostic equations for cloud fraction and liquid water, and their relation to probability density functions. *J. Atmos. Sci.*, (61) 338-351.

Larson, V.E., J-Ch. Golaz, H. Jiang, and W.R. Cotton, 2005: Supplying local microphysics parameterizations with information about subgrid variability: Latin hypercube sampling. *J. Atmos. Sci.*, (62) 4010-4026.

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.

Larson, V.E., A.J. Smith, M.J. Falk, K.E. Kotenberg, J.C. Golaz, 2006: What determines altocumulus dissipation time? *J. Geophys. Res.,* 3, D19207, doi:10.1029/2005JD007002.

Larson, V.E. and B.M. Griffin, 2006: Coupling microphysics parameterizations to cloud parameterizations. Preprint CD-ROM, Twelfth Conference on Cloud Physics, July 10-14, Madison, WI (AMS).

Leoncini, G., and R.A. Pielke, Sr., 2005: Nonlinear vs. linear mesoscale dynamics. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Leoncini, G., and R.A. Pielke, Sr., 2005: Nonlinear or linear; hydrostatic or nonhydrostatic mesoscale dynamics. Preprint CD-ROM, AGU Fall Meeting, December 6-9, San Francisco, CA.

Longmore, S., A.S. Jones, A. Carheden, and T.H. Vonder Haar, 2007: Experience and lessons learned regarding configuration and control of an advanced 4-dimensional variational satellite data assimilation system. 23rd Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, January 14-18, San Antonio, TX (AMS).

Masarik, M.T., 2007: Potential vorticity and energy aspects of the MJO through equatorial wave theory. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 86 pp.

Masarik, M.T. and W.H. Schubert, 2006: Potential vorticity aspects of the MJO. Preprints, Twenty-seventh Conference on Hurricanes and Tropical Meteorology, April 23-28, Monterey, CA (AMS).

Matsui, T., G. Leoncini, R.A. Pielke, and U.S. Nair, 2004: A new paradigm for parameterization in atmospheric models: application to the new Fu-Liou radiation code. Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, Paper No. 747.

McCarron, M., G. Wichern, M.R. Azimi and M. Mungiole, 2007: An operationally adaptive system for rapid acoustic transmission loss prediction. Proceedings, 2007 International Joint Conference on Neural Networks (IJCNN), invited paper, August 12-17, Orlando, FL.

McWilliams, G., A.S. Jones, C.L. Combs, T. Lakhankar, S. Longmore, G. Mason, M. Mungiole, D. Rapp, and T.H. Vonder Haar, 2007: NPOESS soil moisture satellite data assimilation: Progress using WindSat data. Proceedings, International Geoscience and Remote Sensing Symposium (IGARSS) 2007, July 23-27, Barcelona, Spain.

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).

Newsom, R.K., and R.M. Banta, 2003: Sensitivity analysis of wind and temperature retrievals from coherent doppler lidar data. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Newsom, R.K., and R.M. Banta, 2004: Assimilating coherent Doppler lidar measurements into a model of the atmospheric boundary layer. Part I: Algorithm development and sensitivity to measurement error. *J. Tech,* 21, 1328-1345.

Newsom, R.K., and R.M. Banta, 2004: Assimilating coherent Doppler lidar measurements into a model of the atmospheric boundary layer. Part II: Sensitivity analyses. *J. Tech,* 21, 1809-1824.

Nielsen, M.J., 2005: Remote sensing of water vapor over land using the advanced microwave sounding unit. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, CO, 87 pp.

Nielsen, M.J., A.S. Jones, J.M. Forsythe, and T.H. Vonder Haar, 2004: Effect of antenna pattern correction on AMSU-B radiances. Preprint CD-ROM, Thirteenth Conference on Satellite Meteorology and Oceanography, September 20-24, Norfolk, VA (AMS).

Nielsen, M.J., and T.H. Vonder Haar, 2005: Remote sensing of water vapor over land using the advanced microwave sounding unit. CIRA Technical Report, Colorado State University, Fort Collins, Colorado, 87 pp. [ISSN: 0737-5352-70].

Nielsen, M.J., P.J. Stephens, A.S. Jones, J.M. Forsythe, R.W. Kessler, and T.H. Vonder Haar, 2006: Impact of AMSU-B antenna pattern corrections on physical profile retrieval methods. *J. Atmos. Ocean. Tech.* (submitted).

Niu, J., L. Carey, P. Yang, J.A. Kankiewicz, T.H. Vonder Haar, 2006: A common microphysical structure for midlevel mixed phase clouds in the mid-latitudes: Results from the Cloud Layer Experiment (CLEX-9). Twelfth Conference on Cloud Physics, July 10-14, 2006, Madison, WI (AMS).

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.*, (in press).

Nobis, T., and R.A. Pielke, 2006: Results and sensitivities of an urban parameterization coupled to the Regional Atmospheric Modeling System (RAMS) over Washington DC. Preprint CD-ROM, Sixth Symposium on Urban Environment, January 29-February 2, Atlanta, GA (AMS).

Noh, Y.-J., A.S. Jones, and T.H. Vonder Haar, 2007: Snowfall retrievals over land using high frequency microwave satellite data – in the Great Lakes Region. Proceedings (CD-ROM), The Joint 2007 EUMETSAT Meteorological Satellite Conference and the 15th American Meteorological Society (AMS) Satellite Meteorology and Oceanography Conference, September 24-28, Amsterdam, The Netherlands (poster).

Pielke Sr., R.A. and T. Vukicevic, 2005: Forum on modeling the atmospheric boundary layer. *Bull. Amer. Meteor. Soc.*, 86, 95-96.

Pielke, Sr., R.A., T. Matsui, G. Leoncini, T. Nobis, U. Nair, E. Lu, J. Eastman, S. Kumar, C. Peters-Lidard, Y. Tian, and R. Walko, 2005: A new paradigm for parameterizations in numerical weather prediction and other atmospheric models. *National Wea. Digest*, 30, 93-99.

Pielke, Sr., R.A., G. Leoncini, T. Matsui, D. Stokowski, J.-W. Wang, T. Vukicevic, C. Castro, D. Niyogi, C.M. Kishtawal, A. Biazar, K. Doty, R.T. McNider, U. Nair, and W.K. Tao, 2006: Development of a generalized parameterization of diabatic heating for use in weather and climate models. Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO, Paper No. 776.

Pielke Sr., R.A., D. Stokowski, J.-W. Wang, T. Vukicevic, G. Leoncini, T. Matsui, C. Castro, D. Niyogi, C.M. Kishtawal, A. Biazar, K. Doty, R.T. McNider, U. Nair, and W.K. Tao, 2007: Satellite-based model parameterization of diabatic heating. *EOS,* 88 (8), 20 February, 96-97.

Raff, D.A., J.A. Ramirez, and J.L. Smith, 2004: Hillslope drainage development with time: a physical experiment. *Geomorphology*, 62, 169-180.

Raff, D.A. and J.A. Ramirez, 2005: A physical, mechanistic and fully coupled hillslope hydrology model. *International Journal of Numerical Methods in Fluids,* DOI: 10.1002/_d.1016; 20 pp.

Rapp, D., 2007: Passive microwave measurement of soil moisture using WindSat. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 211 pp.

Rapp, D., M. Mungiole, A.S. Jones, C.L. Combs, and G. McWilliams, 2006: Sensitivity of the MWLSM and its comparison with the CMIS model. CIRA Technical Report, Colorado State University, Fort Collins, Colorado, 60 pp. [ISSN: 0737-5352-75].

Reinke, D.L., J.M. Forsythe, J.A. Kankiewicz, and C.L. Combs, 2003: Improved infrared cloud analysis and regional cloud products from the chances global cloud database. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Reinke, D.L., K.E. Eis, and T.H. Vonder Haar, 2006: Cloud-free line of sight (CFLOS) derived from CloudSat radar data. Preprint CD-ROM, AGU Fall Meeting, December 11-15, San Francisco, CA.

Rockel, B., C.L. Castro, R.A. Pielke Sr., H. von Storch, and G. Leoncini, 2007: Dynamical downscaling: Assessment of model system dependent retained and added variability for two different RCMs. *Geophys. Res. Lett.*, (submitted).

Rojas, R., P.Y. Julien, M. Velleux, and B.E. Johnson, 2008: Grid size effect on watershed soil Erosion Models. *J. Hydrol. Eng.*, (accepted).

Ruston, B., 2004: Characteristics of summertime microwave land emissivity over the conterminous United States. Ph.D. Dissertation, Department of Atmospheric Science, Colorado State University, Fort Collins, CO, 126 pp.

Ruston, B., T.H. Vonder Haar, and A.S. Jones, 2003: Microwave land emissivity over complex terrain. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Ruston, B., and T.H. Vonder Haar, 2004: Characteristics of summertime microwave land emissivity over the conterminous United States. CIRA Technical Report, Colorado State University, Fort Collins, Colorado, 126 pp. [ISSN: 0737-5352-64].

Ruston, B., and T.H. Vonder Haar, 2004: Characteristics of summertime microwave emissivities from the Special Sensor Microwave Imager over the conterminous United States. *J. Geophys. Res., 109*, D19103.

Saleeby, S.M., W.Y.Y. Cheng, and W.R. Cotton, 2007: New developments in the Regional Atmospheric Modeling System suitable for simulating snowpack augmentation over complex terrain. *J. Wea. Mod.,* 39, 37-49.

Sample, L.B., 2005: Sensitivity analysis for the retrieval of aerosol optical properties from measured reflectances. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 114 pp.

Schubert, W.H., and M.T. Masarik, 2006: Potential vorticity aspects of the MJO. *Dynam. Atmos. Oceans.,* 42(2006), 127-151.

Seaman, C.J., 2003: Observed and calculated properties of mid-level, mixed-phase clouds. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, CO, 92 pp.

Seaman, C.J., and T.H. Vonder Haar, 2003: Observed and calculated properties of mid-level, mixed-phase clouds. CIRA Technical Report, Colorado State University, Fort Collins, Colorado, 92 pp. [ISSN: 0737-5352-63].

Seaman, C.J., J.A. Kankiewicz, J.M. Davis, and K.E. Eis, 2005: Simulated transmissivity of mid-level, mixed-phase clouds. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Seaman, C.J., T. Vukicevic, and T.H. Vonder Haar, 2006: Assimilation of GOES radiances to improve forecasting of mid-level, mixed phase clouds. Preprint CD-ROM, Fourteenth Conference on Satellite Meteorology and Oceanography, January 29-February 2, Atlanta, GA (AMS).

Sengupta, M., T. Vukicevic, A.S. Jones, and T.H. Vonder Haar, 2005: Assimilation of satellite radiances to improve cloud analysis and short term mesoscale prediction. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) 2005 Conference, October 11-15, Monterey, CA (ARL).

Sengupta, M., A. Jones, S. Longmore, and T. Vonder Haar, 2007: Cloudy 4DVAR data assimilation of the GOES Sounder. Proceedings CD, Battlespace Atmospheric and

Cloud Impacts on Military Operations Conference (BACIMO) 2007, November 6-8, Chestnut Hill, MA. Oral presentation, Session 2: Data Assimilation and Numerical Modeling.

Smith, A.J., B.M. Griffin, J-Ch. Golaz, and V.E. Larson 2006: Comparison of large-eddy simulations with a single-column model: implications for mid-level cloud parameterization. Preprint CD-ROM, Twelfth Conference on Cloud Physics, July 10-14, Madison, WI (AMS).

Smith, M.A., 2007: Evaluation of mesoscale simulations of dust sources, sinks and transport over the Middle East. Masters Thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, CO, 126 pp.

Smith, M.A., W.R. Cotton, D. Stokowski, and S.M. Saleeby, 2008: Evaluation of mesoscale simulations of dust sources, sinks and transport over the Middle East. *Atmos. Res.,* (submitted).

Stephens, P.J., and A.S. Jones, 2005: Adaptable implementation of the Backus-Gilbert method. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) 2005 Conference, October 11-15, Monterey, CA (ARL).

Stephens, P.J., and A.S. Jones, 2006: Bounds on the variance in the pattern matching criteria. *IEEE Trans. Geosci. Remote Sensing,* 44(9), 2514-2522.

Stephens, P.J., and A.S. Jones, 2007: Geometrical variations of gain patterns. *IEEE Trans. Geosci. Remote Sens.,* 45(2), 376-382.

Stephens, P.J., and A.S. Jones, 2007: A general implementation of a discrete Backus-Gilbert spatial filter for microwave radiometer data. *J. Atmos. and Oceanic Tech.,* (resubmitted, April).

Stokowski, D.M., 2005: The addition of the direct radiative effect of atmospheric aerosols into the regional atmospheric modeling system (RAMS). Masters thesis, Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO, 81 pp. Also available as ATS Paper No. 764.

Stokowski, D.M., W.R. Cotton, 2005: Addition of the aerosol direct effect to the Colorado State University regional atmospheric modeling system (CSU-RAMS). On website, Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) 2005 Conference, October 11-15, Monterey, CA (ARL).

Velleux, M.L., 2005: Spatially distributed model to assess watershed containment transport and fate. Ph.D. dissertation, Department of Civil Engineering, Colorado State University, Fort Collins, CO, 261 pp.

Velleux, M.L., P.Y. Julien, R. Rojas-Sanchez, W.H. Clements, and J.F. England, Jr., 2006: Simulation of metals transport and toxicity at a mine-impacted watershed: California Gulch, Colorado. *Environ. Sci. Technol*., 40(22), 6996-7004.

Vonder Haar, T.H., J.M. Forsythe, J. Luo, D.L. Randel, S. Woo, 2005: Water vapor trends and variability from the global NVAP dataset. Preprint CD-ROM, Sixteenth Conference on Climate and Variability and Change, January 9-13, San Diego, CA (AMS).

Vonder Haar, T.H., J.M. Forsythe, R.W. Kessler, 2006: A pilot study of scientific data stewardship with global water vapor. Preprint CD-ROM, Fourteenth Conference on Satellite Meteorology and Oceanography, January 29-February 2, Atlanta, GA (AMS).

Vukicevic, T., D. Zupanski, T.H. Vonder Haar, and A.S. Jones, 2003: Mesoscale cloud state estimation from visible and infrared radiances. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2003, September 9-11, Monterey, CA (NRL).

Vukicevic, T., T.J. Greenwald, M. Zupanski, D. Zupanski, T. Vonder Haar and A.S. Jones, 2004: Mesoscale cloud state estimation from visible and infrared satellite radiances. *Mon. Wea. Rev.,* 132(12), 3066-3077.

Vukicevic, T., E. Kalnay, T. Vonder Haar, 2004: The need for a national data assimilation education program. *Bull. Amer. Meteor. Soc.,* 85(1), 48-49.

Vukicevic, T., M. Sengupta, T. Vonder Haar, A. Jones, and F. Evans, 2004: 4D assimilation of cloudy satellite radiances. Preprint CD-ROM, Thirteenth Conference on Satellite Meteorology and Oceanography, September 20-24, Norfolk, VA (AMS).

Vukicevic, T., M. Sengupta, A. Jones and T. Vonder Haar, 2005: 4DDATA assimilation of the GOES imager IR radiances in cloudy conditions. Preprint CD-ROM, Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (9IOASAOLS), January 9-13, San Diego, CA (AMS).

Vukicevic, T., M. Sengupta, A.S. Jones and T.H. Vonder Haar, 2006: Cloud resolving satellite data assimilation: Information content of IR window observations and uncertainties in estimation. *J. Atmos. Sci*., 63(3), 901-919.

Wang, J., M.R. Azimi-Sadjadi, D. Reinke 2004: A temporally adaptive classifier for multi-spectral imagery. *IEEE Transactions on Neural Networks*, 15 (1), 159-165.

Wang, N., and C. Matsumoto, 2005: A comparison study of data compression techniques for the battle-scale forecast model grids. On website, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 12-14, Monterey, CA (NRL).

Wang, N., and C. Matsumoto, 2006: A comparison study of data compression techniques for the battle-scale forecast model grids. CIRA Technical Report, Colorado State University, Fort Collins, Colorado, 11 pp. [ISSN: 0737-5352-76].

Wells, K., M. Witek, P. Flatau, S. Kreidenweis, and D. Westphal, 2007: An analysis of seasonal surface dust aerosol concentrations in the western U.S. (2001-2004): Observations and model predictions. *Atmos. Environ.,* 41, 6585-6597.

Wichern, G., 2006: Adaptive methods for rapid acoustic transmission loss prediction in the atmosphere. Masters thesis, Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado, 165 pp.

Wichern, G., M.R. Azimi-Sadjadi, M. Mungiole, 2005: Environmentally adaptive acoustic transmission loss prediction with neural networks. Proceedings, 2005 Unattended Ground Sensor Technologies and Applications Conference, SPIE Defense and Security Symposium, March 28-April 1, Orlando, FL.

Wichern, G. and M.R. Azimi-Sadjadi, 2006: An environmentally adaptive system for rapid acoustic transmission loss prediction. Proceedings DVD-ROM, IEEE World Congress on Computational Intelligence Conference, July 16-21, Vancouver B.C., Canada.

Wichern, G., M.R. Azimi-Sadjadi, M. Mungiole, 2007: Environmentally adaptive acoustic transmission loss prediction in turbulent and non-turbulent atmospheres. *Neural Networks Journal,* 20, 484-497.

Zupanski, D., 2005: Quantifying and reducing uncertainty by employing model error estimation methods. Pre-print CD-ROM, Eighty-fifth American Meteorological Society Annual Meeting, Ed Lorenz Symposium, January 9-13, San Diego, CA.

Zupanski, M., 2005: Maximum likelihood ensemble filter: theoretical aspects. *Mon. Wea. Rev.,* 133, 1710-1726.

Zupanski, M., D. Zupanski, T. Vukicevic, K. Eis, and T. Vonder Haar, 2005: CIRA/CSU four-dimensional variational data assimilation system, *Mon. Wea. Rev.*, 829-843.

Zupanski, M. and D. Zupanski, 2006: Model error estimation employing an ensemble data assimilation approach. *Mon. Wea. Rev.*, 134(5), 1337-1354.

DEPARTMENT OF DEFENSE

DoD Center for Geosciences/Atmospheric Research (CG/AR)

Nighttime Applications

Co-Principal Investigators: Steven D. Miller/Thomas H. Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: NPOESS, VIIRS, Day/Night Band, Moonlight

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

The overarching objectives of the Nighttime Applications project (done in collaboration with the Naval Research Laboratory, Monterey) is to prepare researchers and operational users of the future Visible/Infrared Imager/Radiometer Suite (VIIRS) Day/Night Band (DNB) sensor to fly on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) in the coming decade. The DNB provides continuity to the Operational Linescan System (OLS) sensor which has been carried on board the Defense Meteorological Satellite Program (DMSP) constellation for several decades. In comparison to the OLS, the DNB represents a paradigm shift in terms of improved spatial and radiometric resolution, and will be coupled with multi-spectral information from other channels on the VIIRS sensor.

