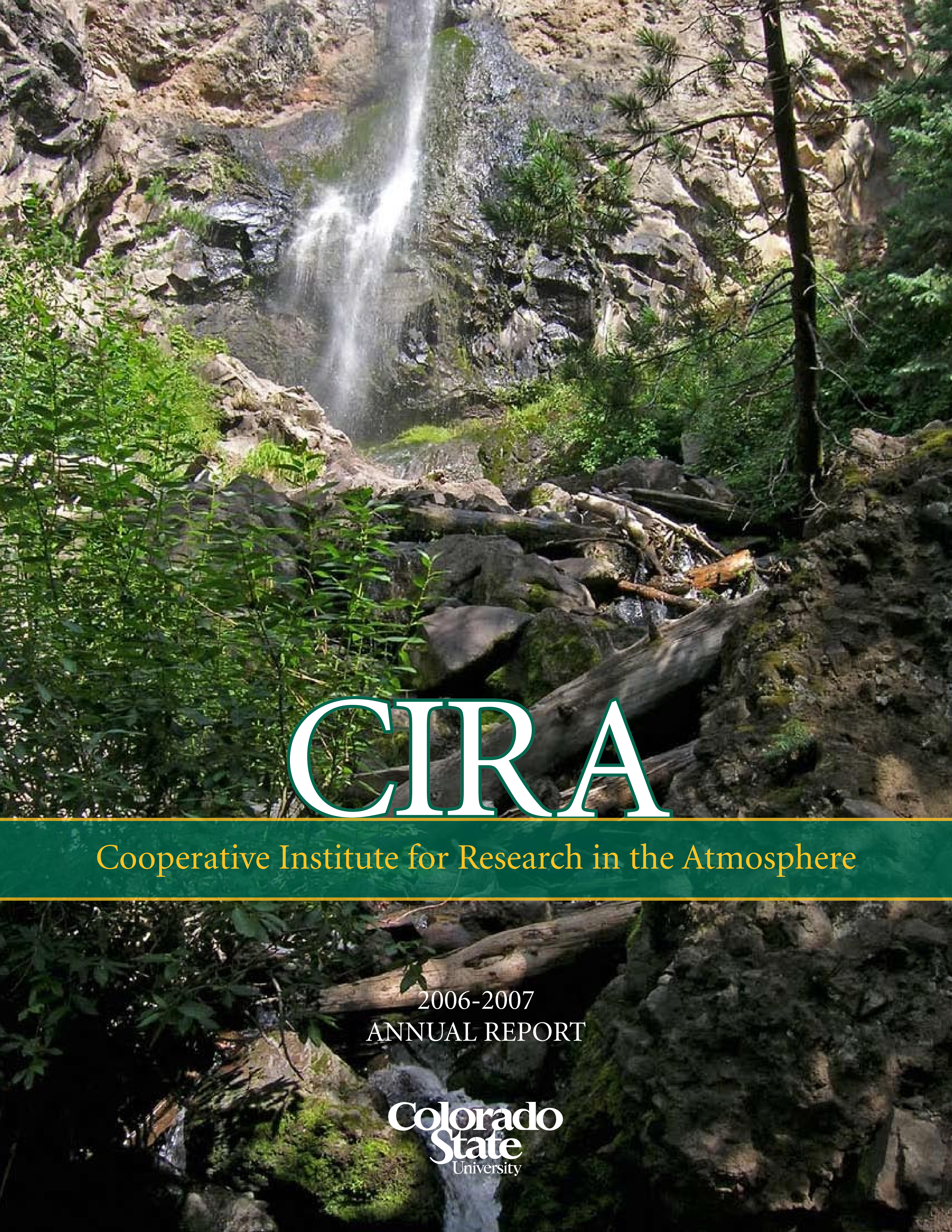

CIRA

Cooperative Institute for Research in the Atmosphere

2006-2007
ANNUAL REPORT

Colorado State University

CIRA ANNUAL REPORT FY 06/07

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE

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TABLE OF CONTENTS

INTRODUCTION

This report describes research funded in collaboration with NOAA's cooperative agreement and the CIRA Cooperative Institute concept for the period July 1, 2006 through June 30, 2007. 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. These research activities (and others) are synergistic with the infrastructure and intellectual talent produced and used by both sides of the funded activities.

For further information on CIRA, please contact:

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

Or

Professor Thomas H. Vonder Haar, 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.

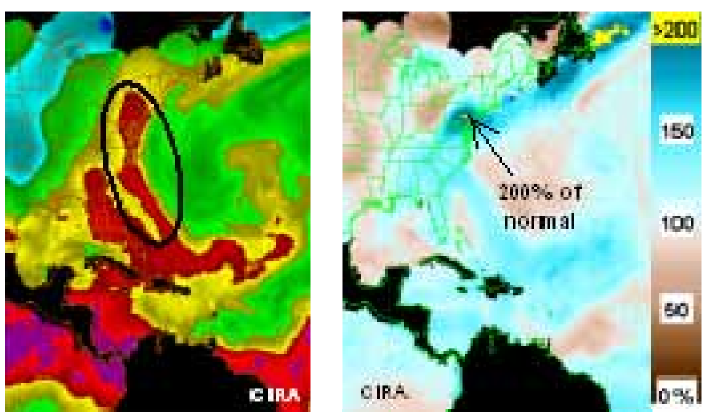
EDUCATION, TRAINING AND OUTREACH ACTIVITIES

Air Quality (Education and Outreach)

Dr. Marco Rodriguez presented the talk “Simulaciones numéricas de la calidad del aire usando el modelo regional CAMx y una aplicación directa a los parques de los USA” as part of the *VI Simposio sobre Contaminación Atmosférica* that took place in Mexico City, Mexico on April 17 to 19, 2007. During this presentation Dr. Rodriguez had the opportunity to expose some of the recent modeling research developments done by the NPS group here at CIRA. This symposium brings together many researchers of different Mexican universities and research institutes interested in air pollution. The symposium was also open to the general public including college and high school students. Dr. Rodriguez's talk focused on the efforts by the NPS group to use Eulerian photochemical models to predict the impacts of different pollutants in the National Parks. This talk attracted the attention of the media and the newspaper “Reforma” interviewed Dr. Rodriguez about his activities as a Mexican researcher in the United States.

AMSU (Education and Outreach)

CIRA experimental blended total precipitable water (TPW) products from AMSU/SSM/I, GPS and GOES sounder have received 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.



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.

AN Display System for Improved NWS Forecasts (Training and Outreach)

An NCAR **AN** display system (CIDD) was installed at the Fort Worth-Dallas WFO. This allows forecasters to review the several types of **AN** products (real-time and forecast) that are available within the system. The benefit to the NWS is an improved situational awareness, thus improving NWS forecasts. 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.

CloudSat (Education and Outreach)

The CloudSat Data Processing Center provides several different levels of data to the science community. Scientists can order data from the ordering system, which they would then have to manipulate and analyze for themselves. For scientists and interested non-scientists, we offer Quicklook images that show the processed radar reflectivities from each CloudSat orbit. The Quicklook images can be viewed from the following link: http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php). Occasionally, CloudSat will fly over an interesting weather phenomenon such as a hurricane. The DPC compares a regular satellite image, like those from the GOES satellites, to the CloudSat overpass so that those interested can see the similarities and differences in the images. Comparing these two images is interesting because the regular satellite image will usually show the entire hurricane, whereas the CloudSat image will show a narrow swath of the vertical distribution of clouds within the hurricane. We make these images available to teachers, students, scientists, or anyone who is interested in weather. You can view these Case Studies on the following website: http://www.cloudsat.cira.colostate.edu/CaseStudies.php.

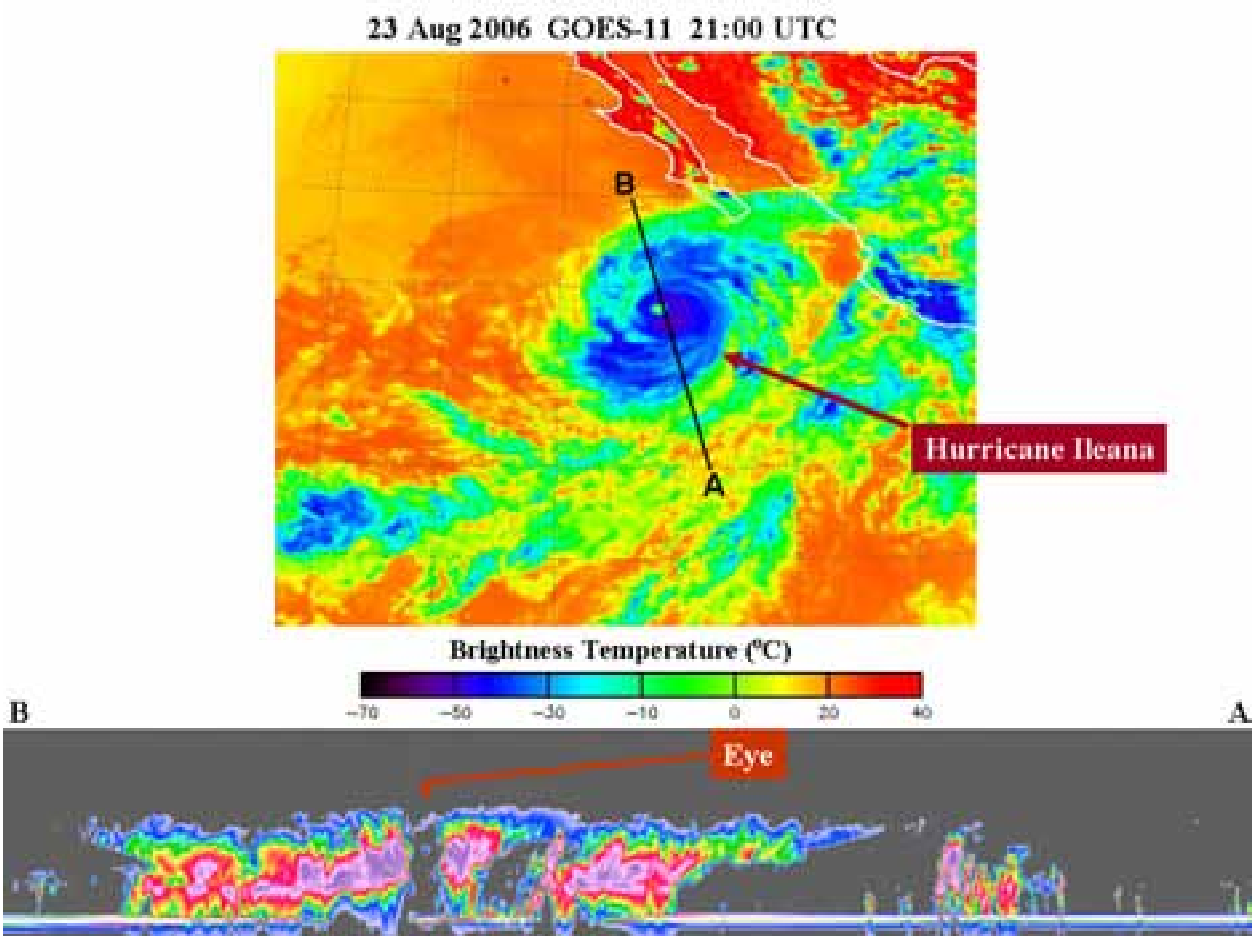
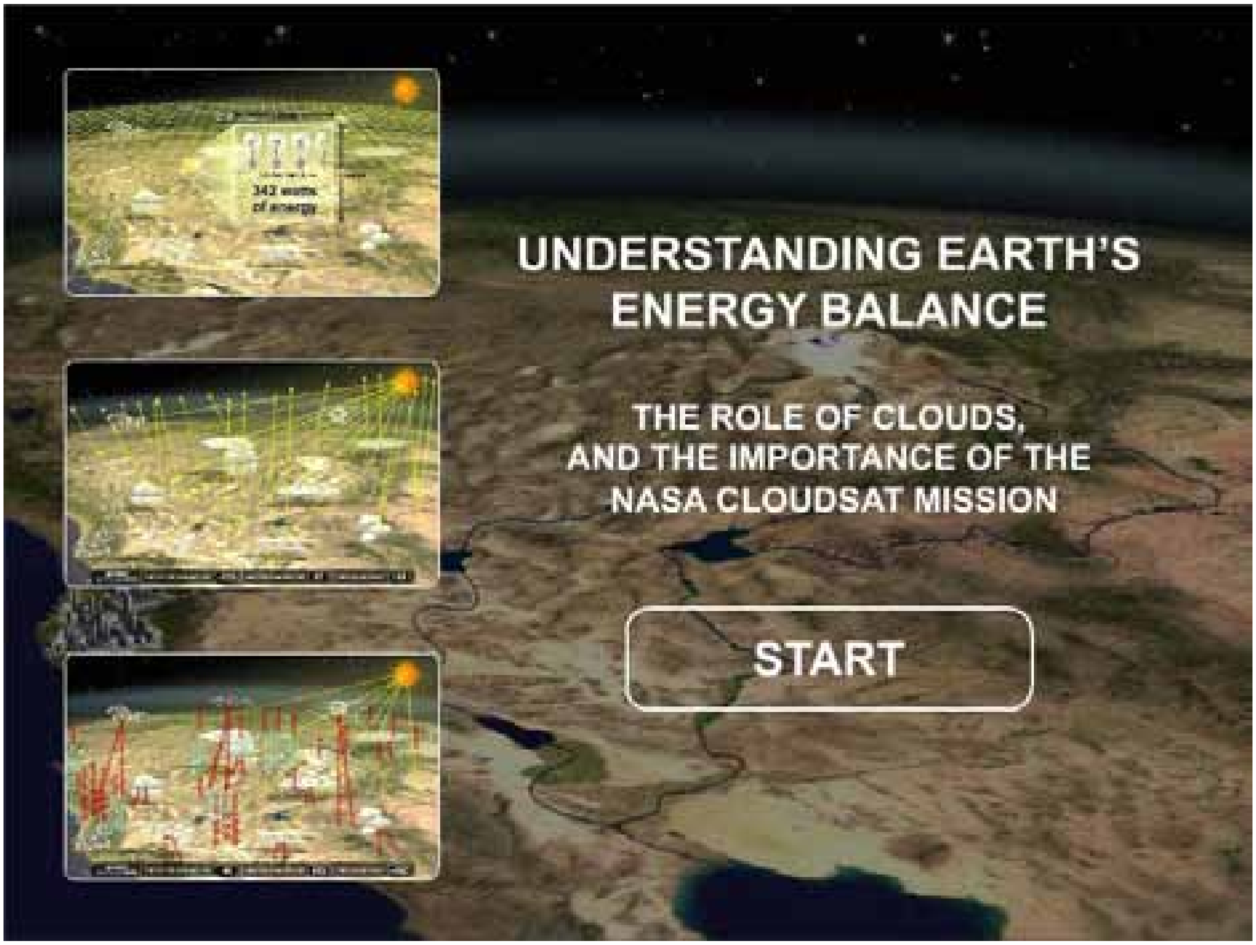


Figure 1. CloudSat Captures the Eye of Hurricane Ileana in August of 2006. This is an example of a CloudSat Case Study.

CloudSat Mission and the Earth Energy Balance (Education and Outreach)

To increase the education and outreach information on the importance of the CloudSat Mission, it is important for students and teachers to understand the important role that clouds play in maintaining a constant surface temperature and their impact on global warming and climate change. In understanding this role, one needs to first understand the Earth's Energy Balance and how Earth, its atmosphere, and space each gain and lose energy. Changes in cloud type and cloud coverage affect these gains and losses and directly impact the average surface temperature of the Earth. CIRA has produced a test CD and Educator's Guide on "Understanding Earth's Energy Balance". This CD and Guide have recently undergone beta testing in a number of U.S. and international schools. Refinements to this CD and Guide are planned for 2007-08.



Centers of Excellence-CoEs (International Training and Outreach

CIRA collaborates with Centers of Excellence (CoEs) which have been designated by the World Meteorological Organization (WMO) (previously known as Regional Meteorological Training Centers (RMTCs). 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. Participants from countries in Central and South America and the Caribbean view the same imagery using the VISITview tool and utilize Yahoo Messenger for voice over the Internet. CIRA collaborated and participated in the virtual High Profile Training Event (HPTE) held globally during October and November 2006. Four core lectures were delivered in both English and Spanish.

In addition, CIRA continues to work with the CoEs 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://www.cira.colostate.edu/RAMM/TRNGTBL.HTM#vlab for more information on various RMTC activities.

CoCoRaHS (Education, Training and Outreach)

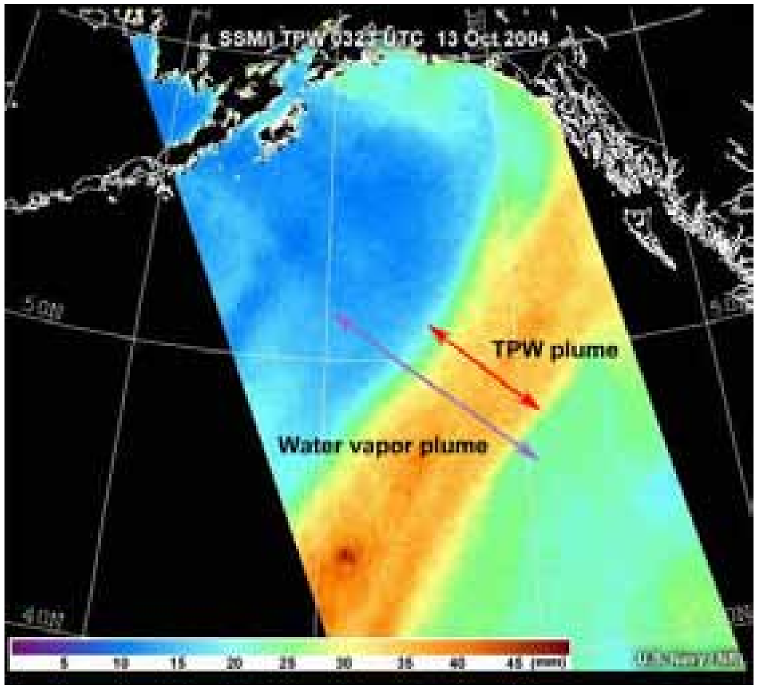
The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) headed up by the Colorado Climate Center at Colorado State University was select for funding in 2006 by NOAA's Office of Education Environmental Literacy Program. CoCoRaHS is a large and growing collection of volunteers of all ages who 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 continues to assist CoCoRaHS in its expansion efforts. Eight new states and several thousand new volunteers have been added in just the past 12 months. Along with instructional resources for participants, CoCoRaHS is also developing training resources for Cooperative Extension Programs across the country. Lesson plans for 4-H leaders and for Master Gardeners are currently under development. CoCoRaHS has also become a regular participant in the American Meteorological Society's annual WeatherFest. Many families were shown how to measure precipitation at this year's program in San Antonio, TX. CoCoRaHS will kick off in Louisiana in 2008 with a display at the AMS Annual Meeting in New Orleans.

A young attendee at AMS Weatherfest in San Antonio, January 2007, drops a ball-bearing on a hail pad to simulate hail.

COMET Meted Forecaster Users Program (Education and Outreach)

http://www.meted.ucar.edu/npoess/microwave_topics/clouds_precip_water_vapor



Example of an atmospheric river from the UCAR COMET Meted program used to educate forecasters and users of satellite data. CIRA contributed towards and reviewed the technical content of the UCAR tutorial on satellite microwave remote sensing.

Dunn Elementary First Graders Visit CIRA (Education and Outreach)

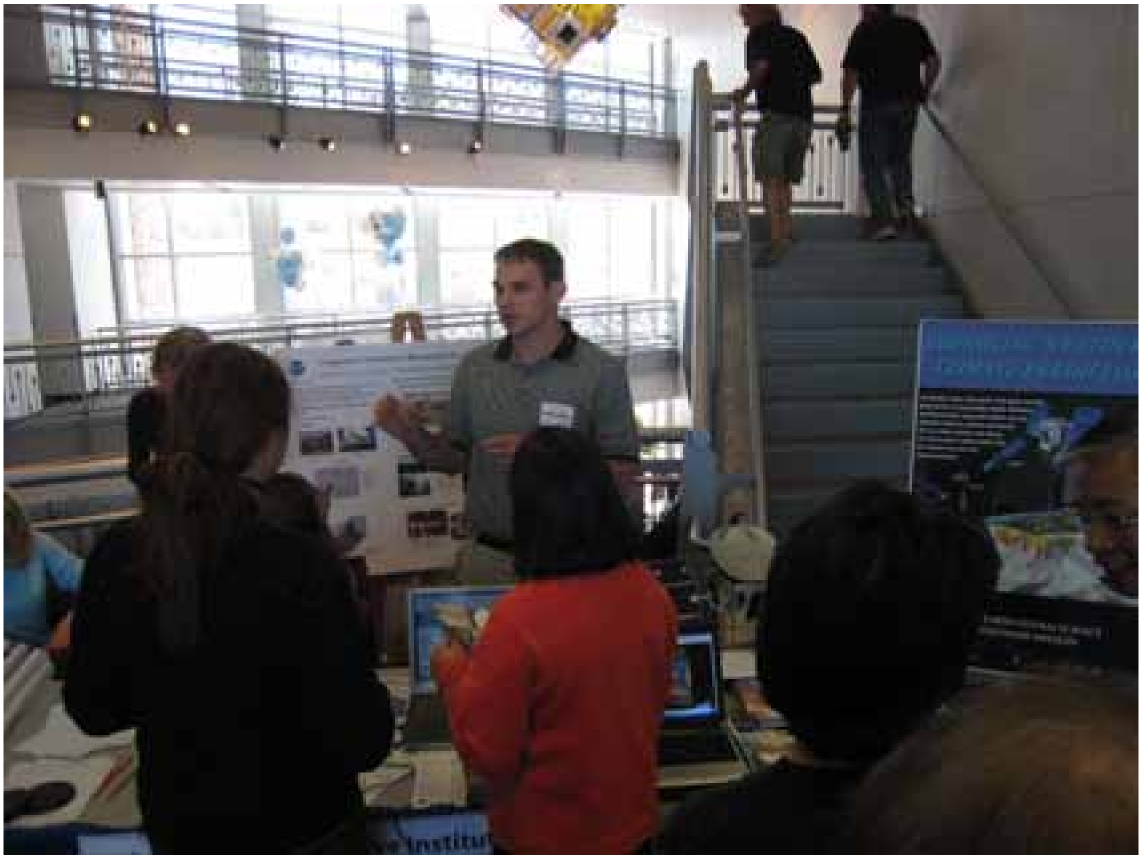
On February 7, 2007 with sunny skies and unseasonably warm temperatures nearly 70 first graders from Dunn Elementary, an IB World School, visited CIRA. Accompanied by 20 teachers and parents, the kids, with notepads in hand were ready to go. They had been studying clouds in their classes and were especially interested in how clouds form and the types of clouds they saw in the sky. The trip was organized by Mrs. Jamie Romero and hosted by CIRA’s Education and Outreach Coordinator, David Cismoski (Ski). Assisting him in this endeavor were Holli Knutson, Don Reinke, Don Hillger and two very observant photographers. This large group was split into two sections with Ski leading one section and Holli the other. As one group listened to Mr. Reinke show the launch of the CloudSat spacecraft, and explain CloudSat’s mission to profile clouds; the second group watched an animation on the types of clouds in the atmosphere and discussed how clouds are formed.

After about 15 minutes Holli's group went to the CIRA computer lab where Mr. Hillger showed real-time computer images prepared from data being transmitted from various satellites. Ski's group had gone to hear Mr. Reinke's second presentation. In one hour both groups were able to listen to three presentations and ask many imaginative questions such as: Why doesn't the CloudSat satellite get pulled into a "black hole", and does the satellite ever see any aliens? A follow-up packet of thank you letters received from the kids indicated to us that the visit and presentations were a great success.

The above picture features Don Reinke showing CloudSat's orbit to interested Dunn School first graders**.**

Earth Day Open House at NOAA in Boulder (Education and Outreach)

To commemorate Earth Day on April 20th 2007, CIRA participated with NOAA at its Boulder facility to showcase to the public its science through displays and interactive demos. CIRA's exhibit included brief descriptions of its extensive research, a poster showing a rendering of the CloudSat satellite cloud profiling capability, a program showing the tracking of the CloudSat satellite orbit in real time, and the Beta test version of an animated educational program, on the Earth's Energy Balance. Through this outreach event, CIRA, NOAA Boulder and participating organizations will enhance environmental literacy among the public and improve their understanding of the value and use of weather and water information and services.



The above picture shows Matt Hansen talking to interested visitors at the CIRA exhibit.

FX-Collaborate Project (Training and Outreach)

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. This year's effort focused on improving the output from the HYSPLIT model and enhancing the system functions. In collaboration with other GSD staff, the input weather model for HYSPLIT was shifted to NAM12 since it provided better temporal and spatial resolution. Also, the HYSPLIT control parameters were adjusted to provide a better representation of the plume.

FX-Net System (Outreach)

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. The system delivered to the NWS's IMET program, the

National Interagency Fire Center GACC offices, and NWS WSO users was based on AWIPS v. OB6. A new version of the FX-Net Client (v.5.0) is also scheduled for release at the end of July 2007 that will include the addition of significant new data analysis and display tools. In April 2007, two CIRA members of the FX-Net development team were awarded a Certificate of Recognition by the Director of the National Weather Service. The award was: “In recognition of . . . leadership to ensure operational excellence via innovative development and maintenance of critical software for our IMETS.”

GLAPS topography images for Google Earth Application (Training and Outreach)

Further testing and development was done on a global LAPS analysis called "GLAPS". LAPS software was updated so it can localize and display domains using a cylindrical equidistant (latitude/longitude) projection that can allow full coverage over the globe (unlike the gaps near the poles in the previously used Mercator projection). Analyses of (unbalanced) 3-D state variables on a 21-km cylindrical grid are now being generated. GLAPS localization output on an experimental 15km grid has been fed to the FIM model development team that they are in turn interpolating to provide topography and related static grids. GLAPS topography images are also being provided for import into Google Earth applications.

GLOBE (Education and Outreach)

GLOBE technology team comprised of 6 CIRA researchers successfully designed and released the new GLOBE Web Site this past year. With the selection by NSF and NASA of the four Earth System Science Programs (ESSPs)—Seasons and Biomes, Carbon Cycle, From Local to Extreme Environments (FLEXE), and Watershed Dynamics—plans are to provide improved data visualization and analysis tools for student collaboration on projects and better support for student research projects including tools, content, and data portals for the ESSPs. The international GLOBE network has grown to include representatives from 109 participating countries and 135 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 16 million measurements to the GLOBE database for use in their inquiry-based science projects.

High Profile Training Event (HPTE)-Training and Outreach

The HPTE was held during 16-27 October 2006, in conjunction with WMO training events in Melbourne, Australia (Asia Pacific Satellite Applications Training Seminar (APSATS 2006)) and Nanjing, China, (Regional Training Seminar).as well as EUMETSAT supported training events in RA I. Many of the sites that logged into the lectures had multiple participants, and initial counts indicate that well over 1,000 people received the lectures. Four core lectures were developed in English in PowerPoint and converted to VISITView format. The lectures were reviewed by each of the VL partners prior to distribution to the registered participants in each WMO Region. A special fifth lecture was prepared specifically for the Africa Users Forum in Maputo, Mozambique. WMO sponsored Satellite Training Events occurred in Australia and China during HPTE, while EUMETSAT sponsored training activities took place in Kenya, Mozambique, Niger, Oman, Portugal, and South Africa during that same period. Each of the above training events either utilized and/or provided on-line lectures during the HPTE. See http://rammb.cira.colostate.edu/training/wmovl/ for more information on the HPTE

Gridded FX-Net Forecaster Workstation (Outreach)

Enhancements to the Gridded FX-Net Forecaster Workstation included the addition of data 'Pull' capability to the Compression Relay Management System (CRMS) that allows users to individually retrieve products and observations that are not automatically distributed via the CRMS LDM data distribution. A new encoder and decoder pair were developed that improves efficiency of both computation and memory usage. These improvements allow faster retrieval of 2D and 3D data sets when using the Gridded FX-Net D2D client. A new grid compression scheme was also developed to allow more flexible encoding and decoding of super large datasets. This improvement allows users to retrieve a single layer of a 3D data set (gridded model data) instead of retrieving the entire data set. As the data are compressed one layer at a time, data sets are distributed and displayed faster.

LAPS in Support of Fire Weather Applications (Training and Outreach)

To support Fire Weather applications, a new 500-m resolution LAPS analysis over a domain mainly in Boulder County was created. This is envisioned to be re-locatable in support of fire fighting operations, particularly with high-resolution wind fields. The analysis utilizes a downscaled RUC background together with the latest observational data. Graphics plots were developed to potentially display surface winds generated by the balance package thus showing terrain effects more accurately. A web interface was developed that allows the end user to automatically move a fire analysis/forecast domain so that the system can quickly respond to evolving fire situations.

Linux Prototype System ALPS (Training and Outreach)

The AWIPS Linux Prototype System (ALPS) has provided a platform for evaluating new operational concepts, including remote access to forecast models for the HMT (Hydrometeorological Testbed). Using the plug-in interface, ALPS also provided the ideal tool for demonstrating an advanced drawing capability desired by the NWS for some time, i.e., describing a warning area by a polygon that encompasses the hazardous weather area instead of only the traditional description by counties (CWA). The AWIPS WarnGen program was modified to include the polygon, storm centroid, and the direction of motion.

Science on a Sphere® (Education and Outreach)

Science on a Sphere® (SOS) was installed at seven new permanent public venues—Great Lakes Maritime Heritage Center in Alpena, MI, Imiloa Astronomy Center in Hilo, HI, James Madison University in Harrisonburg, VA, McWane Science Center in Birmingham, AL, Fiske Planetarium in Boulder, CO, Orlando Science Center in Orlando FL, and Museum of Science and Industry in Chicago IL. Enhancements to the program software this past year included: 1) a new display mode that allows direct display of sequences of images in equatorial cylindrical equidistant (ECE) map projection; 2) addition of the display of MPEG-4 encoded files that reduce storage requirements and increases animation rates; 3) addition of a picture-in-a-picture (PIP) capability that allows introductory slides or related still images to be overlaid on the underlying SOS imagery; and 4) the development of additional new data visualizations of meteorological and climate model data.

Service Oriented Architecture (Outreach)

CIRA researchers have initiated investigations into Service Oriented Architecture (SOA) concepts with focus on experimenting with the standards for web access to geospatial data that the Open Geospatial Consortium (OGC) is developing. CIRA participated in the development of "One-NOAA" prototype software that displays a variety of data from NOAA organizations on Google Earth as well as SOS. Weather, oceans, fisheries, satellite and coastal services data were included.

SHyMet (Training and Outreach)

The Satellite Hydrology and Meteorology Training Course for Interns was delivered 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

TAMDAR Data for Commercial Aircraft RUC Weather Forecasts (Training and Outreach)

During the past year, TAMDAR data continued to be taken from ~50 commercial aircraft servicing both large and a number of much smaller airports from the Midwest to the lower Mississippi Valley. 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 also continued this past year.

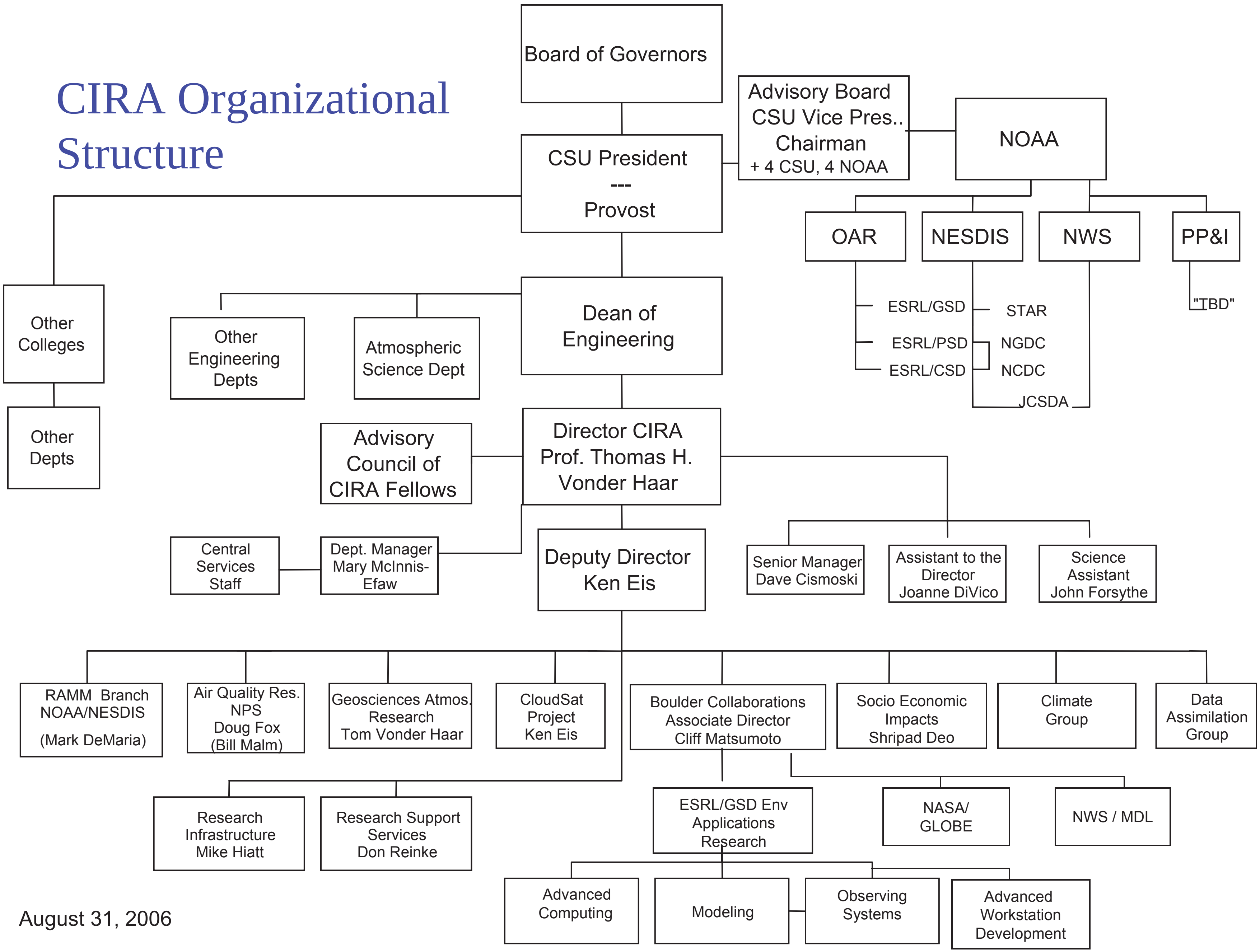
VISIT (Training)

The Virtual Institute for Satellite Integration Training (VISIT) program continues to offer a broad range of topics through teletraining distance learning for National Weather Service personnel and others. Topics developed at CIRA, and supported by software developed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, allow for synchronous teletraining sessions to be administered by CIRA personnel. Research results for Severe Weather, Tropical Weather, and other satellite related topics are translated directly into materials for these training programs. http://rammb.cira.colostate.edu/visit/visithome.asp

Volcanic Ash Collaboration Tool Mesoscale (Training and Outreach)

In February 2007, the Federal government members of the VACT development team were awarded the 2006 US Department of Commerce Bronze Medal "for developing the Volcanic Ash Collaboration Tool, a new tool which provides collaborative forecasting capabilities during volcanic eruptions and is essential to preventing volcanic ash damage to lives and property." CIRA researchers were integral to the success of this project and the lead CIRA engineer was recognized with the Colorado State University Distinguished Administrative Professional Award.

CIRA Organizational Structure



August 31, 2006

CIRA RESEARCH HIGHLIGHTS
July 1, 2006 – June 30, 2007

Global and Regional Climate Dynamics

--A report on the potential for the use of UAS for Arctic observations was written to support the development of an Arctic UAS Testbed. The report detailed the feasibility of using Eielson AFB for ground operations and launch/recovery of UAS, as well as the capabilities of existing UAS and Autonomous Underwater Vehicles (AUV) and instrumentation suitable for use on these vehicles.

--Six Science on a Sphere® demonstrations illustrating the fourth IPCC model results have been refined and completed. The demonstrations show the changes in surface temperature and sea ice cover in the A1B scenario from the NCAR CCSM, Hadley, and GFDL climate models.

--During the past year, regional climate simulations were performed for the summer months of 2004 and 2005 with the WRF model to study the effects of soil moisture on precipitation and to compare results obtained with different convective parameterizations and with explicitly resolved convection. Results indicate that the quality of the lateral boundary conditions had a large effect on the simulations in the high resolution domain (1.667 km). Examination of the behavior of different convective closures with ensemble members of the Grell-Devenyi parameterization yielded several interesting results.

--Progress was made on the CSU-ESRL/GMD collaboration entitled Regional Transport Analysis for Carbon Cycle Inversions to provide influence functions for selected CO_2 towers in North America. This past year, work was started on parameterization of convective transport (cloud venting) in the CSU Lagrangian Particle Dispersion Model (LPDM) linked to the RUC. LPDM simulations were performed and influence functions derived for 30 towers (existing and planned) for all longer periods with available RUC fields in the period from March 2005 to May 2006.

--The first climate sensitivity experiment conducted using a GCM with explicit representation of clouds was conducted by Prof. Randall.

--Created the longest RCM summer climatology to date for the contiguous U.S. and Mexico. This was accomplished by dynamically downscaling the NCEP-NCAR global reanalysis for the period 1950-2002.

--Prof. Denning's group has developed and tested a method for extrapolating surface-layer measurements of CO_2 at flux towers to atmospheric mixed-layer values under convective conditions. As a result of this and other work, they have produced a dramatic reduction in the uncertainty in the annual net North American CO_2 flux and its interannual variations as compared to current publications.

Mesoscale and Local Area Forecasting and Evaluation

--In February 2007, the Federal government members of the VACT development team were awarded the 2006 US Department of Commerce Bronze Medal "for developing the Volcanic Ash Collaboration Tool, a new tool which provides collaborative forecasting capabilities during volcanic eruptions and is essential to preventing volcanic ash damage to lives and property." CIRA researchers were integral to the success of this project and the lead CIRA engineer was recognized with the Colorado State University Distinguished Administrative Professional Award.

--CIRA researchers continued to investigate and implement new ways to deploy upgrades and new verification capabilities to a Real-Time Verification System (RTVS) configuration to the NWS Headquarters in Silver Spring, MD. The transfer provides the NWS, through the system housed at the Telecommunications Gateway Operations Center, with the ability to perform long-term quality assessments of operational aviation weather products issued from the NWS Aviation Weather Center.

--Dr Knaff is preparing the Annular Hurricane Eyewall Index (AHI) for operational use for this year's hurricane season. This product will be used to forecast hurricane intensification.

--Further testing and development was done on a global LAPS analysis called "GLAPS". LAPS software was updated so it can localize and display domains using a cylindrical equidistant (lat/lon) projection that can allow full coverage over the globe (unlike the gaps near the poles in the previously used Mercator projection). Analyses of (unbalanced) 3-D state variables on a 21-km cylindrical grid are now being generated. GLAPS localization output on an experimental 15km grid has been fed to the FIM model development team that they are in turn interpolating to provide topography and related static grids. GLAPS topography images are also being provided for import into Google Earth applications.

--The success of the GSD efforts during the 2005-2006 Hydrometeorological Testbed (HMT) winter field campaign to provide a single, high-resolution NWP forecast for the forecasters in the NWS weather forecast and river forecast offices led to the group's efforts to examine whether ensemble methods could improve guidance of probability of precipitation and precipitation amount. This led to an ensemble NWP model forecasts being implemented for the 2006-2007 winter field campaign for the American River Basin in northern California. The ensemble consisted of three configurations of the WRF-ARW and one configuration of the WRF-NMM. The forecast domain was identical to the one used during the 2005-2006 field campaign, i.e., 3-km grid point spacing over a domain of 450-km X 450-km. Collaboration with HMT participants at the National Severe Storms Laboratory led to the coupling of WRF model precipitation forecasts with a hydrological model. This appears to be a promising application of WRF ensemble data.

--To support Fire Weather applications, a new 500-m resolution LAPS analysis over a domain mainly in Boulder County was created. This is envisioned to be relocatable in support of fire fighting operations, particularly with high-resolution wind fields. The analysis utilizes a downscaled RUC background together with the latest observational data. Graphics plots were developed to potentially display surface winds generated by the balance package thus showing terrain effects more accurately. A web interface was developed that allows the end user to automatically move a fire analysis/forecast domain so that the system can quickly respond to evolving fire situations.

--During the past year, TAMDAR data continued to be taken from ~50 commercial aircraft servicing both large and a number of much smaller airports from the Midwest to the lower Mississippi Valley. 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 also continued this past year.

--One of the crucial issues related to variational data assimilation is how to determine background statistical error covariances. A method to construct background error covariances using time-phased ensemble forecasts was developed this past year that appears to possess many advantageous features over traditional methods. It is able to show clear mesoscale structures relevant to weather situations and possesses a flow-dependent property.

--The time-phased multi-model ensemble system developed last year using the LAPS hourly data assimilation system was further refined and applied in various forecast and field experiments such as the NOAA Hydrometeorological Testbed campaign. The time-phased multi-model ensemble forecast appears to show better skill than each deterministic forecast.

--An NCAR AN display system (CIDD) was installed at the Fort Worth-Dallas WFO. This allows forecasters to review the several types of AN products (real -time and forecast) that are available within the system. The benefit to the NWS is an improved situational awareness--thus improving NWS forecasts. 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.

--Evaluated Ocean Heat Content (OHC) data into the current Tropical Cyclone Intensity Forecast Model (TCHP). The new STIPS intensity model has improved intensity forecasts by ~2% and has been incorporated into NRLMRY models to support JTWC. Fundamental to this process has been CIRA’s prototype production of OHC maps since October 2006.

Applications of Satellite Observations

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 aerosol temporal changes are much slower than cloud temporal changes. Although the various measures of aerosol effects on cloud microphysics are consistent, they were demonstrated to likely be too low.

--Comparisons were performed 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). 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 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.

--Developed code based on "atmospheric rivers" where water fluxes can be computed for wind fields under geostrophic, linear, or nonlinear balance conditions. Research that improves the balance approximations is also showing improved accuracy in the derived winds.

--Currently transitioning the CIRA Wind Regime Cloud Climatology application and database to the AWIPS environment. This system output is being used for VISIT training and within NWS' Weather Event Simulator for case studies.

--Synthetic GOES-R ABI imagery was produced for three weather events to simulate Mesoscale scenarios using the CSU RAMS model cloud physics modules to test prototype algorithms for ABI. Additionally idealized fire hot spots were generated for fire spotter algorithm development. Tropical cyclone proxy data and intensity estimation algorithms were produced for 12 named storms.

--GIMPAP activities at CIRA have included: 1) Tropical Web page has been released for public use; 2) The Mesoscale Convective System (MCS) Index is running in real time and being validated using GOES IR imagery; 3) Winter Weather Atovs analysis; 4) Fog Fires and Volcanic Ash/Dust Product development; 5) Cloud Climatologies for Regional Training Centers in Central America; and 6) Inter-satellite calibration/validation comparisons (GOES 12/13).

--deAlwis designed a fully-automated calibration/validation system for NOAA 16,17 and 18 which was able to recover records that had been discarded in the heritage system.

--Developed numerous GOES-R proxy data sets including a16 band ABI simulation from SEVIRI data.

--Louis Grasso and Manajit Sengupta received the CIRA Research Initiative Award for their work on the GOES-R risk reduction project.

Numerical Modeling

--CIRA researchers have been an integral part of the team that has brought the ESRL Finite-volume Icosaheral Model (FIM) code to a level of maturity where the model will soon begin retrospective testing. Specifically, they have been directly involved in adding GFS physics to FIM. Using the Scalable Modeling System (SMS), the output of FIM was tuned and enabled to occur in parallel to the computations thus hiding the cost of the output and speeding up FIM by 30% so that now FIM scales from 120 processors to 240 processors by a factor of 1.95X which is an efficiency of 98%.

--CIRA researchers also developed the Icosahedral grid generation for FIM. Several efficient algorithms such as k-d tree and 2D space filling curve have been developed or adapted. An efficient grid generator for an Icosahedral grid was implemented. The new software reduces the computation time from hours to minutes thereby making it possible to generate the grid "on the fly."

--As part of the Terrain Rotor Experiment (TREX) project, graphic products 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, Richardson number, Scorer parameter, Na/U and Nh/U (which describe the atmospheric response to orographic gravity waves) for vertical cross sections were automatically generated following runs of the WRF Rapid Refresh ARW and NMM models running over a 2 km X 2 km domain with 50 vertical levels in the vicinity of the Sierra Nevada mountain range. The products are made available for viewing and comparison on a web page (http://www-frd.fsl.noaa.gov/mab/trex/). To examine how the model runs performed, aircraft data from the HIAPER (High-performance Instrumented Airborne Platform for Environmental Research), the BAe-146 (British Aerospace), and the National Center for Atmospheric Research King Air were also collected to be used for comparison with the resultant model forecasts.

--CIRA researchers developed a Java application called WRF Domain Wizard that is the GUI for the new WRF Preprocessing System (WPS). 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. Two new features are currently being added: a vertical leveleditor, and visualization module that enables users to visualize the NetCDF output.

--Developed a state-of-the-art, physically based micrometeorological model (MicroMet) that can serve as an interface between the course-resolution Mesoscale atmospheric models and fine-resolution hydrological and ecological models. This model development included collaboration with NOAA/FSL.

--A new real-time objective method for selection of a optimal ensemble configuration for rainfall forecasting has been developed by Dr. Isidora Jankov and colleagues.

--The Maximum Likelihood Ensemble Filter (MLEF) used as the front end to the NCEP Global Forecasting System (GFS) was developed and tested using a 5-day data period in January 2004. Preliminary results suggest the MLEF is producing correct statistical results without noticeable outliers. 100 ensemble members were used. Significantly this system is currently the only Ensemble Data Assimilation algorithm not based on statistical sampling.

--A new SHIPS model has been developed to evaluate vertical shear tropical storms that improves statistical intensity forecast models. A parallel version of SHIPS with this new shear predictor and GFS vortex predictor was implemented in real time beginning in September 2006.

--A visible radiative transfer mode (SHDOMPPDA) l and its adjoint were developed and compared the DISORT and is 5 times faster. This model has been incorporated into RAMDAS in support of JCSDA activities.

Education, Training, and Outreach

--GLOBE technology team comprised of six CIRA researchers successfully designed and released the new GLOBE Web site this past year. With the selection by NSF and NASA of the four Earth System Science Programs (ESSPs)—Seasons and Biomes, Carbon Cycle, From Local to Extreme Environments (FLEXE), and Watershed Dynamics—plans are to provide improved data visualization and analysis tools for student collaboration on projects and better support for student research projects including tools, content, and data portals for the ESSPs. The international GLOBE network has grown to include representatives from 109 participating countries and 135 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 16 million measurements to the GLOBE database for use in their inquiry-based science projects.

--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. The system delivered to the NWS' IMET program, the National Interagency Fire Center GACC offices, and NWS WSO users was based on AWIPS v. OB6. A new version of the FX-Net Client (v.5.0) is also scheduled for release at the end of July 2007 that will include the addition of significant new data analysis and display tools. In April 2007, two CIRA members of the FX-Net development team were awarded a Certificate of Recognition by the Director of the National Weather Service. The award was: “In recognition of . . . leadership to ensure operational excellence via innovative development and maintenance of critical software for our IMETS.”

--Over 18,000 training certificates have been awarded by the VISIT training program.

--Enhancements to the Gridded FX-Net Forecaster Workstation included the addition of data ‘Pull’ capability to the Compression Relay Management System (CRMS) that allows users to individually retrieve products and observations that are not automatically distributed via the CRMS LDM data distribution. AWIPS software was also upgraded to v. OB6.

--The wavelet compression software for the gridded FX-Net also underwent significant improvement. A new encoder and decoder pair were developed that improves efficiency of both computation and memory usage. These improvements allow faster retrieval of 2D and 3D data sets when using the Gridded FX-Net D2D client. A new grid compression scheme was also developed to allow more flexible encoding and decoding of super large datasets. This improvement allows users to retrieve a single layer of a 3D data set (gridded model data) instead of retrieving the entire data set. As the data are compressed one layer at a time, data sets are distributed and displayed faster.

--Science on a Sphere® (SOS) was installed at seven new permanent public venues—Great Lakes Maritime Heritage Center in Alpena, MI, Imiloa Astronomy Center in Hilo, HI, James Madison University in Harrisonburg, VA, McWane Science Center in Birmingham, AL, Fiske Planetarium in Boulder, CO, Orlando Science Center in Orlando FL, and Museum of Science and Industry in Chicago IL. Enhancements to the program software this past year included: 1) a new display mode that allows direct display of sequences of images in equatorial cylindrical equidistant (ECE) map projection; 2) addition of the display of MPEG-4 encoded files that reduce storage requirements and increases animation rates; 3) addition of a picture-in-a-picture (PIP) capability that allows introductory slides or related still images to be overlaid on the underlying SOS imagery; and 4) the development of additional new data visualizations of meteorological and climate model data.

--CIRA researchers have initiated investigations into Service Oriented Architecture (SOA) concepts with focus on experimenting with the standards for web access to geospatial data that the Open Geospatial Consortium (OGC) is developing. CIRA participated in the development of a “One-NOAA” prototype software that displays a variety of data from NOAA organizations on Google Earth as well as SOS. Weather, oceans, fisheries, satellite and coastal services data were included.

--The AWIPS Linux Prototype System (ALPS) has provided a platform for evaluating new operational concepts, including remote access to forecast models for the HMT (Hydrometeorological Testbed). Using the plug in interface, ALPS also provided the ideal tool for demonstrating an advanced drawing capability desired by the NWS for some time, i.e., describing a warning area by a polygon that encompasses the hazardous weather area instead of only the traditional description by counties (CWA). The AWIPS WarnGen program was modified to include the polygon, storm centroid, and the direction of motion.

--Dr. Purdom lectured at APSATS, a high profile training event in Melbourne Australia, to students on satellite data utilization. Topics included: spectral bands and their application, severe weather and heavy rainfall, and satellite capabilities and use of the Virtual Laboratory.

--COCORAHS has grown to 20 states and over 4500 climate observations. This citizen-science project is now a nationally-recognized outreach program for which Nolan Doesken has received a NOAA Environmental Hero Award.

--The first SHyMet Intern course was offered to NOAA individuals and others. NOAA has begun tracking the course with their e-Learning Management System. 113 NOAA/NWS employees have participated; 50% of these have completed the Intern course.

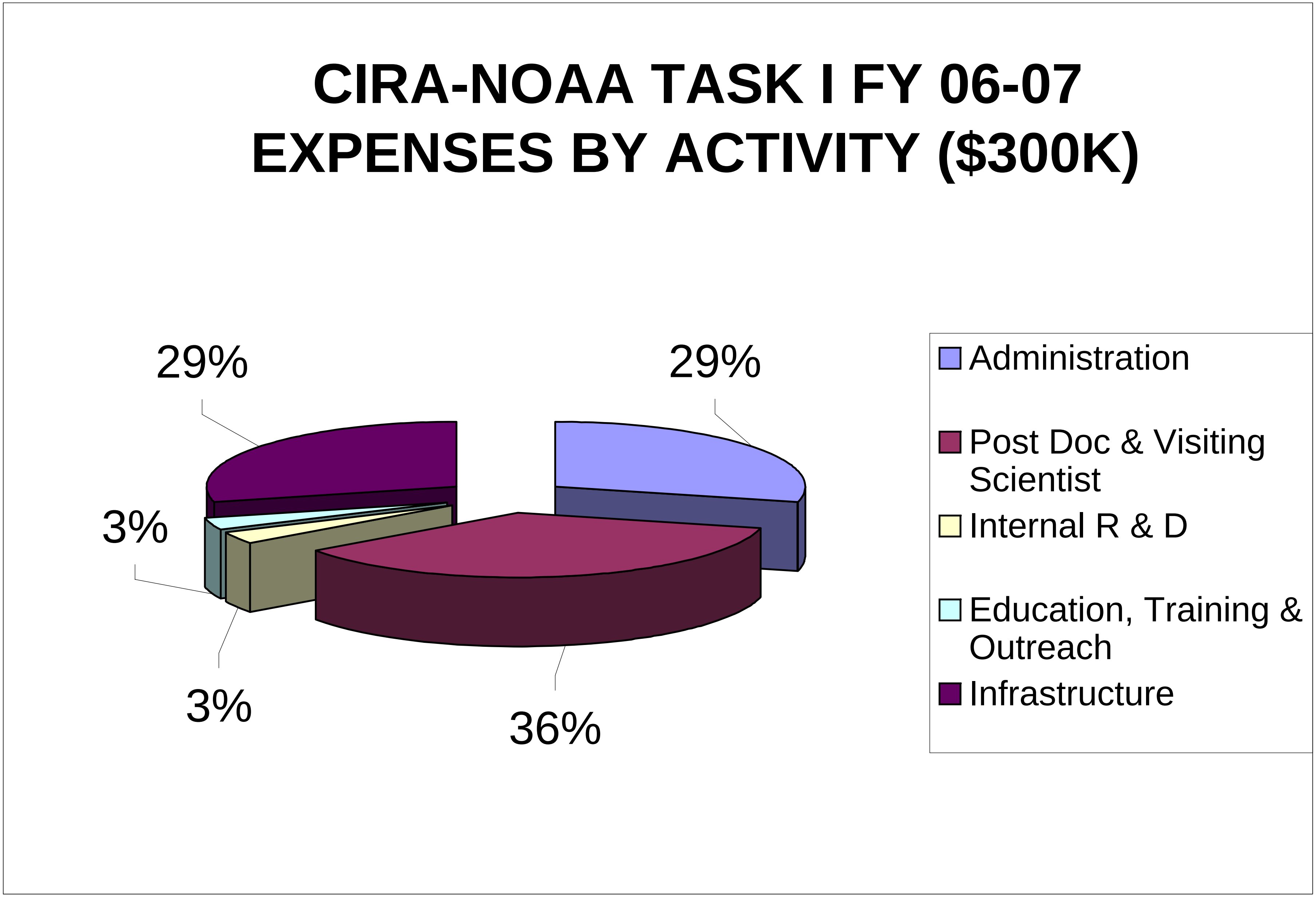
Societal and Economic Impacts

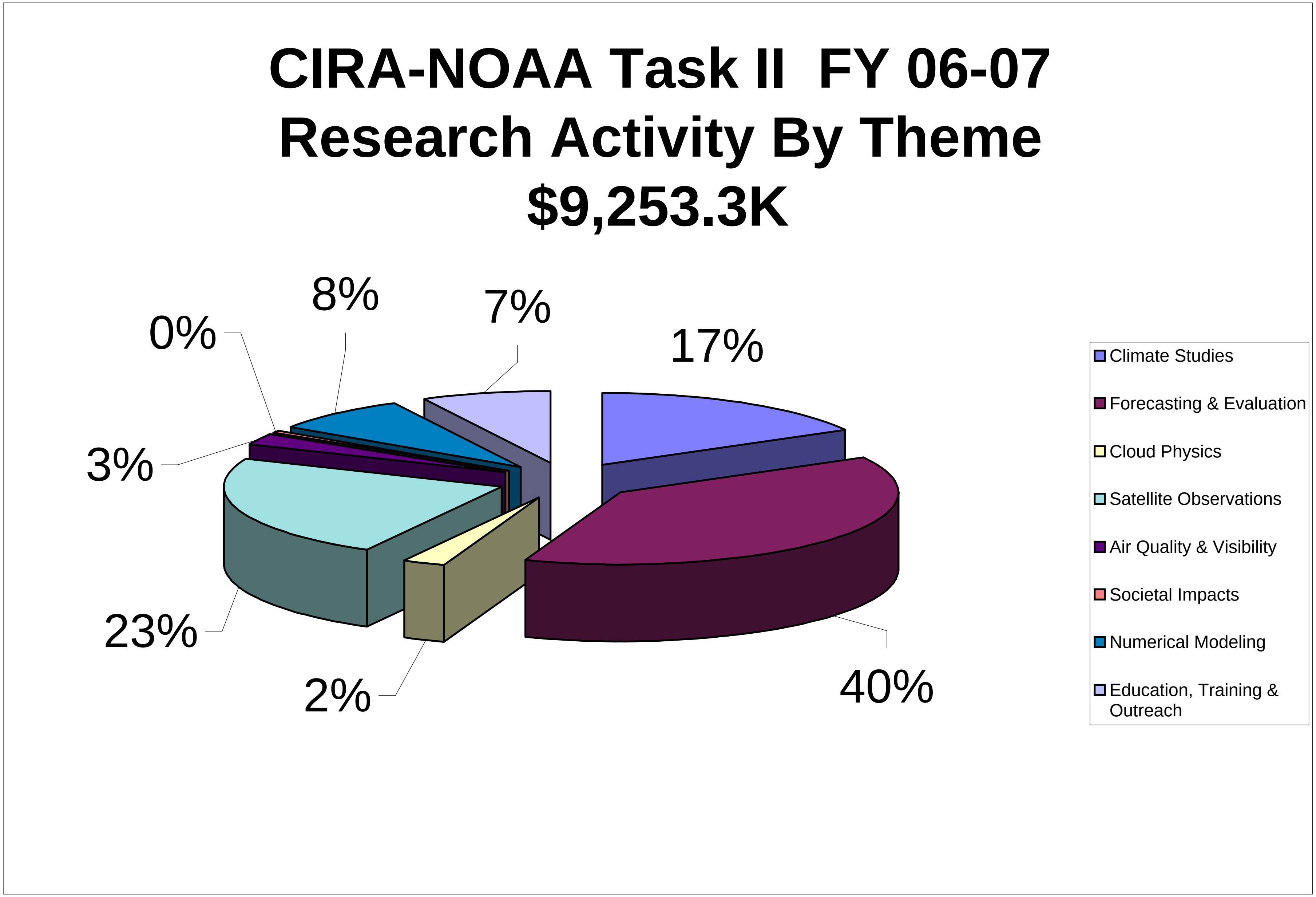
--The objective of the FX-Collaborate (FXC) project is to develop an interactive display system that allows forecasters / users at different locations to collaborate in real-time on a forecast for a particular weather or weather-dependent event. FXC is currently being implemented and or evaluated for 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. This year's effort focused on improving the output from the HYSPLIT model and enhancing the system functions. In collaboration with other GSD staff, the input weather model for HYSPLIT was shifted to NAM12 since it provided better temporal and spatial resolution. Also, the HYSPLIT control parameters were adjusted to provide a better representation of the plume.

--Dr Deo's work on product improvement and customer fitness using Census data for severe weather watches and warnings received a Regional Excellence Award in Oct 2006.

Infrastructure

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


CIRA-NOAA TASK I FY 06-07
EXPENSES BY ACTIVITY ($300K)
29%
29%
3%
3%
36%
Administration
Post Doc & Visiting Scientist
Internal R & D
Education, Training & Outreach
Infrastructure


CIRA-NOAA Task II FY 06-07
Research Activity By Theme
$9,253.3K
0%
8%
7%
17%
3%
23%
2%
40%
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 a paper summarizing its performance (see below).

3. Comparison of Objectives Vs. Actual Accomplishments:

--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. “In progress.”

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:

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 (see the publication listed below).

6. Awards/Honors: None to date.

7. Outreach:

<u>Conference and meeting presentations</u>

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Rocky Mountain Research Station, USDA Forest Service, 8 December, Fort Collins, Colorado. Invited presentation.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Tsukuba University, October 18, Tsukuba, Japan. Invited presentation.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Frontier Research Center for Global Change, October 13, Yokohama, Japan. Invited presentation.

Liston, G. E., 2006: How can we link large-scale atmospheric and climate features with small-scale alpine snow processes? Alpine Snow Workshop, University of Munich, October 5-6, Munich, Germany. Invited keynote address.

Liston, G. E., C. A. Hiemstra, K. Elder, and D. Cline, 2006: Local- to basin-scale snow distributions for the Cold Land Processes Experiment (CLPX). American Geophysical Union, Fall Meeting, 11-15 December, San Francisco, California.

Liston, G. E., and L. Lu, 2006: Merging MicroMet and SnowModel to create high-resolution snow distributions in complex terrain. NOAA CPPA PI's Meeting, 14-16 August, Tucson, Arizona.

Liston, G. E., and L. Lu, 2006: A meteorological distribution system for high resolution terrestrial modeling (MicroMet). Integrated Land Ecosystem-Atmosphere Process Study (iLEAPS) Science Conference, 21-26 January, 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.

Lu, L., G. E. Liston, A. S. Denning, and R. A. Pielke, 2006: Characterizing the local-scale terrestrial processes within global climate-system models. The 10th Three-Sphere Interaction Workshop, 1 September, Beijing, China.

Lu, L., and G. E. Liston, 2006: Further development of the high-resolution meteorological distribution system, and its application to land-surface process modeling. Western Pacific Geophysics Meeting, 24-27 July, Beijing, China.

Lu, L., G. E. Liston, A. S. Denning, and R. A. Pielke, 2006: Characterizing the local-scale terrestrial processes within global climate-system models. The 8th Three-Sphere Interaction Workshop, 10-12 January, Beijing, China.

8. Publications:

Liston, G. E., and K. Elder, 2006: A meteorological distribution system for high-resolution terrestrial modeling (MicroMet). J. Hydrometeorology, 7, 217-234.

Liston, G. E., and K. Elder, 2006: A distributed snow-evolution modeling system (SnowModel). J. Hydrometeorology, 7, 1259-1276.

Liston, G. E., C. A. Hiemstra, K. Elder, and D. W. Cline, 2007: Meso-cell study area (MSA) snow distributions for the Cold Land Processes Experiment (CLPX). J. Hydrometeorology, in review.

Liston, G. E., D. L. Birkenheuer, C. A. Hiemstra, D. W. Cline, and K. Elder, 2007: NASACold Land Processes Experiment (CLPX): Atmospheric analyses datasets. J. Hydrometeorology, in review.

A SATELLITE ANALYSIS OF ATMOSPHERIC RIVERS

Principal Investigator: T.H. 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.

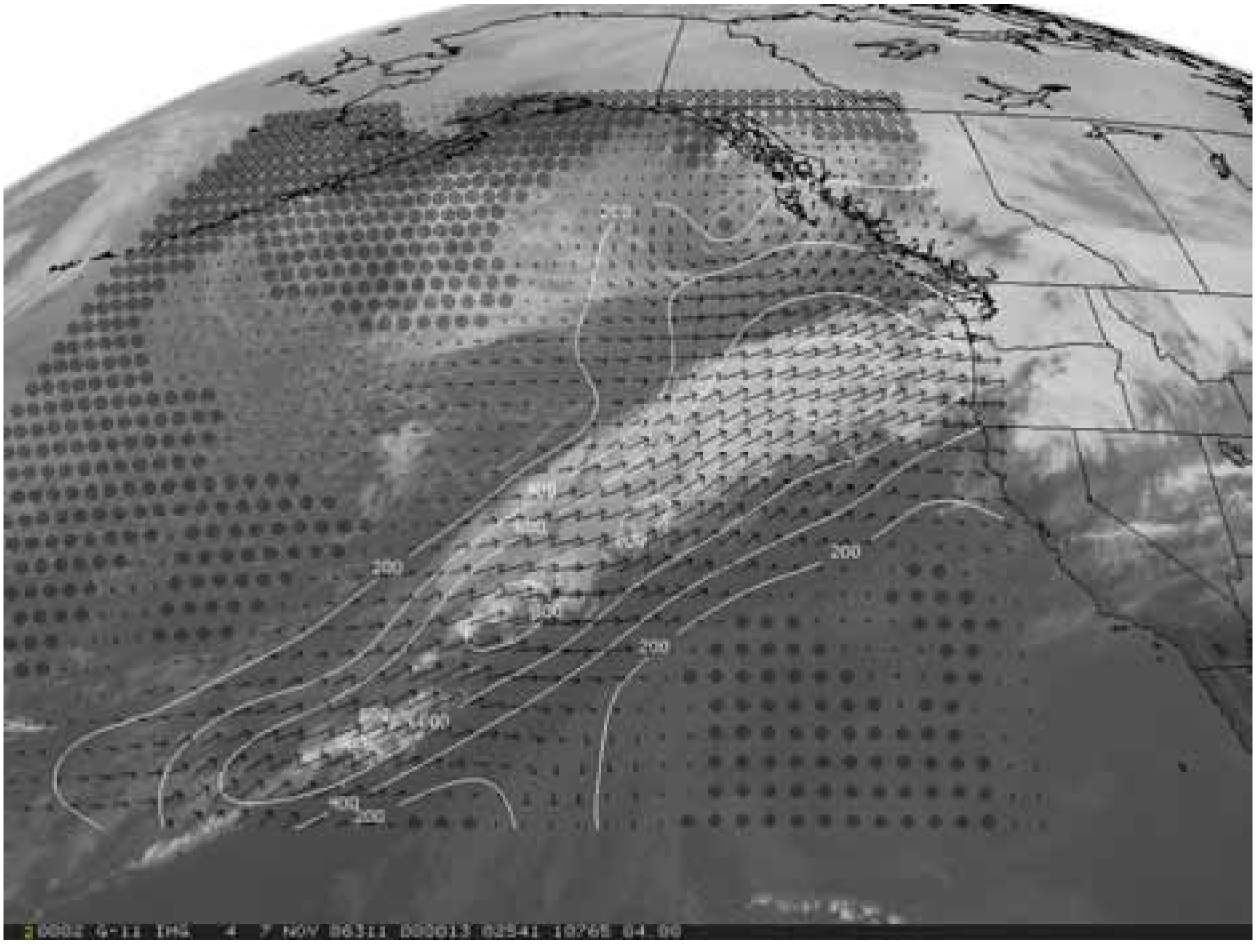


Figure 1. Total column water vapor flux vectors for the 7 November 2006 atmospheric river event. The winds used in the computation are from the nonlinear balance equation. The magnitude of the flux is contoured in units of kg m^{-1} s^{-1}.

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.

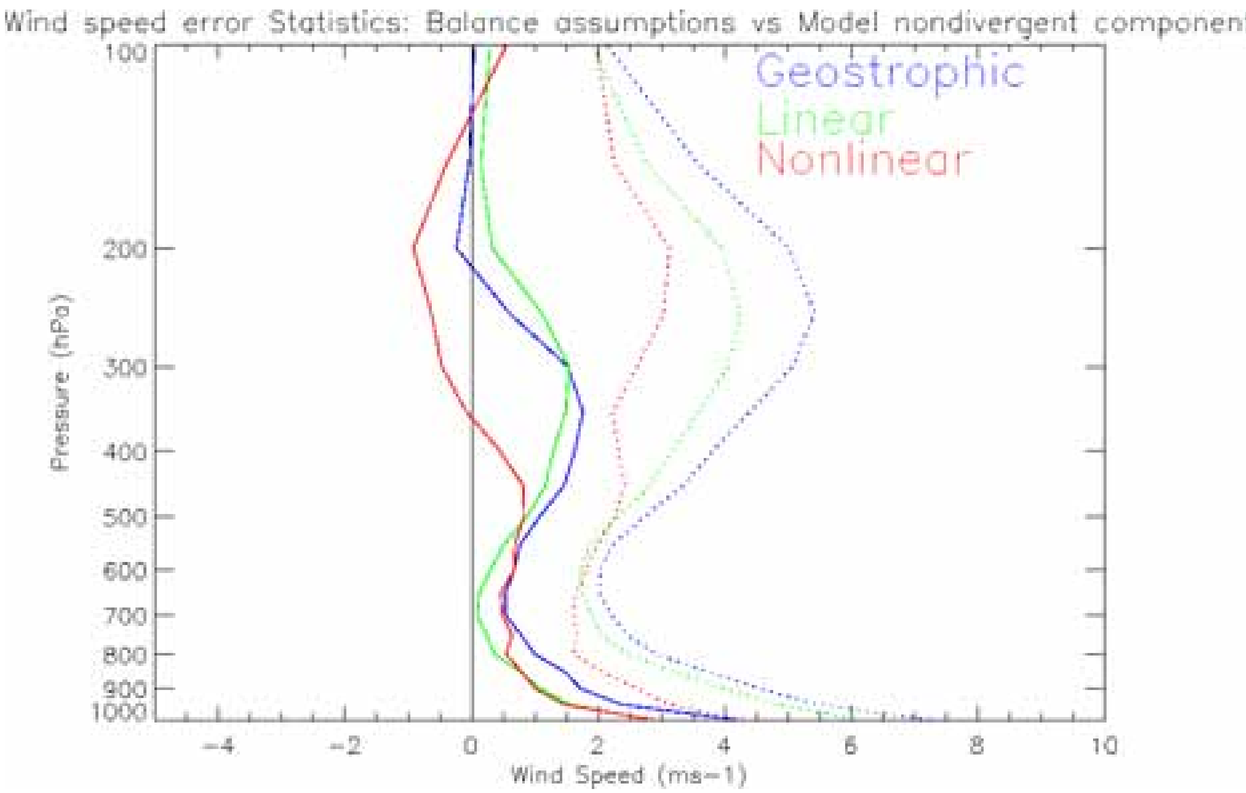


Figure 2. Using the height field from the GFS model, the winds associated with the geostrophic, linear, and nonlinear balance were compared to the model's nondivergent wind component.

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.

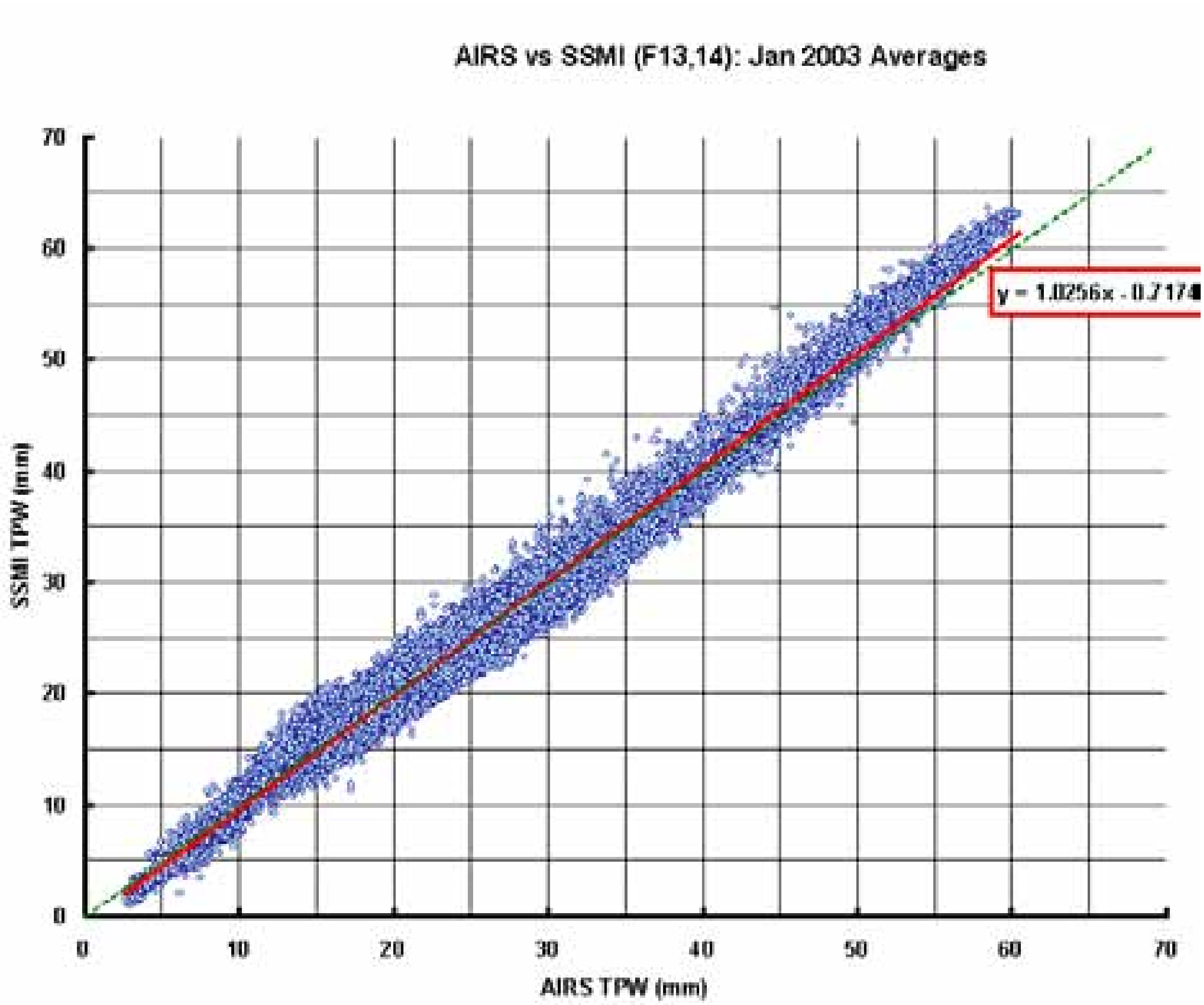


Figure 3a. Comparison of TPW as measured from AIRS and SSM/I.

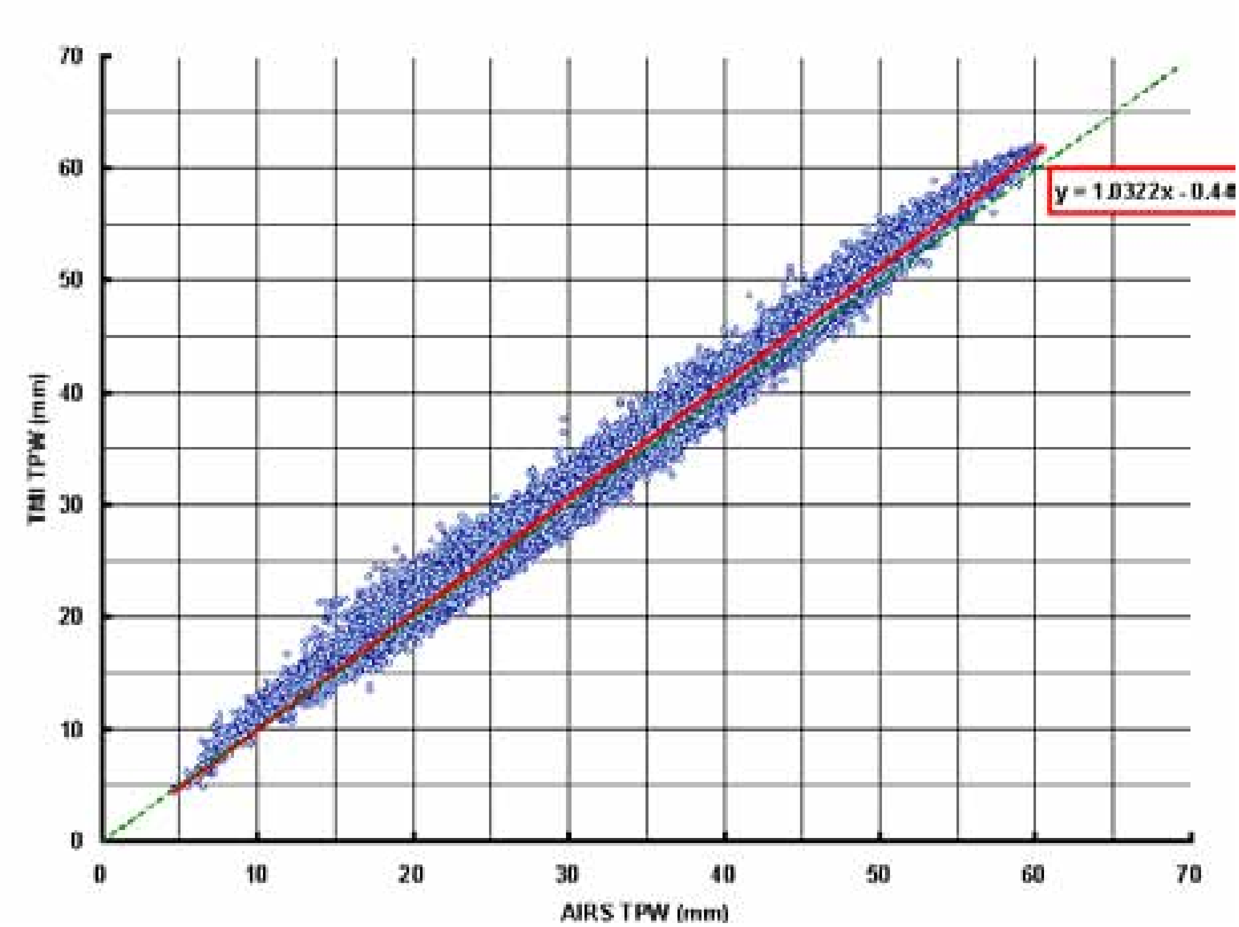


Figure 3b. Comparison of TPW as measured from AIRS and TMI.

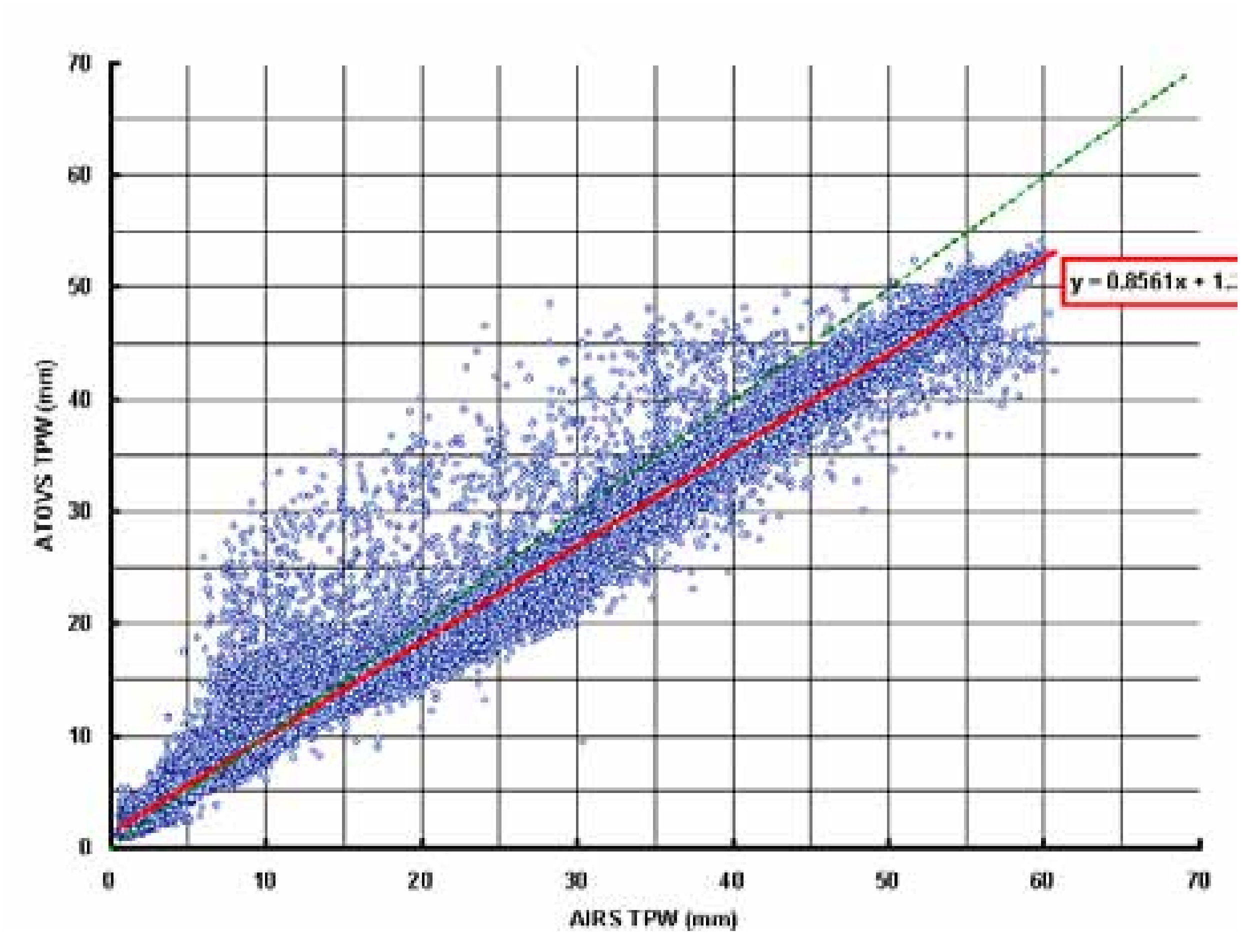


Figure 3c. Comparison of TPW as measured from AIRS and ATOVS.

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. Levergaing/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 communictation 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:

(a) 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.

8. Publications:

<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.

ADVANCED ENVIRONMENTAL SATELLITE RESEARCH SUPPORT

Principal Investigator: James F.W. Purdom

NOAA Project Goal: Weather and Climate

Key Words: Future Satellite Systems, Advanced Satellite Data Utilization, Satellite Training, GOES-R System Architecture

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

Advanced environmental satellite research to investigate advanced utilization of systems and satellite-derived information for current and future satellite systems through presentations and publications on satellite data utilization; global leadership for evolution of the Global Observing System; recommendations for future NOAA satellite system evolution; international outreach and training activities.

2. Research Accomplishments/Highlights:

--Asia Pacific Satellite Training Event (APSATS 2006) and CGMS/WMO High Profile Training Event (HPTE), Melbourne, Australia, October 15-October 31

--Lectures provided to APSATS 2006 students on satellite data utilization
--High Profile Training Event brought to fruition, exceeds expectation

--Sole Author of three of the four core lectures which were used globally for the HPTE – this included PowerPoint with detailed notes for each slide and animation as well as providing VISITView format lectures with notes and voice

--Spectral Bands and Their Applications
--Severe Weather and Heavy Rainfall
--Satellite Capabilities and Use of the Virtual Laboratory

--Leading WMO in addressing the role of satellites in the redesign and evolution of the Global Observing System.

--Investigations of the spectral, spatial and temporal requirements for geostationary satellites as part of a space based Global Observing System, with particular emphasis on satellite system synergy

3. Comparison of Objectives Vs. Actual Accomplishments:

4. Leveraging/Payoff:

Research and training activities under this activity will help NOAA define future satellite systems while helping assure full utilization near the beginning of the systems space life. Early utilization is worth approximately $60,000 per day of satellite lifetime.

5. Research Linkages/Partners/Collaborators and Planning Activities:

--WMO's Members through Chairing Commission on Basic Systems (CBS) Open Program Area Group (OPAG) on Integrated Observing Systems (IOS) and as a member of the WMO CBS Management Group

--WMO Representative to the Coordination Group for Meteorological Satellites (CGMS) which includes heads of all operational and many research satellite agencies or their representatives

--Co-Chairing the WMO CGMS Virtual Laboratory for Satellite Data Utilization and Training Focus Group which joins together major satellite operators and WMO Centers of Excellence for Global Satellite Training

--Planning on the future use of satellite data as part of the THORPEX International Implementation Planning Team

--Co-chair of THORPEX Observing System Working Group that is setting goals and objectives for both pace-based and in-situ observing systems to support THORPEX

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

6. Awards/Honors: None during this period

7. Outreach: Committees and advisory roles

--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 to World Meteorological Organization (WMO) at WMO Congress

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

--Member WMO Commission on Basic Systems Management Group

--Chair, GOES-R Algorithm Working Group Technical Advisory Committee

--Member GOES I/M Technical Advisory Committee

--Member GOES R Risk Reduction Technical Advisory Committee

--Member THORPEX Executive Board

--Member NAS Panel on Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft

--Member NRC committee on Multipurpose Mesoscale Observing Networks

8. Publications:

Refereed Publications

Chapter 44 and 51 “The Space-Based Component of the World Weather Watch’s Global Observing System (GOS)” and “The CGMS/WMO Virtual Laboratory for Education and Training in Satellite Matters” for 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. I was co-author with Donald Hinsman on Chapter 44 and lead author with Hinsman on Chapter 51.

Internationally Invited Presentations

Asia Pacific Satellite Training Event (APSATS 2006) and CGMS/WMO High Profile Training Event (HPTE), Melbourne, Australia, October 15-October 31 (see Highlights section)

Invited Presentations at Workshops and Conferences

Participated on IGARSS panel on “Reducing Disaster Losses through Earth Observations” that was chaired by Helen Wood of NOAA, July 31, 2006.
Invited presentation: “Focusing Earth Observation Technology to Reduce the Impact of Severe Weather hazards”

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

Principal Investigator: B.H. Connell

NOAA Project Goal: Weather and Water

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

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

Long term research goals include: 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:

The AWIPS component of the project is operational. In addition, hardware for the latest NWS Weather Event Simulator (WES) has been procured and configured. The AWIPS and WES provide RAMMB/CIRA researchers with both real-time forecast and archived case review capabilities. Hardware for case study data archive has been procured and installed. To date, 4 severe weather cases have been archived. One of the cases is being used for a WES simulation that will be made available to the field. The other 3 cases will be used in VISIT and perhaps future ShyMet teletraining.

Efforts to transition the CIRA Wind Regime Cloud Climatology application and database to the AWIPS environment are underway. After initial meetings with forecasters and Science and Operations Officers in Cheyenne, WY, software to run the Graphical Forecast Editor (GFE) used in NWSFO's has been installed. Additional climatologies are being implemented in collaboration with the Eureka, CA, forecast office and will then be ported to the GFE.

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

The project is on schedule of its goal to complete NOAAPORT/AWIPS implementation and begin collaboration with NWSFO's to port RAMMB/CIRA applications by fall 2007.

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

Several of the training cases were presented at the COMAP symposium at COMET in June 2007.

8. Publications: None as yet

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

Principal Investigator: Dr. 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 rain gauges, 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 also will 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 is being 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 are being 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 US. 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 data products 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.

In Progress – We have published a journal article on the initial findings of these analyses (Lang et al. 2007). The Ph.D. student on this grant is due to finish his work in December and will submit for publication thereafter.

In Progress – The M.S. student on this grant is wrapping up this work this summer and will defend and submit for publication soon.

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 rain gauge data, and analysis of the data

Vaisala Corporation – Providers of long-range NLDN data

6. Awards/Honors: None as yet

7. Outreach:

(a.) L. Gustavo Pereira, Ph.D. candidate

(b.) 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. 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.

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. 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.

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. 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.

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

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 and 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 to above:

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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.

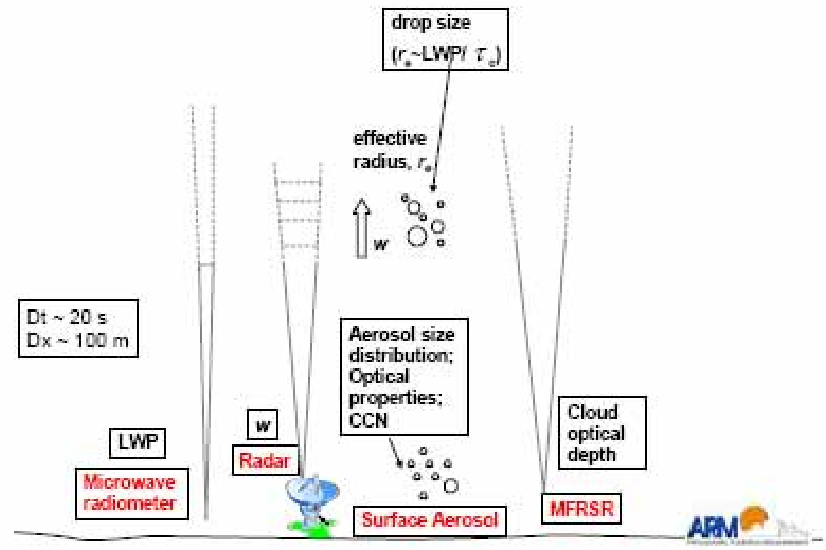
Twomey, S., 1977: The influence of pollution on the short wave albedo of clouds. J. Atmos. Sci., 34, 1149-1152.

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.

Figure 1 shows the experimental set-up at Point Reyes, CA during 2005.



Schematic of experimental set-up of AMF at Point Reyes, CA, 2005

Primary instruments are the microwave radiometer (LWP), cloud radar (updraft), MFRSR (τ_c) and various *in situ* surface aerosol instruments (CCN and aerosol optical properties). Drop size and concentration are retrieved from LWP and τ_c. (Drop concentration is derived assuming adiabatic cloud.)

Variable names for cloud and aerosol properties

LWP: liquid water path (gm^{-2})

τ_c: cloud optical depth

r_e: cloud drop effective radius (values presented here have been determined by the relationship 1.5(LWP/ τ_c)

N_{CCN}: cloud condensation nucleus concentration (cm^{-3}); concentrations presented here are at supersaturation of 0.5-1.0%

N_d: cloud drop concentration (cm^{-3})

σ_{sp}: aerosol light scattering (0.55 μm) (Mm^{-1})

åi: aerosol index, the Ångström exponent (0.45/0.75 μm), **å* σ_{sp}**

Figure 1. Experimental set up (from Aerosol-Cloud Interaction Studies at Point Reyes, CA by McComiskey, Feingold, Frisch, Turner, Min, and Miller, 2007)

Figure 2 shows a summary of the results of the study.

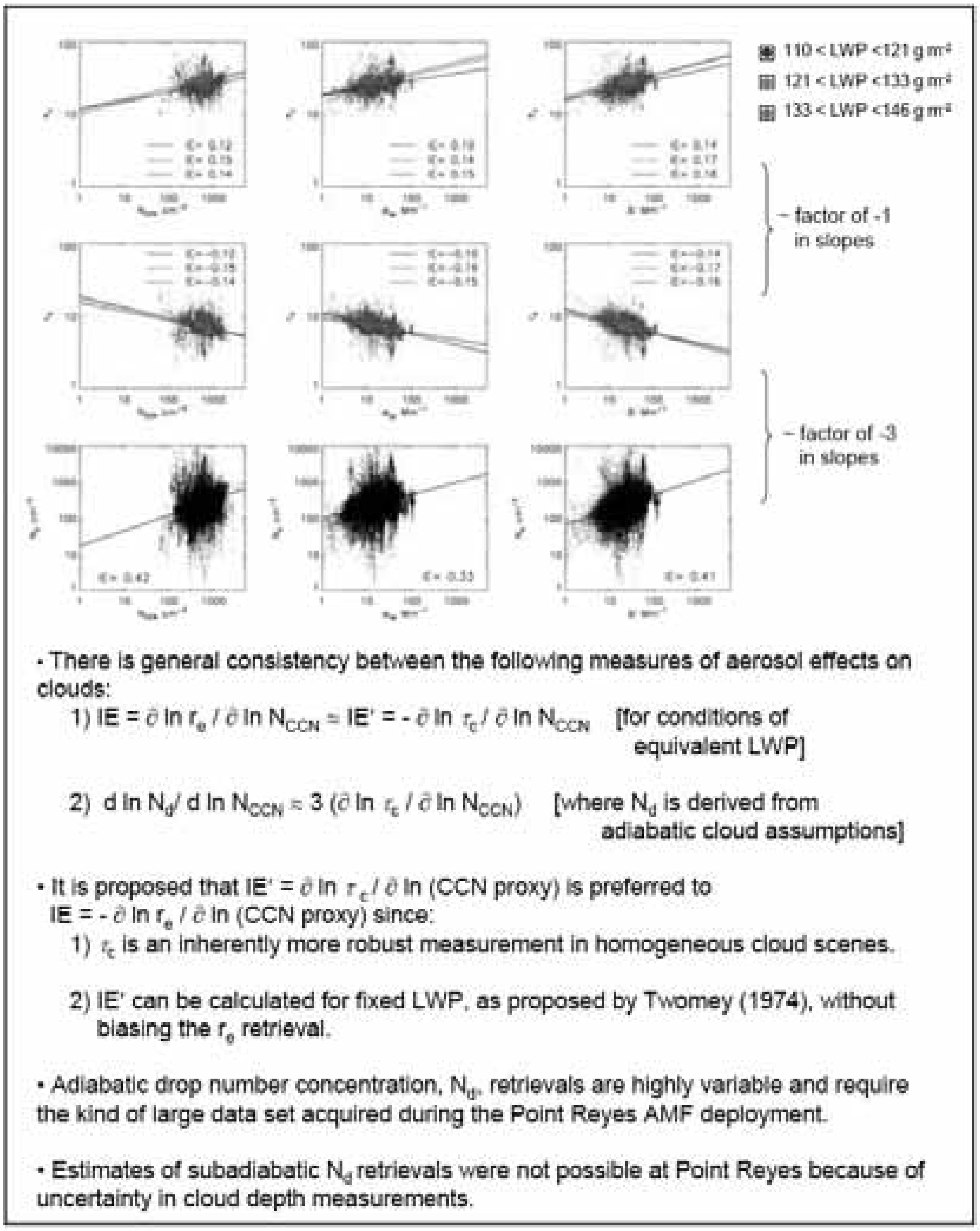
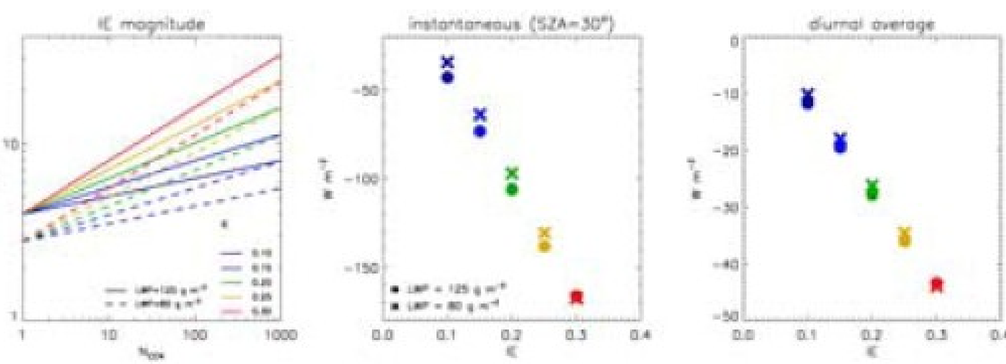


Fig. 2. (from Aerosol-cloud interaction studies at Point Reyes, CA by McComsikey, Feingold, Frisch, Turner, Min, and Miller, 2007).

Figure 3 shows the uncertainties in IE' translated into large uncertainties in the radiative forcing per unit change in IE'.

Radiative transfer modeling has been used to establish the sensitivity of cloud forcing to anthropogenic aerosol influences.The shortwave (0.28 - 4.0 μm) radiative forcing was calculated for the range of IE′ values.

The change in cloud optical depth with increasing CCN, used as model input, is shown for the range of IE′ at two fixed LWP. Instantaneous and average forcings are calculated for these IE′ as the difference in irradiance for N_{CCN} = 500 cm^{-3} and N_{CCN} = 25 cm^{-3}. Forcing at the surface is shown here.



Uncertainties in IE′ = $\partial \ln \tau_c / \partial \ln N_{CCN}$ translate to large uncertainties in radiative forcing per unit change in IE.

LWP = 125 gm^{-2}
- instantaneous: 19 W m^{-2}
- average: 4 W m^{-2}

LWP = 80 gm^{-2}
- instantaneous: 36 W m^{-2}
- average: 7 W m^{-2}

Fig. 3. (from Aerosol-cloud interaction studies at Point Reyes, CA by McComsikey, Feingold, Frisch, Turner, Min, and Miller, 2007).

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

4. Leveraging/Payoff:

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

University of Colorado Boulder, NASA and DOE

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

McComiskey, A., G. Feingold, S. Frisch, Q. Min, D. Turner, and M. Miller, 2007: Aerosol-cloud interactions at Point Reyes, California, ARM Science Team Meeting, Monterey, CA, March 26-30, 2007.

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 to develop proxy GOES-R data for mesoscale weather and hazard events using a sophisticated cloud model and accurate radiative transfer modeling. ABI radiances will be provided for six case studies, along with the model fields for “ground truth”. These case studies include a severe weather case, a lake effect snow case and two hurricane cases. Also included will be simulations of fire hotspots embedded in the severe weather case as well as an additional fire case in the tropics that contains both cloudy and clear regions. AVHRR and MODIS data for tropical cyclone cases will be provided as proxy GOES-R data for the tropical cyclone intensity algorithm development. The simple version of the Objective Dvorak Technique for hurricane intensity will be applied on the dataset as a preliminary test.

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:

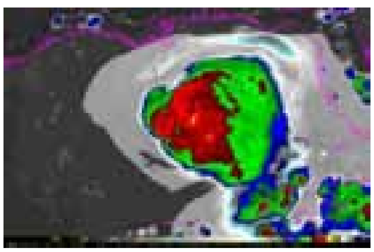
The goal of this project is to develop proxy GOES-R data for mesoscale weather and hazard events. The project can be split into two categories:

A) Mesoscale simulations and fire hot spot proxy data and B) Tropical Cyclone Proxy Data and Intensity Estimation Algorithm.

A) Mesoscale simulations and fire hot spot proxy data

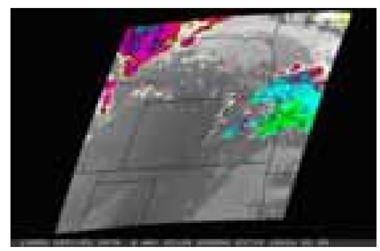
Synthetic GOES-R ABI imagery was produced for three different mesoscale weather events: A severe weather event which developed over the mid-western United States in May 2003, a lake-effect snow storm which occurred in February 2002, and hurricane Lili from October 2003.

Using the CSU RAMS mesoscale model, which can be considered a state of the art mesoscale model with unique capabilities for producing cloud properties for various weather events, forecast fields ("ground truth") were produced every 5 minutes for a total forecast period of 6 hours. Simulated radiance and brightness temperature fields for the ten upper GOES-R ABI channels were derived from these fields (band 7 through 16).



Hurricane Lili Oct 2002

Lake Effect Snow Feb 2003



Severe Weather May 2003

Figure 1. Synthetic imagery of the three mesoscale events: GOES-R at 10.35 µm 2 km.

Idealized fire "hot spots" were added into the 8 May 2003 severe weather case with the objective to enable the development and testing of fire algorithms. 135 equally spaced fire hot spots of different temperature and different size were inserted into the simulations to generate radiance fields under a variety of conditions.

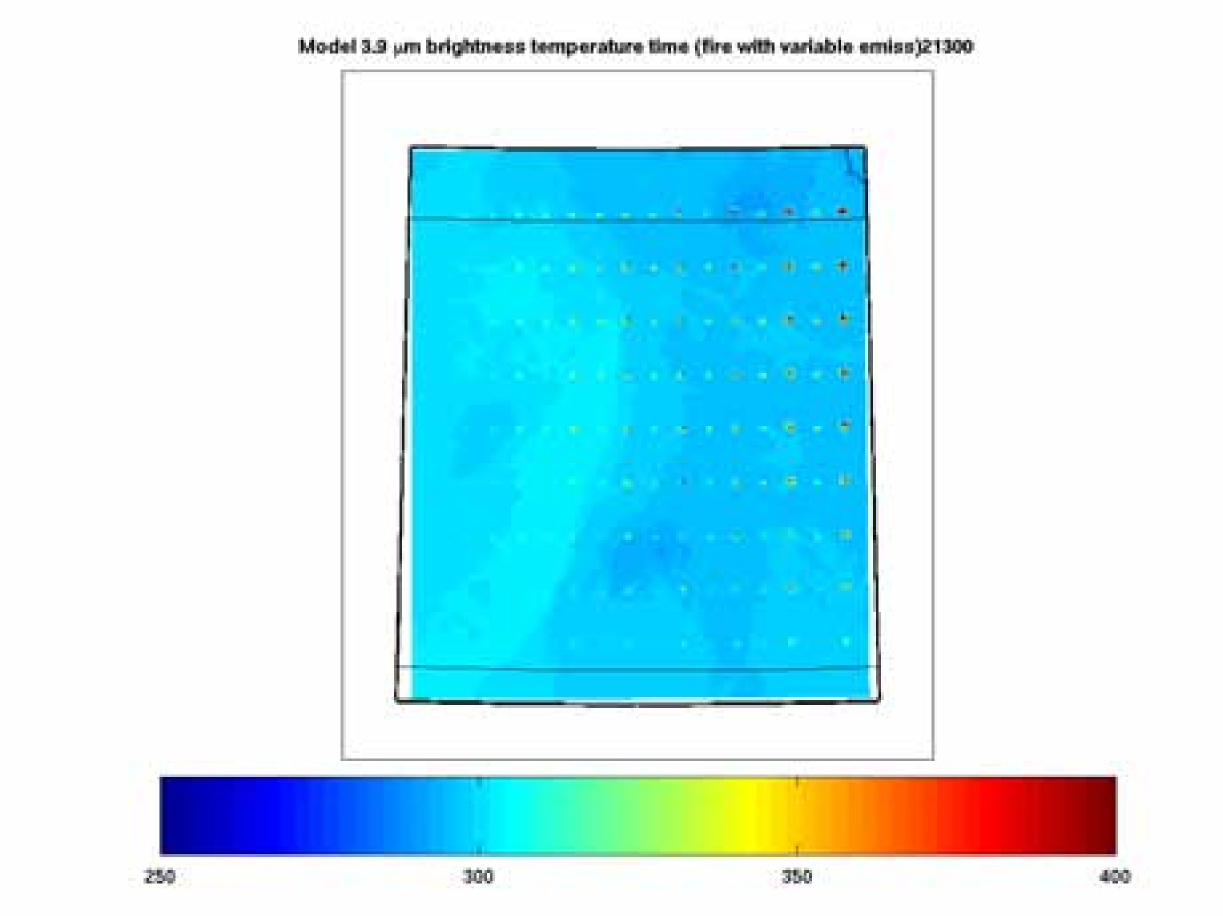


Figure 2. GOES-R 3.9 µm brightness temperature for 135 equally spaced fire hot spots. The fire temperature ranged from 400K (bottom) to 1200K (top) in 100 K intervals, the fire hot spot size increases from left to right.

Software has been written to create (McIDAS) AREA files for simulated GOES-R ABI radiances generated by model output. The particular case of interest consists of artificial fire hot spots, to see how they will appear in future GOES imagery. This required the use of McIDAS 2007 which includes (simulated) ABI calibration and navigation modules. One interesting aspect that was investigated is how identical fires (with the same size and temperature) will appear as GOES-R ABI grid samples. Results of these tests showed clearly "significant" differences that are observed due to how ABI samples the data, even without using fancy regridding/resampling techniques. Our conclusion is that sampling/regridding issues are very important for fire detection/monitoring. We also found that fires will not saturate for GOES-R ABI band-7 (3.9 µm) until 400 K, compared to about 340 K for current GOES imagery.

B) Tropical Cyclone Proxy Data and Intensity Estimation Algorithm

MODIS and AVHRR imagery has been collected for tropical cyclone research. This imagery will be used to simulate resolutions similar to what will be available from

GOES-R. The imagery resolution was degraded from 1 to 2 km (for simulated imagery of GOES-R) and from 1 to 4 km (for comparison to the current GOES). A database of a wide variety of 11 tropical cyclone cases at each of these resolutions was assembled and archived. There are a minimum of 9 and a maximum of 81 individual "scenes" (imagery at a certain date and time) for these storms. For each scene we stored: polar full imagery, time-matching (as close as possible) full-size current GOES IR, AVHRR or MODIS IR 1km, reduced resolution IR 2km (resembling the GOES-R footprint), reduced resolution IR 4km (resembling the current GOES footprint), and current GOES IR 4km. All scenes are available in McIDAS and in GIF format. An accompanying BestTrack ground truth dataset was also created.

Storm Name & Year	Scenes	Size (MB)
Lili 2002	21	150
Isabel 2003	66	469
Emily 2005	41	286
Katrina 2005	59	392
Rita 2005	45	318
Stan 2005	13	93
Wilma 2005	66	470
Alpha 2005	8	58
Beta 2005	9	66
Hilary 2005 (EP)	12	87
Ernesto 2006	28	201
Total	**368**	**2590**

Table 1. Archives storm names, years, scenes and image sizes.

A website was developed which allows for access to all of the archived gif imagery. The website URL is: http://rammb.cira.colostate.edu/projects/awg

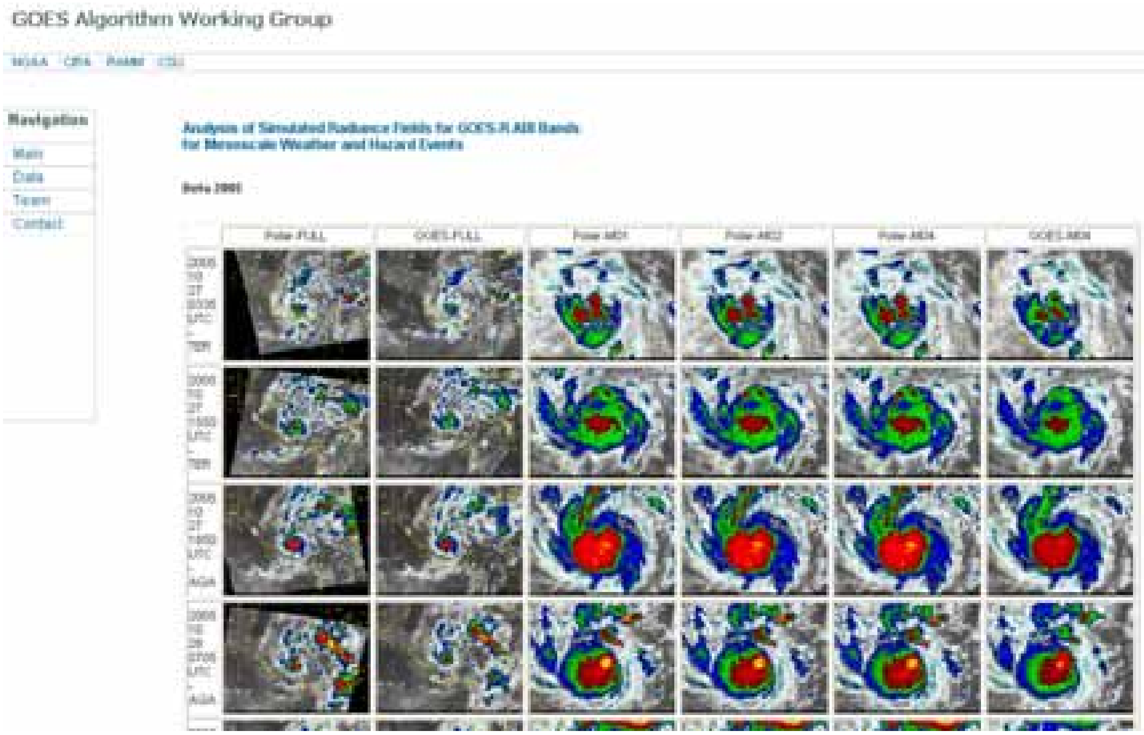


Figure 3. The Tropical Cyclone Webpage displaying the Hurricane Beta data page

The simulated proxy dataset was used to investigate the impact of the GOES-R resolution on the CIRA/RAMM digital Dvorak tropical cyclone intensity calculation.

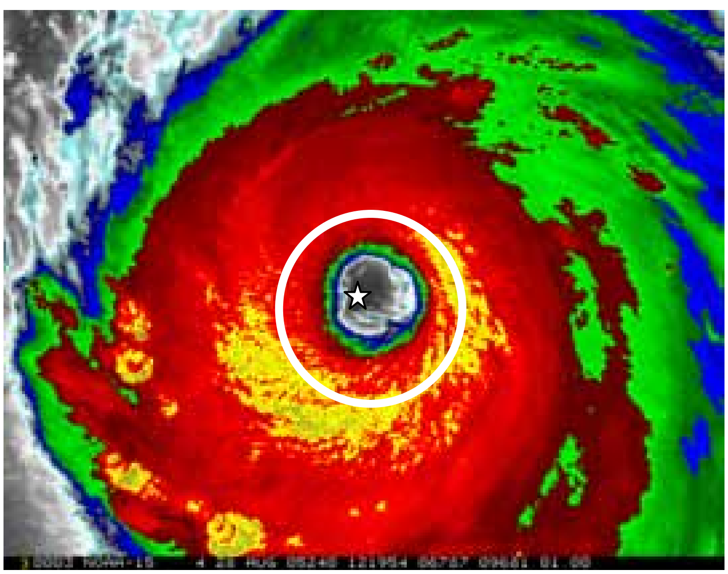


Figure 4. Katrina 28 Aug 2005 1219 UTC 909 hPa. Marked in white are a star at the center and a circle going through the coldest surrounding temperature. The warmest pixel near the center is the eye temperature.