The specific objective of work done in this period was to develop a top-of-atmosphere down-welling lunar spectral irradiance model at 1 nanometer spectral resolution. The purpose for doing so lies in our desire to relate VIIRS DNB measurements of reflected moonlight to atmospheric and surface-based physical parameters. Without knowledge of the lunar input to the system, one cannot compute a reflectance from the measurement of upwelling moonlight from the scene. This model takes into account the variable lunar phase angle (i.e., new moon, crescent, quarter, gibbous, full), the current Sun/Earth/Moon geometry (considering elliptical orbits), and the spectral variation of the lunar albedo. This information can then be used together with collocated near and thermal infrared band information from VIIRS to construct algorithms for numerous applications relegated heretofore to the daytime passes. In summary, our goal is to provide a capability to enable quantitative environmental applications from the DNB.

The approach used for this research was to begin with an extensive review of lunar observations from the astronomy community. Piecing together the data from several sources, an analytical function for the highly non-linear lunar phase function was developed and coupled to simple radiative transfer calculations and ancillary solar spectral irradiance data to compute the top-of-atmosphere down-welling spectral irradiance. This model was then coupled with a highly accurate celestial body model capable of predicting the location of the Sun, Moon, and Earth at any moment in time. To provide a less computationally tedious version of the calculation, a ‘mean geometry’ solution (based on 1 AU Sun-Earth distance and mean Earth-Moon distance) was developed. The database, a set of tables generated at 1-degree lunar phase angle resolution, can be de-normalized to the current Sun/Earth/Moon geometry through supplied conversion factors at high precision. The mean geometry table, along with data necessary for de-normalization, are supplied as a deliverable of this work; enabling any user to convolve the scaled 1 nanometer data with the sensor response function of the DNB to obtain the lunar information relevant to any given pixel in the VIIRS scene.

2. Research Accomplishments/Highlights:

Both an 'exact' and approximate model for the lunar spectral irradiance over the range [0.2,2.8 m] were produced along with auxiliary data and codes needed to scale the mean geometry results to an arbitrary date/time over the period 1 Jan 2000 to 1 Jan 2100.

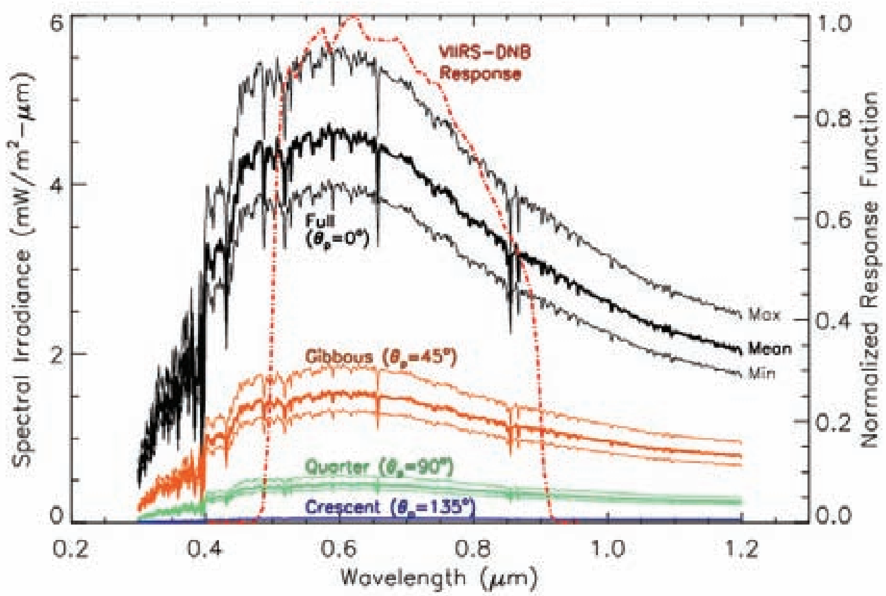


Figure 1: Results from the standard lunar spectral flux tables for selected lunar phase angles ranging from crescent to full-moon. Heavy curves ("Mean") correspond to the standard geometry (1 AU, mean moon-earth distance). Light curves ("Max" and "Min") correspond to perigee/perihelion and apogee/aphelion geometries, respectively. The VIIRS DNB spectral response function (courtesy Raytheon Santa Barbara Remote Sensing) is shown as a red dashed-dot curve. (From Miller and Turner [2008])

Results for selected lunar phase angles are shown in Fig. 1, along with the VIIRS DNB spectral response function (SRF). Correction terms corresponding to the extreme conditions of apogee/aphelion and perigee/perihelion applied to the bold standard curves show the possible spread in the solution space arising from variable Sun/Earth/Moon geometry. A comparison of the exact and standard lunar flux at 600 nm for the waxing mode of the lunar cycle, shown in Fig. 2 (for a case near mean Sun/Earth/Moon geometry), confirms close agreement (within 0.05%).

3. Comparison of Objectives Vs. Actual Accomplishments:

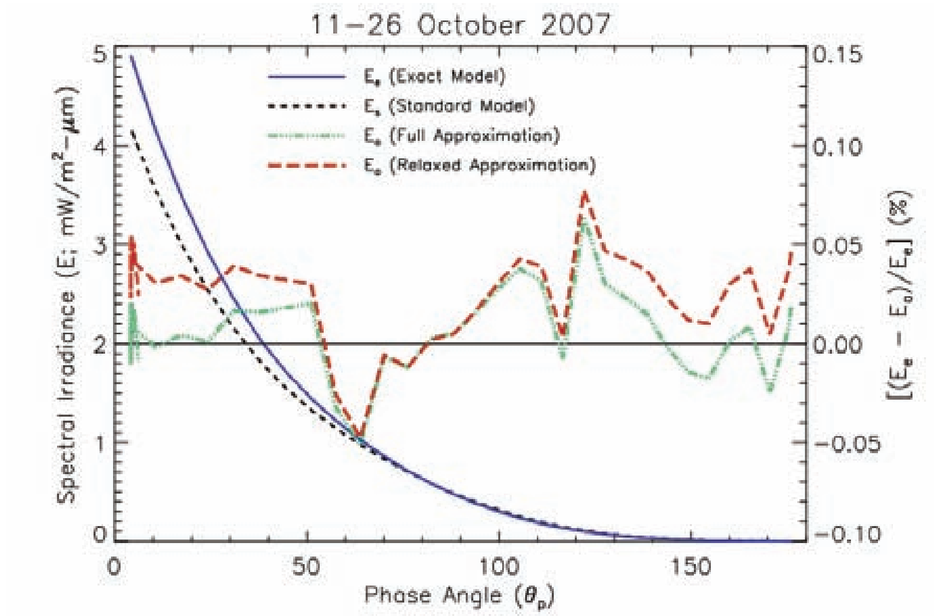


Figure 2 Left ordinate: comparison between the standard (using mean sun-earth and earth-moon distances) lunar flux model and exact calculations at =600 nm for the waxing moon over 11-26 October 2007. Right ordinate: percent-differences between exact and adjusted-standard models using the conversion factors described in the text. (From Miller and Turner [2008])

The objective of work during this period was to complete a user-ready tool for calculating the down-welling, top-of-atmosphere lunar spectral irradiance for a given date and time. This tool is a standard geometry table which is an approximation to the exact geometry calculations. The standard table can be applied to any date/time provided knowledge of the current Sun-Earth distance, Moon-Earth distance, and lunar phase angle. An auxiliary dataset of hourly values for these quantities has been computed and will be supplied with the standard tables. The general procedure for applying these tables to a sensor with arbitrary SRF (confined to the valid spectral interval [0.2, 2.8 m]) is as follows: (i) given the current date and time, interpolate the auxiliary dataset to obtain the corresponding Sun-Earth and Moon-Earth distances and lunar phase angle information, (ii) linearly interpolate the 1-degree standard lunar spectral flux tables according to the phase angle determined in step (i), (iii) scale the standard spectral flux according to the current Sun-Earth and Moon-Earth distances interpolated in step (i), and finally, (iv) convolve the interpolated/scaled lunar spectral flux data with a normalized SRF to yield a sensor-specific TOA lunar flux.

4. Leveraging/Payoff:

Improving the ability to detect and characterize environmental parameters at night enables forecasters to provide superior guidance to weather-sensitive end-users. For example, the ability to detect a low cloud/fog layer beneath an overriding cirrus shield (i.e., thin-over-thick cloud overlap) by combining conventional split-window brightness temperature differences (11-12   m) with measurements of moonlight reflectance provides information particularly important to the aviation community. Likewise, the ability to identify a new snow field at night (which was cloud-obscured during the day) provides forecasters with new surface information that may improve their ability to predict incipient nocturnal fog formation that is of use to commerce/transportation.

5. Research Linkages/Partnerships/Collaborators:

Outcomes of this research are anticipated to have far-reaching impacts to algorithm developers in the research community seeking to make quantitative use of the VIIRS/DNB under conditions of moonlight illumination. The research is in partnership with Department of Defense (in cooperation with the Naval Research Laboratory in Monterey, CA), and leverages the NPOESS Integrated Program Office sponsored 'NexSat' project for demonstration of various future NPOESS/VIIRS capabilities based on current heritage and risk-reduction systems on orbit. The recently initiated NOAA Satellite Proving Ground, designed specifically to prepare NOAA Weather Forecast Offices for new satellite capabilities, may also benefit from applications emerging from the current research when the NPOESS Preparatory Project (NPP; scheduled for launch in mid-2010) begins providing data.

6. Awards/Honors: N/A

7. Outreach:

Nighttime applications are demonstrated via the NexSat webpage (www.nrlmry.navy.mil/NEXSAT.html). The purpose of NexSat is to educate the broad community (research, operations, and the general public) on future capabilities anticipated from the NPOESS program, with a particular emphasis placed on VIIRS multispectral applications for improved characterization of the environment.

8. Publications:

Miller, S. D., and R. E. Turner, 2008: A Dynamic Lunar Spectral Flux Dataset for NPOESS/VIIRS Day/Night Band Environmental Applications, Submitted to *IEEE Trans. Geosci. Rem. Sens*.

Miller, S. D., S. H. D. Haddock, C. D. Elvidge, and T. F. Lee, 2007: Milky Seas: A New Science Frontier for Nighttime Visible-Band Satellite Remote Sensing. Joint EUMETSAT Meteorological Satellite Conference and 15th Satellite Meteorology & Oceanography Conference of the American Meteorological Society, Amsterdam, The Netherlands, September 24- 28.

Lee, T. F., S. D. Miller, F. J. Turk, J. D. Hawkins, C. Mitrescu, and M. Haas, 2007: Improving the Usability of Nighttime Imagery from Low Light Sensors. Joint EUMETSAT Meteorological Satellite Conference and 15th Satellite Meteorology & Oceanography Conference of the American Meteorological Society, Amsterdam, The Netherlands, September 24- 28.

Lee, T. F., S. D. Miller, F. J. Turk, C. Schueler, R. Julian, S. Deyo, P. Dills, and S. Wang, 2006: The NPOESS/VIIRS day/night visible sensor, *Bull. Amer. Meteor. Soc*., 87(2), 191-199, doi:10.1175/BAMS-87-2-191.

JET PROPULSION LABORATORY

CloudSat Arctic Energy Budget Science and Data Processing

Principal Investigator: Tom Vonder Haar (Aaron Schwartz)

NOAA Project Goal: Climate Observations and Analysis

Key Words: CloudSat, Arctic, Clouds, Climate

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

Masters thesis using CloudSat data examining the Arctic. Working with Dr. Vonder Haar and other CIRA researchers to examine CloudSat data and its relevance in regards to the Arctic, with results leading to at least one publication in a peer-reviewed journal.

2. Research Accomplishments/Highlights:

Paper submitted to JGR Atmos in 2/08, M.S. successfully defended 5/08. Validation of CloudSat 2B products and initial scientific observations and hypothesis' drawn from CloudSat data.

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

Poster presented at AMS General: Completed

Paper submitted to JGR Atmos: Completed

M.S. Defense: Completed

2nd Paper submitted to TBD journal: In progress

4. Leveraging/Payoff:

Using new CloudSat data to examine Arctic climate; Arctic climate is a "canary in the coal mine" with regard to global climate change and is not well understood.

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

Met with Dr. Jeff Key and his NOAA team at CIMSS (Madison, WI) in Jul 07 for discussion and data exchange. Met with Dr. Jennifer Francis from Rutgers at AMS General for discussion at AMS Meeting in 1/08. Several discussions with committee member Dr. Jennifer Kay at NCAR.

6. Awards/Honors:

7. Outreach: Aaron Schwartz, M.S. Thesis, May 2008

8. Publications:

Schwartz, A., and T.H. Vonder Haar, 2008: A Preliminary Arctic Cloud Climatology and Radiation Budget from CloudSat and CALIPSO. Submitted to Journal of Geophysical Research.

Future submissions planned.

MISSISSIPPI STATE UNIVERSITY

1. Evaluation of GPM Precipitation Estimates for Cross-Cutting Earth Science Applications Via Land Data Assimilation

2. Optimizing GPM Precipitation Estimation Using High Resolution Land Surface Modeling for Decision Support

3. A Rapid Prototyping Capability to Evaluate Potential Soil Moisture Retrievals of Aquarius Radiometer and Scatterometer

Principal Investigator: Steven D. Miller (Collaborating with Dr. Joe Turk, Naval Research Laboratory, Monterey)

NOAA Project Goal: Weather and Water

Key Words: Precipitation, Soil Moisture, Land Data Assimilation

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

The past two decades have witnessed the rapid evolution of the low Earth-orbiting (LEO) passive microwave (PMW) imaging sensor from a research setting into routine operational and climate applications. Following the launch of the Tropical Rainfall Measurement Mission (TRMM), increased attention was focused on the development of blended-satellite, high resolution precipitation products (HRPP) that capitalize on rapid-update visible (VIS) and infrared (IR) observations available from geostationary-based imagers, to augment the infrequent time sampling of the PMW rainfall datasets. One of the key applications for this type of precipitation analysis is for hydrological models which require knowledge of precipitation accumulations to couple with land surface models. Satellite-derived precipitation is often the only source of routine and timely precipitation data over large parts of the Earth where surface-based radar and/or rain gauge precipitation analyses are unavailable. The current research, which is a consolidation of the three projects listed above, looks toward the future Global Precipitation Measurement (GPM) program and its role in providing quantitative precipitation estimation (QPE) information for hydrologic processes in land surface models.

The Naval Research Laboratory (NRL) Blended (hereafter, 'NRL-Blend') precipitation retrieval algorithm is a multi-platform/multi-sensor technique that uses intermittently available passive microwave (PMW) satellite-derived rainfall information to 'adjust' space/time-matched geostationary visible/infrared (IR) datasets to the PMW-derived local instantaneous rain rates through a process of histogram matching. The technique is predicated on the fact that PMW observations provide a more direct and physical measurement of precipitation processes than IR information. On the other hand, the geostationary (IR-only) observations provide the temporal refresh information required to derive rainfall accumulations from rapidly evolving precipitating cloud systems. The intermittent tuning enables leveraging of the PMW information to provide improved estimates of precipitation from subsequent geostationary observations of the evolving cloud system.

A global, dynamically updating set of co-located PMW rain rates and geostationary IR brightness temperatures is maintained in real-time to build updated lookup tables. This enables rapid computation of instantaneous rain rates from all geostationary sensors (the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES)-11/12, the European Meteosat-7 and MeteoSat Second Generation, and the Japanese MTSAT). Every 3 hours, the NRL-Blend builds 3, 6, 12 and 24-hour accumulations from the time integration of all PMW and geostationary-derived rain rates. The geostationary-derived rain rates are weighted according to the PMW data revisit (e.g, if the time of the geostationary data is near the time of a PMW overpass, the geostationary data are given a smaller weight, and vice versa when the PMW data are less current).

2. Research Accomplishments/Highlights:

The NRL-Blend satellite precipitation product has been running continuously over the continental United States and surrounding areas (0N-50N, 130W-50W) since June 2007, with the exception of one outage between 19 Jan and 28 Feb 2008. The current configuration of the NRL-Blend incorporates data from eleven different satellite platforms (NOAA-Polar-orbiting Operation Environmental System (POES) 15/16/17/18, MetOp-A, TRMM, the Defense Meteorological Satellite Program (DMSP) F-13/14/16, the National Aeronautics and Space Administration (NASA) ‘Aqua’, and the joint NASA/Department of Defense (DoD) / Integrated Program Office (IPO) ‘Coriolis’). These satellites provide either active or passive microwave (PMW) sensors capable of retrieving instantaneous-level precipitation rates. The sensors included in this analysis are the Advance Microwave Sounding Unit (AMSU; passive) on NOAA/POES, the Microwave Humidity Sounder (MHS; passive) on METOP, the TRMM Microwave Imager (TMI; passive) and Precipitation Radar (PR; active), the Special Sensor Microwave Imager (SSM/I; passive) on DMSP F-13/14, the Special Sensor Microwave Imager/Sounder (SSMI/S; passive) on DMSP F-16, the Advance Microwave Scanning Radiometer for the Earth Observing System (AMSR-E; passive) on Aqua, and WindSat (passive) on Coriolis.

For the current projects, which are geared collectively towards NASA’s Global Precipitation Mission (GPM) goals, the NRL-Blend was run in 10 parallel modes, each simulating a different possible GPM-era ‘satellite constellation’ configuration. Since the exact configuration of which satellites and sensors will be orbiting during the GPM era currently is unknown (and will not be known until near or during the GPM mission) these various scenarios provide a means to analyze the impact of i) including/omitting particular sensor types (e.g., radar, radiometer), ii) including/omitting particular scanning types (e.g., cross-track, conical), ii) including/omitting certain crossing times (e.g., sun-synchronous morning/afternoon, TRMM-like low-inclination asynchronous, etc), and iii) simulating various types of potential GPM-era constellations.

For the RPC project the 10 simulated constellations are:

1) All satellites (baseline constellation)
2) Omit all cross-track sounders from baseline constellation
3) Omit morning crossing cross-track sounders
4) Omit afternoon crossing cross-track sounders
5) Omit both TRMM radar and radiometer, and Aqua
6) Omit TRMM radar only
7) Omit TRMM radiometer only
8) Omit both TRMM radar and radiometer
9) Omit all morning crossing satellites
10) Omit all afternoon crossing satellites

The 3-, 6-, 12- and 24-hour accumulations (as well as the instantaneous rain rate files that go into these estimates, and also quick-look images for each) from each of these configurations have been converted to easily-accessible binary and packaged into monthly tar-bundles. These data (up until the end of May 2008) have been delivered to Yangrong Ling at the MS State Geo-Resources Institute (GRI) for subsequent analysis and post-processing. The MS State group will utilize these datasets in the precipitation forcing to their land surface models.

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

A separate validation was undertaken to verify these ten different precipitation products and examine their performance relative to a gauge network and between each other. In this work, the recently developed 0.5-degree global Unified Gauge analysis developed by Mingyue Chen and Pingping Xie of the NOAA Climate Prediction Center (CPC) were used. The analysis includes the number of gauges included in each 0.5-degree box for better quality control by the users, and adapts an optimal interpolation approach for less spreading of point-type gauge data into neighboring areas.

Figure 1 shows four performance statistics for these 10 constellations, from top to bottom, bias, Equitable Threat Score (ETS), Probability of Detection (POD) and False Alarm Rate (FAR). For comparison, these same scores are shown with one numerical model forecast, the Navy Operational Global Atmospheric Prediction System (NOGAPS). These statistics are presented for the northern hemispheres summer (June-July-August) and winter (December-January-February) seasons as box-and-whiskers figures where the top and bottom of each colored box indicates the 25^{th} and 75^{th} percentiles. A threshold of 1 mm per day is used. Note that while there is not any particular constellation that lies too far from the others, the removal of all of the cross track sounders (constellation 2) appears to have the biggest impact relative to the others, most notably the morning crossing-time satellites (constellation 9). This is noted by a decrease in the ETS and the POD. Overall, the performance of all of the satellite algorithms suffers in the winter months and the performance of the model forecast is superior to any satellite product, the opposite being true in the summer months (this characteristic of model and satellite precipitation has been previously demonstrated with similar studies that have been done in Australia, Europe and Japan). This is likely due to difficulties with current PMW methods in detecting/retrieving snowfall.

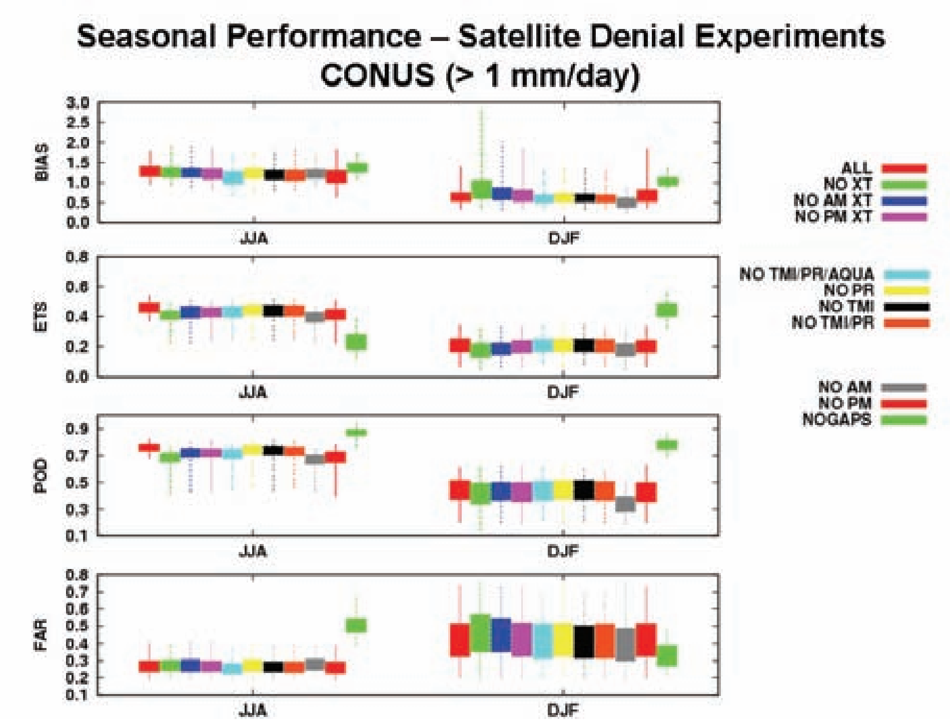


Figure 1. Bias, Equitable Threat Score (ETS), Probability of Detection (POD) and False Alarm Rate (FAR) for the ten satellite constellations and also for one model, the Navy Operational Global Atmospheric Prediction System (NOGAPS), relative to the NOAA/CPC daily (24-hour accumulations) gauge analysis. "No XT" refers to "No Cross Track Sounders", "No AM XT" refers to "No Morning Cross Track Sounders", etc. TMI and PR are the radiometer and radar onboard the TRMM satellite.

4. Leveraging/Payoff:

In the United States, the NEXRAD and dense rain gauge networks cover the majority of the CONUS and are expected to be superior to satellite-derived precipitation when compared quantitatively. However, in many other parts of the world, satellite-derived precipitation is the only source of wide area, real-time precipitation information. These various satellite-precipitation estimates, along with radar and rain gauge data over the Arkansas-Red River basin, will form the precipitation inputs to the land data assimilation system (LDAS) being investigated in the current work.

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

The next workshop for this project will be held July 16-17, 2008 at GRI where initial results from the land modeling will be discussed. We will collaborate with other investigators on this project in the coming months to prepare these datasets and work closely with their input and analysis into the LDAS. We will also examine the impact of the various precipitation datasets on stream flow, evapotranspiration, etc. This is a novel way to validate a precipitation analysis (the LDAS model outputs are compared against observations), rather than trying to directly or indirectly compare with rain gauges (where the LDAS model inputs are compared against observations).

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

NASA – CloudSat

Report Provided by: Ken Eis and 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: N/A

4. Leveraging/Payoff:

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

6. Awards/Honors:

7. Outreach:

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 28, 2006 and the CloudSat Data Processing Center (DPC) has been fully operational since the first CloudSat data were downlinked on May 20, 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 that CloudSat is flying in formation with other Earth Sciences missions dubbed the A-Train (fig 1). CloudSat is 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).

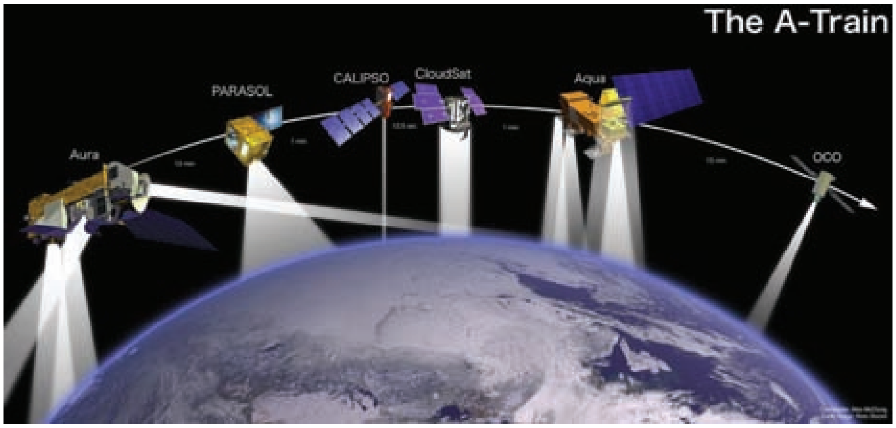


Figure 1. "A-Train" satellite constellation

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.

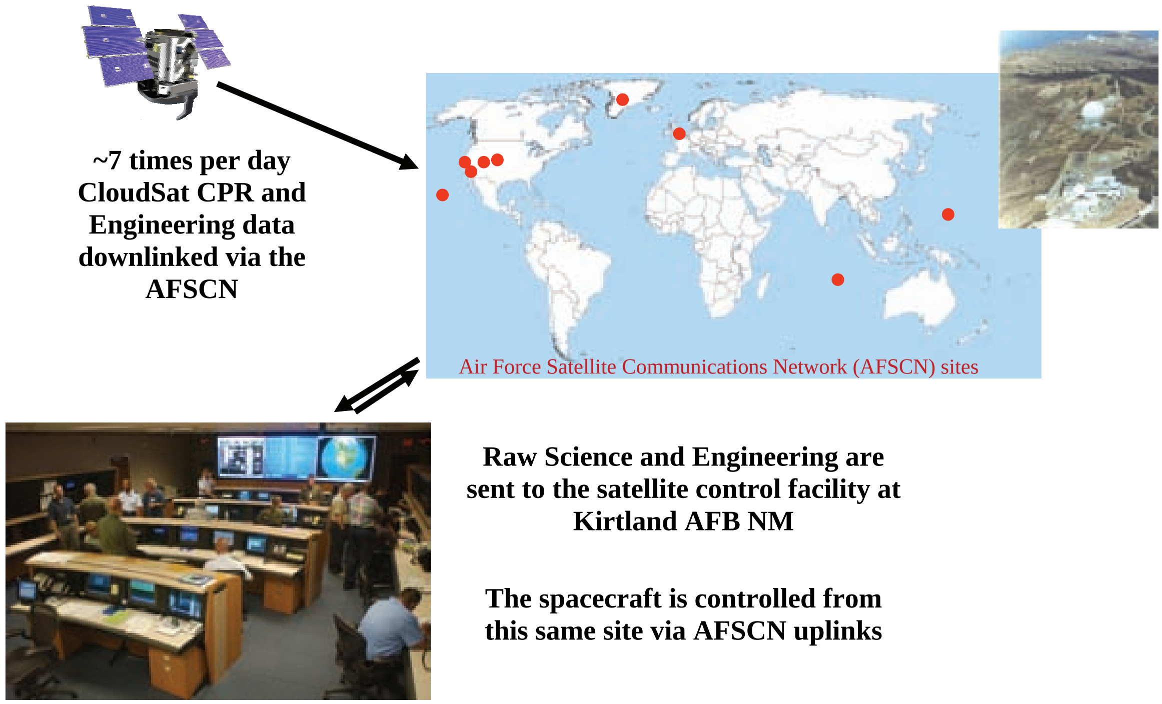


Figure 2. CloudSat Data Flow – Satellite to USAF site at Kirtland AFB.

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.

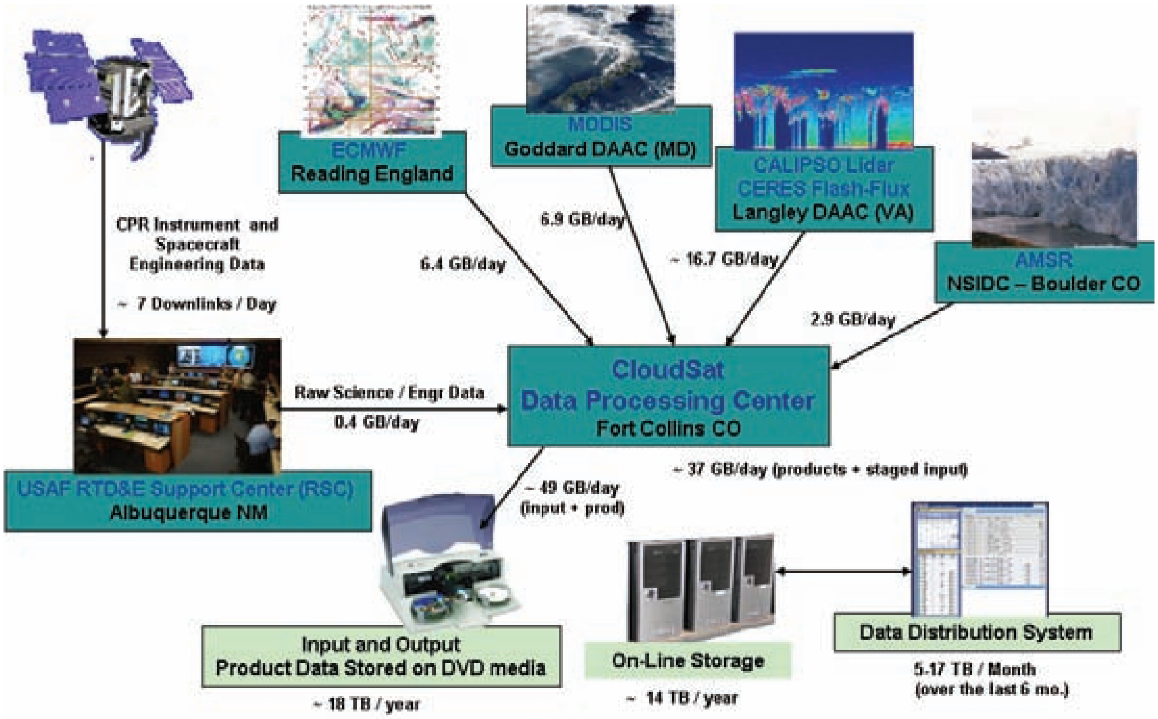


Figure 3. Data Flow through the CloudSat Data Processing Center

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 April 1, 2008 (the end of the CloudSat Prime Mission), the data distribution system has provided data to over 670 users/groups in 47 different countries. Some pertinent statistics as of 4/1/2008:

Granules (Orbits) Processed	Profiles (37,088/Granule)	240-m Vertical Bins (125/Profile)
9502	352,410,176	44.1 Billion

Cumulative through Apr 1st 2008	Product Files	Data Volume (TB)
General Science Comm.	1,158,817	82.7
CloudSat Research Teams	459,567	24.8

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 formation flying.

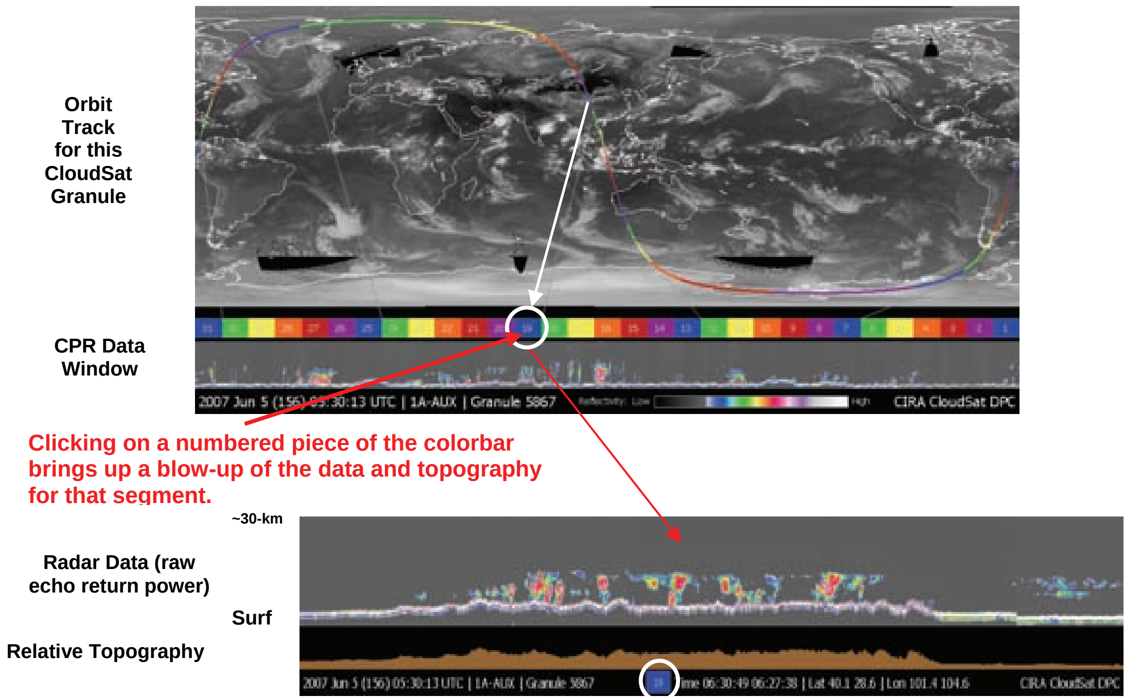


Figure 4. CloudSat “Quicklook” imagery. To view these images and learn more about the content, visit the quicklook page at http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php .

The CloudSat DPC website 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.

NOAA relevance

The DPC’s computer system is being considered as a low cost flexible data processing alternative for several future NASA missions. NOAA has also shown some interest in the technologies used by the CloudSat mission to lower the cost of their future missions.

NASA - Defining Subgrid Snow Distributions within NASA Remote-Sensing Products 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. "Yet to be started."

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. “Yet to be started.”

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, Communications 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 as yet

7. Outreach: None as yet

8. Publications: None as yet

<u>NASA</u> – Ensemble Data Assimilation of Precipitation Observations

Principal Investigators: Dusanka Zupanski and Christian D. Kummerow

NOAA Project Goal: Weather and Water

Key Words: Ensemble Data Assimilation, Global Precipitation Mission (GPM), Non-Linear Observation Operators

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

This is a two-year collaborative research project between Colorado State University and NASA/GMAO including D. Zupanski, M. Zupanski and C.D. Kummerow, from CSU and Arthur Y. Hou and Sara Q. Zhang from NASA/GMAO. The report period corresponds to the first year of this research. The major objective is to address the problem of assimilation of precipitation observations in support of the Global Precipitation Mission (GPM) Program. We will develop an ensemble data assimilation system for assimilation of surface precipitation observations from multi-sensors and test this system using real observations. We will also evaluate the application of the ensemble assimilation method in assimilating satellite data with complex non-linear observation operators. Our research objective is also to understand the connections between the information content of precipitation data and the dynamical states of the atmosphere.

We will employ and further develop an ensemble-based data assimilation algorithm developed at CIRA/CSU, the Maximum Likelihood Ensemble Filter (MLEF). In this research, we will use the MLEF to assimilate real precipitation observations using the global GEOS-5 AGCM. We will develop and test the integrated system of the MLEF (smoother version) and the GEOS-5 AGCM. In addition, we will develop the observation operators and data interface for precipitation. This will also involve developing additional constraints and interfaces for the non-control-variables in the ensemble assimilation system, and running the GEOS-5 Data Assimilation System (DAS).

As a result of this research we expect to develop a robust data assimilation system for assimilation of precipitation observations and satellite data with complex non-linear observation operators, which can be used in data assimilation at NASA/GMAO.

2. Research Accomplishments/Highlights:

During the report period we have developed the basic version of the data assimilation algorithm and tested it in assimilation of the real satellite precipitation observations (TRMM and SSM/I data). In particular, we developed and evaluated a smoother, the Maximum Likelihood Ensemble Smoother (MLES), which was especially useful for assimilation of precipitation data. The data assimilation algorithm is installed on the NASA Columbia computer and made available to the NASA GPM research. The results indicate positive impact of assimilation of precipitation data, especially in producing dynamically balanced precipitation analyses (e.g., precipitation analyses in agreement with model dynamical variables such as wind, temperature and pressure). An example of results is given in Fig. 1.