The results of the CIRA/RAMM digital Dvorak algorithm have been compiled with the following records: Dvorak intensity (T-number to the nearest 0.1), Eye temperature, Surrounding temperature, Dvorak intensity converted to maximum wind speed (Vmax), Dvorak intensity converted to central pressure (MSLP, minimum sea-level pressure). Those records are compiled for each image type using each of the 2 center positions. In addition, differences of those quantities are compiled using the Ground Truth Datasets.

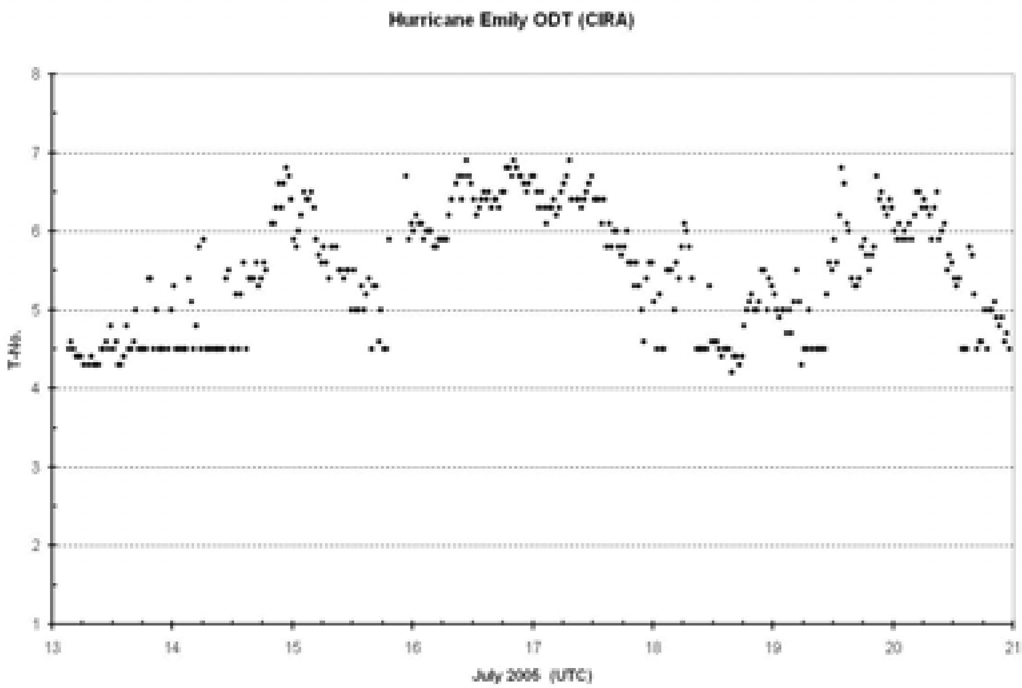


Figure 5. Digital Dvorak "Intensity T-Number" computations for Hurricane Emily using 30-min interval GOES IR images.

First results of the digital Dvorak algorithm measurements seem to indicate that the impact of the improved GOES-R spatial resolution on hurricane intensity estimates will most likely be quite small.

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 receive 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 and CIMSS

6. Awards/Honors: None as yet

7. Outreach:

a) A college undergraduate student is supported by this project (Greg DeMaria).

8. Publications:

Presentations:

DeMaria, M., 2007: Description of the CIRA AWG project to develop proxy data for mesoscale weather events and fire hot spots. GOES-R Algorithm Working Group (AWG) Meeting, Leesburg, VA, 14-18 May.

Publications:

Grasso, L.D., M. Sengupta, J.F., Dostalek, R. Brummer, and M. DeMaria, 2007: Synthetic Satellite Imagery for Current and Future Environmental Satellites. International Journal of Remote Sensing. (Paper was accepted with revision and is still pending).

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

Principal Investigator: J.A. Knaff

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:

Operational tropical cyclone intensity forecasting skill continues to lag that of track forecasting. One limitation is the proper inclusion of ocean feedback effects, which depend on the surface and subsurface ocean structure. Several tasks are proposed to improve intensity forecasting through better use of sea surface height measurements from satellites. A spectrum of intensity forecast models is included, which ranges from simple statistically-based predictions to full three-dimensional coupled ocean-atmosphere systems. Methods to validate and improve ocean heat content retrievals are also proposed.

The CIRA portion of this work for this time period had two parts.

The impact of the OHC on the forecasts will be evaluated from a large sample of western North Pacific typhoon forecasts.

Maps of the OHC along the JTWC forecast tracks will be made available via a web site at CIRA for qualitative evaluation. Feedback on the utility of this web site will be obtained from Typhoon Duty Officers at JTWC.

2. Research Accomplishments/Highlights:

The STIPS intensity model that was run during 2006 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 311 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 ~ 2 % through 72 hours. This improvement has lead NRLMRY to use this version of the STIPS model for their STIPS consensus intensity forecasts which will make these improvements available to the forecasters at JTWC.

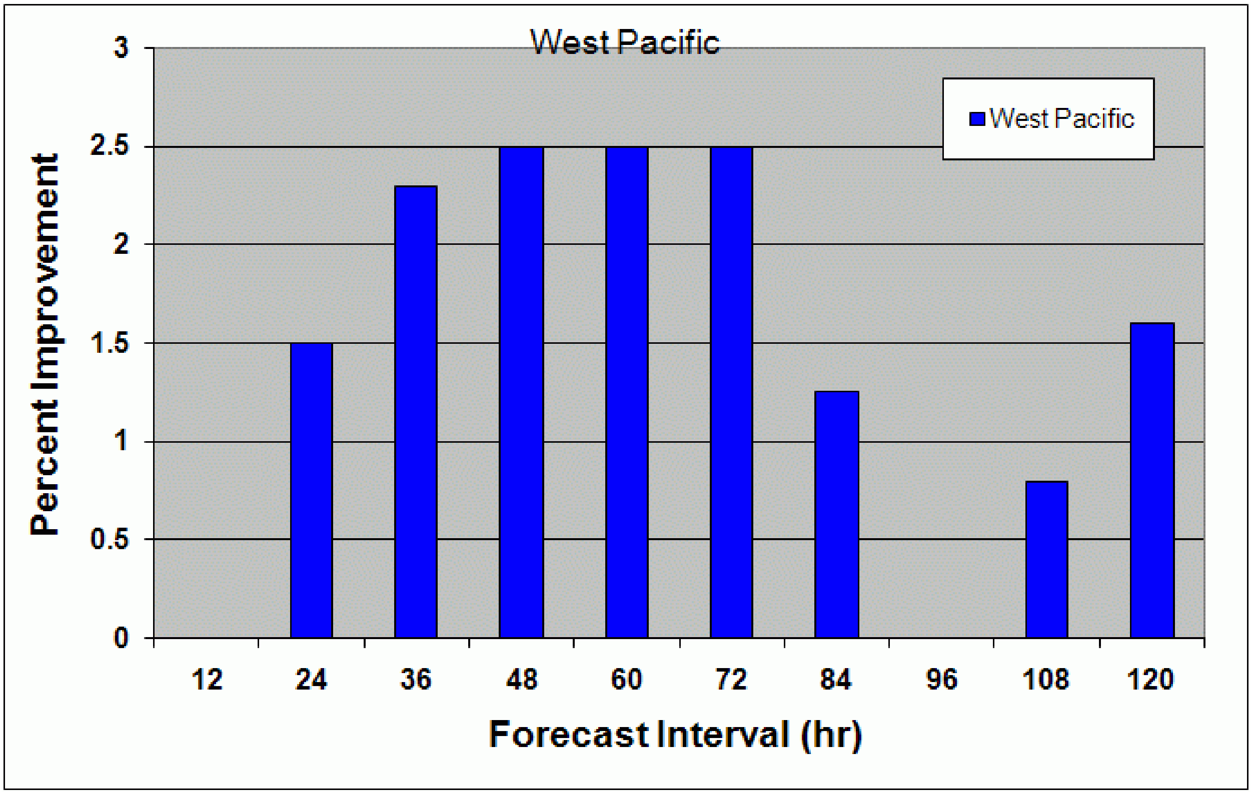


Figure 1. The percent improvement in the dependent version of the STIPS model at each forecast interval (blue bars) when TCHP is added as a predictor. The sample size is 311 STIPS forecasts.

The second task related to this project was also completed in October of 2006. Since that time maps of OHC with the forecast tracks overlaid have been available from the CIRA/RAMMB tropical cyclone web page (http://rammb.cira.colostate.edu/products/tc_realtime/index.asp) Figure 2 shows examples from Tropical Cyclone Dora in the South Indian Ocean and Typhoon Cimaron from the western North Pacific.

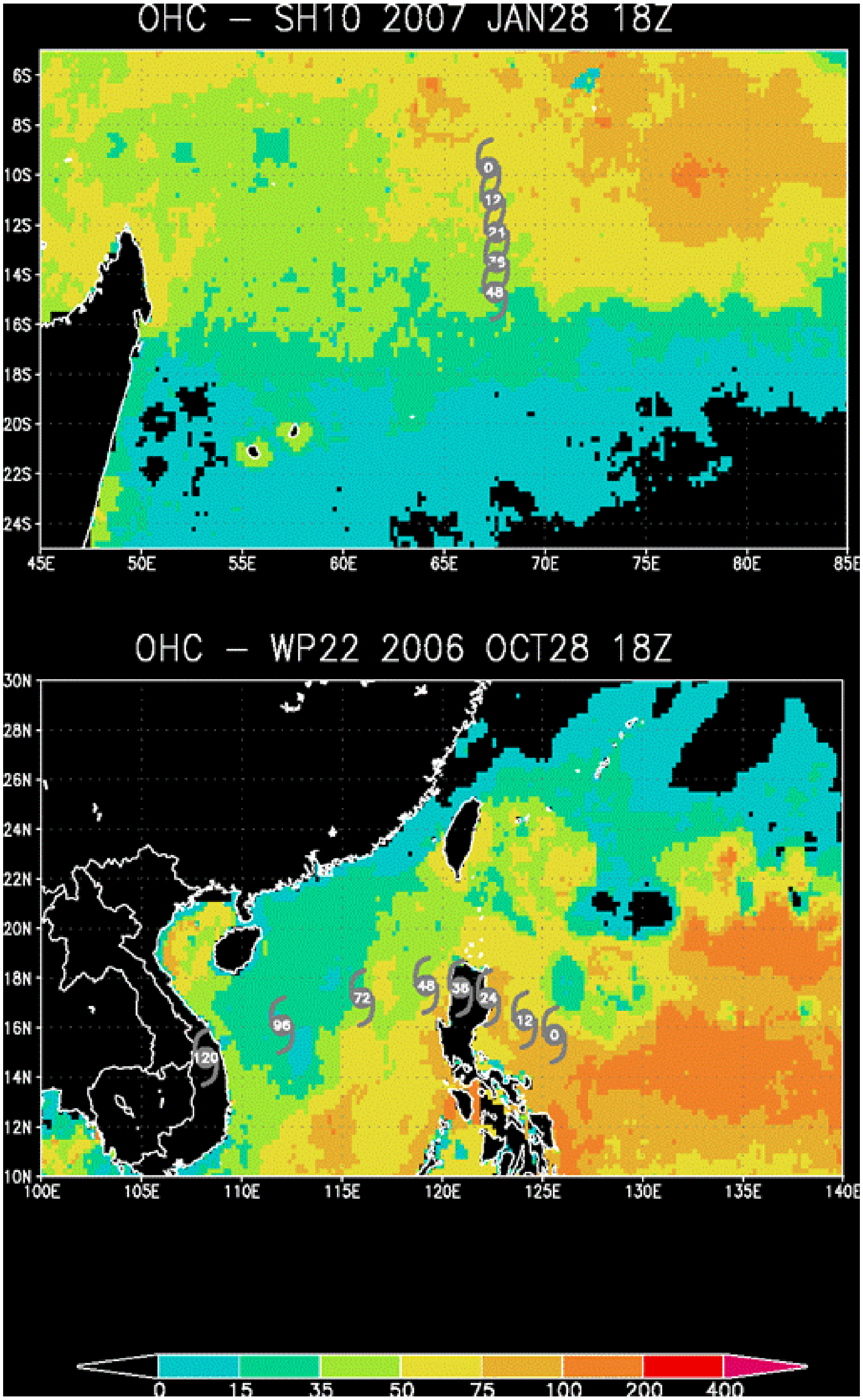


Figure 2. Examples of the OHC maps that are being generated at CIRA and disiminated via the web to forecasters at JtWC and other tropical cyclone forecast centers. The maps are of OHC in kJ/cm^2 with the latest JTWC forecast overlaid.

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 with NOAA, the university community, the Department of Defense. These including the NOAA/NESDIS Office of Research and Applications, the NOAA/NCEP TPC, NOAA/OAR/AOML, The Naval Research Laboratory, The Naval Research Laboratory in Monterey, The Joint Typhoon Warning Center, and Colorado State University.

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

<u>Refereed Journal Articles</u>

Mainelli, M., M. DeMaria, L. Shay, G. Goni, 2006: Application of Oceanic Heat Content Estimation to Operational Forecasting of Recent Atlantic Category 5 Hurricanes. Wea. Forecasting, in press.

<u>Presentations</u>

Knaff, J.A.,M. DeMaria, A. Krautkramer, B. Sampson, and G. Goni, 2007: Introducing the CIRA/NESDIS – Regional and Mesoscale Meteorology Branch Tropical Cyclone Web Page. *61st Interdepartmental Hurricane Conference*, 5-9 March, New Orleans, LA.

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

Principal Investigator: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: GOES, Imager, Sounder, product development

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

In early 1994, NOAA introduced a new geostationary satellite series, GOES-I/M. Recognizing the need to insure transition from GOES-7 to GOES-I/M day-1 products and beyond, NESDIS developed a GOES-I/M Product Assurance Plan, GIMPAP. The GIMPAP provides the means to assure the viability of GOES-I/M day-1 products, to improve initial products and develop advanced products, and to insure integration of the results into NESDIS operations.

The GIMPAP program at CIRA will help ensure the opportunities offered by the new GOES system for supporting NOAA's mission will be realized. It addresses evaluation and validation of GOES day-1 products, day-1 product enhancements and evolution toward future products and sensor systems. There are three major phases: a) during Pre-launch - simulations, establish baselines and ground system preparation; b) intensive 6 month to one year effort after launch of each GOES to evaluate the quality of Imager and Sounder data and assess their utility for product development and utilize the GIMPAP product management structure to assure that the initial GOES product stream is at least equal to or better than the same from previous GOES; and, c) on a continuing basis, as unique spacecraft characteristics become understood, enhance the initial product data sets to take full advantage of the GOES-I/M system to develop advanced meteorological and oceanographic products. In all phases CIRA plans an active role in technology transfer and user training.

At CIRA the means currently exist for the acquisition and analysis of ancillary data from selected platforms such as ground based profilers, radar, model output, aircraft, and other geostationary satellite data. GOES data are received both directly for analysis using CIRA unique software and processing systems as well as over Internet. Two basic type products validation activities are undertaken at CIRA: a) qualitative, such as satellite images or image loops; and, b) quantitative, such as winds, soundings and combined radiometric products. Product quality is measured relative to: current levels of performance for GOES-7; specified performance requirements for GOES-I/M; and user response.

2. Research Accomplishments/Highlights:

The contributions to the GIMPAP from the NESDIS/CIRA RAMM Team fall into the following categories: A) Product Development, B) Calibration/Validation, and C) Training. Accomplishments in each of these areas are listed below.

A. Product Development

1. Tropical Cyclones

The CIRA/RAMMB Tropical Cyclone Web Page, which displays global real-time tropical cyclone information with an emphasis on experimental or recently transitioned products developed at CIRA/RAMMB, was publicly introduced. The web site, which is integrated into a database for archival of past events, has been under development for six months and currently shows 10 products of which 3 are experimental, 2 are recently transitioned to operations, 2 are storm information related, and 3 are imagery products. This web site is a test-bed for obtaining user feedback for new experimental products and the dissemination of information derived from products created at CIRA/NESDIS-RAMMB. The webpage was presented as a poster at the Interdepartmental Hurricane Conference in New Orleans as shown in Figure 1.

The announcement was made via the tropical cyclone mailing list that has some 700 members – many international. The response to the announcement was extremely positive. For example, Alipate Waqaicelua wrote “RSMC Nadi commends you and the CIRA team for opening up a new window, with new, real-time data sources, into operational TC forecasting.”

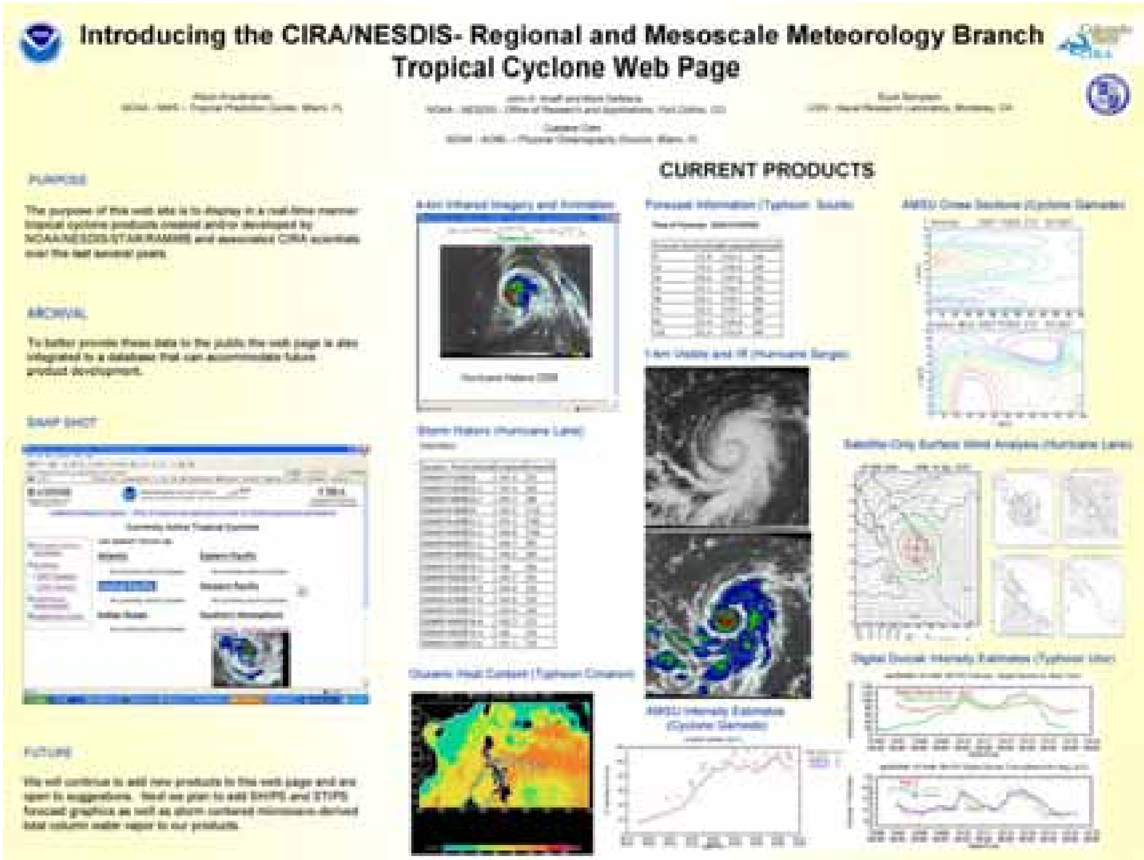


Figure 1. Poster describing the CIRA/RAMMB real-time tropical cyclone page that was presented at the 61st Interdepartmental Hurricane Conference in New Orleans, LA.

2. Severe Weather/Mesoscale

The Mesoscale Convective System (MCS) Index is running in real-time on this page: http://rammb.cira.colostate.edu/projects/mcsindex/mcsindex.asp. Validation of the product using GOES IR imagery is currently underway, and real-time validation should commence in April. The example in Figure 2 shows the index at 18 UTC on 1 March 2007, during a severe weather outbreak in the southeast.

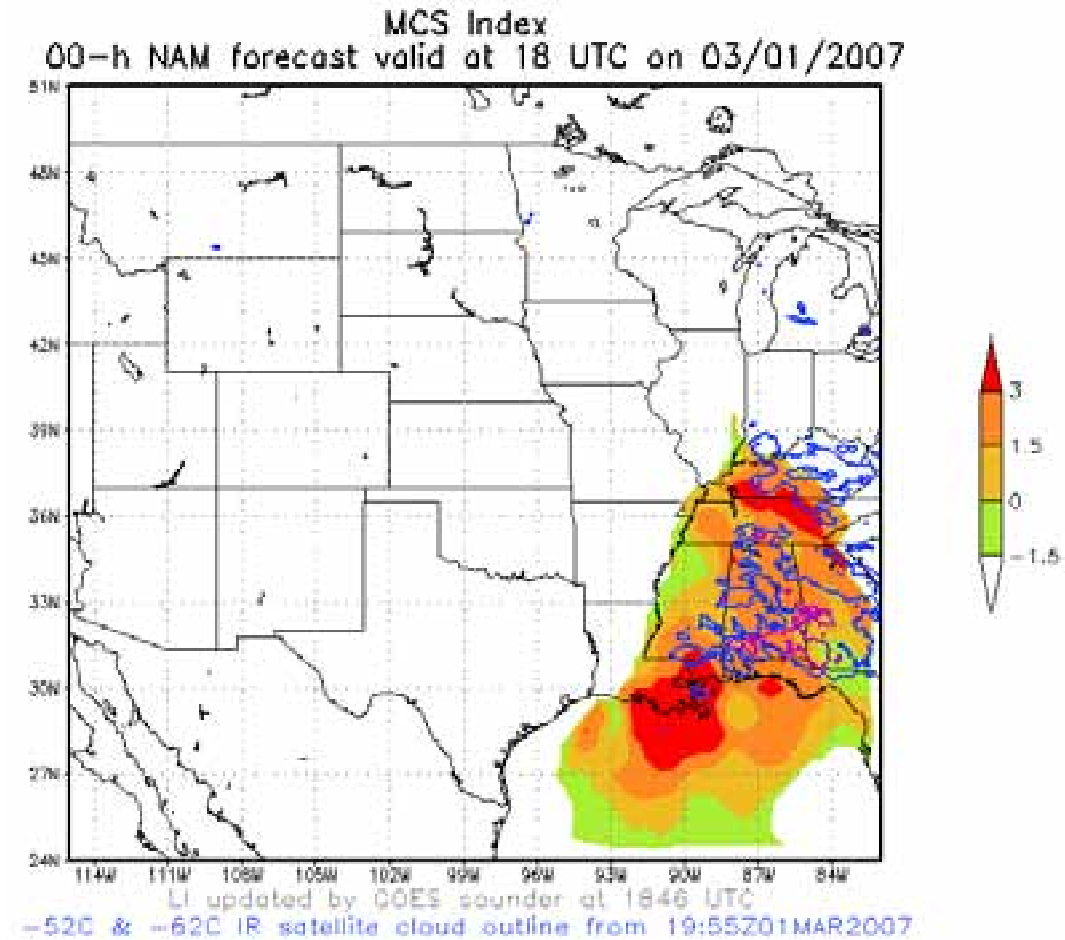


Figure 2. An example of the MCS Index from 1 March 2007 at 1800 UTC.

3. Winter Weather/Mid-latitude applications

Using temperature and moisture retrievals from the ATOVS (Advanced-TOVS) product suite, along with the GFS 50 hPa height field as a boundary condition, the hydrostatic equation was integrated downward to the surface to get the height field as a function of pressure. Using the derived height field (which defines the geostrophic wind), along with the ATOVS temperatures, the quasi-geostrophic omega equation was solved over a mid-latitude cyclone which was located off the West Coast on 19 December 2002. Figure 3 shows the 00 UTC 700 hPa ω field plotted over a GOES-10 infrared image. The solid contours correspond to rising motion, and the dashed contours correspond to sinking motion. The units are μbar s^{-1}. The pattern of vertical motion field appears quite accurate, with rising motion over the cyclone, and sinking motion behind it. Rising motion also exists with another system further out in the Pacific. The vertical motion field, along with other meteorological variables, is stored in a McIDAS GRID file. A McIDAS program was written which takes the output of the ATOVS analysis software and writes a McIDAS GRID file, allowing for easy overlay of the results onto satellite images.

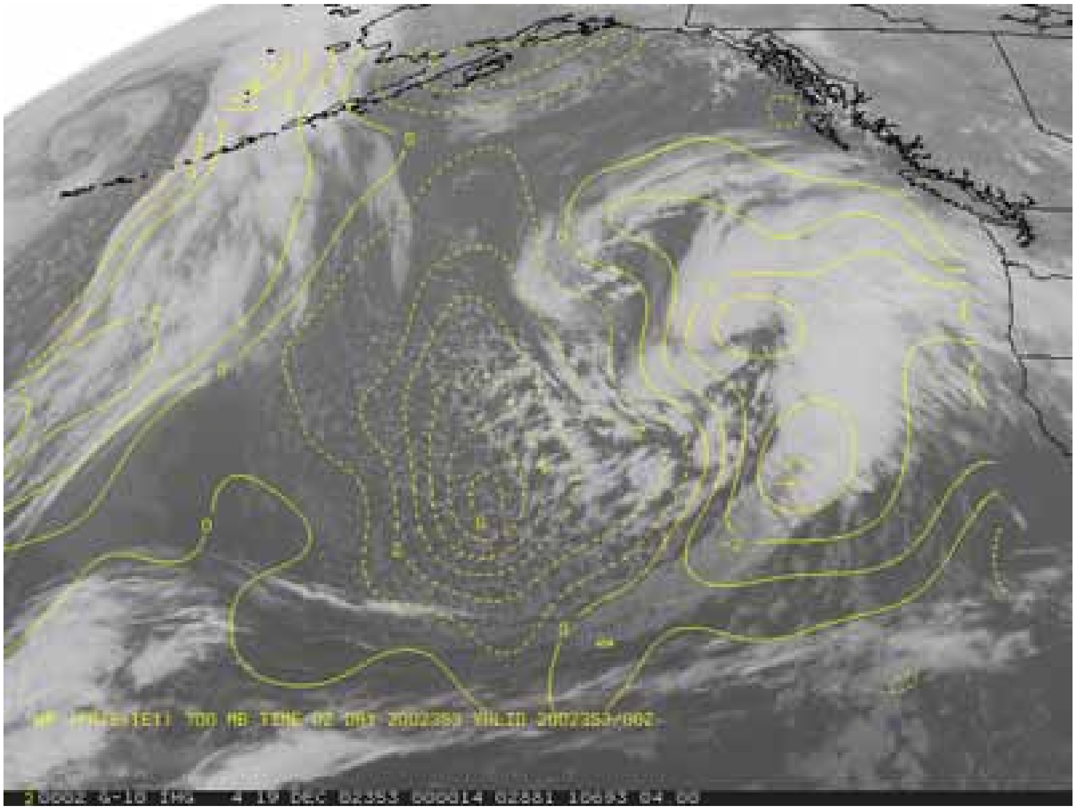


Figure 3. GOES-10 infrared image from 00 UTC 19 December 2002 with 700 hPa quasi-geostrophic ω (μbar s^{-1}) overlaid. The vertical velocity field was derived using ATOVS data.

4. Hazard Products (Fog, Fires, Volcanic Ash, Dust)

A new image product in Figure 4, utilizing current GOES-East or West imagery, has been created by combining two already-useful GOES image products. Both the Visible Albedo and Shortwave Albedo products generated from GOES imagery are combined with the GOES IR window band (10.7 µm) using three-color techniques to create a single product with capabilities to detect both smoke and fires, capabilities inherited from the albedo products that are input. Both the visible and shortwave albedo products are solar-zenith-angle corrected images, known to show smoke and fire hot spots, respectively. This new product has been dubbed the “psychedelic” color product by local users because of its vivid coloring. Interest in the product was shown by visitor Davida Street for possible operational use at the Satellite Analysis Branch.

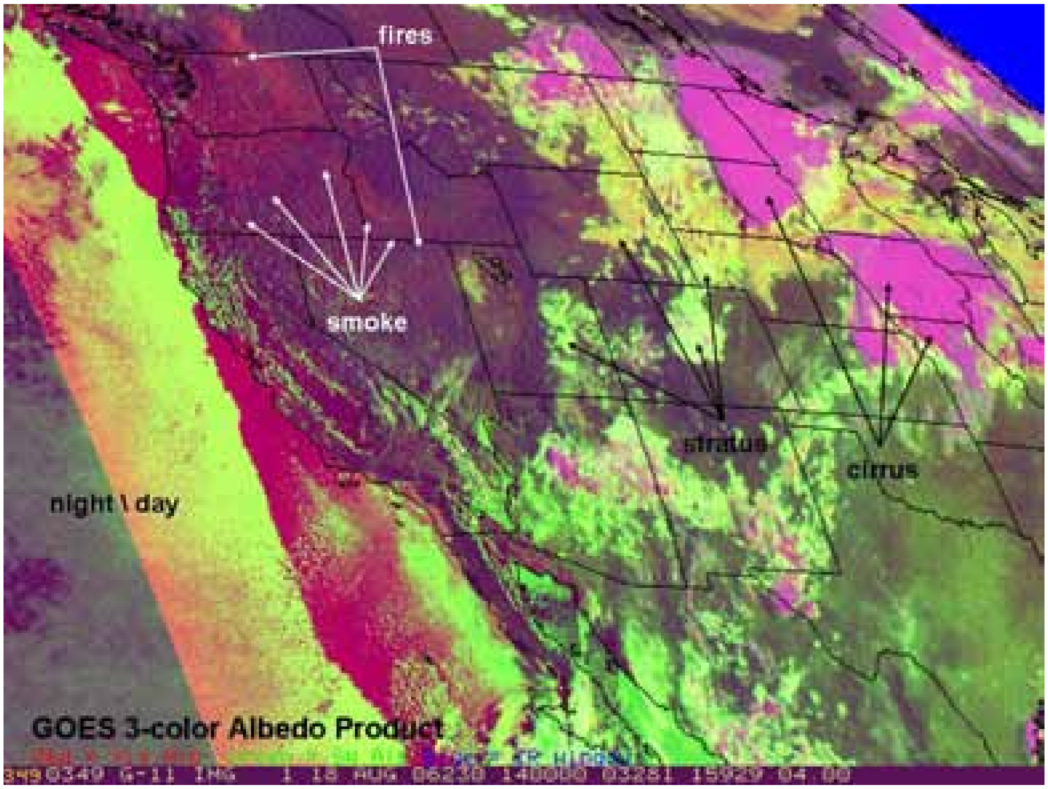


Figure 4. Three-color Albedo Product created by combining the GOES-West (GOES-11) Visible Albedo, Shortwave Albedo, and IR Window band (10.7 µm) as the Red, Green, and Blue components, respectively. The new product shows both smoke and fires, as seen in this image at 1400 UTC on 18 August 2006. The smoke (red haze) appears best as a strongly-forward-scattered signal immediately after sunrise due to the visible albedo component of the image, but almost completely disappears when the solar zenith angle increases and vertical mixing of the atmosphere takes place with solar heating. Fire hot spots (white) are due to the excessive shortwave radiation in the shortwave “albedo” component, and are confirmed by temporal continuity of those spots in the image loop. There is also color discrimination between low-level water/stratus clouds (white to light green) and high-level ice/cirrus cloud (magenta) due to the shortwave albedo component. The product is indeterminate during the transition between day and night and is most useful during the day, although it can be generated day and night with appropriate substitute imagery at night in lieu of the visible band.

5. Cloud Climatologies

GOES-12 imagery for March through May 2007 were processed for the Regional Meteorological Training Centers (RMTCs) in Costa Rica and Barbados. The archives are being used to look at cloud frequency during the rainy and dry seasons and detect local variations from year to year. The archived imagery also provides access to examples for use in satellite focused training efforts. The monthly cloud frequency composites for March through May 1997-2007 by 10.7 µm temperature threshold technique for Costa Rica are presented in Figure 5a.

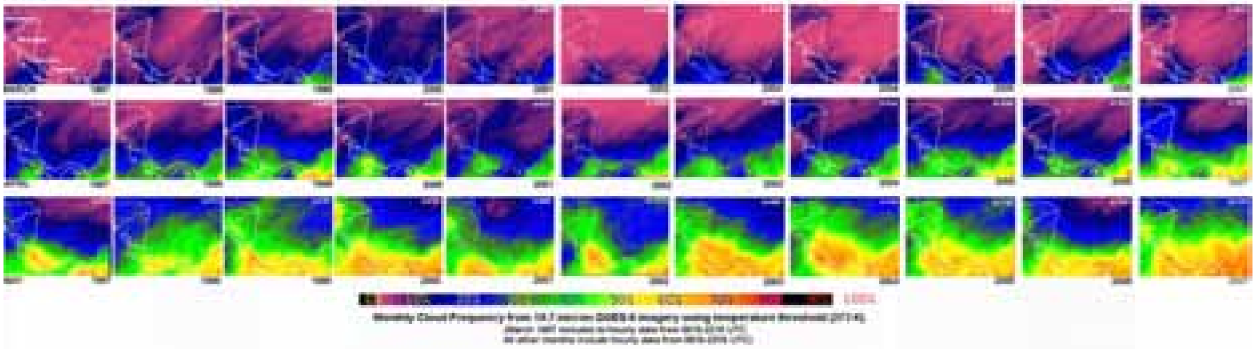


Figure 5a. Monthly cloud frequency composites for March through May 1997-2007 by 10.7 μm temperature threshold technique for Costa Rica.

A comparison of cloud frequency derived by temperature threshold of 10.7 μm imagery for March through May 1999-2007 for Barbados is shown in Figure 5b.

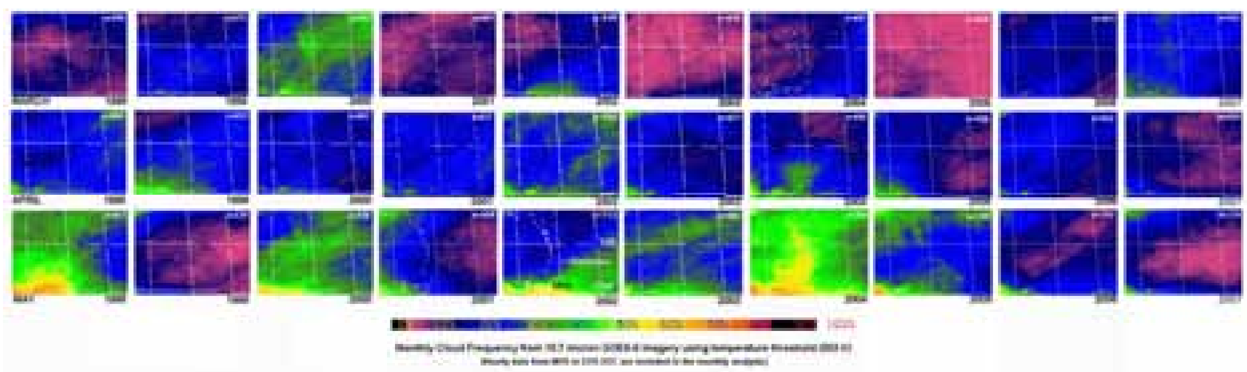


Figure 5b. Comparison of cloud frequency derived by temperature threshold of 10.7 μm imagery for March through May 1999-2007 for Barbados.

B. Calibration/Validation

Figure 6a and Figure 6b compare GOES-13 to GOES-12 images through eclipse. Rather than one long gap while the sun is behind the earth, there are two gaps when the sun is within view on each side of the earth. See the GOES-13 Science Test page (http://rammb.cira.colostate.edu/projects/goes_n/) for a PowerPoint presentation with more details on GOES-13 through eclipse. The Web page also includes more examples from CIMSS/ASPB of stray solar radiation from the sun next to the earth during "eclipse" of GOES-13, where it appears that there is a temperature effect on the longwave IR bands as well as the shortwave (3.9 μm) band.

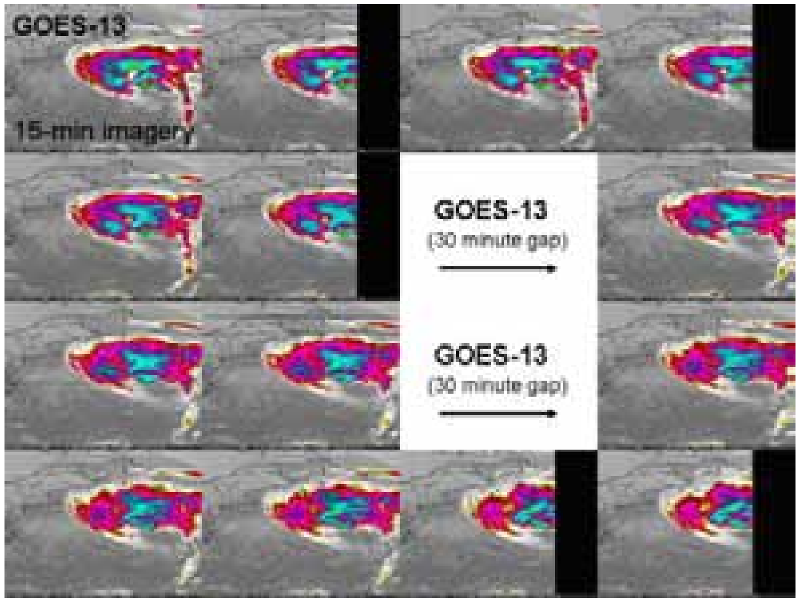


Figure 6a. GOES-13 band-4 (10.7 µm) through eclipse. Note the shorter gaps when the sun is next to and on each side of the earth.

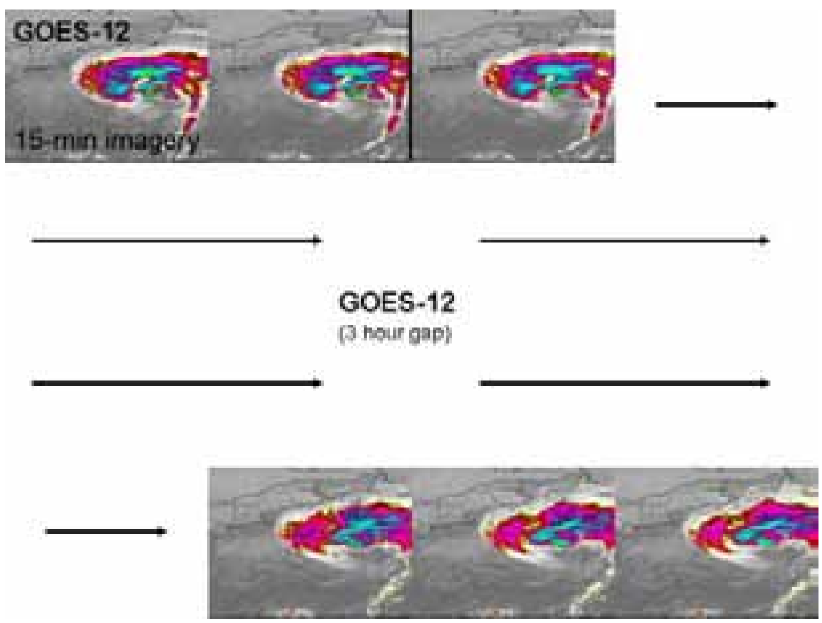


Figure 6b. Same as Figure 6a, but for GOES-12 band-4 (10.7 µm). Note the much longer gap in imagery when the sun is next to and behind the earth.

C. Training

A Weather Event Simulation (WES) case is being developed by D. Bikos for the 28 March 2007 tornado outbreak that occurred in the Great Plains. Collaboration with Jonathan Finch (NWSFO/Dodge City, KS) is ongoing to supply additional data and insight into the case. This will include a simulation guide and be made available via the SOO/STRC (Science and Training Resource Center) web-page (as all other WES simulations are officially released to the field).

SHyMet Teletraining Numbers (since April 2006): GOES Sounder: 53 completions; GOES High Density Winds: 48 completions; Cyclogenesis: 54 completions; Severe Weather: 52 completions.

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

Most objectives of this project are being completed. Objectives that are incomplete will continue as action items in the following years of this project.

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.

5. Research Linkages/Partnerships/Collaborations:

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

6. Awards/Honors: None

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness

(a) One college undergraduate assisted in the project (Daniel Coleman).
(b) See section 8
(c) None
(d) None
(e) See Tropical Cyclones, Section 2.A.1.

8. Publications:

Refereed Journal Articles

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

Chen, S.S., J.A. Knaff, and F.D. Marks, Jr., 2006: Effects of Vertical Wind Shear and Storm Motion Tropical Cyclone Rainfall Asymmetries Deduced from TRMM. Mon. Wea. Rev., 3190-3208.

Jones, T. A., D. J. Cecil, and M. DeMaria, 2006: Passive Microwave-Enhanced Statistical Hurricane Intensity Prediction Scheme. Wea. Forecasting, 21, 613-635.

Knaff, J.A., and R.M. Zehr, 2007: Reexamination of Tropical Cyclone Pressure Wind Relationships. Wea. Forecasting, 22:1, 71–88.

Kossin, J.P., J.A. Knaff, H.I. Berger, D.C. Herndon, T.A. Cram, C.S. Velden, R.J. Murnane, and J.D. Hawkins, 2007: Estimating hurricane wind structure in the absence of aircraft reconnaissance. Wea. Forecasting, 22:1, 89–101.

Landsea, C.W., B.A. Harper, K. Hoarau, J.A. Knaff, 2006: Can we detect trends in extreme tropical cyclones? Science, 313, 452-454.

Lindsey, D. T., D. W. Hillger, L. Grasso, J. A. Knaff, and J. F. Dostalek, 2006: GOES climatology and analysis of thunderstorms with enhanced 3.9 μm reflectivity. Mon. Wea. Rev., 134, 2342-2353.

Mueller, K.J., M. DeMaria, J.A. Knaff, T.H. Vonder Haar:, 2006: Objective Estimation of Tropical Cyclone Wind Structure from Infrared Satellite Data. Wea. Forecasting, 21:6, 990–1005.

Tuleya, R.E., M. DeMaria, and R.J. Kuligowski, 2007: Evaluation of GFDL and Simple Model Rainfall Forecasts for U.S. Landfalling Tropical Storms. Wea. Forecasting, 22:1, 56–70.

Conference Proceedings

Connell, B.H., V. Castro, M. Davison, A. Mostek, T. Whittaker, A. Tupper, J. Wilson, and J.F.W. Purdom, 2007: Training or Focus Group – Virtually there with VISITview. 4th International Workshop on Volcanic Ash, 26 - 30 March, Rotorua, New Zealand.

DeMaria, M., 2006: Has there been any progress in tropical cyclone intensity forecasting? AGU Fall Meeting, 11–15 December, San Francisco, CA.

DeMaria, M., K.S. Maclay, and J.A. Knaff, 2006: Tropical cyclone structure analysis: a multi-sensor approach. AGU Fall Meeting, 11–15 December, San Francisco, CA.

Hillger, D.W., T. Schmit, D.T. Lindsey, J.A. Knaff, J. Daniels, 2007: An overview of GOES-13 science test. 3rd Symposium on Future National Operational Environmental Satellites, 14-18 January, San Antonio, TX.
Knaff, J.A., M. DeMaria, A. Krautkramer, B. Sampson, and G. Goni, 2007: Introducing the CIRA/NESDIS – Regional and Mesoscale Meteorology Branch Tropical Cyclone Web Page. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

Lindsey, D.T., and L.D. Grasso, 2007: Modeling GOES-R 6.185-10.35 μm brightness temperature differences above cold thunderstorm tops. 3rd Symposium on Future National Operational Environmental Satellites, 14-18 January, San Antonio, TX.

Schumacher, A.B., DeMaria, M., J.A. Knaff, A. Irving, N. Merckle, 2007: A New Tropical Cyclone Formation Product: Operational Implementation for the Atlantic and Eastern Pacific in 2006 and Extension to the Western N. Pacific in 2007. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

Schumacher, A.B., J.A. Knaff, T. Cram, M. DeMaria, and J. Kossin, 2007: Operational Implementation of an Objective Annular Hurricane Index. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

Sengupta, M., L.D. Grasso, D.T. Lindsey, and M. DeMaria, 2007: Validation of mesoscale model output with satellite observations. 3rd Symposium on Future National Operational Environmental Satellites, 14-18 January, San Antonio, TX.

Newsletters

Hillger, D., 2007: GOES-13 Science Test, CIRA Newsletter, 27, Fort Collins CO, (Spring), 23-25.

Presentations

Many RAMM/CIRA scientists attended and presented talks at the 3rd Annual NOAA/NESDIS/CoRP Science Symposium hosted by CIRA in Ft. Collins on 15-16 August 2006. http://rammb.cira.colostate.edu/corp/Symposium/PostSymposium/Index.htm

D. Lindsey traveled to Washington DC to meet with individuals from the Satellite Analysis Branch (SAB) concerning operational use of the experimental Mesoscale Convective System (MCS) Index. SAB expressed interest, and agreed to begin viewing and evaluating this product. Additionally, D. Lindsey traveled to CICS at the University of Maryland and gave a seminar entitled "Is there a relationship between thunderstorm-top ice crystal size and updraft strength?"

D. Hillger traveled to Suitland MD to discuss the GOES-13 Science Test schedules with several NOAA engineers at Satellite Operations. Kevin Ludlum, as GOES scheduler, will work out the test schedules for both the Imager and Sounder. Proposed tests and a testing schedule were presented and discussed. Hillger also visited Camp Springs to consult with Satellite Analysis Branch (SAB) personnel on new 3-color albedo software they are testing for potential use in the detection of smoke and fires with GOES imagery. Part of the code is the shortwave albedo algorithm that may also be used separately. The software was downloaded and compiled to be sure that all the necessary components were available.

CLIMATE PROCESS TEAM ON LOW-LATITUDE CLOUD FEEDBACKS ON CLIMATE SENSITIVITY

Principal Investigators: David Randall (PI), Marat Khairoutindov, Cara-Lyn Lappen

NOAA Project Goal: The goal of the proposed CPT project is to reduce uncertainty in models that predict climate change by better representing the processes that affect cloud feedbacks. This will be accomplished with a core group of 10 scientists with expertise in different areas of modeling cloud feedback processes.

Key Words: Clouds, Climate, Models

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

Our CPT work has two objectives:

--Use of the CSU Multiscale Modeling Framework (MMF), which is the “super-parameterized” Community Atmosphere Model Version 3 (CAM3), in order to better understand cloud feedbacks in a model with explicit deep convection;

--Use the cloud resolving model (CRM) called the CSU system for Atmospheric Modeling (SAM) to perform and analyze detailed simulations of tropical deep and low-levels clouds with the goal to better understand the cloud dynamics and thus contribute to development of improved parameterization in general circulation models (GCMs).

--Further develop the ADHOC unified planetary boundary layer (PBL) model to include-consistent momentum fluxes and pressure terms.

--Implement a variety of PBL schemes (both unified and non-unified) into the single column version of CAM3 in order to assess the strengths and weaknesses of using unified schemes for different clear and cloudy boundary layers.

--Provide an interface between CPT and GEWEX Cloud Systems Study Working Group 1 (GCSS WG1; GEWEX is the Global Energy and Water Experiment).

2. Research Accomplishments/Highlights:

a) Climate sensitivity experiment

A SST+2K Cess-type climate sensitivity experiment in which the sensitivity to uniform increase of SSTs by 2K is rested, has been conducted using the CSU MMF. This was the first climate sensitivity experiment conducted using a GCM with explicit representation of clouds. Two simulations have been performed, the control 4-year long simulation forced by climatological SSTs and 5-year long perturbed SST simulation. The results of the experiment are described by Wyant et al. (2006). Figure 1 illustrates the effect of SST perturbation on the global distribution of the column water vapor and cloud effect. One can see that in MMF simulation clouds feedback to warmer oceans is negative, about -1.7 W m^{-2}, that is their combined effect is to reduce the amount of radiation absorbed by the Earth and thus cool the oceans. The feedback sign is different, however, for the outgoing longwave radiation (OLR) and absorbed shortwave

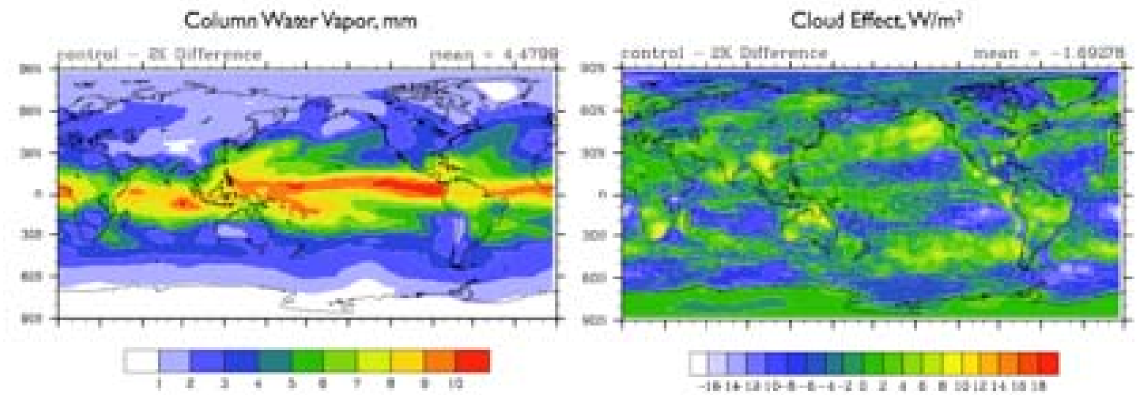


Figure 1. Perturbation of annual mean column water vapor (mm; left) and cloud effect (W m^{-2}; right), as simulated by the CSU MMF in response to a uniform SST increase of 2 K.

radiation (ASR). For OLR, the feedback is actually slightly positive indicating a reduction of high cloud amount, which for the ASR the feedback is negative and much larger which indicates the increase of low-level cloud amount. The climate sensitivity parameter for the MMF run is only 0.41 K/(W m^{-2}) which corresponds to the lower end of the range produced by other GCMs.

b) Cloud-resolving modeling

One of the goals of the CPT is to define potential improvements to parameterizations used in GCMs. The cloud-resolving models can be quite useful tools that allow one to get insight into cloud dynamics and better understand interactions of clouds with the large-scale dynamics which ultimately could lead to better parameterization of cloud processes in GCMs. As our contribution to CPT, the SAM CRM was made available to several CPT funded researchers and has been used in CPT related research.

Our research has focused on one of the main problems with conventional parameterization of convection in GCM which is representation of diurnal cycle of precipitation over land. We use the case of shallow-to-deep convection transition based on idealization of observations made during the Large-Scale Biosphere-Atmosphere (LBA) experiment in Amazonia during the TRMM-LBA mission. In this case, the shallow convection is first developing for a few hours starting in the early morning in response to surface fluxes. As the day progresses, the shallow convection transitions to mid-level congestus-type convection, and finally, late noon, a few deep convective towers appear. Despite a considerable amount of CAPE in the range 1600 to 2400 J/kg, and low convective inhibition, the cumulus convection starts as shallow and becomes deep only toward the end of simulation. Analysis of the simulation results shows that precipitation and the associated cold pools are needed to generate thermals big enough to support the growth of deep clouds. Bigger clouds are far less diluted above their bases than their smaller counterparts as hence penetrate deeper as demonstrated by the joint probability distribution function of cloud size and several in-cloud variables (Fig. 2). The results suggest that there is close coupling between the boundary layer processes and convection which should be incorporated into improved parameterizations.

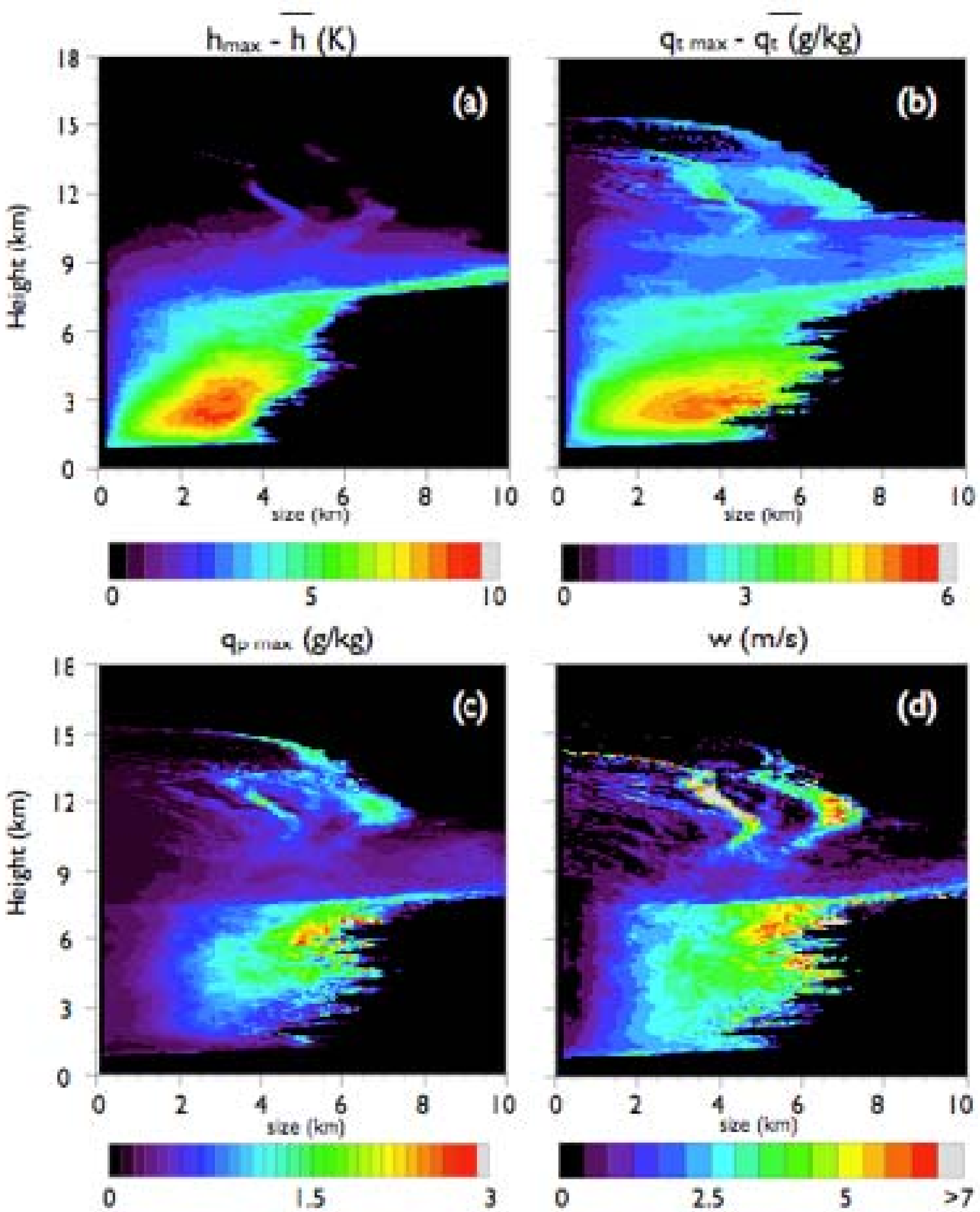


Figure 2. Joint PDF of cloud size and several in-cloud characteristics: maximum deviation from the mean of (a) moist static energy and (b) total water content; (c) precipitating water content; and (d) vertical velocity.

c) Further development of ADHOC

We have made significant progress with ADHOC. We have published 2 papers with regard to this work. The first paper deals with a new method to predict momentum fluxes in any PBL mass-flux model (Lappen and Randall, 2005). The second paper describes a mass-flux consistent method to diagnose the pressure terms in the model

(Lappen and Randall, 2006). In these works, we abandon the use of an assumed PDF distribution (the tophat PDF for the mass-flux model) and move towards using an assumed spatial distribution function (SDF). The added information we obtain with the SDF allows us to describe the momentum fluxes and pressure terms in a manner consistent with the thermodynamic fluxes.

We have successfully done this for 2 different assumed SDFs- that of a sheared roll and that of a clear convective plume. We believe that other SDFs could be represented by using a Richardson-number based weighting of these two coherent structures.

Fig. 3 shows results from our new pressure parameterization from a fully developed clear convective boundary layer. The new parameterization shows significant improvement over the standard methods, especially near the surface and near the inversion

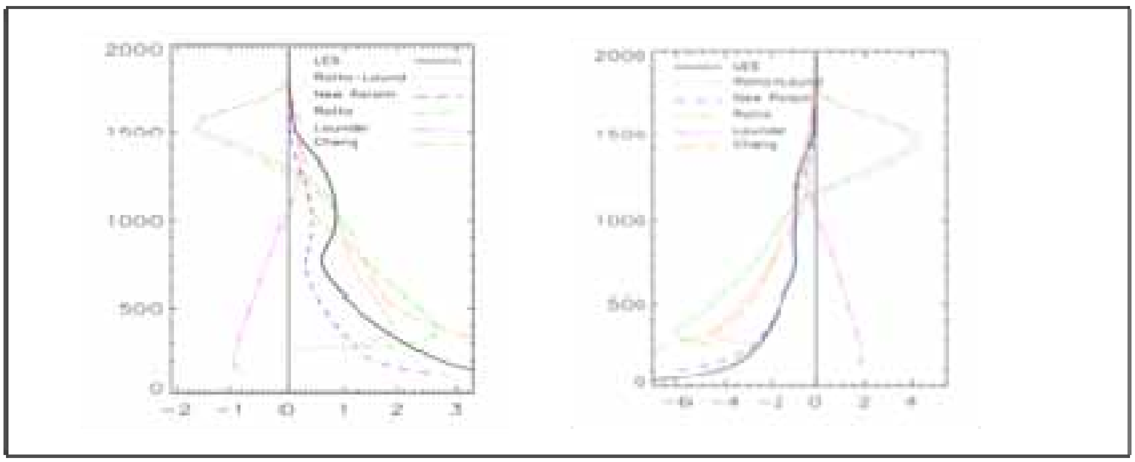


Figure 3. Comparison of the simulated pressure terms in the uu (left) and ww (right) equations for a fully-developed clear convective boundary layer

Fig. 4 shows the diagnosed structure of a 100% parameterized sheared roll. The ADHOC model diagnosed the vertical and horizontal winds, as well as the tilt and length of the roll. This is very close to the structure of an observed roll).

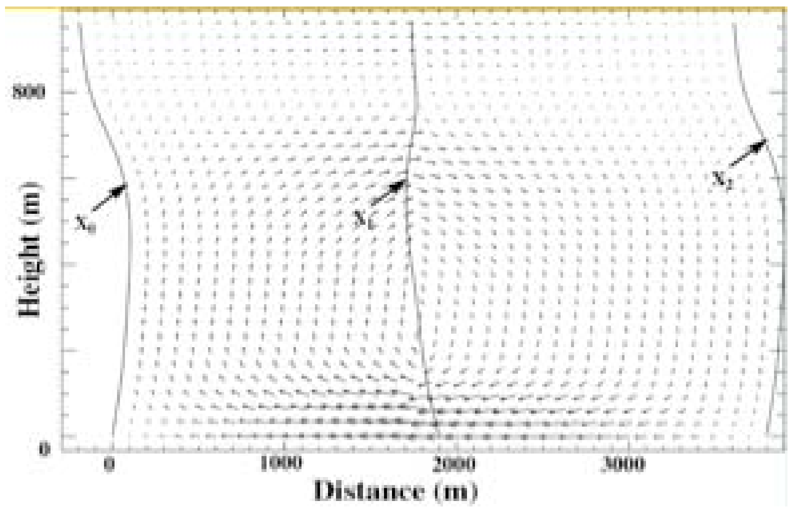


Figure 4. A sheared roll that is 100% parameterized by ADHOC2

d) Implementation and analysis of PBL schemes in CAM3

The ADHOC model described above is a unified parameterization of turbulence and shallow convection. My second task for CPT was to analyze such unified approaches and assess whether we could avoid some of the presentational problems in current GCMs, where deep cumulus, shallow cumulus and boundary layer turbulence parameterizations often compete with unintended results.

To this end, we implemented a variety of unified and non-unified PBL schemes into the same version of the single column model of the NCAR CAM and compared them with the same test cases. We felt this was the least biased way to compare the various schemes. Table 1 shows the schemes that were used and their degree of unification. The test cases that were done with these schemes in CAM include GABLS-1 and GABLS-2 (sheared cloud free PBLs), Dycoms-1 and Dycoms-2 (Sc-topped PBLs), and RICO and BOMEX (shallow-Cu PBLs).

For the cloudy cases, the results showed that more unified schemes (ADHOC, Golaz) seemed to be better able to handle getting LWP and entrainment correct at the same time, something that has been difficult for PBL models in general. For the Sc-topped PBLs, all schemes aggressively tried to decouple, whether or not decoupling was observed; however, the unified schemes were not as aggressive as the non-unified schemes. In general, the more unified schemes produced too much in-cloud turbulence. ADHOC was able to accurately capture some of the higher order statistics (e.g., skewness).

Table 1: The various PBL models used in the intercomparison.

CAM	CAM-UW	Siebesma/Koehler	ADHOC2	Golaz/Larson
No unification	No unifications	Unified in first-order closure	Unified in higher-order closures with a tophat PDF	Unified in higher-order closure with a double Gaussian PDF

Table 2: Comparison of the entrainment rates for DYCOMS-I (in cm-s^{-1}) simulated with the PBL models listed in Table 1

Observed	CAM	CAM-UW	ADHOC2	Golaz/Larson	Siebesma/ Koehler
~0.4	0.32	0.54	0.42	0.42	0.68

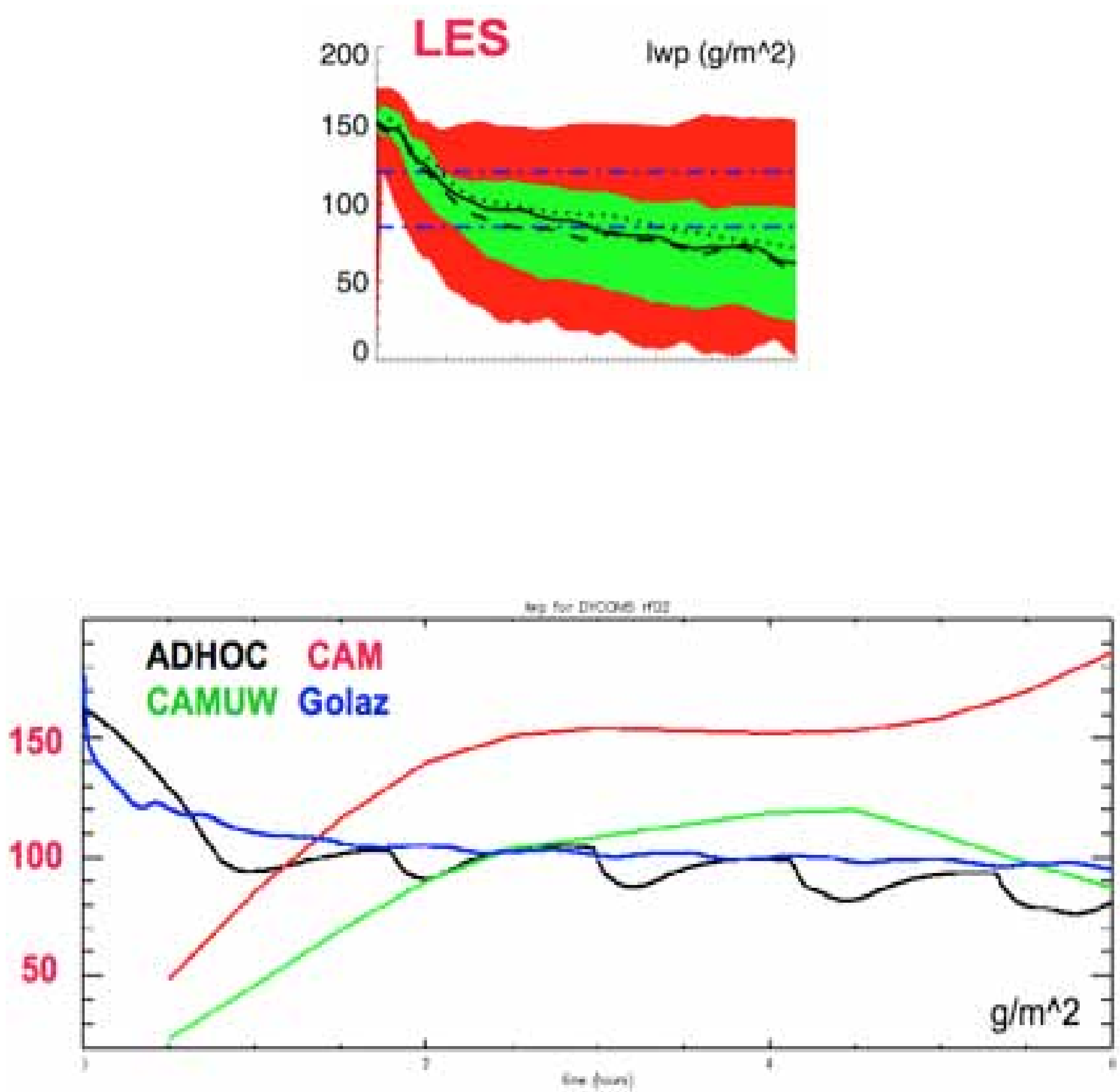


Figure 5. Comparison of the integrated LWP simulated by LES models (top-green) and observed (top-black line) with that simulated by models tested in CAM3 (lower panel).

Fig. 5 and Table 2 show some results from these simulations. Both support the findings discussed above.

e) CPT-GCSS link

I have provided the important link between the CPT and the international GCSS effort. With this role, I have helped to prepare the forcing data sets for the single-column CAM for past and upcoming GCSS WG1 (boundary layer cloud) case studies, and have compared the impacts of alternative parameterizations of turbulence and shallow convection on these case studies. For the most current GCSS case (GABLS-2) and for the upcoming GCSS case (RICO), I have run the CAM, CAM-UW and ADHOC models and prepared all model output for inclusion in the GCSS intercomparison workshops.

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

4. Leveraging/Payoff:

We have produced important new simulations with the super-CAM, and we have created and successfully tested them.

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

We collaborated with the University of Washington.

6. Awards/Honors: None as yet

7. Outreach (students, seminars)

No students were supported on this project.

8. Publications:

Blossey, P.N., C.S. Bretherton, J. Cetrone, and M. Khairoutdinov, 2006: Cloud-resolving model simulations of KWAJEX: Model sensitivities and comparisons with satellite and radar observations. *J. Atmos. Sci*. (in press).

Khairoutdinov, M., and D.A. Randall, 2006: High-resolution simulations of shallow-to-deep convection transition over land. *J. Atmos. Sci*. (in press).

Lappen, C.-L., and D.A. Randall, 2005: Using idealized coherent structures to parameterize momentum fluxes in a PBL mass-flux model. *J. Atmos. Sci*, 62, 2829-46.

Lappen, C.-L., and D.A. Randall, 2006: Parameterization of pressure perturbations in a PBL mass flux model. *J. Atmos. Sci*., 63(7), 1726-51.

Wyant, M.C., M. Khairoutdinov, and C.S. Bretherton, 2006: Climate sensitivity and cloud response of a GCM with a superparameterization. *Geophys. Res. Lett*., 33, L06714.

CLOUD AND MICROWAVE EMISSIVITY VERIFICATION TOOLS FOR USE WITHIN THE CTRM

Principal Investigator: Andrew Jones

NOAA Project Goal: Weather and Water

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

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

New quality control, standardized innovation vector analysis verification tools, and microwave emissivity analysis capabilities will be added to the CRTM for use within operational 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 data sets 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 data sets as an important new cloud verification tool for the JCSDA.

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

Add the CSU Microwave Land Surface Model (MWLSM) (Jones et al., 2004) to the CRTM.

2. Research Accomplishments/Highlights:

Research project start May 2007 (funds are approved but not yet received at CIRA).

Attended the JCSDA workshop in Camp Springs, MD, May 2007.

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

New project start.

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: None as yet

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 (choose one Project Goal and any Programs that the work would fall under- see attached chart) – 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: To help educate citizens across the United States about Rain, Hail and Snow through taking precipitation observations in their own back yards. By participating in the project the "learn by doing," CoCoRaHS daily maps and other web resources will help with the education process as well.

Objective 2: To help fill in the "precipitation reporting gaps" across the country with accurate observations which will provide critical data to many agencies and end users.

Objective 3: To provide very important "now-time" data to the National Weather Service through "Intense Precipitation Reports" which can and often do save lives.

Objective 4: Develop a long-term climatology of precipitation patterns in participating states.

Objective 5: Develop a citizen-scientist outreach relationship between observers and scientists through collaborations and interactions with the general public that would not exist otherwise.

Objective 6: Provide accurate quality data for potential research applications in the fields of hydrology, meteorology, climatology, environmental science, etc.

2. Research Accomplishments/Highlights:

This project began in 1998 along the Front Range of Colorado. It has now grown to 20 states (4 more coming on board by year end) with over 4,500+ observers. Through word of mouth and the media, CoCoRaHS is now known throughout the country as a premier citizen-science project which adds potential benefits to communities on a daily basis.

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

Expansion into 5-7 states a year has already been surpassed with Montana, Alaska, Illinois, Tennessee, Nevada, Wisconsin, South Dakota, Iowa, New York, North Carolina and Florida added within a 12 month period.

Educational materials are being developed with 4-H and master gardener programs as scheduled.

Meetings with NOAA national and regional headquarters and other regional agencies have taken place as scheduled.

Development of revised training brochure well underway. Development of "NOAA Resources" page currently in progress as scheduled.

4. Leveraging/Payoff:

The measurement and inter-action of citizen making timely precipitation reports in the U.S. has been a great help to NOAA and the public. Listed below are several benefits that CoCoRaHS has already provided to NOAA which include: Warning Operations, Climate Services, Hydrologic Services, is a public expectation and highly valued for applications

Warning Operations:
CoCoRaHS offers a form for observers to enter reports of hail or intense rainfall amounts. This includes information on damage or flooding that is occurring at the observer location, as well as time of observation. This information is available in real-time as an AWIPS text product called DENCCRAHS. This product is set up for all WFO's in participating states and is filtered to only alarm for reports from counties within the forecast 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 data set of good quality, as the observations are taken by trained observers using officially recognized standard 4-inch rain gauges. The data set 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 the office hydrologic program as well. The network provides additional data at a very high 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 of such 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 data set of good quality observations that proves valuable for local research applications. A better understanding of variability in the amounts of rainfall and snowfall across a small area will be gained, as well as a truer picture of hail stone distribution. High density data fosters more effective studies of small scale climatology within a forecast area.

Co-op Network:
In addition to the above mentioned benefits of supplementing and enhancing the Co-op network, the CoCoRaHS network provides a group of highly interested observers. This proves to be a benefit when a forecast office is looking for a new cooperative observer, as there will be a group who is already dedicated enough to participate in the CoCoRaHS network. Drawing from this pool can provide candidates for new co-op observers.

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, television stations, and local 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.

Environmental and Science Education:
CoCoRaHS allows the NWS another outlet to aid in the enhancement of environmental and science education. Observers have included many school aged children, and several schools have adopted the program into their curriculum. The observer training program is built around standard observer training practices and also encourages study of rainfall and snowfall patterns in science education.

5. Research Linkages/Partnerships/Collaborators:

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 the projects collaborators which have leveraged NOAA’s funding:

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, University of Wisconsin, Wisconsin State Climatology Office, North Carolina 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:

NOAA Environmental Hero Award: Nolan Doesken: CoCoRaHS Network, April 2007

7. Outreach:

(a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree);

(b) Seminars, symposiums, classes, educational programs;

(c) Fellowship programs;

(d) K-12 outreach;

(e) Public awareness: Public awareness is CoCoRaHS's forte.

A high priority for the first year of this grant was to establish closer ties with several NOAA partners who share a need for more and better precipitation data, and who are committed to enhancing the environmental literacy of the public. To help meet this goal, meetings have been scheduled with four regional offices of the National Weather Service, NWS Headquarters, the NOAA Office of Education, the National Climatic Data Center and the National Weather Service Operational Hydrologic Remote Sensing Center. As of March 31, we have visited in person with two regional offices of the NWS (Western and Southern), we have conducted a conference call with the NWS Central Region and we visited the NOAA Office of Education and NWS Headquarters. In the months ahead, we will be visiting NOAA's National Climatic Data Center, NWS Eastern Region and the NOHRSC. Each visit includes a briefing on CoCoRaHS but emphasizes exploring NOAA's education and outreach goals so that we can make use of our large and growing grass-roots partnerships to extend the reach of NOAA's educational programs.

As a result of meetings with NOAA partners, many new ideas for content for CoCoRaHS education and outreach were gathered. Concepts such as "Turn Around, Don't Drown" and other weather awareness facts were woven into CoCoRaHS "Message of the Day" and "The Catch" – bi-monthly e-newsletter. A new "NOAA Resources" page was developed to help introduce CoCoRaHS participants and visitors to the vast array of NOAA sciences available to the public. Finally, some progress was made to improve and streamline training materials for new and existing CoCoRaHS volunteers. The biggest question and concerned voiced by NOAA scientists and other researchers has been "How can we be sure that data from your precipitation network is any good?" Much of the answer to that question lies in how well our volunteers are trained and supported.

An unexpected large success of the CoCoRaHS network in the first 6 months of the project was media coverage and publicity. There have been dozens of newspaper articles written about the project in several states, plus several radio talk shows featuring the network. National Weather Service offices in at least 3 states were highlighted in local television interviews describing CoCoRaHS. Articles in the Chicago Tribune, the Nashville Tennessean, and the San Antonio Express-News were especially effective at recruiting new volunteers. An Internet News article distributed by Reuters and picked up by the Associated Press and several other internet news services brought national attention including dozens of new volunteer applications and inquiries from 49 out of 50 states.

CoCoRaHS staff had several opportunities to present posters and papers at professional conferences including an NWS sub-regional climate services workshop in College Station, TX as well as Peachtree City, GA, the American Geophysical Union annual meeting in San Francisco, The American Meteorological Society Annual Meeting in San Antonio, TX, the Western Regional Agricultural Climate and Natural Resources Coordinating Committee in Reno, NV, the NWS Western Regional Data Acquisition meeting in Salt Lake City. We also gave an invited seminar at the NOAA Library in Silver Spring, MD, while visiting the NOAA Office of Education in February 2007. Outreach opportunities have been incredible is helping pave the way for more NOAA partnering for the duration of the project.

An important logistical enhancement was accomplished that is greatly helping meet CoCoRaHS expansion goals. An informal agreement with a small company in rural Wisconsin, WeatherYourWay.com, has resulted in extremely convenient access to rain gauges for CoCoRaHS volunteers and sponsors and with wholesale prices and prompt delivery. This is saving weeks of time for CoCoRaHS headquarters staff to focus on network development rather than shipping and receiving. We are now exploring a similar arrangement for hail pads and other CoCoRaHS supplies.

8. Publications:

Doesken, Nolan, 2007: Let it Rain – How one grassroots effort brought weather into America's backyards. Weatherwise, July/August 2007, pp 50-55.

Reges, H., N. Doesken, R. Cifelli, and J. Turner, 2006: The Community Collaborative Rain, Hail and Snow network (CoCoRAHS) – Hands-on Science for Communities right in their own backyards. AMS 15th Symposium on Education, Atlanta, GA, paper 1.6A.

Reges, H., N. Doesken, R. Cifelli, and J. Turner, 2006: The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) A great way to collect and disseminate web-based climate data. AGU Fall Meeting, San Francisco, CA, December.

Reges, H, N. Doesken, R. Cifelli and J. Turner, 2007: The Community Collaborative Rain Hail and Snow network (CoCoRaHS) – Volunteers monitoring precipitation across the nation – The next step. AMS, 16th Conference on Applied Climatology, paper 5.3, January.

CONTINUED DEVELOPMENT OF TROPICAL CYCLONE WIND PROBABILITY PRODUCTS

Principal Investigator: J.A. Knaff/S. Kidder

NOAA Project Goal: Weather and Water

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

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

Under previous JHT support a new, a Monte Carlo-based method for estimating the probability of 34, 50 and 64-knot winds from tropical cyclones for 0 through 120 hours (or MC) was developed. This method combines randomly sampled track and intensity error distributions from National Hurricane Center (NHC) official forecasts, and wind radii error distributions from a radii CLIPER model. This algorithm has been supplied to TPC, and is currently running every 6 hours for all tropical cyclone basins in the Northern Hemisphere.

Because this new and now operational product represents a significant change to the operational probability product produced by TPC for the last two decades, a tropical cyclone wind committee within the National Weather Service is providing oversight for the development of new operational products from the MC model output.

Because of the numerous changes this model will bring to operations, the operational implementation of these products extends well beyond the time period and scope of the original JHT proposal and requires many additional tasks not anticipated in the previous JHT sponsored work. This proposal specifically seeks funding for these additional efforts by the developers, which will be required until and during the final implementation phase of all of the MC products. These efforts include, continued testing and modification of the existing methods, updating error distributions, coordination with TPC personnel related to operational transition, expertise provided for the development of probability training material and NWS products, and the development of a verification package for the tropical cyclone wind probabilities.

2. Research Accomplishments/Highlights:

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 the NOAA Tropical Prediction Center (TPC or National Hurricane Center) and the Joint Typhoon Warning Center (JTWC). The verification code creates statistics that answer specific questions about the MC forecasts. Table 1 shows those statistics and the questions they answer.

Table 1. 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?

Before one can calculate the statistics there were several steps that were necessary to create matching grids associated with the best track and the OFCL forecasts and the MC grids produced during the hurricane season. These include

1. Special code (FORTRAN 90 modules) was developed to read the Automated Tropical Cyclone Forecast databases for the advisories (A-decks), and best tracks (B-decks), and MC grids, which were in GRIB1 format.
    a. grib1 and grib2 readers were developed for the MC grids

2. Since the deterministic forecast (i.e., OFCL) does not contain forecasts of the wind radii through 120-h, special procedures were developed to insert the forecasts of the five-day wind radii CLIPER model (DRCL) forecasts where TPC made a forecast of location and maximum winds, but not of wind radii. This capability is only needed if comparisons between the NHC deterministic forecast and the probabilities are desired.

3. Since the wind probabilities are valid for a specific time interval, best track and deterministic forecasts were interpolated to the same time periods (i.e. 2-hourly) that the MC program uses to integrate individual realizations. This is a variable that can be changed as the MC code itself evolves.

4. Since the best track can exist when the determinist forecast does not exist (e.g., following extratropical transitions), special procedures were developed to clip (set values to missing) the best track at times when the OFCL forecasts were unavailable.

5. Since several storms can be active at the same time and on the same grid, each MC grid, deterministic forecasts and best tracks are matched in a time-relative manner.

6. Subroutines to calculate the Brier Score, Brier Skill Score, reliability diagrams, and the relative operating characteristics were created. These are called for each grid time and the statistics are accumulated during the time stepping.

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. There is evidence of a slight low bias in the Atlantic R34 and R50 wind probabilities, a rather pronounced positive bias in the R34 wind probabilities in the East Pacific and some evidence of under confidence in the R34 probabilities in the West Pacific. The central Pacific reliability diagram is solely based on Hurricane Ioke. The statistics (not shown) also indicate the wind probabilities are 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).

The Western North Pacific probabilities have larger initial biases and do not outperform the deterministic forecast until beyond 48 hours. We speculate that this problem as well as the under confidence of the R34 wind probabilities are likely due to the initial wind radii being misperceived (likely 0 values) at t=0 (i.e., no persistence) and the resulting sole reliance on the wind radii climatology. The JTWC decks are missing 34, 50 and 64-kt wind radii when the storm intensity is equal to 35, 50 and 65 kt, respectively.

Other issues involve the use of the East Pacific wind radii climatology and persistence model for Typhoon Ioke west of the dateline. The later problem has been fixed and revised code has been provided to TPC.

Finally, the verification code package and updated track and intensity error distributions have been provided to TPC.

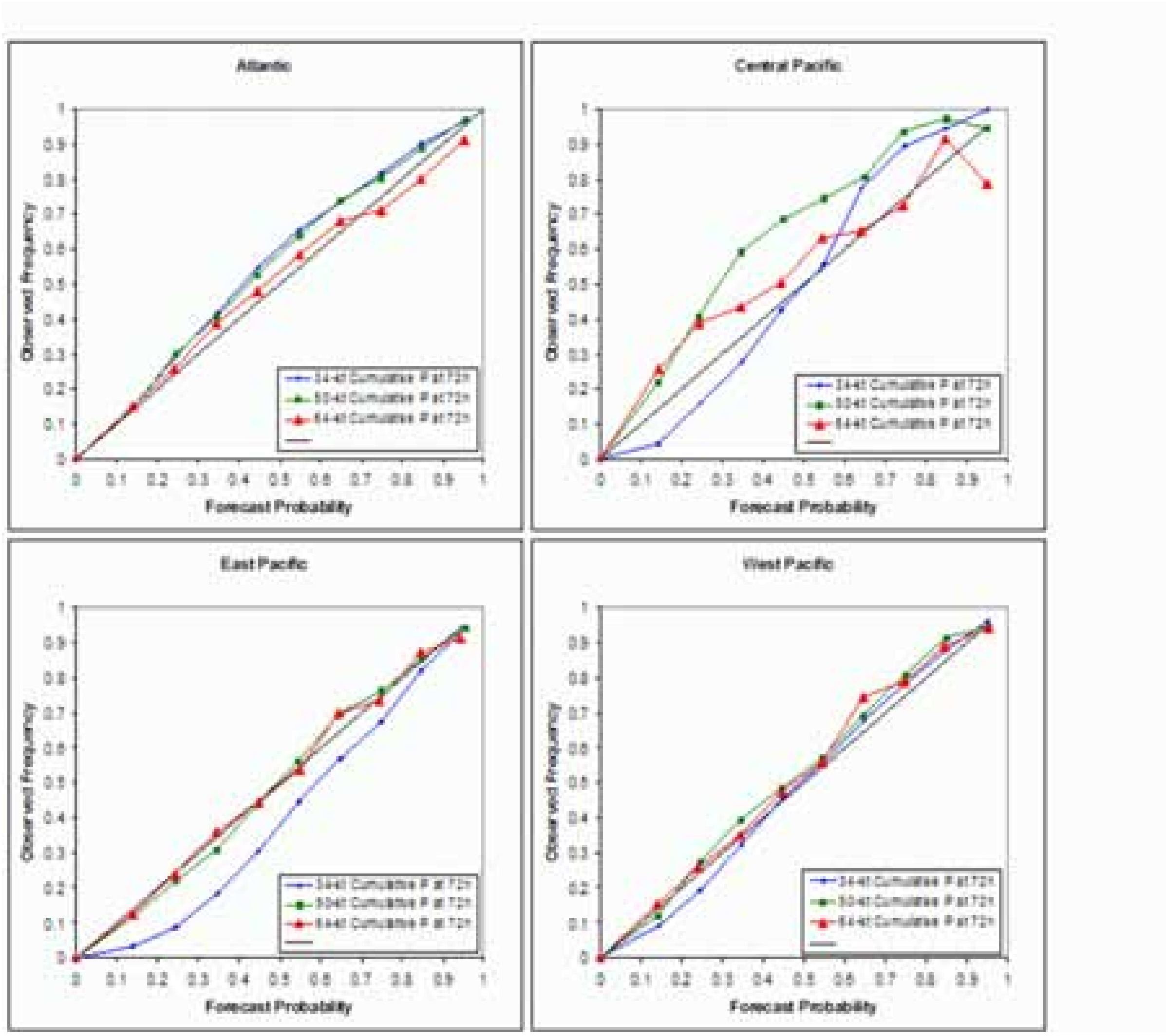


Figure 1. Reliability diagrams for cumulative 72-h tropical cyclone wind probabilities at 34-, 50-, and 64-kt wind thresholds in the Atlantic (110W-1W), Central Pacific (180W-140W), East Pacific (95W-140W), and the West Pacific (100E-180). The latitude domain is 1N to 60N.

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

This project is on schedule and has been completed.

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 improved intensity forecasts should help to narrow down the regions that require coastal evacuations because the size of these regions are proportional to the forecasted intensity, but are increased to account for intensity forecast uncertainty. The new probability program will provide a quantitative measure of the risk of various wind thresholds, 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

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) One undergraduate student (Greg DeMaria) was supported by this project.

(b) See Section 8 below

(c) None

(d) Simplified versions of the difficulties of hurricane intensity forecasting have been included in talks given to K-12 students

(e) As part of this project, input on non-technical training was provided to the Tropical Prediction Center to be used as part of their public outreach program, as new operational products are developed from the Monte Carlo probability model. This training is now included on the Tropical Prediction Center web page as part of the description of the new probability products (see www.nhc.noaa.gov).

8. Publications:

DeMaria, M., J. A. Knaff, and C. R. Sampson, 2007: Evaluation of Long-Term Trends in Tropical Cyclone Intensity Forecasts, Met. Atmos. Phys., in press

Knaff, J. A., C. R. Sampson, M. DeMaria, T. P. Marchok, and J. M. Gross, 2007: Statistical tropical cyclone wind radii prediction using climatology and persistence. Wea. Forecasting, in press.

Presentations

DeMaria, M. and J. Franklin, 2007: Long-Term Trends in National Hurricane Center Watches and Warnings. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

Knaff, J.A., M. DeMaria, and C. Lauer, 2007: Verification of the Monte Carlo Tropical Cyclone Wind Speed Probabilities: A Joint Hurricane Testbed Project Update. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

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

Principal Investigators: Roger A. Pielke, Sr. (Lead PI), University of Colorado, Christopher L. Castro, University of Arizona

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:

Accomplishments are as follows:

Dynamically downscaled the NCEP-NCAR global reanalysis for the period 1950-2002 (Castro et al. 2006a). 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, 2006a) 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. 2006b). 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. 2006b). 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. 2006c). 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.

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

Due to the PI move to CU 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 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.

6. Awards/Honors:

Dr. Castro accepted a professorship at the University of Arizona in Tucson and started there effective July 2006. Dr. Adriana Beltrán 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. nstituto 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., 2007: 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:

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

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

Principal Investigators: Kenneth J. Davis, and A. Scott Denning

NOAA Project Goal: Climate

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

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

We expect to achieve the following objectives:

Development and evaluation of a comprehensive analysis system for estimation of monthly CO_2 exchange across North America at high spatial resolution based on the existing and emerging N. American mixing ratio and flux networks;

Dramatic reduction in the uncertainty in the annual net North American CO_2 flux and its interannual variations, as compared to currently published results;

Attribution of CO_2 sources between fossil fuel combustion and ecosystem exchange using CO and other trace gases;

Application of AmeriFlux tower CO_2 flux observations to evaluate the mechanisms responsible for seasonal to interannual responses of ecosystem carbon exchange to climate variability (temperature, radiation, precipitation);

Evaluation of the flux and mixing ratio predictions of the forwards and inverse models;

Evaluation of the strengths and weaknesses of atmospheric and ecosystem models, and the flux and mixing ratio observational networks used in these studies.
The methods explored here will be portable to other parts of the globe.
To achieve these goals, we have used measurements of both local surface fluxes and near-surface atmospheric mixing ratio of CO_2 in a comprehensive model of photosynthesis, ecosystem respiration, and atmospheric transport over North America. We have studied the mechanisms that control the high-frequency (diurnal-synoptic) variations in atmospheric CO_2, We have developed and evaluated a global model of atmospheric CO_2 for use in specifying boundary conditions to the regional model, and performed nested grid simulations of weather and CO_2 over North America. We have used a backward-in-time Lagrangian transport model to compute the influence of upstream fluxes on the measured concentrations at the tower sites, and tested a procedure for correcting model estimates of these sources and sinks.

2. Research Accomplishments/Highlights:

We have developed and tested a method for extrapolating these surface-layer measurements of CO_2 at flux towers to atmospheric mixed-layer values under convective (daytime) conditions, creating inexpensive "virtual tall towers (VTT)." These VTT estimates have been compared to six years of actual vertical differences measured at the WLEF tall tower. We find that hourly daytime mixed-layer mixing ratios can be estimated from surface layer values and measured fluxes to within 0.5 ppm in winter, within 0.2 ppm in summer, and within 0.05 ppm in fall and spring (Butler *et al.*, in prep). Accurate extrapolation of surface-layer data to the mixed-layer allows Ameriflux towers to contribute to regional flux estimation by inversion of large-scale transport models which cannot resolve surface-layer gradients.

We have developed several different methods for estimation of continental carbon budgets from CO_2 mixing ratio observations which combine traditional weekly flask sampling with continuous in-situ measurements. This is very challenging because of the vastly greater data volume with hourly compared to weekly observations. Older methods have estimated monthly fluxes for large regions, but this leads to unacceptable bias due to errors in the assumed spatial patterns of fluxes within regions. Finer resolution is possible using mesoscale models, but variations of CO_2 at the lateral boundary conditions is required in this case. Our strategy has been to use a global model to perform relatively coarse estimation of monthly mean fluxes, and then to use the resulting optimized 4-dimensional CO_2 field as a "first guess" for lateral boundary conditions for much higher resolution inversions using a mesoscale model.
Global inversions and transport modeling have been performed with additional support from NASA using the Parameterized Chemical Transport Model (PCTM), which is driven by analyzed meteorology produced by the NASA Goddard Modeling and Assimilation Office. We are using this model to separately estimate monthly photosynthesis and respiration for 47 regions, with 10 in North America.

At the regional scale, we have developed a method to perform flux estimation on a 100 km x 100 km grid over North America using the CSU Regional Atmospheric Modeling System (RAMS) and a backward-in-time Lagrangian Particle Dispersion Model (LPDM). RAMS transport fields are archived and used by LPDM to calculate influence functions, (partial derivative of observed CO_2 variations with respect to upstream fluxes at previous times). With a continental network of 10-20 towers making hourly measurements, it is not possible to estimate fluxes every hour for every 100 km grid cell. We aggregate fluxes for 10 days at a time using the Simple Biosphere (SiB) model coupled to RAMS, which estimates photosynthesis (GPP) and respiration every 5 minutes from physiological principles and satellite imagery. We have evaluated SiB-RAMS by comparing simulated fluxes to eddy covariance measurements. We convolved the LPDM-derived influence functions separately with simulated GPP and respiration in SiB-RAMS to produce maps of the influence of each component flux at every grid cell over 10 days on the observed mixing ratio at each tower in each hour. The inverse problem was then formulated as an estimation of multiplicative model bias in GPP and respiration in SiB-RAMS for each grid cell. Optimal estimates of these biases were applied to the simulated gridded fluxes at each time step to produce time-varying maps of GPP and respiration on the 100-km grid which are consistent with the mixing ratio variations.

We found that uncertainty in GPP and respiration was substantially reduced only in a very limited region (a few hundred km radius) around each tower unless spatial error covariance structures were introduced into the optimization. We have applied a very flexible procedure based on the Maximum Likelihood Ensemble Filter (MLEF) to perform the optimization of model bias. Unlike previous studies, we allowed for generalized error covariance and did not specify an exponential decay of spatial autocorrelation with distance. We found that with sufficiently dense observing networks (e.g., the DOE-supported Ring of Towers in 2004); the method could recover complicated spatial structures in model bias quite well. On the other hand, we found that without allowing for spatially correlated model bias the current observing network at the continental scale is insufficiently dense to constrain spatial structures over many areas. We have used observed fluxes to study the impact of uncertain model parameters in SiB on errors in simulated fluxes (Prihodko et al, in press), and showed that model skill at synoptic to seasonal time scales was often controlled by a handful of parameters. Ricciuto et al (in press) confirmed that a model with a small number of parameters could simulate daily, synoptic and seasonal flux variability well, but Ricciuto (2006) showed that even a tuned ecosystem model had limited skill in predicting interannual variability of net ecosystem-atmosphere exchange (NEE) of CO_2 across 5 eastern U.S. temperate forest AmeriFlux sites. This suggests that changes in model structure, rather than simple parameter tuning may be required to capture interannual variability. Assimilation of multi-year records from the flux towers yielded good convergence of the parameters governing photosynthesis and forest phenology, and the parameter values were similar across these sites. Convergence of parameter values governing heterotrophic respiration, however, was weak and relatively inconsistent.

We showed that synoptic to seasonal variations were coherent across a number of towers, but that mean annual fluxes were surprisingly heterogeneous, even over a small area. Different processes control variations at different time scales. Butler et al (in prep) show that spatially coherent responses to climate anomalies can influence timing of seasonal fluxes across a large region, producing widespread anomalies in CO_2 mixing ratio that should be interpretable via inverse modeling.

We have studied the nature of the very strong synoptic variability in CO_2 mixing ratios at continental sites using observations at six towers, the global PCTM and the coupled SiB-RAMS models. We found that variations are predominantly driven by horizontal advection rather than changes in vertical mixing, and that they can be predicted reasonably well by the models. This is encouraging for the feasibility of regional flux inversion using these models.

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

Development and evaluation of a comprehensive analysis system for estimation of monthly CO_2 exchange across North America at high spatial resolution based on the existing and emerging N. American mixing ratio and flux networks;
In progress: development is done, and evaluation is ongoing. Expect a paper in 2006.

Dramatic reduction in the uncertainty in the annual net North American CO_2 flux and its interannual variations, as compared to currently published results;
In progress. Expect to submit paper by end of 2006.

Attribution of CO_2 sources between fossil fuel combustion and ecosystem exchange using CO and other trace gases;
Determined to be inappropriate. Requires active chemistry in the model. We have adopted another strategy in collaboration with Kevin Gurney (Purdue) under NASA sponsorship.

Application of AmeriFlux tower CO_2 flux observations to evaluate the mechanisms responsible for seasonal to interannual responses of ecosystem carbon exchange to climate variability (temperature, radiation, precipitation);
In progress. Two PhD students at Penn State have studied this, and one just defended. Two papers forthcoming.

Evaluation of the flux and mixing ratio predictions of the forwards and inverse models;
In progress, in parallel with objective 1

Evaluation of the strengths and weaknesses of atmospheric and ecosystem models, and the flux and mixing ratio observational networks used in these studies.
In progress, in parallel with objs 1 and 5

4. Leveraging/Payoff:

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

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

Strong linkages to other related projects at CSU funded by NASA and DOE

Collaboration with Randall Kawa and James Collatz at NASA GSFC

Links to Peter Thornton at NCAR

The North American Carbon Program (NACP: an integargency collaboration sponsored by 9 federal agencies):

Denning chairs NACP Science Steering Group

Davis co-chairs Midcontinent Intensive Task Force

Denning serves on MCI Task Force, Data Systems Task Force, and Synthesis Task Force

6. Awards/Honors: None as yet

7. Outreach:

Grad Students at CSU:
Aaron Wang (received M.S. in 2005)
Nick Parazoo (will defend M.S. in 2006)
Lara Prihodko (partially supported on this, received PhD in 2004)
Joanne Skidmore (partially supported on this, received M.S. 2004)
Grad Students at Penn State:
Dan Ricciuto (PhD 2006)
Martha Butler (will defend PhD 2007)

8. Publications:

Ricciuto, D.M., *Diagnosing uncertainty and improving predictions of terrestrial* CO_2 *fluxes at multiple scales through data assimilation*, Ph.D. dissertation, The Pennsylvania State University, 2006.

Wang, J.-W., *Observations and simulations of synoptic, regional, and local variations of atmospheric* CO_2, M. S. The Wang, J.-W., *Observations and simulations of synoptic, regional, and local variations of atmospheric* CO_2, M. S. Thesis, Colorado State University, 146 pp, 2005.

Prihodko, L., A.S. Denning, N.P. Hanan, I. Baker, K. Davis, Sensitivity, uncertainty and time dependence of parameters in a complex land surface model. *Agric. and Forest Meteorol*., in press.

Ricciuto, D. M., M. P. Butler, K. J. Davis, B. D. Cook, P. S. Bakwin, A. Andrews, R. M. Teclaw, Determining the causes of interannual variability in ecosystem-atmosphere carbon dioxide exchange in a northern Wisconsin forest using a Bayesian synthesis inversion, *Agriculture and Forest Meteorology*, in press.

Skidmore, J., A. S. Denning, K. J. Davis, P. J. Rayner, K. R. Gurney, J. Kleist, and TransCom 3 Modelers. Evaluation and prioritization of continuous measurements of [CO_2] from flux tower for inverse modeling. In prep for *Journal of Geophysical Research*.

Wang, J.-W., A. S. Denning, L. Lu, I. T. Baker, K. D. Corbin, and K. J. Davis. Observations and simulations of synoptic, regional, and local variations in atmospheric CO_2. Submitted to *J. Geophys. Res.*

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

Principal Investigators: J.A. Knaff, L.D. 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 North Pacific and the western North 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 a 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 a 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 and 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 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. The product will be developed for the Atlantic, Eastern north Pacific and the western North 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 completed during the prior report year, and were reported as such in the FY06 report. (2) Development of the Tropical Cyclone Formation Probability product for the central and western North Pacific has been completed. In addition, updates were made to the Atlantic & eastern N. Pacific product. These improvements include the addition of 2004 and 2005 to the dependent dataset and the inclusion of 850 hPa horizontal divergence as a predictor. This updated product is currently running real-time at CIRA.

A product website was developed for the updated TCFP and is available at http://rammb.cira.colostate.edu/projects/gparm/index.asp. It includes a main page highlighting regions of enhanced TC formation likelihood and a 24-hour water vapor image loop over the entire domain. Each of the three main basins (Atlantic, eastern N. Pacific, western N. Pacific) has its own product page displaying predicted and climatological TC formation probabilities, input parameter values, and time series values. To date, the extended/updated TCFP product has verified favorably for the early 2007 season (examples provided in Figs. 2-4).

A formal request has been submitted to JTWC for evaluation of the product for the 2007 season. Final product evaluation will be conducted at the end of the 2007 season, after which the new TCFP product will be transitioned to an operational platform with the help of personnel from NOAA/NESDIS/IPB.

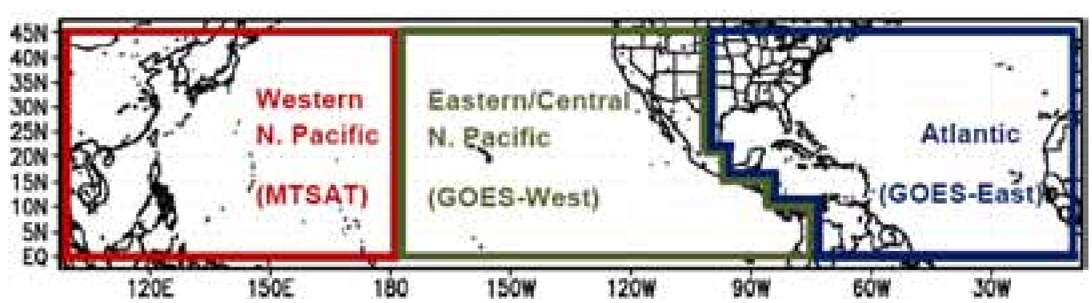


Figure 1. The TCFP product was extended to the Western and Central N. Pacific regions and the total domain was divided into 3 main basins, based on satellite coverage and agency boundaries.

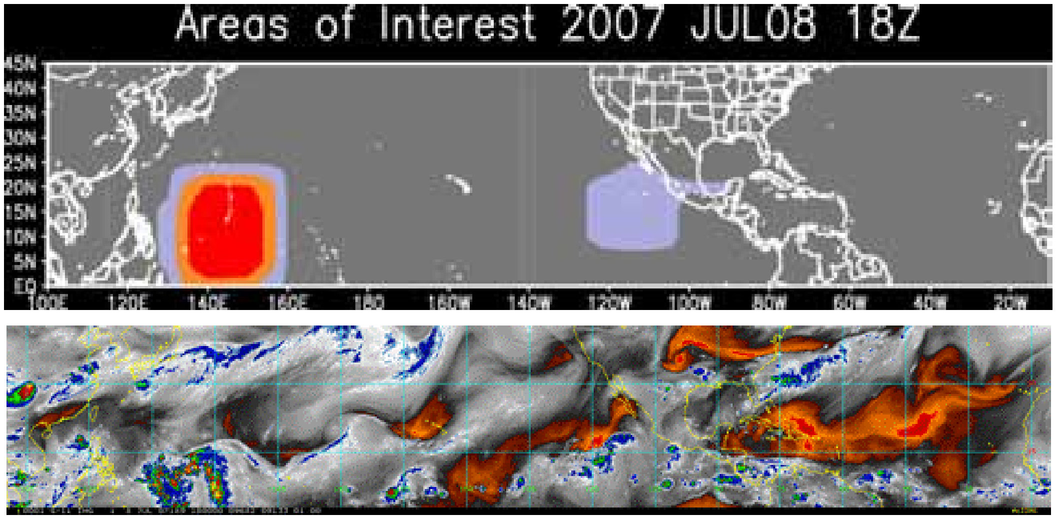


Figure 2. The main web page for the new TCFP graphic highlights regions throughout the entire product domain where the probability of TC formation is elevated and provides the corresponding 24-hr water vapor images as an animated loop, allowing forecasters to quickly identify areas where TC formation is possible. This example is for 7/8/07 18Z, the time period 18 hrs prior to the development of WP04 on 7/8/07 12Z at 11.2N, 140.2E.

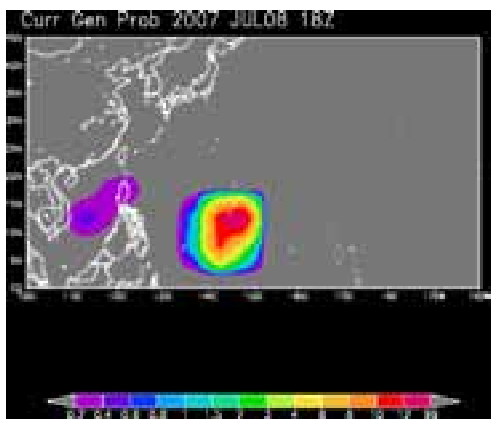


Figure 3. The TCFP predicted probabilities over the western N. Pacific for 7/8/07 18Z.

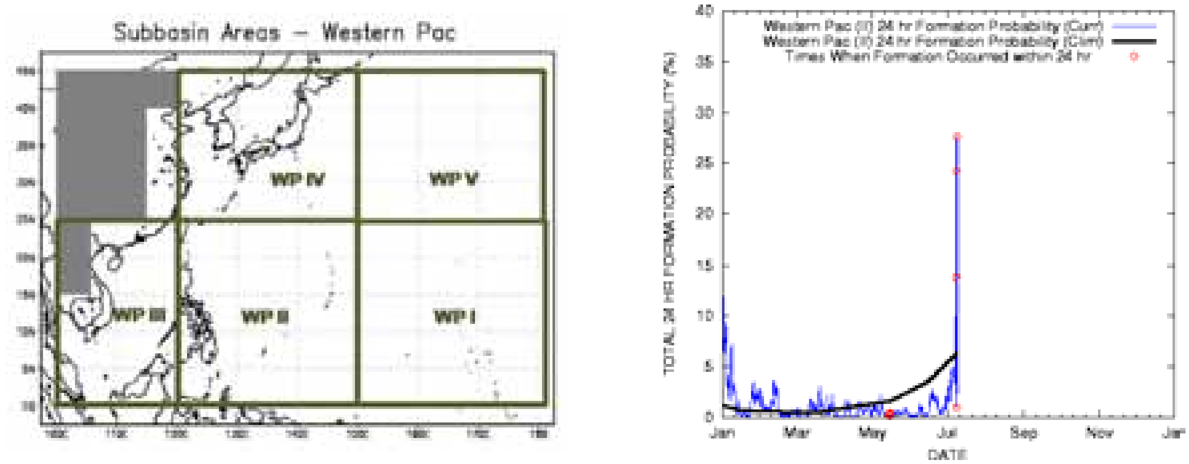


Figure 4. WP04 formed in western N. Pacific sub-basin WPII (left). The time series plot of summed formation probabilities over WPII shows a sharp increase in sub-basin probabilities just prior to the formation of WP04 on 7/9/07 12Z. The red dots indicate the times at 6, 12, 18, and 24 hours prior to formation.

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 develop the TCFP product for the central and western N. Pacific and get it running real-time in its pre-operational phase at CIRA.

4. Leveraging/Payoff:

Operational forecasters at NHC and JTWC 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: None

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) An undergraduate student in the Department of Computer Science at Colorado State University (Robert DeMaria) assisted with coding for the database development for the tropical cyclone formation parameter, and an undergraduate student at Colorado State University (Greg DeMaria) assisted with the web page product display for the tropical cyclone formation parameter.

DeMaria, M., Knaff, J., Zehr, R. and A. Schumacher, May 31, 2007: Improvements in Real-Time Tropical Cyclone Products, Star Science Forum, Camp Springs, MD (presented via teleconference), available online at http://www.orbit.nesdis.noaa.gov/star/past_seminars_2007.php#DeMaria20070531 .

(c) None

(d) None

(e) None

8. Publications:

Conference Proceedings

Schumacher, A. B., M. DeMaria, J. Knaff, A. Irving, and N. Merckle, 2007 Presentation (Poster): A New Tropical Cyclone Formation Product: Operational Implementation for the Atlantic and Eastern Pacific in 2006 and Extension to the Western N. Pacific in 2007. 61st Interdepartmental Hurricane Conference, New Orleans, LA, available on-line at http://www.ofcm.gov/ihc07/Presentations/posters/p-17schumacher.ppt

DEVELOPMENT OF AN ANNULAR HURRICANE EYEWALL INDEX FOR TROPICAL CYCLONE INTENSITY FORECASTING

Principal Investigator: J.A. Knaff

NOAA Project Goal: Weather and Water

Key Words: Tropical Cyclones, Hurricanes, Microwave Imagery, Hurricane Eyewall

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

Although there has been some slow progress in the ability to forecast hurricane intensity change, the prediction of rapid intensity changes remains problematic. Rapid intensification and rapid decay are associated with processes in the hurricane eyewall such as concentric eyes and eyewall replacement cycles. In these cases hurricane intensity is highly transient. In the other extreme, a new type of storm called an “annular” hurricane has recently been identified (see Figure 1), which has a large and stable eye, and tends to remain intense for longer than usually anticipated by hurricane forecasters. In this project, an objective technique to identify annular hurricanes will be developed. Input will include infrared data from Geostationary Operational Environmental Satellites (GOES) and synoptic scale information and sea surface temperatures from global analyses. The Annular Hurricane Index developed here will be tested in TPC operations in the 2007 hurricane season.

2. Research Accomplishments/Highlights:

Last year, an index that objectively determines whether a tropical cyclone is an annular hurricane was developed using GOES IR data and the environmental diagnostic information derived from the NCEP GFS model. This index was derived using a two-step approach. The first step is to prescreen the cases that are extremely unlikely to be Annular (using environmental and structural conditions specified in Knaff et al. 2003). Once the data are prescreened a linear discriminant analysis is used to determine the likelihood a storm is annular or non-annular.

Several modifications were made to the annular hurricane identification algorithm developed last year to get it ready for operational transition for the 2007 season. The algorithm uses the Statistical Hurricane Instensity Prediction Scheme (SHIPS), which has evolved throughout the time of development. The most current version of the SHIPS developmental data (SDD) uses a different calculation of vertical shear than the previous version. Hence, it was necessary to run the analysis again using the most recent version of the SDD. In addition to rerunning the analysis, years 2004-2006 were added to the development dataset. Also, an annular hurricane index (AHI) was developed as the main output for the operational product. The AHI is calculated by scaling the linear discriminant function value from 0 to 100, where 0 indicates “not an annular hurricane” and values 1 to 100 indicate that the case is likely an AH, with larger values indicating greater confidence.

The final algorithm was implemented at NOAA/TPC before the start of the 2007 season. It will be tested in a real-time setting at the National Hurricane Center through the entirety of the season and, given a favorable post-season evaluation, the transition from experimental to operational product will be pursued.