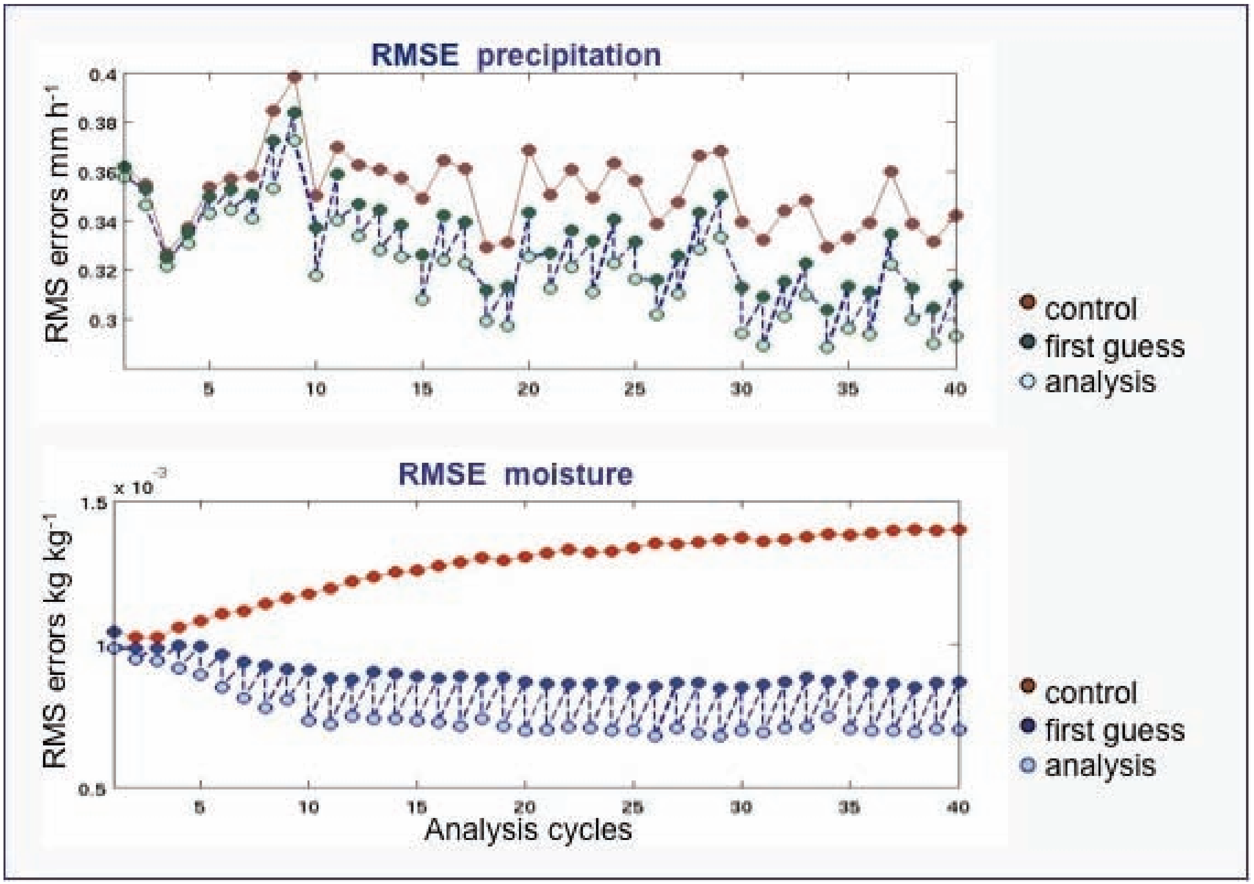


Fig. 1. Ensemble smoother with a modest ensemble size of 48 members is able to reduce analysis errors in precipitation and moisture, and improve short-term forecasts. Real TRMM and SSM/I observations of precipitation and pseudo observations of specific humidity, from the GEOS-5 Data Assimilation System (GEOS-5 DAS), are assimilated. The control experiment is the experiment without data assimilation.

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 purposes of the GPM Program. Technology transfer is accomplished employing the NASA models and data and by implementing the algorithms on the NASA supercomputer Columbia.

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

None as yet

6. Awards/Honors: None as yet

7. Outreach:

One Ph.D. level Graduate Student: Fang Wang

8. Publications:

Zhang, S.Q., D. Zupanski, A.Y. Hou, and M. Zupanski, 2008: Application of an ensemble smoother to precipitation assimilation. *Geophysical Research Abstracts*, Vol. 10, EGU2008-A-04209, 2008, *EGU General Assembly*, 13-18 April 2008, 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*. (in press).

Zupanski, D., A. Y. Hou, S. Q. Zhang, M. Zupanski, C. D. Kummerow, and S. H. Cheung 2007: Applications of information theory in ensemble data assimilation. *Quart. J. Roy. Meteor. Soc.*, 133, 1533-1545.

Zupanski, D., M. Zupanski, A.Y. Hou, S.Q. Zhang, and A.S. Denning, 2007: An ensemble-based approach to information content analysis and some new applications. *The IUGG XXIV General Assembly*, July 2-13, Perugia, Italy.

NASA - GLOBE – Inspiring the Next Generation of Explorers

Principal Investigator: Cliff Matsumoto

NOAA Project Goal:

Key Words: International Education and Science Program; Student Research; Climate Change; 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 collect environmental data in areas around their schools and post their observations and measurements through the Internet on the GLOBE Website (www.globe.gov). 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. Years of student data collection have resulted in a significant contribution to science. GLOBE's unique global database holds more than 18 million student measurements of atmospheric, soil, land cover, hydrological, and phenological data, all of which are universally accessible on the website for research. 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 more than 100 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, along with the Atmospheric Science Department at CSU, comprise the CSU team. On the UCAR side, representatives from the UCAR Office of Programs (UOP) and NCAR are part of the GLOBE staff.

2. Research Accomplishments/Highlights:

The Next Generation GLOBE (NGG) plan was approved in September 2005 by NASA and NSF. In response, the GLOBE Program Office (GPO) has 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 2008, GPO's attention is shifting towards providing a more collaborative space to promote student research around various themes such as climate change and sustainability.

Major areas of work towards the GLOBE vision in the past year:

Support student research through collaborations with large-scale Earth System Science Projects (ESSPs) and local and regional community projects. (See Fig. 1)

Fig. 1. Example of a student research activity

Catalyze the development of six Regional Consortia in Africa, Europe, Latin-America-Caribbean, Near East, and North America.

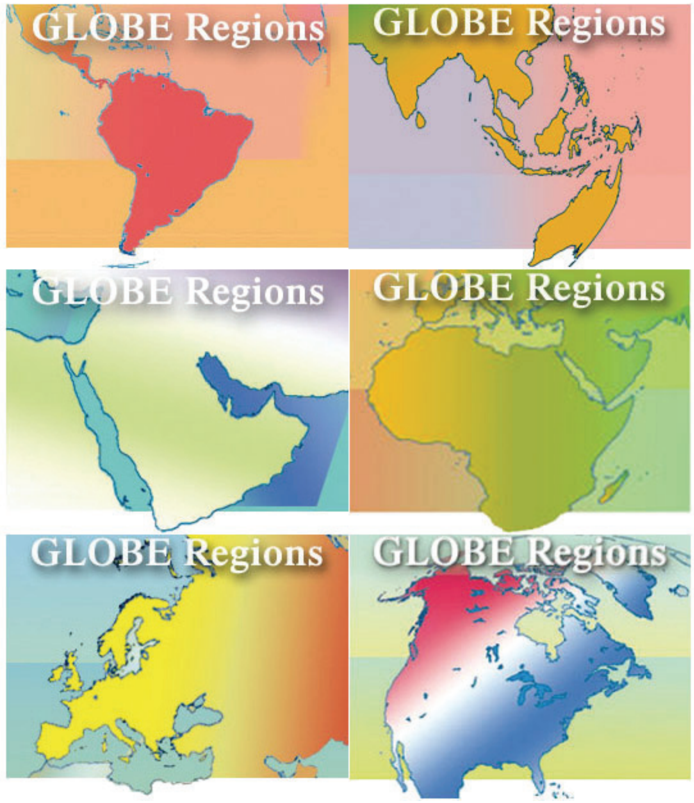


Fig. 2. GLOBE's six Regional Consortia.

Enhance long-term GLOBE and GPO sustainability through planning for the formation of an international GLOBE foundation and diversification of the GPO funding base.

Continue to provide quality and timely core services to the GLOBE community.

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 last 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. GPO staff put in extra effort to finalize reports which provided statistics and other documentation to NASA. At the end of the review process, NASA determined how the management of GPO should move forward and at which level to continue funding the GLOBE Program.

During the past year, the four ESSPs collaborated with GPO staff on implementing the projects and held various activities for the GLOBE community to participate in. Some highlights of ESSP activities:

Seasons and Biomes:

In April 2008, Seasons and Biomes held “Pole to Pole video conference and follow-up web chats”. See more at http://www.globe.gov/fsl/html/templ.cgi?ipy_video08

During March – December 2008, Seasons and Biomes is running a student research campaign that organizes GLOBE schools by biomes into eight Global Learning Communities and students monitor differences and similarities in seasons or seasonal indicators in their biomes. See more at http://www.globe.gov/fsl/html/templ.cgi?seasonsresearchcampaign

The development of Ice Phenology and Frost Tube protocols is nearing completion.

Carbon Cycle:

Development and piloting of tools and educational materials is occurring.

From Local to Extreme Environments (FLEXE):

On 19 December 2007, FLEXE held “GLOBE HQ to Alvin, Come In Please”, a web-streamed phone call from GLOBE Headquarters to the research cruise Alvin. See more at http://www.globe.gov/fsl/html/templ.cgi?flexe-cruise_phone
This was part of the FLEXE Research Cruise that sailed 8 - 22 December (http://www.globe.gov/fsl/html/templ.cgi?flexe-cruise_mission).

Tools for writing and peer reviewing student research project reports are being developed as part of FLEXE that will be an enhancement to the report submission tool that is currently available.

Watershed Dynamics:

Development and piloting of tools and educational materials is occurring.

Fig. 3. The four Earth System Science Programs supported by GLOBE

The new GLOBE Website 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, including projects related to the ESSPs (Earth System Science Projects), and local and regional 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.

Research Accomplishments/Highlights for the GLOBE Technology Team:

The Technology Team's (CIRA) central task is the support of the partner, science and education teams of the program. The development of new webpages, maintenance of the GLOBE data entry web and email systems, updates to GLOBE data access and visualization pages, adding student-submitted study site photos to the Website, and support for material preparation for various presentations throughout the year consume most of the Team's time. The products of these efforts result in web graphic artwork, special images and photos for presentations, high-resolution products for posters, and GLOBE flyers and brochures in six different languages.

The initial release of the new GLOBE Website met with a very positive response from the GLOBE community. Plans are underway for future versions of the site. These plans include:

Presenting tools for student collaboration on projects in an organized, integrated "Research Collaboratory" to better support conducting student research projects. This includes the development of improved tools, content, and data portals for the ESSPs.

Data Access will evolve into a portal giving integrated access to historical GLOBE data, external datasets (ESSP and "reference" data), and future regional project data in a manner suitable for use by students.

Data Visualization and Analysis tools will evolve to support student work on ESSP projects.

Providing a robust API (application programming interface) for integrating data access into third party systems/services.

Implementing an iterative process whereby improvements are made and feedback received to fuel the next iteration.

Using new backend technology that will facilitate rapid evolution of online content and tools.

Another primary focus for the system team remains the development/maintenance of the GLOBE Partner Administration Website. This is a website that the GLOBE office staff and Partners can use to track partner activities, workshops, trainers, teachers and schools involved. There is continuous improvement to make more user-friendly pages, better tools to support the partners with their training and monitoring efforts, improved regional organization of information, and a detailed partner administration manual.

In early 2008, the annual GLOBE partnership survey was conducted entirely on line for the third year. The technology team is heavily involved in the technical design, operation, and data analysis of the results. The outcome of this survey is for the GPO to better support partnerships and regional collaborations around the world. The survey includes over 100 questions on topics such as funding and sustainability, program implementation, and teacher/trainer support. Results will be shared with the GLOBE community at the annual conference and GLE in Cape Town, South Africa scheduled for 22– 27 June 2008.

Fig. 4. Banner for the GLOBE Annual Conference and GLE designed by CIRA's graphic designer.

The graphics support continues to be a significant contribution to the program and helps to ensure that the GLOBE brand is preserved. Website graphics and GLOBE study site photo processing are needed as well as graphics needed for print such as GLOBE brochures, flyers, certificates, bi-annual NASA performance reports, and business cards.

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, frequent updates to the content on the website, 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 as yet

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

None as yet

6. Awards/Honors: None as yet

7. Outreach:

Today, the international GLOBE network has grown to include representatives from 110 participating countries and 138 U.S. Partners coordinating GLOBE activities that are integrated into their local and regional communities. Due to their efforts, there are more than 40,000 GLOBE-trained teachers representing over 20,000 schools around the world. GLOBE students have contributed more than 18 million measurements to the GLOBE database for use in their inquiry-based science projects.

8. Publications: None as yet

<u>NASA</u> – High Resolution Dynamic Precipitation Analysis for Hydrological Applications

Principal Investigator: Dusanka Zupanski, Milija Zupanski and Christian D. Kummerow

NOAA Project Goal: Weather and Water

Key Words: Ensemble Data assimilation, Global Precipitation Mission (GPM), Dynamic Precipitation Analysis

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

This is collaborative research supported by the Global Precipitation Mission (GPM) Program. It involves researchers from CSU (D. Zupanski, M. Zupanski and C.D. Kummerow), NASA/GMAO (Arthur Y. Hou and Sara Q. Zhang) and the University of California (Samson H. Cheung). Since this research uses the NCEP operational observations and forward observational operators, it relies on some help from NCEP personnel, which is coordinated by Zoltan Toth, the NCEP ensemble-forecasting leader. The research is expected to last two years, with the potential for extension to the third year. The report period covers the first half of the first year. 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. During Stage I (first year) of this research, we will develop a basic (prototype) system consisting of the Weather and Research Forecasting (WRF) model, the Maximum Likelihood Ensemble Filter (MLEF) data assimilation algorithm, and the NCEP mesoscale Grigpoint Statistical Interpolation (GSI) forward observation operators (NCEPos). We will validate the basic system with WRF at 20 ~30km/29lev resolution and with a subset of the observation data used in the operational NCEP mesoscale 3DVAR analyses.

We will deliver a prototype WRF-MLEF-NCEPos with primary validation results by the end of the first year. The basic system should be ready for the further development to incorporate WRF with nested high-resolution (2km) domains, and to include precipitation observations in radiance or retrievals.

In the second year we plan to further develop and improve the WRF-MLEF in high-resolution (2km) data assimilation experiments. The high-resolution application will involve more extensive experimenting with the model error and will include more precipitation-related observations.

Potentially, the research would be extended to a third year, when we will extensively verify the full-blown high-resolution WRF-MLEF data assimilation system.

2. Research Accomplishments/Highlights:

During the report period, we have successfully finished the first major task: Implementing the NCEP's operational GSI codes and a sub-set of the NCEP's observations (including conventional and satellite data), which we plan to use in data assimilation experiments, on the NASA Columbia supercomputer. Currently, we are interfacing the MLEF algorithm with the GSI forward operators. This is another major task that has to be accomplished before we can start performing data assimilation experiments. We will report the progress in data assimilation in the next year.

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.

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

None as yet

6. Awards/Honors: None as yet

7. Outreach:

One Ph.D. level Graduate Student: Fang Wang

8. Publications:

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. (in press).

Zupanski, M. 2008: Dynamical approach to non-linear ensemble data assimilation. Invited presentation at the Workshop on Mathematical Advancement in Geophysical Data Assimilation. February 3-8, 2008, Banff International Research Station, Banff, Canada.

NASA – Mesoscale Carbon Data Assimilation for NACP

Principal Investigator: Scott A. Denning, Co-PI: Dusanka Zupanski

NOAA Project Goal: Weather and Water

Key Words: Mesoscale Carbon Data Assimilation, North American Carbon Program (NACP), Model Error and Parameter Estimation

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

The North American Carbon Program (NACP) is a multi-year program of integrated research supported by many U.S. agencies which seek to quantify the current budget of CO2, CO, and CH4 over North America, to understand and predict the processes governing these fluxes, and to provide timely and practical information products to support management decisions. A major component of NACP is a greatly enhanced system for observing temporal and spatial variations for carbon gases in the atmosphere over North America and adjacent coastal oceans.

We are developing a generalized framework for flux estimation from multiple streams of carbon observations. These include spectral vegetation and land cover imagery, eddy covariance flux observations, meteorological data, and both in-situ and remotely sensed observations of atmospheric carbon gases. This will be accomplished using Ensemble Data Assimilation (EnsDA) techniques applied to a fully coupled model of regional meteorology, ecosystem carbon fluxes, and biomass burning (SiB-CASA-RAMS). The coupled model simulates terrestrial carbon fluxes over North America due to photosynthesis, autotrophic respiration, decomposition, fires, and a “residual” time-mean source or sink. Unknown parameters related to light response, allocation, drought stress, phonological triggers, combustion efficiency, PBL entrainment, convective efficiency, and the time-mean sink will be estimated to obtain optimum consistency with a wide variety of ecological, meteorological, and trace gas observations.

2. Research Accomplishments/Highlights:

The report period corresponds to the third (final) year of this research project. This is a collaborative research project involving investigators and collaborators from the Denning research group, CIRA, NASA and other universities. Major data assimilation related accomplishments during the report period include development of three different assimilation systems: one based on the Maximum Likelihood Ensemble Filter (MLEF), the other on Markov Chain Monte Carlo (MCMC) approach, and the third based on the Kalman filter approach. All three systems have been used for the continental scale assimilation of CO2 concentrations over North America, giving comparable results in experiments with real and simulated observations. We have also employed the MLEF system to optimize parameters of the Simple Biosphere (SiB) model to further improve carbon transport simulation. The SiB model and its coupled version, SiB-RAMS, have also been applied to simulate carbon fluxes over North America, producing realistic C02 concentrations, in remarkable agreement with the observed second Ring of Towers data (Ring 2007).

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

The objectives for this year were fully accomplished. Development and testing of three different data assimilation systems rather than using only one system was an additional accomplishment not originally envisioned.

4. Leveraging/Payoff:

This research project will contribute to improved understanding of carbon processes and to provide timely and practical information products to support management decisions, especially under the NACP. Technology transfer is achieved through implementing the algorithms on the NASA supercomputer Columbia and through making them available to the NACP researchers.

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

This research benefits from collaborations between project leaders and team members of the NACP core projects (more information about the NACP core projects can be found at http://www.nacarbon.org/cgi-nacp/web/investigations/inv_profiles.pl).

6. Awards/Honors: None as yet

7. Outreach:

Two M.S. level Graduate Students: Erica McGrath-Spangler and Nick Parazoo
Two Ph.D. level Graduate Students: Kathy Corbin and Andrew Schuh
One B.S. level student: John Heizer

8. Publications:

Lokupitiya, R.S., D. Zupanski, A.S. Denning, S.R. Kawa, K.R. Gurney, M. Zupanski, W. Peters, 2008: Estimation of global CO_2 fluxes at regional scale using the maximum likelihood ensemble filter. J. Geophys. Res. (submitted).

Zupanski, D., A. S. Denning, M. Uliasz, M. Zupanski, A. E. Schuh, P. J. Rayner, W. Peters and K. D. Corbin, 2007: Carbon flux bias estimation employing Maximum Likelihood Ensemble Filter (MLEF). J. Geophys. Res., 112, D17107, doi:10.1029/2006JD008371.

Zupanski, D., A.S. Denning, M. Uliazs, R.S. Lokupitiya, and M. Zupanski, 2007: Model bias estimation in carbon data assimilation. The IUGG XXIV General Assembly, July 2-13, Perugia, Italy.

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. "In progress."

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. "In progress."

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. “In progress.”

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, Communications 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 as yet

7. Outreach:

Conference and meeting presentations:

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Snow cover distribution on Alaska’s Arctic Slope: modeling 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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

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, in press.

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, in press.

<u>NCAR</u> - CIRA-NCAR/MMM WRF-VAR Collaboration Work Plan

Principal Investigators: Andy Jones and Steve Fletcher

NOAA Project Goal: Weather and Water

Key Words: Satellite Data Assimilation, Preconditioner, Microwave Emissivities, WRF, 3DVAR, 4DVAR

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

This collaborative work plan will transition CIRA-developed data assimilation technologies into the WRF-Var framework. In particular, NOAA AMSU A/B calibration and microwave surface emissivities will be implemented and tested within WRF-Var. Also computational and accuracy improvements to the WRF-4DVAR preconditioner will be performed based on our experiences with our CSU 4DVAR system, the Regional Atmospheric Mesoscale Data Assimilation System (RAMDAS). The preconditioner improves the computational efficiency of the data assimilation minimization process.

Approach:

The NOAA AMSU A/B calibration methods and microwave surface emissivity implementation and tests will be performed on the WRF-Var 3DVAR system. The microwave surface emissivity products will be inserted as new radiative boundary conditions for WRF. WRF performance differences will be compared to baseline results using the standard CRTM Microwave Emissivity Model. Similarly, the NOAA AMSU calibration methods will be tested to determine if removing known sensor biases can improve existing WRF-Var performance.

The 4DVAR preconditioner research will involve modification of an existing CSU 4DVAR preconditioner to make it mathematically suitable for the WRF-4DVAR incremental data assimilation system.

The project goals are as follows:

Implement CIRA and NOAA/NESDIS APC for NOAA AMSU-A/B within WRF-Var.

Implement CIRA microwave surface emissivity fields within WRF-Var.

Improve the WRF-Var preconditioner performance through: a) mathematical analysis, b) computational implementation, and c) testing of the new WRF-Var preconditioner.

2. Research Accomplishments/Highlights:

Determined several new methods for the WRF-Var preconditioner and determined that the WRF-Var Empirical Orthogonal Functions (EOFs) were hindering the use of the

Zupanski preconditioner methods which are used successfully in the CIRA 4DVAR data assimilation system. Several alternate recommendations were presented to NCAR for consideration.

Delivered the new CIRA-developed WRF-Var codes to NCAR. These codes allow the insertion of satellite microwave emissivities into the WRF-Var framework. This also includes the addition of a new satellite data interpolation scheme to handle missing satellite field-of-views.

Hosted the CSU/CIRA – NCAR/MMM WRF-Var Data Assimilation Workshop at Fort Collins, CO, March 13, 2008.

Completed our final technical report in late March 2008.

Research project completed on schedule January 31, 2008.

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

This project was completed on schedule. WRF-Var is now running in several configurations at CIRA for research development purposes. CIRA diagnosed several portability issues with the existing WRF-Var configurations, and has communicated that information back to NCAR for further WRF-Var system improvements.

In the preconditioner research, Dr. Fletcher derived several new approaches to improve the WRF-Var preconditioner performance. Currently the ECMWF preconditioner, as an EOF-compatible preconditioner, is being considered by our CIRA-NCAR WRF-Var team for possible WRF-Var use. Future collaborations to extend this work have been proposed.

The WRF-Var radiance-related work has created an observed microwave emissivity database for insertion into the WRF-Var data assimilation system. That work is now in the testing phases. The APC research is pending the completion of that work; however the CRTM now includes an APC explicitly, so we expect that to be added easily once the initial WRF-Var radiance experiments are completed.

4. Leveraging/Payoff:

This is a collaborative CSU/CIRA-NCAR/MMM WRF-Var work plan and leverages WRF-Var development activities with those that involve use of the NOAA CRTM. Payoff will be improved WRF-Var performance in terms of accuracy and computational performance.

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

This work is funded by NCAR. Our NCAR collaborators are Drs. Dale Barker and Zhiquan Liu.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Publications are pending completion of the WRF-Var experiments which are in their testing phase.

NCAR - Implementation and Evaluation of an Improved Mellor-Yamada level-3 Turbulence Closure in WRF

Principal Investigator: Mariusz Pagowski

NOAA Project Goal: Weather and Water

Key Words: Atmospheric Modeling, Planetary Boundary Layer, WRF

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

This project involves implementation of a boundary layer scheme in the Weather Research and Forecasting model. If evaluation of the performance of the improved scheme proves favorable, consideration should be given to it becoming a part of future WRF distributions.

2. Research Accomplishments/Highlights:

Until recently, second-order (Level-3) closures were considered impractical in weather forecasting due to excessive computational burden. However, thanks to advances in computing, their application for this purpose is no longer unavailable.

Second order closures demonstrate advantages in both unstable and stable boundary layers over the lower-order closures and over most popular 1.5-order Mellor-Yamada (MY hereafter) type closures. In the unstable conditions, lower order closures tend to underestimate vertical mixing and entrainment by neglecting transport that occurs in thermals in well mixed layers where gradient of scalars can be close to zero or negative. In the stable conditions, lower-order closures rely on tuning adjustable parameters such as mixing length and stability functions to obtain better performance of models.

An improved Mellor-Yamada closure after Nakanishi and Niino (2004, 2006) imposes additional restrictions on original MY closure parameters to assure its reliability and numerical stability. It treats condensation physics consistently in the boundary layer by considering liquid-water potential temperature and total water content and allows for partial condensation in a model grid to assure proper interaction with microphysics and radiation.

The scheme evaluated positively against LES and was successfully used in modeling of radiation fog. We believe that WRF would benefit from this enhancement especially in conditions when phase changes in the boundary layer occur.

The scheme has been implemented in WRF and is being evaluated. Meetings with NCAR staff are planned to discuss results.

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

In progress.

References Used:

Nakanishi, M. and Niino, H., 2004: An improved Mellor-Yamada level-3 model with condensation physics: Its design and verification. *Boundary Layer Meteorology*, 112, 1-31.

Nakanishi, M. and Niino, H., 2006: An improved Mellor-Yamada level-3 model: Its numerical stability and application to a regional prediction of advection fog. *Boundary Layer Meteorology*, 119, 397-407.

4. Leveraging/Payoff: None as yet

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

<u>NPS</u> – 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 three main 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 new 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 project to design and evaluate methods for accurately measuring these species. Work is also underway to investigate the composition of organic nitrogen in precipitation in order to better understand its natural or anthropogenic sources.

During 2007 our team cooperated with NPS/CIRA researchers on an intercomparison of measurement methods for gaseous and particle phase inorganic nitrogen species. We are also working with Aerosol Dynamics, Inc. to design and evaluate a new sampling module for the CASTNet program to add measurements of gas phase ammonia as part of their routine monitoring network. A prototype denuder for this module has been collected and is currently undergoing testing in our laboratory. If successful, this new sampling module may also be incorporated into measurements made in urban locations as part of EPA's fine particle chemical speciation network.

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

The status of our 3 key project objectives is as follows:

Characterizing N transport and deposition in RMNP (in progress)

Development and testing of methods for organic N measurement (in progress)

Development and evaluation of methods for ammonia measurement (in progress)

4. Leveraging/Payoff:

A recent MOU between the National Park Service, USEPA, and the State of Colorado calls for reducing excess N deposition in Rocky Mountain National Park. Findings from the RoMANS study are an important contributor to informing future policy decisions regarding the regions and source types contributing to this problem.

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 as yet

7. Outreach:

The following students were partially or fully supported by this project: Courtney Gorin (PhD), Katie Beem (MS), Amanda Holden (MS), Misha Schurman (MS), Ezra Levin (MS), Gavin McMeeking (PhD), Laurie Mack (MS), Ali Bote (BA) and Nick Powers (BA).

Public presentations and findings from this work were presented at the following:

International Air Pollution Congress in Vienna, Austria, March 19 & 20, 2007:

Collett, Jr., J. L. Status quo of air pollution in the U.S.A.

The George Wright Society Biennial Conference, St., Paul, MN, April 16-20, 2007:

Morris, K., Blett, T., Porter, E., Collett, J., Gorin, C., Schichtel, B., and Malm, W., Science Informing Policy: Implementing a Critical Load for Rocky Mountain National Park.

The Rocky Mountain States Section Air and Waste Management Conference, May 2007:

Carrico, C.M., Collett, Jr., J.L., Kreidenweis, S.M., Lee, T., Raja, S., Sullivan, A., Gorin, C., Beem, K., McMeeking, G.R., Malm, W.C., Day, D.E., Schichtel, Barna, M., Gebhardt, K., Hand, J.L., and Rodriguez, M., Air quality observations during the 2006 Rocky Mountain Atmospheric Nitrogen and Sulfur Study (RoMANS).

Air and Waste Management Association 100th Annual Meeting, Pittsburgh, Pennsylvania, June 26-29, 2007:

Campbell, D. H., Nanus, L., Bohlke, J. K., Harlin, K., and Collett, J. Nitrogen saturation in the Rocky Mountains: Linking emissions, deposition, and ecosystem effects using stable isotopes of nitrogen compounds.

Collett, J., Gorin, C., Raja, S., Carrico, C., Lee, T., Schwandner, F., Day, D., Sullivan, A., McMeeking, G., Kreidenweis, S., and Malm, W. Observations of airborne pollutants and deposition during the 2006 Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study.

Malm, W.C., Schichtel, B.A., Barna, M.G., Gebhart, K.A., Day, D.E., Collett Jr., J.L., Kreidenweis, S.M., Carrico, C.M., Raja, S., Lee, T., Schwandner, F., Gorin, C. and Sullivan, A. An overview of the Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS).

The NADP Conference, Boulder, CO September 10-12, 2007:

Beem, K.B., Raja, S., Schwandner, F.M., Sullivan, A.P., Lee T., Carrico, C.M., Collett, Jr., J.L., Kreidenweis, S.M. and Malm, W.C. Deposition and possible sources of organic nitrogen in Rocky Mountain National Park.

Campbell, D.H., Nanus, L., Bohlke, J.K., Harlin, K. and Collett, Jr., J.L. Nitrogen saturation in the Rocky Mountains: Linking emissions, deposition, and ecosystem effects using stable isotopes of nitrogen compounds.

Collett, Jr., J., Gorin, C., Raja, S., Carrico, C., Lee, T., Schwandner, F., Day, D., Sullivan, A., McMeeking, G., Beem, K., Kreidenweis, S., Hand, J., Schichtel, B., and Malm, W. Observations of airborne pollutants and deposition during the 2006 Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study.

Malm, W.C., Collett, Jr., J.L., and Schichtel, B.A. What modifications in the national deposition monitoring networks are required to be able to measure and source apportions representations of all reactive nitrogen species?

Schwandner, F.M., Raja S., Beem, K.B., Sullivan, A.P., Lee, T., McMeeking, G.R., Carrico, C.R., Gorin, C.A., Day, D.E., Collett, Jr., J.L., Kreidenweis, S.M., Hand, J., and Malm, W.C. Airborne gas and particle concentrations during the 2006 Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study.

The 26th Annual AAAR Conference, Reno, NV, September 24-28, 2007:

Levin, E., McMeeking, G.R., Carrico, C.M., Collett, Jr., J.L., Kreidenweis, S.M. and Malm, W. Aerosol number and volume concentrations during the Rocky Mountain Nitrate and Sulfate study (RoMANS).

The AGU Fall Meeting, San Francisco, CA, December 10-14, 2007:

Collett, J., Raja, S., Taylor, C., Carrico, C., Schwandner, F., Beem, K., Lee, T., Sullivan, A., Day, D., McMeeking, G., Kreidenweis, S., Hand, J., Schichtel, B. and Malm, B. Nitrogen transport and deposition during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study.

Collett, J., Raja, S., Taylor, C., Carrico, C., Schwandner, F., Beem, K., Lee, T., Sullivan, A., Day, D., McMeeking, G., Kreidenweis, S., Hand, J., Schichtel, B., and Malm, W., Nitrogen emission, transport, and deposition in Colorado.

Colorado Department of Public Health and Environment Agricultural Air Quality Subcommittee, Fort Collins, CO, Feb. 22, 2008.

The European Geophysical Union Meeting, Vienna, Austria, April 14-18, 2008:

Air and Waste Management Association Specialty Conference on Aerosol and Atmospheric Optics: Visual Air Quality and Radiation, Moab, UT, April 28- May 2, 2008

Collett, J., Mazzoleni, L., Herckes, P., Schwandner, F., Beem, K., Raja, S., Liu, Y., Sun, Y., and Zhang, Q., Organic nitrogen in clouds and precipitation.

Collett, J., Raja, S., Schwandner, F., Lee, T., Sullivan, A., Taylor, C., Carrico, C., Day, D., McMeeking, G., Beem, K., Hand, J., Kreidenweis, S. and Malm, W., Spatial and temporal variability in trace gas and aerosol nitrogen species during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) Study.

Day, D., Beem, K., Schurman, M., Collett, J., and Malm, W., Ammonia and nitrate measurements from various network sampling systems.

Gebhart, K., Malm, W., Schichtel, B., Barna, M., Rodriguez, J., Hand, J., Collett, J., Carrico, C., Lee, T., and Sullivan, A., Preliminary back trajectory-based source assessments for airborne particulate matter and deposited ions at Rocky Mountain National Park, CO.

Hand, J., Collett, J., Taylor, C., Raja S., Carrico, C., Lee, T., Schwandner, F., Day, D., Sullivan, A., McMeeking, G., Beem, K., Kreidenweis, S., Gebhart, K., and Malm, W., Spatial patterns in wet deposition during the 2006 Rocky Mountain atmospheric nitrogen and sulfur study (RoMANS).

Malm, W., Barna, M., Schichtel, B., Gebhart, K., Collett, J., and Carrico, C., Source apportionment of sulfur and nitrogen species at Rocky Mountain National Park using modeled conservative tracer releases and tracers of opportunity.

Malm, W., Kreidenweis, S., Levin, E., Carrico, C., Day, D., and Collett, J., Using high time resolution aerosol and number size distribution measurements to estimate atmospheric extinction.

8. Publications:

Carrico, C.M., Kreidenweis, S.M., Collett, Jr., J.L., Lee, T., Sullivan, A.P., McMeeking, G.R., Raja, S., Schwandner, F.M., Beem, K.L., Taylor, C.A., Day, D.E., Hand, J.E., Rodriguez, M.A., Barna, M.G., Gebhart, K.A., Schichtel, B.A. and Malm, W.C.. The Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) Study of 2006, *The Improve Newsletter,* 2007.

Lee, T., Yu, X.-Y., Ayres, B., Kreidenweis, S. M., Malm, W. C., and Collett, Jr., J. L. (2008) Observations of fine and coarse particle nitrate at several rural locations in the United States. Atmos. Environ., 42:2720-2732; doi:10.1016/j.atmosenv.2007.05.016.

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., in press.

<u>NPS</u> – Analysis of Levoglucosan K+ and Water Soluable Organic Carbon in Archived Filter Samples

Principal Investigators: Jeffrey L. Collett, Jr. and Amy Sullivan

NOAA Project Goal: Air Quality

Key Words: Smoke, Visibility, Air Quality, Particles

New project started February 5, 2008; no input as yet.

<u>NPS</u> – Assistance for Visibility Data Analysis and Image Display Techniques

Principal Investigator: Ken Eis

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 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 the 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 (RHR). RHR 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 is 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, we are studying the region associated with Rocky Mountain National Park in Colorado, with a field experiment known as RoMANS. As part of this study, our 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 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 websites 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).

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

Specific objectives for this year have included:

Ongoing data analyses from the RoMANS special study field campaign and ongoing data analyses;

The development of adequate meteorological and emissions inventory input data for the regional air quality model to be used in the modeling phase of the RoMANS study;

Ongoing work on the source apportionment and air quality modeling efforts for the RoMANS study;

The simulation of spring and summer RoMANS episodes with a state-of-the-art air quality model and the preliminary analysis and model performance evaluation of these modeling results;

Continuing work on developing and implementing improved QA/QC for IMPROVE data;

Continuing work on the integration of IMPROVE and STN (Speciated Trends Network) network-wide data;

Continuing 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;

Continuing work on developing hybrid-receptor source apportionment models to estimate the contributions of primary and secondary particulate matter from biomass burning;

Completion of a special study to quantify the contributions of particulate carbon from fossil sources, e.g., mobile emissions, and from biogenic sources, e.g., biomass burning;

Continuing work on the analysis of aerosol composition and hygroscopicity data from the second phase of laboratory measurements of biomass smoke;

Continuing work on investigation of different network sampling systems for ammonia and nitrate measurements;

Completed participating in the organization of the AWMA and AAAR specialty conference on Aerosol & Atmospheric Optics: Visual Air Quality and Radiation held in Moab, Utah, April 28 to May 2, 2007.

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, Communications 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: None as yet

7. Outreach:

(b) Seminars, symposiums, classes, educational programs.

Jenny Hand, Research Scientist, April 2008, presented "Spatial variability in the seasonal distribution of PM2.5 speciated aerosol composition data from the IMPROVE and STN networks" at the CSU Atmospheric Chemistry group meeting.

Marco Rodriguez, Research Scientist, April 2008, presented "Regional air quality model simulation of the Rocky Mountain Atmospheric Nitrogen and Sulfur study: Preliminary results" at the CSU Atmospheric Chemistry group meeting.

(e) Public awareness.

IMPROVE Site Operator Calendar 2008: 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.

Spanish Version of the Touch Screen Exhibit at Grants Grove Visitor Center, Sequoia Kings Canyons National Parks: In 2007 we translated the public kiosk program at

Sequoia National Park to Spanish and implemented it at the Grants Grove Visitor Center in Sequoia. This is the first bilingual presentation at a major national park in the United States.

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.

8. Publications:

Bench, G., Fallon, S., Schichtel, B. A., Malm, W. C., and McDade, C. E. 2007. Relative contributions of fossil and contemporary carbon sources to PM2.5 aerosols at nine Interagency Monitoring for Protection of Visual Environments (IMPROVE) network sites. Journal of Geophysical Research, 112, doi:10.1029/2006JD007708.

Carrico, C. M., Petters, M. D., Kreidenweis, S. M., Collett, J. L., Jr., Engling, G., and Malm, W. C. 2008. Aerosol hygroscopicity and cloud droplet activation of extracts of filters from biomass burning experiments. Submitted to the Journal of Geophysical Research, in press.

Chin, M., Diehl, T., Ginoux, P., and Malm, W. C. 2007. Intercontinental transport of pollution and dust aerosols: Implications for regional air quality. Atmospheric Chemistry and Physics, 7, 5501-5517.

Geiser, L., Byterowicz, A., Ingersoll, A., Copeland, S. A. 2008. Evidence of enhanced atmospheric ammoniacal nitrogen in Hell's Canyon National Recreation Area: Implications for natural and cultural resources. Journal of the Air & Waste Management Association, Special Issue: Agricultural Air Quality.

Hand, J. L. and Malm, W. C. 2007. Review of aerosol mass scattering efficiencies from ground-based measurements since 1990. Journal of Geophysical Research, 112, doi:10.1029/2007JD008484.

Lee, T., Xiao-Ying, Y., Ayres, B., Kreidenweis, S. M., Malm, W. C., and Collett, J. L., Jr. 2008. Observations of fine and coarse particle nitrate at several rural locations in the United States. Atmospheric Environment, 42, 2720-2732.

Lee, T., Xiao-Ying, Y., Kreidenweis, S. M., Malm, W. C., and Collett, J. L., Jr. 2007. Semicontinuous measurement of PM2.5 ionic composition at several rural locations in the United States. Submitted to Atmospheric Environment.

Moosmüller, H., Kreidenweis, S. M., Collett, J. L., Jr., Hao, W. M., and Malm, W. C. 2007. Characterization of particle emissions from laboratory combustion of wildland fuels. iLEAPS Newsletter, volume 3.