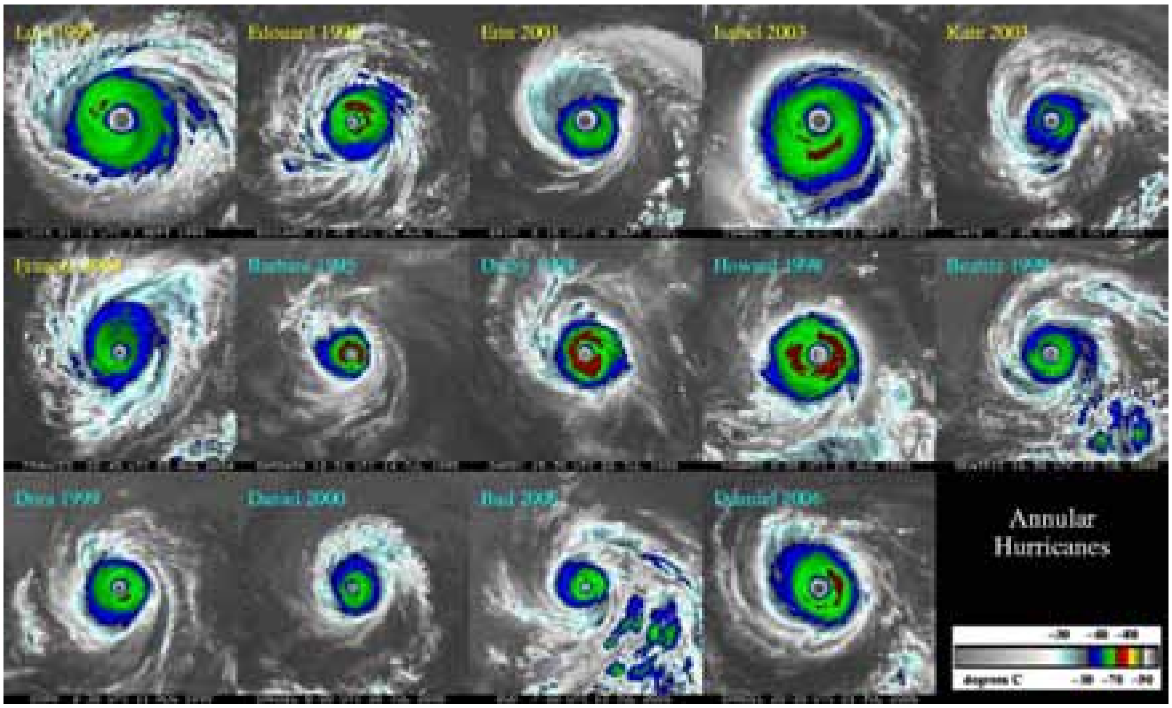


Figure 1. Color enhanced GOES infrared satellite imagery of the fourteen annular hurricane cases at or near peak visual annular characteristics. Storm names, dates and times are given at the bottom of each individual image panel. In addition, storm names and year are listed in the upper left of each image panel with North Atlantic and eastern/central North Pacific storm names indicated by yellow and cyan text, respectively. Taken from Knaff et al (submitted 2007).

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

This project is on schedule.

4. Leveraging/Payoff:

Since annular hurricanes have special intensity trend characteristics that are poorly recognized by current intensity predictions systems, this research will help to improve operational hurricane intensity forecasts. As a result, 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 with NOAA and the university community, including the NOAA/NESDIS Center for Satellite Applications and Research (STAR), the NOAA/NCEP TPC, Colorado State University and the University of Wisconsin.

6. Awards/Honors: None

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) None
(b) Schumacher, A.B., J.A. Knaff, T.A. Cram, J.P. Kossin, and M. DeMaria, 2007 Presentation (Oral): Operational Implementation of an Objective Annular Hurricane Index, 61st Interdepartmental Hurricane Conference, New Orleans, LA, available on-line at http://www.ofcm.gov/ihc07/Presentations/s6-04schumacher.ppt
(c) None
(d) None
(e) None

8. Publications:

Refereed Publications:

Knaff, J.A., Cram, T.A., Schumacher, A.B., Kossin, J.P., and M. DeMaria, 2007: Objective Identification of Annular Hurricanes, Submitted to Weather and Forecasting.

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

Principal Investigator: T.H. 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 streamfunction, 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 temperature and wind retrievals against radiosonde measurements.

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

Comparison of the sounder nonlinear balance winds with other methods, such as feature-tracked wind measurements.

Collection of a larger dataset for validation against radiosondes and comparison to other techniques.

2. Research Accomplishments/Highlights:

This project is a collaboration among different institutes testing various methods to retrieve winds over the polar region. One of the participants, CIMSS (Cooperative Institute for Meteorological Satellite Studies), generates feature-tracked winds using three consecutive passes of the MODIS instrument, which flies aboard the Terra and Aqua satellites. In preparation for a comparison between the feature-tracked winds and the balance winds, files containing the MODIS winds were collected for the 2-17 December 2004 period of study. An example of the MODIS feature-tracked winds is given in Figure 1 and an example of the AMSU balance winds is given in Figure 2.

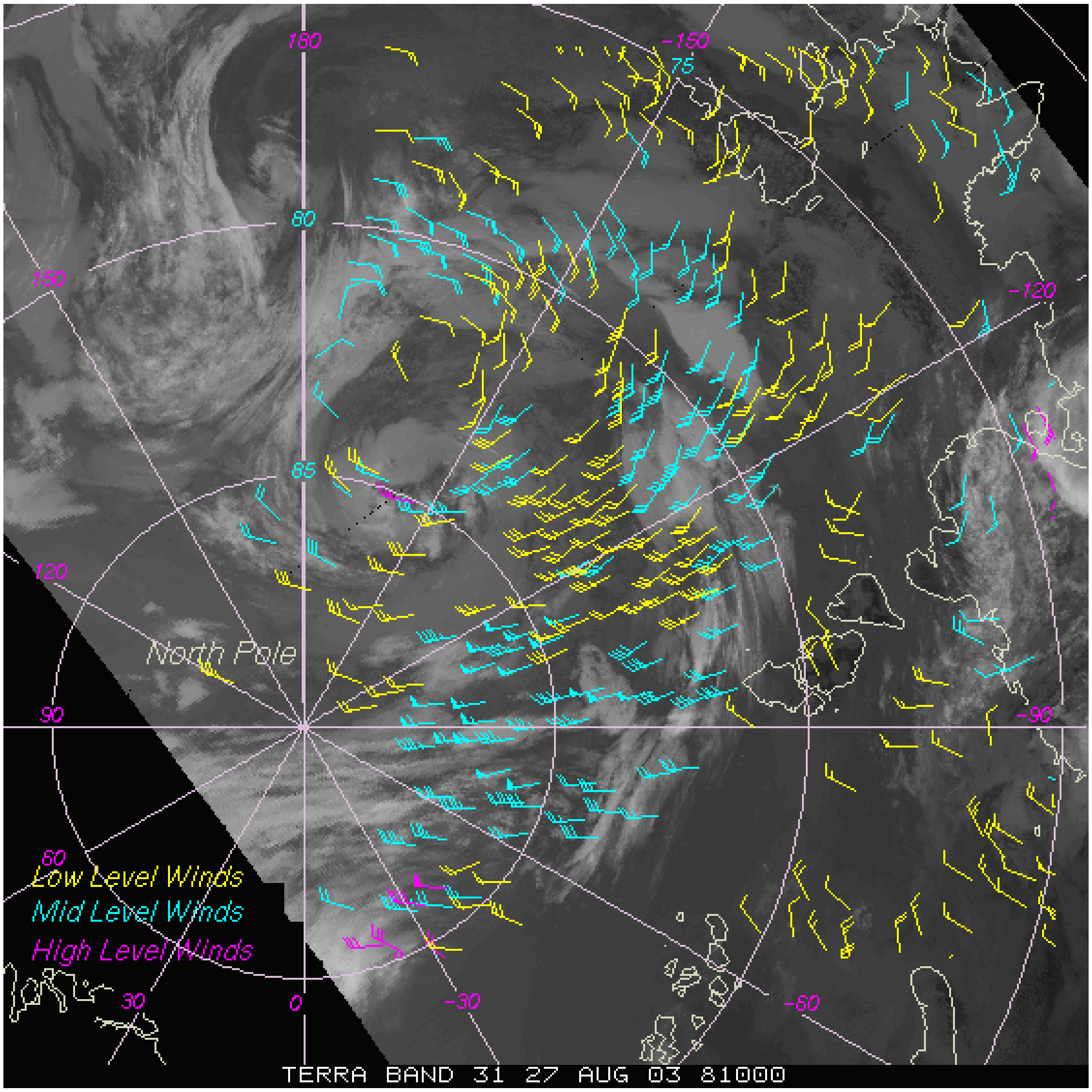


Figure 1. An example of MODIS feature-tracked winds from CIMSS.

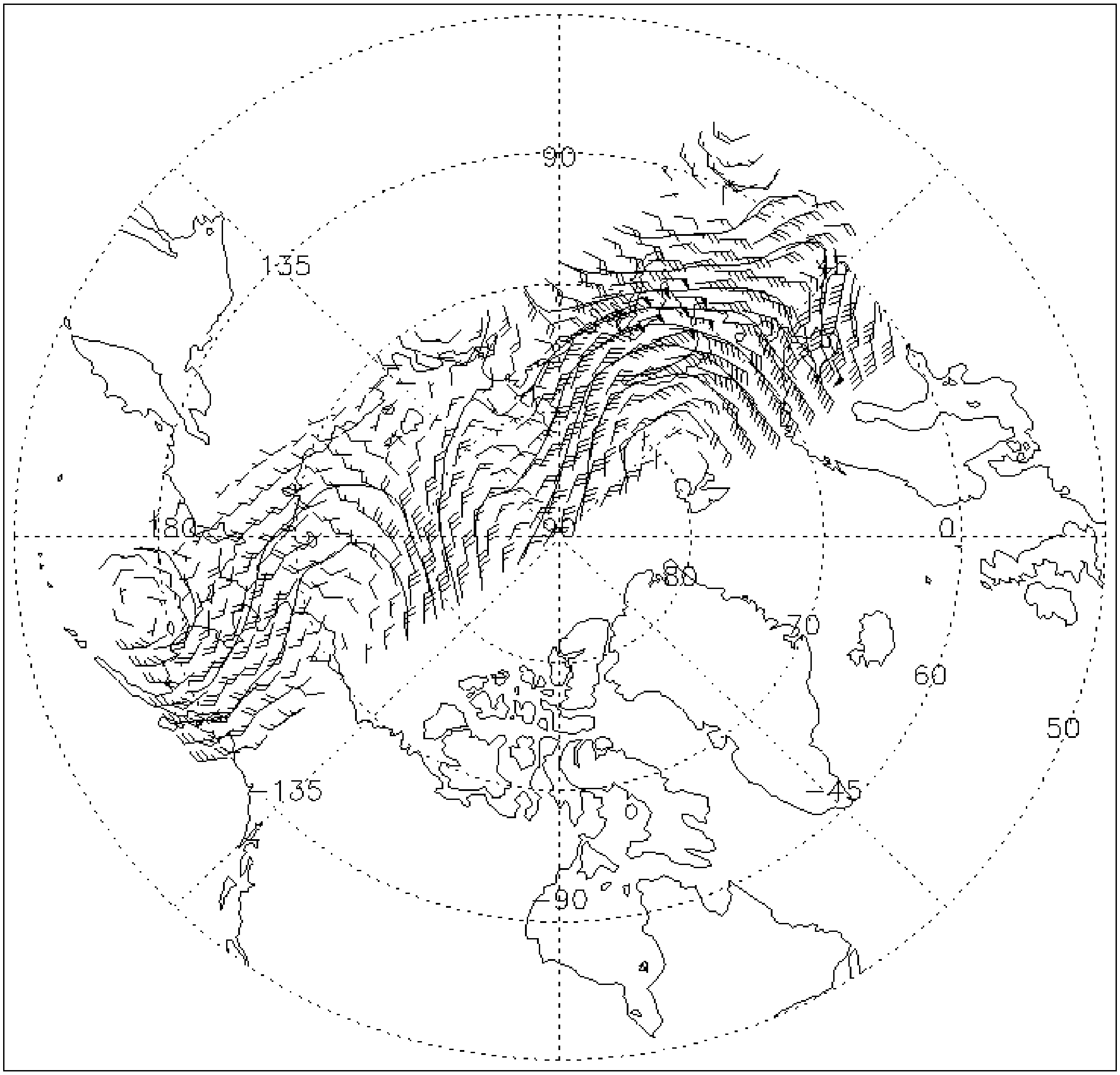


Figure 2. An example of AMSU balance winds. The 500 mb heights and geostrophic winds are from 00 UTC 17 December 2004.

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

This study is a three-year effort. Last year, the first two bullets in section 1 were completed. This year, work on the third bullet has begun. In the coming year, the comparison between the two methods will be completed, including the 2-17 December 2004 case as well as a summertime case, which is currently being collected.

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

Key Words: 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 Aircraft 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 Aircraft 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 Aircraft 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:

A report on the potential for the use of UAS for Arctic observations was written to support the development of an Arctic UAS Testbed. The report detailed the feasibility of using Eielson AFB for ground operations and launch/recovery of UAS, as well as the capabilities of existing UAS and Autonomous Underwater Vehicles (AUV), and instrumentation suitable for use on these vehicles.

In support of the OSSE project, code was developed in Matlab which will generate synthetic observations for UAS observational systems. The code uses output from the OSSE Nature Run to calculate the flight of the UAS in the modeled wind field, the location and timing of dropsonde release, tracking of dropsonde and drifting sondes, and interpolation of measurements taken by the sondes.

A diagnostic examination of Rossby wave packets in the Nature Run was performed to support a possible OSSE for the T-PARC Pacific campaign, which may employ UAS as part of a larger observational network. The dynamical characteristics (such as wavenumber, amplitude, group velocity, and phase speed) of midlatitude upper-tropospheric Rossby waves were compared with waves observed in the ECMWF and NCEP reanalyses.

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: This objective is in progress. Code for the generation of synthetic UAS observations is close to completion. Diagnostic evaluation of the Nature Run is ongoing.

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

Status: The first draft of a report on the feasibility of an Arctic testbed based in Alaska has been completed. A panel of UAS testbed leads is being formed, and will determine 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:

6. Awards/Honors:

7. Outreach:

Presentation at the NOAA/NESDIS/StAR/CoRP Symposium, August 15-16 2006.

8. Publications:

Project Title: IPCC Climate Model Demonstrations for Science on a Sphere®

Principal Researcher: Nikki Prive'

NOAA Project Goals / Programs: Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate predictions and projections; Cross-cutting priorities of environmental literacy, outreach and education

Key Words: Climate model projections, Science on a Sphere®

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

The objective of this project is to illustrate current climate model results for public outreach using Science on a Sphere® to increase understanding of climate change science. [See Section VI. C. for additional information on the SOS Development project.]

2. Research Accomplishments/Highlights:

Six Sphere demonstrations illustrating the fourth IPCC model results have been refined and are complete. The demonstrations show the changes in surface temperature and sea ice cover in the A1B scenario from the NCAR CCSM, Hadley, and GFDL climate models.

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

Complete.

4. Leveraging / Payoff:

The climate model SOS demonstrations help to bring the most recent results from climate research into the public awareness.

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

Several of the SOS demonstrations have been distributed to museums around the country for public showing, as well as in-house use at NOAA.

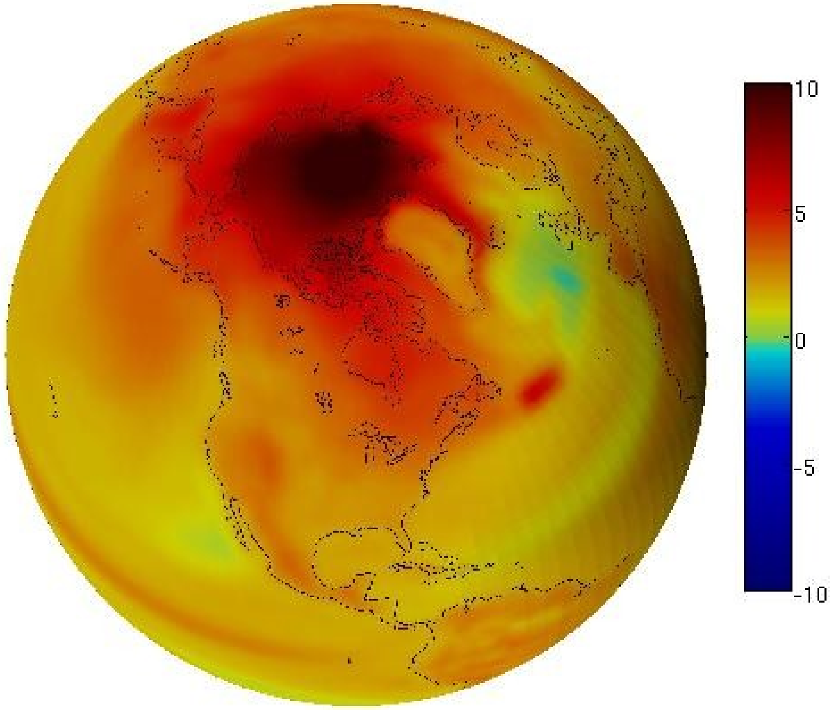


Fig. 1. A visualization of surface temperature change in the year 2100 from the NCAR CCSM model such as used in one of the SOS demonstrations.

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

Principal CIRA Coordinator: 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 forecasting exercise involving the use of 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, which has proven to be a challenging area to forecast. Tasks for this project include display of several model variables on a number of isobaric and height levels, and display of model and diagnostic parameters through three defined cross sections.

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, 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 the WRF Rapid Refresh ARW and NMM models running over a 2 km X 2 km domain with 50 vertical levels. The products are made available for viewing and comparison on a web page (http://www-frd.fsl.noaa.gov/mab/trex/).

Adjustments were made to the aforementioned web page and scripts. The web page was modified to accept 27 different runs of two Weather Research and Forecasting (WRF) based models: the National Mesoscale Model (NMM) and the Advanced Research WRF (ARW) model. This was designed to allow easy comparison of the output of the models following particular model parameter adjustments. The scripts were modified for aesthetic changes to the graphical output. Images from the runs using the best parameter settings were placed on the official T-REX catalog (http://catalog.eol.ucar.edu/trex/).

To examine how the model runs performed, aircraft data from the HIAPER (High-performance Instrumented Airborne Platform for Environmental Research), the BAe-146 (British Aerospace), and the National Center for Atmospheric Research King Air were collected to be used for comparison with the resultant model forecasts. Each aircraft, at varying times, collected data along the pre-determined cross section path B (see Figs. 1

and 2). By isolating the data collected on section path B, software was written to interpolate the model data to the aircraft data points, and comparison plots of potential temperature and vertical velocity were created. An example of a vertical velocity comparison plot is shown in Fig. 3

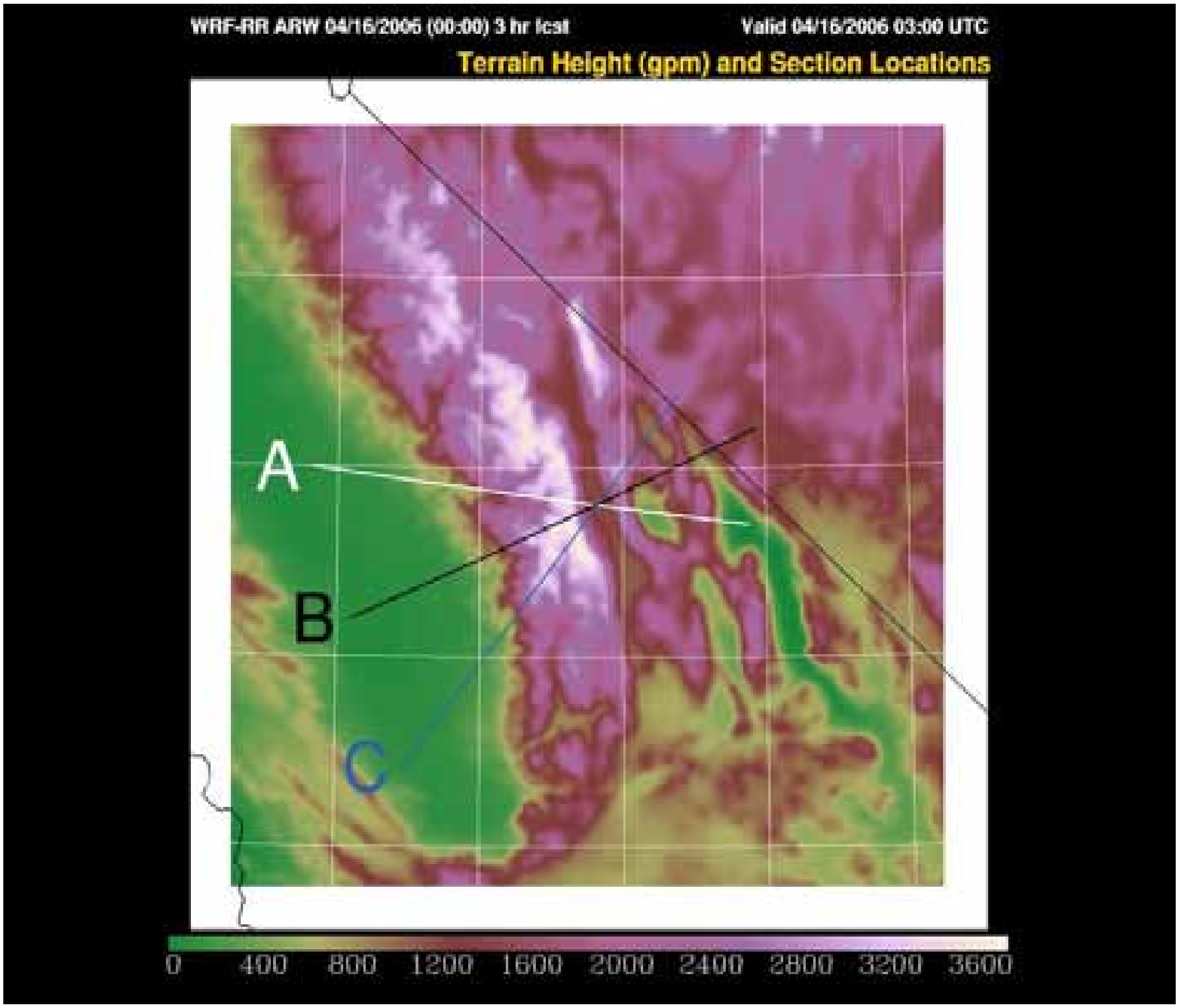


Fig. 1. WRF ARW terrain height over the Sierra Nevada Mountains showing pre-selected sections A, B, and C.

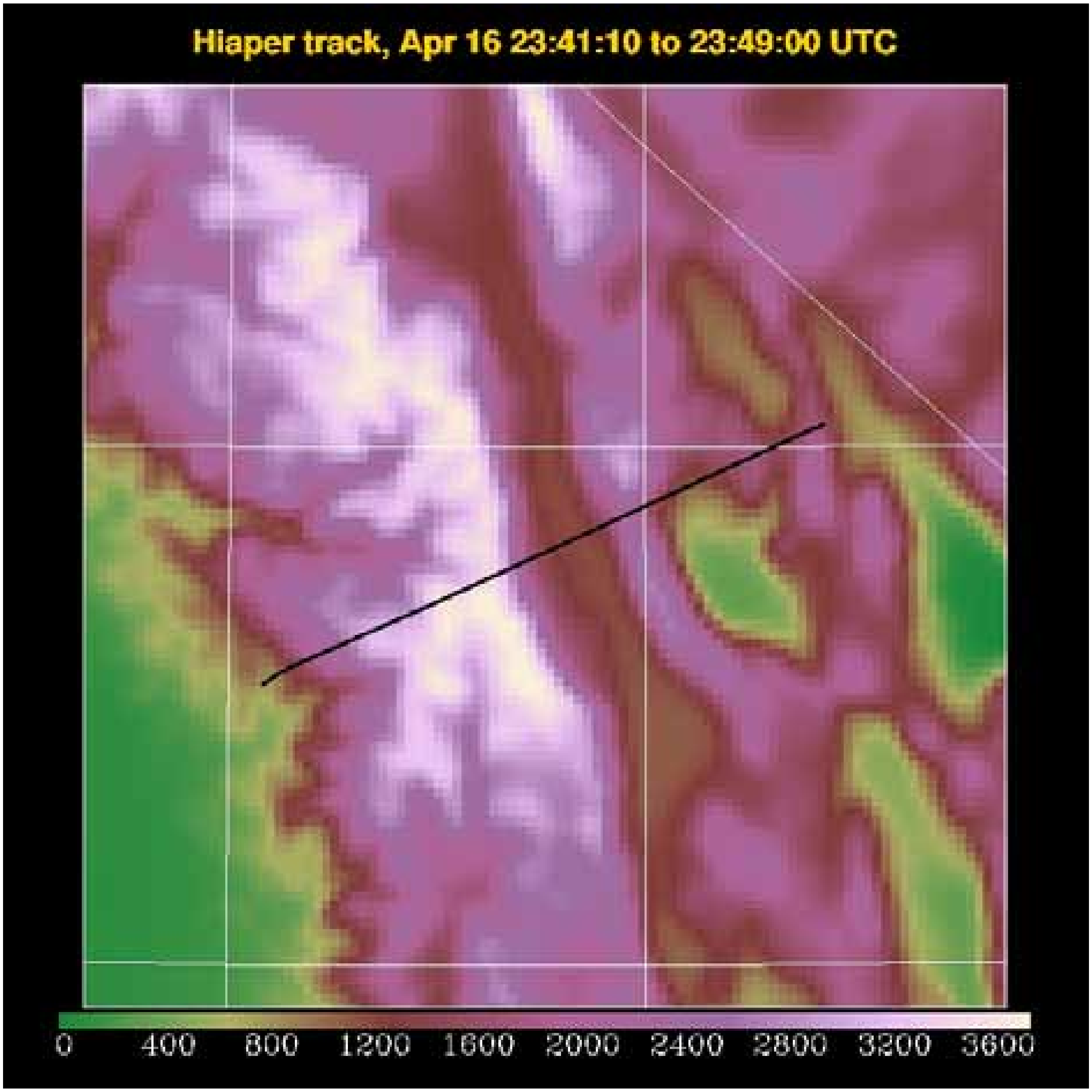


Fig. 2. As Fig. 1, but showing the HIAPER aircraft track along section B.

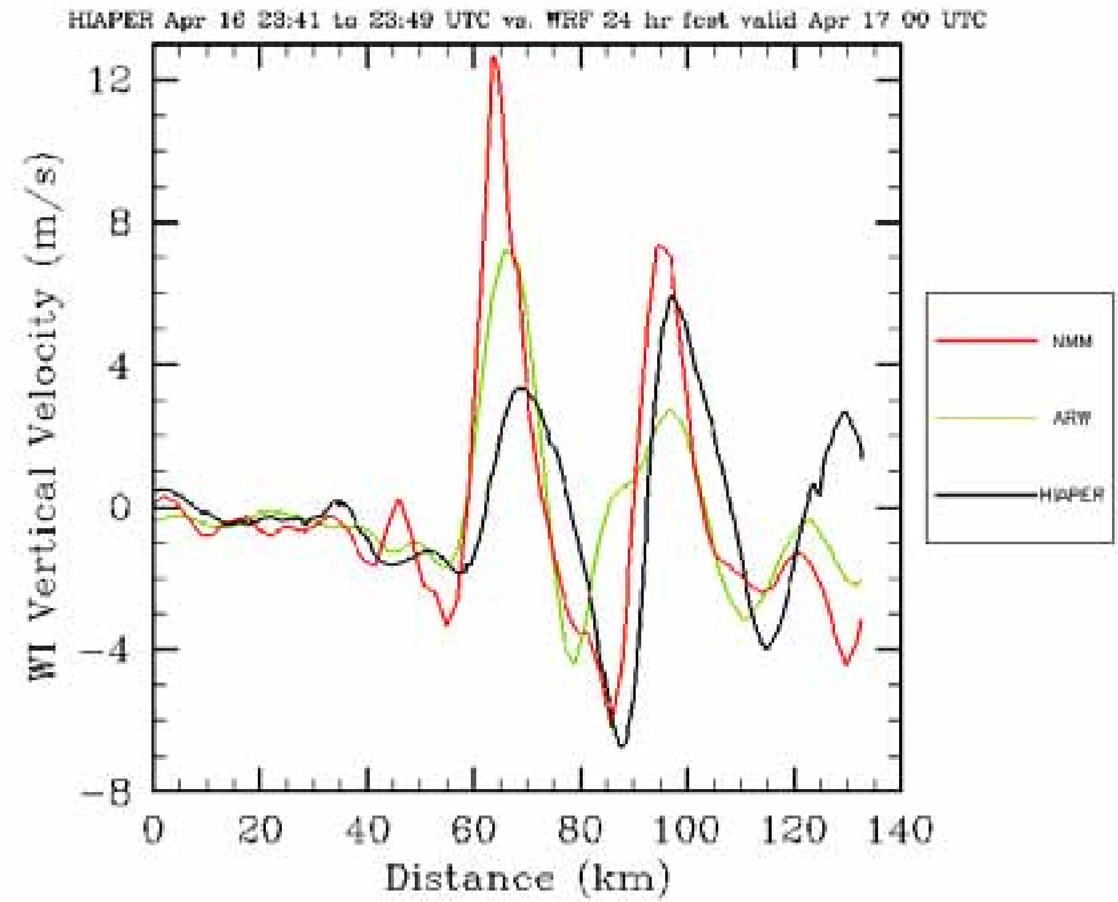


Fig. 3. Comparison plot of vertical velocity from the WRF-NMM model, the WRF-ARW model, and the HIAPER aircraft along the flight segment shown in Fig. 2.

In addition to these comparison plots, software was written to generate vertical plots of model and actual terrain, and vertical plots of model potential temperature and vertical velocity with the superimposed aircraft flight tracks. Verification results were placed on an internal web page to facilitate analysis. The results were presented at an AMS conference.

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.

Project Title: International H_2O Project (IHOP)

Participating CIRA Researcher: Brian Jamison

NOAA Goal/Programs: Weather and Water—Serve society's needs for weather and water information/Environmental modeling

Key Words: IHOP, International H_2O Project

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

IHOP, a field project that took place in 2002, was comprised of a number of projects. One of these is the Bore project. A Bore is a gravity wave that propagates between air of different densities, and depending upon the stability of these air masses and the depth of the gravity wave, a Bore can become turbulent. This task involves in-depth analysis of the data observed during a Bore event.

One of the instruments deployed for IHOP was the Goddard Lidar Observatory for Wind (GLOW), which is a mobile direct detection Doppler lidar system. For IHOP, GLOW was located at the Homestead Profiling Site in the Oklahoma panhandle, and was the primary observation system for our analysis of a Bore event given its data interval (3 minutes) and its vertical resolution (100 meters).

2. Research Accomplishments/Highlights:

GLOW data files were collected for June 20, 2002 04:32 to 08:52 UTC and concatenated to produce one large file. Scripts were written to plot wind speed, speed error, and direction error as a function of time and altitude. Knowing the Bore speed and direction (previously determined from other data sources), software was written to translate the GLOW observed winds to be "Bore-relative", i.e., in the framework of the Bore. This was done by first using a conventional coordinate transformation, and then subtracting the motion of the Bore from the resultant winds. Using the Bore-relative winds, the surface wind was extrapolated, and divergence was computed. Then, using the anelastic continuity equation, the vertical winds were derived. Scripts were written to plot the resultant vectors of the vertical component and the component parallel to the direction of the Bore. This final plot clearly shows the undulation of the Bore waves (Fig. 1). Additionally, since speed and direction errors vary, a method of quality control was performed using the inverse square root of the sum of the photon counts, which removed spurious higher level data.

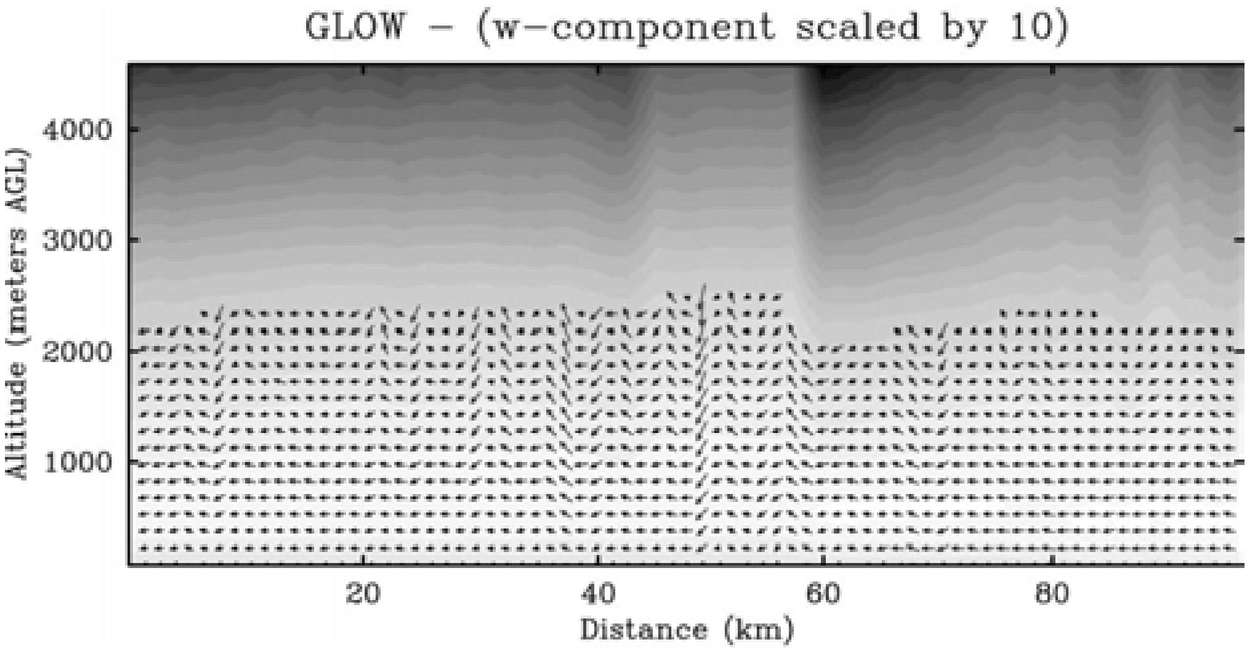


Fig. 1. Plot of the resultant wind vectors of the vertical component and the component parallel to the direction of the Bore. This final plot clearly shows the undulation of the Bore waves.

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

Completed.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Koch, S.E., C. Flamant, J.W. Wilson, B.M. Gentry, and B.D. Jamison, 2007: An atmospheric solution observed with Doppler radar, differential absorption lidar, and molecular Doppler lidar. Accepted by *J. Atmos. Oceanic Tech*.

II. Research Collaborations with the GSD Aviation Branch

A. High Performance Computing-Advanced Computing

Project Title: Advanced High-Performance Computing

Principal Researchers: Jacques Middlecoff and Dan Schaffer
CIRA Team Member: Jeff Smith

NOAA Project Goals/Programs:

In the area of High Performance Computing-Advanced Computing, CIRA proposed six research efforts. All six 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; TeraGrid; gridpoint statistical interpolation; model parallelization; WRF portal

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

a) For the MAPP project, CIRA researchers would 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 jet. CIRA researchers will also investigate the feasibility of enhancing and optimizing the GSI and, if feasible, do the enhancements and/or optimizations. Finally, 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 Portals work flow management to support a wider variety of WRF tasks, they will develop an integrated Java workflow manager to support runs on systems that don't have Ruby workflow manager installed, and they will improve the WRF Portal's visualization capabilities.

b) CIRA researchers would 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.

c) CIRA researchers would 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 with Tom Henderson at NCAR on adding SMS capabilities to the WRF code.

d) CIRA researchers would 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. CIRA researchers have been in regular meetings with the SI (standard initialization) team at NCAR to ensure that the tool will be compatible with the newest version of WRF.

e) CIRA researchers will collaborate with ESRL scientists to adapt their codes to the new Linux cluster to be installed in August and be available to provide design advice and expertise on a variety of software/web/database technologies for incorporation into the Lab's various research endeavors.

2. Research Accomplishments / Highlights:

Objective A:

The GSI code uses MPI2 I/O to enable multiple processors to write simultaneously to a single file. CIRA researchers are engaged in an ongoing effort to understand how this use of MPI2 I/O impacts the wjet file system. CIRA researchers continue to fix bugs in GSI and help meteorologists who encountered problems with GSI.

CIRA researchers developed a Java application called WRF Portal that configures, runs, and monitors the runs of WRF-NMM and WRF-ARW models on a variety of computers. WRF Portal also supports 2D visualization and it includes a module called Domain Wizard that enables the easy selection and localization of domains (and replaces the legacy WRFSI GUI application). CIRA researchers created the wrfportal.org website, presented a paper at AMS, co-authored a poster at AMS, and gave presentations at the 2007 Winter WRF-NMM tutorial as well as at the 8th Annual WRF User's Workshop (both in Boulder).

Objective B:

CIRA researchers have been an integral part of the team that has brought the FIM code to a level of maturity where we will soon begin retrospective testing. Specifically, CIRA researchers have been directly involved in adding GFS physics to FIM. CIRA researchers took the lead in debugging FIM with GFS physics, most notably finding and fixing a bug that caused unusually large cooling rates at levels 12 and 14 and minimal cooling rates at levels above 14. Using the Scalable Modeling System (SMS), CIRA researchers tuned the output of FIM and enabled the output to occur in parallel to the computations thus hiding the cost of the output and speeding up FIM by 30% so that now FIM scales from 120 processors to 240 processors by a factor of 1.95X which is an efficiency of 98%.

CIRA researchers developed the icosahedral grid generation for FIM. The software for grid generation consists of three parts: a) procedures that create the reference order, b) procedures that layout the grid points in desired memory order, and c) procedures that compute the boundary of the grid points. Several efficient algorithms such as k-d tree and 2D space filling curve have been developed or adapted. An efficient grid generator for an icosahedral grid was implemented. The new software reduces the computation time from hours to minutes thereby making it possible to generate the grid on fly.

CIRA researchers have created software packages to process the FIM output data. The software incorporates schemes for spherical linear interpolation, layer model vertical interpolation, and includes GrADS scripts to produce graphics.

Objective C:

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 D:

CIRA researchers developed a Java application called WRF Domain Wizard that is the GUI for the new WRF Preprocessing System (WPS). 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 currently adding two new features: a vertical level editor, and visualization module that enables users to visualize the NetCDF output.

Objective E:

CIRA researchers helped users get their codes running the newly procured supercomputer wjet, helped ITS debug wjet, and added the FIM code to the jet benchmarking suite.

Additional Accomplishments:

CIRA researchers have come up with a preliminary design and will begin development of OGC compliant web services in July 2007.

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

Objective A--In progress

Objective B--Successful

Objective C--In Progress

Objective D--Successful

Objective E--Successful

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

Jeff Smith received the Global Systems Division 2006 Web Award for Best New Site (Java Zone).

Mark Govett and Jeff Smith received the 2007 AMS Poster Award for Use of WRF Portal to support the Developmental Testbed Center.

7. Outreach:

CIRA researchers created a "Core Java" course and corresponding website called Java Zone (http://www-ad.fsl.noaa.gov/ac/javazone/), and taught classes to twenty students on Java, SQL databases, HTML, web development, and Web services.

8. Publications:

Devenyi, D., T.W. Schlatter, S.G. Benjamin, K.J. Brundage, J.F. Middlecoff, and S.S. Weygandt, 2007: Adaptations of Gridpoint Statistical Interpolation for the Rapid Refresh System. *2nd CIRES Science Conference*, 14 April 2007, Boulder, CO.

Govett, M. and J. Smith, 2007: Use of WRF Portal to support the Developmental Testbed Center (DTC). *23rd International Conference on Interactive Information Processing Systems for Meteorology,Oceanography, and Hydrology*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Lee, J.L., R. Bleck, A.E. MacDonald, J.W. Bao, S.G. Benjamin, J.F. Middlecoff, N. Wang, and J. Brown, 2007: FIM: A vertically flow-following, finite-volume icosahedral model. *22nd Conference on Weather Analysis and Forecasting/18th Conference on Numerical Weather Prediction*, 24-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Smith, J., M. Govett, and P. McCaslin, 2007: WRF Portal and WRF Domain Wizard. *23rd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Smith, J., 2007: Java Zone website and 28 Powerpoint presentations on Java, SQL databases, web development, and Web services. Located at http://www-ad.fsl.noaa.gov/ac/javazone/

Smith, J. and P. McCaslin, 2007: WRF Domain Wizard: The WPS GUI, *8th Annual WRF User's Workshop*, 15 June 2007, Boulder, CO.

B. Aviation Systems—Development and Deployment

Project Title: FXC AI (Aviation Initiative) Demonstration

Principal Researcher: Jim Frimel
CIRA Team Members: Young Chun and Lisa Gifford

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 FXA 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.

2. Research Accomplishments/Highlights:

During the summer of 2006, CIRA researchers in the Global Systems Division's Aviation Branch, along with FXC engineers from the Information Systems Branch, concentrated its efforts on Aviation Initiative development. This development was based on the Earth System Research Laboratory technologies and services being developed by CIRA engineers at the Prototyping Aviation Collaborative Effort (PACE) facility at the Fort Worth ARTCC. For a description of PACE and related FXC Development, refer to the

FXC TMU project description. The FX-Collaborate (FXC) software, developed at NOAA's Earth System Research Lab, was the major software system used in the Aviation Initiative Demonstration.

During this time period, hardware, computer systems, and communication lines were purchased, configured, and integrated at each of the participating client locations and at GSD in support of the demonstrations requirements. All systems were configured with Voice Over IP services using Skype. This provided forecasters and TMU managers voice services for local and remote weather briefings. Additionally, a 50” plasma display tied to FXC was configured and installed for the Traffic Manager weather briefings. The FXC software was enhanced with a new menu configuration capability depending if the user was the TMU Manager (BriefEE Menu) or the CWSU (BriefER Menu). Also added was the ability for FXC to support remote procedures. A weather briefing procedure could now be created by either the CWSU or the WFO forecaster, uploaded to the server, and then viewed by the TMU Manger. The AWIPS code base was enhanced by moving the NCWF2 impacted jet routes from the display side to the decoders. The impacted route information was now being decoded in advance rather than being rendered on the fly in the display. This greatly improved the speed at which these products loaded in the display. Additional enhancements to the systems included map backgrounds local to the Washington DC area ARTCC and in maps in support of the initiative requirements.

Following is an excerpt from the National Weather Service draft summary:

The FXC Aviation Initiative offered on-demand services, remote briefing capabilities, new graphical products, and tactical decision aids. Despite some “start-up” connectivity and server stability issues, remote operations were judged effective by both NWS and FAA users when communications and technology were functional.

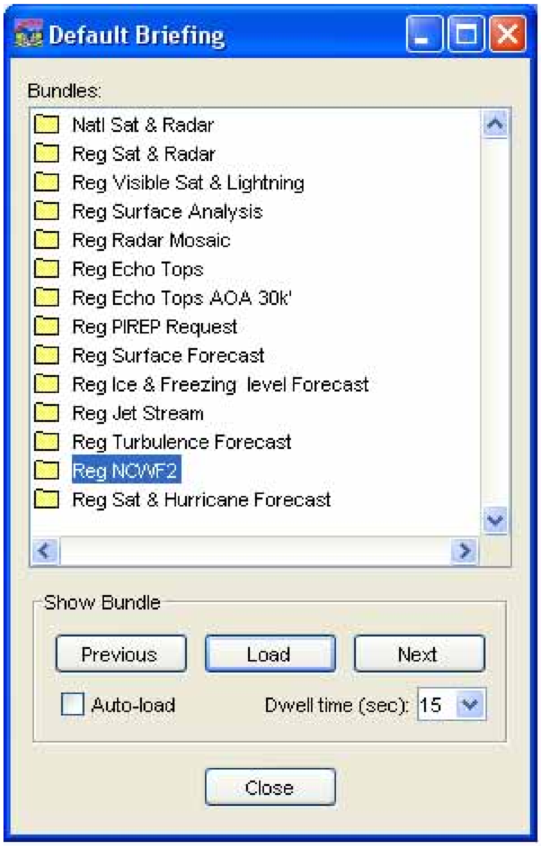


Fig. 1. View of the remote briefing play list.

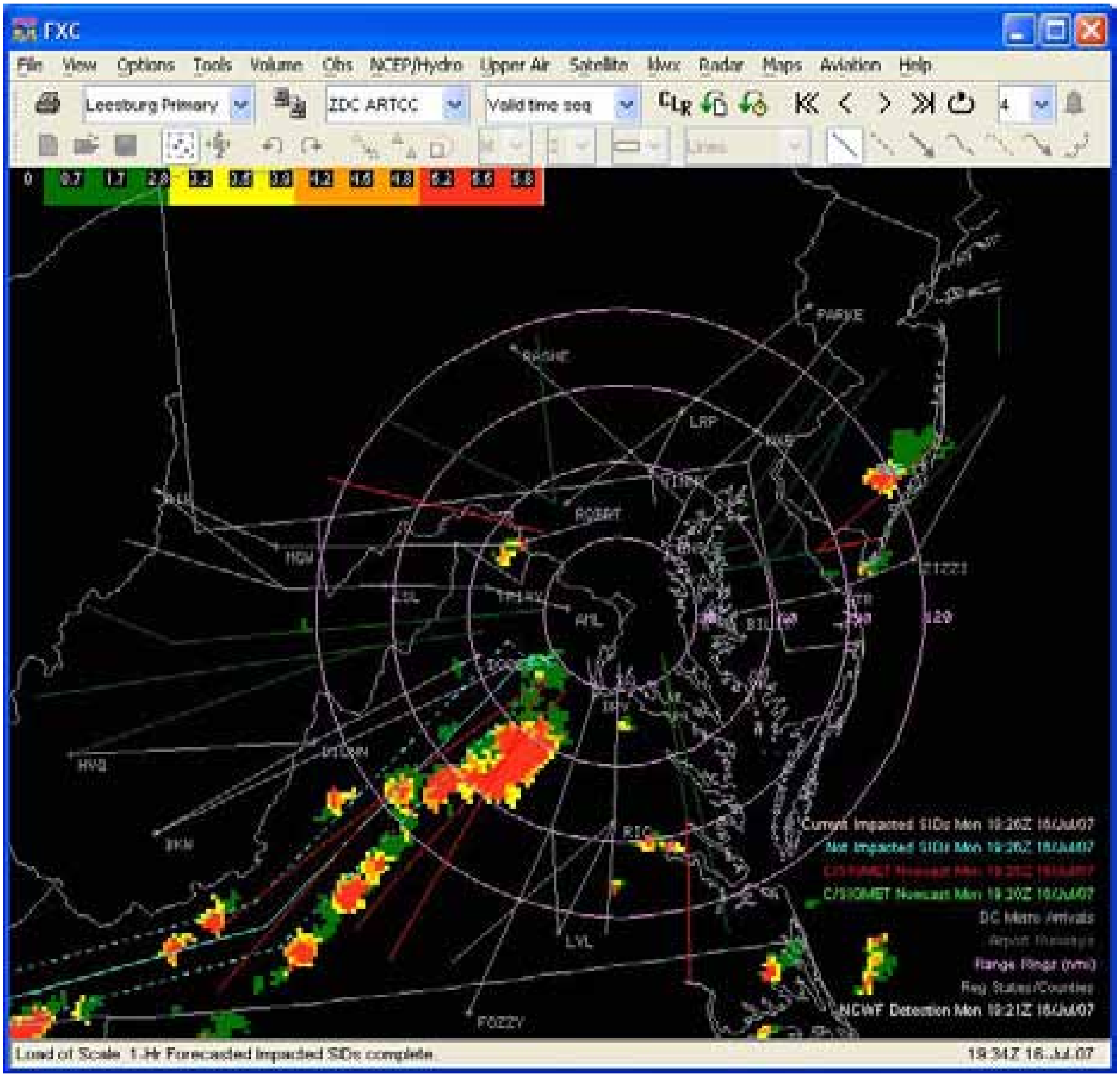


Fig. 2. View of the FXC AI BriefEE display with map enhancements and impacted DC Metro departure routes.

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

4. Leveraging/Payoff:

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
CIRA Team Members: Young Chun and Lisa Gifford

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

Key Words: Volcanic ash advisories, data ingest and display system, collaborative tool

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

The FXC VACT project is an experimental client/server based application utilizing the Internet and is based on the FX-Collaborate (FXC) system architecture. The participating agencies are currently the National Weather Service Alaska Region Headquarters (NWSARH), Anchorage Volcanic Ash Advisory Center (VAAC), Alaska Volcano Observatory (AVO), and the Anchorage Air Route Traffic Control Center, Center Weather Service Unit (CWSU).

The FX-Collaborate (FXC) software, developed at NOAA's Earth System Research Lab in the Global Systems Division's Information Systems Branch, is a major component of the FXC VACT project. The major system used to acquire, distribute, create and provide the required data sets for FXC is the AWIPS Linux data ingest and display system. The FXC and AWIPS software is being tailored, modified, extended, enhanced, and utilized in the FXC VACT project. The FXC software allows for the remote access and display of AWIPS data sets over the Internet, a collaboration capability among participants at physically different locations, and the ability to utilize tools to aid in discussing forecasts

The FXC VACT project is a research and development effort in direct response to investigating the collaborative approaches and needs of agencies involved in generating

Volcanic Ash Advisories. The FXC Volcanic Ash Coordination Tool is being tested at each of these operational sites to investigate forecaster productivity tools and collaboration capabilities in response to aviation hazards posed by volcanic eruptions. The system is designed to help locate and determine the extent and movement of volcanic ash so that more accurate, timely, consistent, and relevant ash dispersion and ash fallout watches, warnings, and forecasts can be issued. These watches, warnings, and forecasts can be disseminated using current approaches and standards (societal impact statements) but will also be tailored for end user needs in the form of societal impact graphics (i.e. jet routes or runways turning red when ash is present). Graphics tailored to aviation needs focus on making the National Airspace System (NAS) safer and more efficient during a volcanic ash event. Efforts are focused on integrating the latest advancements in volcanic ash detection and dispersion from the research community, allowing users to overlay and manipulate this information in real-time; developing tools to generate end user impact statements and graphics; and disseminating the impact statements in a timely fashion so that hazard mitigation plans can be activated.

The VACT system allows users at different sites and with different expertise to simultaneously view identical displays of volcanic ash and other related data sets (i.e. shared situational awareness) and collaborate in near real-time. The expertise from all participating agencies is used in the determination of location, extent, and movement allowing for forecasts of fallout and dispersion to be consistent and more accurate. Relevant data on local agency systems and on the Internet can be pulled into the VACT system during collaborative sessions among the agencies to help in the analysis phase of an event. Societal impact forecasts can be disseminated faster through the development of a smart-system, which will automatically center on the area of eruption and display or highlight all key data sets for the volcanic ash event. Users of the VACT system aren't tasked with determining which data is relevant and can focus their attention on location, extent, dispersion, and societal impact. Societal impact statements can be disseminated following current standards and practices or by interactive briefings tailored to meet the needs of the end user (i.e. the public, emergency managers, FAA, airlines, armed services, state agencies, etc.). All volcanic ash events are captured and archived to help improve detection and dispersion methodologies, train new users on VACT functionality, detect and eliminate problems with multiple agencies collaborating in real-time on volcanic ash events, and improve dissemination techniques.

2. Research Accomplishments / Highlights:

During the 2006/2007 research year, CIRA engineers at NOAA's Earth System Research Lab in the Global Systems Division's Aviation Branch shifted their priorities to support the FXA Aviation Initiative demonstration during July through September 2006. Prior to this, FXC VACT systems migration to Red Hat Enterprise 3 and the FXC software port reached a point where the VACT software was going through integration testing for the next release.

During the time since June 2006, FXC development has progressed towards a new revision control system, using subversion, and a new major release and port to java 1.5.

Airmet and Sigmet displays were added, along with corrections to the sectors background maps. Enhancements to the FXC VACT software will be inherited from the work performed on the FXA Aviation Initiative demonstration along with enhancements from the FXC TMU Project. Additional benefits will be gained through reorganization and planned improvements to the servers and operating infrastructure environment. It was agreed to perform the next VACT delivery to include all these enhancements. Some of these enhancements will include the Voice Over IP Skype configuration and Remote Procedures framework for interactive briefings with the Traffic Managers. Also, from the TMU Decision Aid development, there will be a framework to follow to create Web-based Decision Aids and impact database using Volcanic Ash and convection for the Alaska Region, along with FXC override capability. This is significant and will require a major revisit and realignment to the tasking, planning and testing of the code base and systems. Throughout the year, continued support to the current operation prototype systems was provided as needed.

In February 2007, the Federal government members of the VACT development team were awarded the *2006 US Department of Commerce Bronze Medal* " for developing the Volcanic Ash Collaboration Tool, a new tool which provides forecasting capabilities during volcanic eruptions and is essential to preventing volcanic ash damage to lives and property." The Bronze Medal is the highest honor award that can be granted by the US Undersecretary of Commerce for Oceans and Atmosphere. The entire project team is comprised of:

ESRL/GSD Aviation Branch/Development and Deployment Section—Greg Pratt, Lynn Sherretz, Jim Frimel (CIRA), Young Chun (CIRA), and Chris Masters (Contractor);
NWS Alaska—Tony Hall, Kristine Nelson, Jeffrey Osiensky, Christopher Strager and Craig Bauer; USGS AVO—Dave Schneider and Rick Wessels

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:

Based largely on his contributions to the FXC VACT Project, Jim Frimel was awarded the 2006 Colorado State University Distinguished Administrative Professional Award.

8. Publications:

Frimel, J. and C.R. Matsumoto, 2007: The Volcanic Ash Coordination Tool (VACT) Project. CIRA Magazine, Vol. 27, Spring 2007, pp. 18-22.

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

Principal Researcher: Jim Frimel
CIRA Team Members: Young Chun and Lisa Gifford

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). A major goal of PACE is to investigate aviation data sets and forecast products specifically tailored for the ARTCC air traffic weather forecasting environment among operational weather forecasting facilities, and to investigate the utilization of collaborative weather forecasting.

The FAA PACE effort as it relates to CIRA research at NOAA's ESRL GSD is currently comprised of two separate investigative projects: the TMU project and the FXC FAA project. This effort was spawned from the necessity to research and investigate innovative 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 the web-based research and development of products available directly to the Air Traffic Controllers for their evaluation via the Internet. The FXC FAA project is the research and development of software utilized in the PACE facility for investigating and demonstrating collaboration and prototyping of aviation specific data products.

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 Traffic Manager users.

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 FAA project. The major system used to acquire, distribute, create and provide the required data sets for FXC is the AWIPS Linux data ingest and display system. The FXC and AWIPS software is being tailored, modified, extended, enhanced, and utilized in the FXC FAA and TMU projects. The FXC software allows for the remote access and display of AWIPS data sets over the Internet, a collaboration capability among participants at physically different locations, and the ability to utilize tools to aid in discussing forecasts. The TMU project relies on the AWIPS system for generating the content available on the TMU Web site.

2. Research Accomplishments/Highlights:

During the 2006/2007 research year, CIRA staff at NOAA's Earth System Research Lab in the Global Systems Division’s Aviation Branch concentrated its efforts on the next Major Release of the FXC TMU software. During this time, the major focus was to design, develop and implement a suite of systems that would consist 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 goal was to create a “demonstration” system to show proof of concept and lead the way towards a working prototype.

The initial design and structure of the decision aids relational database was populated with map background information for the ZFW arrival/departures, high-use jet routes, and TRACON arrival/departure gates. Following were changes to the AWIPS impact decoders to create impact information based on the NCWF2 data sets that would then be stored in the database. Work then began on server side processing of the web content generation and presentation. Houston (ZHU) and Washington (ZDC) ARTCC map and impact information have been added to the FXC displays but is not a part of the database.

Some of the Major enhancements to the systems include the following:

--Web content access to Decision Aids RED-Light/Green-Light for Traffic managers.
--Addition of Yellow-Light to above WEB page to show partial impact to airspace.

--Enhancements to drill down graphics to capture complete arrival/departure corridors and jet routes.
--Separate departure and arrival corridor drill down images.
--Enhanced line thickness for easier viewing.
--Continue to investigate and improve access performance to database.
--Time matching of WIDA products with other AWIPS products was implemented and continues to be tested in AWIPS.
--Timing problems between WEB delivery and real-time display systems.
--Created one DGM file per forecast period for editing.
--FXC TMU End-to-End Override Edit capability.
--Major AWIPS enhancements in order to implement all ingest, impact decoding, and displays for FXC End-to-End functionality.

In addition to developing and designing an FXC End to End capability, the team had met and reviewed plans for the next generation architecture requirements to support ASDAD projects. Goals for design were to centralize data requirements for all projects, allow for the development of clearly defined interfaces from data storage to data display, reduce maintenance costs, reduce security risks, address machine space, power and cooling limitations in the GSD computer rooms and provide systems scalability. We are currently working on a transition plan to take us from our current platforms to the next generation of systems based on the architecture discussions. In order to address the requirements, we began exploring virtual machine technology. We had implemented virtual machines for our AWIPS content generation side. Early tests indicated that system load limits and performance were not meeting our requirements and further testing and investigation are needed. In order to centralize and share documentation, we also implemented a wiki to house and share our internal project and systems documentation.

A goal of the TMU web site is to consolidate all tactical aviation weather hazards information into a suite of products for presentation to TMU decision-makers in an easily understood format (A, GO-NO-GO, approach to air traffic route and flow information). What is important to understand about the Weather Information Decision Aids (WIDA) web content page is that it is a complete end-to-end system, not just a simple web display that provides useful information assisting in tactical and strategic decision making. It is an extremely complex suit of systems that involves AWIPS, FXC, content Generation, web services, and database services. 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 is an excerpt from a GSD hot item written by Michael Kraus: http://www.fsl.noaa.gov/media/hotitems/2007/07Apr30.html:

Tom Amis, The Meteorologist in Charge at the Fort Worth Center Weather Service Unit commends ESRL's Tactical Decision Aid for Terminal TRACON Ops Website for aiding him to direct air traffic during the development of thunderstorms on April 24, 2007. As he puts it, "Your site [developed by the Aviation Systems Development and Deployment section of the Aviation Branch at ESRL's Global Systems Division] was a big hit yesterday in planning for our traffic management units. By using the forecast data, we were able to time when we were going to need to shut down arrivals and move traffic flows to different locations and arrival gates." The WIDA web site was used over 15 times to explain to Operations Supervisors-in-Charge how the thunderstorms were expected to continue to develop and move through the airspace.

WIDA gave us the visualization capability to effectively communicate a consistent and relevant weather picture to our customer." The Aviation Branch of ESRL's Global Systems Division collaborates with the FAA, the National Weather Service, and the Department of Transportation. These collaborations result in improved weather forecasting and visualization capability for use by forecasters, air traffic controllers, air traffic managers, airline dispatchers, and general aviation pilots. This is an example of how NOAA implements a sophisticated assessment and prediction tool to support decisions in the aviation sector, fulfilling our mission goal to "Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation."

The following sequence of images will show North, South, East, West, ZFW TRACON Departure Gates Impact Information based on NCWF2 and then Edited Override information.

Images 3, 4, and 5 show current impact with no Forecaster edits. ZFW TRACON departure gates are displaying green (no impact) and yellow (partial impact). Images 6, 7, and 8 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 Web page used by the TMU Traffic Managers.

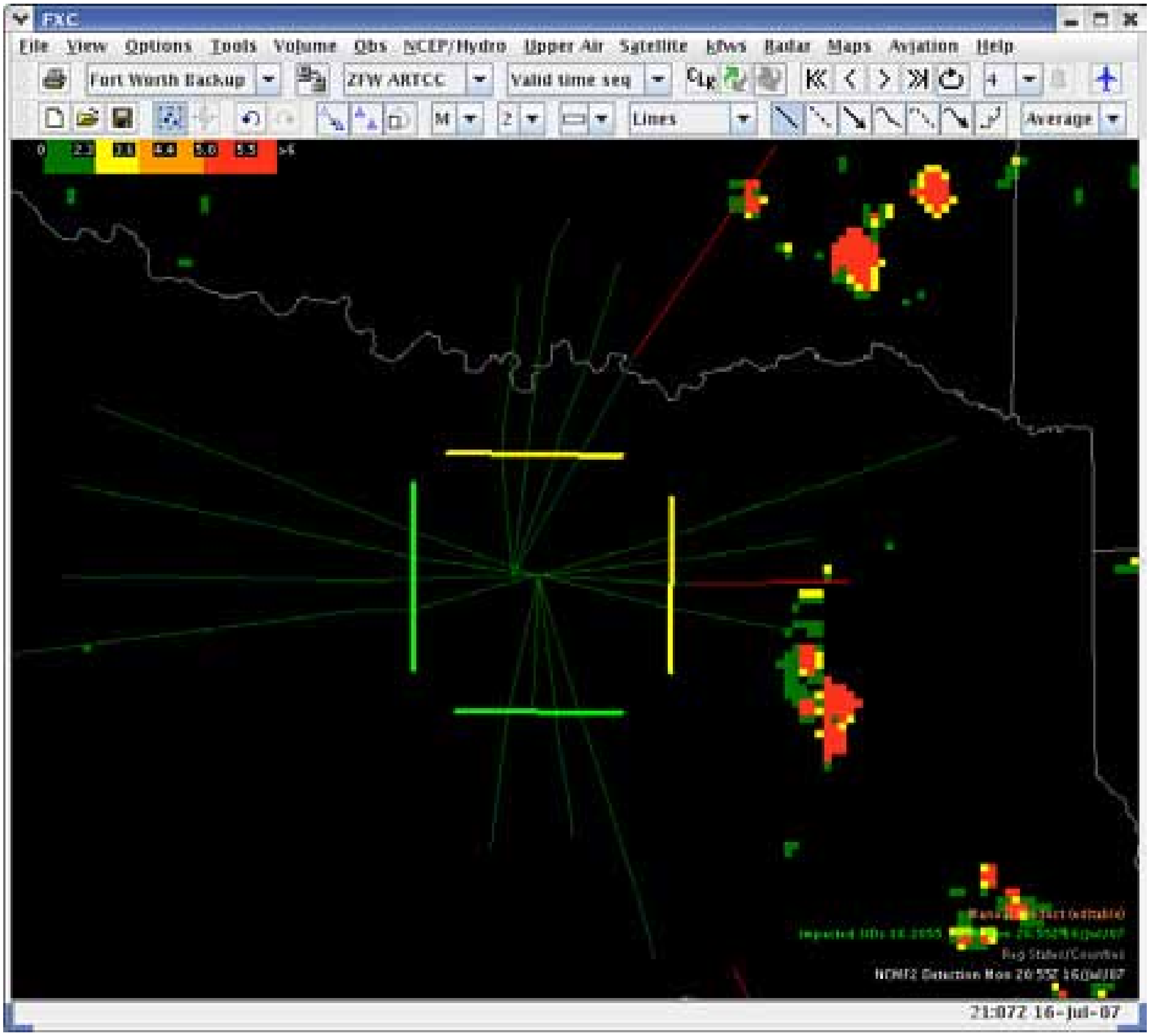


Fig. 3. Forecaster FXC tool showing current ZFW TRACON Departure Gate impacts with NCWF2.

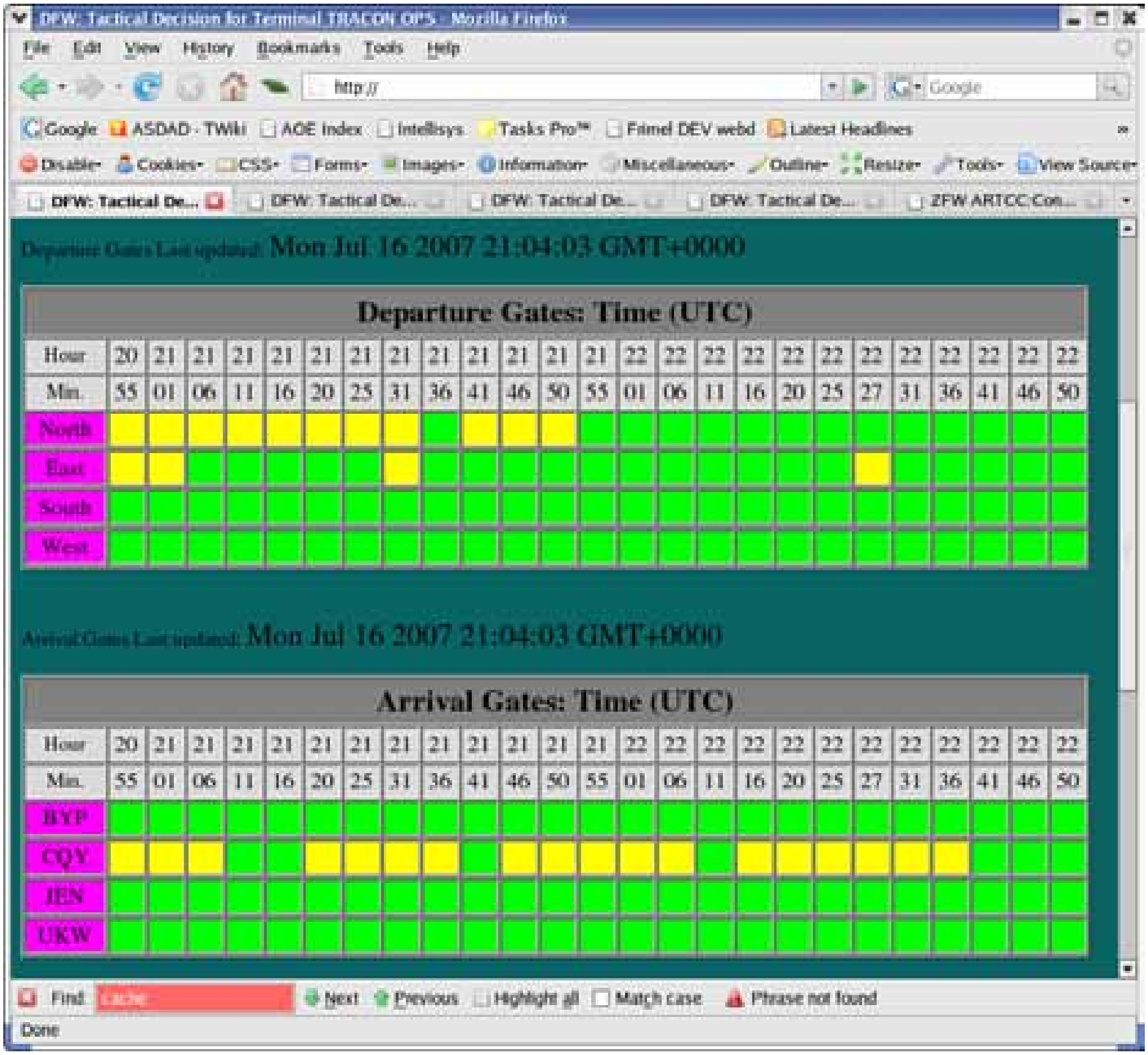


Fig. 4 Traffic Manager (WIDA) Web Display showing concurrent Red-light/Green-light Departure Gate Impact information.

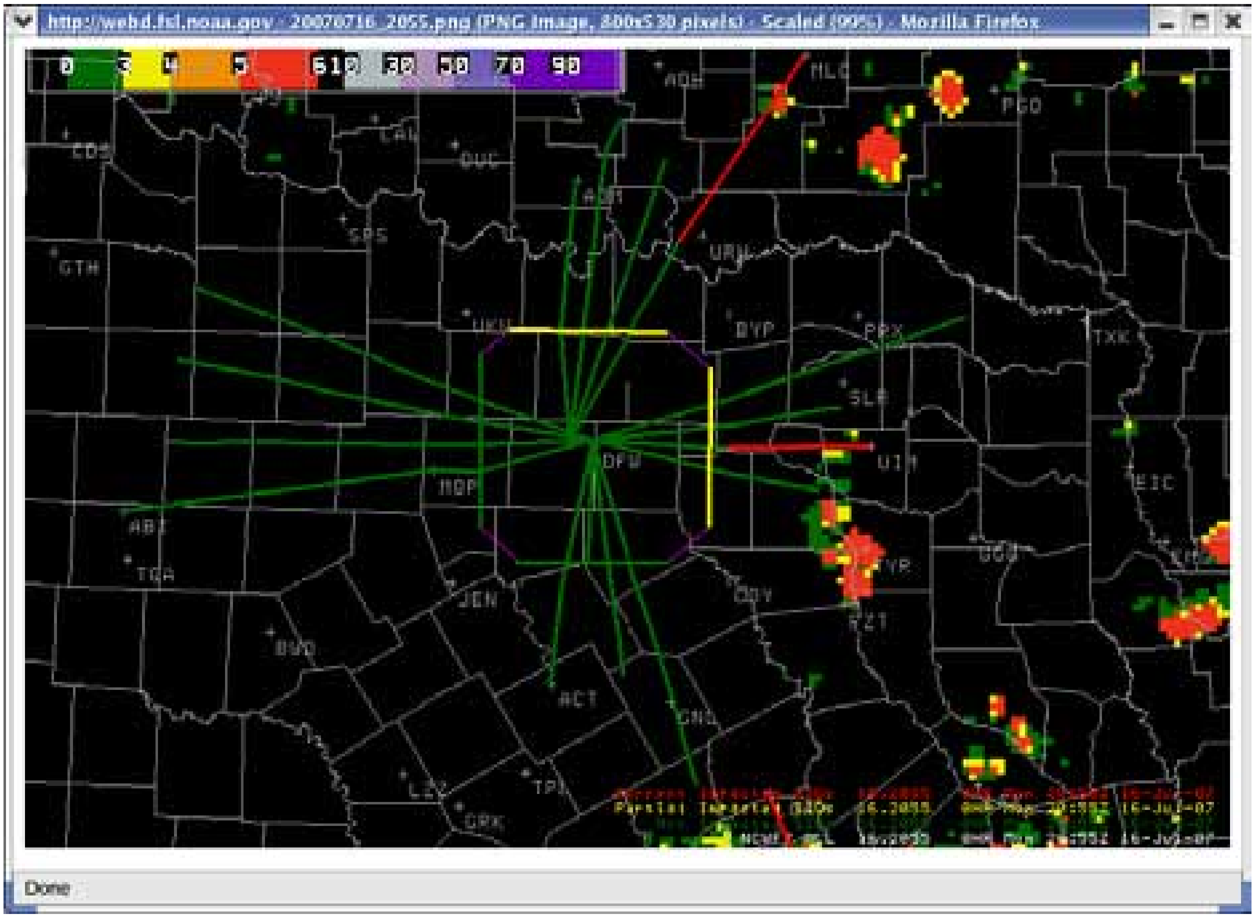


Fig. 5. Traffic Manager (WIDA) Web Display showing concurrent Drill Down image Departure Gate Impact Information (Drill Down image is available by selecting any desired route/time cell within the web page).

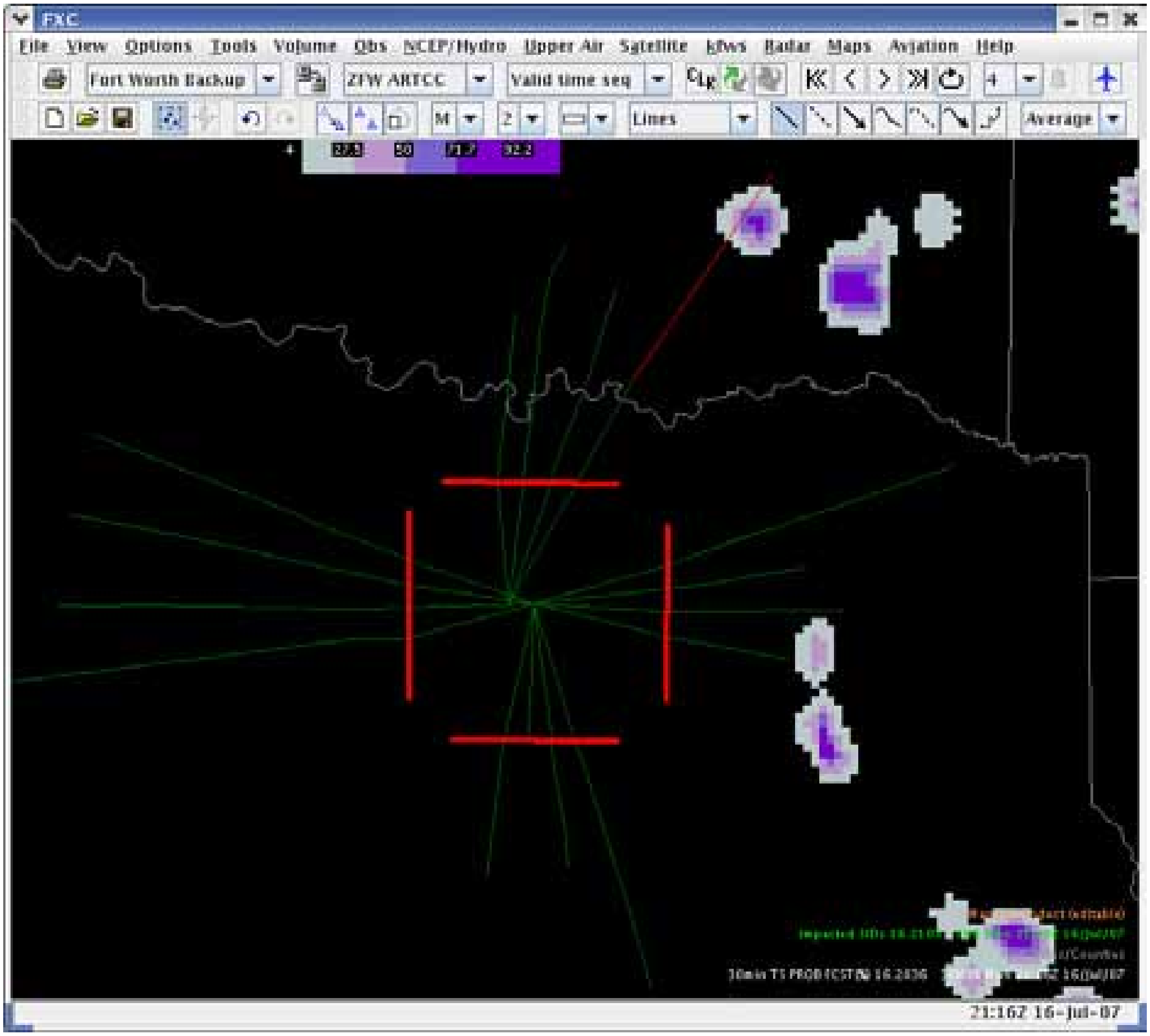


Fig. 6. FXC tool showing FORECASTER EDITS and OVERIDE to all RED of the ZFW TRACON Departure Gate impacts with NCWF2.

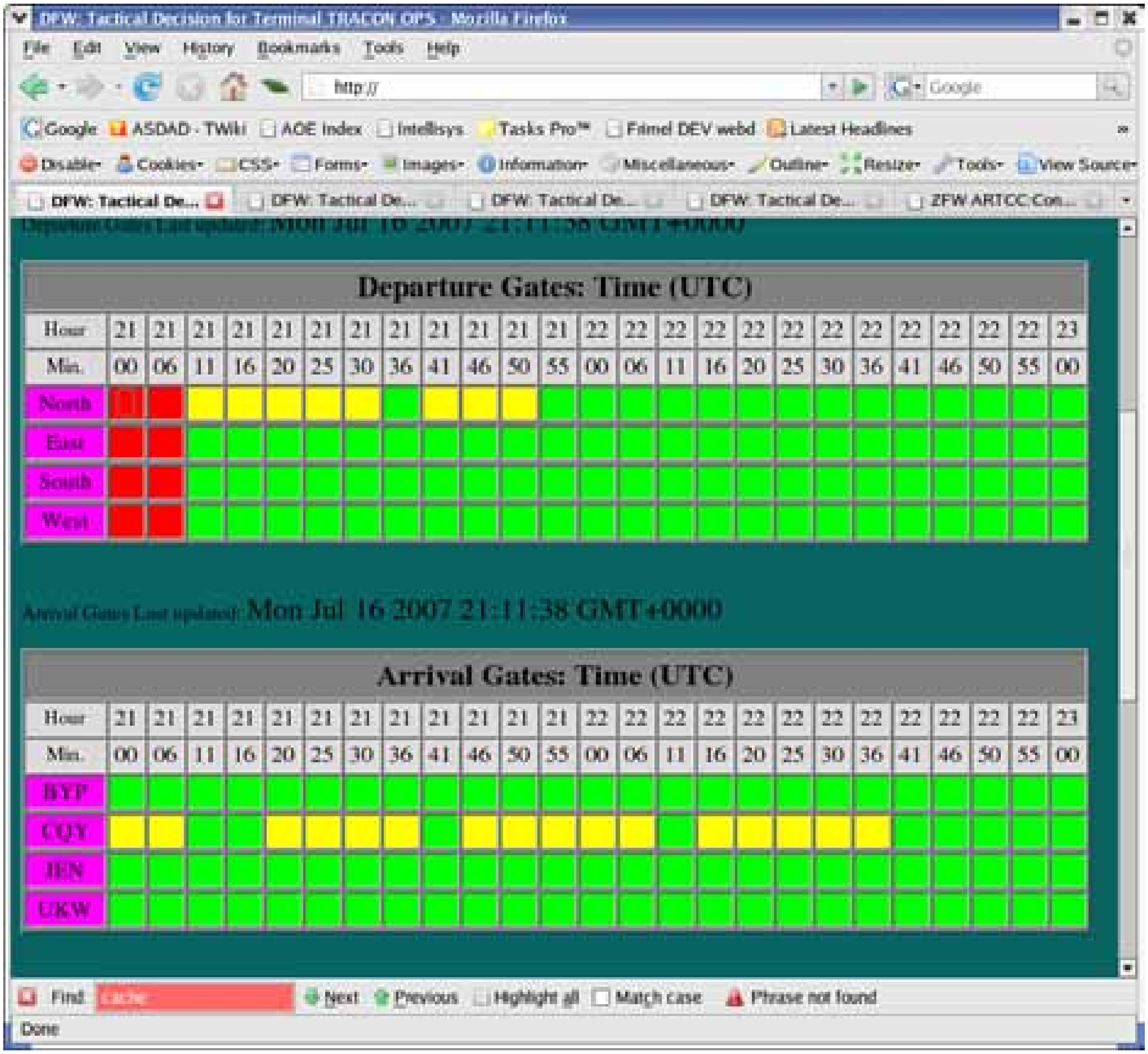


Fig. 7. Traffic Manager (WIDA) Web Display showing updated RED OVERIDE Red-light/Green-light Departure Gate Impact information.

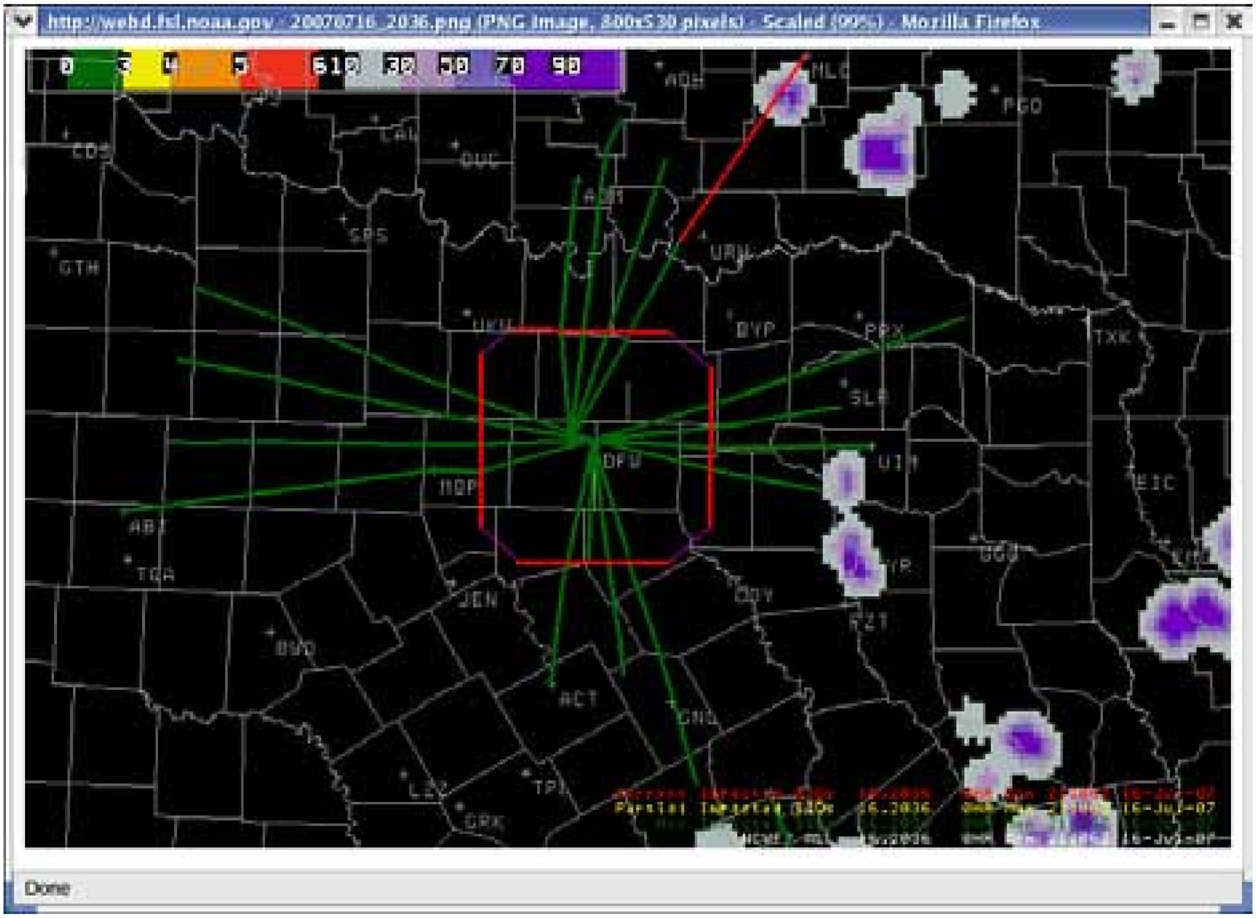


Fig. 8. Traffic Manager (WIDA) Web Display showing updated RED OVERRIDE Drill Down image Departure Gate Impact Information (Drill Down image is available by selecting any desired route/time cell within the web page).

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

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 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 develop the Real-Time Verification System (RTVS). This system, currently operated at GSD, provides statistics and verification displays in near real-time for aviation forecast products being created by the Aviation Weather Center (AWC) and the Alaska Aviation Weather Unit (AAWU), both operational NOAA entities. It also generates statistics for experimental products that are being transitioned to operations through the Aviation Weather Technology Transfer (AWTT) process. 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 Convective SIGMET (C-SIGMET), 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 working on RTVS will continue to collaborate with ESRL/GSD's Aviation Branch in the following areas:

a) Long-term statistical assessment of operational aviation weather products

b) Evaluation of experimental aviation weather products for transition to operations

c) Development of new verification techniques and metrics, particularly for probabilistic forecasts

d) Application of newly available satellite data for verification of global forecast products

e) Design and development of processing infrastructure to support near real-time evaluations

2. Research Accomplishments/Highlights:

a) Design and Development of Processing System for Verification of Operational Icing Forecasts

In support of the operational transition of the Forecast Icing Potential (FIP) product, developed by the FAA's Icing Research Team, CIRA researchers designed and developed a verification data processing system. The system, which provides valuable operational performance metrics, produces statistical plots and graphical displays, available via a powerful web interface, using reports of icing from aircraft pilots (PIREPs) as observations. NOAA collaborators use this tool to create historical records of operational icing forecast performance.

b) Design and Development of Processing System for Intercomparison of Convective Forecasts

Forecasting convection, which significantly impacts air traffic in the National Airspace System (NAS), is of great interest to the air traffic management community. The CIRA team participated in the development of a study to determine the performance of mature convective forecasts, each of which is a candidate for operational use. Beyond the standard meteorological metrics, other user-based approaches were employed. For example, the study examined the quality of forecast products available at specific strategic decision times during the morning hours. This stratification of results allowed better insight into the performance of the forecasts in support of air traffic management.

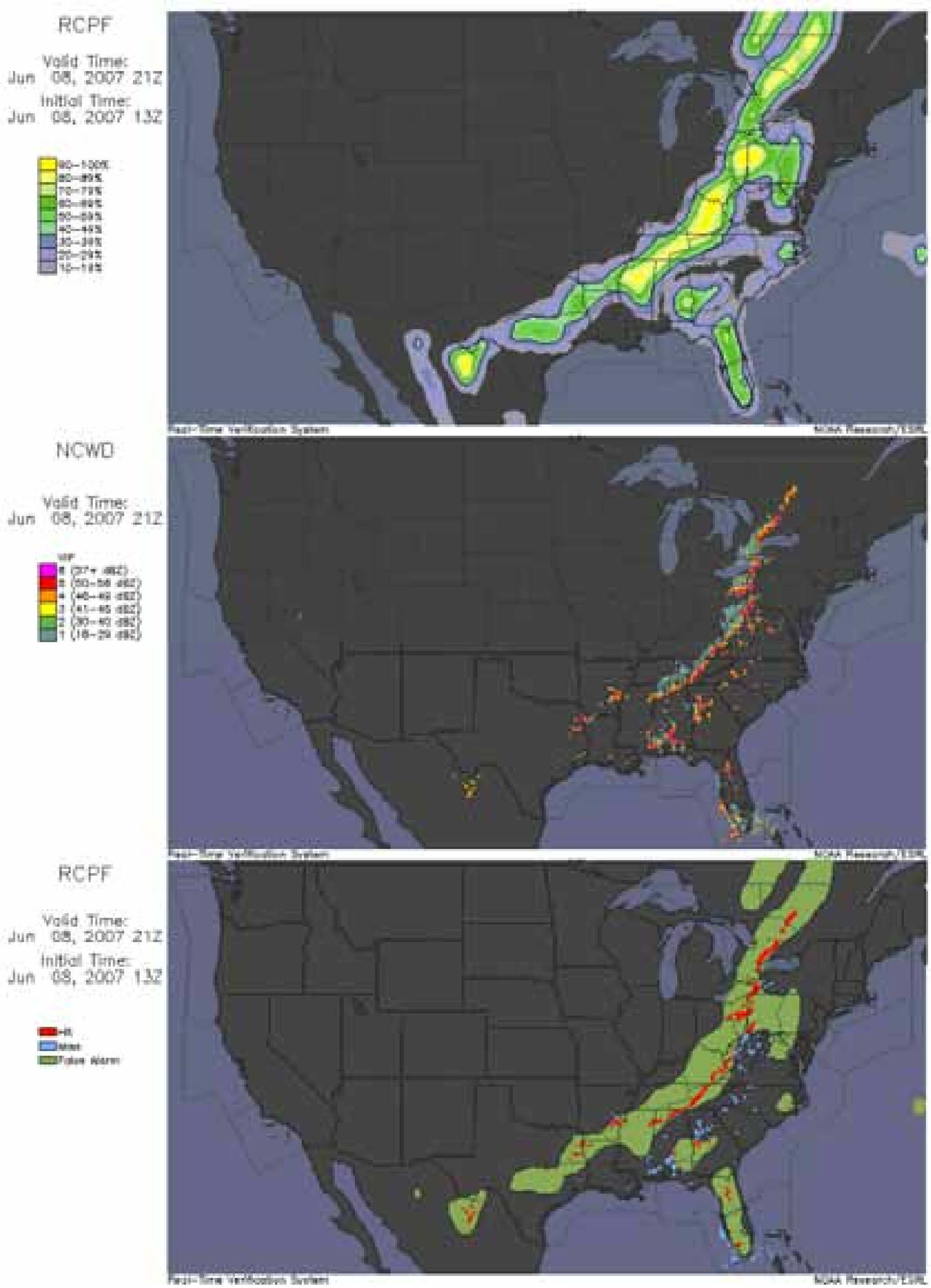


Fig. 2. Example of RTVS verification of a convective forecast product. This display allows a researcher to examine the qualitative behavior of the forecast. Quantitative information is also available from the verification system.

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 continue to collaborate with NOAA to develop a lead-time metric for the ceiling and visibility attribute of the Terminal Aerodrome Forecast (TAF). CIRA researchers have guided the development of a new lead-time metric. During the development, a number of issues were uncovered that warranted additional investigation. These included the effect of climatology on the sensitivity of the metric and possible adjustments to the definition of the forecast.

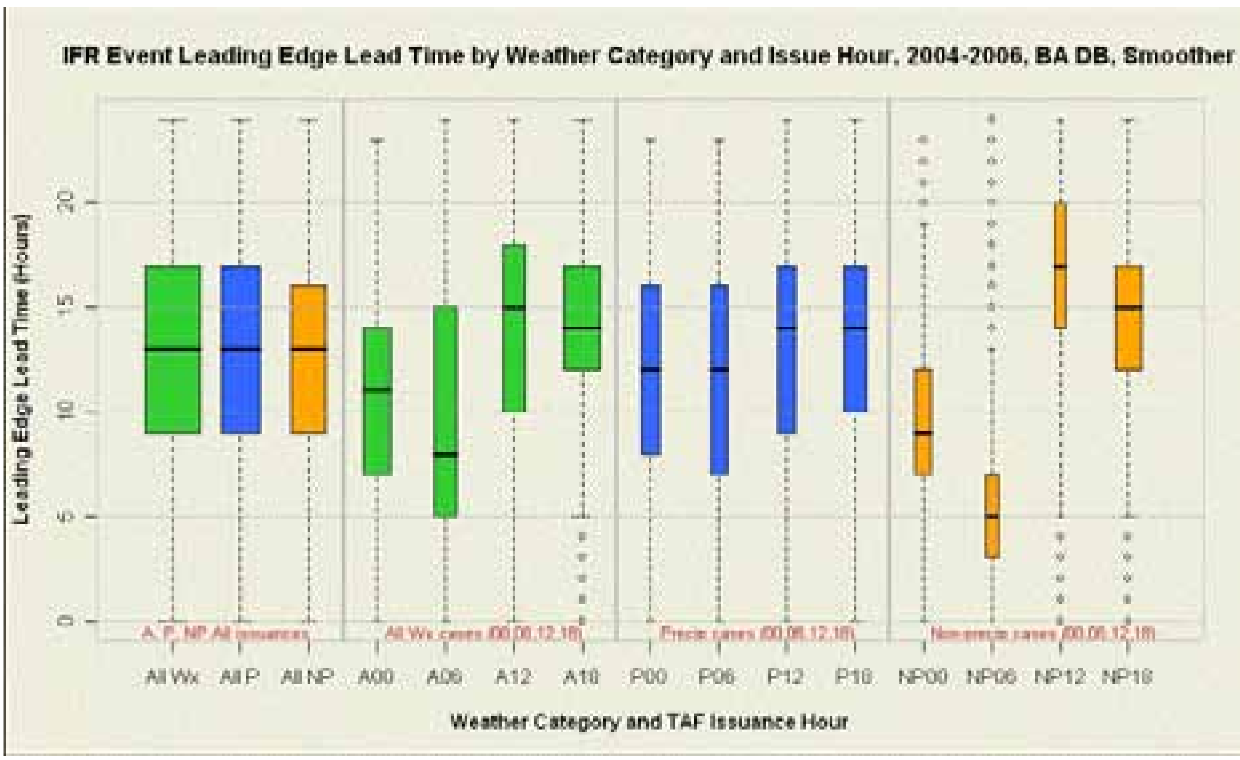


Fig. 3. Summary of the variation in TAF lead time by weather category and forecast issuance hour for three years of forecasts at all major terminal locations in CONUS.

d) Technology Transfer of Latest Version of RTVS to NWS Headquarters Operational Group

CIRA researchers are investigating and implementing new ways to deploy upgrades and new verification capabilities to an RTVS configuration to the NWS Headquarters in

Silver Spring, MD. The transfer provides the NWS, through the system housed at the Telecommunications Gateway Operations Center, with the ability to perform long-term quality assessments of operational aviation weather products issued from the NWS Aviation Weather Center. By adapting the RTVS data system interfaces to the operational standards, CIRA researchers will enhance the ability to deploy verification capability.

e) Development of a Verification Framework for the Aviation and Modeling Communities

Driven by the need to effectively integrate verification information and for collaboration between researchers with different verification code, the CIRA team has developed a verification framework. Working within the framework, researchers can publish, retrieve, and integrate information in powerful ways, which include the ability to incorporate air traffic and other non-meteorological data directly into the verification analysis. CIRA researchers are currently implementing an initial prototype, geared to evaluation of strategic air traffic decisions. The resultant system will serve to demonstrate the value of the approach to sponsors and collaborators.

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 an initial framework and are developing a prototype system to demonstrate the concept to sponsors and collaborators.

--Objective: Research and support for an assessment of the FAA's National Ceiling and Visibility (NCV) product; research and support for an assessment of the FAA's 6-hour National Convective Weather Forecast (NCWF-6) 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 the evaluation of probabilistic convective forecasts for the FAA decision makers.

--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. Work continues to communicate and refine the approach, which will possibly be adopted as a formal operational metric.

--Objective: Evaluation of satellite imagery for inference-based verification of aviation products

Status: On hold. The CIRA team performed an initial investigation into satellite-based products that diagnose volcanic ash in the atmosphere. Work will continue upon FAA request.

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

Status: In progress. As part of the prototype development associated with the verification framework, the CIRA team is integrating air traffic information into the analysis of the performance of convective forecasts. Results from this effort will be available during the next fiscal year.

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

Status: In progress. The CIRA team is creating a data interface for RTVS that will allow for a more seamless transfer of technology to NWS operations.

4. Leveraging/Payoff:

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

CIRA researchers in the RTVS group collaborated and/or partnered with the following organizations during the 2006-2007 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:

Kay, M.P., S. Madine, and J. Mahoney, 2006: National convective hazard detection product. *NOAA Technical Report*, Forecast Systems Laboratory, Boulder, CO.

III. Research Collaborations with the GSD Information & Technology Services

Project Title: Data Systems Group (DSG) Research Activities

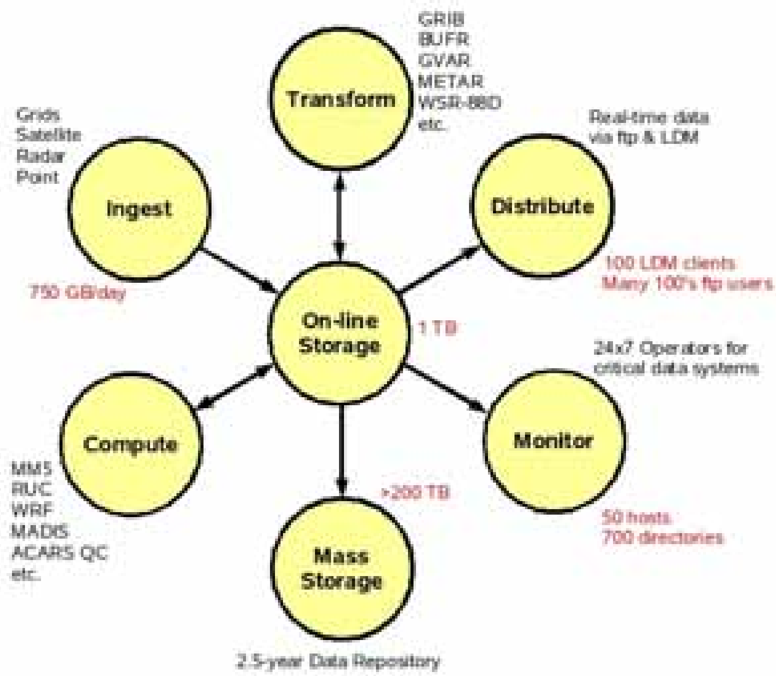
Principal Researcher: Christopher MacDermaid
CIRA Team Members: Leslie Ewy, Paul Hamer, Patrick Hildreth, Bob Lipshutz, Glen Pankow, Richard Ryan, Amenda Stanley, and Jennifer Valdez

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:

CIRA researchers in DSG collaborate with the NOAA Global Systems Division (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 Fig. 1. These services include data ingest, data transformation, data distribution, system and data monitoring, data saving, compute services, and on-line storage.



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

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

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

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

2. Research Accomplishments/Highlights:

DSG's highlights of the past year include:

--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 data sets

--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 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 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 data sets
  --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 some observations from around the world. The richness of this meteorological database is illustrated by such diverse data sets 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 data sets continue. Use of ODS applications and methods will expand as legacy translators and product generation methods are replaced by the new techniques including OO software development for point data.

Status: This work is in progress.

--Goal: Metadata Handling

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

Status: This work is in progress.

4. Leveraging/Payoff:

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

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

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

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

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

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 #2, 5, 9, and 13)
--Coasts, Estuaries, and Oceans (for activity #3)
--Hydrology (for activity #13)

Commerce and Transportation—Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation (for activity #8)
--Surface Weather (for activities #7 and 10)

Key Words: Local Analysis and Prediction, High Resolution Modeling

LAPS / WRF Improvements

Participating CIRA Scientists: Steve Albers and Chris Anderson

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

The Local Analysis and Prediction System (LAPS) integrates data from virtually every meteorological observation system into a very high-resolution gridded framework centered on a forecast office's domain of responsibility. Thus, the data from local mesonetworks of surface observing systems, Doppler radars, satellites, wind and temperature (RASS) profilers (404 and boundary-layer 915 MHz), radiometric profilers, as well as aircraft are incorporated every hour into a three-dimensional grid covering a 1040km by 1240km area. 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, including universities such as Univ. of Oklahoma ("OLAPS"), and Univ. of North Dakota. LAPS is running on-site at each National Weather Service Forecast Office (WFO) as an integral part of AWIPS. LAPS software is also being implemented at various U.S. government agencies such as Federal Highways Administration (MDSS), Range Standardization and Automation (RSA) at the U.S. Space Centers, National Ocean Service, U.S. Forest Service, and for international government weather bureaus such as China, Italy, Taiwan, Thailand, and Korea.

Research objectives related to LAPS continues to be the improvement and enhancement of the system in providing real-time, three-dimensional, local-scale analyses and short-range forecasts for domestic and foreign operational weather offices, facilities, and aviation and other field operations.

2. Research Accomplishments/Highlights:

Improvements were made in the Local Analysis and Prediction System (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. 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.

LAPS Observational Data Sets

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

Surface Observations

Support was added so LAPS can now ingest urban mesonet (MADIS Urbanet) data to facilitate high resolution analyses. Initial changes were made to read soil moisture from meteorological towers into the surface observation database. Quality control was improved for surface maritime observations, including sea surface temperature. A surface observation blacklist update was supplied by the Wichita WFO and will filter out many additional suspect observations, winds particularly. The observation blacklist was also updated for better QC of the surface winds.

Upper Air Observations

Profiler and RASS ingest software was modified so that we can more easily specify the use of MADIS boundary layer profilers via namelist, and we now have better results when processing MADIS profilers. This software was also reorganized with improved error handling and specification of output file unit numbers. The error handling for profiler/RASS NetCDF reads was improved by rearranging the if-then-else blocks. This should prevent memory overwrites by skipping the variable read when the variable doesn't exist. Boundary layer profiler/RASS ingest was made more robust in sorting out valid data reports from various times. SODAR ingest was flipped to read data in the normal convention from lower to higher levels. These improvements are benefiting various runs such as RSA range data ingest.

Aircraft ingest of automated TAMDAR observations were turned on since they have now been validated in ESRL studies. Quality control of aircraft observation altitude was improved.

In the sounding ingest program, we added a new top level driver routine that splits off the access of global parameters to help with the "one executable" version of LAPS. RAOB ingest was streamlined to run more efficiently on large domains.

A fix was made for the observation reader and converter that FAB colleague Yuanfu Xie has written so that it can simultaneously read wind and temperature observations. This benefits the Gridded Statistical Interpolation (GSI) and potentially the Homeland Security (DHS) projects. Several library subroutines are being generalized to help with the converter software. Various ingest software programs were modified to better manage log file size for large domains.

Surface Analysis

Changes were made to the surface analysis to be more compatible with a one-executable version of LAPS, particularly in the top-level routines.

Allowable background dewpoint values were reduced to 70K as these can be returned by the 'make_td' routine when the model background (LGA) process generates LGB files. This will allow the surface dewpoint analysis to read in the background AVN/GFS field more reliably, albeit with some of the low dewpoint values present. The acquisition of first guess fields at the 700mb and 500mb levels was corrected so that it dynamically picks the appropriate levels to use regardless of the layout of the vertical grid. These fields are used to help constrain the surface analysis.

The analysis now reads in separate grid spacings for the X and Y directions to improve results with a 'latlon' grid. We added code to use a more efficient bilinear interpolation for the surface analysis verification and for other grid to station interpolation. This is an important consideration for the LAPS run time in large area or global domains, allowing an order of magnitude improvement for the surface analysis package. Roughly another factor of five speed improvement was obtained from rearranging a less critical background weights routine.

Units were corrected within the surface dependent data wind verification. Observation capacity was increased in logging and verification formatting.

Space-Time Mesoscale Analysis System (STMAS)

We continued to maintain several STMAS analysis runs of which some are operational and some are experimental. This included setting up both primary and backup STMAS analyses (along with web products) on separate machines to improve reliability for our MIT/LL collaborators. We entertained a visit from Jonathan Hurst of MIT/LL to assist him in STMAS/LAPS software installation on-site at LL.

Radar Processing

We have worked towards more efficiency and other functional improvements for radar remapping and mosaicing, described in detail as follows.

An Initial version (1.0) of ODS software from ITS to generate polar NetCDF Nexrad radar files was added to LAPS. This is designed to work with either Archive-II radar data files or a live radar LDM feed. This provides the front end executables that other LAPS scripts can operate with to provide an end-to-end capability for Nexrad processing.

Scripts that drive the Archive-II to NetCDF converter were made more robust and flexible for both real-time and case study runs. For example, the script that processes Archive-II radar data has new error checking and more flexible handling of naming with 'TarNexrad2NetCDF' and related executables. The LAPS sample real-time cron file now has commands/instructions that show users how to run the Archive-II processing. We also have a new domain radar list generator in place that runs during the localization.

Radar polar-to-cartesian remapping code has a new error check for the number of radials. The remapping was further generalized towards the goal of accepting data with number of gates and gate spacings that differ from our standard WSR-88D datasets. This should benefit the LAPS implementation at the Finnish Meteorological Institute (FMI). The data compression for wideband (Level-II) radar data was reworked to use more integer arithmetic so it can give accurate results with high-resolution domains. We also use double precision trigonometric functions such as 'dcosd' to help make the compression more reliable on various platforms.

Quality control was improved in the 5km resolution regime. Radar data analysis in the vertical dimension now has improved gap filling capabilities between successive tilts. Memory allocation was also streamlined.

In the radar mosaicing program, we reworked the looping strategy to allow a future memory saving option of rereading each radar individually. This program was also improved to more gracefully handle cases with missing radar data.

In support of the climate research collaboration "carbon run", the number of wideband radars that can be processed is being increased (in a 21 level LAPS grid) from about 20 radars to about 50.

Wind/Temperature Analyses

Further changes were made to the wind analysis to be more compatible with a one-executable version of LAPS, particularly in the top-level routines. For example, the main program now allocates the 3-D wind arrays and passes them into the processing subroutines. We also pass global parameters such as 'ilaps_cycle_time' into the processing routines.

Array naming in the modified Barnes analysis routine was reworked to allow the input of ensemble generated background error (collaborating with Okyeon Kim and Chungu Lu). This is now the strategy instead of an earlier idea to output analysis error. The wind and temperature analyses (as well as the surface analysis) were reorganized to facilitate data flow of the background weight arrays.

Analysis time variables are now passed among wind analysis subroutines in a more unified way. Loop structure was modified slightly to help improve analysis efficiency. Error handling was improved in the wind analysis when reading aircraft observations.

Separate weighting has been added for I and J directions to allow future flexibility with non-conformal grids (such as LAT/LON). So far, this is set up just for the wind analysis. This includes some compensation that prevents the horizontal weighting scaling factor from being applied twice. A new routine was added to calculate grid spacing separately in the X and Y directions to help the wind analysis work with a LAT/LON grid. We now bypass the omega calculation and set it to missing if we're using a LAT/LON grid; thus we at least get output for the more widely used U and V fields. Efficiency was improved for the map factor 'get_sigma' subroutine used in divergence calculations.

We improved the radar subsampling options allowing the wind analysis to run more efficiently on high resolution domains. The subsampling strategy thus allows for a greater number of multiple-Doppler radial velocity observations being fed into the wind analysis. One of these options filters the single-Doppler radar obs using a 5x5 window instead of a 3x3 window to pare them down better. Future changes are envisioned that would allow superobs to be constructed from the radar data. The wind analysis now handles cases where the number of Doppler radars exceeds the number of LAPS levels.

A capability was added to analyze single level soundings/towers from the SND intermediate file that should help with the Finnish Meteorological Institute (FMI) database. Wind profile instrument error is now read in by the profile data access routine while the handling of wind profiler surface observations was improved. A new wind observation library was created to allow more widespread use of these routines in the observation converter program for GSI, WRF/DHS, and related endeavors. Wind analysis post- processing routines were added to this library area to allow GSI and other software to utilize them.

Verification of independent observations has been set up in the wind analysis software to compare withheld observations (e.g. RAOBs) to the analysis. This will help in a collaborative research effort with Ok-Yeon Kim and Chungu Lu with an eye towards a journal publication of ensemble background weighting techniques. Wind verification reporting was improved for large domains. The wind verification statistics text output is now more user friendly.

The temperature analysis software was refined and optimized so that it can run on large global domains with many observations. Theta checking calculations are now done in a more efficient way to help with global LAPS runs. Mixing ratio handing was made more efficient and straightforward in the hypsometric equation for the hydrostatic integration that generates the height field. Calls were added to a new temperature verification routine that includes statistics partitioned by data type. So far, dependent observation innovations are being compared to the background and analysis. Initial changes were made to allow withholding of RAOB data in such a way that they can be used for independent temperature data verification.

Stability Indices

We collaborated with Brent Shaw of Weather News Inc. (WNI) to be able to handle terrain above 500mb (e.g. the Himalayas) in the calculation of stability indices.

Cloud / Precipitation Analyses

Software was updated and reorganized to help pave the way to improving the loop efficiency when analyzing the in-situ cloud observations (e.g. METARs). For example, analyzing the differences of cloud fraction from level to level instead of the total cloud cover runs more quickly. New double precision calculations were added to assist in this transition. It is anticipated these strategies will greatly speed up the cloud analysis on large regional or global domains. Related changes include the ability to withhold radar data from the analysis if needed for testing.

The 'maxlut' parameter was increased from 700 to 1400 allowing for larger domains (with visible satellite normalization). Several cloud and radar related vertical velocity scaling parameters were added to the user definable namelist instead of being hard coded to aid in running LAPS hot-start experiments. The radar cloud-omega bogusing routine was reworked slightly so that the random number small-scale structure generation will now give the same results when rerun at a given analysis time. Logging of precipitation type verification information was improved to facilitate studies of surface precipitation type as a function of temperature, dewpoint, and elevation.

General Software Improvements & Portability

LAPS documentation (including software comments), logging, software organization, reliability, and error checking were improved. Module diagrams were updated. Obsolete software was removed. Several library and ingest routines were reworked to avoid unnecessarily repeating the same calculations, including the removal of subroutine calls from inside FORTRAN DO loops, thus improving runtime efficiency. Software was streamlined and made more portable to run on various platforms, including 64-bit machines. Scheduling and LAPS localization scripts now run more flexibly on our EJET Linux cluster. Other software was modified to run better with the compiler on EJET. Scripts that summarize what data got into the LAPS analyses were improved.

Routines that do vertical interpolation were made more efficient. Standard temperature conversion routines were implemented more widely within LAPS.

We continue to maintain regular LAPS software builds on various platforms including posts to our website. LAPS Makefiles and build scripts were revised to improve reliability on various platforms. LAPS build scripts were further optimized for PBS systems. Software build scripts were recast so that they are able to work (with both architectures) in the new JET firewall environment. LAPS execution scripts were made more flexible to enable web based localization. Scripts were added and improved that access and pre-process raw data for case reruns from the Mass Store. Cronfile generation scripts were updated and made more general. Library subroutine 'get_systime' is now equipped with an environment variable override of the file based LAPS systime time. Collaborating with Linda Wharton, we updated some C system timing code to keep current with new C compilers.

Removed includes of 'lapsparms.cmn' in several library and other routines so that namelist variables are now accessed via subroutines. This makes the software more transparent with respect to ongoing changes in parameter naming and handling. Some parameters are being made more dynamic to help in this reorganization. The GRIB2 library and the related LAPS2GRIB program are now more complete in the software repository.