Pitchford, M. L., Malm, W. C., Schichtel, B. A., Kumar, N., Lowenthal, D., and Hand, J. L. 2007. Revised algorithm for estimating light extinction from IMPROVE particle speciation data. Journal of the Air & Waste Management Association, 57, 1326-1336.

Rodriguez, M. A., Brouwer, J., Samuelson, G. S., and Dabdub, D. 2007. Air quality impacts of distributed power generation in the South Coast Air Basin of California 2: Model uncertainty and sensitivity analysis. Atmospheric Environment, 41, 5618-5635.

Schichtel, B. A., Malm, W. C., Bench, G., Fallon, S., McDade, C. E., Chow, J. C., and Watson, J. G. 2008. Fossil and contemporary fine particulate carbon fractions at 12 rural and urban sites in the United States. Journal of Geophysical Research, 113, doi:10.1029/2007JD008605.

Winchester, J. 2008. Environmental Education and Public Outreach. CIRA Newsletter, volume 29.

PRESENTATIONS AND CONFERENCE PAPERS:

Archuleta, C. M., Adlhoch, J. P., Copeland, S. A., et al. 2008. IMPROVE data substitution methods for regional haze planning. Poster presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Arnott, W. P., Lewis, K., Paredes-Miranda, G., Winter, S., Day, D. E., Chakrabarty, R. K., Chen, A., and Moosmüller, H. 2007. Relative humidity influence on aerosol light absorption and scattering by biomass burning aerosol. Presented at the American Association for Aerosol Research Annual Conference, Reno, September.

Barickman, P., LeBaron, B., Moore, T., and Sprott, R. 2008. The WRAP Technical Support System (TSS) as a model for technical data sharing. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Barna, M. G., Rodriguez, M. A., Malm, W. C., Schichtel, B. A., and Gebhart, K. A. 2008. Predicting total nitrogen deposition at national parks. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Barna, M. G., Schichtel, B. A., Rodriguez, M. A., Gebhart, K. A., and Malm, W. C. 2008. Simulating nitrogen tracers from regional sources for RoMANS. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Brewer, P. and Moore, T. 2008. Source contributions to visibility impairment in the southeastern and western United States. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Carrico, C. M., Kreidenweis, S. M., Collett, J. L., Jr., McMeeking, G. R., Sullivan, A. P., Prenni, A. J., DeMott, P. J., Petters, M. D., Holden, A. S., Lee, T., Malm, W. C., Day, D. E., Hand, J. L., Gebhart, K. A., and Schichtel, B. A. 2007. Investigation of the properties of smoke from wildland fires: The relationship to visual impacts of smoke. Presented at the International Association of Wildland Fires Human Dimensions Conference, Fort Collins, October 23-25.

Carrico, C. M., Petters, M., Kreidenweis, S. M, Prenni, A. J., DeMott, P. J., McMeeking, G. R., Sullivan, A., Mazzoleni, L. R., Collett, J. L., Jr., Malm, W. C., Wold, C., and Hao, W. M. 2008. Hygroscopic growth and cloud condensation nuclei activity of primary biomass smoke aerosol. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Carrico, C. M., Petters, M., Kreidenweis, S. M, Prenni, A. J., DeMott, P. J., Sullivan, A., Rinehart, L., Wold, C. E., Hao, W. M., Collett, J. L., Jr., and Malm, W. C. 2007. Hygroscopic growth and cloud condensation nuclei activity and chemical composition of primary biomass smoke. Presented at the American Association for Aerosol Research annual meeting, Reno, September.

Collett, J. L., Jr., Beem, K., Raja, S., Scheandner, F., Carrico, C. M., Lee, T., Taylor, C., Sullivan, A., 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 21st Regional Meeting of the American Chemical Society, June.

Collett, J. L., Jr., Gorin, C., Raja, S., Carrico, C. M., Lee, T., Schwandner, F., Day, D. E., Sullivan, A. P., McMeeking, G. R., Beem, K., Kreidenweis, S. M., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2007. Observations of airborne pollutants and deposition during the 2006 Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. Presented at the National Atmospheric Deposition Program meeting, Boulder, September.

Collett, J. L., Jr., Raja, S., Schwandner, F., Lee, T., Sullivan, A. P., Taylor, C., Carrico, C. M., Day, D. E., McMeeking, G. R., Beem, K., Hand, J. L., Kreidenweis, S. M., and Malm, W. C. 2008. Spatial and temporal variability in trace gas and aerosol nitrogen species during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Collett, J. L., Jr., Raja, S., Taylor, C., Carrico, C. M., Schwandner, F., Beem, K., Lee, T., Sullivan, A., Day, D. E., McMeeking, G. R., Kreidenweis, S. M., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2007. Nitrogen transport and deposition during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Copeland, S. A. 2007. Analysis of air quality impacts from oil and gas at Weiminuche. Presented at the IMPROVE steering committee meeting, Durango, September.

Copeland, S. A., Pitchford, M. L., and Ames, R. B. 2008. Regional haze rule natural level estimates using the revised IMPROVE aerosol reconstructed light extinction algorithm. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Day, D. E., Beem, K., Schurman, M., Collett, J. L., Jr., and Malm, W. C. 2008. Ammonia and nitrate measurements from various network sampling systems. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Day, D. E., Hand, J. L., McMeeking, G. R., Kreidenweis, S. M., Collett, J. L., Jr., Wold, C. E., Hao, W. M., Laskin, A., Desyaterik, Y., and Malm, W. C. 2007. Humidification factors (f(RH)) for fresh biomass smoke from laboratory controlled burns. Presented at the American Association for Aerosol Research Annual Conference, Reno, September.

Gebhart, K. A., Malm, W. C., Schichtel, B. A., Barna, M. G., Rodriguez, M. A., Hand, J. L., Collett, J. L., Jr., Carrico, C. M., Lee, T., and Sullivan, A. P. 2008. Preliminary back-trajectory-based source assessments for airborne particulate matter and deposited ions at Rocky Mountain National Park, CO. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Hand, J. L., Collett, J. L., Jr., Taylor, C., Raja, S., Carrico, C. M., Lee, T., Schwandner, F., Day, D. E., Sullivan, A. P., McMeeking, G. R., Beem, K., Kreidenweis, S. M., and Malm, W. C. 2008. Spatial patterns in wet deposition during the 2006 Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS). Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Hand, J. L., Day, D. E., and Malm, W. C. 2008. Comparisons of particle morphology and composition from individual particle analysis of biomass burning aerosols from young and aged smoke. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Hand, J. L., Schichtel, B. A., Debell, L. J., Malm, W. C., Ashbaugh, L. L., McDade, C. E., and Pitchford, M. L. 2008. Spatial variability in the seasonal distribution of $PM_{2.5}$ speciated aerosol composition data from the IMPROVE and STN networks. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Holden, A. S., Sullivan, A. P., Kreidenweis, S. M., Collett, J. L., Jr., Schichtel, B. A., Malm, W. C., and Bench, G. 2007. Application of anion exchange chromatography with pulsed amperometric detection for measurement of levoglucosan in ambient aerosol samples. Poster presented at the American Association for Aerosol Research annual conference, Reno, September.

Hutchings, J., Herckes, P., McMeeking, G. R., Sullivan, A. P., Kreidenweis, S. M., Collett, J. L., Jr., Hao, W. M., Wold, C. E., and Malm, W. C. 2007. Investigation of biomass combustion aerosols by 1H-NMR spectroscopy. Poster presented at the American Association for Aerosol Research annual conference, Reno, September.

Hygroscopicity measurements and comparisons with theoretical values for fresh biomass smoke obtained during laboratory burns. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April 2008.

Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program. Presented at the Environmental Protection Agency's U.S.-Canada Visibility Workshop, Research Triangle Park, October 2007.

Kreidenweis, S., Carrico, C. M., Petters, M., Prenni, A., DeMott, P., McMeeking, G., Sullivan, A., Rinehart, L., Collett, J., Malm, W., Wold, C., Hao, W. M. 2008. Hygroscopic growth and cloud condensation nuclei activity of primary biomass smoke aerosol. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Levin, E., McMeeking, G. R., Carrico, C. M., Collett, J. L., Jr., Kreidenweis, S. M., and Malm, W. C. 2007. Aerosol number and volume concentrations during the Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) study. Poster presented at the American Association for Aerosol Research annual conference, Reno, September.

Mack, L., Obrist, D., Moosmüller, H., Lewis, K., Arnott, P., McMeeking, G. R., Levin, E., Kreidenweis, S. M., Wold, C. E., Hao, W. M., Collett, J. L., Jr., and Malm, W. C. 2007. Experimental and theoretical closure experiments for biomass smoke using extinction cell, photoacoustics, and nephelometry. Poster presented at the American Association for Aerosol Research annual conference, Reno, September.

Malm, W. C. 2007. RoMANS update. Presented at the IMPROVE steering committee meeting, Durango, September.

Malm, W. C., Barna, M. G., Schichtel, B. A., Gebhart, K. A., Collett, J. L., Jr., and Carrico, C. 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 Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Malm, W. C., McMeeking, G. R., Kreidenweis, S. M., Levin, E., Carrico, C. M., Day, D. E., and Collett, J. L., Jr. 2008. Using high time resolution aerosol and number size distribution measurements to estimate atmospheric extinction. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Malm, W. C., Schichtel, B. A., Bench, G., McDade, C. E., Chow, J. C., and Watson, J. G. 2007. Fossil vs. contemporary carbon at 12 rural and urban sites in the United States. Presented at the Mid-Atlantic/Northeast Visibility Union (MANE-VU) Regional Planning Organization (RPO) Science Meeting, Baltimore, July.

McClure, S., Schichtel, B. A., Moore, T., Ames, R., and Fox, D. G. 2008. VIEWS/TSS: An integrated systems solution for air quality and regional haze planning. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

McMeeking, G. R., Kreidenweis, S. M., Collett, J. L., Jr., Kirchstetter, T., Hao, W. M., Wold, C., and Malm, W. C. 2008. Characterization of light absorption from organic and elemental carbon emitted by biomass burning. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

McMeeking, G. R., Kreidenweis, S. M., Collett, J. L., Jr., Kirchstetter, T., Lunden, M. M., Hao, W. M., Wold, C., E., and Malm, W. C. 2008. Properties of light-absorbing organic carbon emitted by biomass burning. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

McMeeking, G. R., Sullivan, A. P., Carrico, C. M., Kreidenweis, S. M., Collett, J. L., Jr., Kirchstetter, T., Lunden, M., Chen, A., Obrist, D., Moosmüller, H., Chow, J. C., Wold, C. E., Hao, W. M., Day, D. E., and Malm, W. C. 2007. A comparison of thermal-optical carbon measurements methods for aerosols emitted during a series of controlled biomass burning experiments. Poster presented at the American Association for Aerosol Research annual conference, Reno, September.

Oil and gas implications for air quality in USDA FS class I areas. Presented at the annual USDA Forest Service Staff Directors Meeting, Breckenridge, August 2007.

Petters, M. D., McMeeking, G. R., Lee, T., Levin, E., Kreidenweis, S. M., Carrico, C. M., Collett, J. L., Jr., Ziemann, P., Malm, W. C., and Hao, W. M. 2007. Observations of hygroscopic and optical properties of biogenic secondary organic aerosol generated using a simple continuous flow reaction chamber. Poster presented at the American Association for Aerosol Research annual conference, Reno.

Pitchford, M. L., Schichtel, B. A., Malm, W. C., and Poirot, R. 2008. Characterization of the winter midwestern particulate nitrate bulge. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Regional impacts of oil and gas development in the western United States. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April 2008.

Rivera-Rivera, N. I., Hand, J. L., Gebhart, K. A., Gill, T. E., Bleiweiss, M. P., and Fitzgerald, R. 2008. Wind modeling of Chihuahuan Desert dust outbreaks. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Rodriguez, M. A., Barna, M. G., Gebhart, K. A., Schichtel, B. A., and Malm, W. C. 2008. Regional air quality model simulation of the Rocky Mountain Atmospheric Nitrogen and Sulfur study: Preliminary results and analysis. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Schichtel, B. A., Malm, W. C., Collett, J. L., Jr., Sullivan, A., and Holden, A. S. 2007. Contribution of smoke to PM2.5 and haze: Development of smoke source profiles and routine source apportionment tools. Presented at the International Biomass Smoke Health Effects (IBSHE) Conference, University of Montana, Missoula, August 21-22.

Schichtel, B. A., Malm, W. C., Collett, J. L., Jr., Sullivan, A. P., Holden, A. S., and Patterson, L. A. 2008. Estimating the contribution of smoke to fine particulate matter using a hybrid-receptor model. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Schichtel, B. A., Malm, W. C., and Pitchford, M. L. 2007. Introduction to Visibility Science. Presented at the Environmental Protection Agency's U.S.-Canada Visibility Workshop, Research Triangle Park, October.

Schichtel, B. A., Malm, W. C., White, W. H., Hand, J. L., Chow, J. C., and Watson, J. G. 2008. Spatial and temporal trends in fine particulate carbon in the United States. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Sullivan A., Holden, A., Patterson, L., Kreidenweis, S. M., Collett, J. L., Jr., Malm, W. C. and Hao, W. M. 2008. A method for smoke marker measurements for determining the contribution of biomass burning to ambient PM2.5 organic carbon. Presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Winchester, J. 2008. Scenic views, optical effects, and visibility impairment. Slide show presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

Winchester, J., Lemke, J., and Malm, W. C. 2008. Inspiring environmental stewardship by linking science, technology, and art. Poster presented at the Air & Waste Management Association Visibility Specialty Conference, Moab, April.

<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 Goal: 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:

We have further developed and validated simplified techniques for the quantification of concentrations of levoglucosan, a biomass combustion tracer, in filter samples of smokes, and have applied these to our FLAME samples (see below). The methodology greatly simplifies the analytical procedures for the detection of this compound, enabling almost-routine measurement and reporting and increasing the utility of the use of levoglucosan concentrations for source apportionment studies, particularly those seeking to quantify the contributions of smoke to atmospheric aerosol concentrations.

We successfully completed the first Fire Lab At Missoula Experiment (FLAME I) in May/June 2006, during which we conducted over 100 burns of various fuels, primarily from the western and southeastern U.S. We conducted a data meeting in February 2007, which was attended by all co-investigators as well as a number of outside collaborators. In addition, Dr. Dennis Haddow of the FWS was in attendance and requested presentation materials for further dissemination.

We successfully completed the second Fire Lab At Missoula Experiment (FLAME II) in May/June 2007. The approach was similar to FLAME I; but we focused on southeastern and Alaskan fuels and also studied differences in smoke properties for fresh/dried fuels. We obtained numerous filter samples that have been analyzed for chemical composition, including source profiles and marker concentrations, and also archived filter samples for future analytical work. We conducted a number of continuous measurements aimed at determining smoke hygroscopicity, optical properties, and size distributions.

With the completion of both planned laboratory studies, FLAME I and II, we have now merged our datasets and are preparing manuscripts on the integrated smoke properties for the wide range of fuels tested. One Ph.D. student (Gavin McMeeking) is completing his dissertation on FLAME data, and several M.S. students are using FLAME data in their theses.

The focus of Year 3 is a field study to measure smoke from prescribed burns of vegetation for which we have gathered source profile information in the laboratory. One objective of the field study is to test the applicability of our emissions profiles to atmospheric conditions. The field experiment will be conducted in May 2008 in Forest Service lands in Montana.

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

Year 2 burn experiments at Fire Science laboratory. *Complete.*

Sample analysis from Year 2 FSL burn experiments. *In progress.*

Data analysis from Year 2 FSL burn experiments. *In progress.*

Peer-reviewed journal articles describing smoke source profiles measured at FSL. *In progress.*

Year 3 field study of prescribed burn smoke*. In progress for May 2008.*

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 smoke 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 as yet

7. Outreach:

The following students were partially or fully supported by this project: Amanda Holden (MS), Ezra Levin (MS), Gavin McMeeking (PhD), and Laurie Mack (MS).

An open data meeting addressing Year 1 results and planning for the Year 2 field study was held in Fort Collins, CO, February 22-23, 2007, and included representation from the USEPA, National Park Service, US Forest Service, and the US Fish and Wildlife Service.

Website: http://chem.atmos.colostate.edu/FLAME/

8. Publications:

Peer-Reviewed Articles

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.

Hopkins, R.J., Lewis, K., Desyaterik, Y., Wang, Z., Tivanski, A.V., Arnott, W.P, Laskin, A., and Gilles M.K., Correlations between optical, chemical and physical properties of biomass burn aerosols, *Geophys. Res. Lett.,* 34, L18806, doi: 10.1029/2007GL030502, 20 September 2007.

Lynn R. Mazzoleni, Barbara Zielinska, and Hans Moosmüller, Emissions of levoglucosan, methoxy phenols, and organic acids from prescribed burns, laboratory combustion of wildland fuels, and residential wood combustion, *Environ. Sci. Technol.*, *41*(7), 2115 – 2122, 2007.

McMeeking, G. R., Kirchstetter, T.W, Carrico, C.M., Chen, L-W., A., Chow, J.C., Collett, Jr., J.L., Hao, H.M., Lunden, M.M., Malm, W.C., Sullivan, A.P., Watson, J.G., Wold, C.E., and Kreidenweis, S.M., Organic and elemental carbon measurements during the FLAME biomass burning study, Atmos. Environ., submitted, 2008.

Obrist, D., Moosmuller, H., Schurmann, R., Chen, L.W. and Kreidenweis, S.M., Particulate-phase and gaseous elemental mercury speciation in biomass combustion: controlling factors and correlation with particulate matter emissions, *Environ. Sci. Technol.,* accepted, 2007.

Obrist, D., Moosmuller, H., Schurmann, R., Chen, L.W. and Kreidenweis, S.M., Particulate-phase and gaseous elemental mercury speciation in biomass combustion: controling factors and correlation with particulate matter emissions, *Environ. Sci. Technol.,* 42, 720-727, 2008.

*Other Article*s

Moosmuller, H., Kreidenweis, S.M., Collett, Jr., J.L., Hao, W.M. and Malm, W.C., Characterization of particle emissions from laboratory combustion of wildland fuels. *iLeaps Newsletter,* 4, 2007

Presentations

The Gordon Research Conference, Big Sky Resort, MT, August 26-31, 2007:

Kreidenweis, S.M., Petters, M., Carrico, C., DeMott, P., Prenni, T., Parsons, M., McMeeking, G., Levin, E., Collett, Jr., J., Wold, C., Hao, W.M. and Malm, W.C., Hygroscopicity and CCN activity of biomass burning particles.

The 2007 5th Asian Aerosol Conference, Kaohsiung, Taiwan, August 26-29, 2007:

Engling, G., Chen, Y-T., Wu, Y-C., Rinehart, L.R., Carrico, C.M., Sullivan, A., Holden, A., Kreidenweis, S.M., Collett, Jr., J.L. and Hao, W.M., Chemical and physical characteristics of smoke particles from laboratory combustion of biomass.

The 2007 IMPROVE Steering Committee Meeting, Durango, CO September 5 & 6, 2007:

Schichtel, B., Malm, W., Kreidenweis, S.M., Collett, Jr., J., Sullivan, A. and Holden, A., Contribution of smoke to PM2.5 and haze: Development of smoke source profiles and routine source apportionment tools.

Annual Meeting of the American Association for Aerosol Research, September 2007:

Aerosol optics measurements and survey of the current state of the science, tutorial.

The 26th Annual AAAR Conference, Reno, NV, September 24-28, 2007:

Lee, T., Collett, Jr., J.L, Kreidenweis, S.M., Jimenez, J. L., Kimmel, J., Kroll, J.H., Onasch, T.B., Trimborn, A.M., Malm, W.C., Hao, W.M. and Wold, C., Characterizing of smoke properties from laboratory combustion of forest fuels using an aerosol mass spectrometer.

Carrico, C., Petters, M., Kreidenweis, S., Prenni, A., DeMott, P., McMeeking, G., Sullivan, A., Rinehart, L. and Collett, Jr., J., Hygroscopic growth and cloud condensation nuclei activity and chemical composition of primary biomass smoke.

Sullivan, A.P., Holden, A.S., Mazzoleni, L.R., Kreidenweis, S.M., Collett, Jr., J.L., Malm, W.C., Hao, W.M. and Wold, C.E., A method for smoke marker measurements for determining air quality impacts of biomass burning.

Holden, A.S., Sullivan, A.P., Kreidenweis, S.M., Collett Jr., J.L., Schichtel, B.A., Malm, W.C. and Bench, G., Application of anion exchange chromatography with pulsed amperometric detection for measurement of levoglucosan in ambient aerosol samples.

Mack, L., Obrist, D., Moosmuller, H., Lewis, K., Arnott, P., McMeeking, G.R., Kreidenweis, S.M., Wold, C., Hao, W.M., Collett, Jr., J.L. and Malm, W., Experimental and theoretical closure experiments for biomass smoke using extinction cells, photoacoustics and nephelometry.

McMeeking, G.R., Sullivan, A.P., Carrico, C.M., Kreidenweis, S.M., Collett, Jr., J.L., Kirchstetter, T., Lunden, M., Chen, A., Obrist, D., Moosmuller, H., Chow, J., Wold, C., Hao, W.M., Day, D.E. and Malm, W.C., A comparison of thermal-optical carbon measurement methods for aerosols emitted during a series of controlled biomass burning experiments.

McMeeking, G.R., Carrico, C.M., Levin, E., Kreidenweis, S.M., Collett, Jr., J.L., Moosmuller, H., Arnott, P., Wold, C., Hao, W.M. and Malm, W.C., Measurements of smoke aerosol size distributions and refractive indices during a series of laboratory biomass burning experiments.

Day, D., Hand, J., McMeeking, G.R., Kreidenweis, S.M., Collett, Jr., J.L., Hao, W.M. and Malm, W.C., Humidification factors (f(RH)) for fresh biomass smoke from laboratory controlled burns.

Onasch, T.B., Trimborn, A., Kroll, J., Worsnop, D., Ulbrich, I., Huffman, J. A., Jimenez, J., Kreidenweis, S. and Hao, W.M., The chemical and physical characteristics of biomass burning particulate emissions studied at the Fire Science Laboratory.

Hutchings, J., Herckes, P., McMeeking, G.R., Sullivan, A.P., Kreidenweis, S.M., Collett, Jr., J.L., Hao, W.M., Wold, C. and Malm, W.C., Investigation of biomass combustion aerosols by 1H-NMR spectroscopy.

Arnott, W.P., Lewis, K., Paredes-Miranda, G., Winter, S., Day, D., Chakrabarty, R.K., Chen, A., and Moosmuller, H., Relative humidity influence on aerosol light absorption and scattering by biomass burning aerosol.

Hopkins, R.J., Wang, Z., Tivanski, A.V., Gilles, M.K., Lewis, K., Arnott, W.P, Desyaterik, Y., and Laskin, A., Diversity of biomass burn aerosols based on fuel.

Lewis, K.A., Arnott, W.P., Moosmuller, H., Dual-wavelength photoacoustic measurements of light absorption and scattering by wood smoke.

The Human Dimension of Wildland Fire Conference International Association of Wildland Fire in Fort Collins, CO, October 23-25, 2007.

Carrico, C.M., Kreidenweis, S.M., Collett, Jr., J.L., McMeeking, G.R., Sullivan, A.P., Holden, A. and Lee, T., Investigation of the properties of smoke from wildland fires: The relationship to visual impacts of smoke.

Peel, J. L., Fluck, J., Lipsey, T., Carrico, C.M., Kreidenweis, S.M. and Collett, Jr., J.L., The potential health effects of smoke from wildland fires: Acute and long-term impacts on wildland fire fighters and the general public.

The 235th ACS National Meeting, New Orleans, LA, April 6-10, 2008:

Parsons, M.T., Petters, M.D., Prenni, A.J., DeMott, P.J., and Kreidenweis, S.M., Heterogeneous ice nuclei measurements: Results for biomass burning particles from FLAME 2 and biogenic aerosols from AMAZE.

The AMWA Moab conference, April 28 -May 2, 2008:

Sullivan, A.P., Holden, A.S., Patterson, L.A., Kreidenweis, S.M., Malm, W.C., Hao, W.M., Wold, C.E., and Collett, Jr., J.L., A method for smoke marker measurements for determining the contribution of biomass burning to ambient PM2.5 organic carbon.

Kreidenweis, S., Carrico, C., Petters, M., Prenni, A. DeMott, P., McMeeking, G., Sullivan, A., Rinehart, L., Collett, J., Malm, W., Wold, C., and Hao, W., Hygroscopic growth and cloud condensation nuclei activity of primary biomass smoke aerosol.

McMeeking, G., Kreidenweis, S., Collett, J., Kirchstetter, T., Hao, Wold, C., W., and Malm, W., Characterization of light absorbance from organic and elemental carbon emitted by biomass burning.

Schichtel, B., Malm, W., Collett, J., Sullivan, A., Holden, A., and Patterson, L., Estimating the contribution of smoke to fine particulate matter using a hybrid-receptor model.

Day, D., Hand, J., McMeeking, G., Kreidenweis, S., Collett, J., Wold, C., Hao, W., Laskin, A, Desyaterik, Y., and Malm, W., Hygroscopicity measurements and comparisons with theoretical values for fresh biomass smoke obtained during laboratory burns.

Moosmuller, H., Chen, L, Arnott, W., and Kreidenweis, S., Repeatability of PM emissions during laboratory combustion of wildland fuels.

Moosmuller, H., Obrist, D., Arnott, W., Mack, L., and Kreidenweis, S., Cavity ring down and cavity enhanced detection measurements of extinction from smoke generated through laboratory combustion of wildland fires.

<u>NSF</u> - Collaborative Proposal to NSF: Ensemble Data Assimilation Based on Control Theory

Principal Investigator: Milija Zupanski

NOAA Project Goal: Weather and Water, Climate

Key Words: Non-Gaussian, Non-differentiable, Non-linear, Minimization, Ensemble Assimilation/Prediction, Maximum Likelihood Ensemble Filter, Weather Research and Forecasting (WRF) model

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

Long term objective of this research is to explore the possibility for using an ensemble assimilation/prediction system in general weather and climate applications. In particular, the use of control theory in ensemble data assimilation has been investigated. Two important issues naturally arising in geophysical problems are specifically addressed: (*i*) non-Gaussian probability distribution assumption, and (*ii*) non-differentiability of prediction model and observation operators. Non-Gaussianity and non-differentiablity are fundamental for cloud microphysics applications of ensemble data assimilations in weather and climate.

In previous years the Colorado State University global shallow-water model was used with the Maximum Likelihood Ensemble Filter (MLEF), with most results already being published. Since this project is currently under no-cost extension, this year's work is a finalization of earlier efforts and also a leveraging with other related projects.

2. Research Accomplishments/Highlights:

The MLEF is presented and tested as a non-differentiable minimization algorithm. Two non-differentiable minimization algorithms are presented: the Generalized Conjugate-Gradient and the Generalized Quasi-Newton algorithm. There is a considerable advantage to using the MLEF-based minimization over the standard gradient-based minimization (Figs.1 and 2). Fig.1 represents the cost-function and Fig.2 shows the gradient norm convergence, in an example of a non-differentiable observation operator.

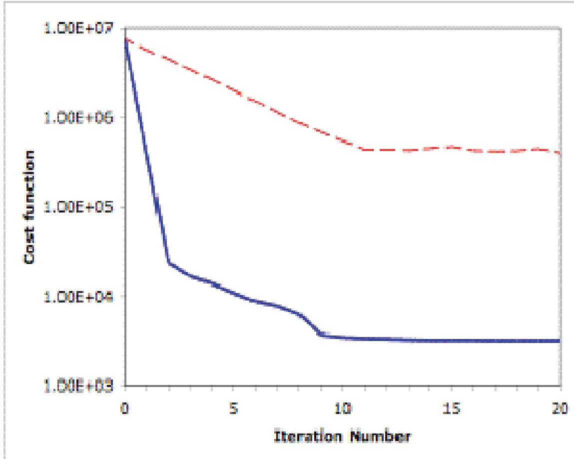


Figure 1. Cost-function minimization for the cubic non-differentiable observation operator. The MLEF results are represented by solid line, and the gradient-based method results (GRAD) are represented by dashed line.

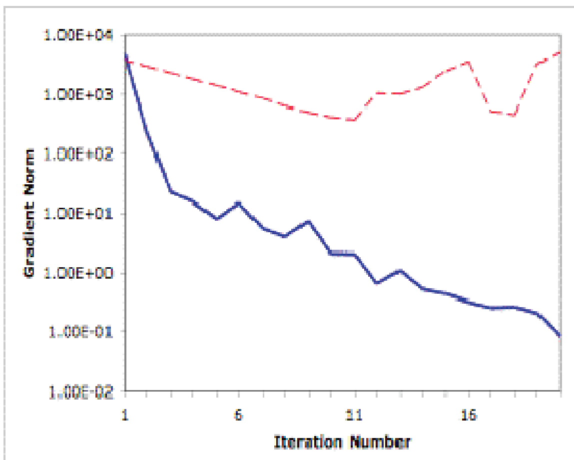


Figure 2. Gradient norm minimization for cubic non-differentiable observation operator. The MLEF results are represented by solid line, and the gradient-based method results (GRAD) are represented by dashed line.

An efficient error covariance localization technique has been developed. This is an upgrade of an existing localization method (Univ. of Maryland), applied in formulation of the information matrix, rather than to the analysis directly. The localization method presently works within the MLEF algorithm but it is transferable to other ensemble data assimilation algorithms.

Application of the error covariance localization to the Hurricane Katrina case, with assimilation of surface and upper-air observations and the Weather Research and Forecasting (WRF) model, shows significant benefit of localization. With localization, the MLEF produces a realistic hurricane forecast, with almost negligible position error. A manuscript with these results has been submitted for publication.

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

None as yet

4. Leveraging/Payoff: None as yet

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

MLEF references

Journal Publications:

Carrio, G.G., W.R. Cotton, D. Zupanski, and M. Zupanski, 2008: Development of an aerosol retrieval method: Description and preliminary tests. *J. Appl. Meteor. Climate*., (*in press*).

Fletcher, S. J., and M. Zupanski, 2006: A Hybrid Normal and Lognormal Distribution for Data Assimilation. *Atmos. Sci. Lett.,* 7, 43-46.

Fletcher, S. J., and M. Zupanski, 2006: A Data Assimilation Method for Log-normally Distributed Observational Errors. *Q. J. Roy. Meteorol. Soc.*, 132, 2505-2519.

Fletcher, S. J., and M. Zupanski, 2008: Implications and Impacts of Transforming Lognormal Variables into Normal Variables in VAR. *Met. Zeit.*, 16, 755-765.

Fletcher, S.J., and M. Zupanski, 2008: A study of ensemble size and shallow water dynamics with the Maximum Likelihood Ensemble Filter. *Tellus*, 60A, 348-360.

Lokupitiya, R.S., D. Zupanski, A.S. Denning, S.R. Kawa, K.R. Gurney, M. Zupanski, W. Peters, 2008: Estimation of global CO_2 fluxes at regional scale using the maximum likelihood ensemble filter. *J. Geophys. Res.* (*submitted*).

Uzunoglu, B., S.J. Fletcher, I. M. Navon, and M. Zupanski, 2007: Adaptive Ensemble Size Reduction and Inflation. *Q. J. R. Meteorol. Soc.,*133, 1281-1294.

Zupanski, M., and I.M. Navon, 2007: Predictability, Observations, and Uncertainties in Geosciences. *Bull. Amer. Meteor. Soc.*, 88, 1431-1433.

Zupanski, D. and M. Zupanski, 2006: Model Error Estimation Employing Ensemble Data Assimilation Approach. *Mon. Wea. Rev.*, 134, 1337-1354.

Zupanski, D., A.Y. Hou, S.Q. Zhang, M. Zupanski, C.D. Kummerow, and S. H. Cheung, 2007: Application of information theory in ensemble data assimilation. *Q. J. R. Meteorol. Soc.*, 133, 1533-1545.

Zupanski, D., A. S. Denning, M. Uliasz, M. Zupanski, A. E. Schuh, P. J. Rayner, W. Peters and K. D. Corbin, 2007: Carbon flux bias estimation employing Maximum Likelihood Ensemble Filter (MLEF). *J. Geophys. Res.*, 112, D17107, doi:10.1029/2006JK008371.

Zupanski, M., D. Zupanski, S. J. Fletcher, M. DeMaria, T. Vonder Haar, and B. Dumais, 2008: Ensemble data assimilation with the Weather Research and Forecasting model: The hurricane Katrina case. *J. Geophys. Res.*, (*submitted*).

Zupanski, M., I. M. Navon, and D. Zupanski, 2008: The Maximum Likelihood Ensemble Filter as a non-differentiable minimization algorithm. *Q. J. R. Meteorol. Soc.*, (*in press*).

Zupanski, M., S.J. Fletcher, I.M. Navon, B. Uzunoglu, R.P. Heikes, D.A. Randall, T.D. Ringler, and D. Daescu, 2006: Initiation of Ensemble Data Assimilation. *Tellus*, 58A, 159-170.

Zupanski, M., 2005: Maximum Likelihood Ensemble Filter: Theoretical Aspects. *Mon. Wea. Rev*., 133, 1710–1726.

Book Chapters:

Zupanski D., 2008: Information Measures in Ensemble Data Assimilation. Chapter in the book titled “*Data Assimilation for Atmospheric, Oceanic, and Hydrologic Applications”*, S. K. Park, Editor, (*submitted*).

Zupanski, M., 2008: 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, Editor, (submitted).

<u>NSF</u> – 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 Antarctic field expedition was 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 websites. 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 as yet

7. Outreach: None as yet

8. Publications: None as yet

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.

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. “Yet to be started.”

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, Communications 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 as yet

7. Outreach: None as yet

8. Publications: None as yet

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.

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

Collect pan-Arctic datasets. “In progress.”

Merge tools and models to simulate Arctic snow-related features. “In progress.”

Produce spatially distributed time-evolving distributions of snow properties and characteristics for the terrestrial pan-Arctic System. “In progress.”

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, Communications 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 as yet

7. Outreach: None as yet

8. Publications: None as yet

<u>NSF</u> – Using a Regional-Scale Model to Analyze the Scale Dependence of Convection, Cloud Microphysics, and Fractional Cloudiness

Principal Investigator: Laura D. Fowler

NOAA Project Goal: Weather and Water

Key Words: Convection, Cloud Microphysics, Fractional Cloudiness, Interactions, Scale-Dependence.

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

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 following 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.

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).

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 2.2, and most recently version 3.0, of the Advanced Research WRF (ARW) model.

We are in the process of testing both parameterizations using two idealized simulations, a two-dimensional squall line to simulate the development of convection, and a moist baroclinic wave to simulate frontal clouds.

Mr. Scott Longmore is leading the effort to develop a MATLAB-based Graphical Unit Interface to display WRF NetCDF outputs. The Mathwork's MATLAB and NCAR VAPOR visualization packages were reviewed to determine the best package for 3-D visualization, and ability to produce publication-quality figures. MATLAB was chosen for its currently ability to meet the two above criteria. Modifications were made to an existing CIRA developed visualization tool based on MATLAB, for visualization of WRF data. These modifications include: WRF NetCDF reading routines using the third party MEXNC library to inventory and read WRF NetCDF files, the development of a data Volume Browser graphical user interface (GUI), and the initial restructuring of the Volume Display GUI.

Figures 1, 2, and 3 show longitude versus pressure cross sections of the cloud water mixing ratio and cloud fraction, cloudy minus cloud-free water vapor mixing ratio, and cloudy minus cloud-free potential temperature during the initial development of convection for the idealized two-dimensional squall-line.

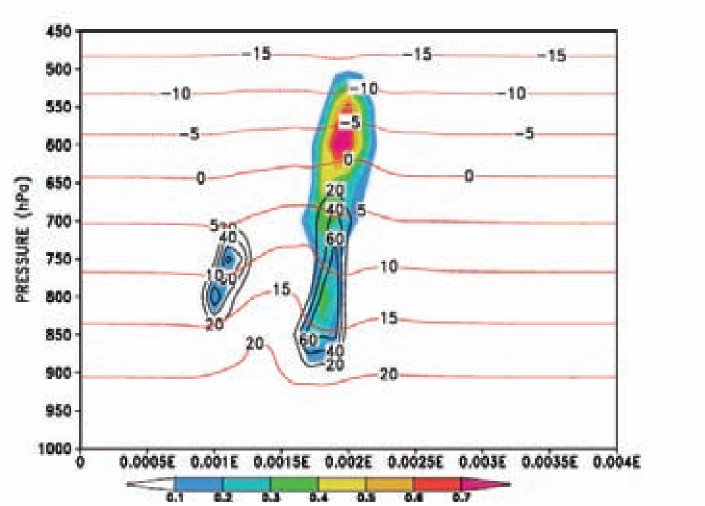


Figure 1. Longitude versus pressure cross section of the cloud water mixing ratio (shaded), cloud fraction (black contours), and temperature (red contours). Units are g kg^{-1} for the mixing ratio, % for the cloud fraction, and °C for the temperature.

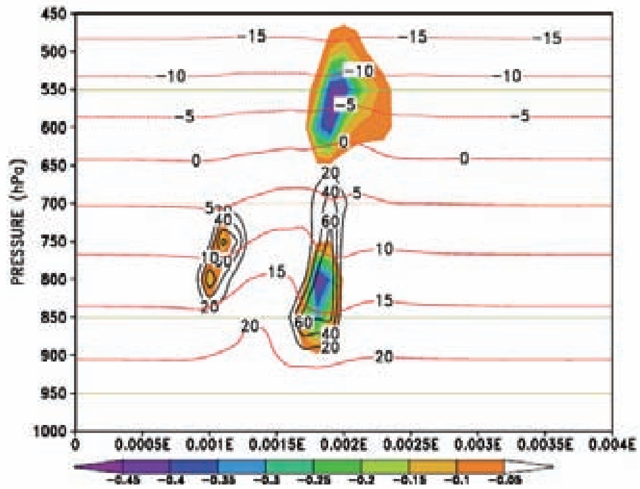


Figure 2. As Figure 1, but for the cloudy minus cloud-free water vapor mixing ratio. Units are g kg^{-1}.