LAPS Implementation

We coordinated a transition of our operational "ROC" LAPS run from a 10-km to a 5-km resolution. We managed LAPS software builds and releases to our website. We also fielded a number of inquiries from both funded and non-funded users about LAPS software and installation.

As part of a collaboration with Isidora Jankov, further testing and development was done on a global LAPS analysis called "GLAPS". LAPS software was updated so it can localize and display domains using a cylindrical equidistant (lat/lon) projection that can allow full coverage over the globe (unlike the gaps near the poles in the previously used Mercator projection). Related updates for more general grid projections were made in various analysis library routines. Examples of these include grid spacing and projection rotation calculations. Routines were made more generic in that they can handle the cylindrical equidistant grid where the grid spacing varies between X and Y directions. They have been implemented to a sufficient extent to allow a switch in our operational GLAPS run to the cylindrical projection grid covering the entire earth including the poles (Fig. 1). Numerous efficiency improvements were made to allow better runtimes on domains such as this covering a large area with many grid points. We are now generating analyses of (unbalanced) 3-D state variables on a 21-km cylindrical grid.

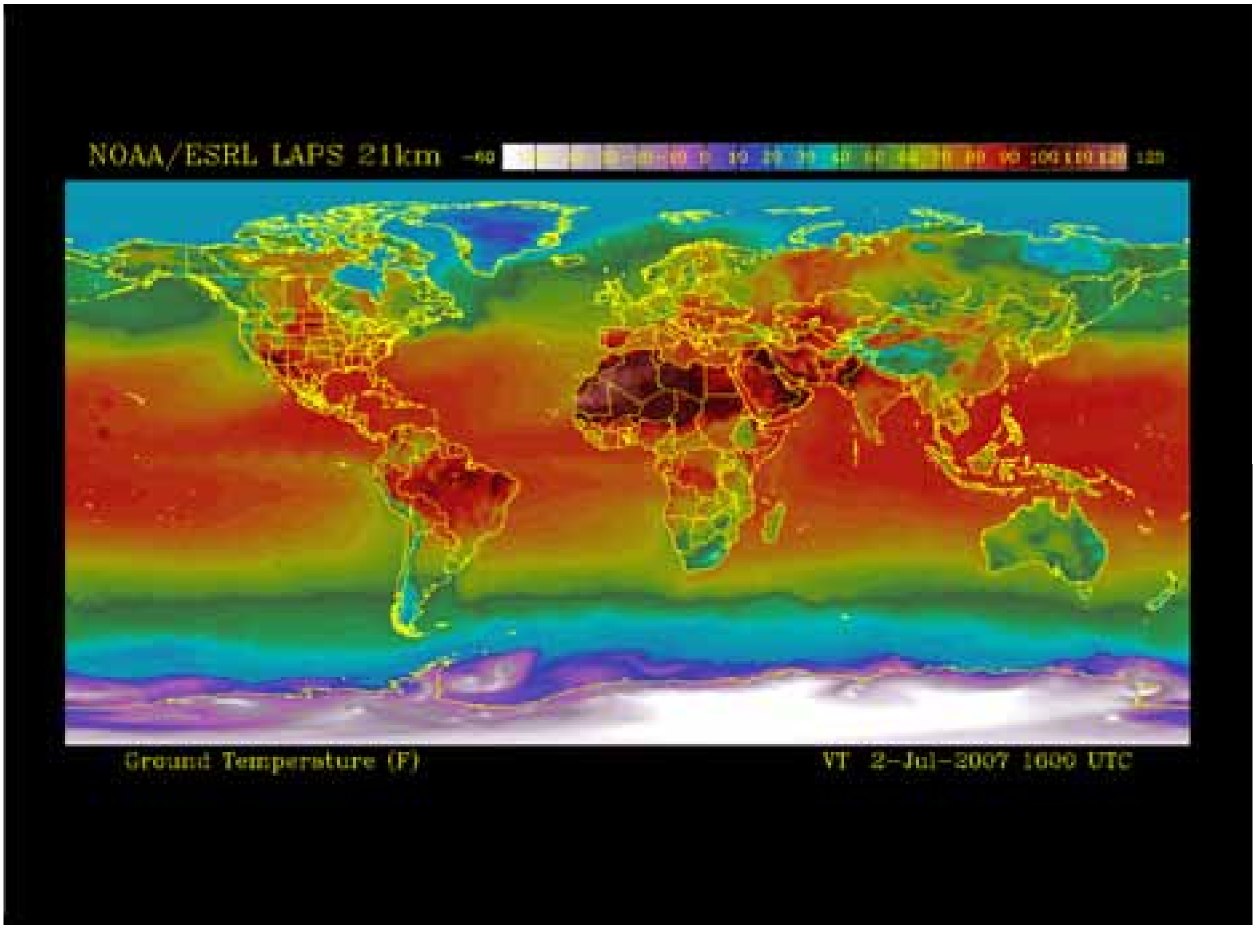


Fig 1. Analyzed surface "skin" temperature on a GLAPS 21-km global domain. Over the oceans, this represents sea surface temperature while over land we see the ground temperature.

Improved GLAPS hourly analysis graphics are being posted to our website and the 21km run is feeding real-time output to Science on a Sphere® (SOS).

GLAPS localization output on an experimental 15km grid has been fed to the FIM model development team that they are in turn interpolating to provide topography and related static grids. Preliminary changes were made to the domain localization software towards the goal of generalizing it enough to set up an icosahedral grid. GLAPS topography images are being given to Paul Hamer of ITS and Paula McCaslin of GSD for import into Google Earth.

WWW LAPS Interface

Scripts were adjusted so that LAPS analysis graphics can be generated behind the new JET firewall. Purging of web products was optimized and products were made more robust when working on various local file systems. The export version of our "on-the-fly" web page interface was updated from our latest in-house scripts. A slight modification was made to the questions asked for plotting satellite data to allow an easier interface with the "on-the-fly" web page. Changes were begun to support the specification of a reference point when zooming in. Station plot legibility was improved when zooming into an area with high station density.

The sense of plan view difference fields was reversed to be consistent with vertical cross-sections. This helps with comparisons of analysis minus background fields. Difference field labeling was improved while plot labeling was updated to reflect our ESRL affiliation. Plan views of balanced height were adjusted so that they now work. We added image capability for THETA plots and set surface U/V images to have a fixed color table. Support of plan view specific humidity image plots was added along with specific humidity background/forecast plots. Preliminary changes were made to add plots of forecast surface precipitation type. Observation plots now distinguish data type better.

Cross-sections were added for background/forecast potential temperature and balanced height. Cross-sections were corrected for background and forecast height. We fixed time labels for analyzed height cross-sections. Cross-section plots are now being displayed at higher horizontal resolution. Radar reflectivity cross-sections for individual radars were improved to use the current vertical gap filling routines. Sounding plots now support surface forecast data and were made more legible.

Various image color tables were improved. The temperature color table was updated to delineate colder regions better. Web plots for CAPE now have a better color table. A new color table was added for greenness fraction plots. The omega colorbar range for small grid spacings was further increased. Static color bar intervals are now used for U & V image plots to help with inter-comparisons between analysis runs. We now allow larger domains to have 20 shades instead of 10 for cloud cover plots.

County, state, and continental boundaries can now all be turned off (if desired) via namelist settings. Plotting labels were cleaned up and improved. Labeling was improved for resolutions finer than 1-km. Image plots will now work better on some of our small fire weather domains.

Mesoscale NWP Model Initialization and Evaluation

We (SA and CJ) collaborated with Isidora Jankov to add a lapse rate correction into our model initialization modules. The correction was needed as a temporary fix to a bug found in LAPS balance package. The bug created large, super-adiabatic lapse rates in the initial condition for mesoscale models. The correction located such layers and modified the thermal stratification to a neutral state. Although the LAPS balance package bug has been fixed, the lapse rate correction has been retained as a general sanity check for all data sources used to initialize mesoscale models.

We participated in drafting a journal article that describes the LAPS diabatic initialization. Chris Anderson provided a suite of experimental LAPS analysis to determine various parameter settings for the LAPS analysis. The primary results were that (1) the vertical velocity should be scaled such that a 10-km deep updraft would have a 10 m/s maximum vertical velocity for mesoscale models with 1-km grid point spacing; (2) the hydrometeor concentration should be scaled such that the scaling factor is unity for mesoscale models with 500-m grid point spacing; (3) it is justifiable to specify cloud liquid and cloud ice concentrations and to ignore rain, snow, and graupel concentrations in the LAPS analysis used as an initial condition to a mesoscale model; and (4) the LAPS analysis provides an initial condition from which thunderstorms can persist for many hours into the mesoscale model forecast. The LAPS group is working together to submit this paper by the end of summer 2007.

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.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

<u>Range Standardization and Automation (RSA) Project</u>

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 US Space Launch facilities (ranges) located at Vandenberg AFB, California and Cape Canaveral Air Station, Florida. In cooperation with Lockheed Martin Mission Systems staff serving as system integrator, ESRL/GSD developed and installed an integrated local data assimilation and forecasting system at the Western and Eastern Ranges with capabilities to incorporate local meteorological sensor data. Upgrades, enhancements and maintenance to the system continues.

2. Research Accomplishments/Highlights:

We continued to maintain LAPS analysis and MM5 forecast runs on our shadow cluster in support of Range operations. We provided support to help Lockheed Martin test their interface to sea surface temperature data for the model lower boundary condition. The procedure involves an ftp process; however, ftp is not supported on the clusters at the Ranges due to security concerns. It is unclear whether the procedures we have developed will be implemented, though one is running on our shadow cluster as a test of concept for the Ranges.

Preliminary tower soil moisture ingest changes were incorporated into LAPS. The goal is to include just the soil moisture observations from range tower data in the surface observation database.

Working with RSA contractors Lockheed-Martin and ACTA, we are characterizing and improving the completeness of the local range data being used in the LAPS analyses. Areas of focus include boundary layer profiler winds, RASS temperature profile availability and quality control, data from NEXRAD Level-III radars, SODARs, and NOAA buoys. A script for tarring up LAPS hourly data at the ranges was developed to assist in trouble shooting these and other issues.

We participated in discussions with the RSA participants about handling of terrain on the different resolution nests. We supported a desire voiced by ACTA to improve the high-resolution (inner-most) nest forecast within the first 2-3 forecast hours. Three solutions were presented in a teleconference that included ACTA staff and Lockheed Martin managers. The solution for which it is feasible to implement within the time frame of the contract has been implemented on our shadow cluster. Evaluation by ACTA and implementation at the Ranges will proceed as directed by Lockheed Martin managers.

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.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships:

6. Awards/Honors:

7. Outreach:

8. Publications:

Coastal Storms Initiative

We received no requests for support during the past year.

WINDPADS (Precision Airdrop)

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

Taiwan Central Weather Bureau (CWB)

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

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

See LAPS/WRF Improvements under previous section

2. Research Accomplishments/Highlights:

We continued to maintain LAPS builds and Taiwan centered domains running on FAB branch machines, JET, and a machine at the CWB in Taiwan. This includes a reference run on EJET for comparing GSI with the "regular" LAPS analysis.

New temperature analysis software is being organized into a library that can be easily utilized by the LAPS to GSI interface. Velocity de-aliasing software issues are being discussed with Dr. Shiow-Ming Deng of the CWB and he is working with us to improve the software. Documentation and organization were improved for the radar vertical velocity algorithm contributed by Dr. Adan Teng of the CWB. Working with Wen-ho Huang, we moved some of the LAPS runs at the CWB over to a new platform. We are collaborating with the CWB to feed real-time full-disk MTSAT IR imagery to GSD for use in global animated satellite mosaics with Science on a Sphere®. We did some training activities for a couple of forecasters in early December. A LAPS project update was presented to visiting CWB officials in June.

A higher resolution WRF domain has been designed. Side-by-side runs of the coarse and higher-resolution forecasts are planned during the next year.

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

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

4. Leveraging/Payoff:

5. Research Linkages/Partnerships:

6. Awards/Honors:

7. Outreach:

8. Publications:

AWIPS Support to the NWS

Participating CIRA Researchers: Ed Szoke and Steve Albers

a) AWIPS/LAPS

We continue a long-term effort to have LAPS software running in the National Weather Service WFO's (on AWIPS) for evaluation and use by operational forecasters. The LAPS software is being periodically updated within successive AWIPS builds in order to use our latest analyses. We continue to support and monitor a shadow run that helps us ensure that the LAPS software is ready for AWIPS releases.

We also continue to work informally with several WFOs to support their on-site implementations of LAPS analyses that are somewhat external to AWIPS. This includes locations such as Norman, Kansas City, Wichita, and Miami. A surface observation blacklist update was supplied by the Wichita WFO and will filter out many additional suspect observations, winds particularly. Our observation blacklist was also modified to include a station mentioned by the Goodland, Kansas WFO.

b) EFF Activities

We continued our interaction with the local National Weather Service (NWS) Weather Forecast Office (WFO) in Boulder, located within the David Skaggs Research Center. This involves GSD staff working some forecast shifts, as well as involvement in some cooperative projects. An ongoing project has been running a local model, the MM5, initialized in a hot-start configuration with LAPS, out to 24 h four times a day. The model is run at GSD and the output sent to the Boulder WFO for display on their AWIPS, where we are then able to get subjective feedback from the forecasters. We also participated in a presentation at UCAR/COMET for the Second Mountain Weather Course (4 - 8 December 2006) organized by Environment Canada and the Meteorological Service of Canada (MSC).

Cooperative projects with the Boulder WFO included two conference papers and presentations—one a review of the Denver Cyclone and non-supercell tornadogenesis associated with the feature for the 23rd AMS Conference on Severe Local Storms, held in St. Louis in November. The other was an examination of two high-resolution experimental models being run by NOAA/NCEP, for the 22nd Conference on Weather Analysis and Forecasting/18th Conference on Numerical Weather Prediction held in Park City, Utah in June 2007.

CIRA researchers continue to give GSD weather briefings several times per month. During this past year, one of the Boulder WFO forecasters also participated and gave a couple of weather briefings. Guest briefings were given in July/August by some of the students working on various ESRL projects during the summer.

c) D3D Activities

Although formal funding for D3D has been absent for over two years, we continue to get occasional questions from NWS WFO forecasters and others that are interested in running the software. Where possible we provide very limited support in addressing these questions, but it is apparent that interest does remain in 3D viewing of atmospheric data operationally.

Federal Highways Road Weather Modeling

(Additional NOAA Mission Goal to Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation / Surface weather)

The Maintenance Decision Support System (MDSS) is a project sponsored by the Federal Highways Administration. The goal of this project is to create a decision support software package to help winter road maintenance personnel decide how to best respond to weather problems on highways. MDSS takes automated weather observations and forecasts and runs pavement conditions models to suggest an optimum combination of plowing and chemical applications, and recommends the time to make these treatments.

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

IHOP

Participating CIRA Scientists: Chris Anderson and Steve Albers

The primary case used to illustrate and test the LAPS diabatic initialization in the journal paper described above (Section 1 - bottom) is the IHOP Intensive Observing Period on June 12, 2002. This case is used also to perform an inter-comparison of diabatic initialization techniques using the LAPS and CAPS methodologies.

Weather Research and Forecast Model (WRF)

LAPS model initialization activities described in Section 1 have some relevance as WRF is one of the primary models we are using. Otherwise, specific funding was unavailable for WRF development efforts this year.

Maintenance Decision Support System Project (MDSS)

(Additional NOAA Mission Goal to Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation / Surface weather)

Please see the above section above on Federal Highways for discussion of MDSS.

LAPS III Ensemble-based LAPS

Participating CIRA Researcher: Steve Albers

We participated in discussions with PhD student Ok-Yeon Kim, Dan Birkenheuer, and Chungu Lu about LAPS verification strategies in the wind and temperature analysis in conjunction with experiments being done with ensemble background error variance input. Verification statistics for dependent data are now being summarized for temperature analysis output. An additional control parameter was added to the temperature analysis that allows RAOB data to be withheld. This can be employed in using the RAOBs as independent data verification.

Spaceflight Meteorology Group (SMG)

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

Hydrometeorological Testbed (HMT)

Participating CIRA Scientists: Steve Albers, Chris Anderson, and Ed Szoke (collaborating with 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 streamflow. The funding materialized after the CIRA statement of work was drafted. The first large field campaign was held December 2005 to March 2006 in the American River Basin (ARB) of the Central Sierra Mountains (Fig. 2). CIRA staff in the Forecast Applications Branch (FAB) are an integral part of ESRL/GSD's effort to provide high-resolution model analyses and forecasts in support of field operations and NWS operational forecasting.

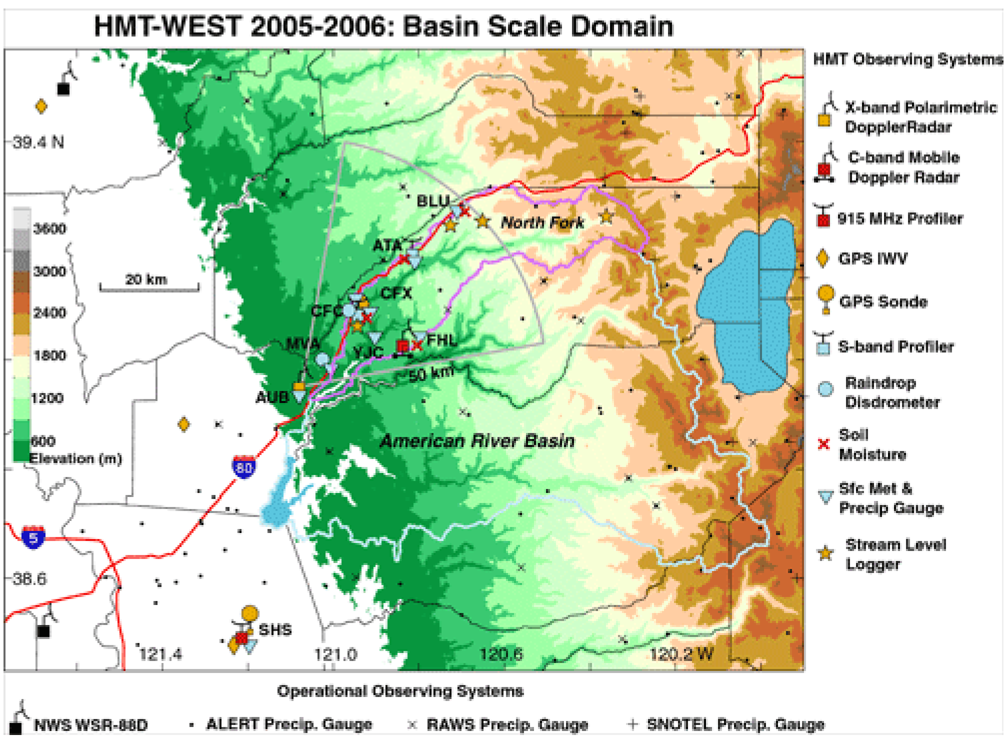


Fig 2. Basin-scale map of the first full-scale deployment of HMT-West 2006; successfully conducted December 2005 - March 2006.

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 we are running 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 several real-time hourly analysis runs over the American River Basin, two running at 3km resolution (figure 3a) and a third running at 1km. The surface temperature and wind fields show a wealth of detail related to the topography and land/sea boundary. In Fig. 3b, we can see where in the HMT domain the precipitation (both liquid equivalent and snowfall) has accumulated over the past day, as well as the current location and type of precipitation. 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.

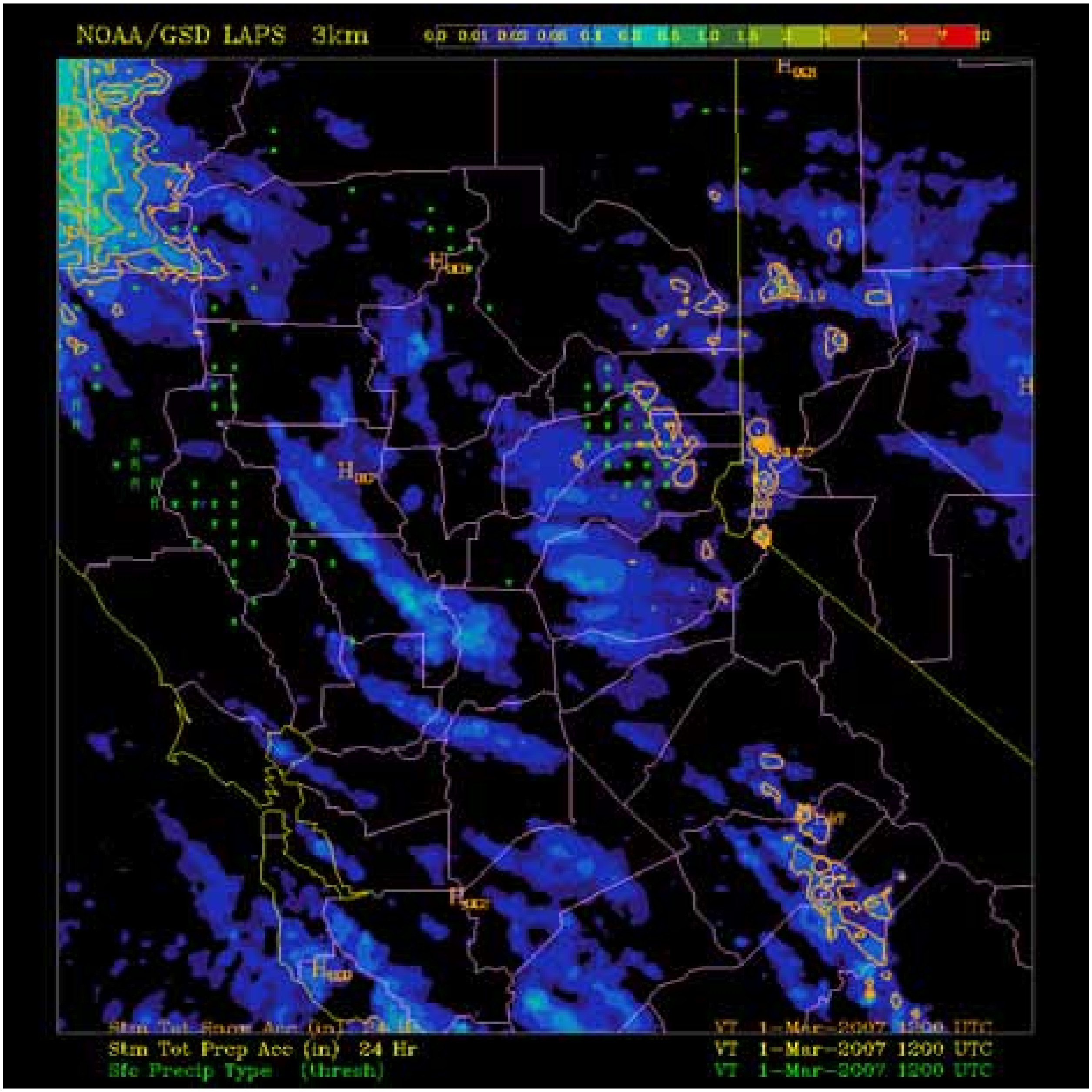


Fig 3a. LAPS hourly analysis of surface temperature and wind for the HMT domain.

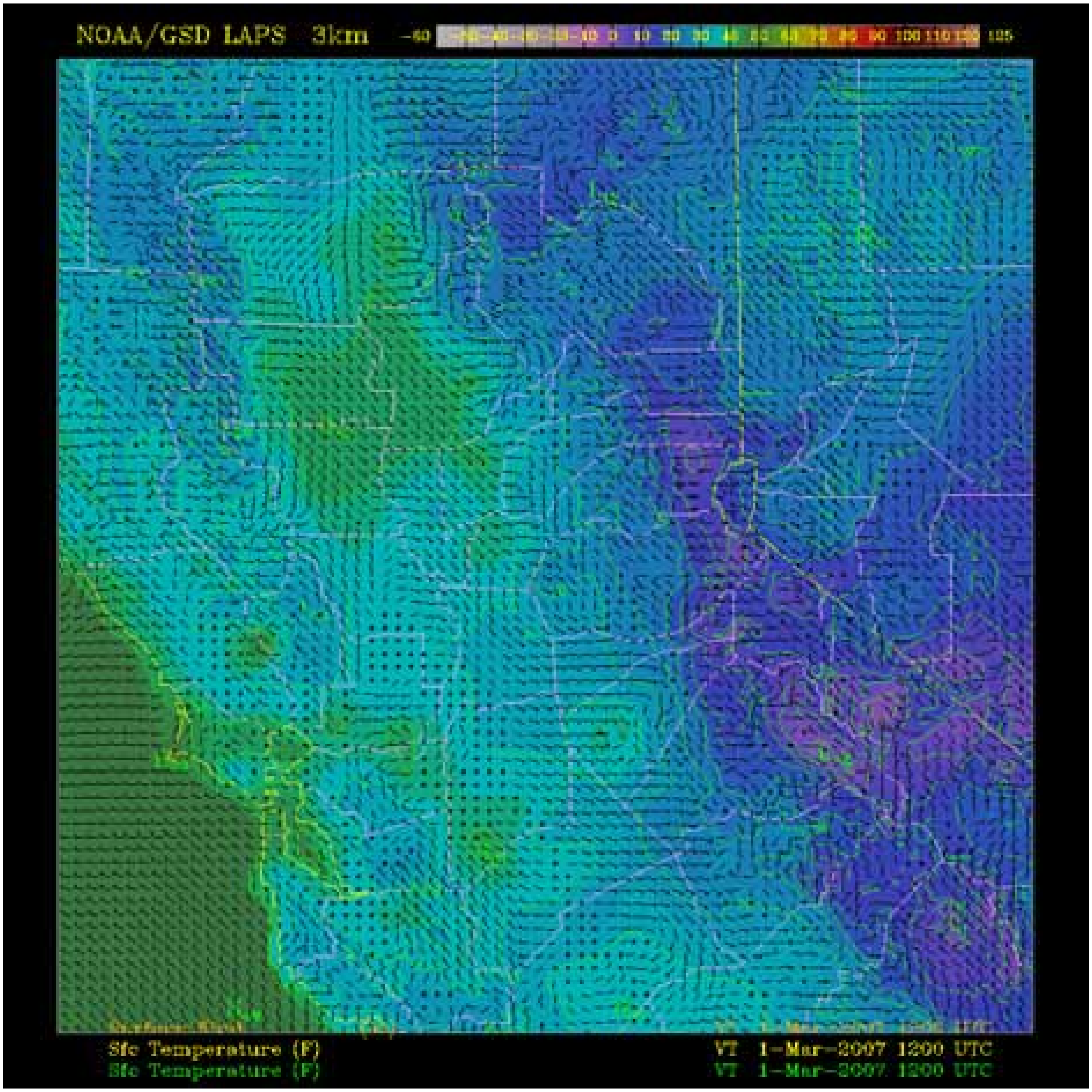


Fig 3b. LAPS analysis of 24-hr accumulated precipitation (shaded colors), current surface precipitation type (green icons), and 24-hr snow accumulation (orange contours).

Fig. 4 shows some of the hydrometeor and related fields that are used in the diabatic "hot-start" process of forecast model initialization. Cloudy and precipitating areas are dynamically included with upward vertical motion for the initial model forecast time steps. This type of plot is also useful in assessing the magnitude and depth of terrain forced upslope flow.

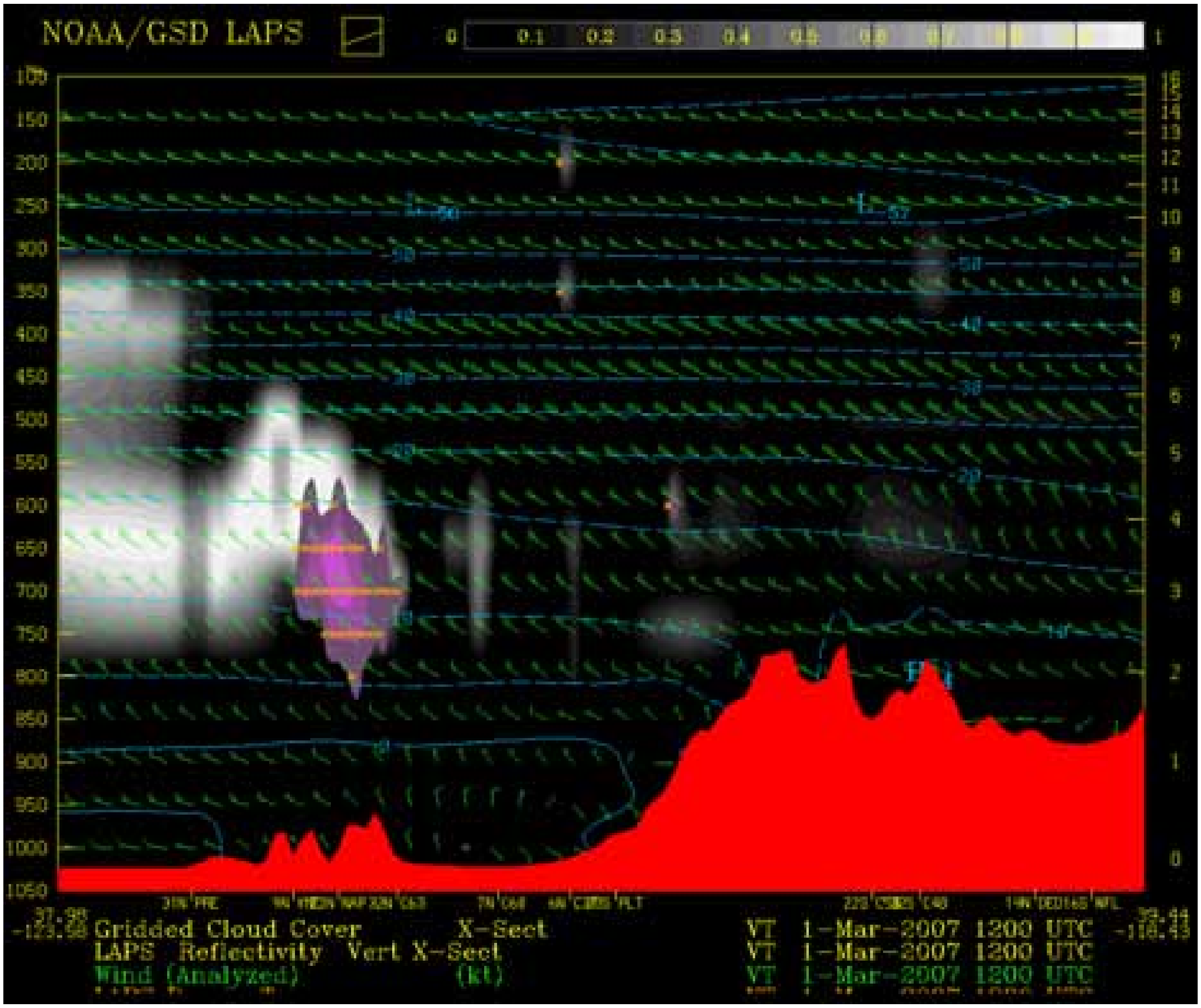


Fig 4. LAPS cross-section of clouds, radar reflectivity and precipitation type showing mid-level precipitation moving over the California coastal range (left). The section is oriented perpendicular to the Sierra Nevada mountain range (right).

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. We have tested the utility of a number of aspects of NWP models:

--Would NWS forecasters find value in high-resolution forecasts not available from the national NWP model center?

--Would the NWP model precipitation forecast be improved by ensemble methods?

--Can the NWP ensemble provide reliable probability forecasts of precipitation?

During the 2005-2006 winter field campaign, our goal was to provide a single, high-resolution NWP forecast for the forecasters in the NWS weather forecast and river forecast offices. Initial evaluations of the NWP forecast output contained high praise. Follow-up discussions with NWS forecasters informed the NWP model design. By late in the 2005-2006 winter field campaign, a single model with 3-km grid point spacing over a domain of 450-km X 450-km was initialized every three hours (eight times daily), providing forecasters with precipitation forecasts out to a 30-hour lead time. An example of NWP model precipitation accumulated through the first 24 hours of the 30-hour forecast is shown below.

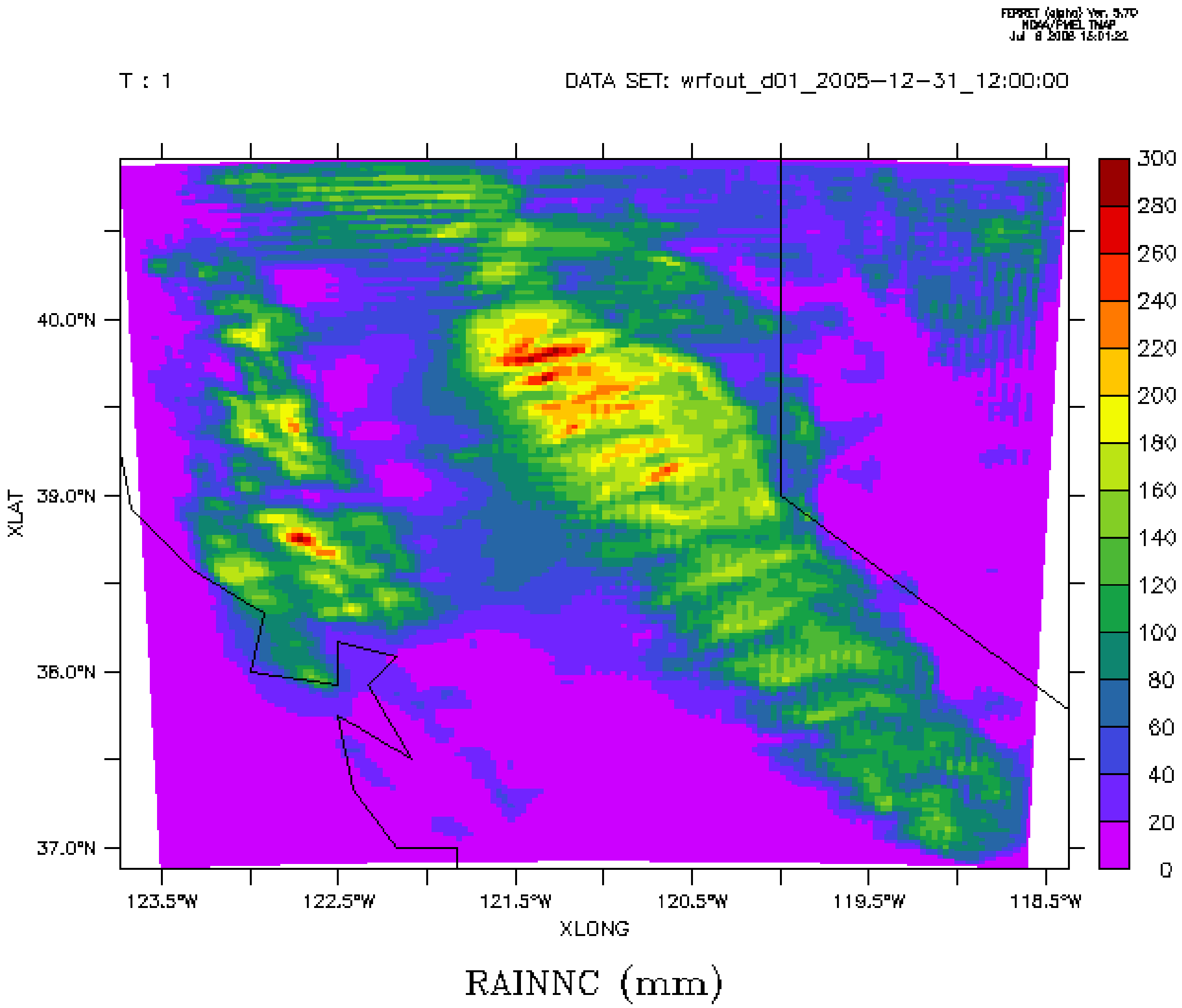


Fig 5a. Evident in this plot are narrow regions of 24-hour precipitation accumulation exceeding 200 mm (~7.9 inches).

These narrow regions correspond to peaks in the terrain. This information is not available in operational forecast models with larger grid point spacing. It is also not often evident in observations, due in part to the lack of observations at the terrain peaks. We are currently collaborating with scientists from ESRL/PSD who deployed radars with the ARB to fill in the gaps for quantitative precipitation estimates with the goal of determining whether such maxima exist at the terrain peaks.

Gridded observations produced by the California Nevada River Forecast Center are shown below (Fig. 5b).

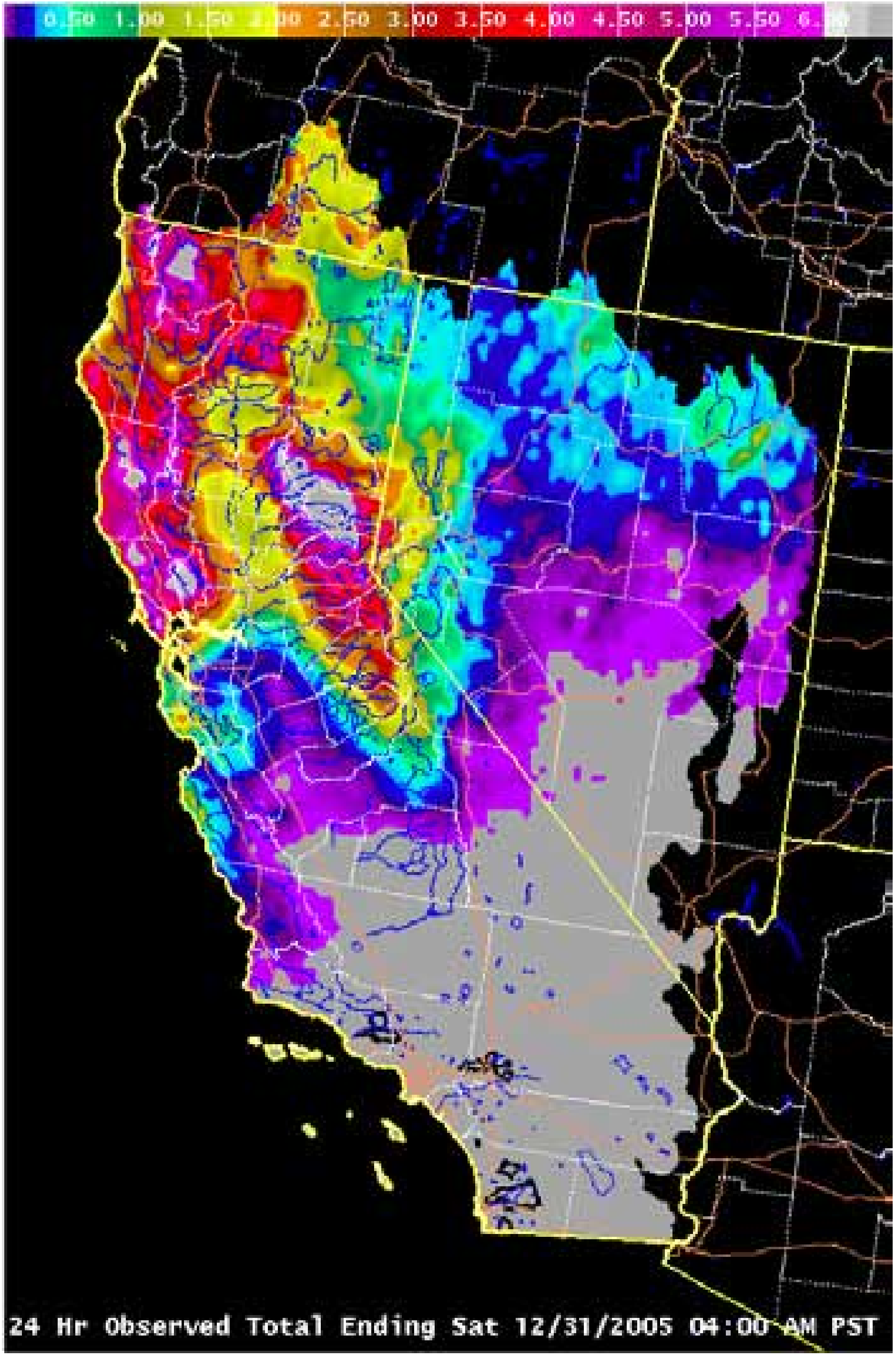


Fig 5b. The gridded observations are produced by sending sparse rain gauge measurements through an interpolation routine. Thus, the spatial variability of the model runs, being unsmoothed, is much larger than observed. Nevertheless, the magnitudes of precipitation are similar. Where the observations show precipitation exceeding 6.5 inches, the model predicts 7-9".

The enthusiastic response to high-resolution NWP guidance by NWS forecasters inspired our efforts to examine whether ensemble methods could improve guidance of probability of precipitation and precipitation amount. To this end, we designed an ensemble consisting of multiple NWP models and software to calibrate ensemble output with observations. A number of NWP models were considered for inclusion in the ensemble: MM5, WRF-ARW, WRF-NMM, and RAMS. The final mix of models was determined from a methodology described below (see *Ensemble Forecast Mix*).

The ensemble NWP model forecasts were implemented for the 2006-2007 winter field campaign. The ensemble consists of three configurations of the WRF-ARW and one configuration of the WRF-NMM. The forecast domain is identical to the one used during the 2005-2006 field campaign. Forecasts are initiated every 6 hours (four times daily). Ensemble data are generated on ESRL/GSD supercomputers and are delivered to the NWS weather forecast and river forecast offices via the next generation AWIPS called ALPS. The forecasters receive 30-hr forecasts of surface and upper-air data, ensemble average precipitation, and reliable probability of precipitation exceeding certain thresholds for 6-hr and 24-hr accumulation periods. (A reliable probability forecast is one for which the event occurs as frequently as predicted. For example, a forecast of 10% for precipitation exceeding 2" is reliable if more than 2" of precipitation occurs during 10% of the forecasts.) Examples of the precipitation output are provided in Fig. 6.

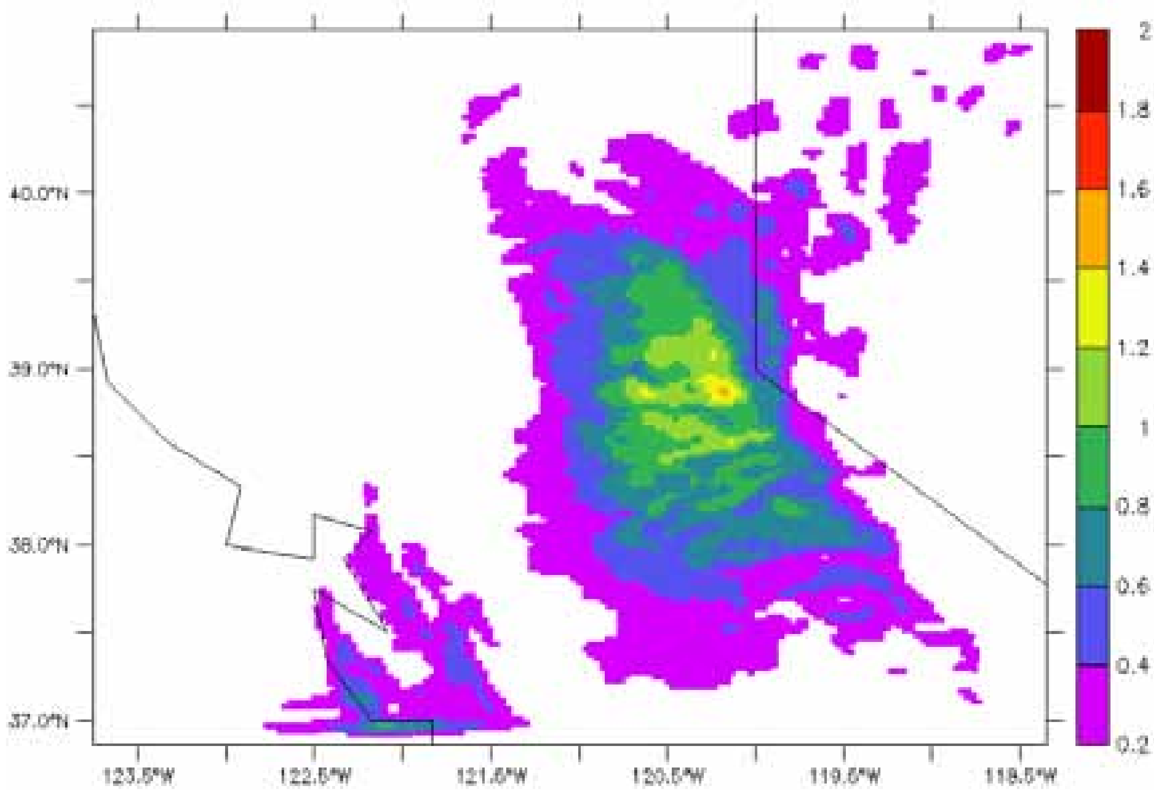


Fig 6a. Ensemble average of 6-hr accumulation of precipitation ending at the 18-hr lead time.

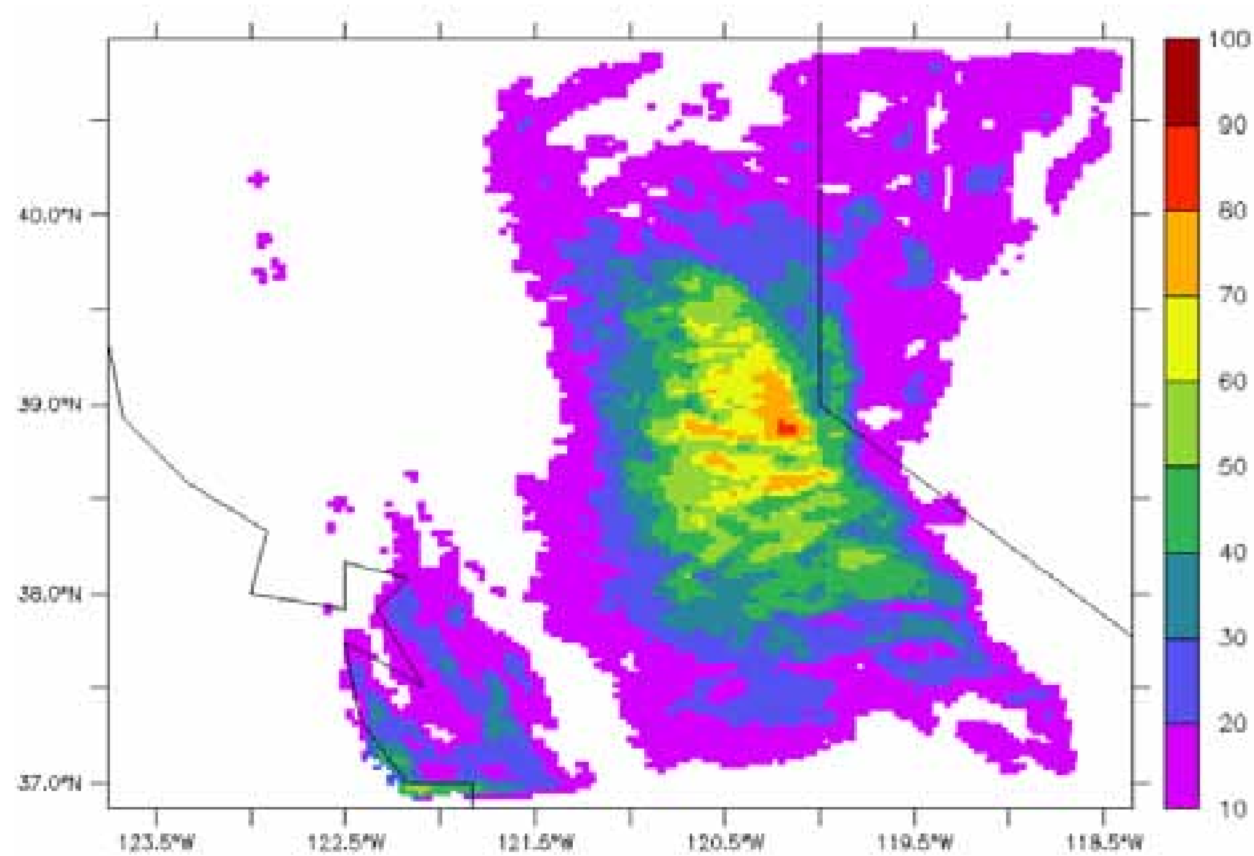


Fig 6b. Ensemble probability of 6-hr accumulation of precipitation exceeding 0.5" ending at the 18-hr lead time.

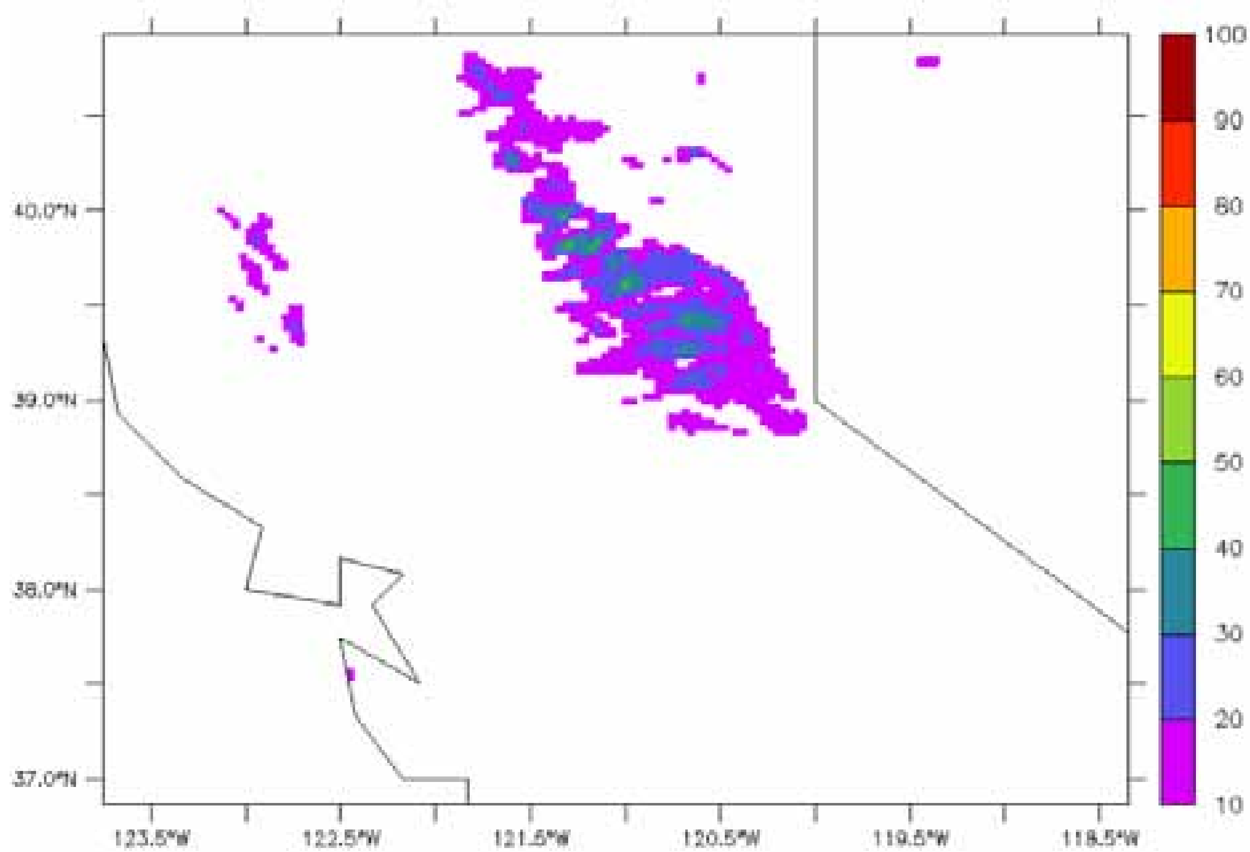


Fig. 6c. Ensemble probability of 6-hr accumulation of precipitation exceeding 1.0" ending at the 18-hr lead time.

Ensemble Forecast Mix

The experimental ensembles were also used to evaluate a strategy to determine an optimal mix of forecast models. The results indicated that by intelligently choosing various parameterization combinations, the accuracy of the ensemble mean and the range of ensemble forecasts are both improved.

In order to improve QPF, the impact of different initial conditions and various microphysical schemes and their interactions with different PBL schemes on cold season, mainly orographically induced rainfall was evaluated. The main focus was on the improvement of rain volume simulation over the ARB area in California. For this purpose, high resolution (3-km horizontal grid spacing, and 32 vertical levels) WRF-ARW model simulations of four HMT events were performed. For each case, four different microphysical schemes were used: Lin et al. (1983) modified by Rutledge and Hobbs (1984), Ferrier et al. (2002), WSM6 (Hong et al., 2004) and Thompson et al. (2004). For each of the four microphysics configurations, two different PBL schemes were used: the local mixing Eta PBL scheme, often referred to as Mellor-Yamada-Janjic 2.5; Janjic (2001), and the non-local mixing YSU PBL scheme (Noh et al. 2003) as an improved version of the MRF PBL scheme (Troen and Mahrt 1986). All runs were initialized with both diabatic the Local Analysis and Prediction System (LAPS) "hot-start" and 40-km Eta model analyses.

To quantify the impacts on simulated rain volume due to changes in initial conditions, microphysics, PBL schemes, as well as due to the interactions between the two different physical schemes (synergy), the factor separation method (Stein and Alpert, 1993) was used. For this purpose, the model run initialized with the LAPS analysis and using Lin microphysics and YSU PBL was chosen as the control configuration. By following the Hamill (1999) resampling method, statistical significance testing of all results was performed. The factor separation method results indicated that for both initializations, the largest, negative, and statistically significant impact on simulated rain volume was due to changes from Lin to Ferrier and to Thompson microphysics. In other words, the factor separation results pointed toward a statistically significant difference in performance between Lin and both Ferrier and Thompson microphysical schemes under these specific conditions. To investigate this in more detail, analyses of precipitable and cloud water tendencies over the area of interest for the four different microphysics were performed. The results showed that Lin microphysics had a tendency to convert all available precipitable water into precipitation, while both Ferrier and Thompson schemes tended to keep the majority of available precipitable water as supercooled water or snow. This was especially the case for the Ferrier microphysics. With regard to WSM6 scheme, its performance was very similar to the performance of MPL, which explains the lack of statistically significant differences of simulated rain volume between the two. It is noteworthy that the precipitable and cloud water tendencies were almost identical for the two different initial conditions. With regard to changes in initial conditions, by switching from the LAPS to the Eta analysis, the change in the PBL scheme as well as all corresponding synergistic effects appeared to be statistically significant.

Furthermore, the factor separation results were used to investigate if the results of the impact of different initializations and physical schemes on simulated rain volume could be used to lessen a large bias associated with the "control" configuration simulation. Using the knowledge about the magnitude and sign of the impact that different physical schemes and initial conditions had on the simulated rain volume, different combinations of model runs were created and various objective measures of the model simulations were calculated. The results showed a decrease in errors for the model combinations that were judiciously selected. Thus factor separation results were used in design of an ensemble for QPF for the 2005-2006 HMT field experiment.

WRF model QPF as Input to Hydrological Models

We have collaborated with HMT participants at the National Severe Storms Laboratory to couple WRF model precipitation forecasts with a hydrological model. Fig. 7 shows traces of streamflow discharge from the North Fork American River. The multiple purple traces are produced by providing a single WRF forecast of precipitation as input to the hydrology model which is then run multiple times with alternative parameter settings. The WRF forecast of precipitation is the ensemble mean precipitation for the 0-hr to 48-hr forecast period. The forecast apparently contained an early onset to precipitation. Nevertheless, the peak discharge rate envelopes the observed rate and most of peaks in the hydrographs are within 50% of the observed peak. This appears to be a promising application of WRF ensemble data.

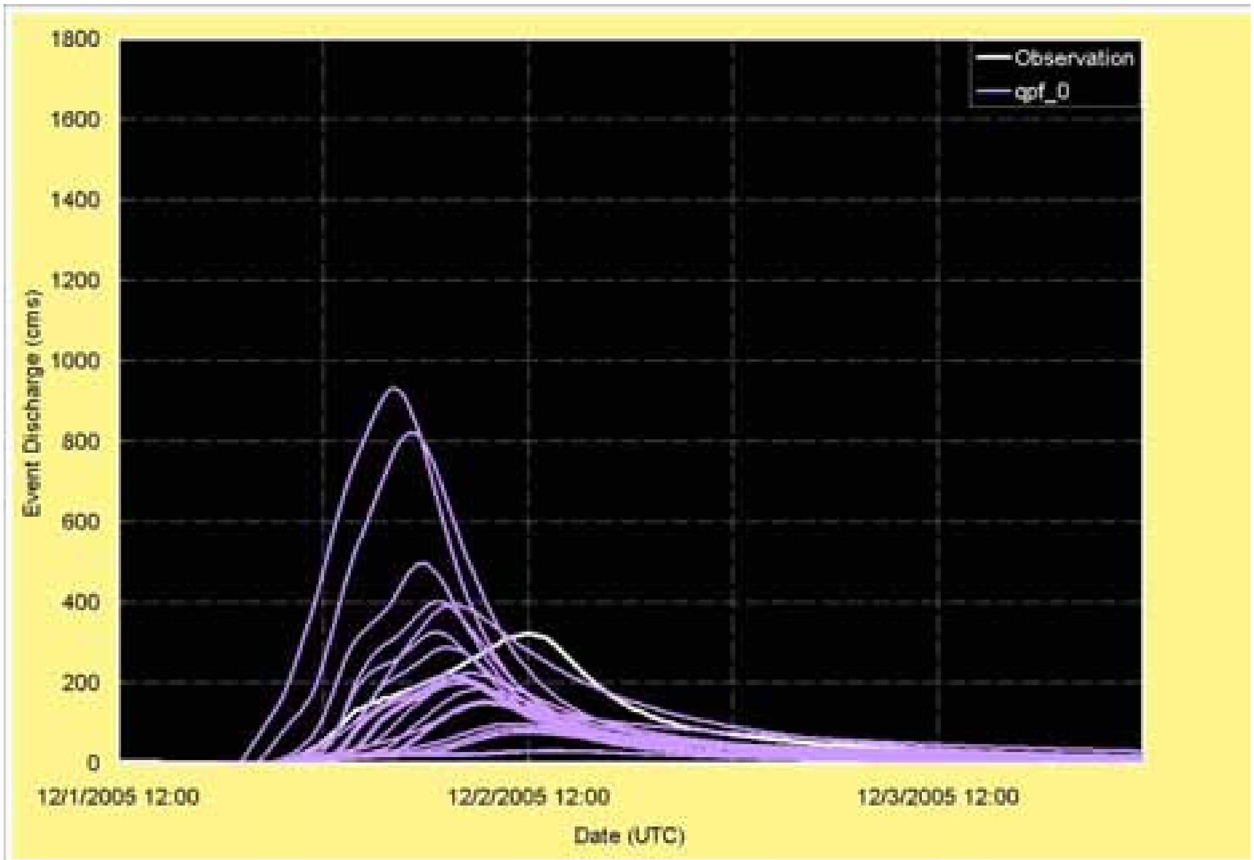


Fig 7. Hydrograph traces for the North Fork American River that were generated using WRF ensemble precipitation forecasts as input to a hydrology model.

Daily Forecast Support

CIRA staff 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 conference calls 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 1230 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 (at 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 2006 HMT exercise, the forecast discussion during the conference call was led by forecasters at the Sacramento WFO, with the other participants, including CIRA staff at NOAA in Boulder, free to add to the discussion at any point. Boulder forecasters were responsible for the written discussion posted to the website. This year, the decision was made to let the Boulder forecasters take the lead role during the conference call, though again the forecast discussion typically involves input from the other participants, particularly when the weather prediction becomes less certain. Recently, 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. Also, new for this season has been a more consistent participation by two NOAA forecasters from ESRL's Physical Sciences Division (formerly the Climate Diagnostics Center), 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 web page 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.

Conclusion

We have finished the 2006-2007 field experiment over the ARB in California. We look forward to conducting further analysis of the results and participating in future HMT field seasons that will cover several locations around the country, each having unique forecast challenges. Discussions are underway with HMT participants to plan Science on a Sphere® presentations highlighting HMT related water issues at the California State Fair that runs during August.

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.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships:

6. Awards/Honors:

7. Outreach:

8. Publications:

Albers, S., C.J. Anderson, I. Jankov, and E.J. Szoke, 2007: CIRA contributes to the Hydrometeorological Testbed. *CIRA Magazine*, Vol. 27, Spring 2007, pp. 6-11.

<u>Other Research</u>

Participating CIRA Scientists: Steve Albers, Chris Anderson, Randy Collander, and Ed Szoke

Fire Weather

We set up a new 500-m resolution LAPS analysis over a domain mainly in Boulder County. This is envisioned to be relocatable in support of fire fighting operations, particularly with high-resolution wind fields. The analysis utilizes a downscaled RUC background together with the latest observational data. Graphics plots were developed to potentially display surface winds generated by the balance package thus showing terrain effects more accurately.

A new software and script configuration was developed for LAPS to allow down-scaled fire forecasts on a high resolution grid having 500m spacing. This includes special LAPS analysis parameter settings. The 500-m resolution forecast can downscale the latest NAM or MM5 run into the future. The use of the ETA background allows us to relocalize the domain anywhere in the continental U.S. if desired and runs in real-time with each large-scale model forecast cycle.

In summary, we are now running both an analysis and downscaled forecast in real-time at 500m resolution. A web interface was developed that allows the end user (Redzone Inc.) to automatically move a fire analysis/forecast domain so that we can quickly respond to evolving fire situations.

Department of Homeland Security (DHS)

Discussions are underway with DHS and the Air Resources Laboratory (ARL) about LAPS and WRF runs over the National Capital Region. This includes supplying LAPS analyses and collaborating in the development of a converter that translates LAPS observations into WRF format for observation nudging experiments. This is being developed on GSD computer systems where two real-time LAPS analysis runs were established at 1.5 and 4.5km resolution covering the National Capital Region. Support was added so LAPS can now ingest urban mesonet (MADIS Urbanet) data to facilitate these high resolution analyses.

ATMET/AFTAC

We participated in discussions with ATMET to plan for a version of LAPS that can run as a single executable (and incorporated as a front-end to RAMS). LAPS software parameter definitions and input were reworked to be compatible with this version. The top level routines for the wind analysis and surface analyses were also reworked to enhance this compatibility. Library modules were added to help interface top level and lower level subroutines for both the "standard" LAPS and the new single executable version.

Finnish Meteorological Institute (FMI)

We enjoyed the visit of PhD student Erik Gregow from FMI and discussed a wide range of topics relating to running LAPS. Test runs were conducted both at GSD and at FMI. Observations such as surface data, meteorological towers, radars and satellites were addressed and their handling was improved within LAPS. In support of LAPS development for FMI, the surface analysis "what-got-in" script should now work better for the FMI runs. We also discussed the setting up of LAPS output on the FMI website. Along these lines "lapsplot" now has improved support for metric units and displays cross-sections at full grid resolution.

TAMDAR

TAMDAR (Tropospheric AMDAR (Aircraft Meteorological Data Relay)) continues to be an evolving program with good support (the NOAA TAMDAR web page is at http://www.crh.noaa.gov/tamdar/, while GSD maintains an AMDAR web site at http://amdar.noaa.gov/, which includes access to the current TAMDAR data). During the past year, TAMDAR data continued to be taken from ~50 commercial aircraft servicing both large and a number of much smaller airports from the Midwest to the lower Mississippi Valley. The data has been used in real-time by National Weather Service (NWS) forecasters, with some examples posted on the NOAA TAMDAR web page. 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. A number of conference papers have been presented during the past year.

Regional Climate Modeling

Chris Anderson developed a modeling system based on WRF that can be used to perform seasonal to decadal regional simulations of climate. A simple experiment was conducted to illustrate the use of the system at the Forecast Application Branch review. The experiment consisted of 60-day simulations of the 1993 Midwestern Flood (June 1 - July 31) in which one simulation was driven by NCEP/DOE Reanalysis-II data and another added a perturbation to the Gulf of Mexico SST to determine the sensitivity of the flood severity to water vapor transported from above the Gulf of Mexico. The results showed (1) a widespread increase of precipitation by 50-150 mm; (2) cooler surface conditions by 5-10 K within and south of the flood region; and (3) a feedback of the cooler surface conditions into the large-scale circulation.

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 and meeting 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 cloudscale model ensemble forecast.

Our achievements in these other research areas significantly exceed the goals projected in the statement of work.

Project Title: Non-LAPS Activities

Forecasting En-Route Turbulence

(Additional NOAA Mission Goal to Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation / Aviation weather)

Participating CIRA Researcher: Ed Szoke

Goals set under GSD Forecast Applications Branch research activities to improve forecasts of clear air turbulence (CAT) through field programs and by developing diagnostic algorithms centered around two main projects: BAMEX and GTG.

BAMEX studies were not funded.

The GTG turbulence forecasting project was funded at a minimal level. This ongoing program involved several GSD scientists in a long-term project with NCAR involved in an effort to evaluate and improve the GTG algorithm. Our involvement focused on attempting to tune the algorithm based on the overall weather pattern present on a given day. We were in Year 2 of the multi-year project when funding was cut way back by the FAA and the GTG project was severely cut back, ending our involvement in the program at the end of September 2006.

Hourly Precipitation Data Quality Control

Participating CIRA Researcher: Randy Collander

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

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

Precipitation observations from several thousand sites in the United States, in hourly and daily resolution, are received by the National Centers for Environmental Prediction (NCEP) in Washington, D.C. on a daily basis. Much of this data is manually inspected and quality controlled at the River Forecast Centers (RFC) and other locations before being disseminated to the National Weather Service (NWS) offices and other users. The Environmental Modeling Center (EMC) at NCEP desires to have an automated, objective system for performing a more consistent quality control on the hourly data, with the expectation that a cleaner data set would be of great value in evaluating current model predictions as well as input to current numerical weather prediction models. This quality-control software was completed in late FY04, with refinement in FY05 and FY06 as needed based upon scrutiny during daily manual evaluation and case studies.

2. Research Accomplishments/Highlights:

In FY07, close collaboration with the EMC yielded additional criteria refinement and successful software test runs were completed in preparation for introduction into daily operations, expected to occur in the latter part of 2007. 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 achievements 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 FY07, including a 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 FY07, a team of NOAA/ ESRL scientists from the Global Monitoring Division (GMD) and the Global Systems Division (GSD) completed the third 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 some 30 miles away entangled in a power line. The AirCore ™ was recovered and returned the same day for trace gas analyses at ESRL laboratories in Boulder. The initial analyses showed that CO2 is not uniformly distributed through the atmosphere, as has generally been believed. Fig. 8 shows the profile of CO2 distribution with altitude plotted with temperature. Note in Fig. 9, showing the CO2 and relative humidity profiles, that AirCore ™ worked well even as it descended through a cloud (between 8 and 10 km).

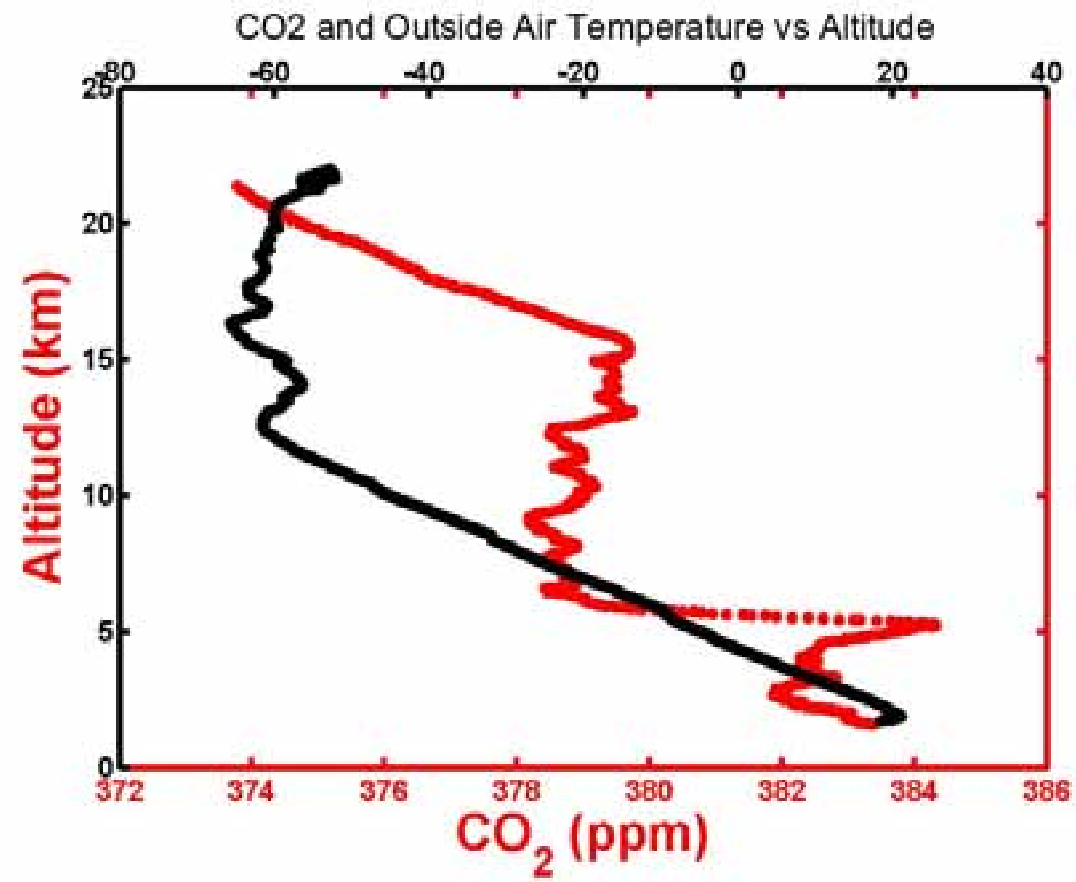


Fig 8. AirCore™ profile of CO2 and air temperature.

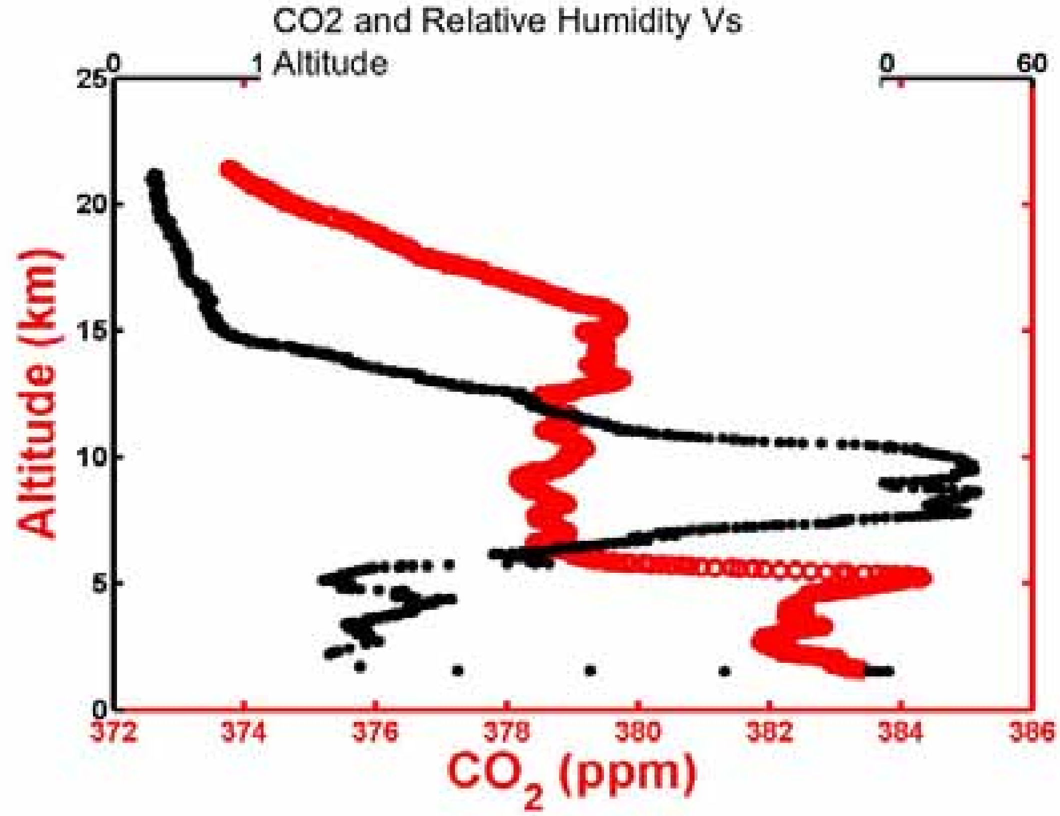


Fig 9. AirCore™ profile of CO2 and air temperature.

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 1000 or more profiles inexpensively on a daily basis around the world as it can be easily deployed on commercial and private aircraft, from Unmanned Aircraft System platforms, or carried aloft with small balloons. The AirCore™ team on the just completed flight consisted of Pieter Tans, Aaron Watson, and Colm Sweeney of GMD, and Russell Chadwick and Randy Collander of GSD.

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.

Development of a Multi-Vehicle Atmospheric Trajectory Prediction System

Participating CIRA Researcher: Randy Collander

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

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

Based on extensive experience in the development and operation of advanced trajectory models related to the Global Air-ocean In-situ System (GAINS) project, CIRA proposed to participate with Global Solutions for Science and Learning (GSSL) in the continuing development of advanced multi-vehicle trajectory models in support of development and flight operations of a wide range of atmospheric vehicles including buoyant, heavier than air, aerodynamic decelerators, and hybrid vehicles. The models would combine atmospheric data and vehicle performance algorithms for the prediction and analyses of flight paths. The potential vehicles include zero-pressure and 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:

Not funded in FY07.

3. Comparison of Objectives Vs. Accomplishments:

4. Leveraging/Payoff:

5. Research Linkages/Partnerships:

6. Awards/Honors:

7. Outreach:

8. Publications:

Benjamin, S.G., W.R. Moninger, T.L. Smith, B.D. Jamison, E.J. Szoke, and T.W. Schlatter, 2007: 2006 TAMDAR impact experiment results for RUC humidity, temperature, and wind forecasts. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Hiemstra, C.A., G.E. Liston, R.A. Pielke, Sr., D.L. Birkenheuer, and S.C. Albers, 2006: Comparing Local Analysis and Prediction System (LAPS) assimilations with independent observations. *Wea. Forecasting*.

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. Submitted to *J. Hydrometeor.*

Kim, O., C. Lu, S. Albers, J. McGinley, and J. Oh, 2007: Improvement of LAPS wind analysis by including background error statistics. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Lu, C., J. McGinely, P. Schultz, H. Yuan, B.D. Jamison, L. Wharton, and C. Anderson, 2006: Short-range QPF and PQPF using time-phased, multi-model ensembles. *Second International Symposium on Quantitative Precipitation Forecasting and Hydrology*, Boulder, CO,

Moninger, W.R., S.G. Benjamin, R.S. Collander, B.D. Jamison, T.W. Schlatter, T.S. Smith, and E.J. Szoke, 2007: TAMDAR/AMDAR data assessments using the RUC at NOAA's Global Systems Division. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Moninger, W.R., S.G. Benjamin, B.D. Jamison, T.W. Schlatter, T.L. Smith, and E.J. Szoke, 2007: TAMDAR and its impact on Rapid Update Cycle (RUC). *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Szoke, E.J., D. Barjenbruch, R. Glancy, and R. Kleyla, 2006: The Denver Cyclone and tornadoes 26 years later: the continued challenge of predicting nonsupercell tornadoes. *23rd Conference on Severe Local Storms*, 6-10 November 2006, St. Louis, MO, Amer. Meteor. Soc.

Szoke, E.J., S.G. Benjamin, R.S. Collander, B.D. Jamison, W.R. Moninger, T.W. Schlatter, and T.L. Smith, 2007: Impact of TAMDAR on the RUC model: A look into some of the statistics. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Szoke, E.J., R.S. Collander, B.D. Jamison, T.L. Smith, T.W. Schlatter, S.G. Benjamin, and W.R. Moninger, 2006: An evaluation of TAMDAR soundings in severe storm forecasting. *23rd Conference on Severe Local Storms*, 6-10 November 2006, St. Louis, MO, Amer. Meteor. Soc.

Szoke, E.J., R.S. Collander, B.D. Jamison, T.L. Smith, S.G. Benjamin, W.R. Moninger, T.W. Schlatter, and B. Schwartz, 2007: Impact of TAMDAR data on RUC short-range forecasts. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Szoke, E.J., S.E. Koch, D. Barjenbruch, and D.A. Wesley, 2007: Evaluation of the NCEP WRF NMM and ARW models for some recent high-impact weather events. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Wesley, D., E.J. Szoke, R.A. Pielke, W. Bua, D. Barjenbruch, S.D. Jascourt, and G. Poulos, 2007: Initial analysis of model guidance for the Colorado Front Range barrage of snowstorms November 2006-February 2007. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Yuan, H., J.A. McGinley, C.J. Anderson, C. Lu, and P.J. Schultz, 2006: Evaluation and calibration of short-range PQPF from multi-model and time-phased ensembles during HMT-West-2006. *AGU 2006 Western Pacific Geophysics Meeting*, Beijing, China, AGU, CD-ROM, A32A-03.

Yuan, H., C.J. Anderson, P.J. Schultz, I. Jankov, and J.A. McGinley, 2007: Precipitation forecasts using the WRF-ARW and WRF-NMM models during the HMT-West 2006 and 2007 winter experiments. *WRF/MM5 User's Workshop*, Boulder, CO, Amer. Meteor. Soc.

V. Research Collaborations with the GSD Assimilation and Modeling Branch

Project Title: Rapid Update Cycle (RUC) / WRF Model Development and Enhancement

Principal Researchers: Tracy Smith and Kevin Brundage

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

Key Words: 4-D Data Assimilation and Forecast System, Rapidly Updated Analyses

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

The primary focus of the GSD Assimilation and Modeling Branch is the refinement and enhancement of the Rapid Update Cycle (RUC) and development of the Weather Research and Forecast (WRF) model. The RUC is a national scale 4-D data assimilation and forecast systems specifically designed to run at a high temporal frequency (1-hour cycle), taking advantage of a variety of special observations such as ACARS, RASS, profiler, radar, GPS integrated precipitable water vapor, and GOES soundings. It is run operationally at the NOAA/NWS National Centers for Environmental Prediction, and in various experimental configurations at the ESRL Global Systems Division. In addition to refinement and enhancements of the RUC, CIRA researchers collaborate on the development of the Weather Research and Forecast (WRF) model used by CIRA and GSD researchers. Development and testing of WRF based components for the Rapid Refresh (RR) system, intended to replace the RUC hydrostatic forecast model now used at NCEP, are currently underway. Overall goals are to continue the development work on the Weather Research and Forecast (WRF) and Rapid Refresh models used by CIRA researchers and to improve the required visualization techniques for the RUC and RR fields. Additionally, CIRA researchers continue to work on applications of the RUC and RR to forecast problems, including investigations into the use of mesoscale model time-lagged ensembles to improve the accuracy of short-range forecasts, in particular QPF and wind energy, would also continue.

2. Research Accomplishments/Highlights:

During the past year, 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.

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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:

Benjamin, S.G., S. Weygandt, J.M. Brown, T. Smirnova, D. Devenyi, K. Brundage, G. Grell, S. Peckham, T.L. Smith, T.W. Schlatter, and G. Manikin, 2007: From the radar-enhanced RUC to the WRF-based Rapid Refresh. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Benjamin, S.G., T.L. Smith. W.R. Moninger, and S.R. Sahm, 2007: Mesonet wind quality monitoring allowing assimilation in RUC and other NCEP models. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Benjamin, S.G., W.R. Moninger, T.L. Smith, B.D. Jamison, E.J. Szoke, T.W. Schlatter, 2007: 2006 TAMDAR impact experiment results for RUC humidity, temperature, and wind forecasts. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

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Moninger, W.R., S.G. Benjamin, R.S. Collander, B.D. Jamison, T.W. Schlatter, T.L. Smith, and E.J. Szoke, 2007: TAMDAR/AMDAR data assessments using the RUC at NOAA's Global Systems Division. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

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.

Stensrud, D. J., N. Yussouf, M.E. Baldwin, J.T. McQueen, J. Du, B. Zhou, B. Ferrier, G. Manikin, F.M. Ralph, J.M. Wilczak, A.B. White, I. Djlalova, J. Bao, R. Zamora, S.G. Benjamin, P.A. Miller, T.L. Smith, T. Smirnova, and M.F. Barth, 2006: The New England High-Resolution Temperature Program. *Bull. Amer. Meteor. Soc.* **87**, 491-498.

Szoke, E.J., R.S. Collander, B.D. Jamison, T.L. Smith, T.W. Schlatter, S.G. Benjamin, and W.R. Moninger, 2006: An evaluation of TAMDAR soundings in severe storm forecasting. *23rd Conference on Severe Local Storms*, 6-10 November 2006, St. Louis, MO, Amer. Meteor. Soc.

Szoke, E.J., R.S. Collander, B.D. Jamison, T.L. Smith, S.G. Benjamin, W.R. Moninger, T.W. Schlatter, and B. Schwartz, 2007: Impact of TAMDAR data on RUC short-range forecasts. *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Szoke, E.J., S.G. Benjamin, R.S. Collander, B.D. Jamison, W.R. Moninger, T.W. Schlatter, and T.L. Smith, 2007: Impact of TAMDAR on the RUC model: A look into some of the statistics. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Project Title: TAMDAR (Troposheric Airborne Meteorological Data Reporting) Project

Participating CIRA Researchers: Brian Jamison, Randy Collander, Tracy Smith, and Ed Szoke

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

Key Words: TAMDAR, Airborne weather sensors, aircraft data impact on model forecasts

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

TAMDAR continues to be an evolving program with good support (the NOAA TAMDAR web page is at http://www.crh.noaa.gov/tamdar/, while GSD maintains an AMDAR web site at http://amdar.noaa.gov/, which includes access to the current TAMDAR data).

The TAMDAR project is an evaluation of a new observing system using sensors placed on a number of regional aircraft. The sensors report temperature, pressure, humidity, winds, eddy dissipation rate, and icing. Tasks primarily involve examining the data for quality, and investigating the impact of the data on weather model forecasts.

2. Research Accomplishments/Highlights:

During the past year TAMDAR data continued to be taken from ~50 commercial aircraft servicing both large and a number of much smaller airports from the Midwest to the lower Mississippi Valley. The data has been used in real-time by National Weather Service (NWS) forecasters, with some examples posted on the NOAA TAMDAR web page. 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.

For these tasks, retroactive runs of the Rapid Update Cycle (RUC) 20 km model were performed. Retroactive runs of the RUC for the period of April 22-28, 2005 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 2005-2006, additional runs for this period include:

a) runs with the relative humidity uncertainty threshold set to 0.15, 0.20, 0.30, and 0.40 (normally set to 0.12), which allowed increasingly more relative humidity data to be utilized by the RUC

b) a run with all TAMDAR data removed.

This time period, however, was an early reporting period for TAMDAR, and there were some problems noted with the humidity sensors. This was also a lower resolution data set. Therefore, a new period (November 26 to December 5, 2006) was selected for retroactive analysis. 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) runs with the relative humidity uncertainty set to 0.18 and 0.25

d) a run using an abbreviated (i.e. "thinned") set of aircraft data

e) a run using a different aircraft reject list, altered to reject TAMDAR relative humidity data

f) a run using a less stringent threshold for TAMDAR wind observations

g) a run with changes made to the RUC background, which allows for a better fit to mositure observations

h) data denial runs, removing GPS integrated precipitable water, all aircraft data, and all profiler data.

Analyzing the differences in forecasts has greatly increased our knowledge of the relative value of the TAMDAR data, and feedback to AirDat (the designers of the TAMDAR sensors) has proven very worthwhile.

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

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

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:

Benjamin, S.G., W.R. Moninger, T.L. Smith, B.D. Jamison, E.J. Szoke, and T.W. Schlatter, 2007: 2006 TAMDAR impact experiment results for RUC humidity, temperature, and wind forecasts. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Moninger, W.R., S.G. Benjamin, R.S. Collander, B.D. Jamison, T.W. Schlatter, T.L. Smith, and E.J. Szoke, 2007: TAMDAR/AMDAR data assessments using the RUC at NOAA's Global Systems Division. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface,* 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Moninger, W.R., S.G. Benjamin, B.D. Jamison, T.W. Schlatter, T.L. Smith, and E.J. Szoke, 2007: TAMDAR and its impact on Rapid Update Cycle (RUC). *22nd Conference on Weather Analysis and Forecasting*, 25-29 June 2007, Park City, Utah, Amer. Meteor. Soc.

Szoke, E.J., S.G. Benjamin, R.S. Collander, B.D. Jamison, W.R. Moninger, T.W. Schlatter, and T.L. Smith, 2007: Impact of TAMDAR on the RUC model: A look into some of the statistics. *11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans*, and Land Surface, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc.

Szoke, E.J., R.S. Collander, B.D. Jamison, T.L. Smith, T.W. Schlatter, S.G. Benjamin, and W.R. Moninger, 2006: An evaluation of TAMDAR soundings in severe storm forecasting. *23rd Conference on Severe Local Storms*, 6-10 November 2006,St. Louis, MO, Amer. Meteor. Soc.

Szoke, E.J., R.S. Collander, B.D. Jamison, T.L. Smith, S.G. Benjamin, W.R. Moninger, T.W. Schlatter, and B. Schwartz, 2007: Impact of TAMDAR data on RUC short-range forecasts. *22nd Conference on Weather Analysis and Forecasting,* 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Project Title: Data Assimilation, Ensemble Forecasting, and Forecast Verification

Principal Scientist: Chungu Lu

NOAA Project Goal/Program: Weather and Water—Serve society's needs for weather and water information / Weather water science, technology, and infusion

Key Words: Background error covariance, data assimilation system, ensemble forecast system, forecast verification, precipitation forecast

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 develop and research data assimilation systems, ensemble forecast methods, and forecast verification, and eventually to transfer these systems and methods to NOAA forecast operations.

2. Research Accomplishments / Highlights:

Following are progress and accomplishments during the past year for the following three aspects of this project:

1) Data assimilation

One of the crucial issues related to variational data assimilation is how to determine background statistical error covariances. We recently developed a method to construct background error covariances using time-phased ensemble forecasts. This method has many advantageous features over the traditional methods used in many forecast centers around the world. Fig. 1 shows the diagnostic of the error covariance (the shaded contours) between the two horizontal wind components u and v (panels a and b) and between the u-component of wind and temperature (panels c and d), in comparison with the potential vorticity field (grey contours). The left column is the background error covariance derived from our time-lagged ensemble method; the right column is from the NCEP's NMC method. Our method shows clear mesoscale structures relevant to weather situation and possesses flow-dependent property.

2) Ensemble forecasting

Last year, we developed a time-phased multi-model ensemble system using NOAA LAPS hourly data assimilation system. This year, this system is further developed and applied in various NOAA forecast and field experiments, such as the NOAA Hydrometeorological Testbed. Fig. 2 shows the time-phased multimodel ensemble precipitation forecast (b) during HMT in the American River Basin in northern California, in comparison with stage IV observation (a) and individual model forecasts (c-f). The time-phased multi-model ensemble forecast possesses better skills than each deterministic forecast.

3) Precipitation forecast verification

To respond to NOAA GSD's long-term goal, we initiated a new project to conduct a global precipitation forecast verification. This project also fits under the WMO's THORPEX initiative. Two sets of satellite data are used: UC-Irvine's PERSIANN and NOAA CMORPH satellite data products. These satellite data provide a global estimate of precipitation. NCEP's Global Forecast System (GFS) 1-7 days precipitation forecasts are verified against the satellite observations. Figs. 3a and 3b show the root-mean-square error (RMSE) for GFS day 1 and day 6 global precipitation forecasts. Fig. 3c shows the global distribution of the Equitable Threat Score (ETS) for GFS 1 day precipitation forecast at threshold of 6.35 mm/day. This research and development has generated several publications listed below.

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

The research is in progress and will be continued next year.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Kim, O., C. Lu, J.A. McGinley, and J. Oh, 2007: Recovery of mesoscale covariance using time-phased ensembles. *22nd Conference on Weather Analysis and Forecasting and 18th Conference on Numerical Weather Prediction*, Amer. Meteor. Soc., 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Kim, O., C. Lu, S. Albert, J.A. McGinley, and J. Oh, 2007: Improvement of LAPS wind analysis by including background error statistics. *22nd Conference on Weather Analysis and Forecasting and 18th Conference on Numerical Weather Prediction*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Lu, C., H. Yuan, B. Schwartz, and S.G. Benjamin, 2007: Short-range numerical weather prediction using time-lagged ensemble forecast system. *Wea. Forecasting,* 22, 580 595.

Lu, C., H. Yuan, S.E. Koch, E. Tollerud, J.A. McGinley, and P.J. Schultz, 2007: Scale-dependent precipitation forecast error in the GFS. *22nd Conference on Weather Analysis and Forecasting and 18th Conference on Numerical Weather Prediction*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Lu, C., H. Yuan, S.E. Koch, E. Tollerud, J.A. McGinley, and P.J. Schultz, 2007: Time-frequency localization and long- and short-term memories in the GFS precipitation forecast errors. *22nd Conference on Weather Analysis and Forecasting and 18th Conference on Numerical Weather Prediction*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Yuan, H., C. Lu, J.A. McGinley, P.J. Schultz, B.D. Jamison, L. Wharton, and C.J. Anderson, 2007: Short-range quantitative precipitation forecast (QPF) and probabilistic QPF using time-phased multi-model ensembles. *Wea. Forecasting* (under revision).

Yuan, H., J.A. McGinley, P.J. Schultz, C.J. 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* (under revision).

Yuan, H., C. Lu, E. Tollerud, J.A. McGinley, and P.J. Schultz, 2007: Analysis of precipitation forecasts from the NCEP global forecast system. *22nd Conference on Weather Analysis and Forecasting and 18th Conference on Numerical Weather Prediction*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

Yuan, H., J. Du, J.A. McGinley, P.J. Schultz,B. Zhou, C. Lu, Z. Toth, and G. Dimego, 2007: Postprocessing of precipitation forecasts for new configured NCEP short-range ensemble forecasting (SREF) system. *22nd Conference on Weather Analysis and Forecasting and 18th Conference on Numerical Weather Prediction*, 25-29 June 2007, Park City, UT, Amer. Meteor. Soc.

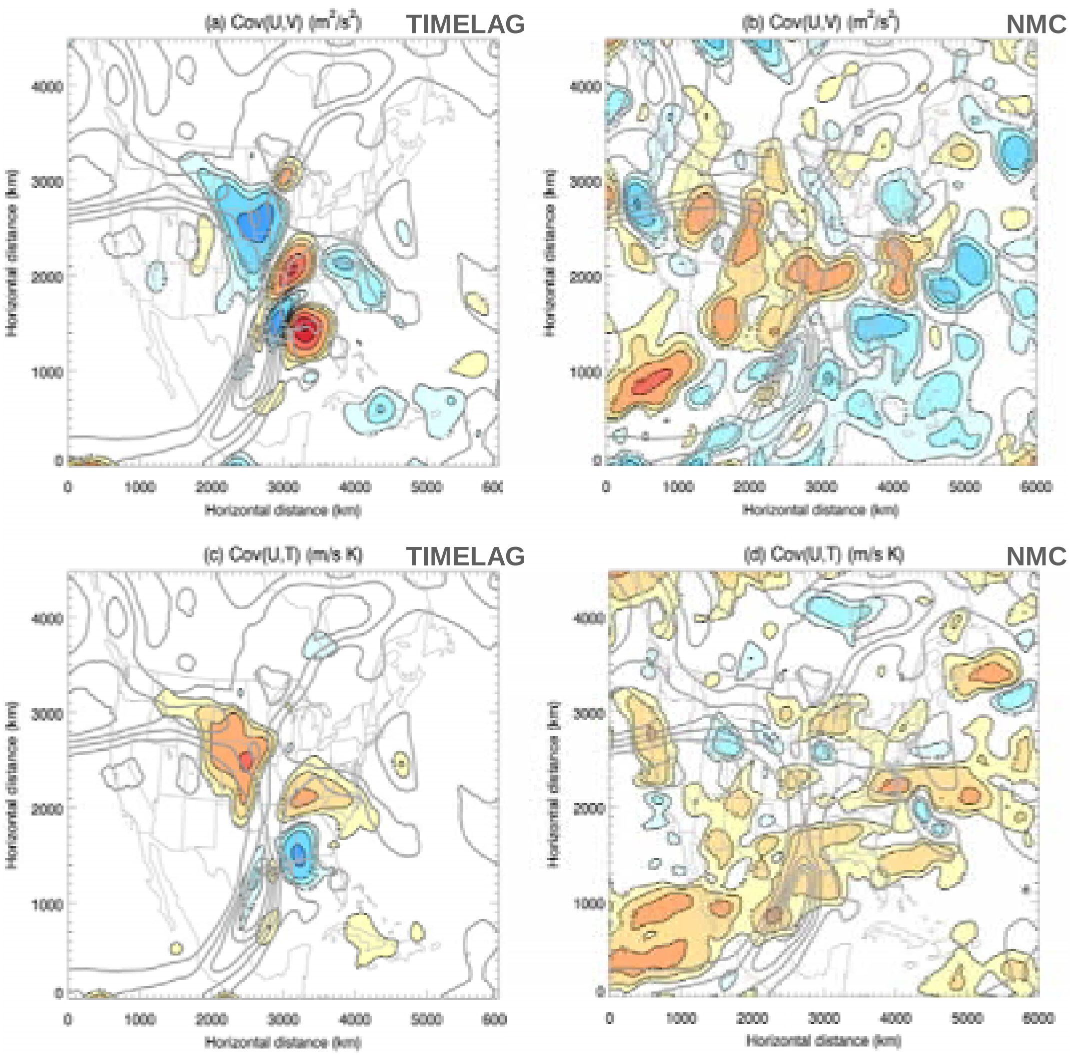


Fig. 1. The 300hPa forecast estimated error covariance between U and V in (a), (b) and U and T in (c), (d). Left column is for time-lagged ensemble method and right column is for NMC method.

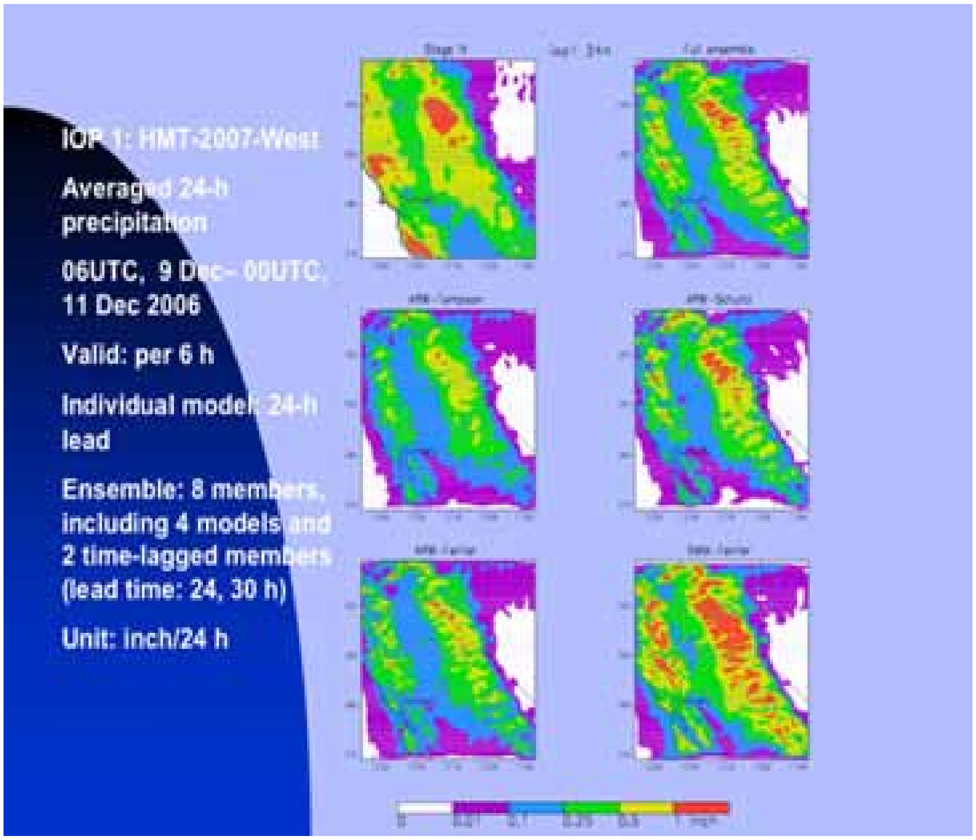


Fig. 2. Precipitation forecast during HMT for the American River Basin in northern California by time-phased multimodel ensemble and different deterministic forecasts.

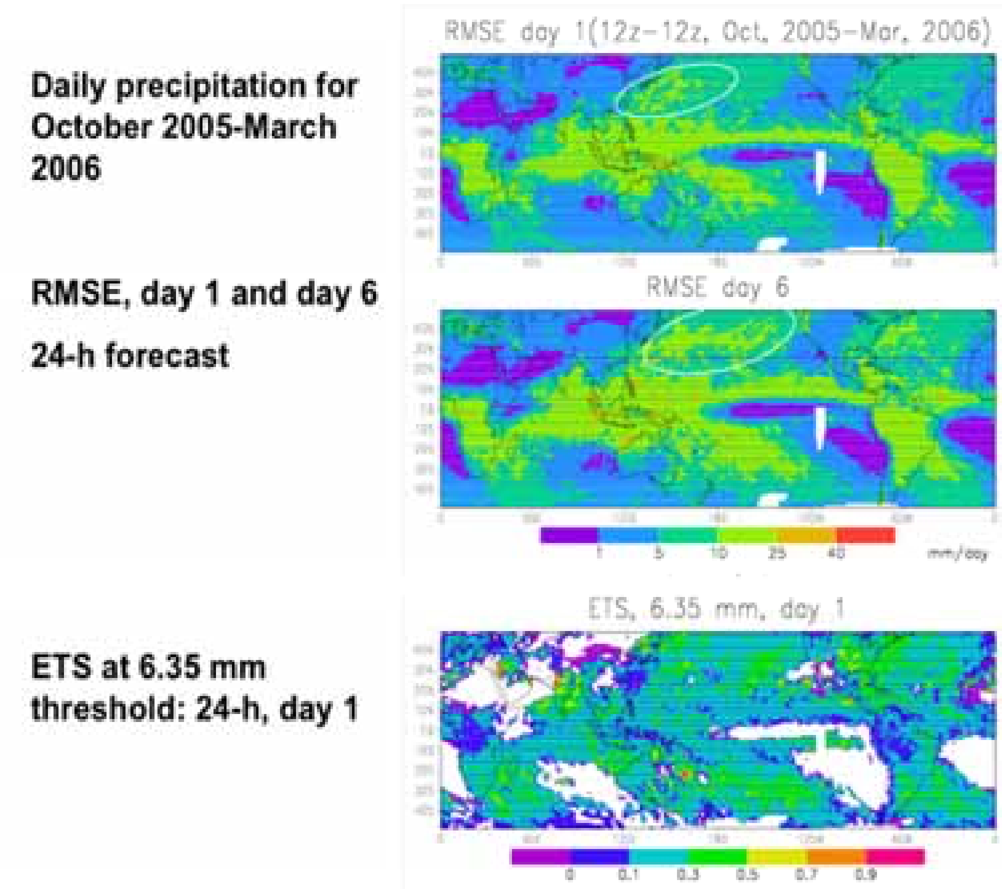


Fig. 3. GFS global precipitation forecast verification. a) RMSE for day 1 forecast; b) RMSE for day 6 forecast; c) EST for day 1 forecast for 6.35 mm/day threshold.

Project Title: <u>Study of gravity waves and turbulence interaction in the upper troposphere</u>

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 a physical understanding of mesoscale gravity-dynamics and turbulence generation in the upper troposphere, and to provide public aviation safety advisory based on the obtained scientific understandings.

2. Research Accomplishments/Highlights:

During the past year, we employed two different research tools to study mesoscale gravity waves and turbulence: theoretical analysis and numerical modeling. For the theoretical analysis, we have developed several spectral and structure-function analysis methods. In particular, we conducted the Hurst parameter and intermittency parameter analyses for the SCATCAT observational data. This research resulted in a better understanding of interaction of turbulence and mesoscale gravity waves in the upper troposphere. Fig. 1 shows how clear-air turbulence (CAT) and gravity waves are mapped in a bifractal parameter space.

We also used the Weather and Research Forecast (WRF) model to conduct the idealized simulation of interaction among upper-level jet, gravity waves, and turbulence. We have generated several nested domain simulations and were able to run WRF with several nested domain with the finest grid spacing of 1.3 km. Currently, we are analyzing these simulation results, trying to understand the impacts of dissipation on the gravity waves. Fig. 2 shows WRF simulated mesoscale gravity waves in the upper troposphere with 1.3-km grid spacing at various simulation times. This research has generated several publications listed below.

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

The research is in progress and will be continued next year.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Koch, S.E. 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, Santa Fe, NM, Amer. Meteor. Soc.

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

Wang, N. and C. Lu, 2007: A two-dimensional continuous wavelet algorithm and its application to meteorological data analysis. *Quart*. *J. Roy. Meteor. Soc*., (Submitted).

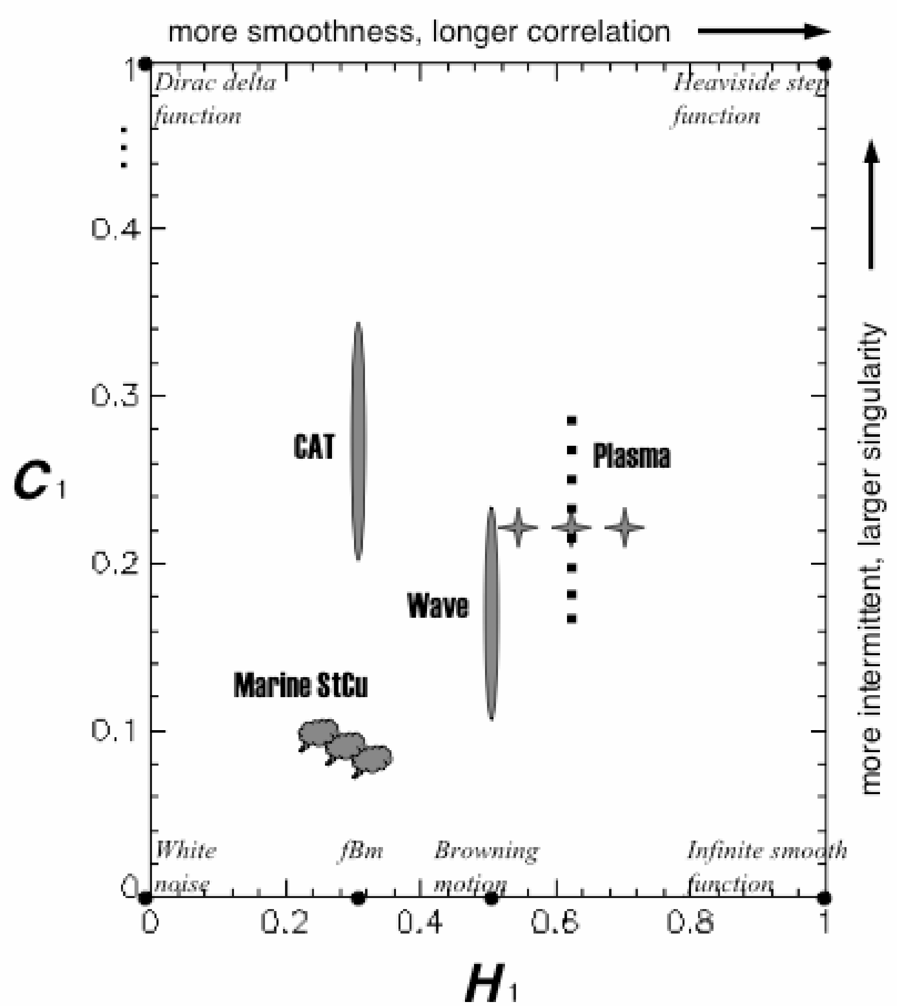


Fig. 1. The bifractal parameter space, with the Hurst parameter as abscissa, and the intermittent parameter as ordinate. CAT and gravity waves are localized in this parameter space.

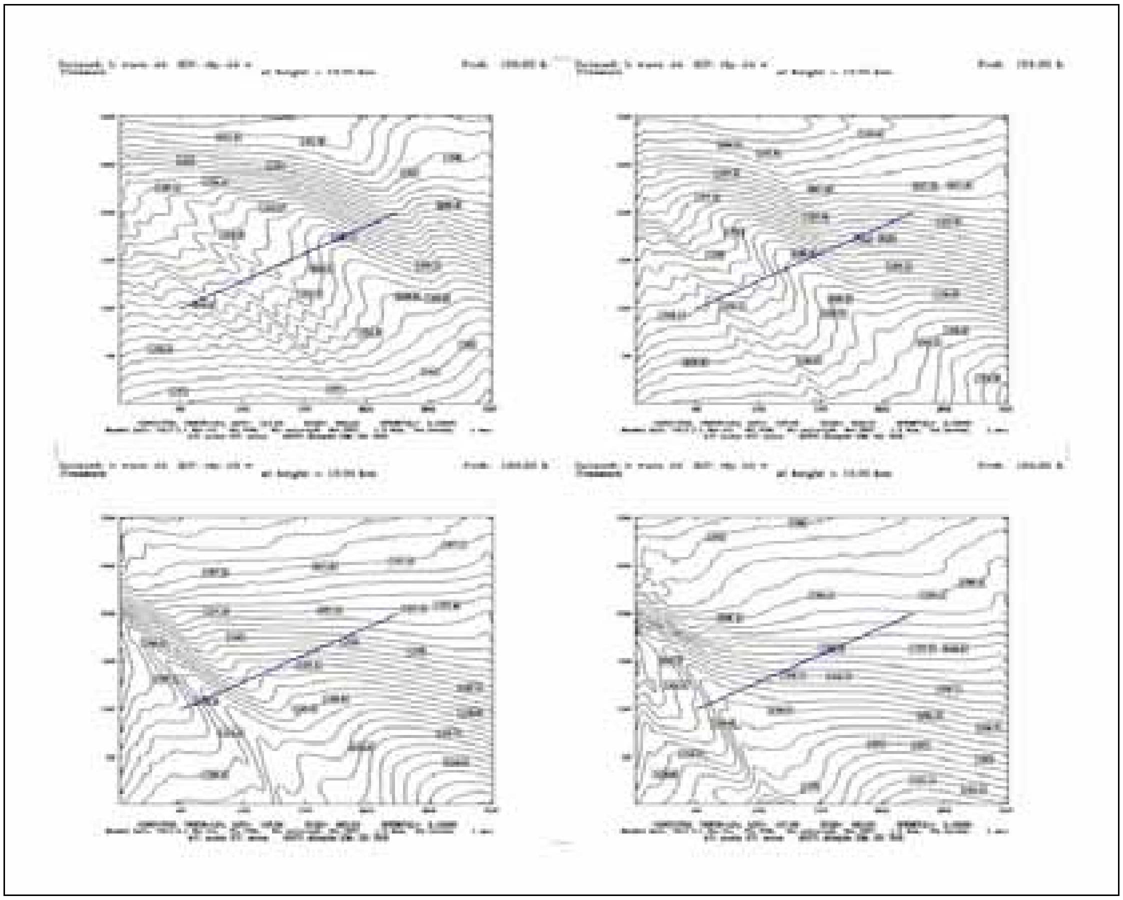


Fig. 2. WRF simulated gravity waves at 13-km level for time at 120, 121, 122, and 123 h. The horizontal grid spacing is 1.3 km.

Project Title: Regional Climate Modeling

Principal Scientist: Mariusz Pagowski

NOAA Project Goal / Program: Weather and Water—Serve society's needs for weather and water information / Environmental Modeling

Key Words: Regional Climate Modeling, Soil Moisture, Precipitation, Convection

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

This project is a funded proposal sponsored by GEWEX Americas Prediction Project (GAPP) Climate Prediction Program at the NOAA Climate Program Office. The main objectives of the project include assessment of the role of soil moisture on precipitation and evaluation of convective parameterizations.

2. Research Accomplishments/Highlights:

During the past year, regional climate simulations were performed for the summer months of 2004 and 2005 with the WRF model to study the effects of soil moisture on precipitation and to compare results obtained with different convective parameterizations and with explicitly resolved convection.