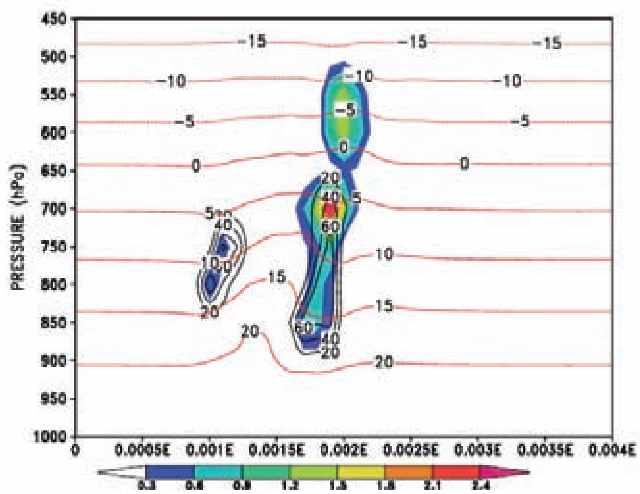


Figure 3. As Figure 1, but for the cloudy minus cloud-free potential temperature. Units are °C.

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

The parameterization of convection remains to be tested before the end of the 1st year funding.

4. Leveraging/Payoff: None as yet

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

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 as yet

7. Outreach: None as yet

8. Publications: None as yet

<u>NSF</u> - 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 are comparing 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. “In progress.”

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, Communications 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 as yet

7. Outreach:

Conference and meeting presentations:

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.

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.

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.

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.

WESTERN GOVENORS ASSOCIATION - 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 website 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 website 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 as yet

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, indices, and related web resources, and a system for responding to user questions and feedback is in place.

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.

Left Intentionally Blank

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
5-31130	Funds for the Cooperative Institute for Research, Task 1	X			X												X		X	X	X	X
5-31133	Continued Investigation of the N.A. Monsoon Sensitivity to Boundary and Regional Forcing….		X		X	X			X					X								
5-31140	Research to Improve Tropical Cyclone Intensity Analyses and Predictions Using Satellite Data	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	
5-31166	Study of the Direct and Indirect Effects of Aerosol on Climate			X					X	X												
5-31176	Development of a Multi-platform Satellite Tropical Cyclone Wind Analysis System	X				X							X	X	X	X						
5-31179	Analyses and Diagnostic Studies from SMN Radar and Related Data in support of NAME		X			X																
5-31180	The role of Africa in terrestrial carbon exchange and atmospheric CO2: Reducing regional and global carbon cycle uncertainty								X	X	X	X										
5-31181	Impact of Fundamental Assumptions of Probabilistic Data Assimilation/Ensemble Forecasting: Conditional Mode vs. Conditional Mean	X								X												
5-31182	Study of Gulf Surges Using QuikSCAT and NAME Observations	X	X		X	X		X				X	X		X							
5-31183	Ship-Based Observations of Precipitation Convection and Environmental Conditions in Support of NAME-2004	X	X			X								X	X							
5-31184	Proposal on Efficient All-Weather (Cloudy and Clear) Observational Operator for Satellite Radiance Data Assimilation				X					X												
5-31187	Sensitivity of the N. Am. Monsoon to Soil Moisture and Vegetation	X	X		X						X	X										
5-31188	A High Resolution Meteorological Distribution Model for Atmospheric, Hydrologic, and Ecologic Applications	X	X		X	X						X										
5-31189	Processing of Organic Aerosols by Heterogeneous and Multiphase Processes			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
5-31192	Continued Development of Tropical Cyclone Wind Probability Products	X				X							X	X	X	X						
5-31193	Improved Statistical Intensity Forecast Models	X				X							X	X	X	X						
5-31194	Research & Development for GOES-R Risk Reduction												X	X	X		X				X	
5-31195	Advanced Hydrologic Prediction Service	X	X		X					X												
5-31198	Investigation of smoke aerosol-cloud interactions using large eddy simulations			X	X	X				X												
5-31201	Applications of satellite altimetry data to statistical and simplified dynamical tropical cyclone intensity forecast models				X	X		X					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		
5-31204	Regional Transport Analysis for Carbon Cycle Inversions			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
5-31210	GOES West ISCCP Sector Processing Center								X								X				X	
5-31212	Development of Three-Dimensional Polar Wind Retrieval Techniques Using the Advanced Microwave Sounder Unit	X			X	X														X		
5-31213	NPOESS Applications to tropical cyclone analysis and forecasting	X				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
5-31214	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													
5-31220	A Satellite Analysis of Atmospheric Rivers		X			X																
5-31221	Advanced Weather (AWIPS) Support for Satellite Hydro-Meteorology (SHyMet) and Virtual Institute for Satellite Integration Training (VISIT) Training and Education		X			X	X											X				X
5-31222	Weather Satellite Data and Analysis Equipment and Support for Research Activities	X				X											X		X		X	
5-31223	Ultrasonic depth sensors for NWS snow measurements in the US: evaluation of operational readiness	X	X			X	X		X		X	X										
5-31224	Continued Development of Tropical Cyclone Wind Probability Products	X				X							X	X	X	X						
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	
5-31230	Evaluation of GOES-13 Imager and Sounder during NOAA's Science Test: Collection and Analysis of Data	X	X		X	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
5-31231	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		
5-31286	Collaborative Research with NIDIS for their web portal		X			X			X			X										
5-31829	Assistance for Visibility Data Analysis & Image Display Techniques			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																	

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
5-32704	CloudSat Artic Energy Budget Science and Data Processing								X	X	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																
5-32723	Optimizing GPM Precipitation Estimation Using High Resolution Land Surface Modeling for Decision Support		X			X					X											
5-32730	GLOBE: Inspiring the Next Generation of Explorers (UCAR-NASA)					X																X
5-32806	Characterizing Pollutant Deposition to Rocky Mountain National Park			X							X											
5-32832	Investigation of the Fate and Origin of Sulfur and Nitrogen Along the Colorado Front Range and in Rocky Mountain National Park and Development of Improved Methods for Characterizing Wildland Fire Particulate Matter Emissions and their Air Quality/Visibility Impacts			X								X				X		X				
5-32864	Development of Improved Methods forCharacterizing Wildland Fire Particulate Matter Emissions and their Air Quality/Visibility Impacts			X								X				X		X				
5-33023	Collaborative Proposal to NSF: Ensemble Data Assimilation Based On Control Theory				X	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										

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
5-33428	CIRA-NCAR/MMM WRF-Var collaboration Work Plan	X			X	X																
5-33444	Implementation and Evaluation of an Improved Mellor-Yamada level-3 Turbulence Closure in WRF				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											
5-34164	Analysis of Levoglucosan, K+, and Water Soluble Organic Carbon in Archived Filter Samples			X							X											
5-35004	Western Regional Air Partnership (WRAP) Technical Support System (TSS): A Web-based Air Quality Information Delivery System			X							X	X						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

August 2007 ESRL/GSD Team Member of the Month: Nikki Privé
GSD Director Steve Koch stated that:

"Dr. Nikki Privé, who has worked with GSD for almost two years, is the recipient of August's GSD Team Member of the Month. Dr. Privé has developed an Observing Systems Simulation Experiment (OSSE) in conjunction with Yuanfu Xie, also from GSD. OSSE's help show the importance to weather forecasts of adding additional measurements. The joint effort involves contributions from several parts of NOAA, as well as NASA and ECMWF. Dr. Privé has also been supplying some of the Science on a Sphere® images which are often shown to visitors. Dr. Privé still finds time to do weather briefings and to assist with the briefings of others."

November 2007 GSD Team Member of the Month: Leigh Cheatwood-Harris
The following nomination comes from Information Systems Branch Chief Carl Bullock.

"I am nominating Leigh Cheatwood-Harris for GSD's November 2007 Team Member of the Month. Leigh has supported a number of important evaluation and training activities in ISB over the past several months. Two of particular note were her work with the AWIPS II development and GFE training for River Forecast Center forecasters.

For AWIPS II, Leigh was persistent in working with the version 1.0 despite many problems typical of a first release of software. She became the de-facto expert on this system helping others learn and use AWIPS II. She also developed test metrics which will be used to evaluate the new AWIPS II system. This development included compiling and evaluating usage logs, interacting with NWS staff at the Boulder forecast office, and running and documenting performance tests. These metrics will form the basis of comparing the performance of the new AWIPS II system.

She has also played a key role for developing and testing training material for initial GFE training conducted with River Forecast Center forecasters from across the nation. She meticulously went through training material before training began and suggested changes to the material in order to make it more meaningful to participants during training. She also assisted during training and answered questions during lab exercises. These contributions helped lead to a successful training experience for the participants, most of whom had little prior experience with the GFE."

December 2007 GSD Team Member of the Month: Sean Madine
The following nomination comes from Aviation Branch Chief Mike Kraus.

"Sean Madine is GSD's Team Member of the Month for December. We in the Aviation Branch would like to recognize Sean's significant contributions to the Forecast Verification Program. Sean is a key contributor to the success of the Verification Program. He provides programmatic coherence, project leadership and vision, and has infused innovative scientific concepts into the verification and evaluation process. For instance, Sean is leading the design of the next generation RTVS, is developing a significant cutting edge project with Boeing Corporation to understand the economic value of weather forecasts, and is working to extend verification concepts and information for automated decision support."

"Thanks Sean for all you do and congratulations!"

April 2008 Group Achievement Award: Don Hillger
Don Hillger was part of a Group Achievement Award presented to the GOES-N Series Team by the National Aeronautics and Space Administration (NASA). The award was recognition “for providing the next generation of advanced weather satellites, a service essential to the Nation.” Hillger coordinated the GOES-13 Science Test, which occurred at the end of Post Launch Testing for GOES-13 in December 2006, and was assisted by many other scientists who analyzed the data from GOES-13, whose efforts were complied into *NOAA Technical Report NESDIS 125*, available at http://rammb.cira.colostate.edu/projects/goes_n/.

May 2008 GSD Team Member of the Month: Chris MacDermaid
The following nomination comes from Information and Technology Services Chief Pam Weber.

"Chris MacDermaid is ITS' nomination for GSD's Team Member of the Month for May 2008. He is recognized for his dedication to providing outstanding customer support as well as his exceptional skills and knowledge of data systems.
Chris leads the Data Systems Group (DSG) within ITS. His group works with GRIB, BUFR, GVAR, METAR and other data. Some of the projects supported by Chris' group are MADIS, FSL to GSD Web project, ATAMS, RUC, WRF and FIM.”

CIRA Research Initiative Awards
Please join in congratulating Jebb Stewart and Glen Liston who each were presented the CIRA Research Initiative Award for 2007! This honor acknowledges their contributions to the overall research environment at CIRA. The staff in Boulder gathered to honor Jebb, and we will honor Glen at our next Coffee Confab on August 22.

Jebb was behind the system design and technical leadership necessary in the development of enabling technology for the Gridded FX-Net system. The system has since been adopted by operational fire weather forecasters working for the National Forest Service, Bureau of Land Management and National Interagency Fire

Center. The data provided by the system is essential to daily fire prediction forecasts.

Glen is well known among his peers for his innovative blowing snow model. His modeling suite represents a tremendous advance forward in the field, and he has been sought after as a collaborator on a number of projects (including treks across Canada and the Antarctic) both here and abroad. Snow research promises to be a growing area thanks to the expertise and reputation Glen brings to CIRA.

Nobel Peace Prize Shared by CIRA Researchers
University Distinguished Professor Tom Vonder Haar and Senior Research Scientist Emeritus Doug Fox worked with the Intergovernmental Panel on Climate Change, which shared the Nobel Peace Prize announced Oct. 12, 2007. Thousands of scientists from across the globe were involved in the IPCC. Vonder Haar made contributions to several chapters, while Doug Fox was the Coordinating Lead Author for the "Impacts of Climate Change on Mountain Ecosystems Chapter" in the IPCC 1995 Assessment. Graeme Stephens (CIRA Director-Select) was another important contributor.

2007 Bronze Award Winners
NOAA is pleased to announce the winners of the 2007 Bronze Medal Awards. Please join me in congratulating the following individuals, groups and organizations for their dedicated service to NOAA:

National Environmental Satellite, Data and Information Service

Ken Knapp
For analyzing terabytes of data from 18 different satellites from more than 20 years of observations in order to create climate data records on hurricane trends and improve the understanding of climate variability and change.

Mark DeMaria, Antonio Irving, Nancy Merckle, John A. Knaff (Andrea Schumacher and Bernadette Connell were also contributors)
For the development and operational implementation of the Tropical Cyclone Formation product that quantitatively predicts storm formation probability.

CIRA Scientist Among Authors of Book Celebrating 50 Years of Earth Observations from Space
Stan Kidder has contributed to a new book celebrating 50 years of Earth observations from space. He is one of a dozen scientists from around the country who have written chapters in the book "Earth Observations from Space: The First 50 Years of Scientific Achievements." The book was sponsored by The National Academies in honor of NASA's 50-year anniversary in 2008.

Dr. Tom Vonder Haar helped manage the book project as a member of the Board on Atmospheric Sciences and Climate. Vonder Haar also serves as the chairman of the interdisciplinary section of the National Academy of Engineering.

"The report sponsored by the National Academies at the request of NASA is timely as we plan the next segment of our space missions to monitor Planet Earth," Vonder Haar said. "Our past accomplishments and lessons learned will assist with the design of future Earth climate and science missions."

Kidder talked about his chapter on the contributions satellites make to weather forecasting on February 17 at the American Association for the Advancement of Science annual meeting in Boston.

"People have been interested in weather for hundreds of years, but you can't forecast when you don't know what the weather is in lots of places," Kidder said. "You've got to see the big area to make the forecast. Satellites provide us with that capability - looking at temperature and humidity all over the Earth."

Before satellites, severe weather surprised people, often resulting in thousands of deaths. Kidder points to the hurricane that hit Galveston, Texas, with no warning in 1900 and killed 8,000 people. "Now, there are no surprise tropical storms anywhere on Earth," he said.

Kidder's research at CIRA focuses on using satellite data to study meteorological problems such as the amount of water vapor in the atmosphere, which is useful for forecasting rain. He takes satellite information and builds products for the scientific community including forecasters.

A sample of Kidder's and CIRA's work:

-CIRA local-scale products: http://amsu.cira.colostate.edu/GOES
-Water vapor imagery, including GPS data: http://amsu.cira.colostate.edu/GPSTPW
-Oceanic water vapor imagery around the world: http://amsu.cira.colostate.edu/TPW

NASA Group Achievement Award

Don Hillger was part of a Group Achievement Award presented to the GOES-N Series Team by the National Aeronautics and Space Administration (NASA). The award was recognition "for providing the next generation of advanced weather satellites, a service essential to the Nation." Hillger coordinated the GOES-13 Science Test, which occurred at the end of Post Launch Testing for GOES-13 in December 2006, and was assisted by many other scientists who analyzed the data from GOES-13, whose efforts were complied into *NOAA Technical Report NESDIS 125*, available at http://rammb.cira.colostate.edu/projects/goes_n/.

GSD Certificate of Appreciation
The following CIRA researchers (along with their federal colleagues) were recognized with a Certificate of Appreciation at the GSD “Town Hall” meeting on April 16 for their contributions to the integrated demonstration of GSD global modeling (Flow-following finite-volume Icosahedral Model – FIM), supercomputing, data management, and information systems efforts for Mary Glackin (NOAA Deputy Under Secretary for Oceans and Atmosphere) during her visit to ESRL on March 6.

Setting Up Real-Time FIM Runs on wJet and Getting Output on /public in a Timely Manner— Bob Lipschutz (Coordination of Team Activities), Paul Hamer, Patrick Hildreth, and Chris MacDermaid

FIM Code Management with Subversion and GForge / Allowing Well-Controlled Frequent Changes to FIM from Developers – Tom Henderson and Richard Ryan

Actual Code Developers for FIM Model and Post-Processing / Many Key Changes Over a Three-Week Period – Jacques Middlecoff and Ning Wang

FIM Display Capabilities on Science On a Sphere® —Steve Albers, Mike Biere, and Jebb Stewart

FIM Display Capabilities Using ALPS—Tom Kent

FIM Display Capabilities for Hall Display—Kevin Brundage and Brian Jamison

NASA Honor Award to Graeme Stephens and Phil Partain
Graeme Stephens received an Exceptional Public Service Medal at an award ceremony held at JPL July 23, 2008. He was honored for his exceptional scientific leadership of the CloudSat Project and for his visionary promotion of combined active and passive measurements for atmospheric science. This is a prestigious NASA award that is presented to a number of carefully selected individuals and teams who have distinguished themselves by making outstanding contributions to the NASA mission.

Phil Partain also received an Exceptional Public Service Medal for his unique contributions to the CloudSat mission. Phil began his association with the CloudSat mission in 2000, when he was assigned to develop the Level 2 science data processing infrastructure for the CloudSat data processing center. Phil combined an existing university prototype with numerous innovations of his own to develop an advanced Level 2 processing system that has been recognized as state of the art by experts from JPL, GSFC, and LaRC.

IRC Gold Medal to Graeme Stephens (CIRA Director-select)
The IAMAS International Radiation Commission (IRC) selected Graeme Stephens as the awardee of an IRC Gold Medal. This medal is given to a world’s key scientist who made a great contribution to the radiation community. Graeme was invited to speak at the International Radiation Symposium 2008 and receive his pure gold medal at that time.

PUBLICATIONS

	Institute Lead Author						NOAA Lead Author						Other Lead Author					
	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Peer-Reviewed	~~~	~~~	29	70	42	46	20	21	20	14	30	26	77	78	40	25	71	80
Non Peer-Reviewed	~~~	~~~	82	128	40	6	73	32	48	52	91	2	108	44	53	46	64	5

PRESENTATIONS

	Institute Lead Author	NOAA Lead Author	Other Lead Author
2007-08	69	27	41

CIRA EMPLOYEE MAXTRIX

Employees who received 50% support or more		Degree			
Category	Number	Bachelors	Masters	Doctorate	Non-Degreed
Research Scientists	10	0	0	10	0
Visiting Scientists	1	0	0	1	0
Postdoctoral Fellows	9	0	0	9	0
Research Support Staff & Administrative Personnel*	65	25	26	6	8
Total	85	25	26	26	8

Employees who received less than 50% support		Degree			
Category	Number	Bachelors	Masters	Doctorate	Non-Degreed
Research Scientists	13	0	0	13	0
Visiting Scientists	1	0	0	1	0
Postdoctoral Fellows	1	0	0	1	0
Research Support Staff & Administrative Personnel*	43	17	7	3	16
Total	58	17	7	18	16

Supported Students		Degree		
Category	Number	Bachelors	Masters	Doctorate
Undergraduate	0	0	0	0
Graduate	5	0	5	0
Total	5	0	5	0

Employees located at NOAA Laboratories		GSD	PSD	CSD	FSL/MDL
Total	46	41	1	2	2

Obtained NOAA Employment within the last year	
Total	0

***CIRA does not differentiate between Research Support Staff and Administrative Personnel**


Colorado
State
University