Based on the results available from last year's efforts (see report for FY 2005 / 2006) and the newer results for the remaining summer months in 2004 and 2005, it was noted that the quality of the lateral boundary conditions had a large effect on the simulations in the high resolution domain (1.667 km). When lateral boundary conditions were specified using simulations at 5 km resolution (which in turn used lateral boundary conditions from 20 km simulations), large dry biases were observed even though simulations in the 5 km resolution domain did not have a significant dry bias. On the other hand, when lateral boundary conditions were specified using the 20 km Rapid Update Cycle (RUC) analyses, the dry bias decreased significantly. Therefore, all subsequent cloud-resolving simulations used the RUC analyses to provide lateral boundary conditions for the high resolution.

In the next step for this project, we examined the behavior of different convective closures with ensemble members of the Grell-Devenyi parameterization. This was achieved by performing simulations in which all closure ensembles were turned off except for one. The closures tested were:

a) Pure stability dependent closure. This closure assumes the removal of Convective Available Potential Energy, CAPE, within a specified time period. In order to easily identify this closure as it was used in the various simulations, we used the identifier "ST" in all experiments that use this ensemble.

b) Closures that depend on changes of CAPE due to effects other than convection as in Grell (1994). In order to easily identify this closure as it was used in the various simulations, we used the identifier "GR" in all experiments that use this ensemble.

c) Closures that depend on changes of Cloud Work Functions in comparison to climatological values, similar to Arakawa-Schubert (1974). In order to easily identify this closure as it was used in the various simulations, we used the identifier "AS" in all experiments that use this ensemble.

d) Closures that depend on the integrated vertical advection of moisture, similar to Krishnamurthi (1980). In order to easily identify this closure as it was used in the various simulations, we used the identifier "MC" in all experiments that use this ensemble.

e) Closures that depend on low level mass flux, similar to Frank-Cohen (1987). In order to easily identify this closure as it was used in the various simulations, we used the identifier "W" in all experiments that use this ensemble.

The spatial patterns of monthly observed and simulated precipitation amounts using the various closure ensembles and for the month of June 2004 are shown in Figs. 1a and 1b. It can be noted that the behavior of the different runs is somewhat similar, possibly with exception of ST_june04, which predicts smaller precipitation amounts, especially on the mountain slopes.

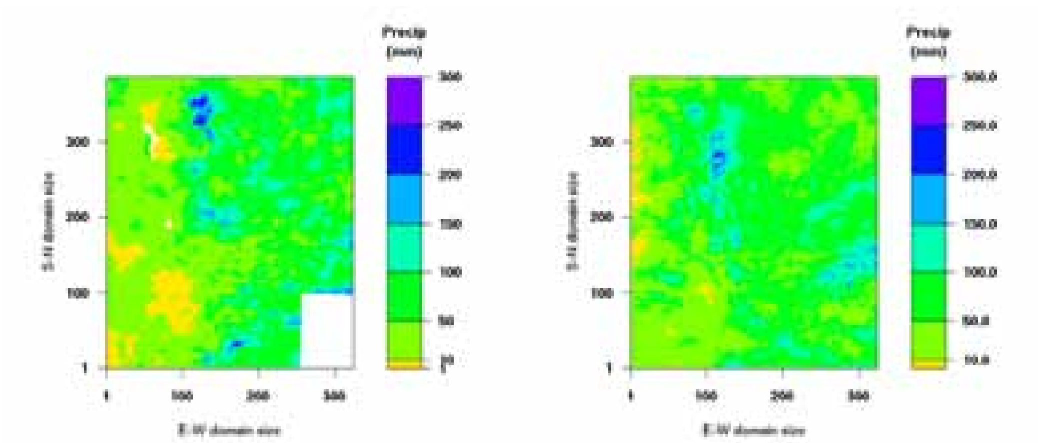


Fig. 1a. Accumulated precipitation in June 2004 for Stage4 data (left) and in the high resolution domain (right). White area in the Stage4 plot represents incomplete data to calculate accumulated monthly precipitation.

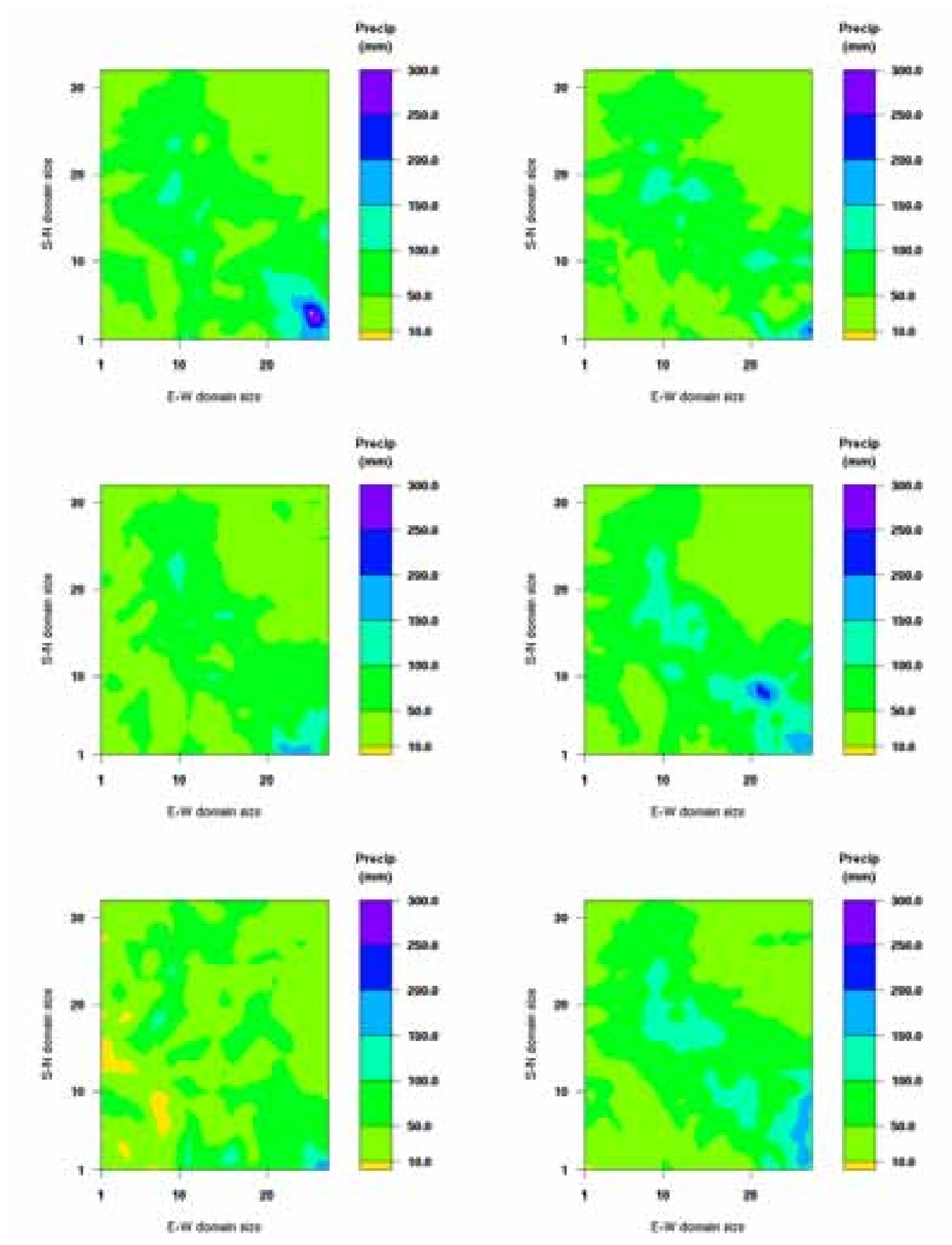


Fig. 1b. Accumulated precipitation as simulated for June 2004 using various different closures. From top to right and down: Grell-Devenyi ensemble parameterization, GR, W, MC, ST, and AS.

Next, we started to examine the soil moisture-precipitation feedback when using the GD convective parameterization in addition to various combinations of Planetary Boundary Layer (PBL) formulations and Land Surface Models (LSMs). As a diagnostic tool, we define the recycling rate as r=ET/(IN+ET), where ET is evapotranspiration and IN is the amount of moisture incoming to the domain. In addition, we use the definition of the precipitation efficiency [p=P/(IN+ET)], where P is amount of precipitation in the domain. Simulations were performed to examine the behavior of these two parameters for different boundary layer schemes, LSMs and varying soil moisture (minimum possible for a given soil, an intermediate value, and maximum possible). The recycling rate and the precipitation efficiency for these simulations in June 2004 are shown in Figs. 2a and 2b. It can be noted that the recycling ratio, which is a measure of the contribution of local evaporation to total moisture, is higher when using the RUC-LSM than the Noah-LSM for the maximum soil moisture.

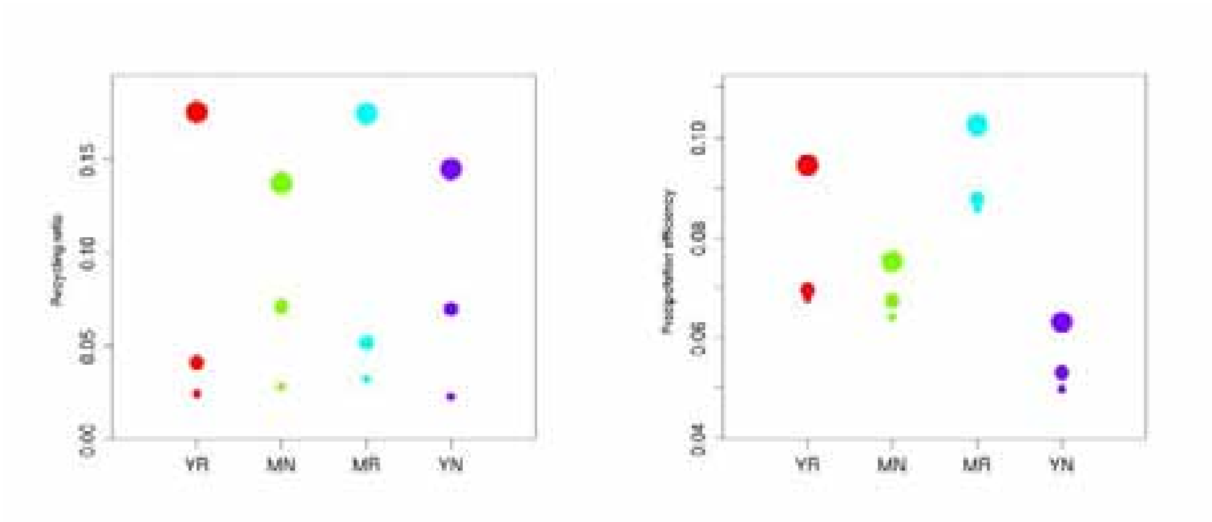


Fig. 2. Recycling rate (left) and precipitation efficiency. The first letter indicates the BL scheme: Y – YSU PBL, M- MYJ PBL. The second letter LSM: N- Noah, R- RUCLSM. Dots increase from the minimum soil moisture to the maximum soil moisture.

Correspondingly, precipitation efficiency is higher when using the RUC-LSM compared to using the Noah-LSM. Some insight into this behavior can be gained from domain-averaged profiles of potential temperature and mixing ratio in Figs. 3a and 3b (since precipitation amount is highest in the afternoon, only profiles at 00 UTC are plotted). In these figures, the runs with a MYJ-RUC-LSM combination for the maximum soil moisture produces a boundary layer that is the coldest and most moist and thus most likely to contribute to fast condensation and cloud formation. Interestingly, the simulations using a YSU-RUC-LSM (YSU - Yonsei University PBL) combination have higher precipitation efficiencies than the ones using the MYJ-Noah (YSU - Mellor-Yamada-Janjic PBL) combination. This is the case despite the fact that the runs using the MYJ-Noah combination have a cooler and moister boundary layer (and lower evapotranspiration - in the denominator of the formula for precipitation efficiency). It can be seen the YSU-RUCLSM combination through stronger mixing leads to deeper boundary layers and more vigorous vertical moisture transport up to the condensation level (LCL).

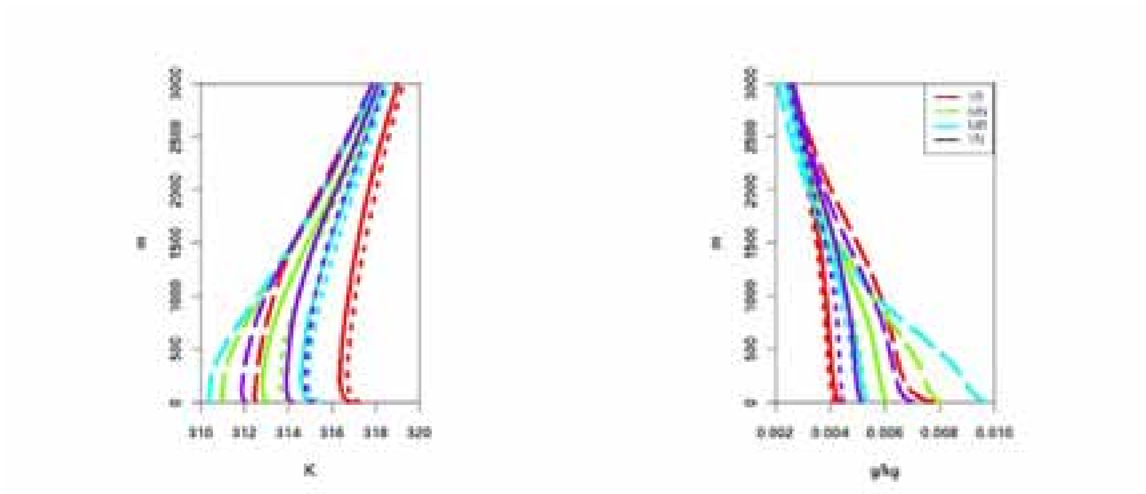


Fig. 3. Domain averaged potential temperature (left) and mixing ratio (right) profiles. Solid line- intermediate soil moisture, short dash – dry soil, long dash – moist soil. Colors for BL-LSM combinations given in the legend.

Some of the results from this research effort were presented at the Conference on Applied Climatology in Ljubljana, Slovenia in September 2006. A manuscript on the soil moisture-precipitation feedback is in preparation.

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

The research is in final stages and a manuscript summarizing the results is being prepared.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Gultepe, I., R. Tardif, S.C. Michaelides, J. Cermak, A. Bott, J. Bendix, M. Mueller, M. Pagowski, B. Hansen, G. Ellrod, W. Jacobs, G. Toth, and S.G. Cober, 2007: Fog research: a review of past achievements. Accepted by *J. Pure and Applied Geophysics.*

Gultepe, I., M. Pagowski, and J. Ried, 2007: A Satellite-Based Fog Detection Scheme Using Air Temperature. *Wea. Forecasting* 22**,** 444-456.

Hacker, J.P., J.L. Anderson, and M. Pagowski, 2007: Improved vertical covariance estimates for ensemble-filter assimilation of near-surface observations. Submitted to *Mon. Wea. Rev.*

Koch, S.E., W. Feltz, F. Fabry, M. Pagowski, B. Geerts, K.M. Bedka, D.O. Miller, and J.W. Wilson, 2007: Turbulent mixing processes in atmospheric bores and solitary waves deduced from profiling systems numerical simulation. Submitted to *Mon. Wea. Rev.*

Pagowski, M, J. Hacker, and D. Rostkier-Edelstein, 2007: Behavior of Weather Research and Forecasting (WRF) model boundary layer and surface parameterizations in 1-D simulations during BAMEX field campaign. Accepted by *Boundary-Layer Meteorology.*

Pagowski, M. and G.A. Grell, 2006: Effects of surface moisture, land-atmosphere exchanges, and turbulent transport on precipitation over the Rocky Mountains and High Plains. *6th Annual Meeting of the European Meteorological Society*, September 2006, Ljubljana, Slovenia.

Project Title: <u>Regional Transport Analysis for Carbon Cycle Inversions</u>

Principal Scientist: Mariusz Pagowski

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

Key Words: Carbon Cycle, Inversion Modeling, RUC

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

The goal of this project was to apply hourly meteorological analyses generated by the Rapid Update Cycle (RUC) assimilation system on the 13-km grid over North America to create a year-long data base of influence functions.

The transport influence function quantifies the sensitivity of each observation at NOAA sampling towers to unit surface fluxes of CO2 or other trace gases at all points upstream in the RUC domain. For the purpose of influence function derivation, the RUC fields were used to drive the CSU Lagrangian Particle Dispersion Model (LPDM) backward in time for specified sampling stations.

2. Research Accomplishments/Highlights:

We have extracted sets of hourly RUC meteorological analyses for the period from March 2005 to May 2006. The selected fields from these sets are written in a format readable by CSU LPDM. The CSU LPDM is generally being used with different versions of CSU RAMS (Regional Atmospheric Modeling System). The interface between RUC and LPDM had to take into account differences in map projections and grid structure. The upgraded version of the LPDM can be now driven both by RAMS and RUC fields.

The RUC-LPDM system is generating a huge amount of data which would be impractical to store and disseminate at full resolution for a year. Thus, we have designed the storage and dissemination system to store all information in the form of Lagrangian particles rather than gridded influence functions. Several versions of this system have been developed and tested.

We used RAMS to investigate whether fields from RUC provide sufficient time resolution for atmospheric transport simulation. We assume that a Lagrangian particle should not cross more than one grid cell within time interval between available meteorological fields. The hourly output from RUC with 13 km horizontal grid spacing violates that assumption. Comparing transport simulations with meteorological fields updated every 15 minutes and every 1 hour, we have found that hourly fields do not cause unacceptable errors in the influence functions derived on a 100km grid.

We analyzed the extracted RUC fields for missing data. It appeared that there were numerous gaps from 1 hour to a couple of weeks resulting from computer downtimes. The missing files in the RUC archive did not allow us to derive influence functions for the entire year as originally planned.

We also analyzed the tracer residence time within the regional domain for different towers. This time varies from 1 to more than 2 weeks and determines what sampling periods the influence functions can be derived for in the presence of data gaps. In general, we need to run particles backward in time for at least 2 weeks for any given sampling time.

We decided to fill short gaps, up to 2 hours, in the RUC fields by interpolation. However, filling the longer gaps would require rerunning the RUC analyses. As an alternative solution to dealing with gaps in RUC fields, we suggested using CSU RAMS driven by available RUC fields or other analysis products, and then running the LPDM. The interface between RUC and RAMS has been developed, providing two options for atmospheric transport modeling and influence function derivation (see Fig. 4): (1) RUC->LPDM, and (2) RUC->RAMS->LPDM.

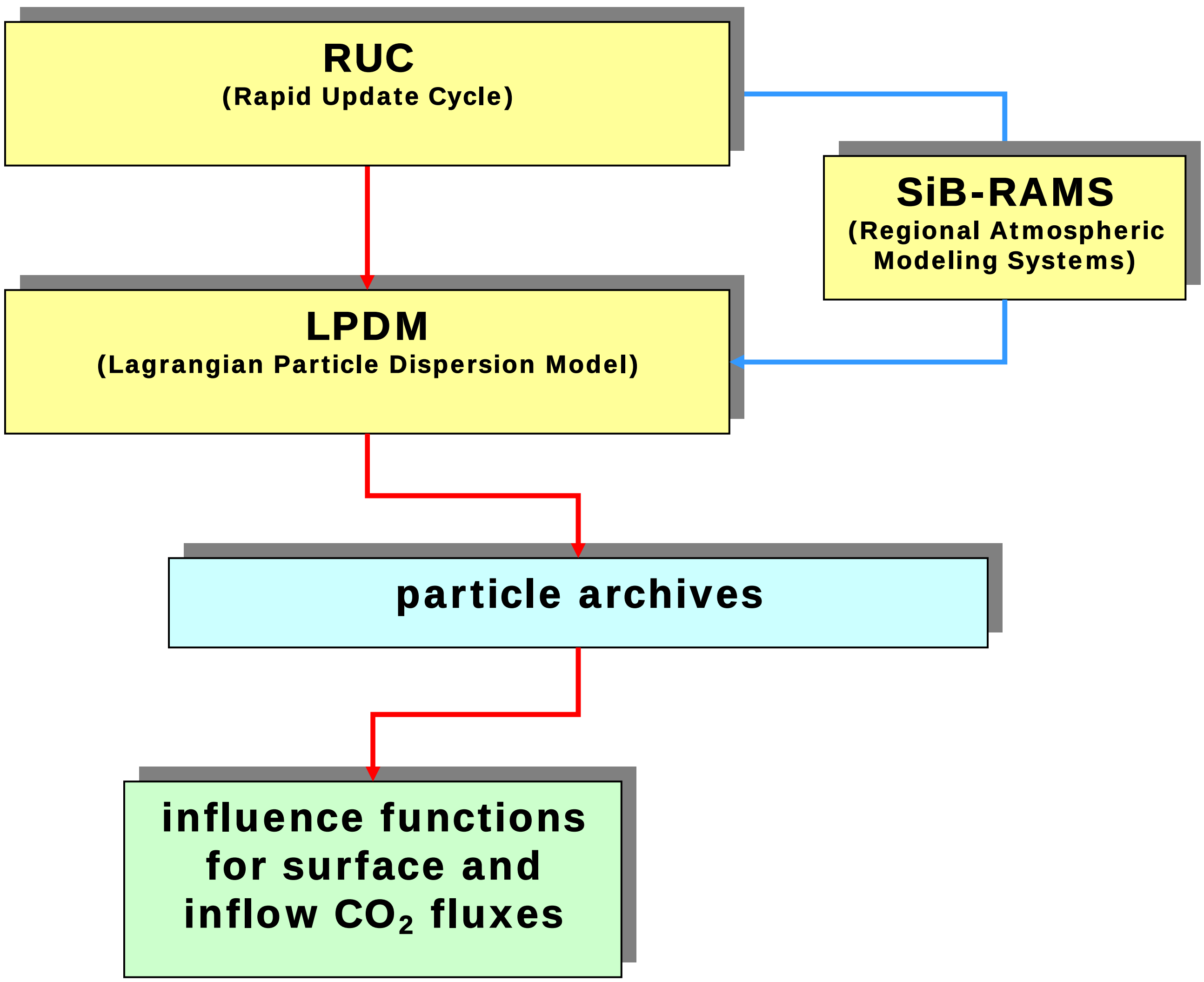


Fig. 4. RUC/LPDM modeling system *with* an optional usage of CSU RAMS.

The second option RUC/RAMS/LPDM provides us with interesting research opportunities, since it is possible in this configuration to run RAMS on a small domain and with higher resolution than RUC instead of running RAMS on a continental scale domain with several nested grids. Several simulations were performed to test this option and the results were promising.

We have started to work on parameterization of convective transport (cloud venting) in the LPDM linked to the RUC. We performed LPDM simulations and derived influence functions for 30 towers (existing and planned) for all longer periods with available RUC fields in the period from March 2005 to May 2006. Composite plot of influence functions for 38-day sampling period (159-197 julian days of 2005) for 31 towers is shown in Fig. 5. Influence functions are integrated with a constant 1 umol/m2/s CO2 flux and presented in ppm.

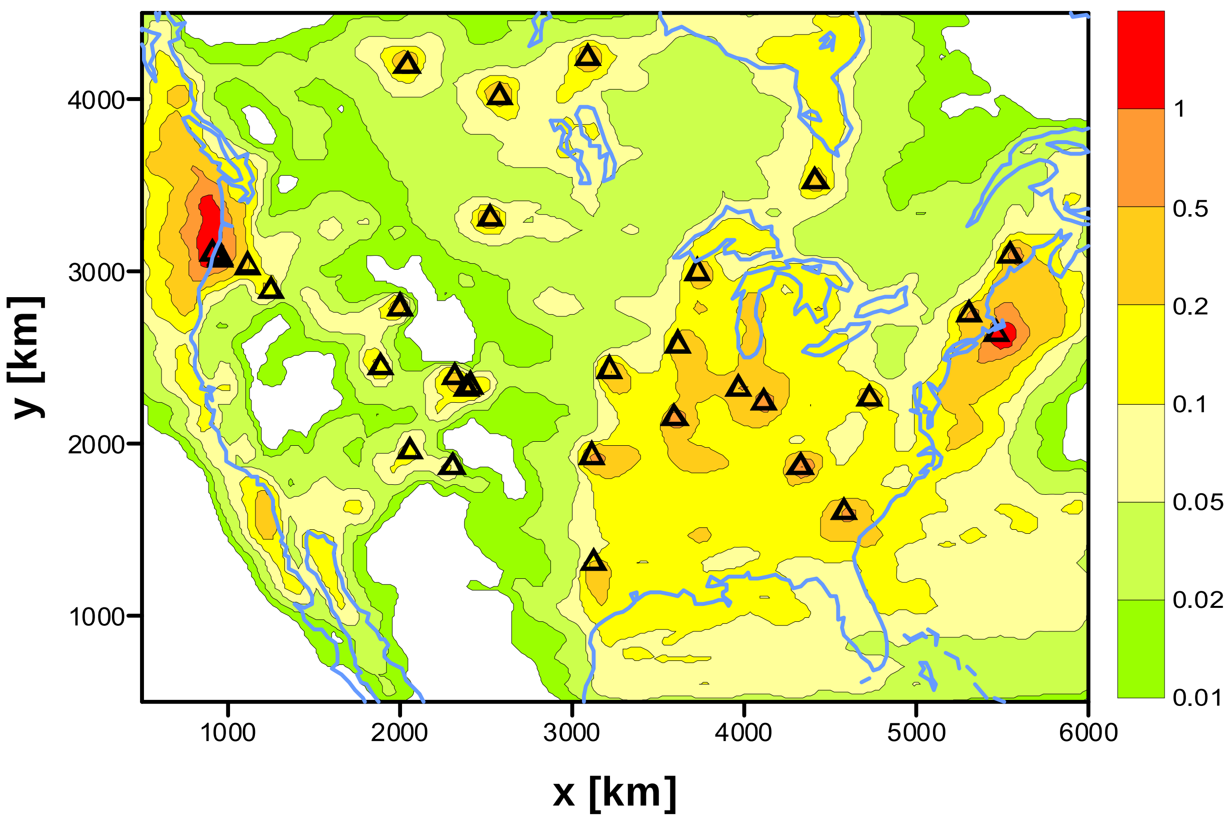


Fig. 5. Composite plot of influence functions for 38-day sampling period (159-197 julian days of 2005) for 31 towers. Influence functions are integrated with a constant 1 umol/m^2/s CO2 flux and presented in ppm.

The extracted and processed RUC fields were transferred by ftp from NOAA to CSU. All LPDM and RAMS simulations were performed on a Linux cluster at CSU. The results of the project were presented as a poster at Earth System Research Laboratory Global Monitoring Annual Conference, May 2-3, 2007, Boulder, CO.

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

This project is not funded for FY07/08 at this time. Further funding of the research is being considered by ESRL/GMD.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Uliasz, M., M. Pagowski, E. Chorak, and S. Denning, 2007: Regional transport analysis for carbon cycle inversions using RUC-LPDM system, May 2007, Project Report to ESRL/GMD.

Project Title: <u>FAA Turbulence Project</u>

Participating CIRA Research Coordinator: 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: Clear Air Turbulence, Diagnostic Turbulence Prediction Algorithms

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

GSD, under support from the FAA Aviation Weather Research Program, conducts research to improve forecasts of turbulence through field programs designed to measure in-situ turbulence and by developing diagnostic algorithms for turbulence prediction. Tasks related to this project include: analysis of in-situ and/or model data, research and development of diagnostic algorithms, and analysis of variables related to turbulence.

The Graphical Turbulence Guidance (GTG) product is an amalgamation of a number of different diagnostic algorithms to provide the best available overall turbulence forecast. Currently, these algorithms are weighted and combined without regard to the particular synoptic weather situation. It is speculated that some of the diagnostic algorithms may perform better than others with respect to the background weather pattern, and thus the weighting of the algorithms for the GTG could be adjusted to provide a more accurate forecast.

2. Research Accomplishments/Highlights:

For this task, a literature review was performed to locate the most well-known patterns that forecasters rely upon to identify potential areas of turbulence. Seven basic patterns were noted: basic jet stream, digging jet streak, confluent jet, upper level cutoff low, sharp upper level trough, basic shortwave with a surface low, and sharp upper level ridge. Cases including those patterns were subjectively recognized and identified during the new test period (November 2005 - March 2006). Plots of pireps were used to validate that turbulence was observed in the areas of interest. For these cases, potential candidate meteorological fields were chosen to locate and outline the patterns of interest. These fields include: omega, shear, stability, temperature and advection, vorticity and advection, vorticity gradient, stretching and shearing deformation, Laplacian of height and vorticity, divergence, and divergence of Q. Scripts were written to generate plots of these fields, and the plots were organized onto a web page to facilitate analysis. The results appear to be quite promising, with fields and combinations of fields correlating well to the observed turbulence (Figs. 1 and 2). The long term goal is to develop a rudimentary objective pattern recognition scheme that correctly identifies these areas which will allow the GTG to adjust the weighting of the algorithms accordingly.

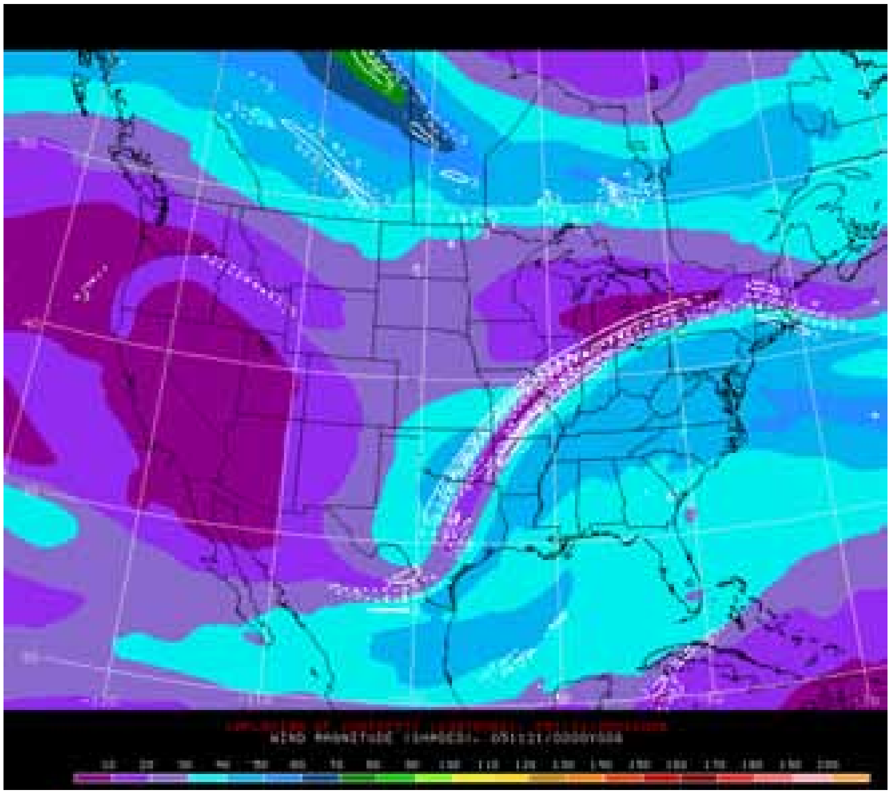


Fig. 1. A plot of Laplacian of vorticity (white contours) with wind magnitude (shaded contours) for a 6 hour RUC forecast verifying on November 21, 2005, 06 UTC. Note the white contours stretching from southern Texas to the Great Lakes area.

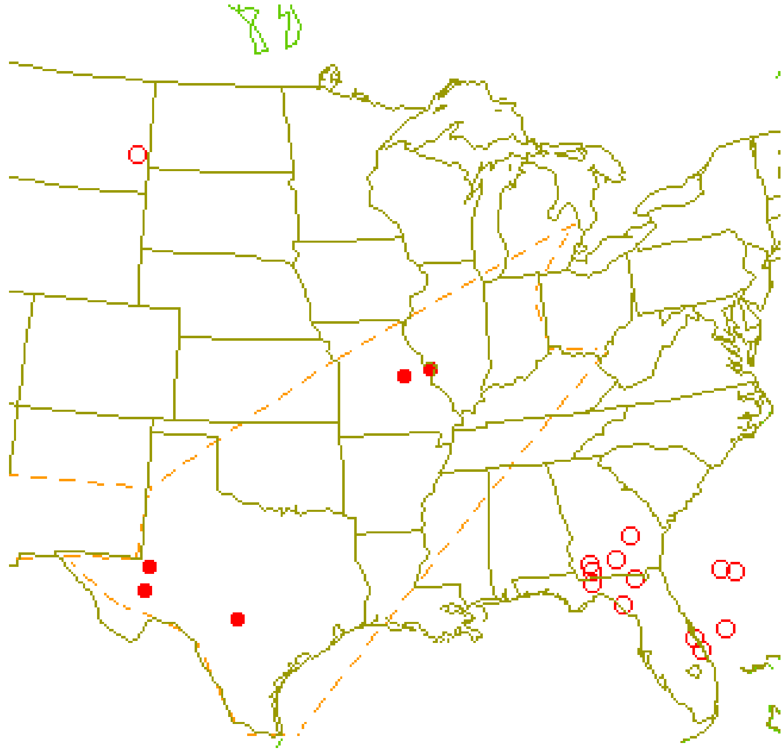


Fig. 2. Pilot reports of turbulence for the same verification time as Fig. 1. The reports in south central Texas and eastern Missouri coincide with the Laplacian of vorticity contours in Fig. 1.

Analyses were done to examine out-of-cloud convectively induced turbulence (OCIT), or more simply, turbulence generated near convective clouds and storms. Four months of the convective season (i.e. April through July) were selected for study. Software scripts were written to plot pireps and RCPF (RUC Convective Probability Forecast) contours superimposed on a satellite infrared (IR) image (see Fig. 3). Since the IR data can be as frequent as every 15 minutes, only those pireps within 7.5 minutes of the image time were plotted. A web page was also developed to display each day's images in a thumbnail fashion for subjective case selection, with added controls to make these selections interactively, allowing identification of a case as "frontal" (in the vicinity of a front), "MCS" (in the vicinity, but not within, a mesoscale convective system) or "other" (not readily identifiable as being associated with a front or an MCS). The OCIT team decided to further restrict cases to pireps at or above 15,000 ft., reporting moderate or greater turbulence, and had accompanying RCPF forecasts. In total, 881 cases were identified for the four month period, with 372 frontal cases, 277 MCS cases, and 232 other cases. Using these cases, a strategy to assess the correlation between RCPF and pireps was employed by examining points extending outward from each pirep to locate the nearest non-zero RCPF value, and computing the distance between the pirep and that point. Since these distances do not in themselves represent easily interpretable values, a "mock" set of pireps generated at random locations were also subjected to the same strategy. The results are shown in Fig. 4, tallying the number of cases in each distance category (where distance is given in whole grid units, approximately 22 km per unit). This plot comprises the total number of cases, irrespective of case type. The difference between the actual cases and the mock cases can be interpreted as an estimate of the potential utility of RCPF to predict OCIT. The general pattern of the histograms suggest that the relative frequency of positive values of RCPF increases steadily with increasing proximity to the pirep.

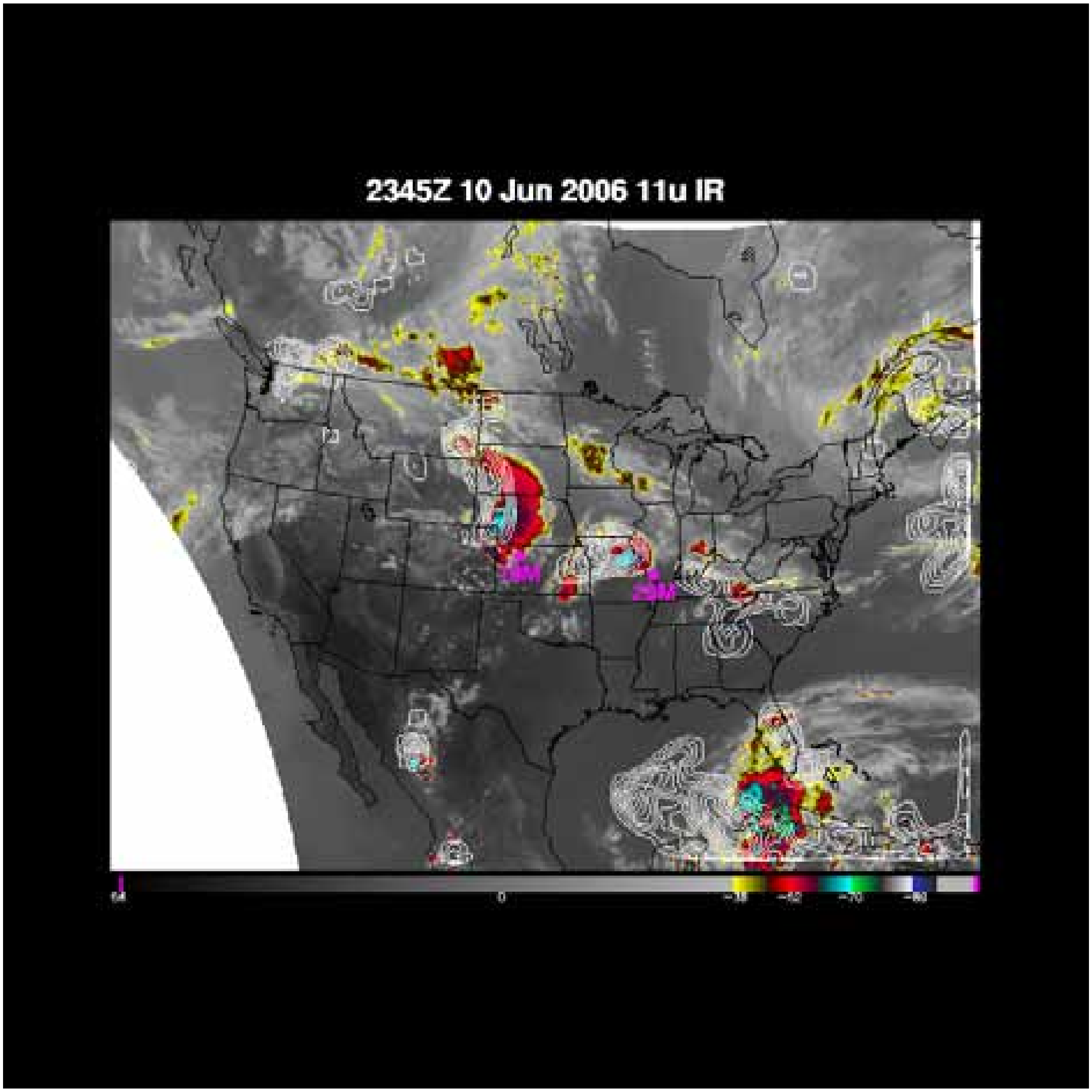


Fig. 3. A Satellite IR image for 2345 UTC, 10 June, 2006 with superimposed pireps of moderate turbulence and contours of RCPF probabilities. The pireps are at 19,000 and 20,000 ft altitude.

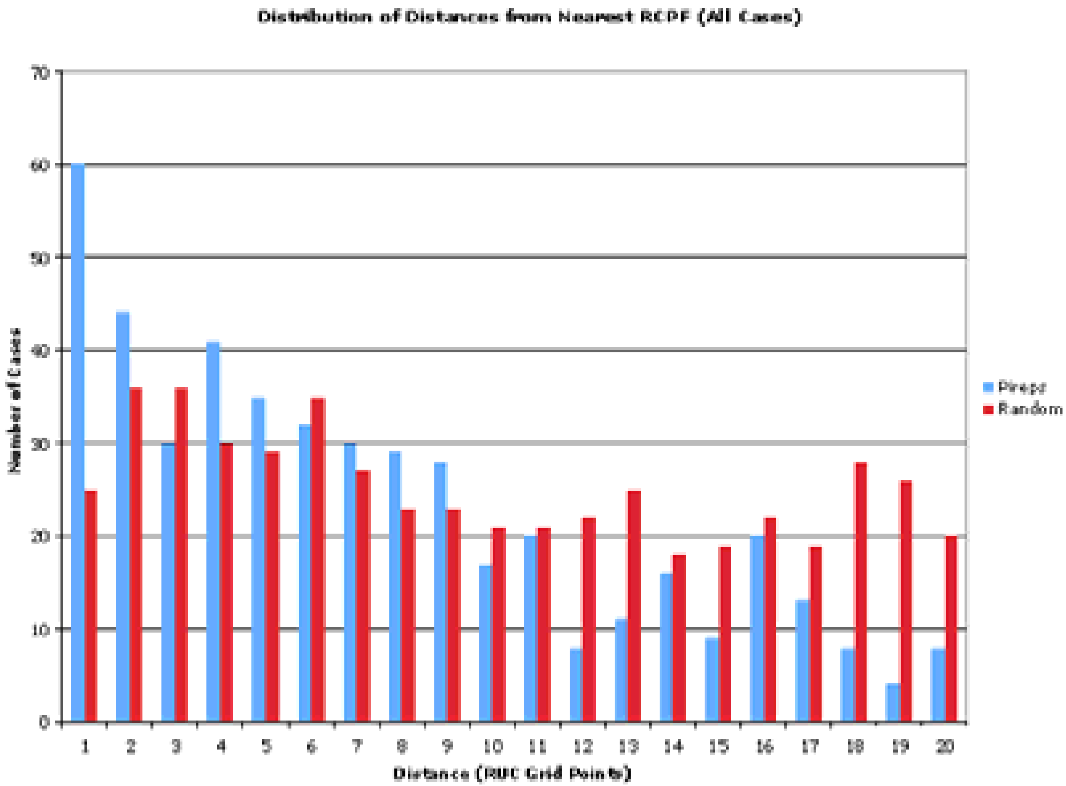


Fig. 4. Histogram showing the number of OCIT pirep cases by distance to the nearest non-zero RCPF value. Distance is given as the number of RUC grid points between the pirep location and the location of the nearest RCPF contour (approx. 22 km per grid point). Actual cases are shown in blue and random "mock" cases are shown in red.

3. Comparison of Objectives Vs Actual Accomplishments**:**

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

4. Leveraging/Payoff:

5. Research Linkages:

6. Honors/Awards:

7. Outreach:

8. Publications:

VI. Research Collaborations with the GSD Technology Outreach Branch

A. 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

FX-Net for Fire Weather/All Hazards

Fire Weather Mission Goal: NOAA's National Fire Weather Program seeks to eliminate weather-related wild land fire fatalities and injuries, and to reduce fire suppression and land management costs by providing more timely and accurate weather information. NWS forecasters at Weather Forecast Offices and the Storm Prediction Center utilize the latest model and observation data to produce national outlooks identifying critical fire weather patterns. The NOAA mission is to provide tools to support the forecasters producing these long and short-range forecasts in support of fire-management decision makers.

When a wild land fire does erupt, the NOAA mission to provide services in support of public safety becomes critical. Forecasters must produce very short-range, 'now' casts of weather hazards that will directly affect fire-fighting activities. Forecasters become dependent on the tools they can carry with them to the fire. Their ability to function effectively as a part of the fire fighting coordination team is dependent on these tools.

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

The long-term goals of the NWS FX-Net fire weather research project are: 1) to provide the most comprehensive real-time atmospheric data set possible to tactically deployed weather forecasters; 2) to provide the tactically-deployed all-hazards user access to additional earth information such as emergent dispersion, GIS, oceanic, and hydrologic data; and 3) provide an integrated data manipulation, analysis, and display system for this wide range of earth information.

A new long-term goal added for FY06-07 was to begin preliminary research into the transition of the FX-Net 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 TACMET (Tactical Meteorologist) deployed anywhere on or offshore. The ultimate system would include inter-system collaboration, dispersion modeling capability, data interrogation and editing capability and a database-independent data retrieval system. These goals are reflected in the future research planning to add these capabilities to the AWIPS II platform.

Research for this project has concentrated on compressing the data as much as possible while retaining data precision, providing extended and newly created data sets and developing tools needed in a field situation. To meet these goals with a very small development team is a major challenge. In order to meet this challenge the development group employs a number of research and development strategies. All members of the group conduct extensive research in tool development, leveraging existing and newly developed code. Code developed for the AWIPS program is used extensively in the FX-Net system. Java code and techniques required for the FX-Net client are developed and leveraged with some help from the World Wide Web, Java web groups, external training and interaction with local web developers at UCAR.

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 (see project 2.0 Gridded FX-Net in this document) research for the FX-Net project continues to concentrate on code optimization, improved compression ratios for image data, and extended precision control capabilities.

2. Research Accomplishments/Highlights and Current Status

3. A Comparison of Objectives Vs. Actual Accomplishments:

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 AWIPS v. OB6.

The new version of the FX-Net Client (v.5.0) (see Fig. 1) is scheduled for release at the end of July 2007. This version of the client includes the addition of significant new data analysis and display tools. Based on a 'wish' list from the IMETS and NIFC fire weather forecasters, the new tools are as follows:

--Text Product Notification:
Includes a registry dialog and new product notifications dialog. Give users the capability to set up a notification list for text products. Fire Weather forecasters are interested in all severe weather and special weather statements for the area surrounding the fire. This feature provides them with an immediate notice of significant new text products of their choosing.

--Enhanced Auto-Refresh:
Already loaded products can be seamlessly reloaded at user requested intervals. The auto-refresh feature allows forecasters to setup layers of products that will continuously update without requiring user intervention.

--Drawing Tools Feature:
Full-featured drawing tools dialog allows users to draw fronts, lines, regions, weather symbols, and text. Context-sensitive drawing pop up menu allows modification of a drawing's characteristics. This is a significant addition to the client analysis tools. Fire weather forecasters providing nearly continuous briefings while mobilized to a fire incident. These briefings can now be enhanced with filled graphics, lines, weather symbols and text to provide fire incident commanders with products that are annotated with plain language information and graphics.

--Map Descriptor now contains static methods to translate between screen coordinates and lat/long even outside of a scale's valid data domain (outside the "letterbox").

Improved compression algorithms were added to the system. Wavelet Compression algorithm improvement included better memory management which improved display manipulation and product loading performance. It also improved satellite product fidelity.

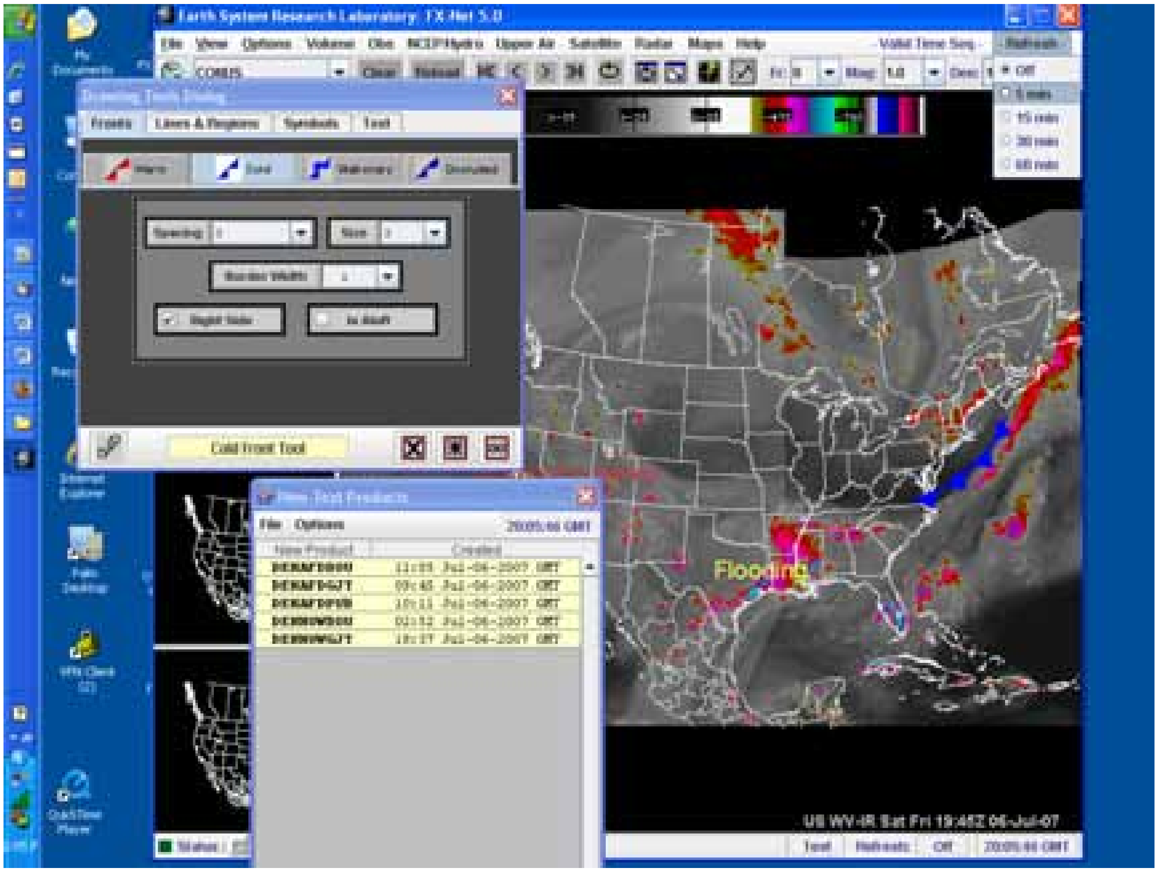


Fig. 1. FX-Net v. 5.0 Client display showing new drawing tools, text alert tool, and product refresh tools.

4. Leveraging/Payoff:

The FX-Net system is highly leveraged in terms of program funding and technology. The project is funded by the National Weather Service, the NOAA Air Quality program (AIRMAP), the US Forest Service and the Bureau of Land Management. It is a prime 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, an oil-spill recovery team, or a HazMat team in the aftermath of a massive natural disaster, such as hurricane Katrina or an oil spill. 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, Communication and Networking:

FX-Net at the National Interagency Fire Center (NIFC)

Via a technology transfer Memorandum of Agreement which began in 2002, the latest version of the FX-Net Client was installed at the Bureau of Land Management's (BLM's) Federal Test Center in Lakewood, Colorado. The system passed the rigorous network and security tests administered at the Test Center, and was certified for use by the 11 Geographical Area Coordination Centers (GACCs), the NIFC, the National Forest Service and the Ag Outlook Board. The FX-Net servers and clients are distributed and maintained by the FX-Net Project team.

In FY06-07, Predictive Services forecasters used FX-Net to view long-range forecasts to aid their fire potential forecasts and utilized real-time data to support NIFC fire suppression resource managers.

BLM users at the above locations provide long-range fire predictions, daily fire indexes, and drought outlook products for various BLM web sites and for operational use by fire weather forecasters. Specialized maps were added to the FX-Net system for these specialized users.

FX-Net and the EPA Air Quality Pilot Project

In FY04, NOAA and the EPA signed a Memorandum of Agreement to pursue a Pilot Project that provided a special air quality FX-Net system to select state and local air quality forecasters on the east coast. The success of that project led to a second Pilot Project Agreement in FY05 which allows state and local air quality forecasters across the U.S. access to the FX-Net Air Quality system.

In FY06, FX-Net clients were distributed to state and local air quality forecasters across the country. The specialized data sets included in the system provide air quality information for the areas of the CONUS experiencing the most serious of air quality issues. Using this system, forecasters are able to visualize forecast weather patterns that affect air quality in their area, and to overlay real-time EPA observations and analysis to verify their forecasting techniques. The forecasters report that the system saves them time when preparing their forecasts as they have all atmospheric and chemical data integrated into one system.

The EPA did not renew the Pilot Project funding for FY07. 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 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 has been used by the University of New Hampshire and Plymouth State University for the past 4 years. 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. 4.5) was delivered to the university community. The system continues to be used in the classroom.

Data sets added to the system included additional EPA AIRNOW products, the updated NOAA/EPA operational CMAQ ozone forecast model, and a new version of the experimental 27km WRF/Chem forecast model.

The new FX-Net v. 5.0 client will be distributed to AIRMAP air quality educators and researchers at the end of July.

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.

A brief FX-Net training session was held at Andrews AFB for Air Force One forecasters in May, 2007. 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

In FY06-07, the ENSCO commercial version of the MetWiseNet system was upgraded to include air quality data sets and menus. Client v. 4.5 was customized for ENSCO to include tools requested by their customer base. This has been a very successful technology transfer project. State and local air quality users who used FX-Net during the EPA Pilot Project are very happy to have a commercial alternative to use now that the Pilot Project has ended.

6. Awards and Honors:

In April 2007, two members of the FX-Net development team were awarded a Certificate of Recognition by the Director of the National Weather Service. The award was: ‘In recognition of your leadership to ensure operational excellence via innovative development and maintenance of critical software for our IMETS‘.

7. Outreach/Education:

--Graduate and undergraduate students: A NOAA EPP undergrad student, studying mathematics at Florida A&M University, is working with the project on compression technologies from May – July, 2007. He will be presenting his findings at NOAA headquarters the first week of August.

--Seminars, etc.**:** Presentations and demonstrations of FX-Net were given to visitors from China, Australia, the State of Colorado Water Board and Hydrology office, 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 San Antonio, January 2007.

--FX-Net training was held at the Annual Incident Meteorologist’s (IMETS) training meeting in March 2007 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, including the David Skaggs Research Center (DSRC) 2007 Earth Day open house and talks with various elementary and secondary school groups.

B. 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, Air Quality, Compression Algorithm

Gridded FX-Net for Fire Weather

Fire Weather Mission Goal: NOAA’s National Fire Weather Program seeks to eliminate weather-related wild land fire fatalities and injuries, and to reduce fire suppression and land management costs by providing more timely and accurate weather information.

NWS forecasters and collaborative forecasters at the National Interagency Fire Center (NIFC) and at the 11 Geographical Area Control Centers (GACCs) utilize the latest model and observation data to produce national outlooks identifying critical fire weather patterns. The NOAA mission is to provide tools to support the NWS and NIFC forecasters producing these long and short-range forecasts in support of fire-management decision makers.

Forecasters become dependent on the tools they can carry with them to the fire. Their ability to function effectively as a part of the fire fighting coordination team is dependent on these tools.

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

Gridded FX-Net is a highly-leveraged, technology transfer research project being developed in collaboration with the National Interagency Fire Center Predictive Services group and the FX-Net development team.

As a technology transfer program, the NIFC Gridded FX-Net system aims to improve the GACC forecaster's capabilities to provide long-term fire behavior and fire potential products. An essential part of producing these products are the numerical prediction models delivered via the NOAAPort to the AWIPS data servers. The research for this project centers on combining the enabling technologies from the FX-Net and AWIPS systems. The goal is to deliver gridded model output data, bit-mapped satellite and radar imagery, as well as all the observational data available via NOAAPort to multiple AWIPS D2D (Display-2D) clients.

The FY06-07 Gridded FX-Net project goals were to upgrade and build on the Phase II 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 and Current Status:

3. Comparison of Objectives Vs. Actual Accomplishments:

Research accomplishments:

Server software:

--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.
--Upgraded AWIPS software to v. OB6.

--Applied all required security and software patches to Linux OS.

Wavelet Compression:

--A new encoder and decoder pair have been developed that improves efficiency of both computation and memory usage. The following performance improvements were realized:

Memory usage before	590 Mb
Memory usage after	290 Mb
Time to compress before	7.4 seconds
Time to compress after	4.6 seconds

These improvements allow faster retrieval of 2D and 3D data sets when using the Gridded FX-Net D2D client.

--A new grid compression scheme has been developed to allow more flexible encoding and decoding of super large datasets. This improvement allows users to retrieve a single layer of a 3D data set (gridded model data) instead of retrieving the entire data set. As the data are compressed one layer at a time, data sets are distributed and displayed faster.

--A lossless compression scheme was added to compress a special group of datasets. This improvement allows data sets with very small values (down to 10^{-5}) to be more efficiently and precisely compressed.

Future Plans:

Plans for FY 2007-2008:

--Design and develop a new compression scheme to compress the dataset that has irregular boundaries, e.g., theta fields.

--Continue to investigate new lossless data compression schemes that will allow better compression of sensitive data sets, such as radar and distributed observations.

--Evaluate new technologies that improve the abilities to distribute large volumes of datasets to multiple remote users.

--Investigate Web Mapping and Web Cataloging services to allow distribution of the full suite of NOAA model and observational data available via NOAAPort, ESRL experimental models and observing systems, and experimental products developed for specialized users such as fire weather forecasters and public emergency managers.

4. Leveraging/Payoff:

The Gridded FX-Net system, by providing BLM, NIFC and GACC offices with gridded model output data, will allow timelier, more accurate delivery of fire behavior and fire danger products to the public.   Algorithms currently unavailable to the GACC offices, due to the lack of gridded data, will become available to forecasters to run with local data and the benefit of local expertise. As a result these localized products become more accurate and local emergency managers, fire weather analysts and the general Public can have access to more accurate products.

5. Research Linkages/Partnerships/Collaborations and 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. Honors/Awards:

7. Outreach:

Numerous demonstrations of this system have been given to public agencies and the private sector

8: Publications:

C. Science on a Sphere® (SOS) Development

Principal Researcher: Michael Biere
CIRA Team Members: Steve Albers and Nikki Prive

NOAA Project Goal: The Science on a Sphere® Development project addresses NOAA's cross-cutting priority of promoting environmental literacy.

Key Words: Dataset display and animation, spherical visualization

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

The NOAA Science on a Sphere® (SOS) project displays and animates global data sets in a spatially accurate and visually compelling way, on a 6-foot spherical screen. CIRA provides key technical support to the project, particularly research into effective user interfaces for the system, new visualization techniques, and new data sets.

2. Research Accomplishments/Highlights:

--A new display mode was developed, allowing direct display of sequences of images in equatorial cylindrical equidistant (ECE) map projection. This allows direct display of the data in real time without a dedicated rendering step that was formerly required.

--Display of MPEG-4 encoded files was added to the system, reducing storage requirements, and increasing animation rates.

--A picture-in-a-picture (PIP) capability was added to the system, allowing introductory slides or related still images to be overlaid on the underlying SOS imagery.

--SOS was installed at seven new permanent public venues—Great Lakes Maritime Heritage Center in Alpena, MI, Imiloa Astronomy Center in Hilo, HI, James Madison University in Harrisonburg, VA, McWane Science Center in Birmingham, AL, Fiske Planetarium in Boulder, CO, Orlando Science Center in Orlando, FL, and Museum of Science and Industry in Chicago, IL.

--New data visualizations were developed of meteorological and climate model data, along with enhancements to existing data sets.

3. Comparison of Objectives Vs. Actual Accomplishments:

--Objective: CIRA proposed to continue the development of new capabilities and data sets for the Science on a Sphere® (SOS) global visualization system. With 8 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 June 2007, there were a total of 15 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. Requests by our sites for new or archival data are sometimes simple and other times unrealistically difficult. Requests for new software features are similar and provide input and ideas for our internal software feature enhancement list. The first SOS User Group meeting was held in Baltimore in January 2007 and provided a wealth of ideas for future data and software enhancements.

A new display mode was developed, allowing direct display of sequences of images in equatorial cylindrical equidistant (ECE) map projection. This allows direct display of the data in real time without a dedicated rendering step that was formerly required. Data in ECE map projection can be stored on the network server node at an SOS site, which simplifies system administration. The pre-rendered data which was used previously requires copying the data to each individual projector host. While this was being done, it could interfere with the smooth operation of SOS. As a result, we are transitioning all of our real-time data sets to use the new ECE projection.

Display of MPEG-4 encoded files was added to the system, reducing storage requirements and increasing animation rates. This also simplifies system administration because an entire SOS visualization can now be one file instead of a directory of many individual frame images. We continue to optimize the MPEG-4 processing stream to maximize image resolution and frame rate.

A picture-in-a-picture (PIP) capability was added to the system allowing introductory slides or related still images to be overlaid on the underlying SOS imagery. We expect to provide this functionality to existing SOS sites in our next software release upgrade.

--Objective**:** CIRA staff will continue to develop and enhance near real-time global data sets 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**:** Efforts are being coordinated with ITS to obtain global IR and other data from NESDIS in real-time from all available geosynchronous satellites. The mosaicing is planned to be done here at GSD for SOS displays. Meteosat IR imagery is now available from ITS as full disk NetCDF files with a 15-minute cycle. Water vapor mosaics from AWC are now being animated in real-time on the SOS with an added map overlay.

Initial displays of Global LAPS (GLAPS) fields have been developed and are now being fed to SOS in real-time. This includes an hourly animation of 500mb heights, wind barbs, and wind speed. We also have green fraction climatology. Graphics plots of GLAPS (Global LAPS) output were improved in various ways including higher resolution and an expanded temperature image color bar (down to -60F). Wind barbs are now reversed to fit the convention used in the southern hemisphere and are overlayed more consistently on top of images using a black color. Continents are now plotted using thicker lines to help them stand out better. Wind barbs can now be plotted specifically for projection on a sphere that helps with showing GLAPS output on SOS, particularly in polar regions. Global LAPS images were resized and color tables were improved for optimal SOS (and WWW) display characteristics.

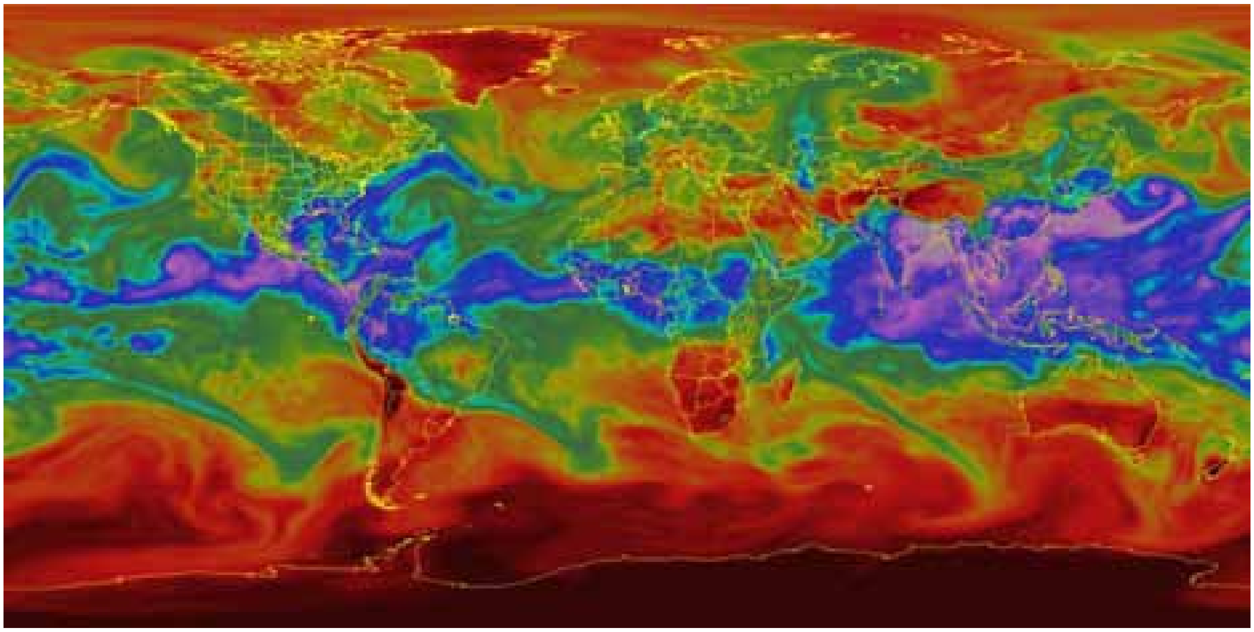


Fig. 1. Realtime GLAPS model data is now being distributed to SOS client sites. Shown here is a GLAPS precipitable water image. Data in this ECE projection is now directly displayable on SOS, without the per-projector rendering step that had been required.

New maps of Mars' moons Phobos and Deimos are now available on SOS. The map of Saturn's satellite Enceladus was improved with some high resolution imagery in the southern latitudes. We also updated the global maps of Saturn's satellites Dione, Rhea, Iapetus, and Titan based on recent Cassini spacecraft imagery.

Many of the solar system dataset visualizations that we developed are featured in NASA's 16-minute "Footprints" animation. This is helping to give SOS wide publicity including Time Magazine (November 13, 2006 issue).

We also developed a set of climate model visualizations this year from the latest Intergovernmental Panel on Climate Change (IPCC) climate models. Data from three of the IPCC models following temperature change from 1870 - 2199 were formatted for SOS. The models available on SOS are the Climate Model 2.1, developed by the Geophysical Fluid Dynamics Laboratory, the Community Climate System Model 3.0 developed by the National Center for Atmospheric Research, and the Hadley Centre HadCM3 developed by the United Kingdom Meteorology Office. A sea ice climate visualization was also developed from the GFDL model.

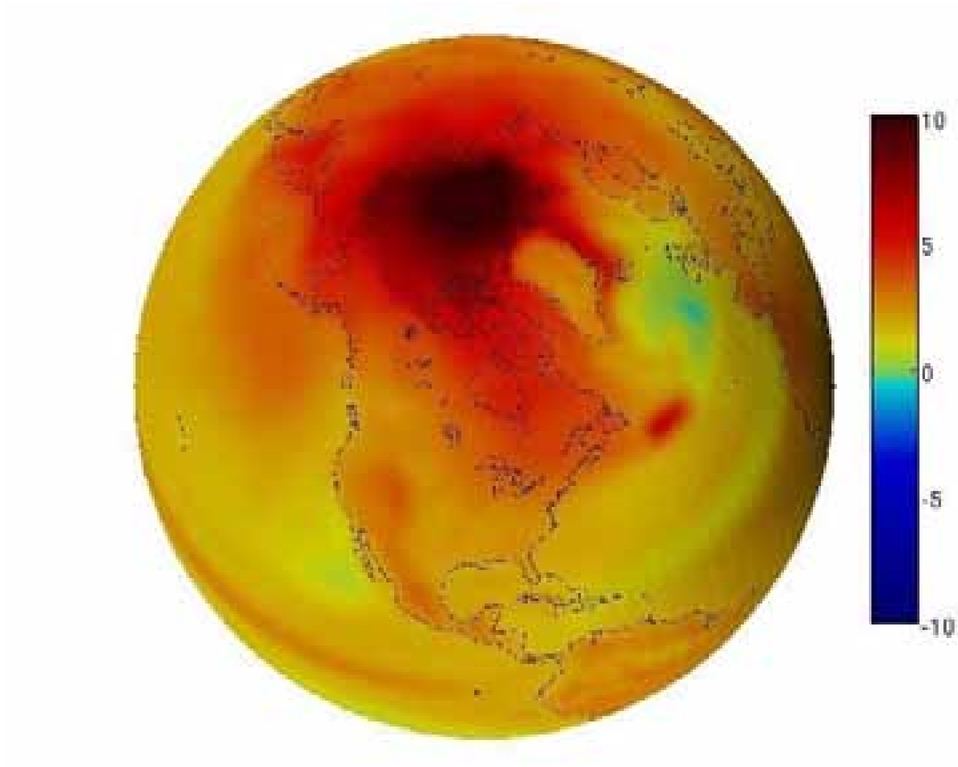


Fig. 2. Recent IPCC climate model data is available on SOS. Shown here is the global surface temperature anomaly in 2100, as predicted by NOAA's GFDL climate model. Climate model data from NCAR and UKMET is also available for display on SOS.

--Objective: The second-generation SOS software will be beta tested at the Bishop Museum installation which requires its capabilities due to a non-standard projector layout. This software features a software edge-warping technique developed in part by CIRA personnel, allowing for much easier and more precise alignment of projectors. It is expected that most sites will upgrade to this new version. Support of the sites with the upgrade process will be an additional task. This software upgrade will also allow other SOS projector configurations, should future installations require innovative geometries.

Status: The second-generation SOS software was successfully tested at the Bishop Museum and then installed at all SOS sites. In addition to the enhanced alignment capabilities, we released the ECE image sequence capability and use of the MPEG-4 file format.

--Objective: Two additional new SOS sites are expected to be awarded by the NOAA Environmental Literacy Grant program in FY 2006, and CIRA researchers will be providing support for SOS installation, training, and operation there and at any additional new sites that may arise.

Status: SOS was installed at seven new permanent public venues this year, including the NOAA Environmental Literacy Grant sites and others—Great Lakes Maritime Heritage Center in Alpena, MI, Imiloa Astronomy Center in Hilo, HI, James Madison University in Harrisonburg, VA, McWane Science Center in Birmingham, AL, Fiske Planetarium in Boulder, CO, Orlando Science Center in Orlando, FL, and Museum of Science and Industry in Chicago, IL.

--Objective: We plan on supporting the SOS museum sites with an on-line Web Forum, and CIRA personnel will likely be maintaining and administering the board content and software.

Status: We established an on-line Web discussion group for the SOS user sites and others interested in SOS operational issues. Administration of the group has been a relatively easy task since to date the level of activity on the group has been low.

--Objective: Possible software upgrades to SOS this year include enhancements to the control protocol, use of MPEG compression to reduce storage and IO bandwidth for streaming SOS presentations, a web-based control interface, and the addition of interactive annotations and graphics.

Status: We did the first software upgrade of our SOS systems in the field this year. The upgrade included the flexible software alignment developed last year and the ECE image sequence and MPEG-4 file format capabilities developed this year.

VII. <u>Research Collaborations with the GSD Information Systems Branch</u>

Project Title: AWIPS Evolution: Web Services Development

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 needed for 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 NWS management are both interested in a more global approach to research and forecasting. CIRA research 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:

--Development of a distributed database prototype for remote storage and retrieval of model data
--Research into OGC standards for data access on the web
--Development of prototype software using OGC standards for accessing data from the web
--Development of prototype software using OGC standards for the access, display and manipulation of Alaska sensor data

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

--Objective: Advanced Linux Prototype System (ALPS): developing a new data distribution paradigm, and accessing data located on different data servers across the country.

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) that has been installed at the NWS Weather Forecast Offices. Last year, ALPS systems were used in a very important field demonstration (HMT West 2007) held by NOAA's Hydrometeorological Testbed (HMT) project. The HMT project is experimenting with ways to move new technology, models and scientific findings from the research environment to operations. The emphasis of HMT West 2007 was on multi-sensor estimations of precipitation, and on ensemble forecasting of precipitation elements in the American River Basin in California. The ensemble forecasting was accomplished using multiple versions of the WRF model, centered on the test area, each one using a different microphysics package. GSD modelers ran the models each day and stored the data on a GSD test system in Boulder, Colorado. CIRA software engineers developed a distributed database capability on ALPS that enabled remote access to the WRF data. ALPS systems with this capability were installed at each test site enabling the forecasters in California to view the remote WRF data along with model data stored locally. The NWS is interested in remote data access techniques to reduce the load on the AWIPS data delivery networks and servers, while still providing its forecasters with the large volumes of data needed to produce accurate and timely forecasts.

CIRA staff also conducted an evaluating of the distributed database capability during the 3-month long demonstration. The evaluation information will be used by the NWS to make decisions regarding future AWIPS development. Ensemble forecasting and distributed data capabilities are not available on the current AWIPS systems, but are desired features.

--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 have begun to investigate Service Oriented Architecture (SOA) concepts. At present, the focus is on experimenting with the standards for web access to geospatial data that the Open Geospatial Consortium (OGC) is developing. Many organizations within NOAA are already using OGC standards for web access to their data. CIRA software engineers are involved in several related efforts in this area:

--One-NOAA prototype. CIRA participated in the development of prototype software that displays a variety of data from NOAA organizations on Google Earth. Weather, oceans, fisheries, satellite and coastal services data were included. This project was ISB's first investigation of web data access, and its success led to the other two efforts described here.

--OGC Web Services Testbed. The goal of this project is for CIRA and GSD staff to develop expertise in OGC concepts by developing OGC-compliant web services for GSD data, and data from other sources. CIRA software engineers and other project team members are developing prototype software that accesses the data and displays it on Science on a Sphere® and on Google Earth. This past year, CIRA conducted research into OGC standards and participated in the design of the prototype. Next year, the software will be developed.

--EIS/ISET. CIRA is collaborating with ISB on the research of a new concept in the area of system development. The idea is to build a framework that allows users to plug in their own applications and tools to access, display, and manipulate data and to produce predictions and probabilistic forecasts. This concept is known as the Earth Information System (EIS). To further the development of the concept, the EIS team has established a cooperative agreement with the University of Alaska Southeast (UAS) as part of the NOAA/ISET program. ISET is a cooperative research program involving ESRL and eight universities, with the goal of introducing university students to NOAA research interests and methods. UAS is in the process of installing a sensor web in the Lemon Creek watershed to collect meteorological and hydrological data. The EIS/ISET project goals are to develop OGC compliant web services for the UAS data, and to develop a prototype EIS framework using the UAS sensor data. This project is also part of the OGC Web Services Testbed described above. The EIS/ISET prototype will demonstrate additional OGC services. Last year, CIRA software engineers contributed to the project plan and to the prototype design. During the next year, the prototype will be developed, and students from UAS will become involved in developing OGC-compliant web services for their sensor data.

4. Leveraging/Payoff:

CIRA's research in the areas of Service Oriented Architecture, distributed databases and OGC standards has benefits in many areas. If web technologies can be integrated with the AWIPS systems at the WFOs, 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 OGC expertise within CIRA and ISB. This knowledge will be used in determining the role of web services in future AWIPS development (including AWIPS II), and will support a more global approach to research and forecasting, which has been stated in both NOAA and NWS goals.

Distributed database technology will enable both WFOs and NOAA research organizations to access the large variety and quantity 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, the Forecast Applications Branch of GSD and the Physical Sciences Division of ESRL to achieve the goals of HMT West 2007. CIRA, ISB, the Forecast Applications Branch, ESRL's Information and Technology Services group, the Aviation Branch of GSD, and the University of Alaska Southeast are cooperating on the OGC investigation and prototyping.

6. Awards/Honors:

7. Outreach:

8. Publications:

Roberts, W.F., N.D. Gebauer, and L.K. Cheatwood, 2007: A OneNOAA concept prototype for data viewing. *23rd International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, 15-18 January 2007, San Antonio, TX, Amer. Meteor. Soc., 9A.4.

Project Title: <u>AWIPS and AWIPS II</u>

Principal Researcher: Joanne Edwards
CIRA Team Member: 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: KAP, Technology Transfer, 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 and 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 impressive 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 priceless 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:

--Successful transfer of most of the current AWIPS applications to Raytheon
--Evaluation of the first three stages of AWIPS II
--Start of evaluation of the current AWIPS for baseline metrics for the new AWIPS
--Research into new SOA capabilities

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

--Objective: Technology Transfer. To transfer knowledge of the AWIPS software to the NWS contractor, Raytheon, so that Raytheon can take over the maintenance of AWIPS software.

Status: This objective has been achieved.

Accomplishments:

CIRA researchers were responsible for the successful completion of the transfer of the following areas of AWIPS:

--WFO-Advanced, which includes the ingest, D2D display, data management and storage.
--AWIPS Common, which includes software libraries common to other applications.
--Communications, which includes inter-process communications, routing, data controllers, data sockets and notification services.
--Radar, which comprises the special radar applications.
--WarnGen, which generates work products used by the text workstation to issue warnings.

The transfer took place as part of a process called the KAP, Knowledge Acquisition Process. The objectives were for the Raytheon team to achieve an understanding of how different applications work together to support AWIPS. They were to learn enough to efficiently support AWIPS, not to become experts. The CIRA researchers would act as advisers should the need arise.

CIRA researchers worked one-on-one with the Raytheon team, providing demonstrations of their applications, overviews, and other training materials that would help the team gain an understanding of the software application. The trainees also provided feedback on how well they had learned the application. The Raytheon team has become the first line of defense in handling problems from the field once a trouble ticket has been generated for the problem. If there are any issues, it will be the responsibility of the Raytheon team member to contact the CIRA researcher.

--Objective: Evaluate the new AWIPS system, which is also called AWIPS II. The objective is to provide an independent (apart from the contractor) 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: This objective is in progress.

Accomplishments:

The proposed next version of AWIPS 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 been leaders in the evaluation of the ADE/SDK beginning with TO4, the first TO to be evaluated. TO4 corresponds to ADE/SDK 0.0. CIRA researchers began evaluating the ADE/SDK by first carefully executing the test cases provided by Raytheon, and then implementing our own test cases. In each case, 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 are in the process of developing test plans for this portion of the project.

4. Leveraging/Payoff:

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.

5. Research Linkages/Partnerships/Collaborators:

CIRA, ISB and Raytheon collaborated on the transfer of AWIPS capabilities to Raytheon. 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: Two-Dimensional Display (D2D) Development and AWIPS 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 warnings

Key Words: AWIPS, D2D, 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 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 has become the central visualization component of the NWS AWIPS system. CIRA, collaborating with ISB, proposed to continue to augment this software base with novel data sources and visualization approaches. In some cases, these new capabilities have been driven by new requirements arising from the adaptation of AWIPS by organizations other than the NWS. For example, CIRA researchers have helped customize AWIPS for the RSA project to meet weather forecast requirements at the Vandenberg AFB and Cape Canaveral space launch facilities.

2. Research Accomplishments / Highlights:

The AWIPS Linux Prototype System (ALPS) development effort began during FY04/05 exploring how the AWIPS system can be redesigned to support the longer term needs of the NWS and possibly other NOAA agencies. Many of the ALPS concepts are now expected to be implemented in the new AWIPS II system that is being developed by a private contractor for the National Weather Service. To date, the ALPS system has been used primarily for evaluating new operational concepts, including remote access to forecast models for the HMT (Hydrometeorological Testbed). Using the plugin interface, the ALPS system also provided the ideal tool for demonstrating an advanced drawing capability (see Fig. 1). The implementation of this capability illustrated the power and flexibility of the new API by integrating large portions of Java code written specifically for FXC. The capability was demonstrated at the Annual Meeting of the American Meteorological Society in January 2007. The work was performed with the help of other GSD staff.

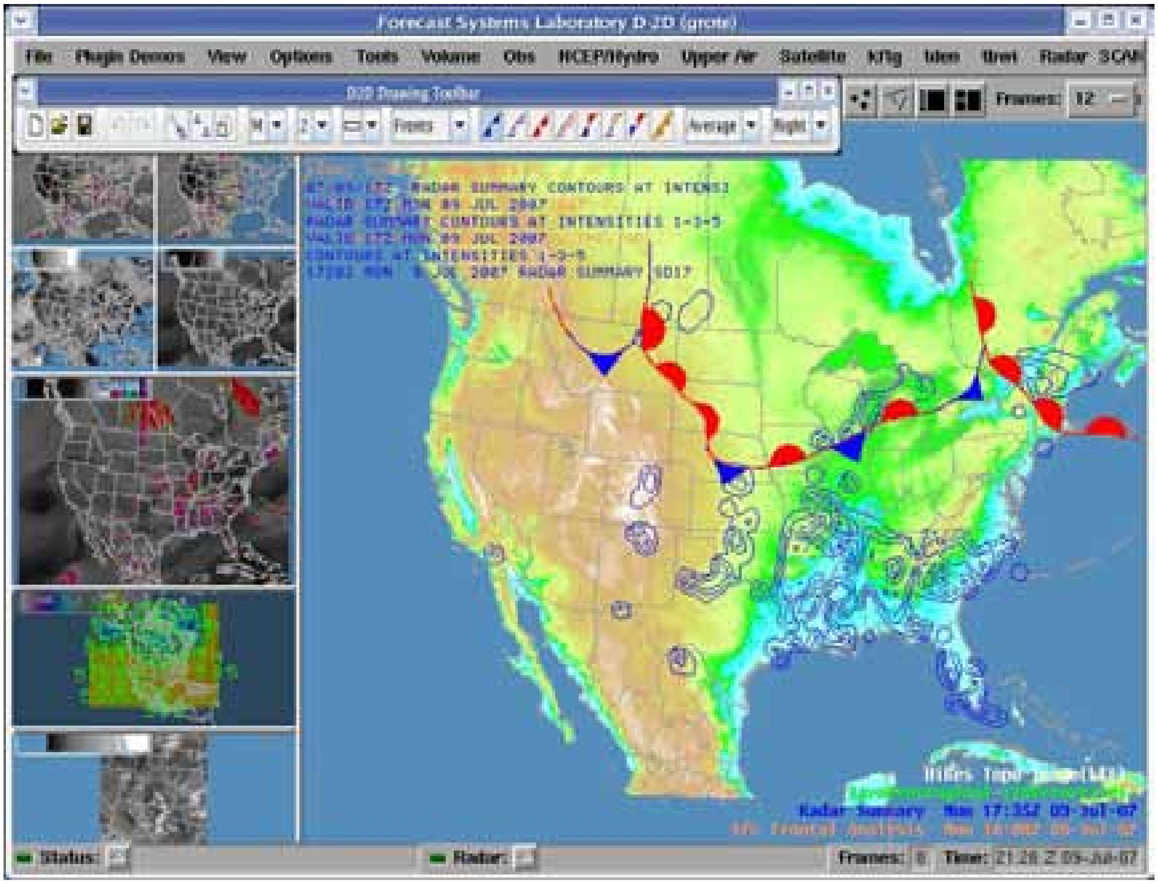


Fig 1. An example of a Java drawing plugin that illustrates the new API.

The current AWIPS system received an enhanced WarnGen program. For some time, the National Weather Service has been interested in describing a warning area by a polygon that encompasses the hazardous weather area instead of only the traditional description by counties (CWA). The AWIPS WarnGen program was modified to include the polygon, storm centroid, and the direction of motion. The Warning-by-Polygon was designed such that no changes were required to the existing text templates to invoke its features.

Another enhancement was the addition of an application to compute EAV (Estimated Actual Velocity). For many forecast applications it is desirable to know the actual velocity of a radar cell and not only its radial component. To assist with the determination of the actual velocity, an application was written that will compute the actual velocity based on the radial velocity and an overall wind heading provided by the forecaster. If the radial velocity differs significantly in direction from that provided by the forecaster, then no value will be computed.

CIRA continues to provide AWIPS software enhancement support, as well as software configuration management (CM) support for local developers working on AWIPS. The CM support includes: keeping the local GSD AWIPS baselines synchronized with the official baseline maintained by Raytheon; converting to the new CM processes put in place by Raytheon; creating new local baselines when needed for AWIPS, RSA and ALPS; and keeping the RSA and ALPS baselines up to date by merging any needed AWIPS changes into them.

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

One of the original goals of ALPS has been met with the integration of a drawing capability. Support of AWIPS D2D continues with developments of new features, as described above, for each new AWIPS build.

4. Leveraging/Payoff:

Many of the projects with other agencies, private companies, and foreign governments are leveraging the AWIPS development. The migration of AWIPS to a linux platform has made it feasible for many users to purchase the required hardware and customize the AWIPS system to meet their specific needs. The RSA, FX-Net, FXC, ALPS, and WINS (CWB) are some of the systems derived from AWIPS.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:
6. Awards/Honors:
7. Outreach:
8. Publications:

Project Title: <u>Real-time Collaborative 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

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 to prepare a consistent forecast, such as a prediction of a severe weather event or dispersion of a toxic chemical, all participants must have a common situational awareness. All participants must have access to the identical data sets and be able to display the data in the same manner. This facilitates the exchange of ideas and allows forecasters and users to get a similar understanding of the weather event. The display system must be able to display a diverse set of real-time meteorological data, allow users to graphically annotate the display, provide a text chat capability, and post and retrieve information from web servers. The system also needs to be able to run dispersion models to help predict movement of volcanic ash, smoke, or toxic chemicals, and must have an alert capability using “reverse 911” vendors.

FXC is currently being implemented and or evaluated for several outside projects and organizations. The most significant are the following:

Geo-targeted Alerting System (GTAS)

1. Background and Research Objectives:

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 FX-Collaborate (FXC) and the HYSPLIT dispersion model developed by ARL. The execution of the HYSPLIT model, collaboration between the offices, and creation of the alert message that is sent to selected vendors for notifying the public is performed by FXC.

2. Research Accomplishments/Highlights:

This year’s effort focused on improving the output from the HYSPLIT model and enhancing the system functions. In collaboration with other GSD staff, the input weather model for HYSPLIT was shifted to NAM12 since it provided better temporal and spatial resolution. Also, the HYSPLIT control parameters were adjusted to provide a better representation of the plume. The network staff at FEMA and at GSD were able to establish a secure communications link between the server at Boulder and the FEMA office in D.C. This made it possible for FEMA staff to request plume information in real-time. Prior to this, animated GIF images were generated at GSD at regular intervals and sent to FEMA. The Urbanet surface observations for the D.C. area were added to the data base. Also, the primary and backup servers at GSD were updated with new software to improve reliability and to add new features.

A picture of a simulated toxic release prepared with FXC is shown in Fig. 2. The shaded areas indicate the areas for which a test notification message (XML) would be generated in an actual situation.

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

All parts of the systems are working as expected. The next step is to install FXC clients in additional FEMA offices in the D.C. area and to test the alert notification with several vendors.

4. Leveraging/Payoff:

GTAS development leverages the development done by ARL on dispersion models, and by GSD on FXC and AWIPS. The system promises to be a valuable tool for alerting the public sector to potentially hazardous material that is easily dispersed by the weather.

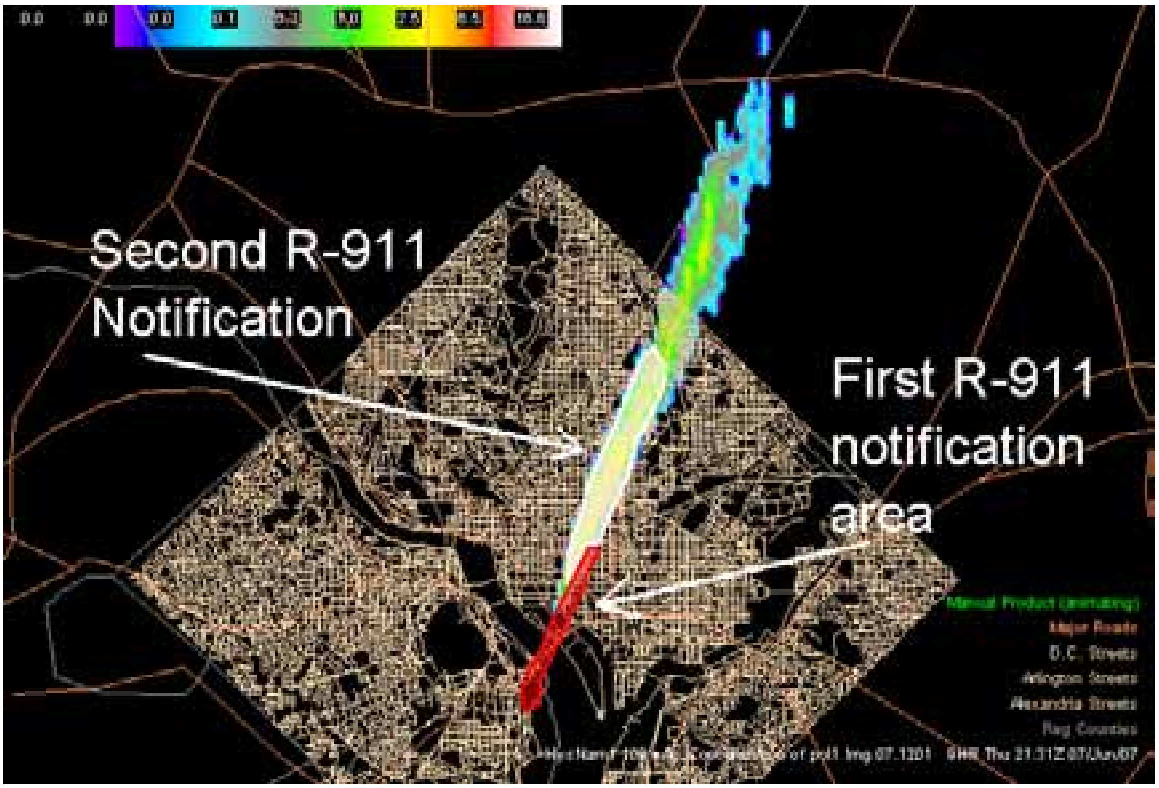


Fig 2. Plume of a simulated toxic release as displayed on FXC.

5. Research Linkages:

The GTAS work is done in collaboration with NOAA/ARL. The developers of the HYSPLIT model are working with CIRA and GSD staff to assure that the model will work appropriately in the GTAS environment.

6. Awards/Honors:

7. Outreach:

FXC has a web site (http://fxc.noaa.gov) available to the public that describes FXC and some of its applications. The site includes a collection of graphical images generated by forecasters, documentation, and links to sites using FXC.

8. Publications:

Graphical Forecast Product Generation

1. Background and Research Objectives**:**

Government agencies at various levels need to be able to communicate hazardous weather information to the public in many different forms. 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.srh.noaa.gov/oun/enhanced.php). These graphical products are posted to the web for public use, included in presentations, and used in briefings to various end users. 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:

Forecasters at the CWB (Central Weather Bureau) in Taiwan are using touch screens for annotating weather data displays. Since touch pens do not support three distinguishable events (similar to the three-button mouse), some changes were required to support the touch screen. The CWB and other users require the display of GIS data with the weather data. To meet these needs, enhanced support to read shapefile data was added to FXC.

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

The objectives for this report period were met. In addition to the work performed for CWB, technical support was also provided to FAA activities at GSD, such as VACT and remote CWSU briefings.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

EPIC ITCZ RADAR DATA

Principal Investigator : Robert Cifelli

NOAA Project Goal: Climate (climate observations and analysis; climate forcing)

Key Words : Rainfall, Radar, EPIC ITCZ, TRMM

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

The goal for this work was to provide validation data sets for numerical models that attempt to simulate the climate statistics in the EPIC region. The specific work objectives included:

--Objective 1: Processing all volumetric radar data collected during EPIC-2001 while the R.V. Ronald H. Brown (RHB) was stationed at 10°N, 95°W into files containing time-varying vertical profiles of the radar reflectivity distribution (PDFs) over the region area scanned by the C-band radar (this is the highest priority objective); and

--Objective 2: Time permitting, attempt to reconcile differences between the time-mean rainfall rate inferred from the radar with those derived from other in-situ (profiler, raingauge, disdrometer, ocean freshwater budget) and satellite (TRMM PR and passive microwave) data.

In order to address (1), radar reflectivity data were interpolated to a Cartesian grid (a 200km x 200 km box centered on the nominal location of the RHB during EPIC with 2km x 2km spacing in the horizontal and vertical). Histograms were constructed for all the radar volumes (~2,900). These data were provided to C. Bretherton at University of Washington during the fall of 2006.

With regard to (2), an algorithm was developed to correlate rain intensity data from the NOAA TAO buoy with the RHB radar reflectivity data for all rainfall events observed during EPIC. The correlation was done over time periods ranging from 10 minutes (one radar volume) to one hour. The coincident TAO buoy and radar data was then used to determine an optimal Z-R relationship for EPIC.

2. Research Accomplishments/Highlights:

The results for Part 2 of the work are shown below in Fig. 1. As Fig. 1 indicates, the EPIC-TAO Z-R relationship is noisy. This is most likely a consequence of the large resolution of the radar footprint (2 km) over the TAO rain gauge. Nevertheless, Fig. 1 also shows that the derived Z-R produces significantly more rain for a given radar reflectivity value compared to the default EPIC Z-R that was derived using aircraft C-130 data. These results are consistent with oceanic freshwater budget analyses that suggested more rainfall accumulation than predicted from the default Z-R.

These results will be used to produce revised radar-rainfall accumulation estimates for EPIC and will be delivered to C. Bretherton during the fall 2007.

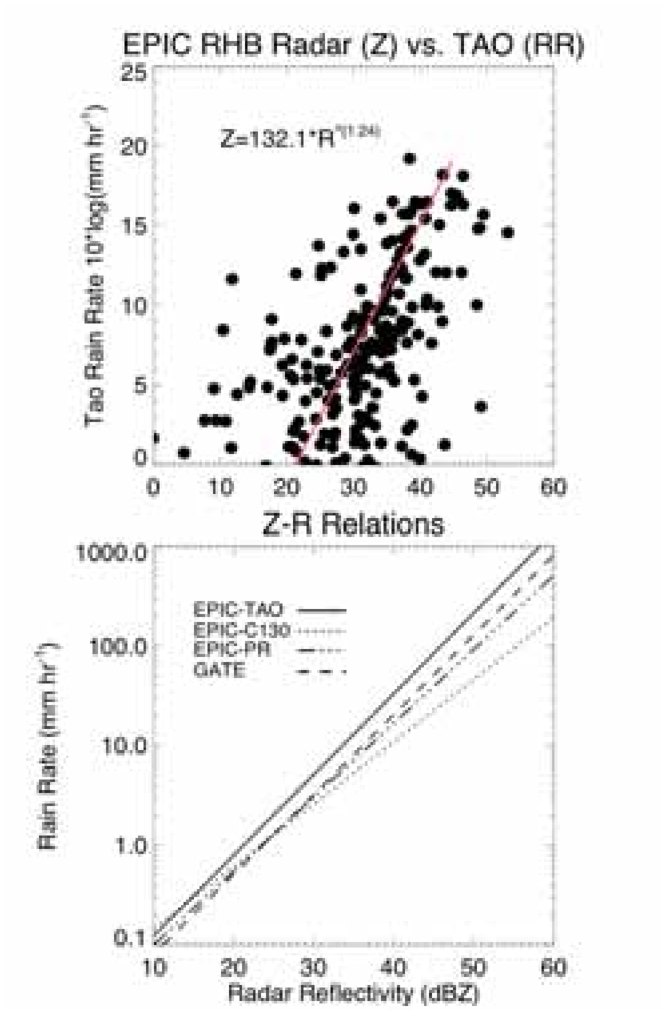


Figure 1. (top) Comparison of 10-minute RHB radar reflectivity over the location of the TAO buoy and TAO rain rate with the best fit shown in red. The resulting best fit Z-R equation is indicated. (bottom) Comparison of selected Z-R relationships as indicated in the legend. EPIC-TAO (result of this analysis); EPIC-C130 (default EPIC Z-R); EPIC-PR (EPIC Z-R based on monthly TRMM precipitation data over the EPIC region); and GATE (GATE Z-R as determined by Hudlow et al. 1979).

3. Comparison of Objectives Vs. Actual Accomplishments:

Objective (1) was successfully accomplished. Objective (2) was nearly completed. However, as anticipated, time constraints limited the level of detail that could be devoted to the rainfall analysis.

4. Leveraging/Payoff:

The payoff is expected to be high, given the relatively small amount of support and the fact that the results of this work can be used as validation for seasonal forecast models.

5. Research Linkages/Partnerships/Collaborators:

C. Bretherton (University of Washington) and Steve Nesbitt (University of Illinois). This work leveraged results that were obtained from an EPIC NSF-supported grant. The data were collected from a NOAA platform – RHB.

6. Awards/Honors: None

7. Outreach: None

8. Publications:

Cifelli, R., S. Nesbitt, W. Petersen, S.A. Rutledge, and S. Yuter. 2007: Radar Characteristics of Precipitation Features in the EPIC and TEPPS Regions of the East Pacific, Monthly Weather Review, 135(4), 1576-1595.

References (*not pubs*): Hudlow, M. D., 1979: Mean rainfall patterns for the three phases of GATE. J. Appl. Meteor., 18, 1656–1669.

EVALUATION OF GOES-13 IMAGER AND SOUNDER DURING NOAA'S SCIENCE TEST: COLLECTION AND ANALYSIS OF DATA

Principal Investigators: Dr. Bernie Connell, in partnership with Dr. Donald Hillger and Dr. 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:

Over the past several years the Cooperative Institute for Research in the Atmosphere (CIRA) has performed basic and applied research to better utilize data from NOAA Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES). The NOAA/NESDIS GOES Improved Measurements Product Assurance Plan, GIMPAP, has supported CIRA research on the use of GOES data for mesoscale analysis of high-impact weather events, including severe weather and tropical cyclones. Past POES research has focused on the utilization of the Advanced Microwave Sounder Unit (AMSU) for tropical cyclone intensity and structure analysis. Beginning in 2002, the NESDIS GIMPAP program has been supplemented with the Product System Development and Implementation (PSDI) program to provide research support for applications of satellite data that have a direct relationship with weather and climate forecasting.

In this CIRA proposal for funding from the PSDI program, research methods are applied to the analysis of the quality of GOES-13 Imager and Sounder data as secured during the NOAA Science Test. Similar to previous GOES checkouts, during this pre-operational period, the instruments were run in both special and operational schedules to provide radiance measurements to be validated, as well as to generate products from the radiances. The Science Test lasted three weeks, following other Post Launch Tests (PLT) during which most of the engineering and control of GOES-13 were being tested and evaluated. GOES-13 Science Test data have all been collected, with the transition of GOES-13 into storage on 5 January 2007. This leaves the analysis of the data and resulting Imager and Sounder products as the main focus of this work.

2. Research Accomplishments/Highlights:

GOES-13 data are unique. Although the last three of the current Geostationary Operational Environmental Satellites (GOES) to be launched, GOES-13/O/P, have instruments similar to the 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-13/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. Initial 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 yet been realized. Finally, there have been improvements in both the navigation and registration of GOES-13 imagery. Frame-to-frame registration appears to be improved from initial looks at the imagery. All these enhancements were monitored during the NOAA post-launch Science Test by the use of special data collection schedules.

As with previous GOES check-outs, there were several main goals for the GOES-13 Science Test. First, the quality of the raw GOES-13 data are to be investigated. This will be 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-13 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 Science Test and results of analyses collected to date have been gathered on the GOES-13 Science Test page at http://rammb.cira.colostate.edu/projects/goes_n/.

The analyses will continue on the different types of data collected during the GOES-13 Science Test. Results will then be gathered not only on the web page noted above, but will be collected into a NOAA Technical Report, a draft of which is to be finished within 6 months of the end of the Science Test. That Technical Report will be distributed within NOAA and made available as a reference for future users of GOES-13. This information will be especially useful when questions arise as to the quality of the data and products that will become operational at that time.

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:

8. Publications:

Refereed Journal Articles

Expected *NOAA Technical Report* by the end of FY07, and possible *Bulletin of the American Meteorological Society* article soon thereafter.

Conference Proceedings

Daniels, J., R. Scofield, G. Ellrod, R. Kuligowski, D.W. Hillger, T.J. Schmit, W. Bresky, J.C. Davenport, and A.J. Schreiner, 2006: Validation of GOES-N Imager data and products during the GOES-N Science Test, *14th Conf. Sat. Meteor. Ocean.,* AMS, 29 January – 3 February, Atlanta GA, 5-p.

Hillger, D.W., T.J. Schmit, D. Lindsey, J. Knaff, and J. Daniels, 2006: An overview of the GOES-N Science Test, *14th Conf. Sat. Meteor. Ocean.,* AMS, 29 January – 3 February, Atlanta GA, 6-p.

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.

Schmit, T.J., G.S. Wade, M.M. Gunshor, J.P. Nelson III, A.J. Schreiner, J. Li, J. Daniels, and D.W. Hillger, 2006: The GOES-N Sounder Data and Products, *14th Conf. Sat. Meteor. Ocean.,* AMS, 29 January – 3 February, Atlanta GA, 6-p.

Other articles

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, AWIPS, GIS

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

There were two primary research projects during the past year—*improvements to the emulation of NCAR's AutoNowcaster Convective Weather Forecasting tool on AWIPS* and improving access to the data embedded in the GIS shapefile data base for MDL's Flash Flood Monitoring Program (FFMP).

The AutoNowcast Prototype Project

The general project objectives are to deliver the NCAR 0- to 1-hour AN forecast products and user interactions to AWIPS' short-term forecaster workstations. This effort provides the NWS forecasters with AN forecast products, while using familiar AWIPS techniques to display and interact with these data.

The project goals are to migrate most of the active 'roles' conducted within the NCAR AutoNowcaster to AWIPS or to an NWS AN server.

NCAR has installed an NCAR AN display system (CIDD) at the Fort Worth-Dallas WFO. This allows forecasters to review the several types of AN products (real-time and forecast) that are available within the system. The benefit to the NWS is an improved situational awareness, thus improving NWS forecasts.

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), and
Data Dissemination.

Previous accomplishments included real-time decoding of NCAR-provided data, their netcdf storage, and generating workstation data notifications as data becomes available to AWIPS (the Data Management sub-task). The display of decoded and stored data would be provided on the AWIPS workstation (Data Display). Only a very limited

Forecaster Interaction had been provided, and limited Data Dissemination was provided.

This year's accomplishments have improved each of these areas greatly.

Data Management:
Several improvements have been added to the data management sub-task. Early in the year, lists of active boundaries and polygons were provided by NCAR and added to the sets of data routinely received from NCAR. Also, forecaster-selected weather regimes are menu-selected to improve NCAR AN modeling.

More recently, the role of ‘data manager' has been reversed. AWIPS is now the active data manager keeping an account of active boundaries and polygons. AWIPS now provides NCAR with 'active' boundary and polygon lists, completely reversing 'data manager' roles.

Data Interactions:
The Boundary Editor is expanded, allowing the AWIPS forecaster to specify a motion vector to a previously defined convective boundary. No longer is the forecaster limited to relying on a statically placed convective boundary. This addition also provides the ability to adjust the boundary motion vector location (dragging the boundary to its preferred location) or to speed-up or slowdown a tracked boundary by a percentage of its velocity vector.

Early in the year, a Polygon Editor was added to the suite of AWIPS forecaster interactions. This provides the forecaster with the ability to enhance or de-emphasize areas (polygons) the forecaster feels are incorrectly represented by the NCAR AN model.

Data Display:
As forecasters generate polygonal areas of emphasis (or de-emphasis), local data products must be provided to provide a 'preview' of the proposed data modifications. These are now being produced locally and are made available for display before these data are sent back to NCAR for inclusion in the next model run or iteration. This saves time, reducing the wait for NCAR to process the data and return the updated display products.

Data Dissemination:
The data generated by the forecaster editors must be returned to NCAR for inclusion in the next model run. A “secure” LDAD method to *export* these data through the AWIPS firewall was previously provided; allowing NCAR to retrieve these files for additional AN processing.

During this past year, the NWS has changed its 'security protocols' more than once, each time making its network much more secure. This also has the side effect of making the necessary NWS<-->NCAR data exchanges much more challenging. Additional routers and firewalls were added even later, further fortifying the AWIPS network.

The new NWS security protocols required that new data communications protocols be rewritten to satisfy the new security measures and more recent adjustments included to 'securely' navigate the additional security appliances.

During the security protocol rewrite, it was agreed that forecaster-generated data returned to NCAR would be enhanced and made far more flexible if it were returned in XML (Extensible Markup Language) format. All data returned to NCAR are now XML encoded.

Operational Testing:
Prior to release, extensive testing was conducted by MDL development staff and interested volunteers. Many minor adjustments were made based on these findings.

Operationally ready software distributions were delivered to FWD WFO for installation and testing in November 2006 and May 2007. We await evaluation and results of NWS operational tests.

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

All planned objectives for this past year were met. The next stage of development focuses less on the forecaster operational needs and more on the migration of NCAR AN modeling to the NWS and the expansion of the forecast domain to a regional scale. This involves integrating weather surveillance radar data from radar sites over a large region, national gridded models, satellite data, as well as various surface observations.

This work will address the issues involved in scaling a local scale, short-term model to a regional scale model.

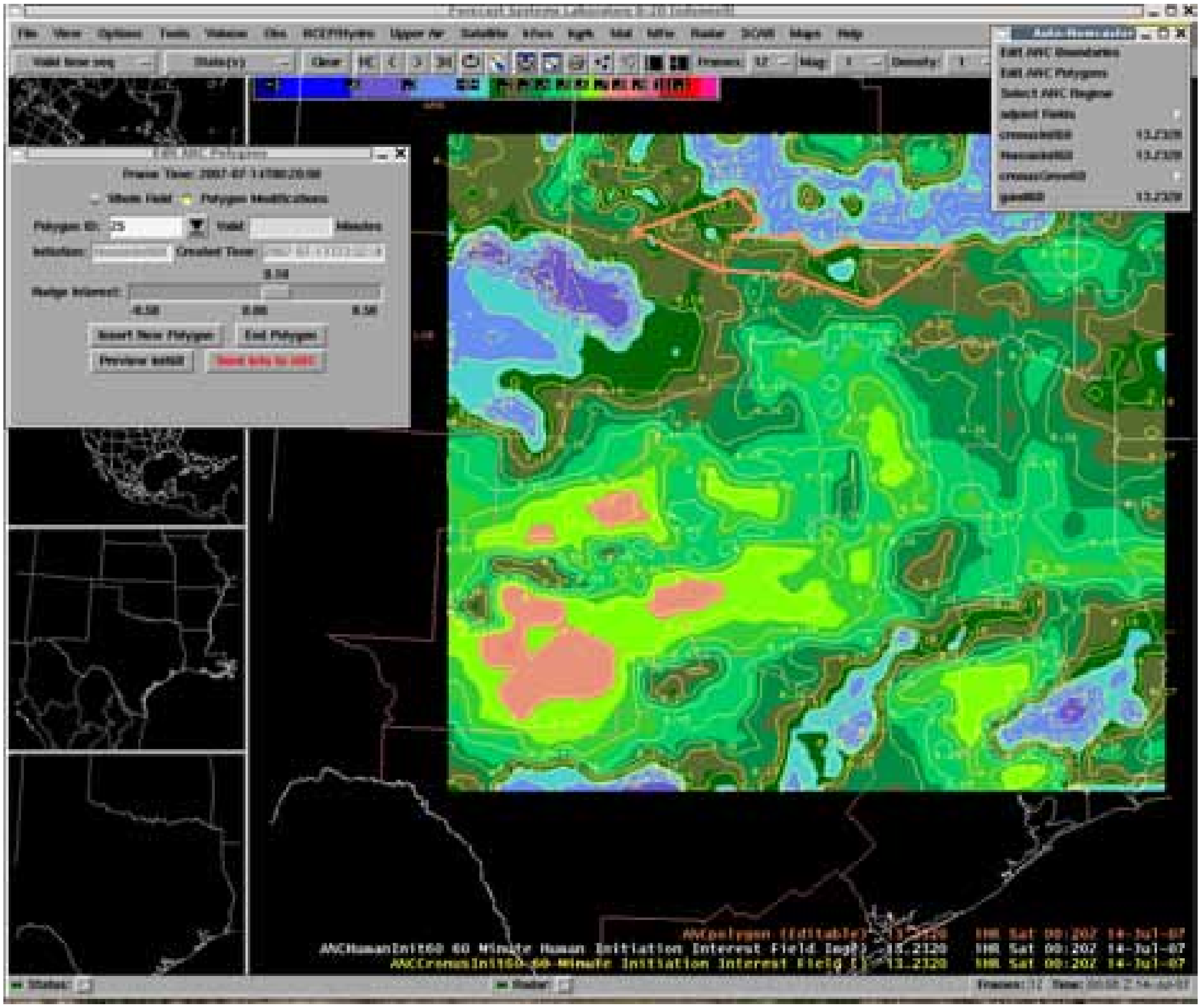


Fig. 1. Polygon Editor overlayed on a 60-minute Convection Initiation forecast. Orange polygon area to be enhanced 10%. Note: Lower left corner showing areas of ~80% chance of convection initiation within the hour.

4. Leveraging/Payoff:

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

The NWS' Modernization Development Laboratory, Decision Assistance Branch (MDL, DAB, Steve Smith, Branch Chief) is the sponsor of this project providing support and direction. The AutoNowcast Interface Project is a collaboration with the NCAR AutoNowcast (AN) development team and the NWS/DAB.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

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

There were two primary research projects during the past year—improvements to the emulation of NCAR's AutoNowcaster Convective Weather Forecasting tool on AWIPS and improving access to the data embedded in the GIS shapefile data base for MDL's *Flash Flood Monitoring Program (FFMP).*

The Flash Flood Monitoring Program (FFMP)

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

Background:
FFMP uses a variety of data to prepare its metadata used operationally. Much of these data are provided in the form of ESRI GIS shapefiles. One of the data sets provided in a shapefile suite is a database (DBF) data file.

The local WFO Service Hydrologist maintains these shapefile data, adding or correcting details, expanding the provided database, and generally improving the contained data. As this work is accomplished, the data fields become somewhat 'randomized'.

When the data contained in the shapefile's deviates from the expected or published format, the database 'readers' cannot extract the required datasets causing the data retrieval to fail.

This task requires a change to the retrieval technique to make the retrieval data order independent and insensitive to variations in changes to attribute names.

2. Research Accomplishments/Highlights:

Accomplishment during the past year has successfully generalized the data retrieval method, allowing that the data may be significantly reordered from the originally provided data, including additional attributes and/or some data attributes provided with altered or changed names.

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

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

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

June 16, 2006, J. Tilley (Univ. of North Dakota). Recent Army-Related Atmospheric Research at the University of North Dakota.

June 20, 2006, Z. Levin (Tel Aviv University, Israel). On the Effects of Dust and Air Pollution on Clouds and Precipitation.

July 17, 2006, H.F. de Campos Velho (INPE/LAC, Brazil). Turbulence Parameterization Based on the Taylor's Approach.

July 18, 2006, H.F. de Campos Velho (INPE/LAC, Brazil). Inverse Problems in Geosciences.

July 26, 2006, S. Fletcher. Lognormal Data Assimilation: Motivation, Theory and the Application to Satellite Data Assimilation.

August 18, 2006, C. Jakob (BMRC, Australia). A Cloudy View of Tropical Climate – Cloud Regimes, Diabatic Heating and Circulation Systems.

September 7, 2006, H. Schmidt (Germany). The Response of the Middle Atmosphere to Solar Cycle Forcing.

September 11, 2006, J. Corbett (Univ. of Delaware). Moving Freight Transport Onto the High Road; Achieving Air Quality Goals Despite Growing Trade and Mobility Needs.

September 12, 2006, S. Kempler (NASA/GSFC). A-Train Data Depot: Integrating and Visualizing Atmospheric Measurements Along the A-Train Tracks.

September 14, 2006, D. Randall. Counting the Clouds.

September 28, 2006, T. Ellis, M. Masarik and M. Smith. Our Department's New Radiosonde System – Overview and Launch Demonstration.

October 12, 2006, M. Barth (NCAR). Convective-Scale Cloud Chemistry Simulations of a Thunderstorm.

October 19, 2006, C. Franzke (NCAR). A Hidden Markov Model Perspective on Regimes and Metastability in Atmospheric Flows.

October 26, 2006, R. Johnson. Fifty Years of Progress in Tropical Meteorology: A Personal View.

November 2, 2006, G. Stephens. CloudSat: Early Highlights, Applications and Science.

November 9, 2006, R. Dickinson (Georgia Tech). Analyzing the 3D Scattering from a Spherical Bush.

November 16, 2006, D. Campbell (U.S. Geological Survey). Blazing a Trail in Rocky Mountain National Park: Application of Monitoring and Research on Nitrogen Deposition to Air and Water Quality Policy.

November 29, 2006, T. Bond (Univ. of Illinois). Energy Shakes Hands with the Climate System: An Engineer's View.

November 30, 2006, B. Otto-Bliesner (NCAR). Simulating Past Abrupt Climate Changes and Ocean-Atmosphere Responses to Freshwater Events in the North Atlantic.

December 7, 2006, J. Hansen. Writing the History of CSU – Again!

January 25, 2007, P. Silvia (Utah State). The Chemistry of Atmospheric particle Formation in Cache Valley, UT, and Implications for Other Rapidly Urbanizing Areas in the West.

February 1, 2007, D. Crisp (NASA JPL). Measuring Atmospheric CO2 from Space: The NASA Orbiting Carbon Observatory Mission.

February 6, 2007, Y. Noh. Snowfall Retrievals Over Land Using High Frequency Microwave Satellite Data.

February 8, 2007, P. Thornton (NCAR). Effects of Carbon-Nitrogen Cycle Coupling on Climate-Carbon Cycle Dynamics.

February 14, 2007, B. Weatherhead (NOAA/CIRES). Detecting Trends in Environmental Data. What Can We Control?

February 15, 2007, D. Henze (Cal Tech). Exploring and Exploiting the Coupling of Sulfate Aerosol with Gas-Phase Precursors Using the Adjoint of a Global Chemical Transport Model.

February 22, 2007, T. Ito. Why Is It So Hard to Explain the Glacial pCO2?

March 1, 2007, L. Ott (NASA GSFC). A Comparison of Convection and Convective Transport in Single-Column and Cloud-Resolving Models.

March 6, 2007, T. Lakhankar. Soil Moisture Retrieval from Microwave Remote Sensing Data.

March 6, 2007, D. Lilly (Univ. of Oklahoma). Defining, Predicting and Verifying Convective Mixed Layers.

March 8, 2007, K. Caldeira (Carnegie Institute). Ocean Acidification.

March 19, 2007, G. Dalu (INRC, Italy). The West African Monsoon and its Impact on the Mediterranean.

March 22, 2007, J. Marshall (MIT). GFD Experiments in Climate and Paleoclimate.

April 2, 2007, D. Frierson (Univ. of Chicago). Tropical Circulations in a Hierarchy of Atmospheric Models.

April 5, 2007, S. Bordini (UCLA). Monsoons as Regime Transitions of a Hadley Cell in an Idealized Aquaplanet GCM.

April 13, 2007, C. Moore (NPS NST). National Park Service Night Sky Team.

April 16, 2007, T. Birner (Univ. of Toronto). The Thermal Structure of the Extratropical Tropopause.

April 19, 2007, V. Larson (Univ. of Wisconsin). Figuring Out Why Your Model is Wrong.

April 24, 2007, K. Fuller (Univ. of Alabama). Absorption of Light by Airborne Particulate Matter.

April 26, 2007, E. Maloney (Oregon State Univ.). The Madden-Julien Oscillation in a General Circulation Model and Observations.

April 30, 2007, A. Shamsheyeva and P. Gabriel. Machine Learning, Classification and Support Vector Machines.

May 2, 2007, P. Gabriel. On the Retrieval of Optical and Microphysical Properties of 3D Clouds.

June 2, 2007, E. Ray (NOAA OAR MASC). Impacts of Tropical Cyclones on the Upper Troposphere.

Fellowship Program

Isidora Jankov – CIRA Post Doc

Project Title: Assimilation and parameterization research for QPF improvement

Principal Researcher: Isidora Jankov (CIRA Post Doc)

NOAA Project Goal: Weather and Water--Serve society's needs for weather and water information / Local Forecasts and Warnings

Key Words: Precipitation Forecast, Physical Schemes, Numerical Model Initialization, Hot Start

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

General long-term research goals include:

--Development of a real-time objective method for an optimal ensemble configuration for rainfall forecasting in support of the Hydrometeorological Testbed (HMT) and Hazardous Weather Testbed (HWT);

--Evaluating high-resolution numerical model performance for events characterized with “atmospheric river” settings;

--Working on an improvement of the non-convective precipitation accuracy and better understanding of microphysical processes by estimating the individual contributions of parameterized processes which lead toward generation and depletion of the bulk hydrometeor quantities;

--An investigation and improvement of the Hot Start technique within the Local Analysis and Prediction System (LAPS);

--Continuation of work on further development and implementation of the Global Analysis and Prediction System (GLAPS).

Specific long-term research objectives include:

--Continuation of work toward improvement of the Quantitative Precipitation Forecast (QPF) for both convective and non-convective precipitation types;

--Developing of a real time objective method for an optimal ensemble configuration;

--Testing the use of a data assimilation package in determining individual impacts of parameterized microphysical processes; and

--Expanding the Local Analyses and Prediction System (LAPS) initialization to global scales.

2. Research Accomplishments/Highlights:

The factor separation method was used to investigate if the results of the impact of different initializations and physical schemes on simulated rain volume of cool season orographically enhanced rainfall could be used to lessen a large bias. Using the knowledge about the magnitude and sign of the impact that different physical schemes and initial conditions had on the simulated rain volume, three different combinations of model runs were created and the mean absolute error was calculated. The results showed a decrease in the mean absolute error for the model combinations that were judiciously selected. The results imply that the factor separation methodology may be used for bias reduction when used to select members of mixed-physics and mixed-initial conditions ensembles for orographically induced rainfall forecasts.

In collaboration with Tomislava Vukicevic and John McGinley, a new real-time objective method for selection of an optimal ensemble configuration for rainfall forecasting has been developed. The diagnostic tool uses an innovative way to model analysis and forecast uncertainty. The technique unifies estimates of a priori (forecast) uncertainties with posteriori (analysis) uncertainties. This was used to evaluate ensemble characteristics including ensemble size, various observation strategies, and configurations including model versions and initial conditions. The analysis Gaussian probability density function was derived from knowledge of the observation network characteristics and estimates of the background model error covariance. The latter was estimated from “reduced rank” error estimates from a suite of models. Ensemble members were assessed on the basis of how well they performed relative to this derived analysis Gaussian probability density function. The new method will be tested by using the “real data” for both HMT and HWT purposes.

A study evaluating a high resolution numerical model performance in the case of significant precipitation events during winter in California (Fig. 1) associated with “atmospheric river” settings was performed. In addition to general model performance evaluation, the model ability to simulate bright band (BB) versus non bright band (NBB) rainfall was assessed. For this purpose, simulation of five “atmospheric river” events was performed by using 3-km grid spacing WRF-ARW model and four different microphysical options (Lin, WSM6, Thompson and Schultz). For the model performance evaluation, several observational data sources in two domains (the coastal region northwest of San Francisco and the interior east of Sacramento) were used. The model ability to depict relevant mesoscale attributes was evaluated by using the 915-MHz wind profiler analysis. S-band radar reflectivity data were used for classifications of the assessed events to BB and NBB categories as well as for an evaluation of the model ability to simulate BB versus NBB reflectivities (Fig. 2). Simulated precipitation accumulations were compared to data available from tipping-bucket rain gages. The results showed that the model generally performed well with simulations of general flow and main mesoscale features. In terms of simulated precipitation accumulations and radar reflectivity, the results indicated a whole range of solutions for various model configurations, locations and for BB versus NBB events (Fig. 3).

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

Objectives related to the design of an optimal ensemble for rainfall forecasting to support HMT have been fully accomplished. Preliminary testing of a new objective method for a real-time optimal ensemble configuration selection for rainfall forecasting showed a lot of potential.

4. Leveraging/Payoff:

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

Work previously performed involved collaborations and communications with Paul Schultz (NOAA/ESRL/GSD), John McGinley (NOAA/ESRL/GSD), Steve Albers (CIRA/ESRL/GSD), Paul J. Neiman (NOAA/ESRL/PSD), Jian-Wen Bao (NOAA/ESRL/PSD), Allen B. White (NOAA/ESRL/PSD), and Tomislava Vukicevic (CIRES/ESRL/GSD). In addition to these collaborators, future work will involve collaborations and communications with Louie Grasso, Renate Brummer, Dusanka Zupanski and Milija Zupanski (CIRA).

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

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 parameterization changes. Wea. Forecasting, 22, 501-519.

Jankov, I., P.J. Schultz, C.J. Anderson, and S.E. Koch 2007: The impact of different physical schemes and their interactions on cold season QPF. J. of Hydrometeorology (in press).

Jankov, I., J.W. Bao, P.J. Neiman, P.J. Schultz, and A.B. White, 2007: Evaluation of high-resolution WRF-ARW model simulations of atmospheric river events during the Hydrometeorology Testbed 2006. Mon. Wea. Rev. (final preparation before submission).

Vukicevic, T., I. Jankov, and J.A. McGinley, 2007: Diagnosis and optimization of ensemble forecasts. Mon. Wea. Rev. (in press).

Conferences

Jankov, I., J.W. Bao, P.J. Neiman, P.J. Schultz, and A.B. White: Evaluation of high-resolution WRF-ARW model simulations of atmospheric river events during the HMT 2006. 18th Conference on Numerical Weather Prediction, 24-29 June 2007, Park City, Utah, Amer. Meteor. Soc. and 8th WRF/MM5 User's Workshop, 11-15 June 2007, Boulder, CO, Amer. Meteor. Soc.

Jankov, I., T. Vukicevic, and J.A. McGinley: Diagnosis and optimizations of ensemble forecasts. 18th Conference on Numerical Weather Prediction, 24-29 June 2007, Park City, Utah, Amer. Meteor. Soc.

Yuan, H., C.J. Anderson, P.J. Schultz, I. Jankov, and J.A. McGinley, 2007: Precipitation forecasts using the WRF-ARW and WRF-NMM models during the HMT-West 2006 and 2007 winter experiments. WRF/MM5 User's Workshop, 11-15 June 2007, Boulder, CO, Amer. Meteor. Soc.

Tarendra Lakhankar – CIRA Post Doc

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 advanced techniques 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 to accurate information on runoff and infiltration.

In a nontraditional combat zone mobility and trafficability of armed vehicles planning can saves of thousands of soldiers' lives and bring 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 the National Aeronautics and Space Administration (NASA) to provide 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 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 two fold. 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 that 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 data sets 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:

Journal Papers

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*.

Technical Reports and Conference Papers

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.

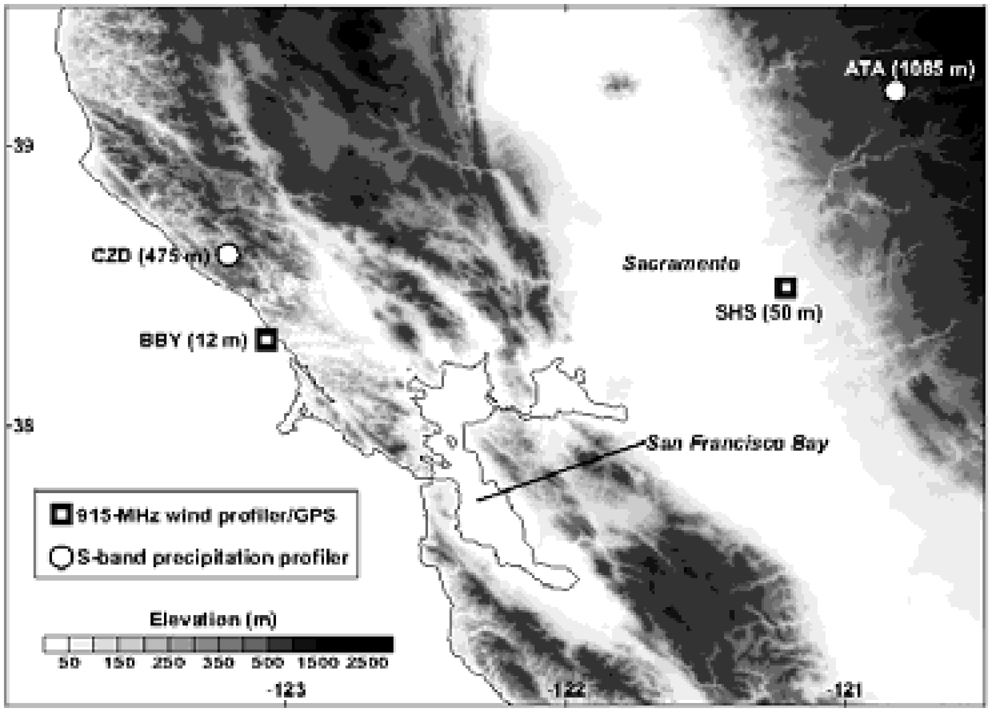


Fig. 1. Terrain base map of California, with the wind profiler sites shown at Bodega Bay (BBY) and Sloughhouse (SHS), and the S-band radar sites shown at Cazadero (CZD) and Alta (ATA).

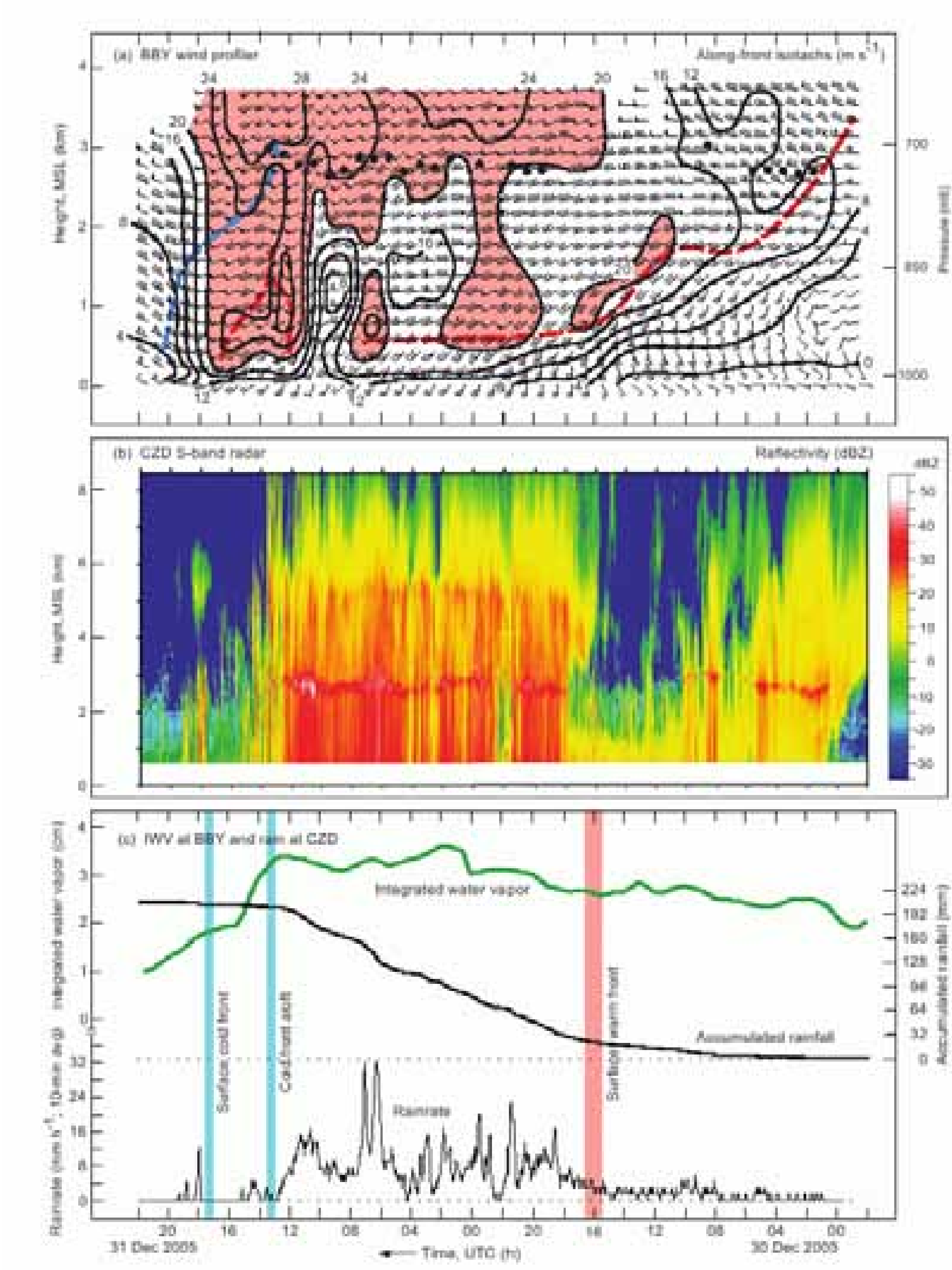
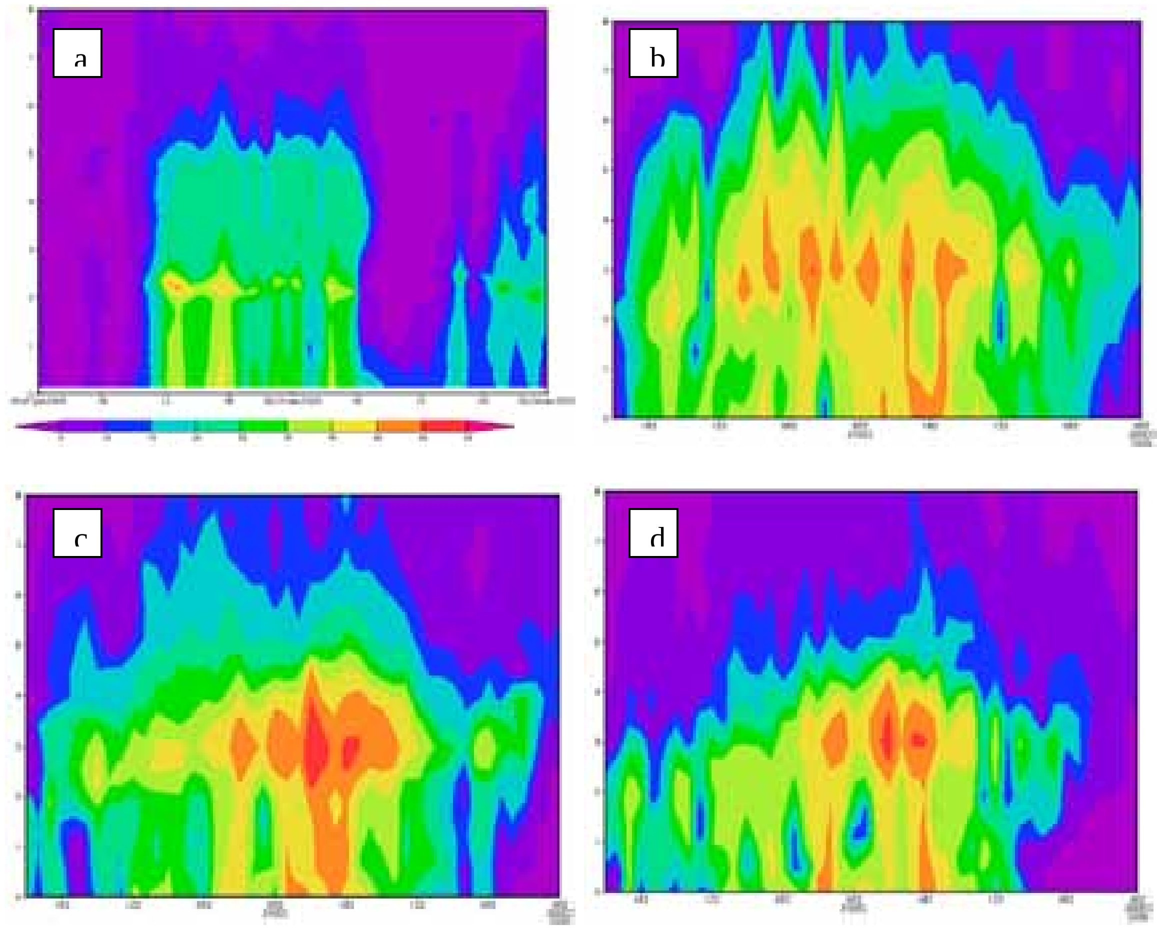


Fig. 2. 3-panel wind profiler/S-band radar/GPS/rainfall figure from BBY and CZD for the period 22 UTC 29 December to 22 UTC 31 December 2005.



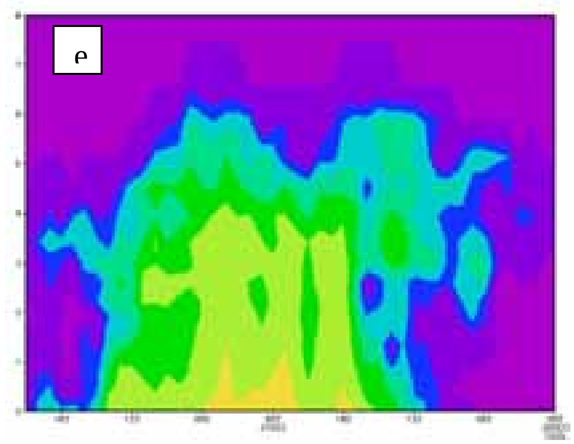


Fig. 3. Reflectivity a) observed and simulated with b) Lin, c) WSM6, d) Thompson, and e) Schultz microphysics for 48-hour period starting at 00 UTC 30 December 2005 at CZD.

Yoo-Jeong Noh – CIRA Post Doc

Project Title: Development of a Snowfall Retrieval Algorithm Over Land Using Satellite Microwave Data

Principal Investigator: T. Vonder Haar

NOAA project Goal: Weather and Water (Weather Water Science and Technology)

Key Words: Microwave, Satellite, Snowfall Retrieval, Surface Emissivity

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

Develop a snowfall retrieval algorithm over land utilizing high-frequency satellite microwave measurements and surface radar data based on Bayesian Theorem

Improve the retrieval over land by using microwave surface emissivity data

2. Research Accomplishments/Highlights:

Focused areas and periods

Selected 15 snowfall cases during winter seasons in 2004-2007 over CONUS.

Main focused areas are Colorado and the Great Lakes and surrounding areas.

Analyses of aircraft measurements during C3VP/CLEX10 (the Canadian CloudSat/CALIPSO Validation Project / the tenth Cloud Layer Experiments) that were jointly conducted during 2006-2007 winter seasons focused on the Great Lakes and surrounding areas are continuing for mixed-phase clouds and snowfall cases.

Collect and examine various data sets including the recently launched CloudSat, AMSU A and B, AGRMET, NEXRAD radar data.

WRF simulations done for 11 cases using several initial/boundary data, grid sizes, and cloud microphysics.

Continue to improve WRF simulations for winter precipitation cases by using the newly released WRF version (V2.2) and GFS and NAM data as initial/boundary data.

For the retrieval over land, calculated microwave surface emissivity from the NOAA Microwave Land Emissivity Model (MEM) using AGRMET data embedded in the CIRA DPEAS (the Data Processing and Error Analysis System).

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

Completed a basic framework for the snowfall retrieval over land for the objectives a) and b).

Attempt to improve WRF simulations for snowfall cases by using GFS initial data, calculate averaged background brightness temperatures of AMSU-B to detect clearer scattering signatures such as the Great Lakes region and add more snowfall cases to diversify the data base of the retrieval algorithm.

4. Leveraging/Payoff:

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

In this research, the CloudSat Science Team and the Data Processing Center provide useful information and data sets. Also, discussions with Dr. Huiling Yuan (NOAA/NRC) and Dr. Isidora Jankov (CIRA) for the WRF simulations will be continued.

6. Awards/Honors: None as yet

7. Outreach:

Presentations

Noh, Y. J., 2007: Multisensor Observations of Snow Clouds during CLEX-10, CloudSat/CALIPSO satellite Joint Science Team Meeting, 11-14 June 2007, San Francisco, CA, USA.

Noh, Y. J., 2007: Snowfall retrievals over land using high frequency microwave satellite data, CIRA/Colorado State University, 6 February 2007, Fort Collins, CO, USA.

8. Publications.

Aonashi, K., T. Muramoto, K. Imaoka, N. Takahashi, G. Liu, and Y. J. Noh, 2007: Physical validation of Microwave Properties of Winter Precipitation over Sea of Japan, IEEE Transaction on Geoscience and Remote Sensing (TGARS) - Special issue on Microwave Radiometry and Remote Sensing of Environment. (accepted)

Noh, Y. J., G. Liu, E. K. Seo, J. R. Wang, and K. Aonashi, 2006: Development of a snowfall retrieval algorithm at high microwave frequencies. J. Geophys. Res. 111, D22216, doi:10.1029/2005JD006826.

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, Amsterdam, The Netherlands. (submitted)

Noh, Y. J., 2007: Observational Analysis and Retrieval of Snowfall using Satellite Data at High Microwave Frequencies. VDM Verlag Dr. Müller, Saarbrücken, Germany, 98 pp. (under revision)

Sarah Tessendorf – CIRA Post Doc

Principal Investigator: Dr. Thomas Vonder Haar

NOAA Project Goal: Climate and Climate Forcing

Key Words: Aerosols, Microphysics, TRMM, MODIS, Lightning, Precipitation

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

This project studied 3 years of TRMM and MODIS satellite measurements of rainfall, lightning, and aerosol optical depth. It is a climatological study to assess relationships between aerosol optical depth, total lightning flash rate, rain yield per flash, and the vertical structure of precipitation, with an overarching goal to determine if a relationship exists on a global scale. The study has found that after normalizing the data by wet-bulb potential temperature (a proxy for thermodynamic instability), an aerosol impact does exist with respect to the flash rate and rain yield per flash. Furthermore, it is shown that rain yield per flash is a good indicator of continental versus maritime regions. The findings of the research motivate more in-depth studies on the relationship between aerosols and microphysical processes, especially because there was more of an aerosol impact than thermodynamic impact on rain yield per flash. This research was conducted though collaboration with Dr. Steve Nesbitt (currently at the University of Illinois, Urbana-Champaign, formerly of Colorado State University). A manuscript is currently in preparation to be submitted for publication in Geophysical Research Letters.

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:

8. Publications:

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8. Funds for CIRA General Publications:

Vonder Haar, T.H., 2007. *Annual Report on the Cooperative Institute for Research in the Atmosphere 01 July 2006 – 30 June 2007*, 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 EDUCTION PROPOSAL

Principal Investigator: B.H. Connell

NOAA Project Goal: Weather and Water; Programs: Local Forecasts and Warnings, Hydrology

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

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

The overall objective of the SHyMet program is to develop and deliver a comprehensive distance-learning course on satellite hydrology and meteorology. This is being done in close collaboration with experts from CIRA, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison, the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, the National Weather Service (NWS) Training Center (NWSTC) in Kansas City, Missouri, and the NWS Warning Decision Training Branch (WDTB) in Norman, Oklahoma. The challenge is to provide necessary background information to cover the many aspects of current image and product use and interpretation as well as evaluate data and products available from new satellite technologies and provide 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:

1. Administer the SHyMet Intern Course http://rammb.cira.colostate.edu/training/shymet/intern_intro.asp .
2. Evaluate feedback from course surveys and comments. Modify the instructional materials as appropriate.
3. Develop a next level "general" track which includes a hydrology component.
4. Port the new course materials, questions, and surveys into the NOAA LMS system.
5. Update CIRA SHyMet webpage to reflect new course offerings.

Further Plans for the longterm include:

1. Ongoing offering of SHyMet Intern course
2. Initial offering of next level SHyMet Course in Spring 2008.
3. Advertise and make SHyMet course materials available nationally and internationally to individuals outside NWS.
4. 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 first SHyMet Intern course was offered (and is continuously open). It consists of 5 online modules and 4 teletraining/online modules representing 16 hours of total training hours. The initial offering of the course overlapped the previous year by 3 months. For completeness, some of that information is included here.

The sessions are:

1. SHyMet Intern Orientation (Online only)
2. GOES Imaging and Sounding Area Coverage, Resolution, and Image Frequency (Online only)
3. GOES Channel Selection (Online only)
4. POES Introduction (Polar Satellite Products) (Online only)
5. GOES Sounder Data and Products (Teletraining and Online)
6. GOES High Density Winds (Teletraining and Online)
7. Cyclogenesis (Teletraining and Online)
8. Severe Weather (Teletraining and Online)
9. Tropical Cyclones (Online only)

See the web page for this at:
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). The teletraining portion of the course was met by utilizing the already established Virtual Institute for Satellite Integration Training (VISIT) program. (http://www.cira.colostate.edu/ramm/visit/visithome.asp) Teletraining sessions were offered April through June 2006. After that, audio recorded sessions were offered. For non-NOAA individuals, the course was only offered through online modules and was tracked at CIRA.

Statistics from Beginning of SHyMet (April 1,2006) through June 30,2007

--113 NOAA/NWS employees/participants have registered at CIRA

--56 of the 113 (50%) individuals have completed SHyMet Intern Course

--16 non-NOAA participants have registered at CIRA (Nationally: Department of Defense (DOD), National Environmental Satellite, Data, and Information Service/ Satellite Applications Branch (NESDIS/SAB) contractors; Internationally: 1 from Peru, and 2 from South Korea)

--9 of the 16 (56%) individuals have completed the SHyMet Intern Course.

--Table 1 shows the number of students registered via the LMS for the various SHyMet training sessions between July 1, 2006 and June 30, 2007. Registrations through LMS tracking indicate that an additional 80 individuals not registered at CIRA have taken SHyMet modules. Due to the nature of the previous LMS, it is difficult to tell how many of these individuals have completed the SHyMet Intern Course. We expect that the reporting features will change with the new LMS.

Note – NOAA switched their LMS May 1, 2007. Participants were not allowed access to the LMS for the month of May and have had limited access in June. This may reflect lower numbers of persons registered in the totals listed in Table 1.

Table 1. Number of students registered via the LMS for SHyMet training sessions between July 1, 2006 and June 30, 2007.

SHyMet training session	Registrations
Orientation	193
GOES Imaging and Sounding Area Coverage	173
GOES Channel Selection	171
Introduction to POES	169
GOES Sounder Data and Products	156
GOES High Density Winds	158
Cyclogenesis	161
Severe Weather	174
Tropical Cyclones	205

In order to develop the outline and content of a second general interest course which will include a hydrology component, it was decided to get feedback from the user community on the importance of training topics. The starting points of training topics for the survey were those that were identified by the SHyMet team during the initial stages of the SHyMet proposal (see Training Topics: http://rammb.cira.colostate.edu/training/shymet/). SHyMet coordinated with the VISIT team and NWS managers and Union representatives to set up and administer a new satellite training topics survey. The survey was advertised to the NWS “all hands” mailing list and included Science and Operations Officers and Forecast staff and those who had taken the SHyMet Course. From the information available to us, there are approximately 1500 persons in the target group. There were 288 responses to the survey which is close to a 20% response rate. The survey results can be viewed here: http://rammb.cira.colostate.edu/visit/Combination_Report_Survey_1.htm

A few important points:

1. Respondent Locality: Most were from Central Region with 32.0% of the total, followed by a near tie between Western Region (15.9%), Eastern Region (15.9%), and Southern Region (19.3%). Alaska and Pacific Regions were not well represented at 3.4 % each.

2. Number of years in a professional forecasting position: The overwhelming majority of those answering this questionnaire (68.5%) have done so for more than 10 years. The numbers trail off as the number of years in the profession decrease (6 to 10 years - 13.2%, 3 to 5 years - 8.3%, 1 to 2years - 5.2%, and <= 1 year - 4.8%)

3. Since SHyMet focuses on satellite topics, many of the questions on the survey were directly applicable to satellite. In reality, the selected topics also reflect weather situations with problem areas that draw on observations from different platforms to adequately analyze the situation at hand. The topics that received the highest interest were in identifying synoptic and mesoscale features related to ongoing or expected (severe) weather, fronts and mid-latitude systems, identifying boundaries for severe weather, and identifying fog/stratus development and dissipation trends.
The challenge of interpreting the results of the survey is in weighing the relative importance of various topics for the different regions and different seasons.

The Satellite Requirements and Solutions Steering Team from NOAA's NWS Office of Science and Technology has expressed a strong interest in the survey results. We will work with them to summarize and release the results in an official manner and as widely as possible.

3. Comparison of Objectives Vs. Actual Accomplishments:

Objectives 1-2 have been fully met. As part of objective 2, a comprehensive survey was administered to the National Weather Service through their "all hands" mailing list. This was the first time a survey of this extent was performed and it took over 3 months to obtain appropriate permissions from the NWS Administration as well as NWS Union to distribute the survey. As a result, the evaluation was also delayed. Some of the highlights of the survey are summarized above. Because of the beneficial feedback and current interest and review of the survey results at the NWS national level, we feel this was a very worthwhile effort, regardless of the delay.

Over the past year, NOAA chose a new LMS. May 1, 2007 marked the end of the original LMS hosted by GeoLearning and the beginning of the new LMS hosted by Learn.com. Because this requires training on use of the new LMS as well as porting the course materials, questions, and surveys of the existing SHyMet course from the old

LMS into the new LMS, objective 4 has been modified to account for this and is almost complete. Objectives 3 and 5 are “in progress”. During the course of the past year, items 3 and 4 under long term plans have been added. It is worthy to note here that progress has begun in both these areas: persons outside NOAA have taken the SHyMet course, and presentations are being made to national and international communities to extend the use of the VISITview tool and SHyMet course materials. These last two points are described further under item 5 below.

4. Leveraging/Payoff:

The training materials being developed will help the user (the weather forecaster, the hazard analyst, other teachers/trainers) better utilize current satellite products that are available. This will in turn lead to better weather/hazard forecasts for the public.

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

Other groups within NOAA, for example the Satellite Applications Branch, and other government and international organizations have expressed a strong interest in the proposed training. Eight personnel from the Department of Defense (DOD) and five contractors to NESDIS/SAB registered for the SHyMet Intern course this past year. 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. The VISITview tool, which is heavily used by SHyMet, has been adopted as an online training tool by CGMS. As such, CIRA, in cooperation with SHyMet and VISIT, has promoted VISITview and shared their expertise in training through:

1) monthly international weather briefings (visitview site http://rammb.cira.colostate.edu/visitview/focus_master_custom_group.asp ,

2) presentations on VISITview and national and international training efforts where appropriate

3) the virtual high profile training event (HPTE) which took place October 16 to 27, 2007.
The HPTE was described as a huge success internationally for training on the use of data and products from meteorological and environmental satellites, the WMO estimates that over 4000 participants from 100 member countries around the globe took part in lectures and weather briefings via the Internet during the HPTE.
CIRA/VISIT partnered with NOAA/NESDIS, the Cooperative Institute for Meteorological Satellite Studies, the National Weather Service’s Training Division and International Desk of the National Centers for Environmental Prediction, and the Cooperative Program for Operational Meteorology, Education and Training. Internationally, VISIT partnered with the Bureau of Meteorology Training Center in Australia, the WMO Centers of Excellence in Costa Rica, Barbados, Argentina and Brazil, and the European Organization for the Exploitation of Meteorological Satellites. The success of the WMO

HPTE was made possible by the extensive use of the VISITview software to deliver the presentations and weather briefings in real-time around the globe through the Internet.

Lectures and weather briefings in the Americas were presented in both Spanish and English. More information on the event can be found at http://rammb.cira.colostate.edu/training/wmovl/ . In NOAA's region of responsibility, the first weather briefing and lecture drew 128 participants from 21 countries. (Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guyana, Guatemala, Honduras, Panama, Paraguay, Peru, Trinidad and Tobago, and Venezuela). During the 2 week period, it is estimated that a total of 380 participants from the Americas and the Caribbean were trained in the various sessions. Upon experiencing online courses, many participants expressed interest in courses such as SHyMet. Because of our strong links with the WMO, SHyMet courses will be included in their Virtual Laboratory. The national and international interest outside NWS indicates that the training research and development activities at CIRA have wide-ranging applications.

6. Awards/Honors:

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree);

(b) Seminars, symposiums, classes, educational programs;

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 2006 and Spring 2007.

CIRA has participated in monthly VISITview weather briefings using GOES satellite imagery (http://rammb.cira.colostate.edu/visitview/focus_master_custom_group.asp) and voice via Yahoo messenger between the US and WMO designated RA III and RA IV countries. Each month there is an 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.

(c) Fellowship programs; (d) K-12 outreach:

(e) Public awareness:

8. Publications:

<u>Presentations</u>

Connell, B., V. Castro, M. Davison, T. Mostek, Berny Fallas, Evelyn Quiros, and Gustavo Murillo. .Presentation was prepared for the 32nd International Symposium on Remote Sensing of Environment titled "International Satellite Weather Briefings via the

Internet" . Three students from the University of Costa Rica (Berny Fallas, Evelyn Quiros, and Gustavo Murillo) gave the presentation June 26, 2007.

Connell, B., June 15, 2007: Presentation on VISITview and International Training activities to visitors from the Autonomous University of Yucatan (UADY), Mexico. The UADY representatives expressed interest in utilizing CIRA products and the VISIT program to educate the academic community at UADY so that it can help surrounding communities prepare for and respond to natural disasters.

Connell, B., Presentation on "National and International Training Highlights" at the 3rd Annual NOAA/NESDIS/CoRP Science Symposium hosted by CIRA in Fort Collins on August 15-16, 2006
http://rammb.cira.colostate.edu/corp/Symposium/PostSymposium/Index.htm

Training

Connell, B. (CIRA), Tony Mostek (NOAA/NWS), Mike Davison (NOAA/HPC/ NCEP)July 5, 2006: The WMO Virtual Laboratory task group gave a session demonstrating the features of VISITview for collaborative weather briefings to a class of 44 participants at training on the Use of MSG data for Environmental Applications. The training was sponsored by EUMETSAT and held at INPE (Instituto Nacional de Pesquisas Espaciais) in Sao Paulo, Brazil.

Workshops

Bikos, D., J. Braun, and B. Connell, May 8, 2007: Presentations on VISITview, National and International Training were given at a NPOESS/COMET workshop. The afternoon sessions were at CIRA.

Connell, B., March 29, 2007: A virtual presentation using VISITview was given to the 4th International Workshop on Volcanic Ash held in Rotorua, New Zealand. The presentation summarized National and International training efforts at CIRA and use of the VISITview software. The voice was done over the Internet through Yahoo messenger. The audience included approximately 40 persons, a mix of meteorologists, volcanologists, and persons from the aviation sector.

GOES-WEST ISCCP SECTOR PROCESSING CENTER

Principal Investigator: T.H. Vonder Haar

NOAA Project Goal: Climate

Key Words: ISCCP, Climate, GOES, CloudSat, Clouds

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

We have two basic responsibilities under this project: Data collection for International Satellite Cloud Climatology Project and validation of the products from ISCCP.

Data Collection:

This process is now nearly completely automatic. Software improvements have made this a hands free process unless there is a data source problem. Software upgrades over the last two years have also made ISCCP data collection simpler to monitor and more reliable.

Data substitution: Alternate data are collected when GOES satellite collection schedule does not include the ISCCP times of interest. Also, a few data files are obtained from NOAA CLASS data archive when our local system is shut down.

2. Research Accomplishments/Highlights:

Our data collection rate with substitute data is better than 99%.

Validation of ISCCP Products:

One of the fundamental mysteries of the ISCCP data set is the fact that the amount of clouds reported from ISCCP has a strong view-angle dependence. By using CloudSat data, we have been able to demonstrate that the ISCCP result comes from the analysis algorithm, not from some fundamental property of clouds. This affects the interpretation of the long time series of ISCCP averages as well as the interpretation of the observed spatial distribution of cloudiness.

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

We have met the ISCCP data collection objectives: Collection of GOES West data and distribution in a timely manor.

Our validation studies have improved the understanding of the ISCCP data set.

4. Leveraging/Payoff:

The ISCCP project is a long term (20 + years) research project. Better validation of ISCCP data products greatly improves its use as a climate monitoring resource.

5. Research Linkages/Partnerships/Collaborators:

Use of CloudSat data from a NASA funded experiment has contributed greatly to the understanding of ISCCP products. This has also fed back to the CloudSat project leading to better understanding of that new data set.

6. Awards/Honors:

7. Outreach:

8. Publications:

Campbell, G. Garrett and T.H. Vonder Haar, 2007: The new angular dependence study was required in the publication of *Global Cloudiness: Nearly constant in time from ISCCP observations* (in press).

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, Environmental Modeling
Weather Water Science, Technology, and Infusion

Key Words: Probabilistic Assimilation/Prediction, Ensemble, Maximum Likelihood, Ensemble Filter, Global Forecasting System

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

The general objective of this research is to explore the potential of ensemble data assimilation (EnsDA) for NOAA's operational applications. In this research we use the Maximum Likelihood Ensemble Filter (MLEF) with the NCEP Global Forecasting System (GFS) model at resolution T62L28. The assimilated observations are all observations available to NOAA's operational weather forecast, including satellite radiances. The MLEF-GFS system is developed and installed on the NOAA computers. This allows an easy code access to NOAA researchers and other collaborators.

The focus of our research is to develop and test the dual-resolution EnsDA system, with high-resolution (e.g., operational) model used as a control, and low-resolution model used for ensemble members. The other component of our research includes development of a modular code such that NCEP operational codes are easily interfaced with the MLEF code, eventually providing the means for straightforward technology transfer. In particular, the GFS spectral model and the Spectral Statistical Interpolation (SSI) data assimilation codes are used as modules in the MLEF algorithm.

The MLEF-GFS is also used in ensemble inter-comparison project, as one of the three ensemble data assimilation algorithms tested by NCEP. After the completion of the current project, the aim of NOAA/NCEP is to develop a prototype EnsDA algorithm that will include components from the MLEF.

2. Research Accomplishments/Highlights:

MLEF-GFS system with assimilation of satellite radiances is developed and tested during a 5-day interval in January 2004 (as agreed for the NCEP ensemble inter-comparison experiment).

Preliminary results suggest that MLEF is producing correct statistical results, without noticeable outliers.

There is a clear benefit of MLEF assimilation, with 100 ensemble members used.

The MLEF-GFS system is currently the only EnsDA algorithm not based on statistical sampling.

Comparison between the SSI and the MLEF 48-hour forecast Root-mean-squared (RMS) errors shows that MLEF is better during the first several days--slightly deteriorating afterwards.

Comparison with other ensemble algorithms (LETKF, ENSRF) shows that MLEF is performing better in the Tropics, but is not as good in the extra-tropical latitudes. Model error (bias) and parameter estimation are being included in the system.

The results of this research are directly related to the NOAA goals and plans through the THORPEX Research Program. The personnel working on this project include Milija Zupanski and Arif Albayrak. We work close with NOAA/NCEP scientists Yucheng Song and Mozheng Wei, as well as with research groups at Univ. of Maryland (Istvan Szunyogh), NOAA/ESRL (Tom Hamill, Jeff Whitaker), NRL Monterey (Craig Bishop), and others.

The work is conducted on the NOAA/NCEP IBM SP computers, employing directly all required operational codes, thus making the results of this research easily transferable to NOAA operations. Some results of this research were reported at the SPIE Defense and Security conference in Orlando, Florida, 9-13 April 2007.

Most of the research is completed, with the exception of detailed testing of the dual-resolution algorithm. The delay was due to the computer connection problems, and due to the change of the computer at NCEP. A one-year no-cost extension was approved for completion of the testing.

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:

Albayrak, A, M., Zupanski, and D. Zupanski, 2007: Maximum Likelihood Ensemble Filter applied to multisensor systems. Proceedings of the SPIE Defense and Security Symposium on Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2007, 6571, p. 311-311, Orlando, Florida, 9-13 April 2007.

IMPROVED STATISTICAL INTENSITY FORECAST MODELS

Principal Investigators: J.A. Knaff/J. Dostalek

NOAA Project Goal: Weather and Water

Key Words: Tropical Cyclones, Hurricanes, Typhoons, Intensity Forecasting

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

This project is to improve statistical intensity forecast models by 1) incorporation of a new formulation of the inland decay component in the operational Statistical Hurricane Intensity Prediction Scheme (SHIPS) model, 2) evaluate new methods for the evaluation of the vertical wind shear in SHIPS, and 3) improve the operational rapid intensity index (RII) by utilization of a discriminate analysis method that would weight the input parameters to provide the optimal separation of the rapid and non-rapidly intensifying tropical cyclones. The work is being performed through the Joint Hurricane Testbed, where procedures are tested in operational conditions at the National Hurricane Center in Miami, and evaluated by the hurricane forecasters.

2. Research Accomplishments/Highlights:

a) New inland decay formulation

The new decay model was implemented on the NCEP IBM for the 2006 hurricane season. Thus, this part of the project is essentially completed.

b) New method for evaluating vertical shear in SHIPS

The SHIPS model averages the winds over an annulus from 200 to 800 km from the storm center. This large area is used to account for potential differences between the official forecast track (used in SHIPS) and the track of the storm in the NCEP GFS model. In order to test smaller or non-circular averaging areas, the storm circulation must first be removed. Two methods for removing the storm circulation were tested. The first method involves removing the symmetric storm circulation, and the second involves a "Laplacian filter" where the wind fields inside a specified radius centered on the model storm location are replaced by solutions of $\nabla^2 u = \nabla^2 v = 0$. Results showed that the Laplacian filter method was inferior because the procedure does not remove the linear horizontal shear component of the vortex circulation, and it is not easy to distinguish between areas of cyclonic and anticyclonic rotation for the filtering.

The most difficult aspect of the circulation removal method was determining the storm center in the GFS analysis. Special methods were developed that track the point that maximizes the 850 hPa tangential wind. In addition, quality control checks were implemented to make sure that the vortex moves at a speed that is smaller than the maximum observed in the best track, where the upper limit is a function of storm latitude. The quality control also requires a minimum value of the cyclonic tangential wind. If either of the quality controls fail, the vortex is not removed for that forecast time onward. This method was found to be robust and often tracked the vortex longer than the operational vortex tracker implemented by NCEP.

Once the vortex center is determined, the mean symmetric tangential wind as a function of radius is calculated at each vertical level in the model. The largest radius where the circulation first becomes cyclonic is determined. The symmetric circulation from this radius inward is then subtracted from the GFS fields. The outer radius for the subtraction nearly always decreases with height resulting in greater modification at 850 hPa than 200 hPa. Because the GFS vortex is removed, smaller averaging radii can be used. For the SHIPS tests, the shear was calculated from 0 to 500 km from the storm center, rather than the 200 to 800 km annulus used in the operational version of SHIPS. The dependent results showed that the new shear was better correlated with the intensity change than the old version.

Because the 0 to 600 km GFS vortex circulation is calculated as part of the vortex removal process, it was also tested as a predictor. It was found that the time tendency of the GFS vortex circulation was a significant predictor. It was also found that the 850 hPa environmental vorticity predictor (Z850), which uses a 0 to 1000 km averaging area has become problematic in the newest version of the GFS with higher resolution. Because the tropical cyclones are better represented, Z850 sometime represents the environment, and sometimes the storm itself. Because of this inconsistency, Z850 was eliminated in the test version of the model in favor of the new GFS vortex predictor, which always measures the storm circulation.

A parallel version of SHIPS with the new shear predictor and GFS vortex predictor was implemented in real time beginning in September of 2006. However, the Atlantic season ended very early, so very few forecast cases were obtained. For this reason, all of the 2006 cases (Atlantic and east Pacific) were re-run after the season, with fully operational input. Figure 1 shows the percent improvement of the test version of SHIPS relative to the operational version. The results in the Atlantic are very positive, with improvements of up to 15% at the longer forecast times. The improvements at 24-120 hours were statistically significant at the 90% level. The results in the east Pacific were more mixed, although the improvements at 24 and 36 hours were also statistically significant at the 90% level. The differences between the experimental and operational SHIPS model for the east Pacific were not statistically significant at the longer times, so the results are considered neutral there.

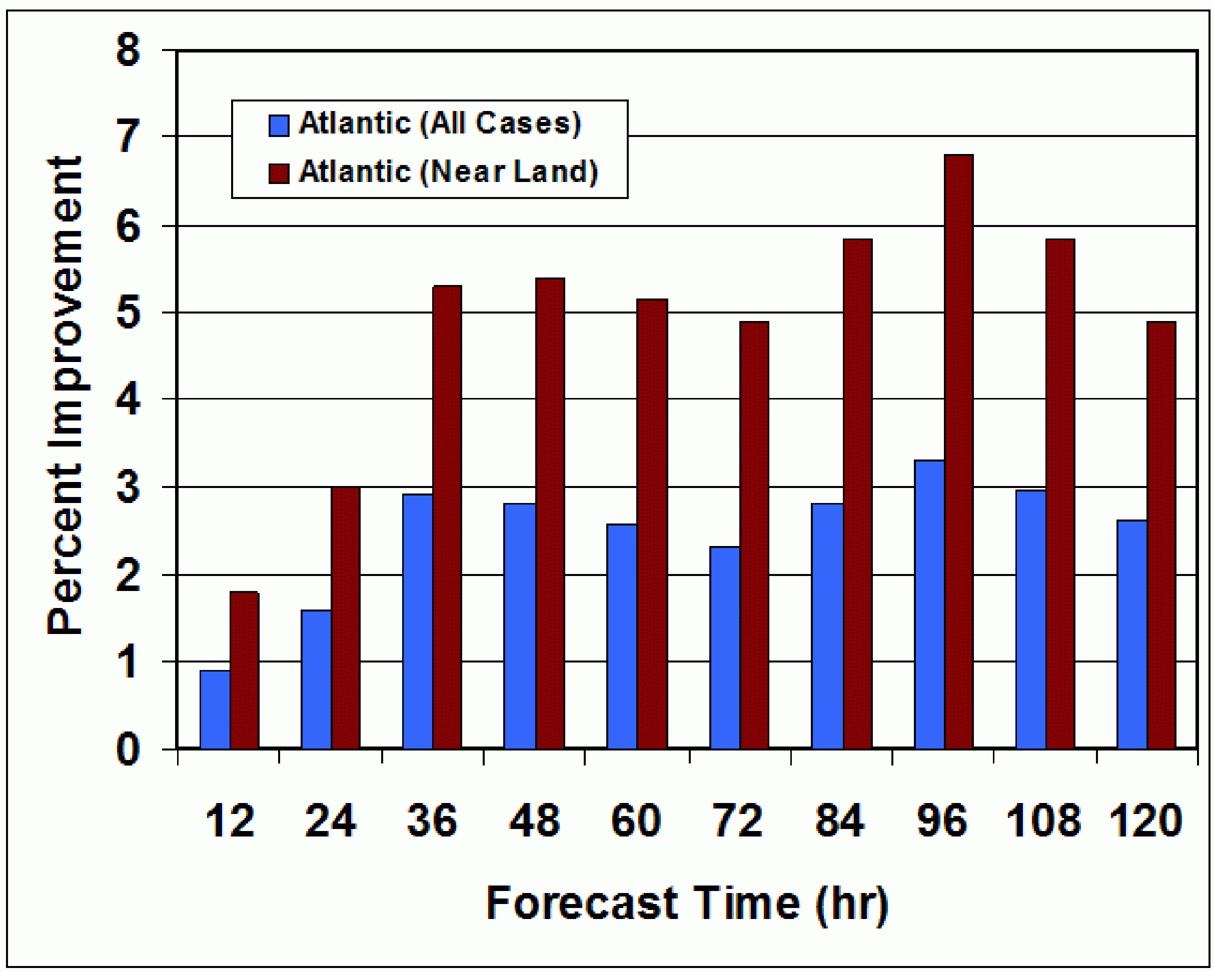


Figure 1. The percent improvement of the experimental SHIPS forecasts with the modified shear and GFS vortex variable in place of Z850 relative to the operational version of SHIPS. All cases from the 2006 season were included.

c) Improved rapid intensity index

The Discriminant Analysis (DA) version of the RII was run in real-time in parallel with the operational version during the 2006 season. The Brier skill score (relative to a climatological rapid intensity probability) for the operational and DA RII were calculated for the dependent sample. Results show that the DA version for the east Pacific had a higher Brier skill score than the operational version however there were not enough cases to properly evaluate the DA version of the RII in the Atlantic this year.

To get a feel for the comparison of the two methods with a larger sample, all of the cases from 2003-2005 seasons were re-run in dependent mode. This sample included 115 RI cases in the Atlantic and 59 in the east Pacific. The Brier skill scores for the DA and operational versions for this larger sample are shown in Fig. 2. The DA version was superior in both basins for this more representative sample. The 2006 cases will be added to the sample and the weights will be re-derived. The methods can again be compared for independent cases in 2007.

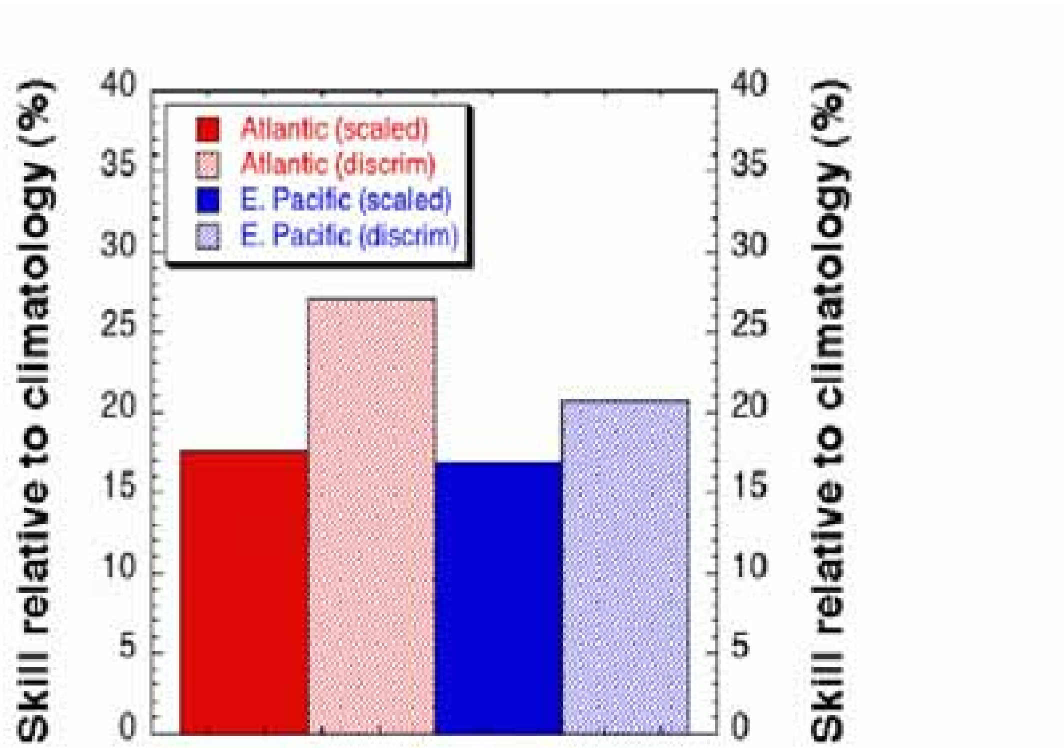


Figure 2. The Brier skill score for the dependent RII forecasts from the 2003-1005 seasons with the operational (solid) and DA (hatched) weights for the Atlantic and east Pacific.

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

This project is on schedule and has been completed. Two of three algorithms has already been transitioned to NCEP/TPC operations and the other two are being tested in real time during the 2007 hurricane season.

4. Leveraging/Payoff:

Accurate hurricane intensity forecasts are of vital importance to the public in coastal regions. The new decay model improved the operational intensity forecasts utilized by NHC by about 5% and the new shear calculation improves that another 5 to 14 %, which contribued to more accurate watches and warnings. Improvements in the RII show promise of being better able to anticipate periods of rapid intensification. The NHC intensity forecasts will continue to benefit as this project continues.

5. Research Linkages/Partnerships/Collaborators, Communication 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, the NOAA/OAR Hurricane Research Division, and Colorado State University.

6. Awards/Honors: None

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) One graduate student worked on this project (Robert DeMaria, completed a MS in Computer Science). Robert has since been hired as a Research Associate.

(b) See Section 8 below

(d) Simplified versions of the difficulties of hurricane intensity forecasting have been included in talks given to K-12 students. High school student employees at CIRA are contributing to the data processing required for this project.

8. Publications:

<u>Refereed Journal Articles</u>

Demuth, J., M. DeMaria, and J.A. Knaff, 2006: Improvement of Advanced Microwave Sounding Unit Tropical Cyclone Intensity and Size Estimation Algorithms, Journal of Applied Meteorology and Climatology, 45:11, 1573–1581.

Jones, T. A., D. J. Cecil, and M. DeMaria, 2006: Passive Microwave-Enhanced Statistical Hurricane Intensity Prediction Scheme. Wea. and Forecasting, 21, 613-635.

<u>Conference Proceedings</u>

Chatzidmitriouu, K., C.W. Anderson, and M. DeMaria, 2006: Robust and interpretble statistical models for predicting intensification of tropical cyclones. AMS 27th Conference on Hurricanes and Tropical Meteorology. 24-28 April, Monterey, CA.

DeMaria, M., J.A. Knaff, J. Kaplan, 2006: Improved Statistical Intensity Forecast Models : A Joint Hurricane Testbed Project Update. 60th Interdepartmental Hurricane Conference. 20-23 March, Mobile, AL.

Kaplan, J., and M. DeMaria, 2006: Estimating the likelihood of rapid intensification in the Atlantic and E. Pacific basins using SHIPS model data. AMS 27th Conference on Hurricanes and Tropical Meteorology. 24-28 April, Monterey, CA.

DeMaria, M., K.S. Maclay, and J.A. Knaff, 2006: Tropical cyclone structure analysis: a multi-sensor approach. AGU Fall Meeting, 11–15 December 2006, San Francisco, CA.

Presentations

DeMaria, M. and J. Franklin, 2007: Long-Term Trends in National Hurricane Center Watches and Warnings. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

DeMaria, M., J.A. Knaff, and J. Kaplan, 2007: Improved Statistical Intensity Forecast Models: A Joint Hurricane Testbed Project Year 2 Progress Report. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

Kaplan, J., M. DeMaria, N. Carrasco, and J. Dunion, 2007: Tropical Cyclone Wind Radii Estimation Utilizing an Empirical Inland Wind Decay Model. 61st Interdepartmental Hurricane Conference, 5-9 March, New Orleans, LA.

INCORPORATION OF CENSUS DATA IN SEVERE WEATHER WATCHES AND WARNINGS

Principal Investigator: Shripad Deo

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

Key Words: Social Science, Communication, Education

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

(a) To infuse new understanding of science and technology to enhance the quality of water resources information,

(b) To improve the understanding of how that information is used by diverse user groups served by NOAA's National Weather Service, and

(c) To improve usability of information and making it socially robust by providing context in which information is developed and it can be used.

The producers of weather information (such as, NWS) need to have an 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 producers of information need to cultivate socio-technical networks, develop appropriate information tools, and understand the context in which these tools are used. They also need to engage the users in a dialogue to understand their changing information needs.

We have developed tools for producers and users of water resources information. 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 and the content of the forecast graphics. As part of educating the forecasters in communication, focus groups were conducted at different locations to ascertain the information needs of customers and to identify problems they encounter with current formats.

The comments and feedback from forecasters and users will enable us to refine or re-conceptualize these tools and suggest changes in presentation of information.

2. Research Accomplishments/Highlights:

a) Effective distribution of water resources information through improved organization of dissemination tools, primarily, the web pages.
b) Increased awareness and appreciation of user information needs to enable them to make better decisions through qualitative social science research methods.

c. Increased awareness and recognition by policy makers 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 five training workshops and five focus groups.

4. Leveraging/Payoff:

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

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

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

6. Awards/Honors:

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

7. Outreach:

8. Publications:

INVESTIGATION OF SMOKE AEROSOL-CLOUD 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.

To explore stratiform clouds in the South Eastern Pacific in preparation for a planned field experiment off the coast of Chile during the fall of 2007 (VAMOS Ocean-Cloud-Atmosphere-Land Study: VOCALS).

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). 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 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 the Reporting Period:

We have made significant progress in our study in the Houston area with one manuscript ready for submission. A separate paper (in preparation) will examine comparisons of observed radiative fluxes and fluxes simulated based on the model output.

The study to explore stratiform clouds in the South Eastern Pacific has been delayed because the VOCALS field deployment was delayed by one year. We have instead focused all of our effort on GoMACCS.

4. Leveraging/Payoff:

The concept of statistical comparisons between models and observations was the goal of the study, with flight planning designed to meet this goal a priori. 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

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., Pilewskie, P: University of Colorado, Boulder, CO

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Jiang, H., G. Feingold, J. Seinfeld, R. Flagan, H. Jonsson, and P.Y. Chuang, 2007: Comparison of statistical properties of simulated and observed cumulus clouds in the vicinity of Houston during the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS). *To be submitted.*

NESDIS POSTDOCTORAL PROGRAM

Principal Investigators: Various (see below)

NOAA Project Goal: Various (see below)

<u>Yong Chen – NESDIS Post Doc</u>

Project Title: Develop and Evaluate Community Radiative Transfer Model (CRTM) for Uses in Numerical Weather Prediction Models

Principal Investigator: Professor Thomas H. Vonder Haar

NOAA Project Goal: Weather and Water, Local Forecasts and Warnings, Hydrology

Key Words: Community Radiative Transfer Model (CRTM), Integration, Validation

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.

2. Research Accomplishments/Highlights:

Integration of the forward Stand-Along Radiative Transfer Algorithm (SARTA) into the JCSDA Community Radiative Transfer Model (CRTM).

The SARTA tangent-linear, adjoint and K-matrix models have also been implemented under the CRTM framework.

Proposed work on the integration of multiple transmittance algorithms into the CRTM was accepted by the CRTM team.

Validation of CRTM-SARTA implementation by comparison between observations and simulations under clear sky for the Infrared Atmospheric Sounding Interferometer (IASI) on Metop-a.

Validation of the CRTM under non-precipitating conditions for thermal infrared and microwave by using CloudSat data.

Attending CloudSat/CALIPSO Joint Science Team meeting held at San Francisco on June 11-14, 2007, and gave a presentation titled: “JCSDA (Joint Center for Satellite Data Assimilation) CRTM validation using CloudSat data”, which provided comparisons between observations and simulations by using the collocated dataset from CloudSat/NOAA-18, allowing for quantification of forward model biases under various cloudy conditions which is a very important step toward uses of cloudy radiances in data assimilation systems.

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

Integration of SARTA transmittance model (including forward, tangent-linear, and adjoint models) into CRTM frame has been completed (09/2006).
Integration of multiple transmittance models (OPTRAN-compact, OPTRAN-v7, RTTOV and SARTA) prototype has been completed; operational code under development (09/2006-now)

Validate the CRTM for infrared, and microwave under various atmospheric (clear, aerosol, and cloudy sky) and surface conditions is in progress.

4. Leveraging/Payoff:

Implementation of different fast transmittance algorithms into CRTM is very important for the satellite data assimilation. For different satellite sensors, choosing best transmittance algorithm will reduce the forward radiation bias for the analysis data and eventually improve the weather forecast accuracy.

Validation of CRTM under cloudy condition is directed towards use of satellite radiances affected by cloud and rain.

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

Prasanjit Dash – NESDIS Post Doc

Project Title: An Improved SST Product from AVHRR/3 Sensor to be Flown Onboard MetOp-A

MetOp-Background:
The EUMETSAT's Polar System (EPS) started operating a series of polar satellites termed as Meteorological Operational (MetOp) satellites, the first of which, MetOp-2 and after launch renamed to MetOp-A, was launched on October-19-2006. Among other sensors, MetOp-A carries an AVHRR/3 sensor onboard, provided by the US (manufactured by ITT aerospace/communications industries). This is a major collaborative step between NOAA and EUMETSAT toward continued and long-term exploitation of data from AVHRR sensors. Among various AVHRR products, sea surface temperature (SST) determination is crucial and NOAA provides SST using linear split-window technique (SWT) since 1970 and nonlinear SWT since 1990. The aim of this project is to construct, validate, and maintain a 24/7 operational SST processor, along with extensive quality control/quality assurance (QC/QA) of the products. The processing is based on CLAVR-x processor and wisdom of heritage Main Unit Task (MUT), with a number of modifications and improvements. Additionally, unlike before where the split-window coefficients were primarily determined through regression (buoy bulk temperatures and top of atmosphere brightness temperatures), the analysis also includes extensive use of radiative transfer model (RTM) in the thermal infrared in order to analyze the information content of the channels and formulate optimal form of SWT. In what follows, several RTMs are also validated and their bias behavior with respect to geophysical variables is being analyzed. CIRA plays a crucial role by supporting the postdoc program in collaboration with NOAA/NESDIS.

Principal Investigator(s):
Postdoctoral Scientist: Prasanjit Dash
Supervisor: Thomas H. Vonder Haar, CIRA
Principal Technical Advisor: Alexander Ignatov, NESDIS/STAR
Team Members: John Sapper (NESDIS/OSDPD),; Xingming Liang, Dilkushi DeAlwis (CIRA postdoc); Y. Kihai, A. Frolov, B. Petrensko (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.

Key Words: Sea Surface Temperature (SST), MetOp, 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:

Since 1981, the Main Unit Task (MUT) has been the primary processor for deriving sea surface temperature (SST) products in which NESDIS heritage SST algorithms have been implemented. With the advent of MetOp-AVHRR, efforts were and are made to design an optimal processor which will preserve the salient advantages of newer processors, *i.e.*, CLAVR-x and wisdom of the heritage processor, *i.e.*, MUT. The CLAVR(-x) processor. For this purpose, the CLAVR-x is being fine-tuned by the MetOp SST Team at NOAA NESDIS, STAR/OSDPD.

The trimmed version of CLAVR-x is named as ACSPO (AVHRR Clear Sky Processor over Ocean) and its improvement is an ongoing process. The first version of ACSPO (β-ACSPO) output is available.

The major changes in ACSPO, in comparison to its original CLAVR-x version, are:

- 28 modules left in ACSPO out of 65 in original CLAVR-x
- excluded land processing as ACSPO will be dedicated to SST/Aerosol over ocean
- removed cloud retrieval process
- missing scan lines processing logic improved
- CRTM separated out into a library linked to ACSPO rather than integrated
- data compression utility included
- ACSPO output data un-scaled (real numbers rather than scaled integer)
- IMPORTANT NEW MODULE: a Global Quality Control/Quality Assurance (QC/QA) Tool (GQT), developed primarily by P. Dash, is used as a post-processing step to control, analyze, and monitor the SST products. GQT was used for multiple years of MUT SST products and selected ACSPO output. Owing to the generic nature of the tool, it is expected to use the GQT for products from all platforms, in future, e.g. NPOESS.

Objective: Optimal SST processor for MetOp-A and extend them to other AVHRR like processors.

Plans:

-- Release the Global QC/QA Tool (GQT-v1) distribution software in DVD, along with test inputs/outputs, User's Guide, and *submitted publication* (writing is in an advanced stage).

-- Improve the GQT-v1 to GQT-v2; add more reading capabilities for different formats, add SST calibration code, and extend its use by sharing it within the Remote Sensing community. The use can be extended to some other products other than SST, e.g., land surface temperature, aerosol products etc.

--While validating MODTRAN4.2 globally, anomalous behavior of some AVHHR channels were observed, e.g., NOAA-16 AVHRR 3B. It appears as if these anomalies are related to errors in relative spectral response (RSR) of the channel. This is a daunting task and needs detailed analysis of sensitivity of the RSR, based on extensive radiative transfer calculations. Work is currently underway, also in collaboration with other calibration scientists. This needs to be solved and is one of the major research plans. Once solved, the same methodology may be applied to rectify RSR issues from any sensor.

2. Research Accomplishments/Highlights:

Along with a multitude of different tasks, e.g., generating progress report for the whole team (ACSPO vs. MUT comparison, report to coral-reef watch), assisting other co-workers in resolving scientific and technical issues and providing ideas, generating presentation slides, providing utility programs to others upon request, collaborating with other scientists outside team for necessary matters etc., the two major research accomplishments are described below:

Radiative Transfer Modeling and Validation of MODTRAN4.2 :

Extensive validation of the MODTRAN4.2 RTM was performed for 3 AVHRR channels onboard five platforms (NOAA-15 through 18 and MetOp-A). Modeling of brightness temperatures were performed using MODTRAN in conjunction with NCEP GDAS profiles and Fresnel's flat reflective surface. Then modeled brightness temperatures were compared with real AVHRR measurements and the bias (model - observation) was analyzed with respect to latitude, zenith angle, column water content, sea surface temperature, air-sea temperature difference, and gridding parameter (number of observations in each grid). The work is unprecedented in the sense that, data from AVHRR onboard five platforms were analyzed simultaneously on a global scale with focus on improvements to SST applications. The work is recently submitted for publication whose abstract is as follows:

Title: Validation of Clear-Sky Radiances over Oceans Simulated with MODTRAN4.2 and Global NCEP GDAS Fields against NOAA15-18 and MetOp-A AVHRRs

Authors: Prasanjit Dash and Alexander Ignatov (Rem. Sens. of Env.)

Abstract: An accurate and globally representative forward radiative transfer model (RTM) is needed to explore improvements in sea surface temperature (SST) retrievals from spaceborne infrared observations. This study evaluates an RTM based on the moderate resolution transmission (MODTRAN4.2) band model, bounded by a Fresnel's reflective flat sea surface. This model is used to simulate global clear-sky Advanced Very High Resolution Radiometer (AVHRR) nighttime brightness temperatures (BT) from NOAA-15 through 18 and MetOp-A platforms for one full day of 18 February 2007. Inputs to RTM (SST fields and vertical profiles of atmospheric relative humidity, temperature, pressure, and geopotenial height) are specified from the National Centers for Environmental Prediction's (NCEP) Global Data Assimilation System (GDAS) data. Model BTs in AVHRR channels 3B (3.7 µm), 4 (11 µm), and 5 (12 µm) are compared with their respective measured counterparts, available in the NESDIS operational SST files. Ideally, the model BTs should match the observation BTs. However, the modeled

BTs are found to be biased high with respect to the observed AVHRR BTs, in all three channels. The "Model-minus-Observation" (M-O) bias asymptotically decreases towards confidently clear-sky conditions. However, it never vanishes and invariably shows channel-specific dependences on view zenith angle, column water vapor and SST (note that SST correlates with water vapor on a global scale), and air-sea temperature difference. Fuller exploration of the potential of the current RTM (e.g., adding aerosols) or improvements to its input (NCEP SST and atmospheric profiles) may reduce this bias, but they cannot fully reconcile its spectral and angular structure. The fact that the M-O biases are closely reproducible for five AVHRR sensors flown onboard different platforms adds confidence in the validation approach employed in this study. We emphasize the importance of establishing a complete and globally adequate forward RTM for the use in SST modeling and retrievals and its comprehensive reconciliation with top-of-atmosphere (TOA) clear-sky radiances measured by satellite sensors and with the global background fields produced by weather prediction models. (copy available upon request per email: prasanjit.dash@noaa.gov)

Geographical distributions of global biases for three channels of AVHRR onboard MetOp-A are shown in
Figure 1.

Example of global biases as a function of air-sea temperature differences for three channels of AVHRRs onboard five platforms are shown in
Figure 2.

Wind-speed effects on global biases for three channels onboard NOAA-18 are shown in Figure 3.

The bias behavior was also analyzed as a function of other variables (SST, Water Content, Latitude) all of which are described in the submission to Remote Sensing of Environment.

For RTM implementation, emissivity for AVHRR channels onboard different platforms is also a required parameter, which was modeled using complex refractive index of water using Fresnel's Law and Snell's Law. Emissivity database is made for AVHRRs onboard NOAA-9 through NOAA-18 and Metop-A and MetOp-B, which may be used by co-workers for implementing other RTMs. Modeled emissivity values and its comparison with other published literature is shown in Figure 4.

Effect of emissivity on top-of-atmosphere brightness temperature was also quantified, as shown in Figure 5.

This work is a major breakthrough in global modeling of satellite measurements using time-consuming and not-so-user-friendly RTM, the MODTRAN4.2, which is considered as an RTM standard in the SST community. The work also established a solid approach, which can be used to validate any other RTM, e.g., the NOAA community RTM (CRTM).

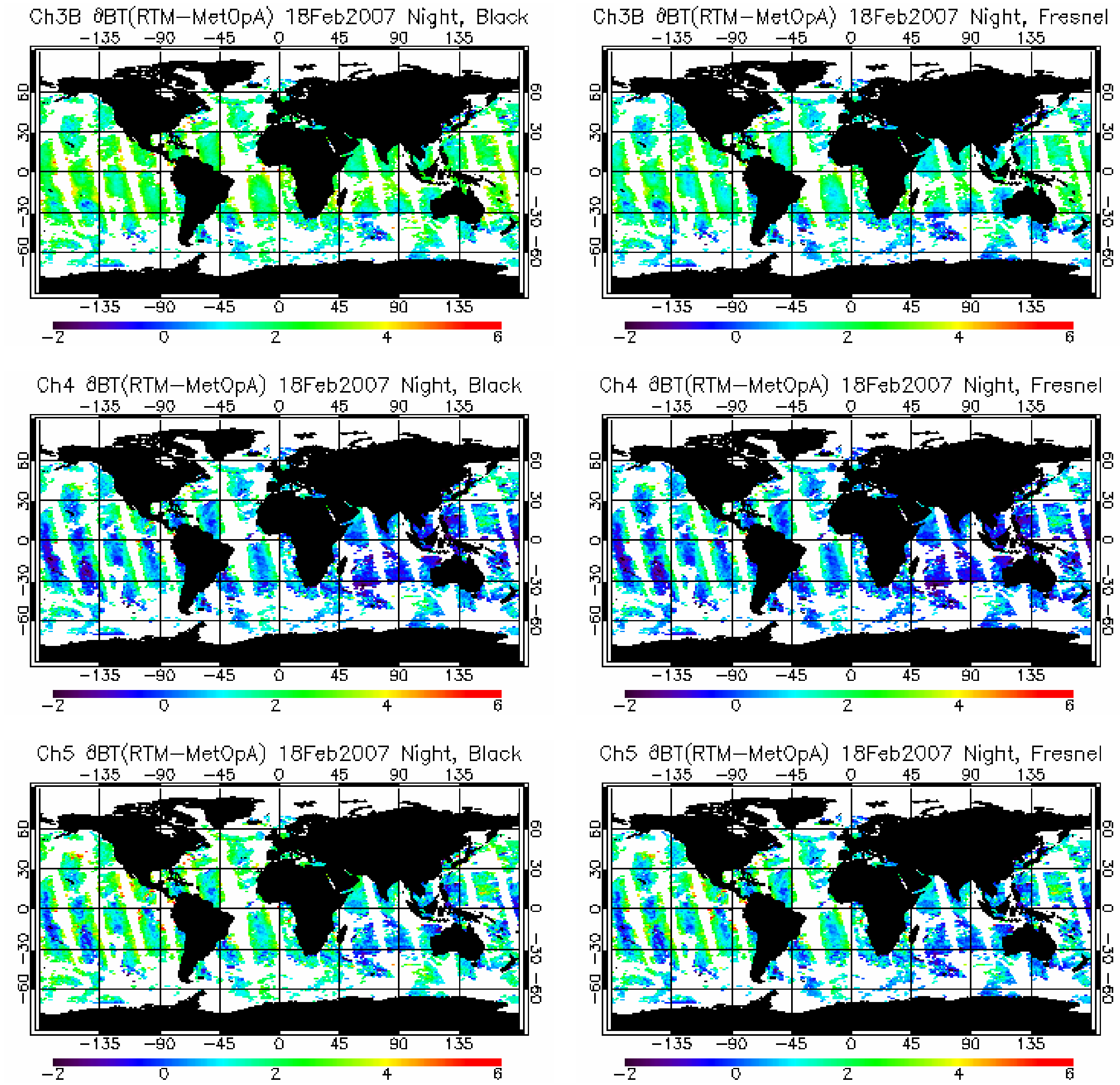


Figure 1. Nighttime M-O bias in MetOp-A AVHRR channels 3B, 4, and 5 on 18 February 2007. Left panel: black surface; right panel: Fresnel's surface. Land mask is rendered in black and areas with no AVHRR data in white. Note that the RTM tends to be biased high with respect to AVHRR in all channels. The bias shows zonal trends and increases towards the edge of the scan. Bias is smaller for Fresnel's than for black surface.

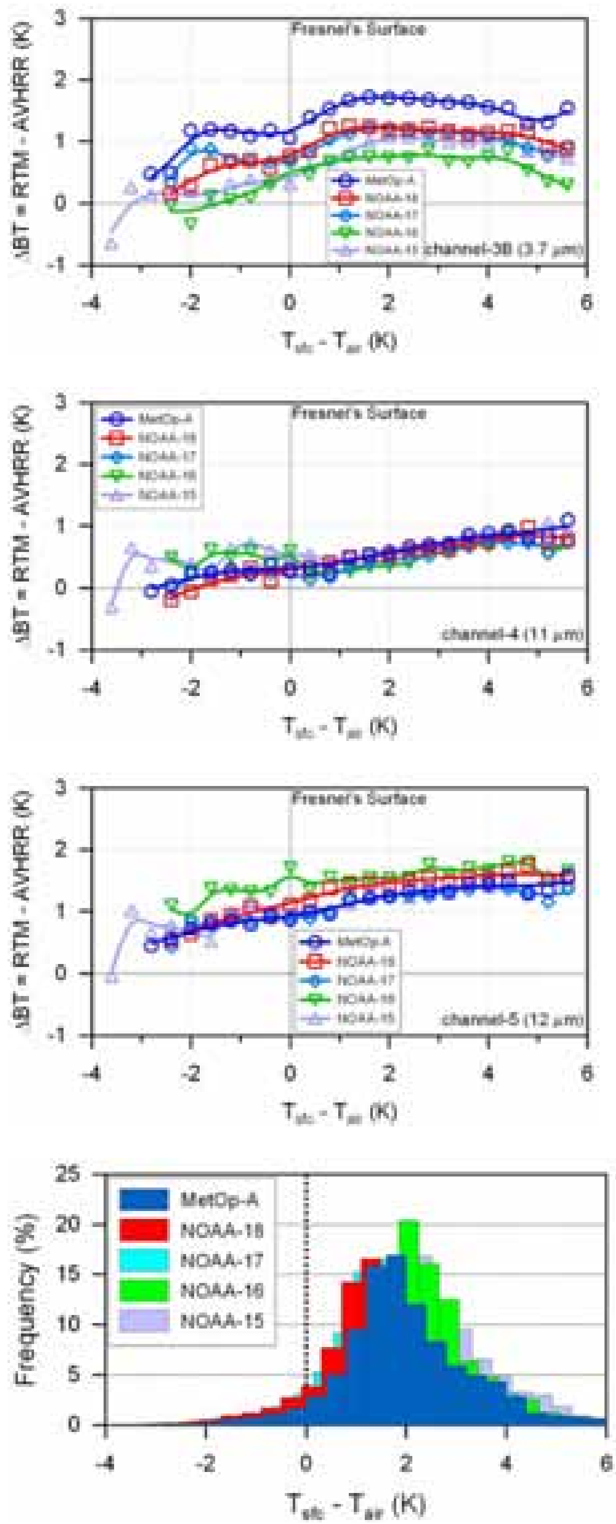


Figure 2. Bias (RTM brightness temperature – AVHRR brightness temperature) as a function of the sea-air temperature difference (T_{sfc}-T_{air}) binned at 0.4 K.

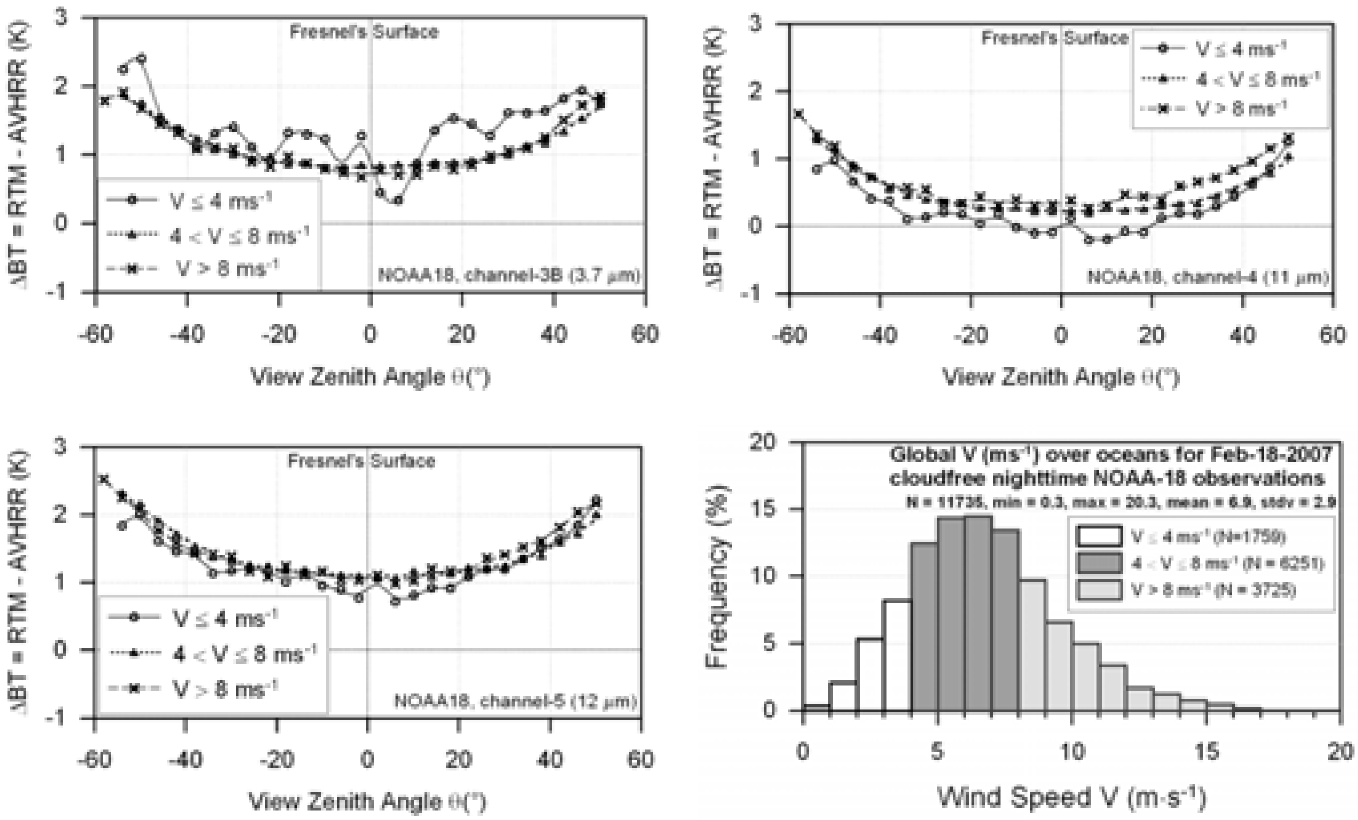


Figure 3. Nighttime M-O bias for NOAA-18 as a function of view angle, θ, for low ($V \leq 4$ ms^{-1}), medium ($4 < V \leq 8$ ms^{-1}), and high ($V > 8$ ms^{-1}) wind speeds on 18 February 2007 in AVHRR channels (a) 3B, (b) 4, and (c) 5. (d) Histogram of near-surface wind speed with the three bins rendered in different shades.

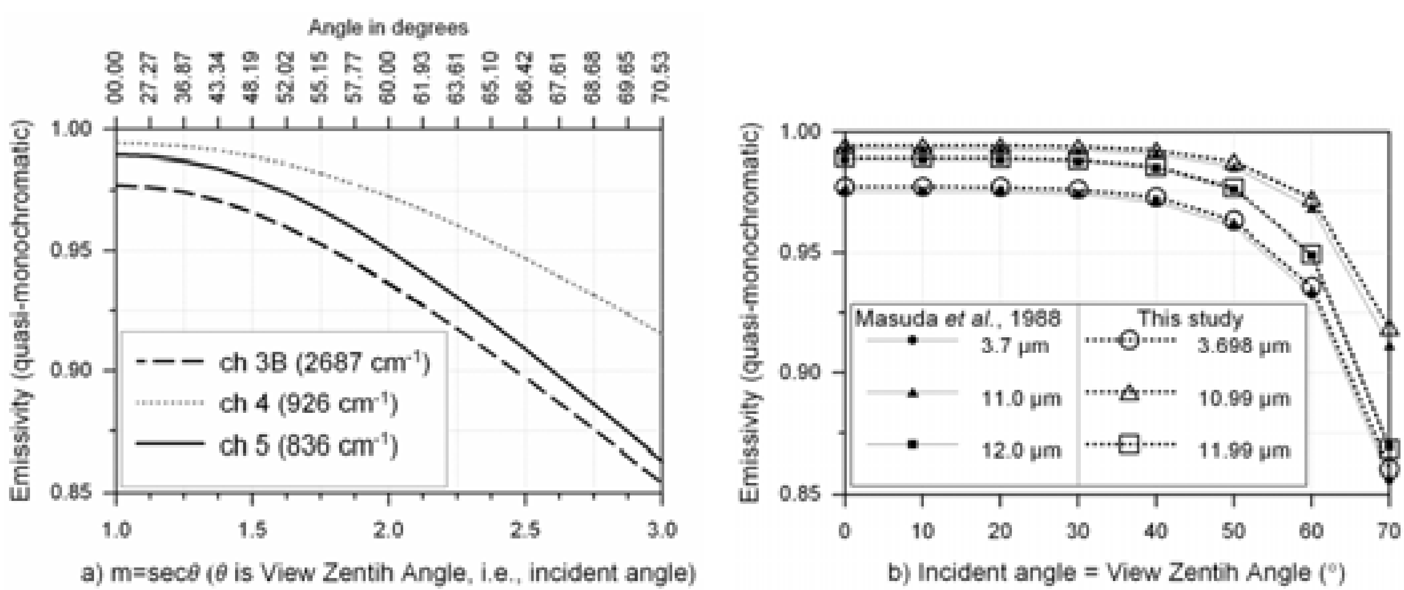


Figure 4. (a) Angular dependence of water emissivity for quasimonochromatic wavenumbers representative of AVHRR channels 3B (2687 cm^{-1}), 4 (926 cm^{-1}), and 5 (836 cm^{-1}). (b) Comparison of emissivities modeled in this study versus corresponding results of Masuda et al. (1988).

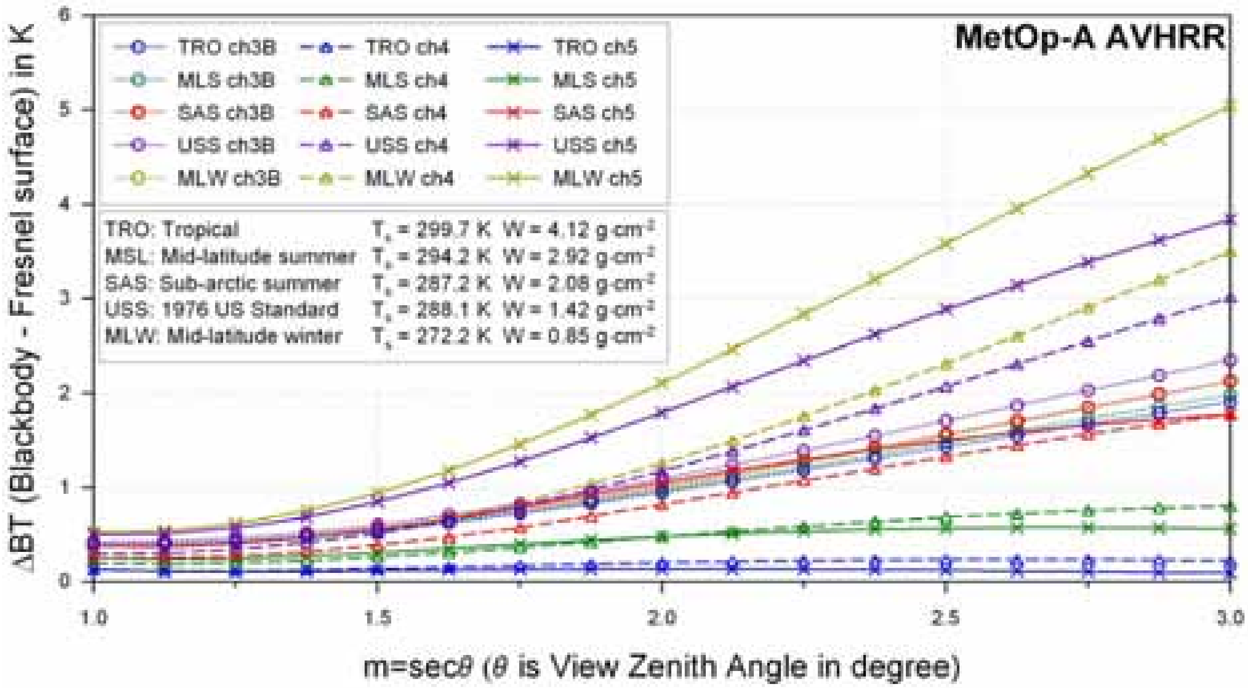


Figure 5. Difference in TOA BT between emissive and blackbody surface, BT(ε=1) – BT(ε=modeled), for five model atmospheres and three channels of MetOp-A AVHRR.

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. The tool is used 24/7 on the heritage SST processor. GQT checks for intra-consistency of the Global SST products and also inter-compares products from different platforms. Development of code is complete (GQT-v1). It takes input via configuration files UNIX scripts are used for operational purposes (cron jobs).

The GQT was employed on several years of SST products from NOAA-15 through NOAA-18 AVHRR. The results will be reported at the EUMETSAT/AMS 2007 Joint Conference and also in a manuscript for peer-reviewed publication is in an advanced stage. A brief summary is provided below:

Title: An automated Global Quality Control/Quality Assurance Tool (GQT) for sea surface temperatures

Summary: National Oceanic and Atmospheric Administration (NOAA) operational sea surface temperature (SST) products are customarily calibrated and validated against *in situ* SSTs from buoy data. However, the match-ups are sparse, geographically biased, and non-uniform in space and time. Additionally, *in situ* data are collected from many independent sensors, and their quality may be suboptimal and non-uniform. Also, space-time mismatch may introduce additional uncertainty in the customary SST calibration/validation. Hence, comprehensive quality control and assurance of the global product are needed, as a supplementary step. This is best achieved by statistical analysis of SST anomalies with respect to a reference state of the retrieved parameter, *i.e.*, SST.

This work describes the development and implementation of a global near real-time quality control/quality assurance (QC/QA) processor based on a set of statistical self- and cross-consistency checks. The Global QC/QA Tool (GQT) relies on the analysis of SST anomalies with respect to three reference states: Bauer-Robinson 1985 climatology, Reynolds SST, and Pathfinder AVHRR Climatology data. The SST anomaly is expected to be normally distributed, although the SST global distribution is known to be highly asymmetric. Analyses are made in both pixel-level and gridded-level; the former is significant for identification of sudden malfunctioning and the latter is significant for evaluating average performances of processor/algorithm. The diagnostics are based on the analyses of the histograms of the anomalies, statistical analysis of the first four moments of the normal distribution (mean, standard deviation, skewness, and kurtosis), and plots of their time-series. In addition, trend plots are used to detect artificial dependency of SST anomaly upon observational conditions (*e.g.*, latitude, view, sun, or glint angles). An extensive effort was also made towards identifying and mapping outliers (unrealistic retrievals) by analyses of statistical extremes based on mean and standard deviations. Future improvement in the outlier detection is also under consideration by employing other approaches.

Several years of NOAA 16 through 18 AVHRR SST data were analyzed and inter-compared. The anomaly histograms from different platforms are typically consistent, with a mean bias of *ca*. 0.3 K and an RMSD of *ca*. 1.0 K with respect to Bauer-Robinson 1985 climatology. Upon successful testing with MetOp SST retrievals offline, the GQT will be implemented at NOAA NESDIS to operationally monitor the quality of all AVHRR SST products, and in the future, of NPOESS/VIIRS and GOES-R/ABI SST products. We emphasize that the GQT is not a substitute for the customary validation procedure against *in situ* data. Rather, it is a useful supplement to it, which provides a robust diagnostic tool for detecting any anomalies in the global SST retrievals (due to *e.g.* malfunctioning of the instrument, residual cloud, or deficiencies in the SST retrieval algorithm), in near real-time.

GQT works on both pixel-level and gridded level data as mentioned above. Figure 6 provides a schematic representation of GQT functionalities and outputs from pixel-level and from gridded-level analysis.

A distribution DVD (Digital Versatile Disk) of the GQT-v1 software is being made (advanced stage), which will also comprise a set of input and test output data, a user’s guide, and a copy of the submitted manuscript. The distribution DVD, once released, can be made available to the community upon request. The contents of the software DVD are shown in Figure 7.

The files with names ‘*.pro’ are the IDL codes which perform specific tasks in pixel-level processing, gridding, and gridded-level processing. The functionalities of the IDL codes and option to generate specific results can be configured via external ‘configuration files’, named as ‘*.par’. The input directory and output directory specification can be set inside IDL code and also externally in command lines. The IDL codes can also be invoked using UNIX scripts, named as ‘*.sh’, under UNIX environment with pre-installed IDL. These ‘*.sh’ files can also be used at pre-set times, under ‘cron’ system processes, in an operational environment. The ‘./TESTDATA’ folder contains samples of compatible inputs and pre-generated outputs. The ‘New Users’ would require generating the outputs after new installation, and subsequently, comparing the newly generated output with the provided output. This is a step to make sure that your installation and understanding of the GQT functionalities are good enough, before using it for further applications. The terms ‘NN’, ‘NM’, ‘NL,’ and ‘NK’ denote NOAA-18, NOAA-17, NOAA-16, and NOAA-15, respectively. Future modifications and more advanced versions of GQT will be based on an ‘add-on’ approach, maintaining its original structure.

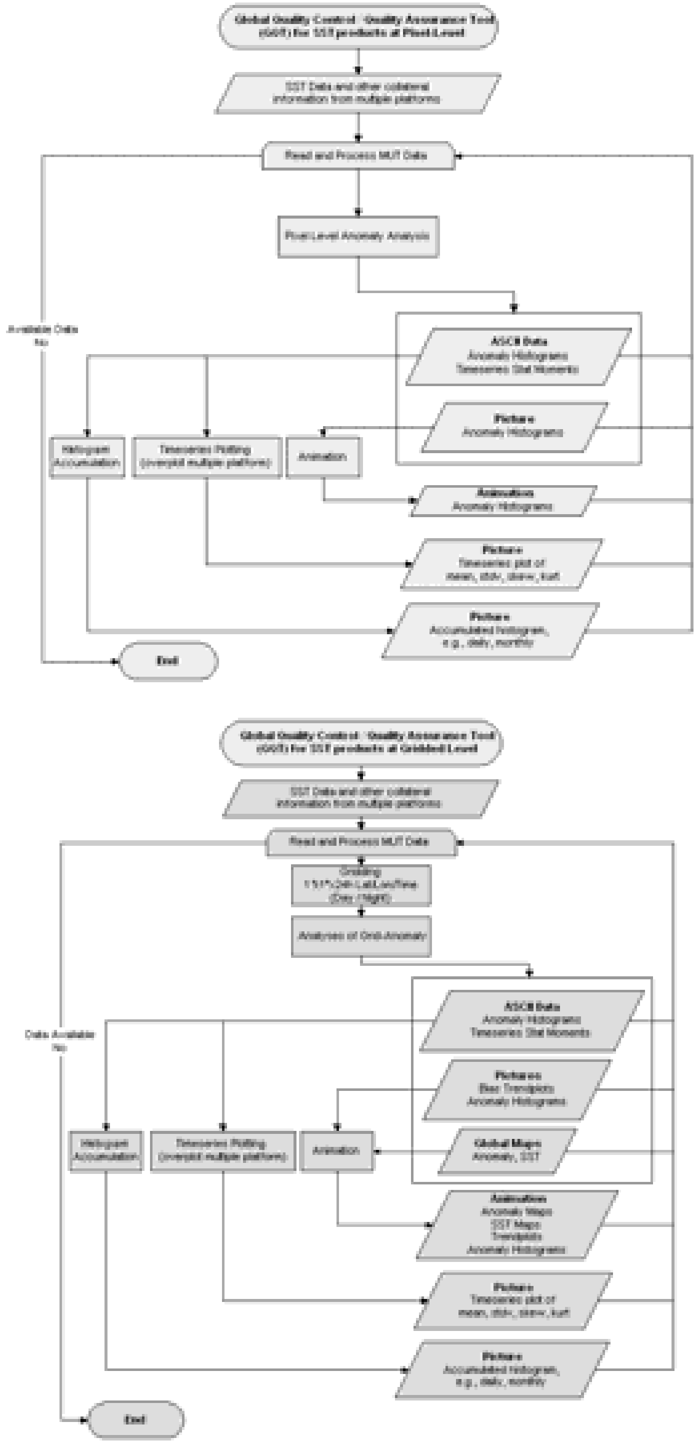


Figure 6. Schematic representation of GQT functionalities. TOP PANEL: pixel-level analysis. BOTTOM PANEL: gridded-level analysis. The input data are from NOAA Main Unit Task (MUT) processor which provides 8-day rotation files with ~8 km spatial resolution of the pixels. Collateral information, *i.e.*, UTC, Lat, Lon, VZA, SZA, day/night flag, RZA, VIS reflectances and TIR BTs, analyzed field SST, and nearest Bauer-Robinson 1985 climatological SST are also appended to SST data. Each of the trapezoids towards the right of the panels represents a particular type of output from the GQT-v1.

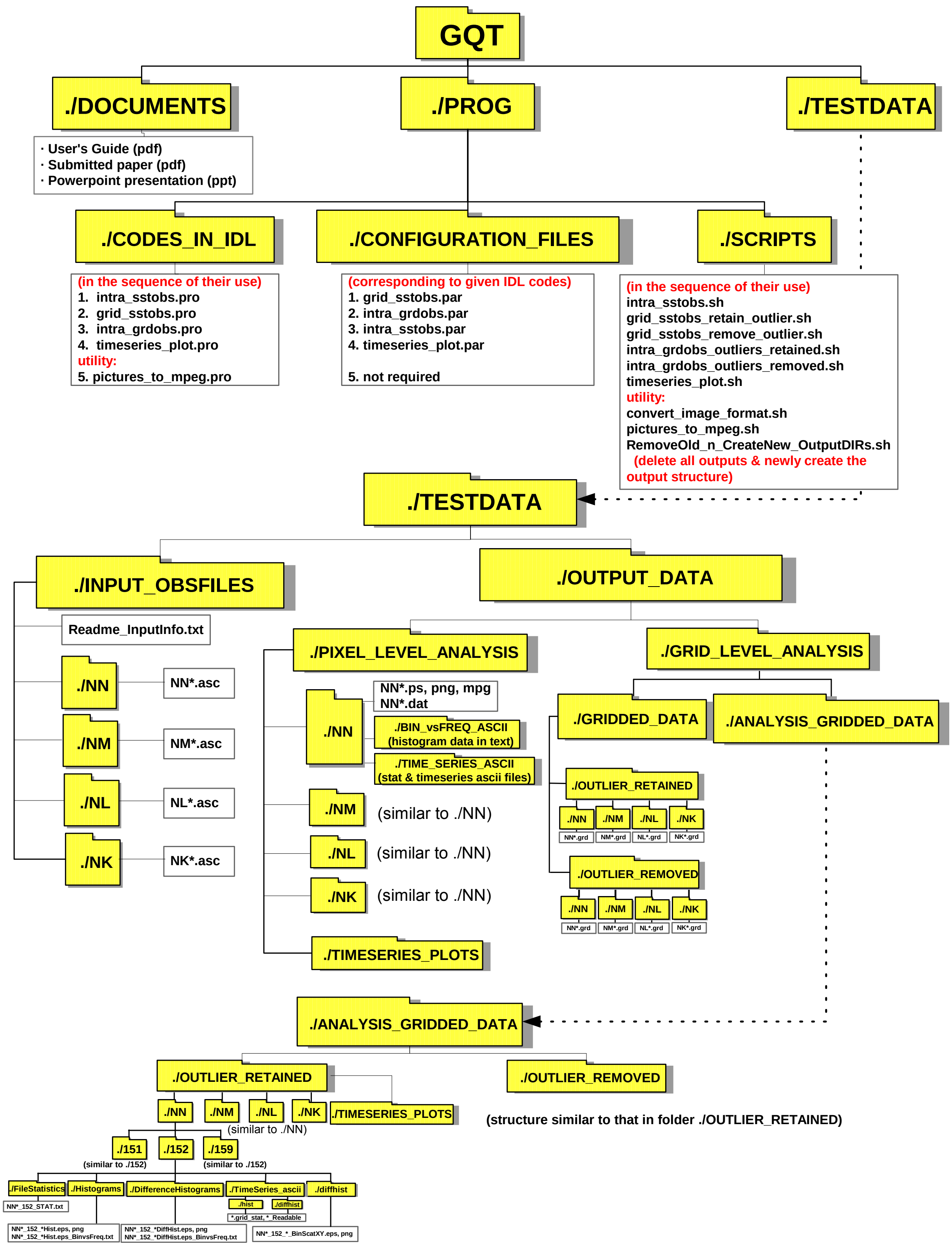


Figure 7. The DIRECTORY and SUB-DIRECTORY structure in the DVD of version 1 of the Global Quality Control/ Quality Assurance Tool (GQT).- version1.

The Global Quality Control/Quality Assurance Tool (GQT) is based on statistical self- and cross-consistency analyses of anomalies in SST against available reference states. In this distribution DVD, the test input datasets contain satellite SST and Bauer-Robinson 1985 climatological reference SST but, functionally, GQT can be tuned by the 'New User' to any available product and reference state. The underlying assumption is: SST anomaly is expected to be quasi-normally distributed, although the SST global distribution is non-Gaussian. The diagnostics are based on analyses of the anomaly histograms, statistical parameters of normal distribution (mean, standard deviation, skewness, and kurtosis), and plots of their time-series. Anomalies are analyzed at both pixel-level and gridded-level. Pixel-level analysis aids in identification of malfunctioning in the processor (sensor, dataflow error *etc.*), and cross-platform product comparison and the latter is significant for evaluation of average performances of SST processors. In gridded level, also trend-plots (anomaly vs. correlating parameters) are used to detect imposed algorithm dependence upon observational conditions *e.g.*, view zenith angle.

The tool was also used to extensively compare SST products from CLAVR-x processor and the heritage MUT processors. The analysis results were distributed as an internal document.

Figure 8 shows the time series of global mean, standard deviation, skewness, and kurtosis of SST anomalies (satellite SST – expected state) for 3 platforms: NOAA-16, 17, and 18 (left panel: daytime, right panel: nighttime).

Figure 9 shows global nighttime SST anomaly maps of NOA-18 AVHRR, with respect to Bauer-Robinson 1985 climatological SST. The data are gridded from MUT SSTOBS file for the period of Apr-09-2007 to Apr-18-2007 and outliers were removed at the pixel-level using 'mean $\pm$ 4 $\times$ standard deviation' condition. The zonal distributions of SST and SST anomalies are shown adjacent to the corresponding global maps. Bias maps are optionally generated using GQT while processing each GRDOBS file and time series of maps are animated for visualization and monitoring purposes.

Figure 10 shows NOAA-18 AVHRR SST anomalies as a function of VZA for 8 days of nighttime data from Apr-09-2007 to Apr-18-2007.

The analysis of the results as well as the tool development and implementation should be published in a peer-reviewed journal. The finalized version of the document will be shared in due time. The distribution DVD can also be shared upon request, after it is finalized and released. Additionally, improvements to GQT-v1 are underway. This also will include SST calibration code (developed and being tested), which will make the GQT-v2 a (almost) complete SST application and analysis tool.

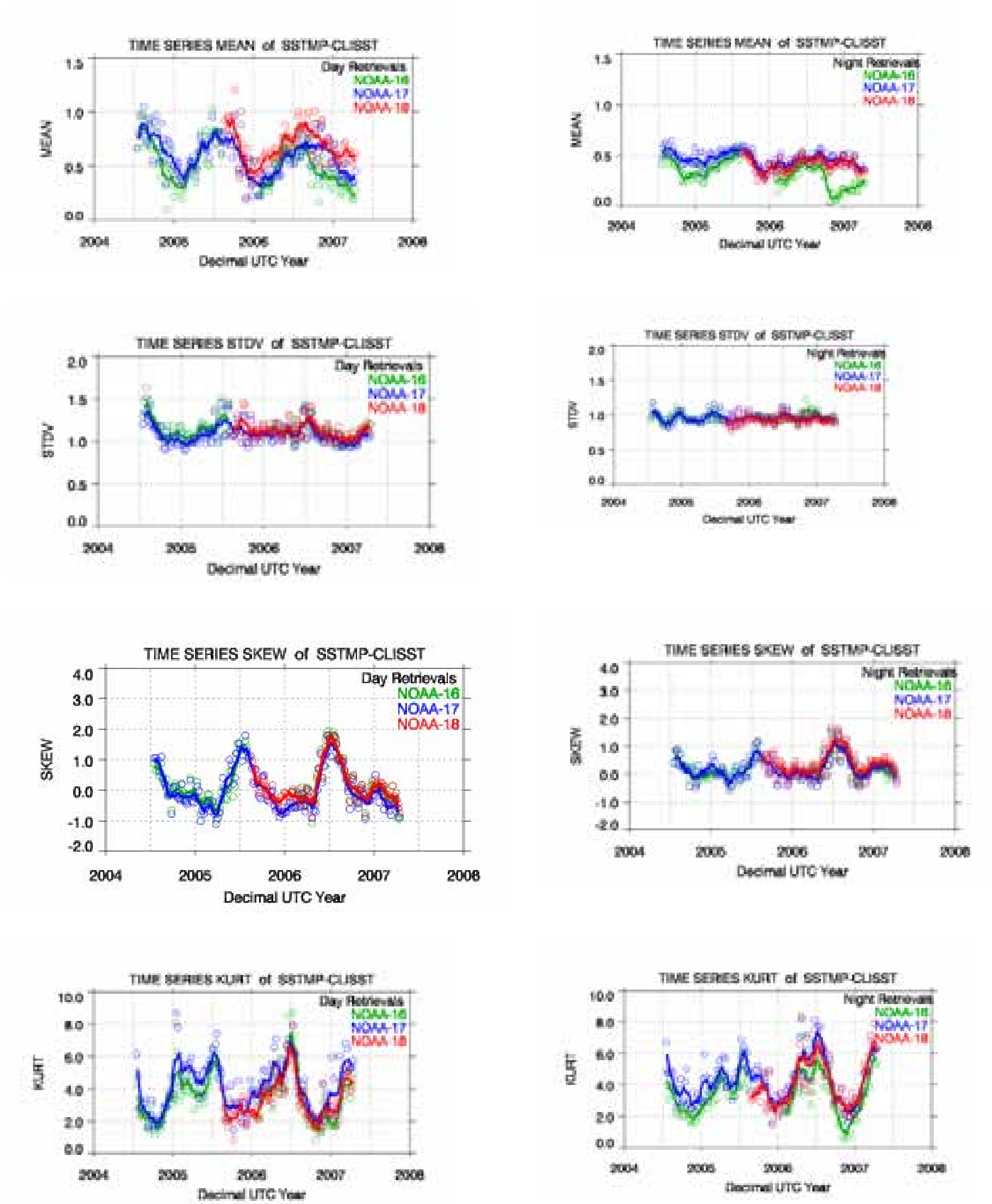


Figure 8. Time series of mean, standard deviation, skewness, and kurtosis of anomalies (satellite SST – expected state SST) for 3 platforms (NOAA-18, 17, 16). Left panel: Daytime anomalies, Right panel: Nighttime anomalies. Each point represents 8 days of global data (~ 500000).

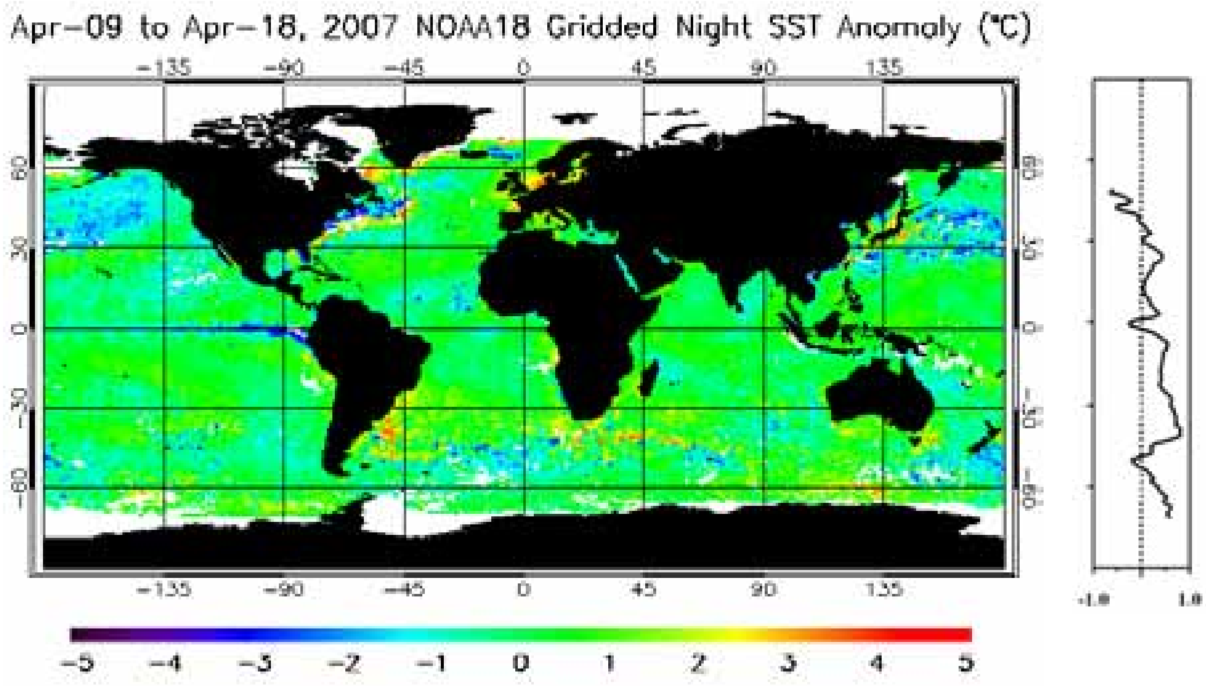


Figure 9. Gridded global gridded anomaly map of NOAA-18 AVHRR nighttime retrievals for 8-days' data from Apr-09-2007 to Apr-18-2007. (anomalies in °C with respect to Bauer-Robinson 1985 climatological SST). Before gridding, the outliers were removed in the pixel-level based on 'mean ± 4 × standard deviation' criterion. Average zonal distribution of SST and anomalies of SST are shown to the right of the corresponding maps (a demonstration of GQT-v1 map-plot module).

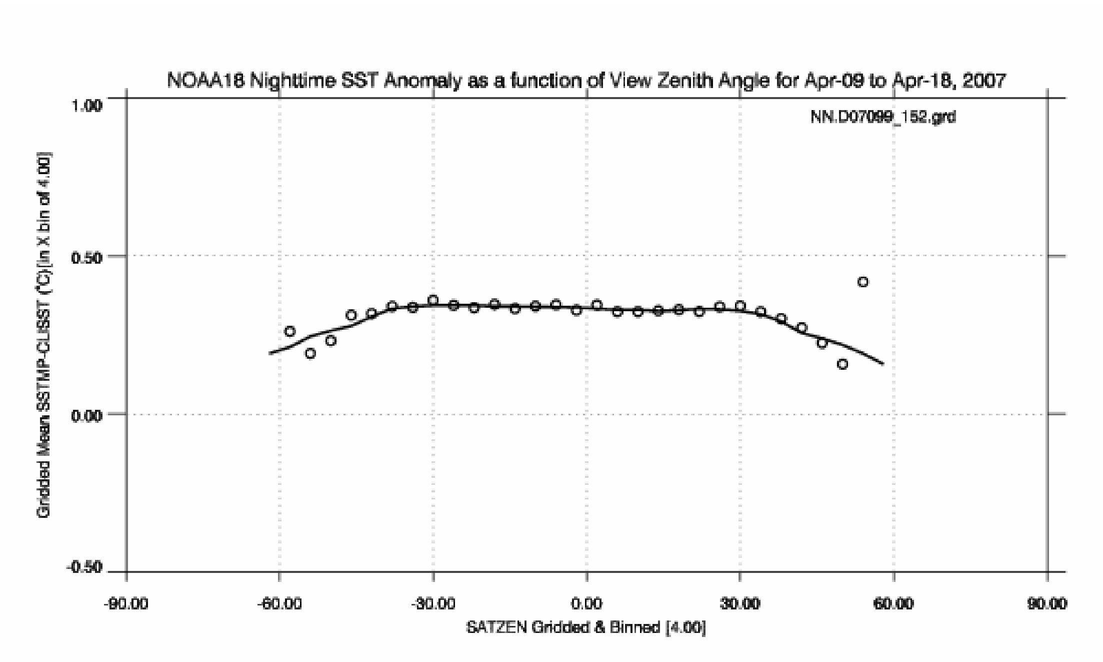


Figure 10. Trend in the mean gridded SST nighttime anomalies as a function of view zenith angle for NOAA-18 AVHRR (a demonstration of GQT-v1 trend-plot module).

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

Radiative Transfer Modeling and Validation:

Completed validation of MODTRAN4.2 and established a generic approach which can be used to validate any other RTM.

Quality Control / Quality Assurance Tools:

Completed the GQT-v1, which soon will be submitted for publication and the software will be officially released for distribution purposes in due time.

Analyze products from current MUT system for time-series (e.g., 1 year):

Completed using GQT-v1.

Emissivity variation with angle, wind-speed:

Finished modeling of emissivity using complex refractive index of water applying Fresnel's Law and Snell's Law. Effect of wind was also analyzed.

Publish the results in the community:

RTM validation results are submitted for peer-reviewed publication.

4. Leveraging/Payoff:

To understand 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, Communication and Networking:

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).

6. Awards/Honors: Not during the reporting period

7. Outreach Not during the reporting period

8. Publications:

Journal

Submitted: Validation of Clear-Sky Radiances over Oceans Simulated with MODTRAN4.2 and Global NCEP GDAS Fields against NOAA15-18 and MetOp-A AVHRRs (submitted to the Remote Sensing of Environment, Dash & Ignatov)

Near-future: An automated Global Quality Control/Quality Assurance Tool (GQT) for sea surface temperatures (*advanced stage of writing and provided first draft to tech. supervisor; finalization depends on his comments/approval*).

Conference/Symposium:

EUMETSAT/AMS 2007: "Global QC/QA Tool (GQT-v1) for SST products" and some other co-authorship to AGU etc.

Dilkushi deAlwis – NESDIS Post doc

Project Title: Document and Improve the NESDIS Heritage AVHRR Sea Surface Temperature Calibration/Validation System

Background:
National Oceanic and Atmospheric Administration (NOAA) satellites provide repetitive daily global coverage of the Earth. Since the early 1980s, the National Environmental Satellite, Data, and Information Service (NESDIS) has been operationally generating Sea Surface Temperature (SST) products from the Advanced Very High Resolution Radiometers (AVHRR), which are onboard several NOAA platforms. Globally, AVHRR data are merged with *in-situ* SSTs in a space and time window of 4 hr and 25 km to create monthly match-up files. Early in each satellite's mission, these match-up files were used to calibrate the SST algorithms (i.e., calculate coefficients in the SST regression equations) and then to validate routinely the SST products throughout the operational lifetime of the platform.

The primary objectives of this project are to describe and document the heritage NESDIS AVHRR SST Calibration/Validation (Cal/Val) system and identify potential improvements to the system. Since *in-situ* SSTs are strongly contaminated due to instrument malfunction or erroneous data acquisition and relay, quality control of the match-up dataset is critically important for ensuring proper calibration and validation of the satellite SST products. Identifying robust methods for outlier removal and documenting its sensitivity to the validation statistics is also a crucial part of the project.

Principal Investigators :
Postdoctoral Scientist: Dr. Dilkushi de Alwis (NESDIS/CIRA)
Supervisor: Prof. Thomas H. Vonder Haar, CIRA
Principal Technical Advisor: Dr. Alexander Ignatov, (NESDIS/STAR)
Team Members: Mr. John Sapper (NESDIS/OSDPD; Dr. Prasanjit Dash (NESDIS/CIRA); Dr. Bill Pichel (NESDIS); Mr. Yury Kihai (QSS contractors); Dr. Alexander Frolov (QSS contractors); Dr. Xingming Liang (NESDIS/CIRA); Dr. Boris Petrenko (QSS contractors)

NOAA Project Goal: Climate: Improve the climate observations and analysis by enhancing the accuracy of the calibration/validation system with scientifically grounded quality control criteria.

Key Words: Sea Surface Temperature (SST), MetOp, AVHRR, Calibration/Validation of SST Products, QC/QA Tools for SST, Outlier Analysis

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

Objective 1: Understand, document and replicate the heritage Cal/Val system
Plans:
--Collect all available documentation and flowcharts and assemble the system together in order to understand the heritage Cal/Val system.

--When documentation and flowcharts are not available, interpret the appropriate programs to derive flowcharts.
Archive all match-up data within NESDIS for 3 NOAA platforms (16, 17, and 18) and set up an offline system to process these data.
Understand and replicate all programs written for the heritage system to execute it in an automated manner.

Objective 2: Suggest improvements to the Cal/Val system and observe its long term implications
Plans:
--Design a semi-automated system (Research mode) to be run offline, which will closely replicate the operational mode. Conduct several case studies to study the long term implications of quality control criteria on validation statistics. Present the validation statistics obtained from case studies at SST quarterly meetings and regular weekly MetOp SST meetings.
-- Integrate a quality control/quality analysis tool to the Cal/Val system
--Design a tool for outlier analysis of physical datasets
--Integrate an automated outlier mapping tool

Objective 3: Design a Cal/Val system to be executed in an operational mode to run in parallel to the heritage system
Plans:
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.

Objective 4: Obtain global statistics pertaining to spatial/temporal variability
Plans:
--Evaluate spatial and temporal statistics pertaining to satellite, in-situ and ancillary parameters.
Objective 5: Screen in-situ data at global scale to identify malfunctioning buoys prior to the integration of the system
Plans:
--Screen in-situ data based on its historical performance and neighboring in-situ data.

Objective 6: Conduct quarterly Cal/Val meetings
Plans:
--Organize quarterly meetings and brain storming sessions. Present and discuss results.

2. Research Accomplishments/Highlights:

--Designing a fully automated system for Cal/Val

One accomplishment over the past year was collecting and systemizing all match-up data from 3 NOAA platforms (16, 17, and 18) and designing automated offline Cal/Val systems to process the data that replicate the heritage system. In the process of replicating the heritage system, some bugs were identified and corrected. Some unjustifiable restrictive screening criteria were also identified in the system and replaced with scientifically grounded quality control criteria. By successfully eliminating the bugs and replacing the stringent screening criteria of the heritage system, we were able to recover the records that were discarded in the heritage system. Shown in figure 1 is the flowchart of the automated Cal/Val system.

--Outlier analysis of physical datasets

An IDL tool was developed to conduct outlier analysis using five methods. The tool outputs the statistics after outlier removal, and a temporal screening criterion that is instrumental to selecting the most appropriate outlier removal method specific to the data. Based on this tool a new technique of outlier detection based on L-moments was identified for SST match-up data and applied to the Cal/Val system. Shown in Figure 1 is the mean and RMSD of Satellite – *in situ* SST anomaly of raw data before removing outliers. Shown in Figure 2 is the mean and RMSD of Satellite – *in situ* SST anomaly of the screened data after removing outliers based on L moments. We observed that by removing less than 3% of records using an appropriate outlier identifier, the RMSD was reduced to vary within the range of 0.43°C and 0.62°C during the daytime and 0.39°C and 0.61°C during the nighttime.

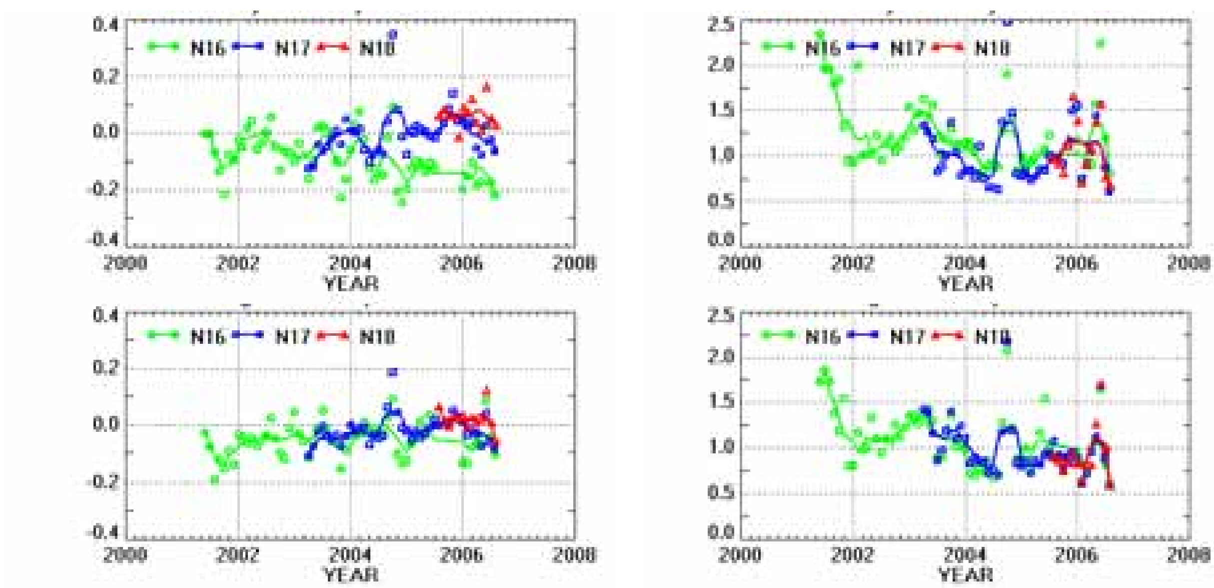


Figure 1. Mean (left panel) and RMSD (right panel) of time series of satellite SST − in situ temperature anomaly of NOAA 16-18 (denoted by green, blue and red) before any quality control steps. The top panel represents all data pertaining to day time and the bottom panel represents data pertaining to night time. Each point on the graph represents one month's match-up data file.

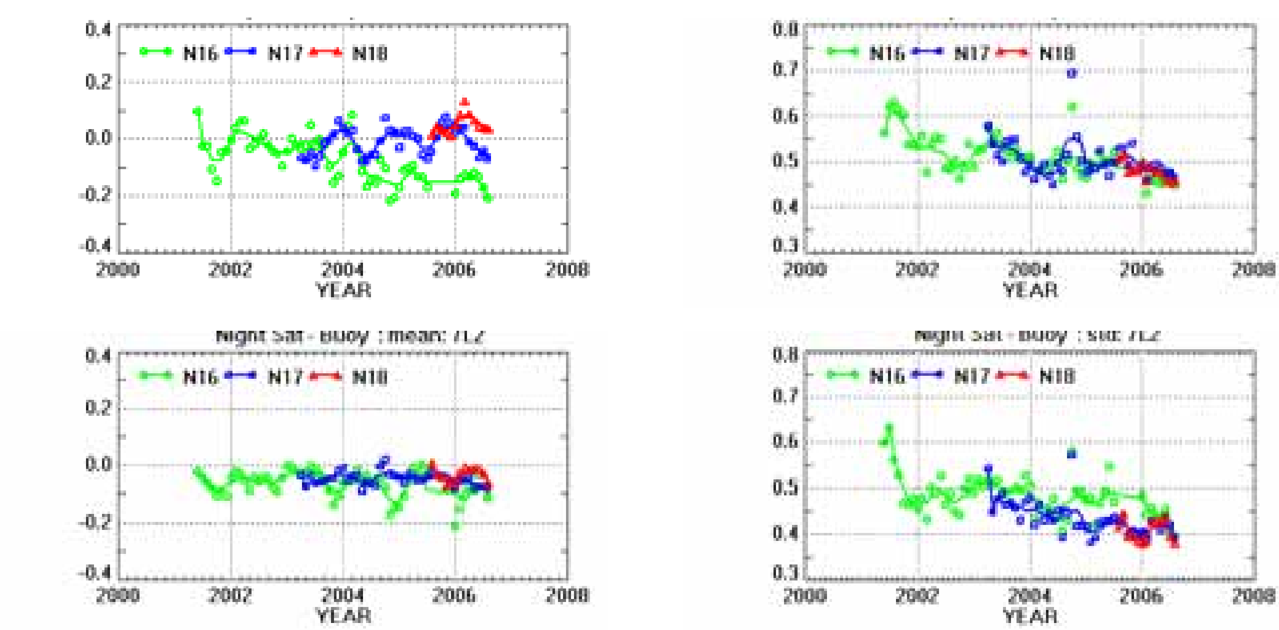


Figure 2. Mean (left panel) and RMSD (right panel) of time series of satellite SST − *in situ* temperature anomaly of NOAA 16-18 (denoted by green, blue and red) after quality control using an outlier identifier based on L-moments (L1 ± 7 L2). The top panel (a, b) represents all data pertaining to day time and the bottom panel (c, d) represents data pertaining to night time. Each point on the graph represents one month's match-up data file.

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

Objective 1:
Most of the heritage system was not well documented and the available flowcharts were obsolete. A flowchart of the heritage Cal/Val system was largely derived by the "reverse-engineering" of the insufficiently documented heritage code. The heritage system was automated up to the creation of the match-up files; Cal/Val analyses of the match-up data were done manually and involved many subjective elements. In the process of replicating the heritage system, some bugs were identified and corrected. Some unjustifiable restrictive screening criteria were also identified in the system. The stringent selective criteria and the programming bugs greatly impacted the number of observations and led to overly optimistic validation statistics. Several case studies were conducted in order to enhance/improve the heritage system with scientifically grounded quality control criteria. Some intermediate results and flowcharts were presented at the internal (e.g. Preliminary Design Review) and external programmatic and management meetings.

Objective 2:
Two systems (research-mode system and pre-operational-mode system) were implemented as an extension of the heritage system, which generates the match-up data sets and Cal/Val statistics.
Research-mode: In the semi-automated research mode, which closely replicates the pre-operational mode, several case studies were conducted to study the impact of quality control on validation statistics. The validation statistics obtained from case studies were documented and presented at SST quarterly meetings and regular weekly MetOp SST meetings.

Pre-operational-mode: Initially the pre-operational was a replica (including the bugs) of the heritage Cal/Val system. The improvements in the research system were evaluated against the benchmark pre-operational system, and the pre-operational system was updated as and when outperformed by the off-line research mode.

The system specifics and flowcharts at high level and detailed level were presented at Cal/Val meetings. The Cal/Val results and the details of the heritage system will be submitted as a peer-reviewed publication and presented at national and international conferences and different programmatic meetings.

The research mode studies indicated that the validation statistics were sensitive to the quality control steps; hence the Global QC/QA Tool (GQT) designed by P. Dash was adapted to the Cal/Val system.

The case studies conducted in the research mode indicated that the outliers have a large impact on the validation statistics; different robust methods of identifying outliers were studied in great detail. An outlier analysis tool incorporating 5 outlier analysis methods was designed and results will be discussed in a peer-reviewed publication. An outlier mapping program was designed and integrated to the automotive system.

Objective 3:

Work in progress

Objective 4.

Not yet started

Objective 5.

Not yet started

Objective 6.

Several Cal/Val quarterly meetings/brain storming sessions were 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: Collaborations: CIRA; Partnership: None

6. Awards/Honors: Not during the reporting period

7. Outreach: Not during the reporting period

8. Publications:

Conferences

de Alwis, D. Alexander Ignatov, Prasanjit Dash, John Sapper, , William Pichel, Xiaofeng Li, Yury Kihai Validation of the NESDIS operational Sea Surface Temperature products from AVHRR onboard NOAA 16-18, [2007 AGU Joint Assembly, Acapulco, Mexico 22-25 May 2007]

de Alwis, D. 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. [submitted to AMS Conference in New Orleans, 20-24 January 2008. Fifth GOES users' conference]

Ignatov, A., John Sapper, Dilkushi De Alwis, Prasanjit Dash, Yury Kihai, Xiaofeng Li, William Pichel Ongoing Cal/Val and QC/QA Analyses of AVHRR SST at NESDIS, [VOAT Mtg, NGST Space Spark, CA. 2006 Oct 04]

Journals

Planned Titles:
Towards a robust outlier removal approach using L-moments: Application to AVHRR sea surface temperature global match-up dataset. Dilkushi de Alwis, Prasanjit Dash, Alexander Ignatov [*Journal undecided, MS under prep.*]

Overview of the NESDIS heritage AVHRR Sea Surface Temperature Calibration/Validation system. Dilkushi de Alwis, Alexander Ignatov, John Sapper, Prasanjit Dash, William Pichel, Yury Kihai, Xiaofeng Li [*Journal undecided, MS under prep.*]

Robert C. Hale – NESDIS Post Doc

Project Title: Evaluation of the Effects of Land Use/Land Cover Changes on Observed Climate in the Conterminous United States

Principal Investigator: Kevin P. Gallo/Robert Hale

NOAA Project Goal: Climate – Climate Observations and Analysis

Key Words: Land Use/Land Cover Change, Temperature, Urbanization, Deforestation, Land Cover Trends Project, Reanalysis

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

The over-arching objective of this project is to examine linkages between observed near-surface air temperature and changes in land use/land cover (LULC) over a multi-decadal time period. The Land Cover Trends Project at the USGS-EROS is currently analyzing LULC and its change in 10 km by 10 km or 20 km by 20 km sample blocks located within the 84 Level III ecoregions of the conterminous U.S. By utilizing results from the Land Cover Trends Project and records of daily maximum, minimum, and average temperature from U.S. Climate Normals stations located within or near these sample blocks, correlations between type and/or amount of LULC change and trends in local or regional climate are being studied. Comparisons are also being made with datasets of reanalysis-derived surface temperatures in an effort to isolate the LULC effects from other climatological influences.

2. Research Accomplishments/Highlights:

To date, the Land Cover Trends Project has completed analysis of 35 of 84 ecoregions, encompassing 963 sample blocks. Of these 963 sample blocks, 829 (occurring in 31 ecoregions) have been intersected with 10-km buffer zones surrounding the 5332 Climate Normals stations of the conterminous U.S. This intersection yielded 526 stations occurring within 10 km of Trends sample blocks. Dominant LULC change type, amount, and time period of change have been determined for each of these 526 stations. In addition, trends in minimum, maximum, and average temperature at these 526 Normals stations have been analyzed, and potential associations of these trends with nearby changes in LULC have been examined. It was found that significant trends were relatively few in number and evenly divided between warming and cooling trends before periods encompassing the greatest nearby land cover/land use change. After these periods, however, significant temperature trends were far more common, and nearly all were warming trends. These findings, which expanded upon results initially reported in *Geophysical Research Letters*, are being published in two new journal articles.

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

Identify U.S. Climate Normals stations located within or near study sites of the first 31 ecoregions completed by the Land Cover Trends Project – Completed

Document the land use/land cover changes that have occurred within 10 km of the U.S. Climate Normals stations identified in (1) for the nominal 1973-2000 period – Completed

Determine trends in minimum, maximum, and average temperature at these stations – Completed

Evaluate linkages between temperature trends and land use/land cover changes – Completed

Expansion of analyses to four ecoregions newly completed by the Land Cover Trends Project and subsequently completed ecoregions – In progress

Comparison of Normals observed temperature trends and means to reanalysis-derived near-surface temperatures to separate LULC effects on temperature trends from other effects – In progress

4. Leveraging/Payoff:

Developing an understanding of how land use/land cover change may affect regional climate is critical to appropriate climate change attribution, and thus to decision-making and public policy.

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

Collaborative effort between the Office of Research and Applications, NOAA/NESDIS (principal investigator K. P. Gallo), the USGS National Center for EROS (co-investigator T. R. Loveland), the National Climatic Data Center (co-investigator T. W. Owen), and CIRA/Colorado State University (postdoctoral research associate R. C. Hale).

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Hale, R. C., K. P. Gallo, T. W. Owen, and T. R. Loveland (2006), Land use/land cover change effects on temperature trends at U.S. Climate Normals stations, *Geophysical Research Letters*, 33, L11703, doi:10.1029/2006GL026358.

Pielke R. A., Sr. and coauthors (2007), Documentation of uncertainties and biases associated with surface temperature measurement sites for climate change assessment, *Bulletin of the American Meteorological Society*, 88, doi:10.1175/BAMS-88-6-913.

Pielke R. A., Sr. and coauthors (2007), Unresolved issues with the assessment of multi-decadal global land-surface temperature trends, *Journal of Geophysical Research*, in press, doi:10.1029/2006JD008229.

Min-Jeong Kim – NESDIS Post Doc

Project Title: GOES-R Proxy Data Management System for AWG Algorithm Assessments, Testing and Developments

Principal Investigator: Dr. Fuzhong Weng

NOAA Project Goal: Supporting NOAA's Mission (programs: geostationary satellite acquisition

Key Words: GOES-R, Radiative Transfer, CRTM, OSSE, Global Forecasting System, Data Assimilation, GSI

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

Long-term Objectives:

Generation of the GOES-R ABI proxy data set applicable for all sky conditions using the Community Radiative Transfer Model (CRTM)

Set up the GOES-R proxy data management systems

Set up GOES-R Observing System Simulation Experiment (OSSE) Framework

Developing the cloudy radiance data assimilation system for NOAA operational forecasting models

GOES-R impacts assessment report

Specific Plans:

To accomplish objective 1:

Computing of ABI radiances using mesoscale model and global forecasting model simulations

Finding the correlations between SEVIRI and ABI measurements

Generating the ABI proxy data set from SEVIRI observations

To accomplish objective 2:

Set up the required templates

Report the research progress for all detailed tasks to GOES-R program office every month

To accomplish objective 3:

Set up 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)

To accomplish objective 4:

Understanding the GSI infrastructure thoroughly

(1) Collecting/reviewing references and (2) contacting/communicating relevant researchers for cloudy radiance assimilation. (e.g. check out the histories, the current status, and challenges of cloudy radiance assimilations in the ECMWF and in the NOAA NCEP)

Set up the strategies to include the cloudy radiance assimilation components in current GSI system

Improving the framework by testing runs (trial and error)

To accomplish object 5:

Employing the ABI proxy data sets 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 the monthly report template in Microsoft Word format and the project progress sheet in Microsoft Excel format have been set up for proxy data team. I have been updating the status of project progress using these forms and send them to the GOES-R program office.

WRF_NMM model has been set up in the local linux machine. The subtropical cyclone "Andrew" hitting the US on May 9th, 2007 has been simulated successfully.

The GSI and GFS model have been set up in a NCEP IBM machine.

2 days forecast using current operational GSI+GFS forecasting models have been implemented successfully.

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

Objective 1: Generation of the GOES-R ABI proxy data set 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: Set up GOES-R Observing System Simulation Experiment (OSSE) Framework

Completed

Objective 4: Developing the cloudy radiance data assimilation system for NOAA operational forecasting models

In progress

Objective 5: GOES-R impacts assessment report

Not yet started

4. Leveraging/Payoff:

This research will benefit the Public by improving weather forecasting skills especially for severe storms.

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

Partnerships with GOES-R Algorithm Working Groups such as CIMSS, NRL, NESDIS, CICS, and NASA LaRC

Collaborating with scientists in JCSDA for OSSE tasks

6. Awards/Honors: AMS full membership

7. Outreach:

Poster presentation in AMS annual meeting in San Antonio, TX

Invited talk in International workshop on “Precipitation retrieval algorithm using satellite microwave radiometer, radar, and IR data” in Tokyo, Japan

Oral presentation in GOES-R AWG Annual Meeting

8. Publications:

Kim, Min-Jeong, J. A. Weinman, D.-E. Chang, Skofronick-Jackson, J. R. Wang, and W. Olson, 2007: A physical algorithm to estimate snowfall using spaceborne microwave measurements, J. Geophy. Res. (Accepted)

Skofronick-Jackson, G., E. Holthaus, C. Albers, and Min-Jeong Kim, 2007: Nonspherical and spherical characterization of ice in Hurricane Erin for wideband passive microwave comparisons J. Geophy. Res. (Submitted)

XingMing Liang – NESDIS Post Doc

Project Title: Physical SST retrieval for NOAA /AVHRR, GOES-R/ ABI

Principal Investigator(s):
Postdoctoral Scientist: Dr. XingMing Liang
Supervisor: Prof. Thomas H.Vonder Haar, CIRA
Principal Technical Advisor: Dr. Alexander Ignatov, NOAA/NESDIS/STAR
Team Members: John Sapper (NESDIS/OSDPD), Yury Kihai; Alexander Frolov(QSS contractor); Prasanjit Dash; Dilkushi DeAlwis (CIRA); Boris Petrenko.

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.

Background:
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 since 1970, while physical SST retrieval still lacks in research and operational implementations. It is due to the 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, highly effective and accurate global physical SST products 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 is comprised 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 resolutions, should be carefully selected and quality-controlled to avoid high anomaly in forward RTM. The 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 simple 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 products and extend them to other IR sensors.

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 is effective and accurate.

--Complete testing and document for 1-5.

--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:
Validation of CRTM brightness temperature against AVHRR using NCEP GFS data.

Accomplishments:
--Incorporated computationally efficient CRTM (Community Radiative Transfer Model) in the newly developed AVHRR (Advanced Very High Resolution Radiometer) Clear-Sky Processor for Oceans (ACSPO). CRTM is used in ACSPO in conjunction with Fresnel's emissivity model, and the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) fields (SST and atmospheric profiles, including pressure, air temperature, water vapor, ozone and geopotential height) to improve cloud mask and to explore physical SST retrievals. (Developed by FORTRAN9-9.5 and C, Compilers are INTER FORTRAN and GCC) .

--Developed automatic and effective Quality Control/Quality Assurance (QC/QA) tools for long-term monitoring of CRTM performance and AVHRR sensor behaviors. This tool can operate directly from Orbit HDF Data (output from Orbit Processor (OP) of ASCPO) in order to more timely validate geophysical and environmental parameters dependence of bias BT(CRTM_BT-AVHRR_BT), such as sensor view angle, column water vapor, sea surface temperature, wind speed and latitude. Also, it can generate bias BT histogram for their parameters to analyze BT bias and anomaly, global maps for CRTM BT, AVHRR BT and Bias BT, as well as the animation for their time series plot. It is useful for validation of BTs and physical SST retrievals. (Developed by IDL6.3) .

--Corrected some bugs in the Clouds from AVHRR Extended (CLAVR-x) which is used for the initial ACSPO cloud mask. One important correction is the improvement of saturation water vapor press calculation. This correction resulted in 1k reduction in water vapor dependence of bias BT and made CRTM to well reproduce AVHRR BT in all three bands (ch3B, ch4 and ch5). (Developed by FORTRAN9-9.5, Compiler is INTER FORTRAN).

--Generated one week global clear sky orbit HDF data (04/19/2006-04/25/2006) for AVHRR onboard NOAA-16,-17 and -18 using the code described at section 1. Validated CRTM BT against AVHRR using the QC/QA tools and found CRTM reproduce well AVHRR BTs in all three bands and very close cross-sensor consistency on three platforms, as well as anomalous behavior in NOAA-16 channel 3B compared to NOAA-17 and -18. Some example graphs are shown in the attached file for this report. (Developed by IDL6.3).

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) Radiances for improved cloud detection and physical SST retrievals”, 5th GOES Users' Conference, 88th AMS Annual Meeting (http://ams.confex.com/ams/88Annual/oasys.epl). 20-24 January, 2008. (Submitted)

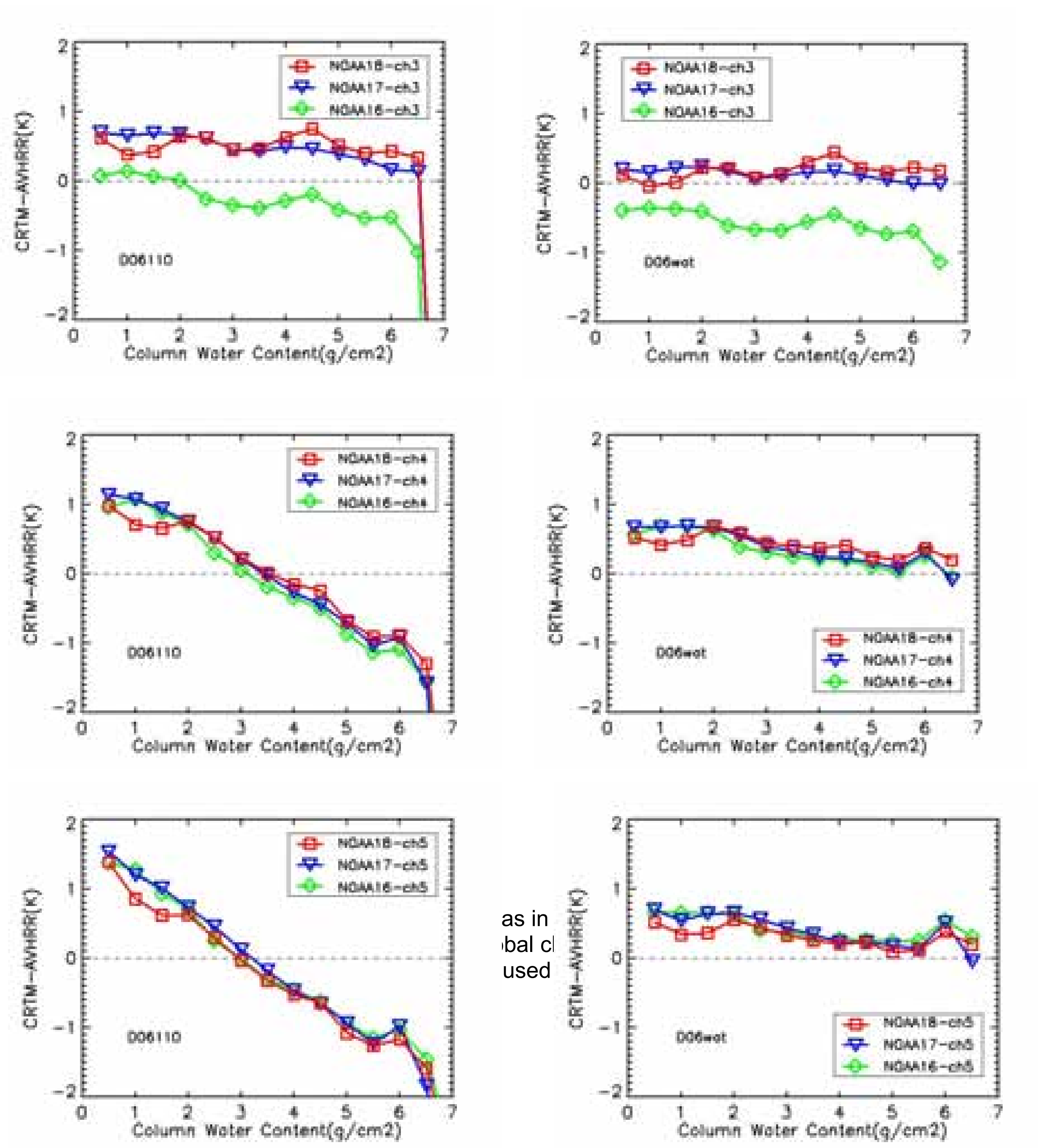
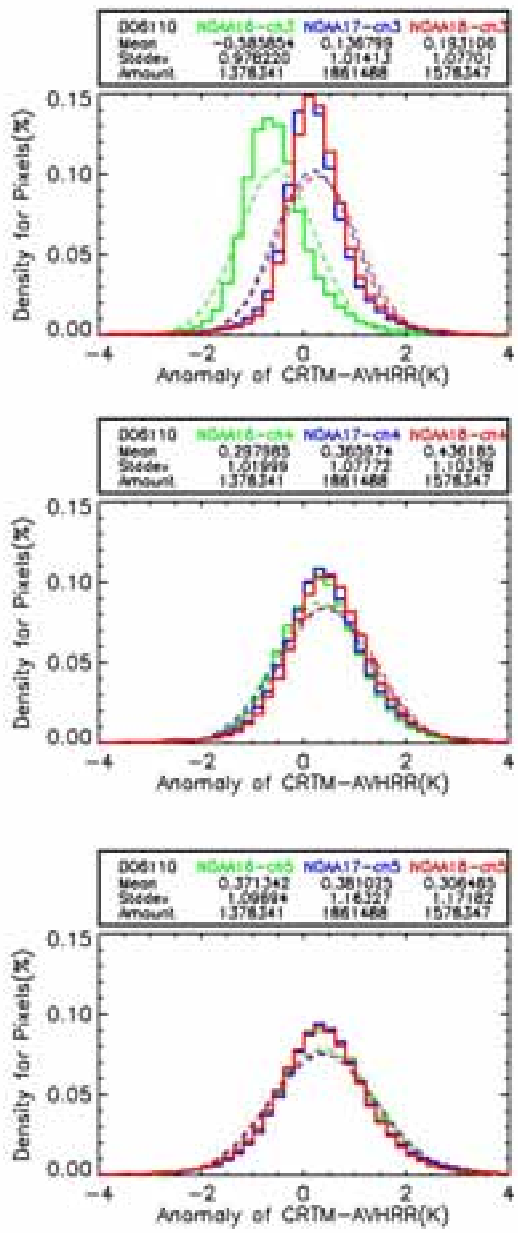


Fig 1. Column Water vapor dependence of Bias in BT (CRTM-AVHRR) for Ch3B, Ch4, Ch5 for NOAA-16, -17 and -18. It is nighttime 04/19/2007 global clear sky data and input data is used NCEP-GFS. Left plots is used original CLAVR-x. Right plots is used improved CLAVR-x.



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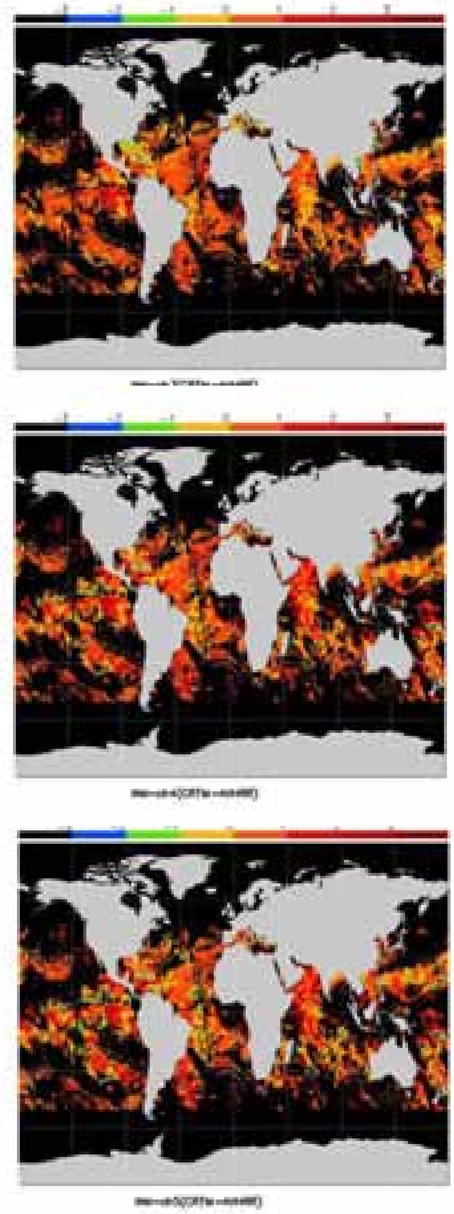


Fig 2. Frequency distribution of Bias in BT (CRTM-AVHRR) with Ch3B, Ch4, Ch5 for NOAA-16, -17 and -18.

Fig. 3. Global map of Bias in BT(CRTM-AVHRR) for ch3B, Ch4 and Ch5 of AVHRR onboard NOAA-17.

Hao Zhang – NESDIS Post Doc

Project Title: Retrieving aerosol information from sun-glitter contaminated satellite imagery.

Principal Investigator: Dr. Menghua Wang (CIRA technical advisor)

Key Words: Satellite Remote Sensing, Ocean Color, Sun Glint

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

When observing the global oceans from space by earth observing system satellites such as MODIS Aqua, the bright reflection of direct sunlight from a wind-roughened sea surface can be significantly large and could make an image unusable in retrieving useful information such as aerosol properties over the ocean. The goal of this study is to try to extract such useful information by using the infrared bands aboard the satellite. Specifically, for these infrared bands the contributions to the radiances measured by the satellite are from sun glint and atmospheric scatterings; by comparing the measured radiances and an appropriate sun-glitter model, one may obtain the aerosol properties from atmospheric scattering contributions.

2. Research Accomplishments/Highlights:

We have compared the measurement with different sun-glitter models and attempted aerosol property retrievals with several candidate models. Currently we are looking at more satellite imageries to see if our findings are valid in general.

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

Work in progress. We have found, among other popular sun-glitter models, the Ebuchi-Kizu Model seems to work better. However, we need to look at more data to validate the results.

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:

8. Publications: None as yet.

Tong Zhu – NESDIS Post Doc

Project Title: Microwave Remote Sensing of Atmospheric and Surface Parameters and Their Applications in Numerical Weather Prediction Models

Principal Investigator: Fuzhong Weng, Tong Zhu

NOAA Project Goal: Weather & Water

Key Words: GOES-R Proxy Data, OSSE

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

For the development of operational-certified GOES-R product algorithms and processing systems, the GOES-R Algorithm Working Group (AWG) program requests a high quality of proxy data for algorithm developments, testing and assessments. The central tasks in the proxy data management system will be the delivery of simulation and observation-based GOES- R level1B data, the development of visualization tools for various formats of proxy data, and the design of a GOES-R Observing System Simulation Experiment (OSSE) framework for demonstrating the potential impacts of GOES-R data on NWP forecasts.

2. Research Accomplishments/Highlights:

Working with other GOES-R Proxy Data members from CIMSS, CIRA, NASA/LaRC, NRL, and UMD, we have developed, archived and delivered about 20 GOES-R proxy datasets to GOES-R Algorithm Working Group (AWG) users.

Among above proxy datasets, the simulated GOES-R ABI 16 bands dataset from SEVIRI data is a very useful data. Many AWG will test their new algorithms with this simulated ABI data. The JCSDA Community Radiative Transfer Model (CRTM) was used to simulate co-located measurements of SEVIRI and ABI. The statistic regression was preformed to obtain the conversion coefficients. The ABI simulation dataset has full disk coverage, high spatial resolution (3 km), and temporal resolution (15-min).

We joined the JCSDA Observation System Simulation Experiments (OSSE) study group to conduct the study of impacts of GOES-R measurements on numerical weather prediction. This is a new project that we just started in June 2007.

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

The project is going well. Now we have developed most of the GOES-R proxy datasets. Datasets delivery time is on GOES-R AWG schedule. The OSSE study framework has been setup for our next GOES-R impacts study.

4. Leveraging/Payoff:

The GOES-R proxy data will be used by scientists from NOAA cooperative institutes and other government laboratories to perform algorithm developments, testing and assessments. The JCSDA OSSE study results will be a great benefit to NOAA/NCEP operational forecasts and will provide guidelines for future NOAA satellite design.

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

We are collaborating with scientists from NOAA/NESDIS, CIMSS, NASA/LaRC, CIRA, NRL, and UMD in developing GOES-R proxy data system. We are participating in the JCSDA OSSE study project in collaboration with NOAA/NECP and NASA scientists.

6. Awards/Honors: None as yet

7. Outreach:

This project offers Dr. Tong Zhu a postdoctoral fellowship at CIRA.

8. Publications:

Weng, F., T. Zhu and B. Yan, 2007 Satellite Data Assimilation in Numerical Weather Prediction Models: Part II. Uses of Rain-Affected Radiances from Microwave Observations for Hurricane Vortex Analysis. J. Atmos. Sci. (in press).

Zhu, T., and D.-L. Zhang, 2006: Numerical Simulation of Hurricane Bonnie (1998). Part II: Sensitivity to Varying Cloud Microphysical Processes. J. Atmos. Sci. 63, 109-126.

Zhu, T., and D.-L. Zhang, 2006: The Impact of SST on Tropical Cyclone Intensity. Advances in Atmospheric Science. 23, 14-22.

Zhu T., F. Weng, and M. Kim, 2007: Simulate GOES-R ABI from SEVIRI measurements. GOES-R AWG Annual Meeting. The Annual GOES-R AWG Conference, May 15-18, 2007, Lansdowne, VA.

Zhu T., F. Weng, M. Kim, M. Goldberg, A. Huang, M. Sengupta, D. Zhou, B. Ruston and Z. Li, 2007: GOES-R Proxy Data Management system. The Annual GOES-R AWG Conference, May 15-18, 2007, Lansdowne, VA.

Zhu T., F. Weng, 2007: GOES-R Proxy Data for Mesoscale Weather Systems. The 87th AMS annual meeting, San Antonio, TX.

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 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) Proxy Datasets

Proxy VIIRS tropical cyclone datasets were collected from MODIS and AVHRR data.The dataset represents ten recent hurricanes, six of which were category five: Lili (2002), Fabian (2003), Isabel (2003), Ivan (2004), Emily (2005), Irene (2005), Katrina (2005), Ophelia (2005), Rita (2005), Wilma (2005).

AIRS and dropsonde data for these 10 storms were retrieved and individual plots of the NOAA aircraft flight paths and dropsonde locations for all 10 storms were produced (Figure 1).

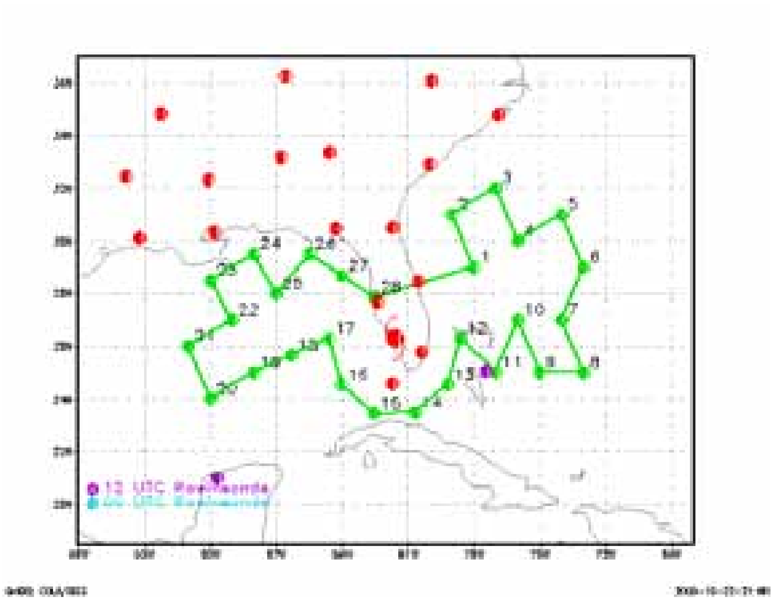


Figure 1. Dropsonde location, NOAA aircraft flight path, and radiosonde locations for Wilma 10/24/05 0530Z

Once the collected AIRS datasets were sorted by storm name and time, individual plots of AIRS data with GPS dropsonde location overlay could be created. An example of these plots can be seen below in Figure 2. This step was taken in preparation for a comparison study of the dropsonde data (ground truth) to the corresponding AIRS data.

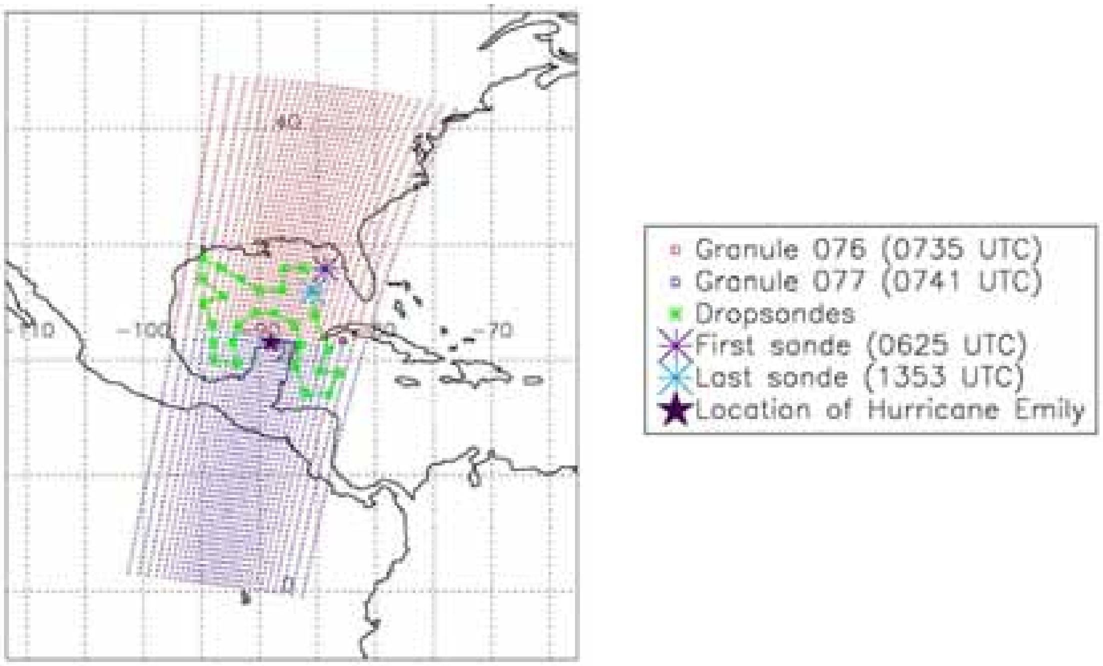


Figure 2. GPS Dropsondes and AIRS Retrieval locations for Hurricane Emily on 20050718 Mission 1. First and last dropsonde locations are marked with purple and light blue stars.

A program was written to find matching AIRS and NOAA Gulfstream Jet GPS dropsonde soundings for the validation study. Table 1 shows the number of matching soundings for each storm in the sample.

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	2002 to 2005	860

A matching set of AIRS and GPS soundings from Hurricane Katrina can be seen in Figure 3.

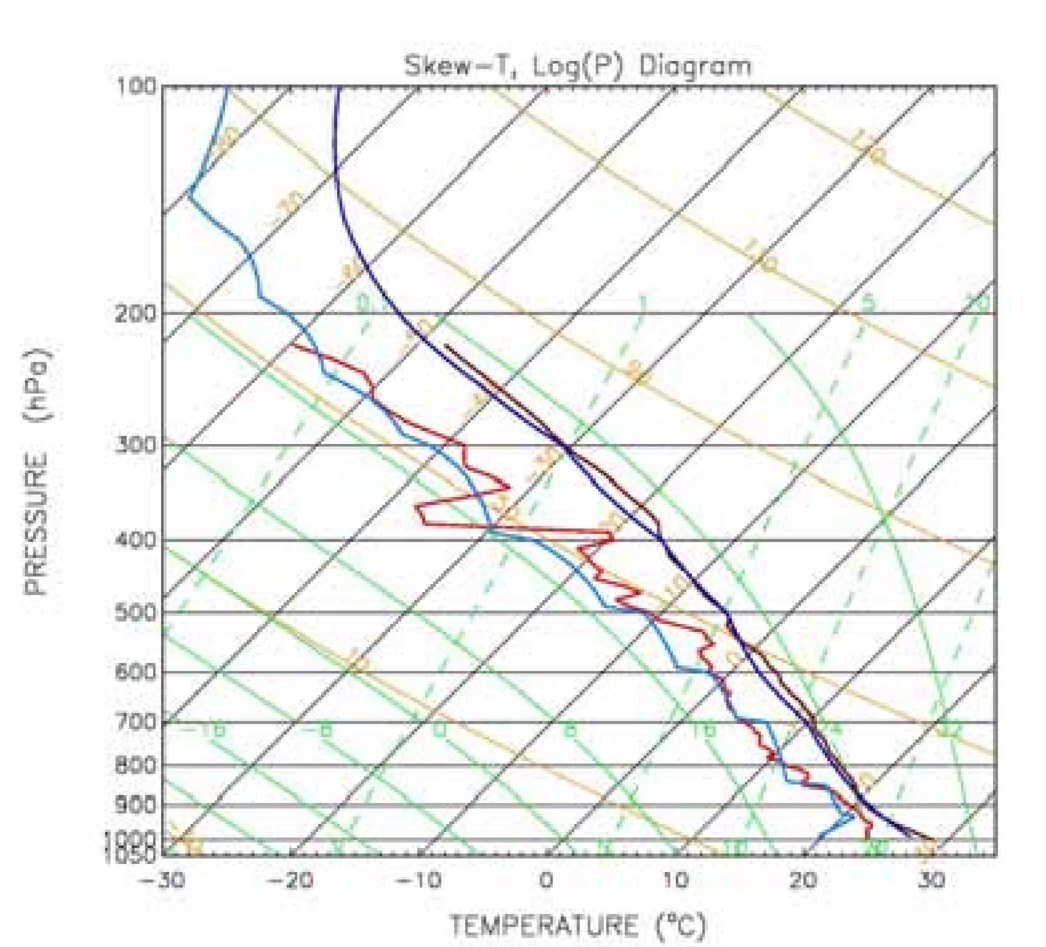


Figure 3. Temperature and dew point temperature soundings from a matching set of AIRS (dark blue, light blue) and GPS (brown, red) soundings from the environment *of* Hurricane Katrina on 24 August 2005.

B) Impact of VIIRS on the Dvorak Intensity Estimation Algorithm

As part of a GOES-R Risk Reduction and Algorithm Working Group (AWG) project at CIRA, we collected a large sample of proxy GOES-R tropical cyclone data (IR window channel) from MODIS and AVHRR at full resolution. For the GOES-R work, the resolution is degraded to 2 km. This same dataset is being used as a proxy for VIIRS, but without degrading the 1 km data to 2 km. The dataset can be seen at http://rammb.cira.colostate.edu/projects/awg/data.html .

Strong emphasis was put on quality control and the elimination of bad imagery. The final dataset for analysis contains more than 200 cases. Statistics on the impact of the 1 km resolution versus 4 km resolution are being calculated from this final dataset.

C) Hurricane Analysis from ATMS/CrIS retrievals

Because the Nunn-McCurdy certification called for the elimination of the CMIS instrument, the ability to estimate ocean surface winds is limited. To address this problem the emphasis of this project was shifted to develop a method for estimating tropical cyclone surface winds from the ATMS/CrIS data. The basic idea is that the temperature moisture retrievals from these instruments can be used as input to the hydrostatic equation and can be 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 running 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 web page (see http://rammb.cira.colostate.edu/products/tc_realtime/).

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

All primary objectives of this research have been accomplished.

4. Leveraging/Payoff:

What NPOESS will recieve for resources invested is:

Advanced product development, and

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 linkage includes:

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

(e) A website was developed to illustrate the utlility of NPOESS with proxy data

8. Publications:

<u>Conference Proceedings</u>

Avila, Lixion A., 2007: Satellite Applications for TC Analysis and Forecasting at NOAA/NHC. *AMS 87th Annual Meeting, 3rd Symposium on Future National Operational Environmental Satellites*. 14-18 January, San Antonio, TX.

<u>Presentations</u>

Results from this study were presented in December 2006 at the fall AGU meeting in an invited talk entitled “Multi-platform analysis of tropical cyclone structure”.

The results from this study were included in a presentation by Lixion Avila from the National Hurricane Center at the AMS Annual Meeting in San Antonio in January of 2007.

Two presentations were given at a UCAR/COMET NPOESS meeting in Ft. Collins on 8 May 2007:

Synthetic and simulated GOES-R and NPOESS data (Louie Grasso)

NPOESS Applications to Tropical Cyclone Forecasting. (Mark DeMaria).

PROCESSING OF ORGANIC AEROSOLS BY HETEROGENEOUS AND MULTIPHASE PROCESSES

Principal Investigators: 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 have implemented into our multiphase chemical conversion mechanism recent laboratory results on aqueous-phase reactions for organic species, made available to us through collaboration with colleagues at Rutgers. In addition, we include a detailed gas phase mechanism of isoprene oxidation into our model that predicts, more precisely than in prior schemes, the yields of water-soluble oxidation products that can be taken up by cloud droplets. This mechanism is implemented in a cloud parcel model, and our long term goal is to use this model framework to evaluate efficiencies of secondary organic aerosol (SOA) formation from isoprene for a variety of chemical scenarios and cloud properties.

We also plan to apply the model 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. In a significant advancement over previous aerosol-CCN-cloud linkage studies, we evaluate the importance of detailed knowledge of CCN composition to the predicted variability of radiative properties of clouds.

2. Research Accomplishments/Highlights:

During the past year of our NOAA award, we focused on the description of SOA formation by gas-phase and heterogeneous chemical processes. We performed an extensive evaluation of laboratory studies appearing in the literature and compiled a consistent set of SOA yield data for potential SOA precursors, namely biogenic compounds and aliphatic carbonyl compounds. Our comparisons of data that were obtained for a wide range of conditions revealed that a thorough understanding of gas phase chemical processes and concentration levels (NO_x) is required for reliable estimates of SOA yields. A compilation of published data and some first estimates of recommended parameters for typical atmospheric conditions are summarized in a recent publication [Ervens and Kreidenweis, 2007].

Since SOA formation is usually expressed in terms of yields from precursor compounds, we have begun work on developing similarly simple expressions for SOA yields from in-cloud oxidation processes. Such a parameterization is highly desirable for large scale models as they usually cannot handle the large computational burden represented by complex multiphase chemical mechanism. Our preliminary model studies show that cloud contact time is an important parameter influencing SOA yield, whereas the available liquid water content (within a defined typically-encountered range) is of minor importance. Other parameters, such as cloud droplet pH and cloud droplet number concentration, also seem to be of minor importance to the final yield. The robustness of predicted yields for a wide range of conditions suggests that considerable simplification of complex multiphase chemical models can be achieved.

We continued our CCN studies in collaboration with colleagues at CU Boulder. Last year, we applied our aerosol-CCN model to a dataset that had been acquired during ICARTT 2004 (Ervens et al., 2007). This year, we used CCN and aerosol data that were acquired during SOAR in Riverside, California (Cubison et al., in prep). Our calculations showed that the mixing state of freshly emitted aerosols is of crucial importance in order to obtain closure between measured and modeled CCN concentrations. In order to evaluate the importance of detailed knowledge of CCN properties for the aerosol indirect effect that refers to clouds, and that also includes dynamical effects, we initialized our cloud model with measured aerosol size distributions, and compared resulting radiative properties (cloud susceptibility, albedo) for different assumptions regarding aerosol component mixing state and composition. In agreement with our previous studies, we concluded that the effects of composition on cloud properties are significantly reduced in actual clouds, as compared to predicted sensitivities from CCN studies that refer only to equilibrium (non-dynamical) conditions.

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 and Dr. M. Cubison (University of Colorado) provided the data sets for CCN closure acquired at Riverside, California, during the SOAR (Study of Organic Aerosol in Riverside, 2005).

The development of the aqueous phase mechanism for the oxidation of glyoxal based on laboratory work was performed in collaboration with Barbara Turpin and Ann Marie Carlton (Rutgers University), and resulted in a joint publication.

6. Awards/Honors: None as yet

7. Outreach:

We have reported results from our work at the following conferences during 2006/07:

AGU Fall Meeting, San Francisco, USA, 2006

7th International Aerosol Conference, St. Paul, MN, 2006

Gordon Conference: Biogenic Hydrocarbons & the Atmosphere, Ventura, CA, 2007

Joint Assembly Meeting AGU, Acapulco, Mexico, 2007

8. Publications:

Publications Resulting from this Research

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 Phase Photooxidation Experiments, Atmospheric Environment, *in press*.

Cubison, M., K. Docherty, I. Ulbrich, J. L. Jimenez, B. Ervens, G. Feingold, R. Denkenberger, and K. Prather, Activation of Los Angeles Urban Aerosol, *in preparation*

Ervens, B. and S. M. Kreidenweis, SOA formation by biogenic and carbonyl compounds: Data evaluation and application, Environ. Sci. Technol., 2007, 41(11); 3904-3910.

Ervens, B., M. J. Cubison, E. Andrews, G. Feingold, J. A. Ogren, J. L. Jimenez, P. DeCarlo, and A. Nenes, Prediction of cloud condensation nucleus number concentration using Measurements of Aerosol Size Distributions and Composition and Light Scattering Enhancement due to Humidity, J. Geophys. Res., 112, D10S32, doi: 10.1029/ 2006JD007426, 2007.

Ervens, B., A. G. Carlton, B. J. Turpin, S. M. Kreidenweis, and G. Feingold, Secondary organic aerosol formation in clouds upon isoprene oxidation, *in preparation*

Invited Talks

Ervens, B.: Chemie und Wolken - Eine wechselseitige Beziehung, Institute for the Atmosphere and Environment, Johann-Wolfgang-Goethe-University, Frankfurt, Germany, 2006.

Ervens, B.: Chemical and physical modification of aerosol particles by cloud processing, Joint Assembly Meeting AGU, Acapulco, Mexico, 2007.

Ervens, B.: Process model studies of SOA formation by biogenics in the condensed phase, Gordon Conference: Biogenic Hydrocarbons & the Atmosphere, Ventura, CA, USA, 2007.

Conference Contributions

Cubison, M. J., Docherty, P. DeCarlo, I. Ulbrich, E. Dunlea, A. Huffman, J. L. Jimenez, B. Ervens, G. Feingold, and A. Nenes: Activation of Los Angeles Urban Aerosol, 7th International Aerosol Conference, St. Paul, MN, USA, 2006.

Ervens, B., A. G. Carlton, B. J. Turpin, G. Feingold, and S. M. Kreidenweis: Isoprene as SOA precursor: Aerosol mass formation by processes in haze particles and clouds, AGU Fall Meeting, San Francisco, USA, 2006.

Ervens, B., G. Feingold, E. Andrews, J. A. Ogren, M. J. Cubison, K. Docherty, I. Ulbrich, J. L. Jimenez, and A. Nenes: CCN studies at different locations, 7th International Aerosol Conference, St. Paul, MN, USA, 2006.

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, 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 would be tested to see the impacts on satellite data assimilation.

2. Research Accomplishments/Highlights:

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 ability 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:

The main objective of this proposal has been previously met and the code has been transferred to the JCSDA. The relevant codes are also publicly available at http://nit.colorado.edu/shdomppda/index.html. 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.

4. Leveraging/Payoff:

The ability to assimilate visible radiances in cloudy atmospheres has previously not been 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:

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:

7. Outreach:

8. Publications:

Sengupta, Manajit, 2007: "SHDOMPPDA: A radiative transfer tool for cloud sky data assimilation" . Journal of Atmospheric Sciences (accepted).

RESEARCH & DEVELOPMENT FOR GOES-R RISK REDUCTION

Principal Investigators: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: GOES-R, Risk-Reduction, Product Development, ABI, HES

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) and Hyperspectral Environmental Suite (HES) 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:

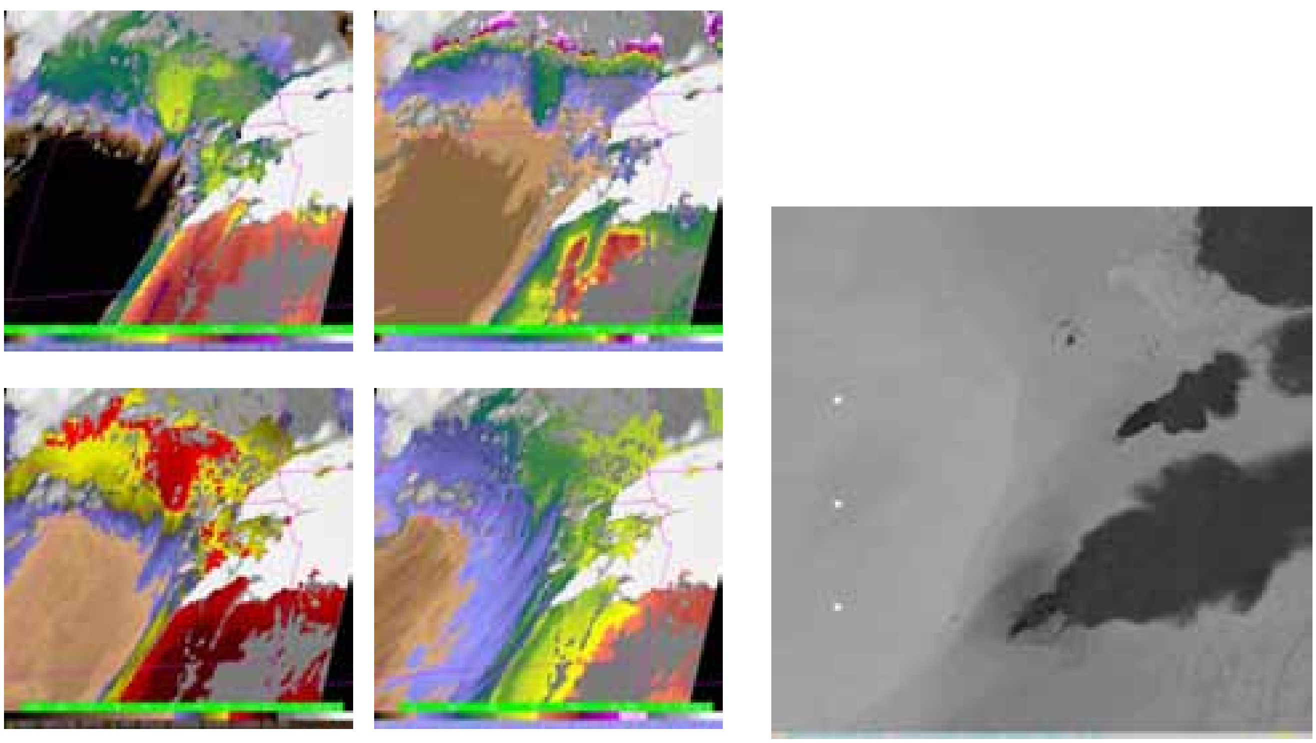
<u>Synthetic GOES-R data generation and analysis</u>

The extensive RAM memory usage for the calculation of 3.9μm synthetic imagery has become a major problem for the generation of GOES-R ABI 3.9 μm imagery. Therefore a considerable amount of time and effort was put into the development of a parallel version of the observational operator. In addition, we found that brightness temperatures were too warm on top of simulated thunderstorms when Modified Anomalous Diffraction Theory (MADT) was used to calculate optical properties. Since emission from the pristine ice field on top of thunderstorms dominates the radiance field, optical properties for pristine ice are now derived from more accurate means. These are then combined with optical properties of other hydrometeor types and fed into SHDOMPP.

A power point presentation was prepared in response to a request from Mitch Goldberg for research to help justify the HES. The presentation is entitled "The Need for the HES for Severe Weather Analysis" and was prepared by L. Grasso, D. Lindsey, J. Dostalek, Justin Sieglaff (CIMSS), M. Sengupta, R. Brummer, and M. DeMaria. The presentation was given via teleconference by M. DeMaria at recent HES meeting in Camp Springs. Figure 1a shows a typical slide from a three hour loop of synthetic HES derived product imagery. The synthetic scene was comparable to the HES scanning in mesoscale mode, covering a 1000 km x 1000 km area with a horizontal footprint of 6 km and a five minute sampling rate. This was generated from the 8 May 2003 severe weather case. Synthetic HES imagery was produced to show the advantage of using a geostationary sensor like the HES with its high temporal resolution as opposed to using the current operational polar orbiting satellites, which would pass over the severe weather region at most twice a day.

Synthetic GOES-R ABI imagery for the 8 May 2003 severe weather case was sent to Iliana Genkova of CIMSS. She is using the synthetic imagery to test a “water vapor derived winds” algorithm. Synthetic GOES-R ABI imagery for hurricane Lili of 2 October 2002 was also provided to her.

In coordination with the Algorithm Working Group (AWG) activities at CIRA, the radiative transfer code was being modified to include synthetic fire hotspots in ABI imagery. An example of hotspots in synthetic 3.9 μm GOES-R ABI image from the severe weather event is shown in Fig. 1b. This scene has a footprint of 400 m and was used to generate synthetic GOES-R ABI fire hotspots with a footprint of 2 km with the aid of a prescribed point spread function. This work is in collaboration with Elaine Prins of CIMSS.



(a) (b)

Figure 1. (a) Synthetic HES CAPE (top left), CIN (top right), LI (bottom left), and PW (bottom right). (b) ABI at 3.9 μm for the 8 May 2003 simulation. Three fire hot spots can be seen on the left side of the image.

For more information visit our website. (http://rammb.cira.colostate.edu/projects/goes_r)

Prototype product development for fog, smoke and volcanic ash analysis

ABI-like simulations were obtained during the GOES-13 NOAA Science Test. The GOES-13 Science Test began on 7 December 2006 and continued for three weeks through 28 December. Of the available test schedules, some ABI-like temporal simulations were possible. For example, continuous 5-minute continental U.S. images were called for the first day to cover lake-effect snows. Also, continuous 30-minute full-disk images were called for the first weekend. In addition, both 30-second and 1-minute images were collected, showing the rapid scan capabilities possible from ABI. One of the remaining tests was an ABI-like 2-km spatial simulation, made possible by a special scan schedule and rapid-interval images. This test turned out to be not feasible. It was discovered that the data were not line-shifted between successive images as needed. As a result, the spatial over-sampling test will need to be redone during the GOES-O Science Test which will most likely be conducted in 2008.

Testing of GOES-13 data at CIRA has concentrated on the noise and detector-to-detector striping for both the Imager and Sounder instruments. While noise for GOES-13 is lower than for previous GOES, the same is not true of striping. We found a significant striping in the GOES-13 Sounder that seems to have an east-west bias across the full disk, possibly related to the emissivity of the scan mirror which varies with angle. The striping is likely more obvious due to the lower noise for GOES-13. Testing continues toward looking for the source of the striping, so that future GOES-R data may be less susceptible to this source of error.

See examples of ABI-like products that have been collected at the GOES-13 NOAA Science Test page (http://rammb.cira.colostate.edu/projects/goes_n/).

Tropical cyclone product development

Work proceeded in three areas. First, the ABI proxy tropical cyclone database was greatly expanded in coordination with the CIRA Algorithm Working Group project. When that is completed, work will begin on a prototype intensity estimation algorithm, again in coordination with the CIRA AWG project. Second, the collection of Meteosat-8 data in the east Atlantic is continuing. A study is being initiated to use that data to determine the utility of the ozone channel in tropical cyclone monitoring. This work is in collaboration with the GOES-R Risk Reduction project at CIMSS. Third, due to the discontinuation of the HES, the emphasis of this project was modified. The study of the HES proxy data from AIRS/AMSU was discontinued, and the emphasis is now on the analysis of proxy ABI data from the SEVERI instrument from MSG and on the proxy ABI data from MODIS and AVHRR. The ozone and other unique channels on SEVERI are being used to investigate their utility in tropical cyclone formation and intensification analysis, and the MODIS and AVHRR data are being used in algorithms for estimating storm intensity and wind structure. The intensity and structure study is being performed in coordination with the GOES-R AWG activities at CIRA.

The analysis of the proxy GOES-R tropical cyclone dataset from MSG collected during the 2005 and 2006 seasons has begun. The emphasis will be on the genesis stage of each storm and the periods of rapid intensification. Storm centered loops of all the MSG SEVERI channels are being created for the 48-hour period that includes 24 hours before and after the time of tropical cyclone genesis and rapid intensification. Special emphasis is on the 9.6 *um* channel which is sensitive to ozone to determine if there are signals near the tropopause level that indicate that a storm is about to form or rapidly intensify.

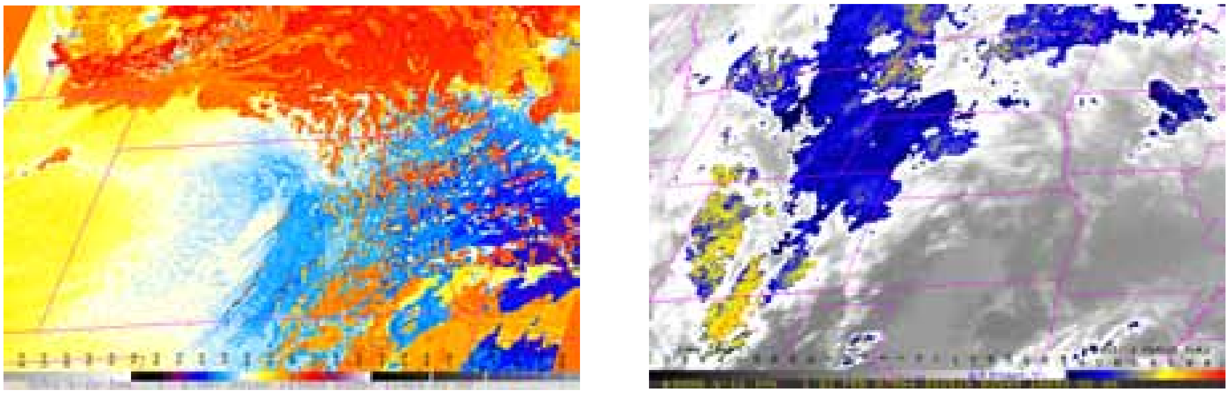
As part of the Algorithm Working Group (AWG) project a large ABI proxy tropical cyclone database (about 450 cases) has been assembled. This database is being used to refine the Digital Dvorak (DD) estimation technique. A limitation of the current technique is that it does not work well for storms below hurricane strength. A new formulation based on storm symmetry is being developed for the weaker cases. Although the AWG project will provide the proxy TC dataset to CIMSS to tune the more sophisticated Automated Dvorak Technique (ADT), the simpler DD technique has utility for detecting relative intensity trends.

<u>Severe weather product development</u>

A new and improved Severe Weather simulation from 8 May 2003 has been performed, and 9 synthetic ABI channels have thus far been created. Using these, different products can be formed from combinations of the various channels. One example is the longwave difference product, or 10.35 μm - 12.3 μm. Water vapor preferentially absorbs radiation at 12.3 μm compared to 10.35 μm, so this product provides information about the amount and depth of low level moisture (Fig. 2a). In this figure, the darker blue areas in central Kansas indicate regions of enhanced moisture convergence, a sign that convective initiation is possible. Products of this sort are valuable for short-term severe storm forecasts. In the coming months, additional products formed as combinations of these simulated ABI channels will be created and tested.

A new paper about “GOES climatology and analysis of thunderstorms with enhanced 3.9 μm reflectivity” appeared in the September edition of Monthly Weather Review. This research will likely lead to both GOES and GOES-R severe weather nowcasting products. The GOES-R ABI will have additional shortwave Infrared channels which are specifically designed to provide information about cloud-top particle size. Using output from the RAMS cloud model and observational operator, these ABI channels will be simulated so that physical retrievals can be developed before the launch of GOES-R. Recent research, as in Lindsey et al. (2006), can then be applied to the particle size retrieval to gain information about thunderstorm updraft strength.

Work continues on a GOES ice cloud effective radius retrieval. Currently, the algorithm uses only the 3.9 and 10.7 μm channels, but optically thin clouds occasionally provide ice crystal sizes which are too small. To screen for these optically thin clouds, the visible channel is being added to the algorithm so that only those clouds with large visible reflectance will be considered. In the figure below (Fig. 2b), many of the cirrus clouds in northeast Colorado and eastern Wyoming are likely optically thin, so the improved algorithm would screen them out. Work is also underway to determine the link between thunderstorm intensity and cloud-top ice crystal size. The GOES-R ABI will add a number of additional channels in the shortwave IR portion of the spectrum, allowing for a significant improvement to products such as this one



(a) (b)

Figure 2. (a) Simulated 10.35 μm minus 12.3 μm product from 8 May 2003 at 1835 UTC. (b) GOES Ice Cloud Effective Radius Product from 23 February 2007. Colors indicate cloud-top ice effective radius values.

Information content analysis using Maximum Likelihood Ensemble Kalman Filter (MLEF) data assimilation

The impact of ensemble perturbations generated from time-shifted forecasts on the information content of satellite observations was examined. This is an approximate, computationally less expensive approach to a full-blown ensemble-based data assimilation and information content analysis of assimilated data. We are examining this approximate approach in preparation for using the NCEP operational models (e.g., Weather Research and Forecasting Non-hydrostatic Mesoscale Model, WRF-NMM) in this research.

At this stage, we performed experiments with calculating information content of simulated GOES-R observations (10.35μm channel) using Regional Atmospheric Modeling System (RAMS) to generate time shifted forecasts. The results were quite encouraging, indicating that a relatively small ensemble size (10-50 ensemble members) may be sufficient to capture essential characteristics of the information measures. These results were presented at the Third Annual NOAA/NESDIS/CoRP Science Symposium, held August 15-16 in Fort Collins. Further, research was conducted on “forecast error covariance localization”, a research area which is currently considered to be one of the most important issues to be solved in ensemble data assimilation approaches. The research focus was on using a “distance” defined in terms of information measures, rather than using a geographical distance (which is commonly used). Using this new distance definition seems to be more adequate, since it depends on the actual atmospheric flow patterns. The new definition of distance had a positive impact on covariance localization and data assimilation results. Our next step was to begin to study the Weather Research and Forecasting Non-hydrostatic Mesoscale Model, WRF-NMM model, which we intend to use in the next stage of our data assimilation work. As a result, we have included the Weather Research and Forecasting (WRF) model into the Maximum Likelihood Ensemble Filter (MLEF). We were able to resolve many issues related to compiling and running the WRF model. We have also resolved the issue of how to prepare observations in an appropriate format for data assimilation.

Task 7: Training Activities
A presentation on 'National and International Training Highlights' was given at the 3rd Annual NOAA/NESDIS/CoRP Science Symposium on GOES-R and NPOESS hosted by CIRA in Ft. Collins on August 15-16. The presentation gave an overview of how training has evolved for the National Weather Service and the International communities and what tools have been used to administer the training.

CIRA participated in the WMO worldwide High Profile Training Event (HPTE) that took place October 16 – 27, 2006. The HPTE provided a unique education and training opportunity to WMO Members through the presentation of 4 key lectures and interactive weather discussions – all online. CIRA contributed to the organization, scheduling, and delivery of the HPTE to 22 countries in Central and South America and the Caribbean. The lectures familiarized the users with current and future space-based components of the Global Observing System.

Discussions were held with the Volcanic Ash community via teleconferencing from Fort Collins to Rotorua, New Zealand, where the 4th International Workshop on Volcanic Ash was on-going at that time. Our presentation was given from Fort Collins through the Internet using our VISITview software for slides and Yahoo Messenger for voice. These discussions helped stimulate collaborative activities in many areas including the development of volcanic ash training materials, and research on products useful for GOES-R.

3. Comparison of Objectives Vs. Actual Accomplishments:

Due to the discontinuation of the HES, some objectives will not be met. As a result, a shift in research was needed in the tropical cyclone product development and synthetic data generation.

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:

Our research linkage includes:
--Coordinate with Elaine Prins of CIMSS.
--Coordinate with Ben Ruston of the Naval Research Lab.
--The collaboration results in efficient production of a final product. That is, we can take advantage of the expertise of the other groups.
--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:

Louie Grasso and Manajit Sengupta recieved the CIRA Research Initiative Award from the Director of CIRA for their work on the GOES-R project.

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) An undergraduate student is partially supported by this project.

(b)
D.W. Hillger, May 24, 2005: Results of the GOES-R Risk Reduction activities at CIRA that can be applied as well to data from NPOESS VIIRS and other instruments. COMET Curriculum Development Workshop, Boulder, CO.

M. DeMaria, April 20, 2005: Tropical cyclone applications of satellite observations. CSU Satellite Meteorology class, Fort Collins, CO

D.W. Hillger, April 19, 2005: Judged posters at the CSU Celebrate Undergraduate Research and Creativity (CURC) Poster Event. Fort Collins, CO.

D.L. Lindsey, March 22, 2005: Reflective thunderstorm tops research. ATMOS/CIRA presentation, Fort Collins, CO.

B.H. Connell and J.F.W. Purdom, March 7-18, 2005: Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV. San Jose, Costa Rica.

D.W. Hillger, December 8, 2004: NOAA's GOES Program: Past, Present, and Future. Fifth Canadian/COMET Winter Weather Workshop, Boulder, CO.

B.H. Connell, November 8, 2004: GOES and the characteristics of its channels. Remote Sensing class at the Metropolitan State College of Denver, Denver, CO.

D.W. Hillger, July 17, 2004: Weather satellite history and RAMM Branch GOES-R Risk Reduction activities. 2nd Rocky Mountain Chinese Society of Science and Engineering (RMCSSE) Annual Conference, Aurora/Denver CO.

(c) None

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

J.F. Weaver, March 7, 2005: My Career in Meteorology and How I Got There. Partnership with RAMMB and the Poudre High School PaCE (Professional and Community Experience) Program, Fort Collins, CO.

D. Watson, H. Gosden, D.A. Molenar, April 13, 2005: Meeting with program directors. Partnership with RAMMB and the Poudre High School PaCE (Professional and Community Experience) Program. Fort Collins, CO.

(e) J.F. Weaver, October 6, 2004: The variety and scope of research taking place at CSU. Series for local business owners. Fort Collins, CO.

D.W. Hillger, October 14, 2005: Work at NOAA/CIRA with weather satellites and the next generation GOES. Windsor (CO) Beacon interview. Windsor, CO.

8. Publications:

<u>Refereed Journal Articles</u>

Grasso, L.D., and T.J. Greenwald, 2004: Analysis of 10.7 micron brightness temperatures of a simulated thunderstorm with two-moment microphysics. Mon. Wea Rev., 132:3, 815-825.

<u>Conference Proceedings</u>

DeMaria, M., D.W. Hillger, C.D. Barnet, J.P. Dunion, and R.T. DeMaria, 2004: Evaluation of Hyperspectral Infrared Soundings in Tropical Cyclone Environments. AMS 13th Conference on Satellite Meteorology and Oceanography, September 20-23, Norfolk, VA.

Dostalek, J.F., L.D. Grasso, M. Sengupta, M. DeMaria, 2004: Applications of synthetic GOES-R observations for mesoscale weather analysis and forecasting. AMS 13th Conference on Satellite Meteorology and Oceanography, September 20-23, Norfolk, VA.

Grasso, L.D., M. Sengupta and M. DeMaria, 2004: Applications of Simulated GOES-R Observations for Advance Product Development for Mesoscale Weather Forecasting. SPIE Annual Meeting, August 2-6, Denver, CO.

Hillger, D.W., M. DeMaria, and J.F.W. Purdom, 2004: Analysis of Simulated GOES-R Data and Products for Mesoscale Meteorology. AMS 13th Conference on Satellite Meteorology and Oceanography, September 20-23, Norfolk, VA.

Hillger, D.W., M. DeMaria, J.F.W. Purdom, and C.D. Barnet, 2004: Risk Reduction Activities for Future GOES-R Instrumentation. SPIE Asia-Pacific Symposium, November 8-12, Honolulu, HI.

Hillger, D.W., M. DeMaria and R.M. Zehr, 2004: Advance Mesoscale Product Development for GOES-R Using Operational and Experimental Satellite Observations. SPIE Annual Meeting, August 2-6, Denver, CO.

Hillger, D.W. and T.J. Schmit, 2004: Quantization Noise for GOES-R ABI Bands. AMS 13th Conference on Satellite Meteorology and Oceanography, September 20-23, Norfolk, VA.

Zehr, R.M., 2004: Satellite Products and Imagery with Hurricane Isabel. AMS 13th Conference on Satellite Meteorology and Oceanography, September 20-23, Norfolk, VA.

Zupanski, D., M. Zupanski, M. DeMaria, and L.D. Grasso, 2005: Critical issues of ensemble data assimilation in application to GOES-R risk reduction program. 9th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS). 10-14 January, San Diego, CA.

Presentations

Zehr, R.M., M. DeMaria, J.A. Knaff, and K.J. Mueller, 2005: NOAA's Next-Generation Polar and Geostationary Satellites; Hurricane Applications. 59th Interdepartmental Hurricane Conference, 7-11 March, Jacksonville, FL.

REGIONAL TRANSPORT ANALYSIS FOR CARBON CYCLE INVERSIONS

Co-Principal Investigators: A. Scott Denning/Marek Uliasz

NOAA Project Goal: Climate

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

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

We expect to achieve the following objectives:

1) Produce a library of influence functions based on mesoscale high-frequency RUC analyses
2) Evaluate the RUC-based influence functions
3) Store and disseminate the output to other researchers for use in carbon cycle inversions.

We will achieve objective 1 by adapting the CSU Lagrangian Particle Dispersion Model (LPDM) to read meteorological fields from the RUC analyses. We will run the model backwards in time from each continuous CO_2 observing tower site in the U.S. for 5 days prior to each observing time. Then we will integrate surface and lateral-boundary particle locations at each previous hour to quantify the influence of surface fluxes in each upstream grid cell at each previous hour on measured CO_2 concentrations at the towers. This step is a lot of work, involving use of the Jet supercomputer for simulations and many terabytes of model output.

We plan to achieve objective 2 by propagating estimated surface fluxes forward in time using the influence functions to reconstruct timeseries of measured concentrations at each tower, and comparing to the observations.

Objective 3 involves making choices about data formatting and compression, and about what products are likely to be most useful to the community of inverse modelers. We have opted for a strategy of saving particle positions rather than influence functions, and generating influence functions “on the fly” in response to user requests through a web interface. This will save enormous amounts of disk space and be flexible enough to allow different users to combine influence functions with their own models of fluxes or space/time covariance.

2. Research Accomplishments/Highlights:

Working closely with colleagues at NOAA, we have obtained test datasets of hourly meteorological analyses generated by the Rapid Update Cycle (RUC) assimilation system on the 13-km grid over North America. We developed and tested subsetting software to extract only the transport fields from these analyses, and adapted the CSU Lagrangian Particle Dispersion Model (LPDM) to read the 13-km RUC fields. We have now verified that we can calculate adjoint, or backward-in-time, transport influence functions for specified sampling stations to quantify the sensitivity of each observation at NOAA sampling towers to unit surface fluxes of CO_2 or other trace gases at all points upstream in the RUC domain.

For each data point, i.e., tower location and sampling time (1 hour or longer), a separate influence function is derived which depends on spatial coordinates of source areas as well as release time of fluxes from the surface. Therefore, the RUC-LPDM system is generating a huge amount of data, which would be impractical to store and disseminate at full resolution for a year.

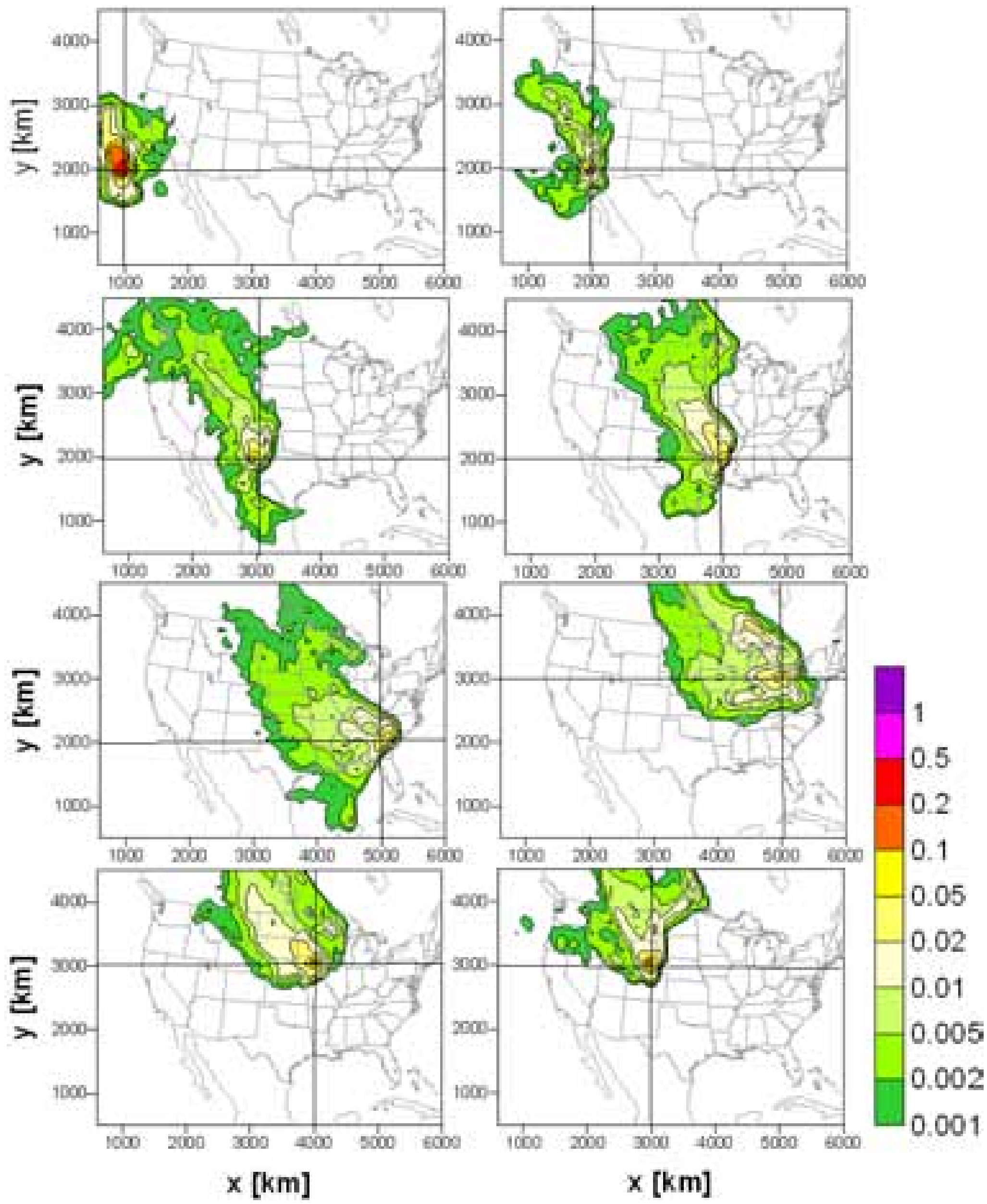


Figure 1. presents a series of influence functions [ppm/umol] calculated during testing the prototype RUC/LPDM system. They are derived for the 10-day period of March 6-16, 2006 and hypothetical 400 m towers spaced every 1000 km across the RUC domain. The influence functions are integrated with unit CO_2 flux from the surface (1 umol/m^2/s). In a similar manner the influence functions can be derived for all active NOAA towers (or any other locations of interest) and can be integrated with the user provided CO_2 fluxes instead of the unit flux.

We have investigated several methods of aggressive data compression to solve this problem. It would be possible and perhaps advisable to convolve the transport influence functions with a surface flux model (such as SiB, which we use at CSU), and integrate over longer periods of time. We have shown that compression on the order of a factor of 100 is possible by this method, which assumes that high-frequency (hourly to daily) variations in surface fluxes are well-captured by the model and that the influence functions would be used to correct the model on time scales of several days. We will apply this approach at CSU/CIRA, but recognize that other users of the influence functions may prefer to use the product at full temporal resolution or apply their own models to the compression and flux inversion problem.

To compromise between the need for data compression and flexibility in applying flux models to the influence functions, we have designed the storage and dissemination system to store Lagrangian particle positions rather than integrated influence functions. The advantage with respect to storage is that, unlike for the case of gridded integrated influence functions, only locations that influence a particular measurement are stored. The system will therefore need to integrate influence functions “on the fly,” at the time that the product is disseminated. The system will offer influence functions convolved with hourly SiB fluxes and deliver vastly compressed data, or to send the gridded functions at full resolution for shorter periods. This approach involves a necessary trade off in increased computational cost in the data system to achieve disk storage savings.

We are currently investigating different approaches for mass-adjustment of the RUC wind fields before they are used in the LPDM. We have also begun work on a new scheme in the LPDM model for subgrid-scale vertical transport associated with parameterized cloud mass fluxes due to cumulus clouds. This work will continue in year 2 of the project during which we will complete the system, and build and deploy a web interface for delivery of the product to other researchers.

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

1) Produce a library of influence functions based on mesoscale high-frequency RUC analyses

In progress. We have successfully adapted the LPDM model and “particle analysis” (PANAL) influence function generation algorithm to the RUC output, and have generated test output (see Fig 1 above). We have tested various options for representing the effects of cumulus convection and enforcing mass conservation.

We have encountered a possibly serious problem with regard to frequent gaps in the RUC analysis. We had been assured that a “second source” of the analysis fields was available for filling gaps, and that gaps would likely be much less than 1% of the hourly data. In reality, the second source has not been archived, and the analysis contains over 3% gaps. We will work with our colleagues at ESRL in the coming weeks to find a way to deal with missing analyses.

2) Evaluate the RUC-based influence functions

In progress. We are evaluating both meteorological variables (wind roses, precipitation, depth of mixing) against direct observations, and also comparing RUC-derived influence functions with those derived from high-resolution transport products derived from RAMS simulations.

3) Store and disseminate the output to other researchers for use in carbon cycle inversions. Yet to be started.

4. Leveraging/Payoff:

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

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

The North American Carbon Program (NACP): an interagency collaboration on carbon cycle research sponsored by 9 federal agencies. Denning chairs NACP Science Steering Group, and serves on the NACP Mid-Continent Intensive Task Force, Data Systems Task Force, and Synthesis Task Force

6. Awards/Honors:

7. Outreach:

8. Publications:

SATELLITE DATA RECEPTION AND ANALYSIS SUPPORT

Principal Investigator/Group Manager: Tom Vonder Haar and Michael Hiatt

NOAA Project Goal: Geostationary Satellite Acquisition, Polar Satellite Acquisition, Information Technology Services

Key Words: IT, Computer Resources, Technology, Earthstation, GOES, MSG, AVHRR, DOMSAT, Information Technology, Security, Cluster, Satellite Data, Archive, CloudSat

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 student hourly's assist with the data archive. 90% of staff time is spent performing operations and maintenance.

Computer Resources

CIRA currently has approximately 200 systems that represent CIRA's core computer base. These systems are custom designed, assembled, and maintained by the group. The following list gives a brief overview of the infrastructure resources managed by this group:

Complete system management: Intel servers/workstations using the Microsoft Windows XP/2003/Vista operating system, hardware acquisition and installation, user support, system upgrades, software acquisition and installation, and service packs.

Central services: E-mail, website, accounts, accounting, domain, FTP, DHCP, DNS, printing, remote access, power control, and property accounting.

Security: firewall, NTFS, antivirus, and antispam.

Network: LAN, WAN, cabling, switches, firewall, IP control.

Infrastructure budget and expenditures: $110k/year hardware/software budget.

Technical group consulting: RAMM, NPS, AMSU, Geosciences, CloudSat, Students, Visiting Scientists.

Linux modeling clusters: (1) 64-bit, 40 processor cluster (1) 32-bit 24 processor cluster

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 100TB of Meteorological data going back to 1994. This data is archived on DVD and searchable via a web page.

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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 PCs 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 than comparable "pizza box" servers. By consuming less power and generating less heat, the room requirements are much lower further saving the CloudSat project significant funds.

The CloudSat data processing center has performed flawlessly over the last year and gained recognition by NASA and JPL.

Archive

CIRA has about 3000 8mm tapes which contain meteorological data from the past decade. Significant progress has been made over the last year converting tapes to DVD. 1000 DLT tapes and 4000 8mm tapes have been transferred thus far. These tapes are at risk since tape technology does not last indefinitely, tape 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's, 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

Several technology advancements have been studied this last year 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 placed away from work areas. Alternative PC form factors have been is use in CIRA for the last 5 years. This year, 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. CIRA plans to continue to deploy these technologies and slowly migrate the Linux cluster into a similar topology.

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 are to continue 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:

Sensitivity of Precipitation to Soil Moisture Variability at 30km Grid Spacing

Numerical modeling of warm season convection relies strongly upon knowing the initial soil conditions. Very wet or dry soil can modify the available moist static energy, latent and sensible heat fluxes, the boundary layer temperature, and the vigor and saturation of developing convection. Furthermore, strong soil moisture anomalies can develop their own localized circulations at their boundaries. As such, knowing the soil moisture is crucial for simulating warm season convective rainfall. For this study we ran four simulations at 30km grid spacing for the 2002, 2003, and 2004 June – August warm seasons, and only varied the initial soil moisture. We selected four soil options to compare. We used a homogeneous option with soil at 25% of saturation (Homog), NCEP-NCAR reanalysis-2 at 2.5° grid spacing (NCEP), the Final Global Data Assimilation System (GDAS) at 1° grid spacing, and the North American Regional Reanalysis (NARR) at 32km spacing.
From analysis of initial soil moisture it is apparent that choosing a homogeneous soil value produces the greatest overall and widespread deviation from any realistic dataset

(see Figure 1). The only area where the homogeneous field is close to the NCEP values is the desert southwest where the soil stays quite dry during most of the year, aside from heavy monsoon periods. Of the three datasets, the GDAS and NCEP initial values produce the least deviation between the two. Generally speaking, however, the GDAS soil is more moist over much of western Mexico, and the southwest and southeast U.S. It tends to be drier over the central plains and portions of the northwest U.S. The NARR is dryer than both NCEP and GDAS over Mexico, the southwest U.S., the GoM coast and the Great Plains states.

As expected, the homogeneous soil simulation varied the greatest compared to the other simulations (see Figure 2). The homogeneous model run produces much less precipitation over most of the U.S. aside from the desert southwest. This is a result of the drier soil moisture and widespread reduced surface latent heat flux. Given that the initial soil values for the GDAS and NCEP were most similar, it is not too surprising that the precipitation differences are the least among the given comparisons. Areas of increased (decreased) rainfall in the GDAS-NCEP comparison tend to co-locate with regions of wetter (drier) initial GDAS soil moisture. The NARR to GDAS and NCEP comparisons are quite similar given that the GDAS and NCEP soil data are similar. The differences are substantially greater than the GDAS-NCEP comparison, but they are still much less than that compared to the homogeneous soil run. A closer look at the NARR-NCEP comparison reveals several key features. The drier NARR soil along the GoM coastal states correlates with reduced precipitation in this region. The wetter soil in the Rocky Mountain region is linked to greater precipitation in this region plus areas east on the central plains. While the plains' soil is relatively dry in the NARR, it is feasible that enhanced moisture in the Colorado and Wyoming mountains could lead to more vigorous convective systems that extend their influence on the western portions of the Great Plains.

While these areas of the domain discussed above tend to exhibit direct relationships between soil moisture and precipitation, the precipitation differences in the desert southwest and southern Mexico do not agree with conventional thought. The lack of precipitation difference in the desert southwest may very well be due to rapid drying of the soil regardless of the initial soil moisture values. The month of June tends to be very dry over AZ/NM and northwest Mexico prior to the onset of the monsoon in the U.S. Any initial soil moisture value may reach a common equilibrium value by the onset period of daily convective rainfall. The desert soil does not hold moisture as well as that over the remainder of the U.S., and there is not nearly as much canopy cover to reduce evaporation. As we turn to southern Mexico, the model differences are even more puzzling and the explanation is more complex. Over southern Mexico there is a complex interaction of sea breeze fronts, orographic flows, and elevated convection. Generally, we would not expect the drier soil in NARR to result in increased precipitation. The change in latent heat flux is reduced or neutral in this region, which means the sensible heat flux is increased to some degree. Increased sensible heating of the interior would increase the temperature gradient between the land and ocean and enhance the sea breeze circulation which would likewise enhance the upslope flow along the nearby Sierra Madre Mountains. While this is a possible scenario, a true determination of the differences in averaged conditions over three monsoon seasons is problematic.

Sensitivity of Precipitation to Soil Moisture Variability at 7 km Grid Spacing

While it is important to examine seasonal impacts related to varying the soil moisture on the large scale, it is also useful to examine short term impacts at a resolution high enough to resolve convection without the use a cumulus parameterization. This will allow the model surface to impact convective rainfall without having to reach any minimum target to trigger convection in a convective mass adjustment scheme. These higher resolution simulations are run from July 11 – 16, 2004 and encompass the monsoon surge event on July 13. These simulations still run the parent grid covering the U.S. and Mexico, but they include a 7 km grid spacing nested grid that covers northwest Mexico, Baja, and southern AZ/NM. For these tests, the same soil moisture datasets are used, but with initialization of soil moisture at 0000 UTC July 11.

The homogeneous soil is much drier than NCEP across the domain of northwest Mexico. Relative to NCEP, both the GDAS and NARR are wetter over extreme northwest Mexico and near the AZ/NM border, and they are drier over southwest AZ and the eastern portion of the domain. Relative to GDAS, the NARR is drier nearly everywhere except a portion of the northwest SMO. At this higher resolution, the fine scale differences in soil moisture become apparent and the dataset differences appear more complex. One can anticipate that differences in resultant precipitation will be even more complex and difficult to determine cause and affect relationships.
From the 5-day total precipitation differences (see Figure 3); the broad, encompassing point to note is that changing the initial soil conditions invokes a response over much of the domain, with maximum differences over the crest and foothills of the Sierra Madres and along the AZ/NM border downstream of the monsoon source region. This is in partial contrast to the 90-day seasonal simulations in which there is almost no response in the precipitation differences fields over extreme northwest Mexico, the northern GoC, and southern AZ/NM. This difference in response is very likely a result of the increased ability to resolve the finer scale flows associated with explicitly resolved monsoon convection. A closer examination of the precipitation differences reveals much apparent randomization with areas of large increase directly adjacent to regions of large decrease. The Homog-NCEP and NARR-NCEP comparisons are generally similar despite the marked difference in initial soil moisture. The Homog run is initially drier over the entire fine-grid domain, but does not illicit a response with widespread precipitation reduction. At this scale, the soil condition apparently plays a single role in a very complex chain of events that produces a highly variable response following the simulation initialization. The variations in initial soil moisture field will modify initial formation of convection. This will then modify the soil moisture field through variable precipitation, and the simulations will further diverge in terms of the finest scale details of the precipitation distribution. The domain-scale precipitation retains the pattern of highest rainfall along the SMO and downstream of the moisture plume, but the imbedded details vary due to the variety of initial soil moisture patterns. Despite being dominated by fine scale perturbations, there is a trend such that the drier soil in the NARR over Baja and the northern tip area of the GoC does coincide with reduced precipitation over northern Baja, northern GoC and adjacent coastline. However, these areas are not as strongly dominated by daily convective outbreaks compared to the

slope areas of the SMO. This makes one speculate that the orographic complexities tend to over-ride any direct and long-lasting soil moisture response.

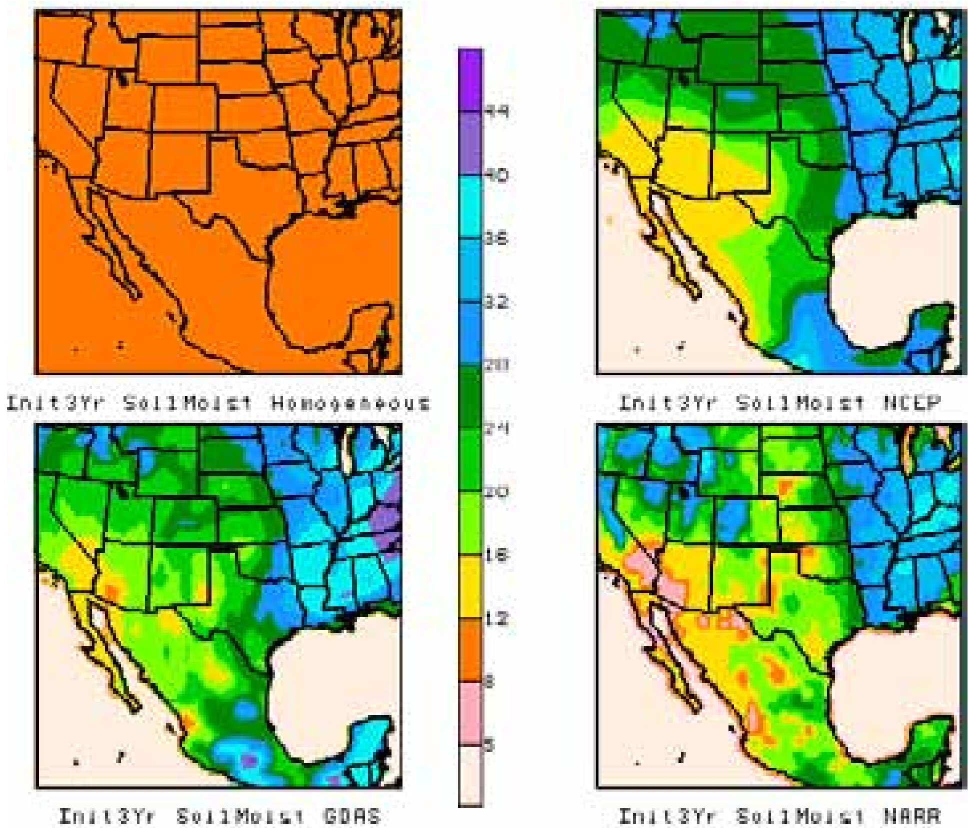


Figure 1. Initial multi-year averaged volumetric soil moisture fraction (m^3/m^3 x 100) from the following data sources: (a) homogeneous, (b) NCEP reanalysis, (c) FNL-GDAS, and (d) NARR.

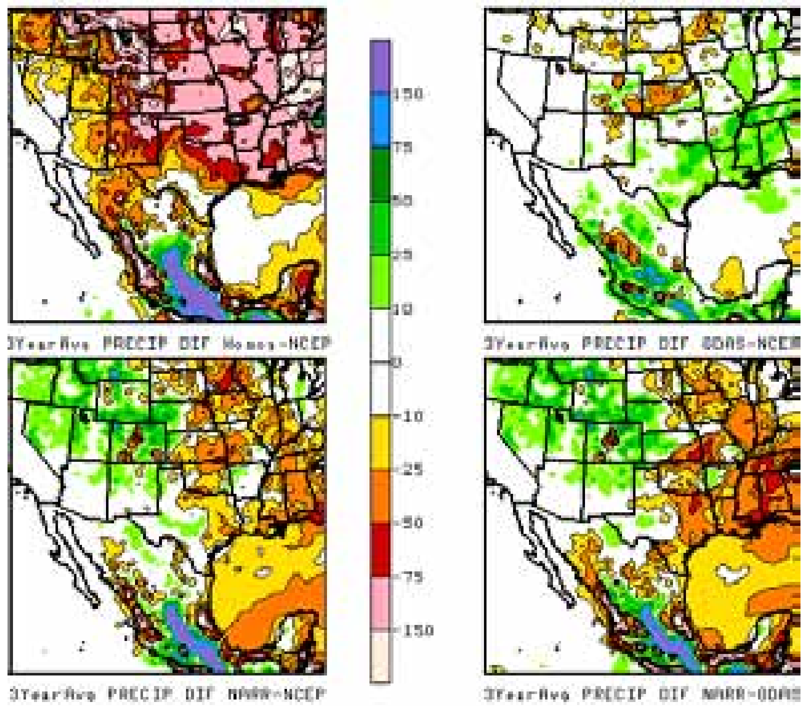


Figure 2. Three year average of the 90-day accumulated precipitation difference fields (mm) that compare the use of the various soil moisture data sets. Panel labels display which simulations are compared. For example, the lower, right panel is labeled with "NARR-GDAS", meaning the GDAS precipitation field was subtracted from the NARR simulations precipitation field.

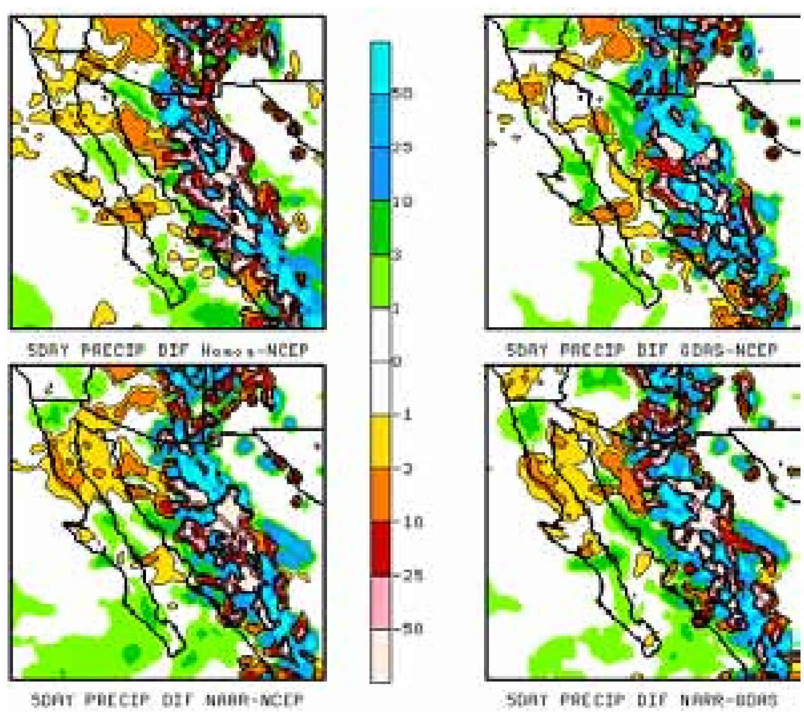


Figure 3. Similar precipitation difference field as in figure 2, except for the July 11-16, 2004 monsoon surge event on the nested 7km spacing grid.

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. We will examine sensitivity to vegetation coverage if time permits.

4. Leveraging/Payoff:

The results of this research should aid in determining which data are most appropriate for model assimilation, so as to improve seasonal forecasts of the NAM and its influence on precipitation over the central U.S.

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

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Saleeby, S.M. and W.R. Cotton, 2006: Sensitivity of simulated monsoonal warm-season precipitation at varying model resolutions to SST forcing from multiple SST datasets. Annual CPPA-PACS PI Meeting, Tucson, AZ.

Saleeby, S.M., and W.R. Cotton, 2007: Sensitivity of monsoon-related warm season precipitation to large and regional scale soil moisture anomalies. Geo. Phys. Lett., (In revision).

Saleeby, S.M. and W.R. Cotton, 2007: Sensitivity of simulated monsoonal warm-season precipitation at varying model resolutions to the choice of initial soil moisture dataset. J. Climate. (In preparation)

SHIP-BASED OBSERVATIONS OF PRECIPITATION CONVECTION AND ENVIRONMENTAL CONDITIONS IN SUPOPRT OF NAME-2004

Principal Investigator: Dr. Steven A. Rutledge

NOAA Project Goal: WEATHER and WATER Programs: Local Forecasts and Warnings; Hydrology; Environmental Modeling.

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:

Since 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 led by M.S. student David Lerach, focusing on the land-based profiler observations acquired by NOAA. Furthermore, the diurnal cycle of sensible and latent heat fluxes measured on the Altair are being related to convection. Thermodynamic sounding data acquired from the Altair are being used to identify synoptic flow patterns and Gulf Surges. These data are being incorporated into the Ph.D. study of Luis Gustavo Pereira who is developing a detailed climatology of convection in NAME. This research is now well underway. 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. We have completed a climatology of convection in NAME, organized by degree of mesoscale organization, using data from the NCAR S-pol radar, and the two digitized SMN radars. Type 1 is isolated convective cells, Type 2 is linear convection below mesoscale proportions, Type 3 is unorganized convection of mesoscale proportions often accompanied by stratiform precipitation, and Type 4 is organized convection (convective lines) of mesoscale proportions, often accompanied by stratiform precipitation. Type 1 dominates in frequency of occurrence while Type 4 dominates in terms of volumetric rainfall (80%). Convective-stratiform precipitation ratios in NAME are approximately 60/40. The NAME radar dataset has also been used to study the diurnal cycle of rainfall, and rainfall rates/amounts as a function of elevation. Rain begins late morning on the high terrain of the SMO and migrates to the coastal plain in the late afternoon, early evening hours. Precipitation over the high terrain falls mainly from isolated convective cells, whereas precipitation falls from convective cells and mesoscale systems over the coastal plain. Peak rain rates are at least a factor of two larger on the coastal plain compared to over the high terrain. We suggest that deeper coalescence zones over the coastal plain (associated with lower cloud base heights) compared to over the high terrain lead to these more intense precipitation rates.

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; *Investigate the coupling of deep convection over both the ocean and nearby land surfaces to changes in ocean fluxes and resulting effects on SST*; this work has not yet started but will be conducted in the coming research period.

4. Leveraging/Payoff:

This work has direct couplings 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 coupled 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:

Graduate/Undergraduate students David Lerach, M.S. – Fall 2006, Vertical Structure and Kinematics of Tropical Monsoon Precipitation Observed From A 2875-MHZ Profiler During NAME

8. Publications:

Higgins, W. et al.: The North American Monsoon Experiment (NAME) 2004 Field Campaign and Modeling Study. *Bull. Amer. Meteor. Soc.,* 87, 79-94.

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,* in press.

Lang, T.J., R. Cifelli, L. Nelson, S.W. Nesbitt, G. Pereira, and S. A. Rutledge: Radar Observations During NAME 2004 Part I: Data Products and Quality Control. 32nd Conference on Radar Meteorology, Albuquerque, NM, 24-29 October 2005.

Lang, T.J., R. Cifelli, D. Lerach, L. Nelson, S.W. Nesbitt, G. Pereira, and S.A. Rutledge: Radar Observations During NAME 2004 Part II: Preliminary Results. 32nd Conference on Radar Meteorology, Albuquerque, NM, 24-29 October 2005.

Lerach, D.G., S.A. Rutledge, and C.R. Williams: Vertical Structure of Precipitation During NAME 2004, *Monthly Weather Review,* submitted.

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.

STUDY OF GULF SURGES USING QUIKSCAT AND NAME OBSERVATIONS

Principal Investigators: Richard H. Johnson

NOAA Project Goal: Climate

Key Words: Monsoon, Precipitation, Moisture Surges

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

Our research is directed toward the investigation of the temporal and spatial characteristics of southerly wind surges in the Gulf of California during the North American summer monsoon. Past attempts to describe and understand these surges have been hampered by a lack of an adequate in situ observing network.

The dynamics of Gulf of California moisture surges have been a long-standing enigma. Recent work by our research group using data from the 2004 North American Monsoon Experiment (NAME) has shed new light on possible dynamical mechanisms for this phenomenon. Gulf surges are important because they provide a significant source of moisture to the southwestern U.S., and make a substantial contribution to summertime precipitation over this arid part of the country.

2. Research Accomplishments/Highlights:

A study of the multiscale variability of the flow during NAME has recently been completed (Johnson et al. 2007). This paper shows that processes on multiple time and space scales affect weather in the NAME region, ranging on the largest scales from the Madden-Julian Oscillation; to medium scales through phenomena such as easterly waves, tropical cyclones, and upper-level inverted troughs; and finally to the mesoscale via low-level jets, convective downdraft outflows, and atmospheric bores. Rogers and Johnson (2007) documented a well-observed Gulf surge that occurred on 13-14 July 2004 and found that its leading edge had the characteristics of an atmospheric undular bore while the disturbance behind it resembled an atmospheric Kelvin wave channeled along the Gulf of California.

A specific atmospheric undular bore event identified in the wind profiler network has been studied using NAME surface and upper-air observations and modeled using the ARW-WRF model (Martin and Johnson 2007). The environment over the Gulf of California is susceptible to bore generation from convective outflows, and these phenomena may be an integral part of some Gulf surges.

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

The proposed effort to study Gulf surges using QuikSCAT and 2004 NAME data has been met with success. Results have been published in the recent papers Bordoni et al. (2004), Johnson et al. (2007), and Rogers and Johnson (2007). Further work is underway by Elinor Martin in connection with her M.S. thesis to investigate atmospheric bores in the NAME region. We have also been able to elucidate some of the dynamical mechanisms for surge propagation, but further studies involving numerical simulation are needed to fully unravel the key processes.

4. Leveraging/Payoff:

This research addresses a number of key issues pertaining to the North American Monsoon System, and is ultimately directed at improving prediction of precipitation over North America. Monsoon rainfall accounts for a substantial fraction of the total annual rainfall in northwestern Mexico and the southwestern U.S. From a practical forecasting standpoint, the proposed research is intended to contribute to model improvements and enhance skill in short-term prediction.

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

In the course of our research, we have developed collaborations with the following individuals: Simona Bordoni, Ph.D., UCLA; Prof. Bjorn Stevens, UCLA; Dr. Michael Douglas, NSSL/NOAA; Dr. Wayne Higgins, NCEP/NOAA; Dr. Kingtse Mo, NCEP/NOAA; Dr. David Gochis, NCAR; and Dr. June Wang, NCAR.

6. Awards/Honors:

PI Richard Johnson has just finished a 3-year term on the NAME Science Working Group and was selected to serve on the CPPA Science Panel.

7. Outreach:

Peter Rogers received the M.S. degree in Fall 2006 under this award. Elinor Martin expects to receive the M.S. degree in Fall 2007. Through the dedicated efforts of Senior Research Associate, Paul Ciesielski, raw and processed NAME atmospheric sounding data have been made available to the NAME scientific community at http://tornado.atmos.colostate.edu/name/. The PI has assisted in planning for NOAA CPPA by attending meetings of the NOAA CPPA Science Panel in 2006.

8. Publications:

Bordoni, S., P. E. Ciesielski, R. H. Johnson, B. D. McNoldy, and B. Stevens, 2004: The low-level circulations of the North American Monsoon as revealed by QuikSCAT. *Geophys. Res. Lett*., 31, L10109, doi:10.1029/2004GL020009.

Higgins, R. W., and CoAuthors, 2006: The North American Monsoon Experiment (NAME) 2004 field campaign and modeling strategy. *Bull. Amer. Meteor. Soc.*, 87, 70-94.

Johnson, R. H., 2006: Mesoscale Processes. B. Wang, Ed., *The Asian Monsoon*, Ch. 8, Praxis-Publishing Ltd., 331-356.

Johnson, R. H., and C.-P. Chang, 2007: Winter MONEX: A Quarter-Century and Beyond. *Bull. Amer. Meteor. Soc*., 88, 385-388.

Johnson, R. H., P. E. Ciesielski, B. D. McNoldy, P. J. Rogers, and R. K. Taft, 2007: Multiscale variability of the flow during the North American Monsoon Experiment. *J. Climate*, 20, 1628-1648.

Martin, E. R., and R. H. Johnson, 2007: An observational and modeling study of an atmospheric internal bore during NAME 2004. AGU Joint Assembly, Acapulco, MX, 22-25 May.

Rogers, P. J., and R. H. Johnson, 2006: Analysis of the 13-14 July gulf surge event during the 2004 North American Monsoon Experiment. *Mon. Wea. Rev*. (in press).

SUPPORT OF THE VIRTUAL INSTITUTE FOR SATELLITE INTEGRATION TRAINING (VISIT)

Principal Investigator: T. H. Vonder Haar

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 seven sessions created by VISIT collaborators in addition to a new teletraining session developed at CIRA. As training needs develop for new research and products, VISIT personnel will address those needs by building new teletraining sessions.

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 over 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). Participation by NWS forecast offices during the period July 1, 2006 – June 30, 2007 can be seen in Figure 3. The VISIT website (http://rammb.cira.colostate.edu/visit) contains stand-alone versions of most sessions, with embedded instructor notes, that can be viewed using a web browser. There are audio versions with instructor's annotations for selected sessions. The web/audio versions make it possible to view the material 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.

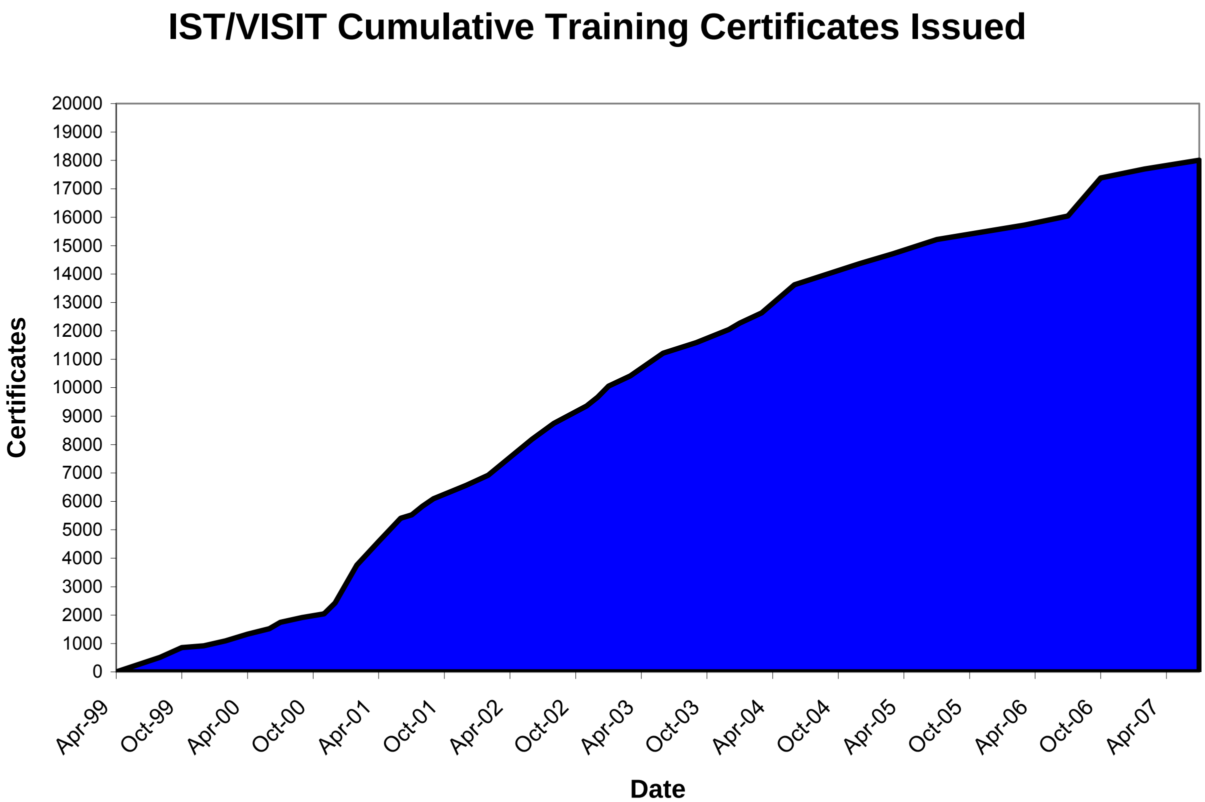


Figure 1. IST/VISIT Cumulative Training Certificates Issued.

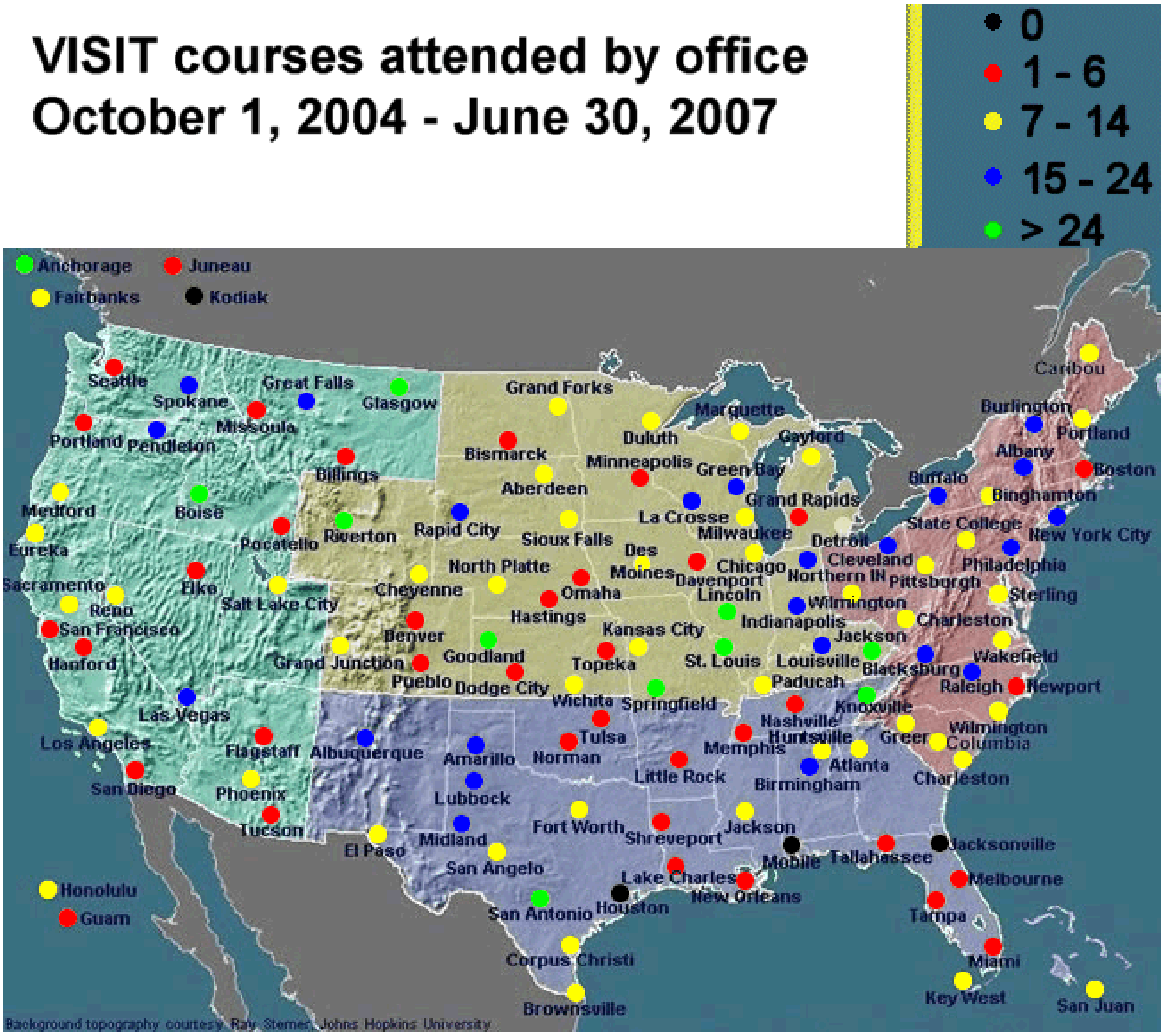


Figure 2. Map showing the NWS forecast offices that have taken VISIT teletraining session(s) since October 2004; number of sessions attended given by the color.

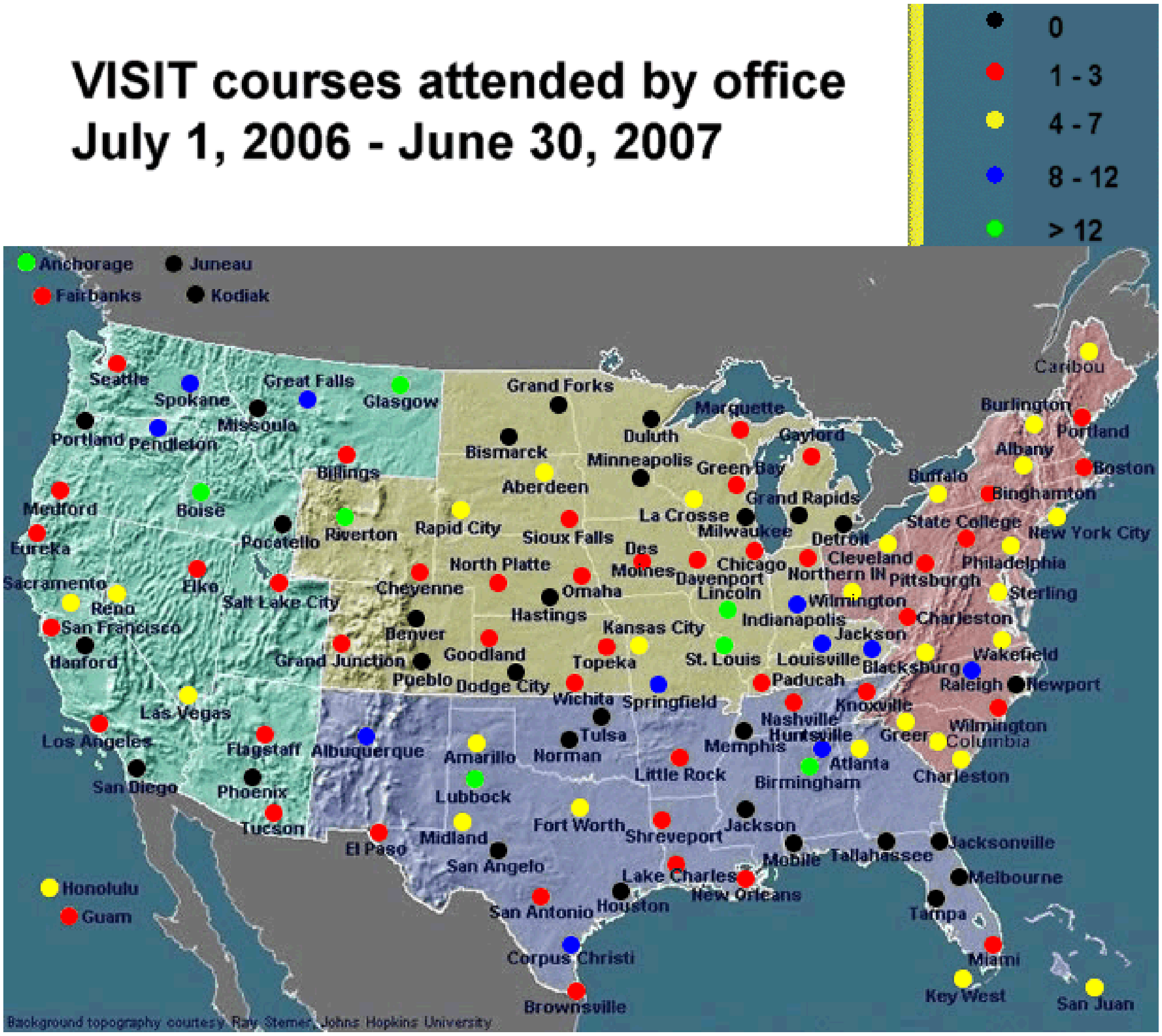


Figure 3. Map showing the NWS forecast offices that have taken VISIT teletraining session(s) since July 2006; number of sessions attended given by the color.

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

In the last year, the VISIT team at CIRA has developed a new teletraining session titled "Satellite Interpretation of Orographic Clouds / Effects". This was done in order to honor the request made by NWS forecasters for a session dealing with this topic. All other objectives of the proposal were also accomplished (see section 5 below).

4. Leveraging/Payoff:

In the late 1990s, NOAA's NWS training requirements began to outpace the availability of travel funds. At the same time, the Internet was becoming more reliable, bandwidth was increasing, and computers were becoming more powerful. The timing was right for the introduction of distance learning. The VISIT program continues to provide an attractive alternative to costly residence training. 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.

5. Research Linkages/Partnershipsw/Collaborators:

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). Summarized below in Table 1 are the number of individuals registered for each VISIT session that was available electronically through the LMS between July 1, 2006 and May 1, 2007 (Note: These numbers also show popularity trends):

VISIT training session	Registrations
Utilizing GOES Imagery within AWIPS to Forecast Winter Storms	17
Cyclogenesis	96
Extended Range Forecasting	66
Interactive Cloud Height Algorithm	12
Lightning Meteorology I	42
Lightning Meteorology 2	33
Mesoscale Analysis of Convective Weather	75
Mesoscale Convective Vortices	45
Monitoring Gulf Moisture Return	26
Predicting Supercell Motion	24
QuikSCAT Winds	23
TROWAL Identification	6
Water Vapor Channel	33

Table 1. Number of students registered via the LMS for VISIT training sessions between July 1, 2006 and May 1, 2007.

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).

--113 NOAA/NWS employees/participants have registered at CIRA

--56 of the 113 (50%) individuals have completed the SHyMet Intern Course

--Registrations through LMS tracking indicate that an additional 80 individuals not registered at CIRA have taken SHyMet modules. Due to the nature of the current LMS, it is difficult to tell how many of these individuals have completed the SHyMet Intern Course.

--16 non-NOAA participants have registered at CIRA (Department of Defense (DOD), National Environmental Satellite, Data, and Information Service / Satellite Applications Branch (NESDIS/SAB) contractors)

--9 of the 16 (56%) individuals have completed the SHyMet Intern Course.

SHyMet support involved putting together and organizing 9 separate recorded audio/visual sessions that corresponded to the original sessions, listing them on the LMS website, providing quizzes for each session as well as a means for evaluation. Between July 1, 2006 and June 30, 2007, the number of those registered for each SHyMet session is summarized below in Table 2:

SHyMet training session	Registrations
Orientation	193
GOES Imaging and Sounding Area Coverage	173
GOES Channel Selection	171
Introduction to POES	169
GOES Sounder Data and Products	156
GOES High Density Winds	158
Cyclogenesis	161
Severe Weather	174
Tropical Cyclones	205

Table 2. Number of students registered via the LMS for SHyMet training sessions between July 1, 2006 and June 30, 2007.

Note: Due to the transition of the LMS, course availability was limited at best during the months of May and June 2007, so the overall numbers for both SHyMet and VISIT would have been higher had this not been the case.

Support for the SHyMet Program continues to include such roles as sending and receiving quizzes and evaluations for Non-NOAA participants; registration and tracking of NOAA/NWS students through the LMS and their training facilitators; webpage maintenence; and correspondence. A combined VISIT / SHyMet survey was also writtien, administered, and disseminated through the combined efforts of the VISIT staff with those of the National Weather Service Training Branch as well as the National Weather Service's Union. The analysis and results of the survey were also performed by VISIT and SHyMet staff and are currently being reviewed by the NWS at the national level. The results of the survey may be viewed here:
http://rammb.cira.colostate.edu/visit/Combination_Report_Survey_1.htm
May 1, 2007 marked the end of the original Department of Commerce's(DOC)/NOAA/NWS LMS hosted by GeoLearning and the beginning of the new LMS hosted by Learn.com. Since May 1, 2007 the VISIT staff has been in the process of training for the new LMS as well as creating new courses and quizzes. The SHyMet Intern Course will be available as a "learning path" (packaged course) by September of 2007. The VISIT staff will continue to administer SHyMet material throught the LMS, including keeping track of the metrics.

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
CIRA contributed content to the new training module 'Detection of Volcanic Ash and SO2' by Jochen Kerkmann of EUMETSAT.
http://www.eumetsat.int/home/Main/What_We_Do/Training/Distance_Learning/index.htm?l=en
3) the virtual high profile training event (HPTE) which took place October 16 to 27, 2007

The HPTE was described as a huge success internationally for training on the use of data and products from meteorological and environmental satellites, the WMO estimates that over 4000 participants from 100 member countries around the globe took part in lectures and weather briefings via the Internet during the HPTE.
CIRA/VISIT partnered with NOAA NESDIS, the Cooperative Institute for Meteorological Satellite Studies, the National Weather Service's Training Division and International Desk of the National Centers for Environmental Prediction, and the Cooperative Program for Operational Meteorology, Education and Training. Internationally, VISIT partnered with the Bureau of Meteorology Training Center in Australia, the WMO Centers of Excellence in Costa Rica, Barbados, Argentina and Brazil, and the European Organization for the Exploitation of Meteorological Satellites. The success of the WMO

HPTE was made possible by the extensive use of the VISITview software to deliver the presentations and weather briefings in real-time around the globe through the Internet

Lectures and weather briefings in the Americas were presented in both Spanish and English. More information on the event can be found at http://rammb.cira.colostate.edu/training/wmovl/ . In NOAA's region of responsibility, the first weather briefing and lecture drew 128 participants from 21 countries. (Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guyana, Guatemala, Honduras, Panama, Paraguay, Peru, Trinidad and Tobago, and Venezuela). During the 2 week period, it is estimated that a total of 380 participants from the Americas and the Caribbean were trained in the various sessions. NOAA and its partners came together for a common goal – to better communicate and share information and training materials with the ultimate goal of saving lives and property around the world.

6. Awards/Honors: None

7. Outreach: (a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

(a) A high school student (Kashia Jekel) and a college undergraduate student (Daniel Coleman) are supported by this project.

(b) D.E. Bikos, and J. Braun Jul 1, 2006 – Jun 30, 2007: 163 VISIT teletraining sessions delivered to NWS offices, and others (1530 participants). CIRA, Fort Collins, CO.

B. H. Connell, July 2006 through June 2007 : Collaboration of 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.: CIRA, COMET, the International Desk at NCEP/HPC, SAB at NESDIS, as well as outside the U.S.: Antigua and Barbuda, Argentina, Bahamas, Barbados, 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 as well as forecasters.

B. H. Connell, July 5, 2006: The WMO Virtual Laboratory task group gave a session demonstrating the features of VISITview for collaborative weather briefings to a class of 44 participants at training on the Use of MSG data for Environmental Applications. The training was sponsored by EUMETSAT and held at INPE (Instituto Nacional de Pesquisas Espaciais) in Sao Paulo, Brazil.

(c) None

(d) J.F. Braun, September 2006: Basic Meteorology for intro to physics, chemistry, and environmental science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, October 2006: Basic Meteorology for intro to physics, chemistry, and environmental science Boltz junior high school, Fort Collins, CO.

J.F. Braun, November 2006: Basic Meteorology for intro to physics, chemistry, and environmental science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, November 2006: Science fair judge, Boltz junior high school, Fort Collins, CO.

(e) VISIT training material is available to the public via the Internet.

8. Publications:

<u>Refereed Journals</u>
Bikos, D., Weaver, J., and J. Braun, 2006: The Role of GOES Satellite Imagery in Tracking Low-Level Moisture. Wea. Forecasting, 21, 232-241.

<u>Presentations</u>
D. Bikos and J. Braun, June 2007: Invited lecturers at the COMET Mesoscale Analysis and Prediction (COMAP) course, Boulder, CO.

Presentation was prepared for the 32^{nd} International Symposium on Remote Sensing of Environment titled "International Satellite Weather Briefings via the Internet" by B. Connell, V. Castro, M. Davison, T. Mostek, Berny Fallas, Evelyn Quiros, and Gustavo Murillo. Three students from the University of Costa Rica (Berny Fallas, Evelyn Quiros, and Gustavo Murillo) gave the presentation June 26, 2007.

B. Connell June 15, 2007: Presentation on VISITview and International Training activities to visitors from the Autonomous University of Yucatan (UADY), Mexico. The UADY representatives expressed interest in utilizing CIRA products and the VISIT program to educate the academic community at UADY so that it can help surrounding communities prepare for and respond to natural disasters.

D. Bikos, J. Braun, and B. Connell, May 8, 2007: Presentations on VISITview, National and International Training were given at a NPOESS/COMET workshop. The afternoon sessions were at CIRA.

B. Connell, April 20, 2007 and November 17, 2006: GOES and the characteristics of its channels. Remote Sensing class at the Metropolitan State College of Denver, CO.

B. Connell, March 29,2007: A virtual presentation using VISITview was given to the 4th International Workshop on Volcanic Ash held in Rotorua, New Zealand. The presentation summarized National and International training efforts at CIRA and use of the VISITview software. The voice was done over the Internet through Yahoo messenger. The audience included approximately 40 persons, a mix of meteorologists, volcanologists, and persons from the aviation sector.

B. Connell gave a presentation on “National and International Training Highlights” at the 3rd Annual NOAA/NESDIS/CoRP Science Symposium hosted by CIRA in Fort Collins on August 15-16, 2006 http://rammb.cira.colostate.edu/corp/Symposium/PostSymposium/Index.htm

THE ROLE OF AFRICA IN TERRESTRIAL CARBON EXCHANGE AND ATMOSPHERIC CO2: REDUCING REGIONAL AND GLOBAL CARBON CYCLE UNCERTAINTY

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 data sets and atmospheric transport models for new and enhanced atmospheric inversion studies. These activities are described in more detail below.

<u>Year 3 Work Plan</u>

--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.

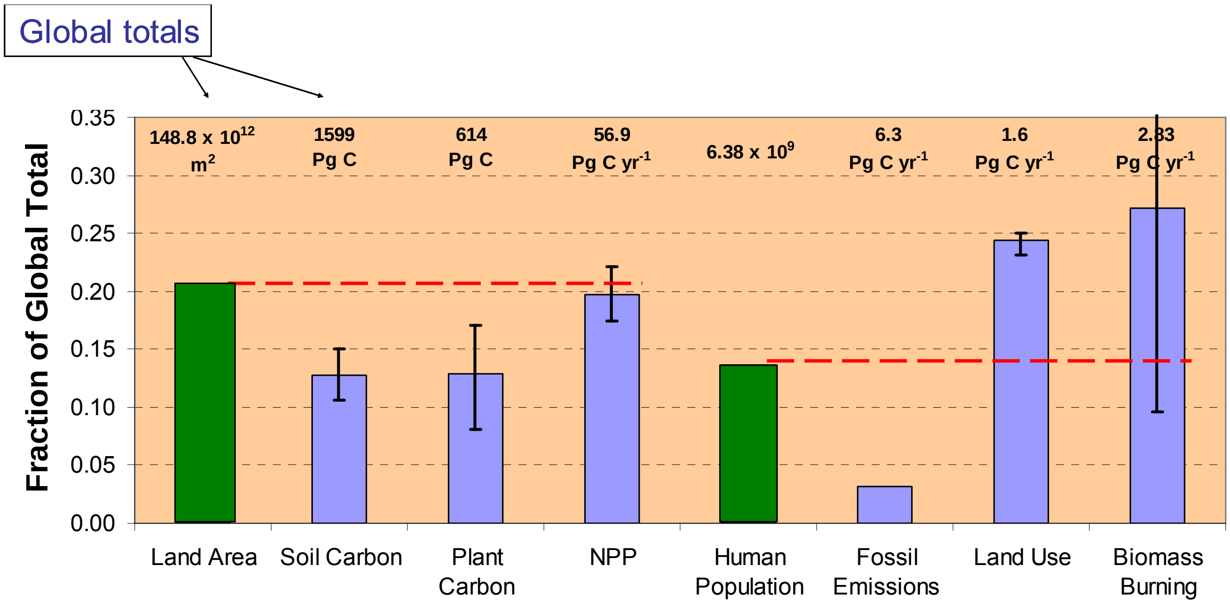


Figure 1. Carbon statistics for Africa expressed as fraction of global totals ('error bars' show range of published estimates). Land area and human population are shown as reference for Africa's fractional contribution to global carbon stocks and fluxes.

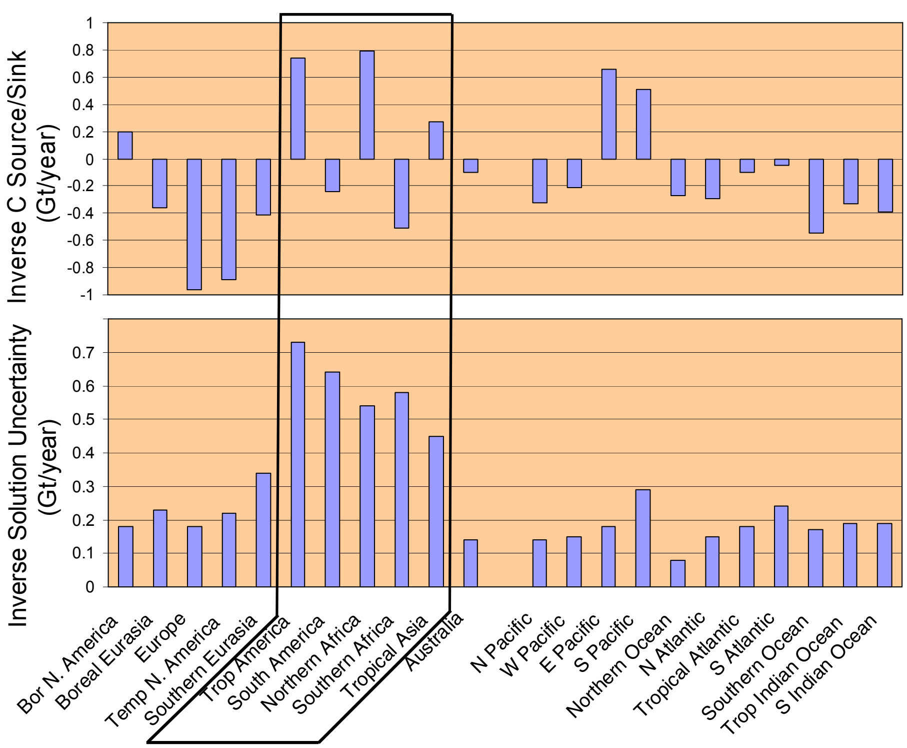


Figure 2. Inverse analysis results showing high levels of uncertainty for Africa and tropical terrestrial regions. (Data from TRANSCOM-2; Gurney et al., 2004).

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

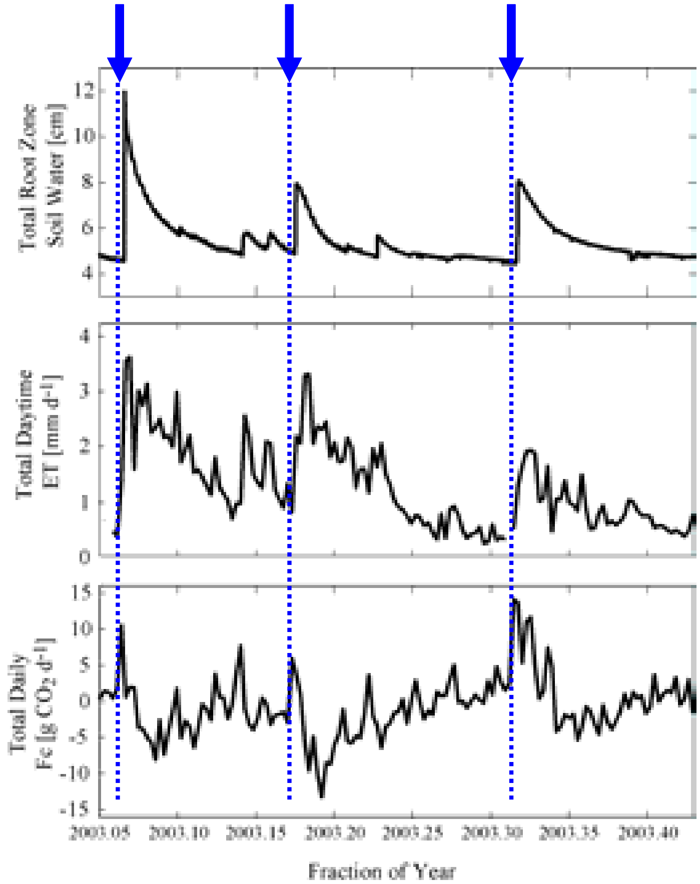


Figure 3. Pulse dynamics in tropical savannas. Measurements at the Kruger Park intensive research site during 2003 show the complex and non-linear response of savanna vegetation to rainfall events that depend not only on soil moisture, but also on phenological status and structural characteristics of 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.

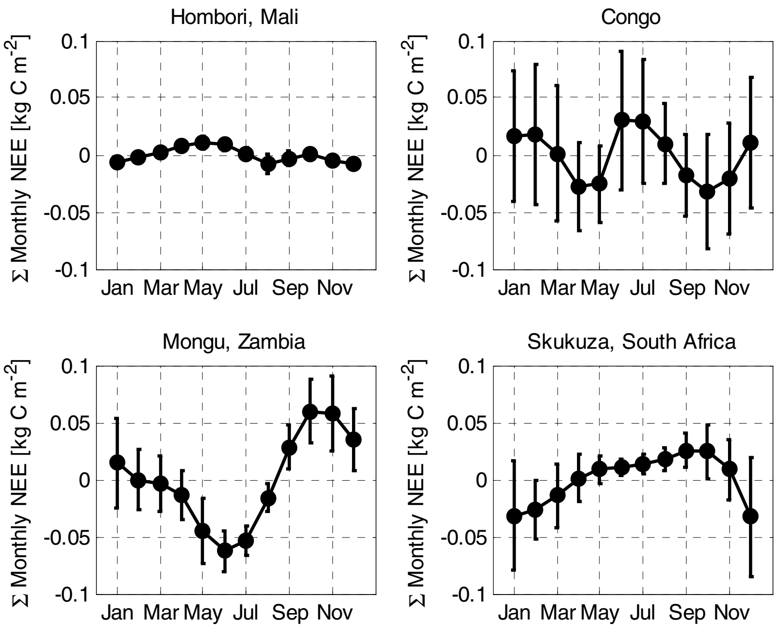


Figure 4. Monthly net ecosystem exchange (NEE) for 4 sample sites in Africa estimated using the Simple Biosphere Model (SiB3) and the long-term (1983-2000) AVHRR dataset. Climate data for the period were obtained from NCEP climate re-analysis fields. Hombori and Skukuza are active ACE field sites for 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.

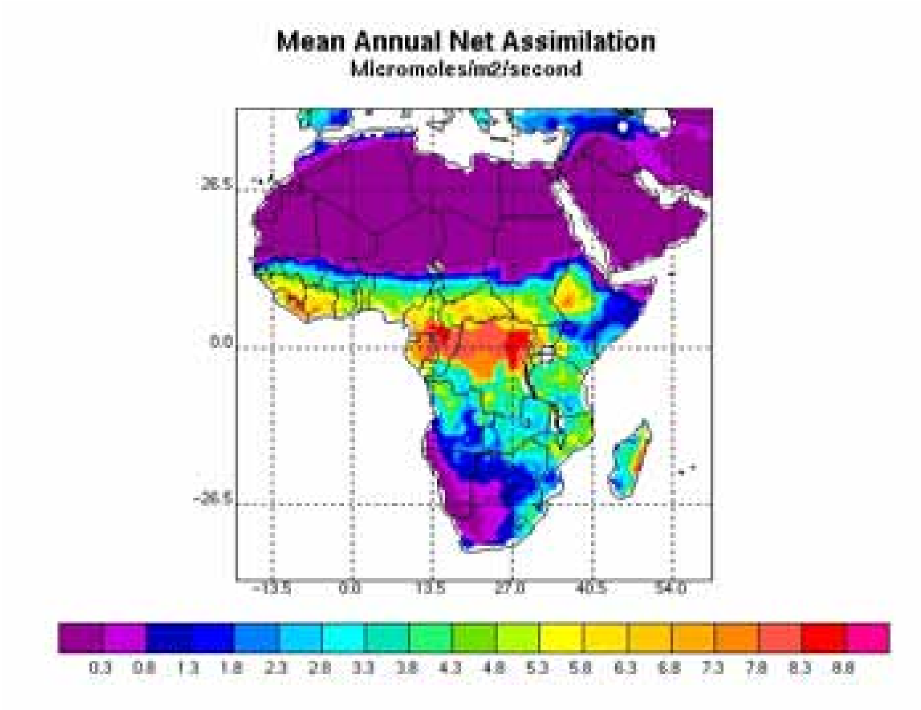


Figure 5. Annual average net assimilation rate (1983-2000) estimated using the SiB3 model, NCEP climate re-analyses and the long-term AVHRR data set.

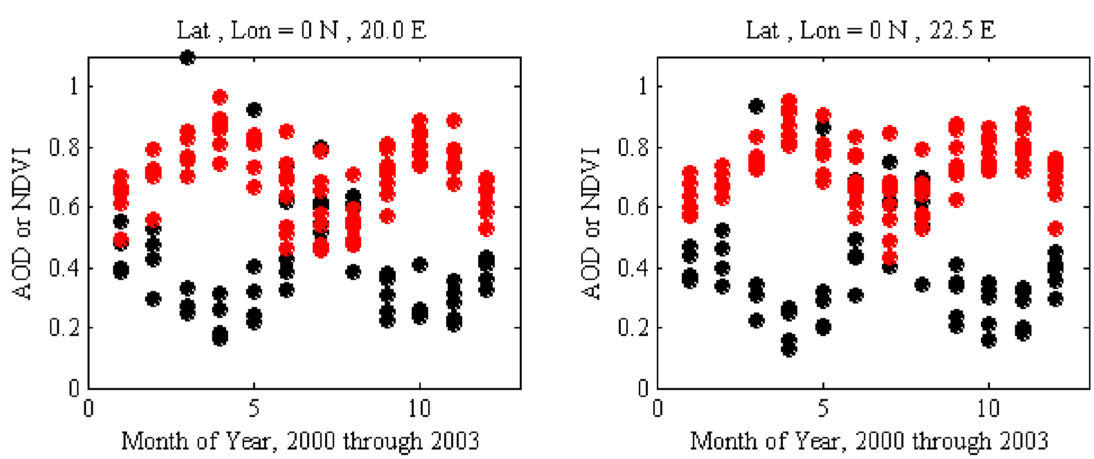
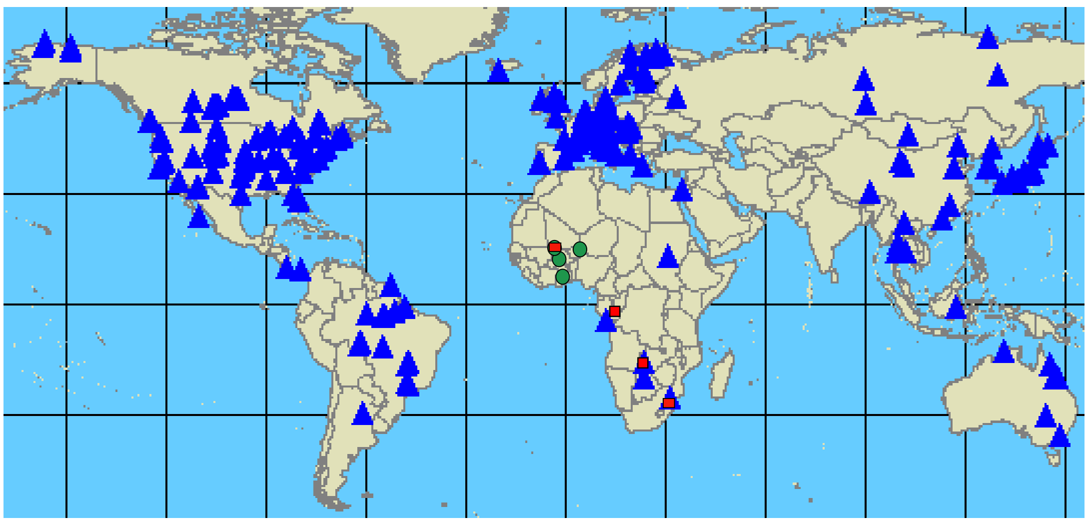


Figure 6. Monthly average AVHRR NDVI (red) and MODIS aerosol optical depth (black) in the moist tropics of Africa. Data are shown for two sites on the equator and for years with overlapping AVHRR and MODIS data availability (2000-2003). Note the strong seasonality in AVHRR NDVI that is negatively correlated 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).

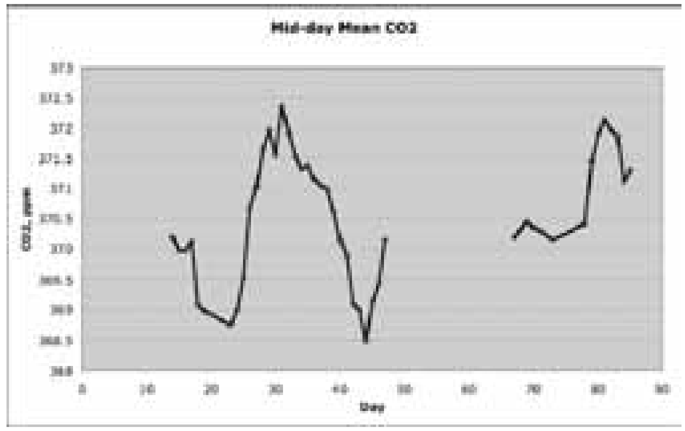


Figure 8. Precision carbon dioxide and flask sampling system (left) and midday atmospheric CO_2 concentration measurements (right) at the Skukuza eddy flux site in the Kruger National Park, South Africa. The system uses automatic calibration with WMO-traceable standards and a temperature controlled infrared gas analyzer to measure CO_2 concentration to an absolute precision of ~0.2 ppm.

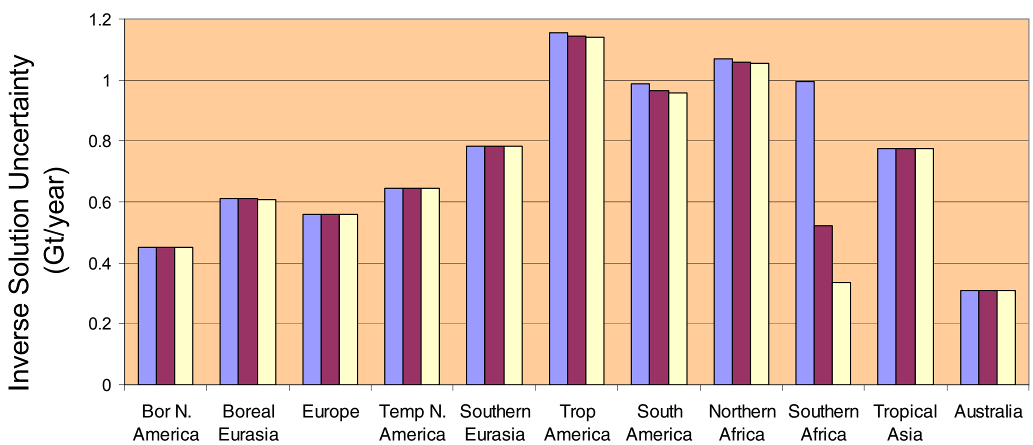


Figure 9. Effect of precision CO_2 sites in Southern Africa on atmospheric inversion uncertainty for Africa and other terrestrial regions (Blue: using existing flask network; Maroon: anticipated effect of adding a precision CO2 site in South Africa; white: adding a precision CO2 site in Zambia). Atmospheric 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.

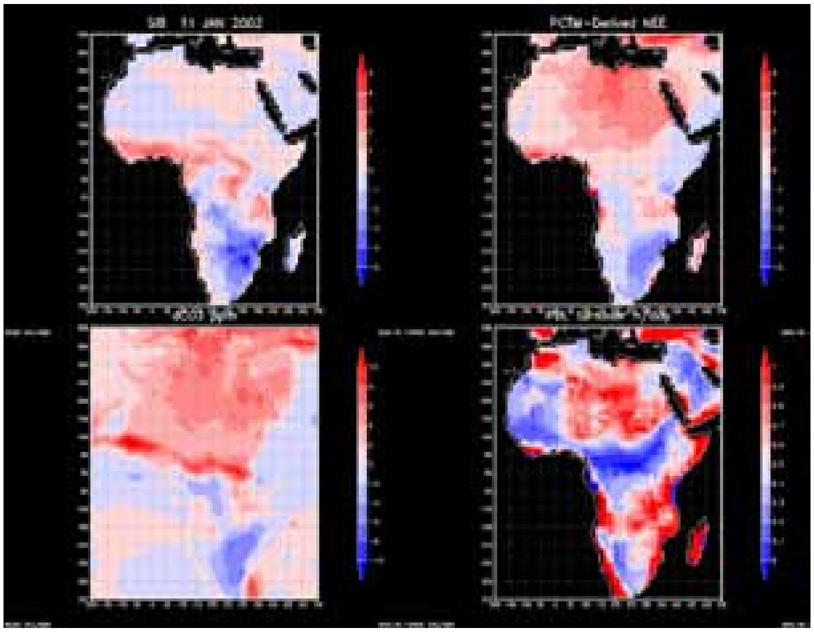


Figure 11. Regional Carbon Flux Estimation using a PBL-budget approach with near-surface [CO2] and atmospheric transport. This figure shows a snapshot (11 January 2002) of an annual simulation. The regional inversion method was described by investigator Berry and collaborators (Betts, Helliker, and Berry, 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 differences 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.

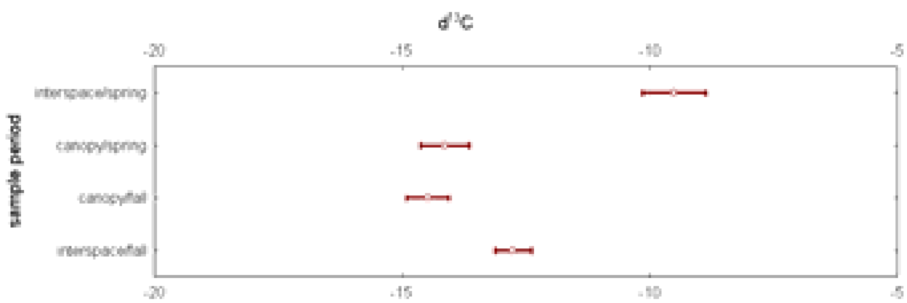


Figure 12. $d^{13}C$ of soil CO_2 flux by season and sampling location for 2006

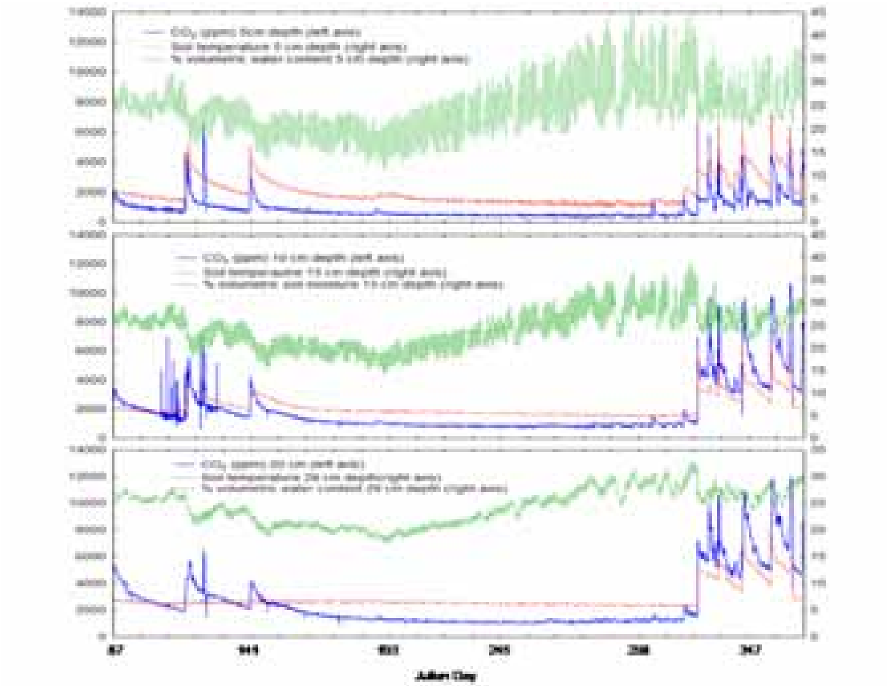


Figure 13. Soil CO_2 concentrations, water content and temperature during 2006 for an undercanopy sampling location. Note the close correspondence between soil CO_2 and water content through the year.

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 (choose one Project Goal and any Programs that the work would fall under- see attached chart) – 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:

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: Evaluation of 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.

2. Research Accomplishments/Highlights:

This project began in May 2006 and has successfully continued toward accomplishing the research objectives. In July 2006, a “Snowfall Workshop” was held at Environment

Canada in Downsview, ON. This was integral in design and deployment of our current snow measurement array. Prior to the 2006-2007 snow season, siting criteria and installation guidelines were put in place for 17 sites located at NWS Weather Forecast Offices across the U.S. Most sites were installed and collecting data by November 1, 2006, however the last installation was completed in late January 2007. Each site collected data from an array of three Campbell Scientific SR-50 sensors at 5-minute intervals. Manual observations of snowfall, total snow depth, depth adjacent to each sensor, snow water equivalent and gauge precipitation were also collected. Both automated data were sent to the project website (http://snowstudy.cocorahs.org) for archival and graphical display. Following completion of the 2006-2007 snow season, a final report and initial analysis of the data was completed and sent to NWS Headquarters for evaluation. Initial research into manual snow measurement uncertainty was also included in the final report. Research into other technologies is also an ongoing task. Snowfall algorithm work has been put on hold until further research into signal processing to remove noise is completed.

3. Comparison of Objectives Vs. Actual Accomplishments:

All objectives except for #3 have been completed.

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:

Environment Canada, National Weather Service, Ultra Sonic Data Study (USDS) website (http://snowstudy.coorahs.org)

6. Awards/Honors: None

7. Outreach: (a.) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness.

b) Symposium on Meteorological Observations and Instrumentation, January 2007.

8. Publications:

Ryan, Wendy A., Nolan J. Doesken, and Steven R Fassnacht. "Evaluation of Ultrasonic Snow Depth Sensors for U.S. Snow Measurements" submitted to the AMS JTECH journal and is still in the review process.

Ryan, Wendy A., Nolan J. Doesken and Steven R. Fassnacht "Preliminary Results of Ultrasonic Snow Depth Sensor Testing for National Weather Service (NWS) Snow Measurements in the U.S." submitted to the Special Eastern Snow Conference Edition of Hydrological Processes and is currently in the review process.

Ryan, Wendy A. and Nolan J. Doesken. "Ultrasonic snow depth sensors for National Weather Service (NWS) snow measurements in the U.S.: Evaluation of operational readiness" by AMS 14th Symposium on Meteorological Observations and Instrumentation, January 13-18, 2007, San Antonio, TX, Paper 6.1.

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, Assimilation, 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 addresses NOAA-relevant concerns. The five CG/AR research theme areas are:

--Hydrometeorology
--Clouds, Icing, and Aerosols Effects
--Environmental Modeling and Assimilation
--Urban and Boundary Layer Environment
--Remote Sensing of Battlespace Parameters

All relate to NOAA's Climate, Weather and Water, and Commerce & Transportation Goal areas.

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 Loretta Wilson at CIRA. This information has been limited to NOAA-relevant research and activities not relevant to at least one of NOAA's goals are not included.

Dust transport using NAAPS and in situ Aerosol Data (Kreidenweis, PI)

Objectives:

Analyze simulations (re-analyses, not forecasts) from the Navy Aerosol Analysis and Prediction System (NAAPS) for seasonal and spatial variations in surface dust mass concentrations across CONUS.

Prior evaluations focus mainly on Middle East and Asia

Research methodology: Compared local (North American) vs. long-range (Asian, Saharan) influences by differences between two runs (all sources, then all except North American sources)

Four years (2001 - 2004)

Compare with available surface observations including IMPROVE aerosol network (rural sites)

Principal Results and Deliverables:

We completed a comparison of 4 years of model and observational data (2001 - 2004), for 28 sites across the U.S.

NAAPS reanalyses run by Marcin Witek, Ph.D. candidate, Warsaw University, under supervision of Dr. Piotr Flatau .

Findings discussed in Johnson, 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,"

M.S. Thesis, Colorado State University.

Purpose of the Research was to generate recommendations for model adjustments to enhance predictions across CONUS.

Principal Results and Deliverables:

We prepared and submitted a manuscript to Atmospheric Environment focusing on the results for the Western U.S.: An analysis of seasonal surface dust aerosol concentrations in the western U.S. (2001-2004): Observations and model predictions:

Kelley Wellsa, Marcin Witekb, Piotr Flatauc, Sonia Kreidenweis, and Douglas Westphald

A) Department of Atmospheric Science, 1371 Campus Delivery, Colorado State University, Fort Collins, Colorado, 80523

B) Warsaw University, Interdisciplinary Centre of Mathematical and Computational Modeling, Pawinskiego 5a, 02-106 Warsaw, Poland and Institute of Geophysics, Pasteura 7, 02-093 Warsaw, Poland

C) Scripps Institute of Oceanography, University of California, San Diego, CA 92093

D) Naval Research Laboratory, Marine Meteorology Division, 7 Grace Hopper Ave, Stop 2, Monterey, California, 93943

Favorable review; revision resubmitted 12 April 2007; awaiting decision

Key findings also presented at this Annual Review in a poster (Wells et al.)

Findings:

Three possibilities for overpredictions of source strength in northern states:

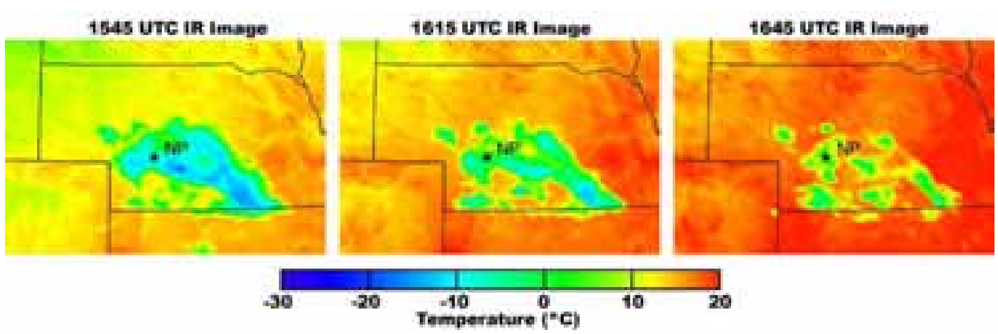
Underestimation of dust concentrations from the IMPROVE samples

IMPROVE tends to overestimate because of assumptions needed to convert available data into dust concentrations. A high bias in NOGAPS surface wind speeds near source regions, generating dust too readily and in too-high concentration. We studied NOGAPS / NCEP biases and found they exist, but NOGAPS was biased LOW.

Excessively strong dust source functions or inappropriate emissions thresholds were the likely cause. We changed friction velocity and also included snow cover in separate, several-month simulations. For the test period of Jan-Feb 2004, the addition of NOGAPS snow cover did improve the overall agreement between NAAPS and IMPROVE. The frequency of NAAPS simulated concentrations falling within a factor of two of the measurements increased from 27 to 43%.

The simulation from Aug-Oct 2004 in which the threshold friction velocity was increased, however, resulted in a decrease in the frequency of simulated concentrations falling within a factor of two of the observations from 42 to 29%.

S. Kreidenweis will conduct a small study of sulfate aerosol simulations vs. IMPROVE observations across U.S. (possibly Europe as well). Initial comparisons (by K. 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, and we simulated two layer clouds observed during CLEX-9.



RAMS Simulations of Urban Landscape

Principal Results and Deliverables:

Results from the simulations demonstrated the capability of RAMS when coupled to TEB to produce a reasonable urban heat island. Comparison with point observations both at the surface and in the vertical demonstrated that RAMS with TEB produced a better urban boundary layer in most instances. The coupled system also had an influence on the mesoscale wind system around Washington D.C. which suggests influence well beyond the urban core of the city. Several sensitivity studies were also conducted to assess what aspects of the urban parameterization were most important at these scales (inner nest 5 km) and the importance of determining the relative roles of linear and nonlinear terms in the dynamic core of models. The linear portion of the dynamic core can be evaluated analytically and exactly and only the nonlinear portion needs to be evaluated numerically thus reducing computational errors.

If the hydrostatic pressure component dominates, then instantaneous diagnosis of the temperature field yields the pressure field showing the importance of determining the hydrostatic pressure relative to total pressure in an atmospheric model simulation. The hydrostatically determined pressure field (based on the temperature measurements) can permit the diagnosis of synoptic scale information such as the large scale wind shear (through the thermal wind relation) for mid- and high-latitudes.

New parameterization approach

This method replaces existing individual parameterizations with look-up tables or its equivalents.
It also replaces the physics of parameterizations for specific physical processes with look-up tables or their equivalent (unified parameterizations).

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.
Goal:
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.

Modeling and Data Assimilation
Project Objectives
--Develop and experimentally test observational operators (IR and MW) for clear and cloudy conditions
--Earlier 4DVAR work used GOES IR Imager data
--Two new major experiments:
    --GOES Sounder

--WindSat

2 Major 4DVAR Experiments

--WindSat soil moisture experiment – Oklahoma Sep. 2003

--Status:

--RAMDAS model initialization is complete,

--All satellite and model data prep is complete,

--Stand-alone Observational Operator (OO) tests are complete (e.g., sensitivity and initial parameter optimizations)

-- WindSat OO “retrievals” successfully demonstrated (RFI and veg. factors)

Integrated 4DVAR OO tests - recently started

--GOES Sounder clear/cloudy radiance experiment – Okla. Mar. 2000

--Status:

--new RAMDAS initialization capabilities are complete,

--All satellite and model data prep is complete including a new GOES Sounder data translator is complete

--Successfully passed minimization cycle tests (>10 iterations)

--Testing and experiment improvements are in progress

Parameterizing Aerosol and Sub-grid Cloud Properties in a Mesoscale Model

Objectives:

To 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

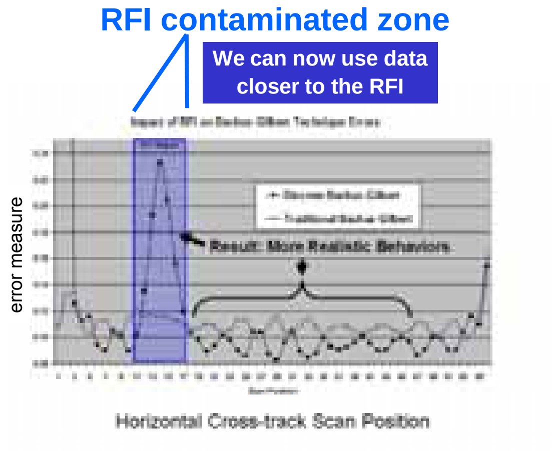
--“How good is the background soil moisture state information?”

--“How much should the DA system rely upon the a priori estimates?”

Soil Moisture Detection

Microwave Spatial Filter:

- **Discrete Backus-Gilbert (DBG) theory extended to RFI conditions**, and analyzed for variations in associated antenna gain patterns (Stephens and Jones, 2006, 2007a)
- **Generalized DBG technique** suitable for all passive microwave sensors has been created and successfully demonstrated (Stephens and Jones, 2007b)
- **Results in accuracy improvements and implementation cost savings for the Govt.**



CG/AR

DoD Center for Geosciences/Atmospheric Research at Colorado State University Annual Review April 17-19, 2007 16

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

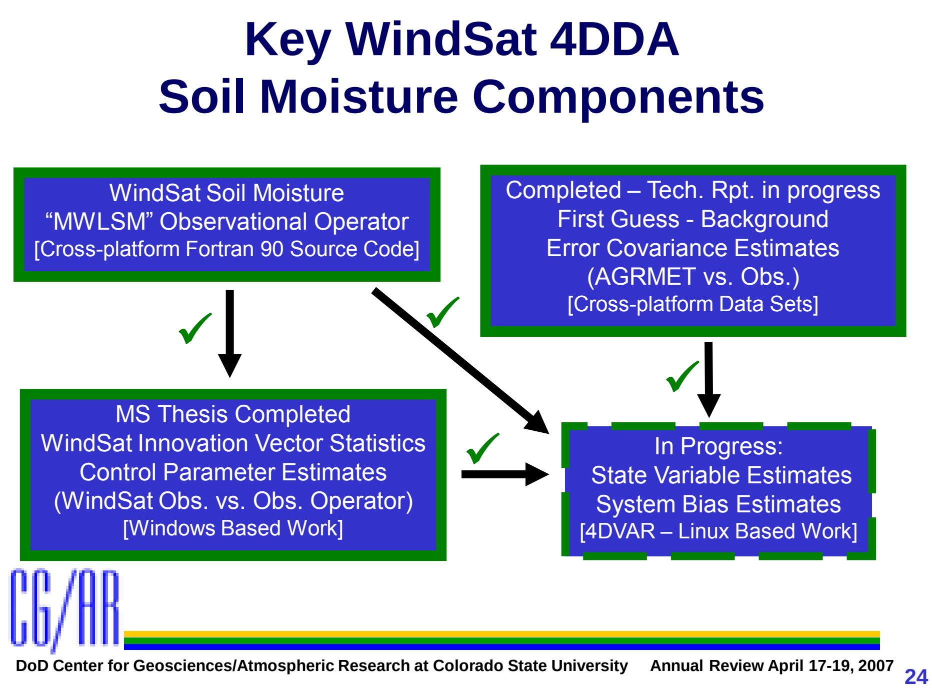
--Soil Moisture is a temporally variable field with a significant delay during drying which is dependent on the depth of the underlying soil moisture.

--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 data sets

- MW datasets provide the strongest physical soil moisture signal, especially low frequency MW data
- IR data sets 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)

Status: In progress…
--Integrated 4DVAR OO tests

Towards improving the satellite remote sensing of mixed phase cloud: A study on its microphysical and optical properties

Objectives:

- To understand mixed phase cloud microphysics and the ice/water distribution within the cloud.
- To investigate the impact on radiative transfer from a vertically inhomogeneous mixed phase cloud
- To establish a database of a mixed phase cloud microphysical and optical properties with a typical vertical structure for further remote sensing and theoretical simulation use.

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DoD Center for Geosciences/Atmospheric Research at Colorado State University Annual Review April 17-19, 2007 1

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

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ENSCO

FX-Net Enhancements for Applications and Technical Transfer to ENSCO's MetWiseNet System – Phases II and III

Principal Investigators: Cliff Matsumoto and Sher Schranz

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

Key Words: FX-Net, Gridded FX-Net, Environmental Information System

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

Background: ENSCO, Inc. provides engineering, science, and advanced technology solutions for the defense, security, transportation, environment, aerospace, and intelligent automation industries. ENSCO has many years of experience operating, interpreting, and modifying various commercial and government transport and dispersion models, offering meteorologists and air quality professional's fast, reliable atmospheric modeling capabilities for local to regional scale. ENSCO's business strategy focuses on the development of future technologies and business opportunities with potential long-term growth. ENSCO plans to focus on expanding the ESRL/GSD- and CIRA-developed FX-Net and associated applications to apply the technology in commercial weather-related areas. Under Phase I of the ENSCO/CIRA collaboration completed in May 2006, several tasks were accomplished. These included the build of FX-Net 4.1 servers and client using AWIPS OB6 and implementation of a password interface.

Phase II Proposed Research: The following proposed tasks comprised the second phase of CIRA's collaboration with ENSCO to transfer applicable FX-Net features and capabilities to ENSCO's MetWiseNet System:

Task 1 – Minimal Reload Capability

Build a GUI allowing users to select predetermined reload intervals, and to provide a disable/enable feature.

Link GUI to FX-Net client to spawn reload at selected intervals.

Task 2 – Build New FX-Net Client

Build a new version of FX-Net Client, based on the current FX-Net v. 4.5, including the Reload capability as described in Task 1.

Perform engineering and capability testing prior to release to ENSCO. This task will require ENSCO to provide operational testers for the ENSCO MetWiseNet 4.5 FX-Net client build, prior to release to customers.

Phase III Proposed Research: The following proposed tasks comprise the third phase of CIRA's collaboration with ENSCO to transfer applicable FX-Net features and capabilities to ENSCO's MetWiseNet System:

Task 1 – Modify ENSCO's FX-Net, AWIPS Air Quality server to ingest and process AIRNOW and NCEP (CMAQ) data.

Modify existing data and file servers to ingest and process the EPA AIRNOW data from the Sonoma Tech data feed, and to ingest and process the NCEP CMAQ air quality Ozone forecast model data.

Test servers to verify stability of ingest and processing functions.

Provide training for modifications installed in support of newly ingested data sets.

Task 2 – Build New FX-Net Client

Build a new version of FX-Net Client, based on the new ENSCO MetWiseNet servers.

Perform engineering and capability testing prior to release to ENSCO. This task required ENSCO to provide operational testers for the ENSCO MetWiseNet 4.5 EPA client.

2. Research Accomplishments/Highlights:

The second phase of CIRA's collaboration with ENSCO to transfer applicable FX-Net features and added capabilities to ENSCO's MetWiseNet™ System were completed as described below:

Task 1 – Minimal Reload Capability

CIRA completed the following tasks and delivered the software to ENSCO, Coco Beach, Florida, on Oct 25, 2006:

Build a GUI allowing users to select predetermined reload intervals and to provide a disable/enable feature.

Link GUI to FX-Net client to spawn re-load at selected intervals.

Task 2 – Build New FX-Net Client

CIRA completed the following tasks, and the new client was released to ENSCO on Nov 1, 2006. ENSCO accepted the client during the CIRA visit to Coco Beach on Nov 15, 2006.

Build a new version of FX-Net Client, based on the current FX-Net v. 4.5, including the Reload capability as described in Task 1.

Perform engineering and capability testing prior to release to ENSCO.

The third phase of CIRA's collaboration with ENSCO to transfer applicable FX-Net features and added capabilities to ENSCO's MetWiseNet^{TM} System were completed as described below:

Task 1 – Modify ENSCO's FX-Net, AWIPS Air Quality server to ingest and process AIRNOW and NCEP (CMAQ) data

CIRA completed the following tasks on April 13, 2007:

Modified existing data and file servers to ingest and process the EPA AIRNOW data from the Sonoma Tech data feed, and to ingest and process the NCEP CMAQ air quality Ozone forecast model data.

Ingest and file servers were tested to verify stability of ingest and processing functions.

Provided training for modifications installed in support of newly ingested data sets.

Task 2 – Build New FX-Net Client

CIRA completed the following tasks on April 17, 2007:

Built new MetWiseNet 4.5 EPA Client

Client sent to ENSCO for testing. No additional changes to the Client were needed.

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

All planned objectives for both Phase II and Phase III were met.

4. Leveraging/Payoff:

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

6. Awards/Honors:

7. Outreach:

8. Publications:

NASA – CloudSat

Report Provided by: Ken Eis/Don Reinke

CIRA provides the operational data processing center for this NASA Earth System Science Pathfinder (ESSP) satellite mission. NOAA relevance is illustrated by the mission's basic science products that fit into the NOAA Climate Goal.

Year-in-Review Summary

CloudSat launched on April 28th, 2006 and the CloudSat Data Processing Center (DPC) has been fully operational since the first CloudSat data were downlinked on May 20th 2006. After a brief checkout of that first test data stream, CloudSat became an operational NASA mission on June 2nd 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 those data through Level 2 products.

Because of the exceptional work done by the DPC team – specifically, being fully operational from day-1 and providing numerous solutions to operational anomalies during the first year on orbit – they were recently presented with a NASA Honor Award for "Public Service Achievement".

Cloudsat Mission Overview and the CloudSat Data Processing Center (DPC)

CloudSat is a satellite experiment designed to measure the vertical structure of clouds from space and, for the first time, will simultaneously observe cloud phase and radiative properties. The primary CloudSat instrument is a 94-GHz, nadir-pointing, Cloud Profiling Radar (CPR). A unique aspect of this mission is the fact that CloudSat is flying in formation with other Earth Sciences missions dubbed the A-Train (fig 1). CloudSat is part of a constellation of satellites that currently includes 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.

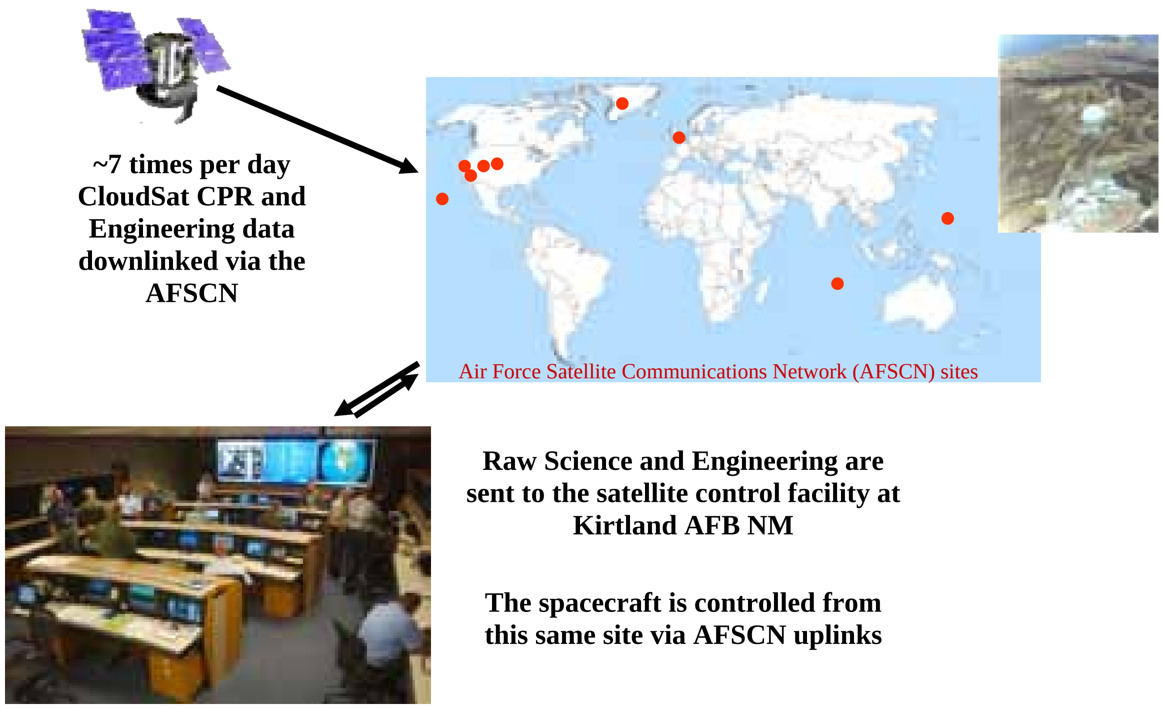

Figure 2.   CloudSat Data Flow – Satellite to USAF site at Kirtland AFB.

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.

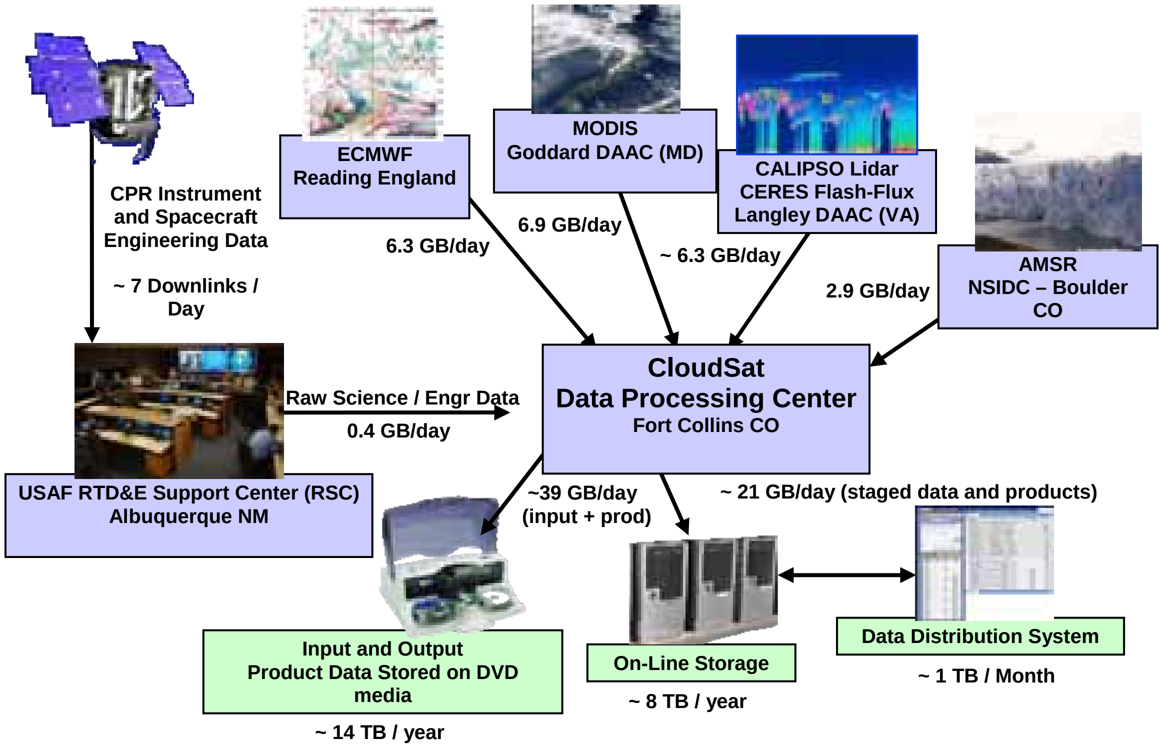

Figure 3. Data Flow through the CloudSat Data Processing Center.

Over the past year, the RSC has collected 99.9% of the possible CloudSat Data downlink opportunities and the CloudSat DPC has ingested 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 for the distribution of products to the science community. As of June 1st, 2007, the data distribution system has provided data to over 600 users/groups in 17 different countries. Some pertinent statistics as of 6/1/2007:

- over 196 million vertical profiles of cloud
- over 450 thousand products distributed - ~ 14 Terabytes
- products distributed to United States, Japan, China, France, Canada, South Korea, United Kingdom, Germany, Italy, Sweden, The Netherlands, Israel, Brazil, Australia, Finland, Switzerland, India (in order by volume)

Accomplishments of Note

The DPC was given a requirement to provide Level 0 and Level 1 products within 30 days of the receipt of data. We are currently generating both products, and displaying a geolocated browse image of the CPR science data within 2 minutes. This quick turnaround of data and the generation of the "quicklook images" (fig 4) was identified as one of two NASA "Firsts" for this mission. The other being the accomplishment of formation flying.

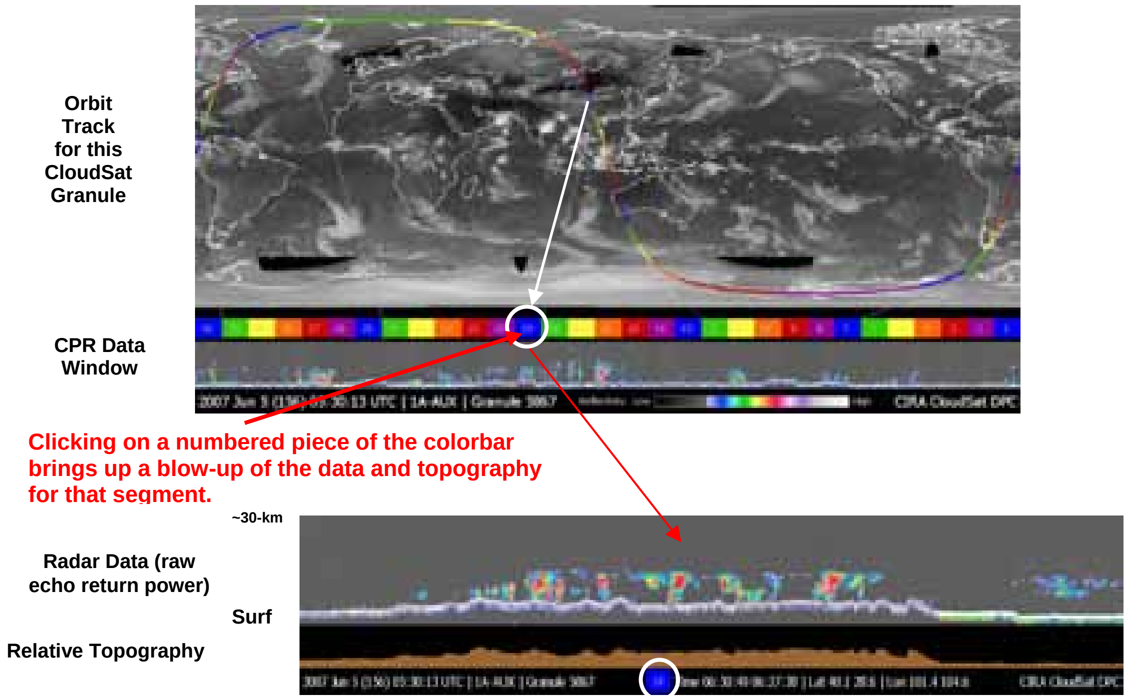

Figure 4. CloudSat "Quicklook" imagery. To view these images and learn more about the content, visit the quicklook page at http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php .

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.

<u>NASA</u> – Ensemble Data Assimilation of Precipitation Observations

Principal Investigator: Dusanka Zupanski and Christian D. Kummerow

NOAA Project Goal: Weather and Water

Key Words: Ensemble Data Assimilation, Precipitation Observations, Earth Observing System

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

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 the Goddard Earth Observing System Atmospheric General Circulation Model (GEOS-5 AGCM), the Maximum Likelihood Ensemble Filter (MLEF) data assimilation algorithm, and the precipitation data available at NASA.

2. Research Accomplishments/Highlights:

We have included the GEOS-5 AGCM into the MLEF algorithm and performed initial data assimilation experiments, assimilating gridded specific humidity data. In the next phase, we will include algorithms for assimilation of precipitation observations.

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

This is a new research project started on April 1, 2007. The objectives for the initial period of the project were fully accomplished.

4. Leveraging/Payoff:

This research project will particularly contribute to improved use of precipitation data under the NASA Precipitation Measuring Mission (PMM) Program. This will lead to the improvement of the precipitation forecasts.

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

This research is performed in collaboration S. Q. Zhang and A. Y. Hou from NASA/Global Modeling and Assimilation Office. It also benefits the interactions with the PMM Science Team members and associates, especially within the PMM Working Group for Data Assimilation.

6. Awards/Honors: None as yet

7. Outreach:

Interactions with the students from Prof. Kummerow group.

8. Publications:

Zupanski D., A.Y. Hou, S.Q. Zhang, M. Zupanski, C.D. Kummerow, and S.H. Cheung, 2007: Ensemble data assimilation using GEOS-5 single column model., PMM Science Team Meeting, May 7-10, 2007, Atlanta, GA.
(available at http://www.cira.colostate.edu/projects/ensemble/publications.php).

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 XXIV General Assembly of IUGG. MS008: Ensembles and Probabilistic Forecasting, 2-13 July 2007, Perugia, Italy.
(available at http://www.cira.colostate.edu/projects/ensemble/publications.php).

NASA - The GLOBE Program

Principal Investigator: Cliff Matsumoto
Team Members: Travis Andersen, Matt Hansen, Mike Leon, Karen Milberger, Maureen Murray, and Dave Salisbury

Key Words: International education and science program; 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 16 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 for the GLOBE Program:

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.

Major areas of work towards the GLOBE vision in the past year:

a) 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.

b) Catalyze the development of six Regional Consortia in Africa, Europe, Latin-America-Caribbean, Near East, and North America.

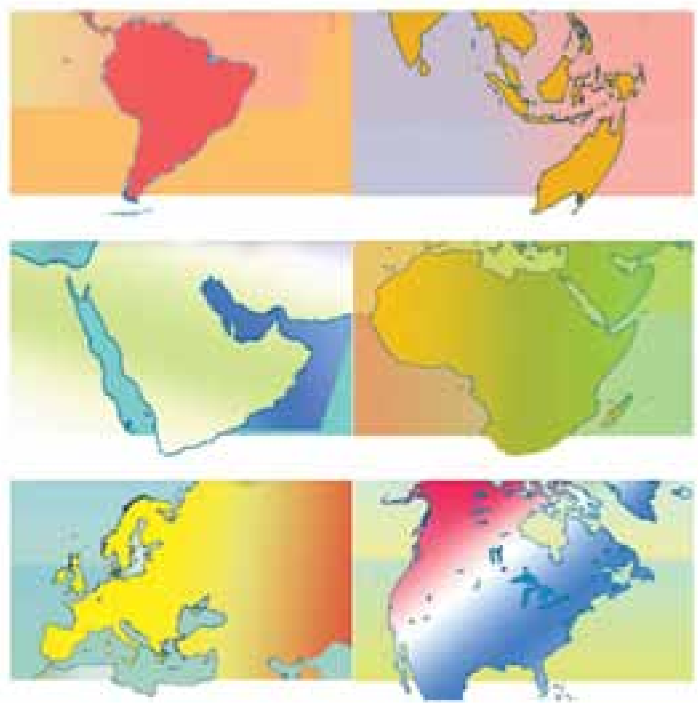

Fig. 2. GLOBE's six Regional Consortia.

c) Enhance long-term GLOBE and GPO sustainability through the formation of an international GLOBE foundation and diversification of the GPO funding base.

d) Continue to provide quality and timely core services to the GLOBE community.

In the summer of 2007, NASA began a review process that will continue through the end of the year. This review assesses GPO's management and operation of the GLOBE Program throughout the last four years. An external panel of education, science, and technology experts has convened to provide input to NASA. The panel will be reviewing GLOBE's recent accomplishments and challenges. They will look 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, has begun to work with GPO in evaluating GLOBE's value and impact around the world. GPO staff has been putting in extra effort to finalize reports which provide statistics and other documentation to NASA. At the end of the review process, NASA will determine how the management of GPO should move forward and at which level to continue funding the GLOBE Program.

During the past year, the first four ESSPs were announced to the GLOBE community, collaborated with GPO staff on planning the projects, and held various activities for the GLOBE community to participate in. The ESSPs are:

--Seasons and Biomes: This project is an inquiry- and project-based initiative that monitors seasons, specifically their inter-annual variability, in order to increase K-12 students' understanding of the Earth system. It connects GLOBE students, teachers, and communities, with educators and scientists from three Earth Systems Science Programs: International Arctic Research Center (IARC), NASA Landsat Data Continuity (LDCM), and Terra Satellite Missions. It will also provide opportunities for the GLOBE community to participate in International Polar Year (IPY) activities.

--Carbon Cycle: This project connects an international team of scientists and educational outreach specialists with the GLOBE educational community. Through field exercises, computer modeling, and remote sensing, primary and secondary grade level teachers and students will gain knowledge about current carbon cycle research, develop strong analytical skills, and increase their overall environmental awareness.

--From Local to Extreme Environments (FLEXE): This project involves study of the deep ocean led by Pennsylvania State University in partnership with RIDGE and InterRIDGE scientists. Through comparative protocols and online interactions with project scientists and partner schools, students will gain an understanding of local and deep-sea environments, the interconnected Earth system, and the process of science.

--Watershed Dynamics: This project will enable students to investigate their own watershed in order to understand the flow of water through the watershed, how human activities within the watershed both depend on and impact its hydrology, and how land use changes can affect the plant and animal communities in the watershed. It will offer GLOBE students the opportunity to conduct science investigations on local and regional watersheds using real-time and historical scientific data from the dataset being constructed by the Consortium of Universities for Advancement of Hydrologic Science (CUAHSI).

Fig. 3. The four Earth System Science Programs supported by GLOBE.

Some highlights of ESSP activities conducted so far are:

--In January 2007, FLEXE held “Seafloor to Space Station Phone Call”. See more at http://www.globe.gov/fsl/html/templ.cgi?flexe-phone

--In March 2007, 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_announce

--Development of tools, educational materials, and protocols for the ESSPs is occurring and various pilots of new materials and protocols have been conducted.

A new website for GLOBE is being developed based on the principles of being more user-friendly and better supporting student research projects, including projects related to the ESSPs (Earth System Science Projects), and local and regional projects. The new site is being implemented in a phased manner. The first version was released on 26 June 2007 (see Fig. 4). It has an updated look and feel, a new homepage, a new “Student” section, and better navigation and search capability. Future versions will have content and tools specifically designed for students based on pedagogical principles (in addition to sections for teachers, partners, scientists, etc.). The new site is being developed using modern technology to support rapid development and easier maintenance of applications.

Fig. 4. GLOBE’s new homepage.

2. 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 web pages, 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:

--Providing improved tools for student collaboration on projects and better support for student research projects including tools, content, and data portals for the ESSPs

--Data Access will evolve into a portal giving integrated access to historical GLOBE data, external data sets (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, and a detailed partner administration manual.

There have been some changes to GLOBE reference data. We no longer have current data for some categories due to their sources no longer providing feeds compatible with our ingesting design and lack of resources to change our system. (We plan to eventually provide portals to "reference" data similar to our historical reference data, but hosted and served by the provider rather than duplicated in GLOBE's database. We do not yet have an expected time for this to be available.)

In early 2007, the annual GLOBE partnership survey was conducted entirely on-line for the second year. The technology team was heavily involved in the technical design, operation, and data analysis of the results. The outcome of this survey was for the GPO to better support partnerships and regional collaborations around the world. The survey included 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 in San Antonio, Texas scheduled for 30 July – 3 August 2007.

Fig. 5. Banner for the GLOBE Annual Conference designed by CIRA's graphics 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 the Report Period:

In Progress.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

Today, the international GLOBE network has grown to include representatives from 109 participating countries and 135 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 16 million measurements to the GLOBE database for use in their inquiry-based science projects.

8. Publications:

<u>NASA</u> - MESOSCALE CARBON DATA ASSIMILATION FOR NACP

Principal Investigator: Scott A. Denning, Co-PI: Dusanka Zupanski

NOAA Project Goal: Weather and Water

NOAA Programs: Environmental Modeling, Weather Water Science, Technology, and Infusion

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 seeks to quantify the current budget of CO_2, CO, and CH_4 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:

We developed and tested a system for estimation of spatially-resolved persistent model biases in predictions of photosynthesis and respiration based on satellite vegetation imagery, weather observations, flux tower measurements, and continuous variations in atmospheric CO2. We have shown that the modeling and analysis system is capable of accurately simulating variations in weather, land-atmosphere exchanges, and CO2. Using simulated observations, we further demonstrated that the system can correctly recover spatial patterns in model bias on scales of tens of km using a fairly dense observing system deployed in the upper Midwest in 2004. The coupled model is now fully implemented in the Ensemble Data Assimilation system and computational performance is adequate. In year 3, we will perform an analysis of model bias at the continental scale using real observations. Finally, we will demonstrate a fully coupled data assimilation experiment in which we simultaneously optimize carbon cycle and meteorological variables based on appropriate observations.

3. Comparison of Objectives Vs. Actual Accomplishments:

The report period is year 2 of this 3-year project. The objectives for this year were fully accomplished.

4. Leveraging/Payoff:

This research project will contribute to improve understanding of the carbon processes and to provide timely and practical information products to support management decisions, especially under the North American Carbon Program.

5. Research Linkages/Partnerships/Collaborators:

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:

7. Outreach:

Two M.S. level Graduate Students: Erica McGrath-Spangler and Nick Parazoo
One Ph.D. level Graduate Student: Kathy Corbin
One B.S. level student: John Heizer

8. Publications:

<u>Publications</u>

Schaefer, K., GJ Collatz, P Tans, AS Denning, I Baker, J Berry, L Prihodko, N Suits, A Philpott (2006), The combined Simple Biosphere/Carnegie-Ames-Stanford Approach (SiBCASA) Model, submitted to Global Biogeochem. Cycles.

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., (in print).
[Available at http://www.cira.colostate.edu/projects/ensemble/publications.php].

Denning, A. S., Rayner, Uliasz, M., P. J., Schuh, A., and Corbin, K. D. Potential “disaggregation error” in CO2 transport inversions: resolution dependence of the surface influence function for atmospheric tracer concentration. In prep for Atmos. Chem. Phys.

Philpott, A., A. S. Denning, M. Branson, I. Baker, and M. Brown. Canopy stress and atmospheric humidity feedbacks in a single column of a General Circulation Model over the southern Great Plains of North America. In prep for Jour. Geophys. Res.

Philpott, A., A. S. Denning, I. Baker, Hanan, N., and W. Hargrove. Simulated surface energy budget at the site level in the southern Great Plains using the Simple Biosphere Model, version 3 (SiB3). In prep for Jour. Geophys. Res.

Presentations

Ciais, P, S. Piao, N. Viovy, C. Roedenbeck, P. Peylin, D. Baker, A. S. Denning, K. Davis, G. Nabuurs, M. Reichstein, R. Houghton, S. Zaehle, and M. Heimann, 2006: Top-down and bottom-up carbon budgets of North America, Europe and Asia. American Geophysical Union Fall 2006 Meeting, San Francisco CA, USA.

Denning, A.S., D. Zupanski, A. Schuh, K.D. Corbin, M. Uliasz, P. Rayner, M. Butler, S. Wofsy, S. Vay, 2006: Continental Carbon Cycle Data Assimilation in SiB- RAMS. American Geophysical Union Fall 2006 Meeting, San Francisco CA, USA.

Zupanski D., A.S. Denning, M. Uliasz, and A. E. Schuh, 2006: Carbon data assimilation using Maximum Likelihood Ensemble Filter (MLEF). The Joint Workshop on NASA Biodiversity, Terrestrial Ecology, and Related Applied Sciences, 21-25, August 2006, Adelphi, MD.

Zupanski D., S. Q. Zhang, A. Y. Hou, A.S. Denning, M. Uliasz,, L. Grasso and M. DeMaria, 2006: An ensemble-based approach for information content analysis. The 2006 AGU Fall Meeting, A13 Data Assimilation session. 11-15 December 2006, San Francisco, CA.

Zupanski D., A.S. Denning, M. Uliasz,, R. S. Lokupitiya, and M. Zupanski, 2007: Model bias estimation in carbon data assimilation., The XXIV General Assembly of IUGG, JMS024: Data Assimilation of the Atmosphere, Ocean and Land Surface, 2-13 July 2007, Perugia, Italy.

<u>NASA</u> – 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 a paper summarizing its performance (see below).

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, testing, and field work, we have been collaborating with Dr. Kelly Elder, USFS (see publications listed below).

6. Awards/Honors: None as yet

7. Outreach: See section 8

8. Publications:

Hiemstra, C. A., G. E. Liston, R. A. Pielke, Sr., D. L. Birkenheuer, and S. C. Albers, 2006: Comparing Local Analysis and Prediction System (LAPS) assimilations with independent observations. Weather and Forecasting, 21, 1024-1040.

Liston, G. E., 2004: Representing subgrid snow cover heterogeneities in regional and global models. J. Climate, 17(6), 1381-1397.

Liston, G. E., and K. Elder, 2006: A distributed snow-evolution modeling system (SnowModel). J. Hydrometeorology, 7, 1259-1276.

Liston, G. E., and K. Elder, 2006: A meteorological distribution system for high-resolution terrestrial modeling (MicroMet). J. Hydrometeorology, 7, 217-234.

Liston, G. E., C. A. Hiemstra, K. Elder, and D. W. Cline, 2006: Meso-cell study area (MSA) snow distributions for the Cold Land Processes Experiment (CLPX). J. Hydrometeorology, in review.

Liston, G. E., and C. A. Hiemstra, 2007: A simple data assimilation system for complex snow distributions (SnowAssim). J. Hydrometeorology, in review.

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.

Strack, J. E., G. E. Liston, and R. A. Pielke, Sr., 2004: Modeling snow depth for improved simulation of snow-vegetation-atmosphere interactions. J. Hydrometeorology, 5, 723-734.

Sturm, M., T. Douglas, C. Racine, and G. E. Liston, 2005: Changing snow and shrub conditions affect albedo with global implications. J. Geophys. Res., 110 (G01004), doi:10.1029/2005JG000013.

Conference and meeting presentations:

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Snow cover distribution: modeling under changing climate. International Symposium on Snow Science, 3-7 September, Moscow, Russia.

Hiemstra, C. A., G. E. Liston, J. E. Strack, and K. Elder, 2004: Measuring and modeling snow accumulation, movement, and ablation in Colorado shrublands. American Geophysical Union, Fall Meeting, December 13-17, San Francisco, California.

Hiemstra, C. A., G. E. Liston, and J. E. Strack, 2005: North Park Projects and Data: Vegetation-Snow Interactions, Observations, and Remote Sensing. North Park Snow Workshop, 14-15 July, Corvallis, Oregon.

Hiemstra, C. A., G. E. Liston, and J. E. Strack, 2006: Sagebrush and snow: linking snow measurements and modeling. American Geophysical Union, Fall Meeting, December 11-15, San Francisco, California.

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., 2004: Merging observations and models to describe snow-related land-atmosphere interactions at local to global scales. Civil and Environmental Engineering Department, Duke University, 12 October, Durham, North Carolina. Invited presentation.

Liston, G. E., and K. Elder, 2004: A distributed snow evolution modeling system (SnowModel). American Geophysical Union, Fall Meeting, December 13-17, San Francisco, California. Invited presentation.

Liston, G. E., C. A. Hiemstra, J. E. Strack, and K. Elder, 2005: Vegetation and variable snow cover: Spatial patterns of shrubland and grassland snow. North Park Snow Workshop, 14-15 July, Corvallis, Oregon.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Tsukuba University, October 18, Tsukuba, Japan. Invited presentation.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Frontier Research Center for Global Change, October 13, Yokohama, Japan. Invited presentation.

Liston, G. E., 2006: How can we link large-scale atmospheric and climate features with small-scale alpine snow processes? Alpine Snow Workshop, University of Munich, October 5-6, Munich, Germany. Invited keynote address.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Rocky Mountain Research Station, USDA Forest Service, 8 December, Fort Collins, Colorado. Invited presentation.

Liston, G. E., C. A. Hiemstra, K. Elder, and D. Cline, 2006: Local- to basin-scale snow distributions for the Cold Land Processes Experiment (CLPX). American Geophysical Union, Fall Meeting, December 11-15, San Francisco, California.

Liston, G. E., and L. Lu, 2006: Merging MicroMet and SnowModel to create high-resolution snow distributions in complex terrain. NOAA CPPA PI's Meeting, 14-16 August, Tucson, Arizona.

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.

Strack, J. E., G. E. Liston, C. A. Hiemstra, and R. A. Pielke, Sr., 2004: Snow, shrubs, grasses, and footprint theory: Measuring moisture and energy fluxes in patchy landscapes. American Geophysical Union, Fall Meeting, December 13-17, San Francisco, California.

Strack, J. E., G. E. Liston, C. A. Hiemstra R. A. Pielke, and L. Mahrt, 2005: Snow, shrubs, grasses, and footprint theory: Measuring moisture and energy fluxes in patchy landscapes. North Park Snow Workshop, 14-15 July, Corvallis, Oregon.

<u>NASA</u> – Weak Constraint Approach to Ensemble Data Assimilation: Application to Microwave Precipitation Observations

Principal Investigator: Dusanka Zupanski

NOAA Project Goal: Weather and Water, Environmental Modeling, Weather Water Science, Technology, Infusion

Key Words: Ensemble Assimilation and Prediction, Model Error Estimation, Earth Observing System, Precipitation Observations.

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

The major objective of this research was to develop an ensemble-based data assimilation methodology, applicable to data assimilation problems involving moist physical processes. During the course of this research we made an additional research objective: to link information theory with the ensemble-based data assimilation, which has resulted in the new capability of the data assimilation system: to extract maximum information from the available observations for a given ensemble size. This was important for obtaining a stable filter performance. This additional effort has replaced our original objective to apply an ensemble-based data assimilation approach to microwave precipitation observations. In this research we employed Maximum Likelihood Ensemble Filter (MLEF, Zupanski 2005; Zupanski and Zupanski 2006) in application to the Goddard Earth Observing System Single Column Model (GEOS-4 and GEOS-5 SCM).

2. Research Accomplishments/Highlights:

During the initial phase of this research we have developed the basic data assimilation system and tested it in application to GEOS-4 SCM. We have examined the performance of the system in the experiments with simulated observations. In particular, we examined Root Mean Square (RMS) errors of the analysis and the forecast, verified with respect to the “truth”. Also, we evaluated the estimated analysis and forecast uncertainties using a chi-square verification test of normalized innovations (e.g., Zupanski 2005), and examined how the observation errors influence the chi-square tests. We concluded that the chi-square test is a useful tool for determining appropriate observation errors, assuming that these errors are Gaussian. The experimental results indicated that data assimilation improves analysis and forecast results and the MLEF had a stable performance over many data assimilation cycles.

In the later stages of this research we have made a transition to a newer version of the SCM, the GEOS-5 SCM, which was better suited for our research due to its more advanced moist microphysical processes. We have included the new SCM into the MLEF algorithm and started rigorous testing of the new data assimilation system. We also upgraded the system with the ability to estimate information measures of observations, such as degrees of freedom (DOF) for signal and entropy reduction. This was accomplished via defining information matrix in ensemble subspace (Zupanski et al. 2007). The main advantages of defining the information matrix in the ensemble subspace are the small dimensions of the information matrix, defined by a typically small ensemble size (e.g., 10-100 ensemble members), and the use of flow-dependent forecast error covariance.

We employed the upgraded MLEF algorithm in data assimilation experiments with the GEOS-5 SCM, using Atmospheric Radiation Measurement (ARM) observations as external forcing, and evaluated the information measures (e.g., DOF for signal and entropy reduction) of simulated temperature and humidity observations. We have also examined the impact of data representativeness error on the data assimilation results, and on the information measures. In particular, we addressed the impact of ensemble size on the representativeness error. Finally, we have defined the Kalman Filter (KF) and the 3-dimensioinal variational (3d-var) approaches as special variants of the MLEF approach and examined the differences between KF and the 3d-var approaches. Comparisons between the KF and the 3d-var approaches provide answers about the advantages of using flow-dependent forecast error covariance.

We have found that employing a flow-dependent forecast error covariance, as in the KF approach, is of fundamental importance for realistic time variability of the information measures. On the other hand, employing a prescribed forecast error covariance, as in the 3d-var approach, results in information measures being insensitive to the changing atmospheric conditions: the experiments where the amount and the quality of observations do not change with time indicated that the 3d-var based information measures remain constant in time. The MLEF results were superior to 3d-var results in other aspects: e.g., analysis and forecast quality. This was demonstrated for ensemble sizes larger than 10 ensemble members. The MLEF results with 10 ensemble members were comparable or slightly worse than the 3d-var results. These results were presented and discussed in Zupanski et al. (2007).

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

4. Leveraging/Payoff:

Ensemble data assimilation and model error estimation methodologies are applicable in all areas of research and everyday public life where observations and mathematical models are used. Some of these examples include weather, climate, oceanic, and hydrological predictions, space weather, and environmental modeling. In addition, information content analysis provides a means for quantifying value added of new observations (e.g., from new satellite missions, such as GPM, CloudSat and GOES-R).

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

This research is performed in collaboration A. Y. Hou and S. Q. Zhang from NASA/Global Modeling and Assimilation Office, and C. D. Kummerow from CSU/Atmospheric Science Department. This research is in synergy with other research projects at CIRA. These projects include: (i) NOAA/NESDIS research project titled “Research and Development for GOES-R Risk Reduction” (PIs: T. Vonder Haar and M. DeMaria). Under this research project similar methodology is employed to estimate value added of the future GOES-R satellite observations. (ii) NOAA/THORPEX research project titled “Impact of Fundamental Assumptions of Probabilistic Data Assimilation/Ensemble Forecasting: Conditional Mode vs. Conditional Mean” (PI: M. Zupanski). Under this project, a similar model error estimation approach is evaluated in application to NCEP GFS. (iii) NASA research project titled “Mesoscale Carbon Data Assimilation for NACP” (PI: S.A. Denning). Under this project similar approaches are used for carbon data assimilation problems. All these research projects employ the MLEF approach.

6. Awards/Honors: None as yet

7. Outreach:

Derek Poselt, a graduate student at CSU/Atmospheric Science Department was collaborating on this research project, supervised by Prof. G. L. Stephens. He has recently completed his Ph. D. thesis.

8. Publications:

Zupanski D., Zupanski, M., DeMaria, M., Grasso L., Hou, A.Y., Zhang, S., and Lindsey, D., 2005: Ensemble data assimilation and information theory. Extended abstracts of the AMS 21st Conference on Weather Analysis and Forecasting and AMS 17th Conference on Numerical Weather Prediction, 1–5 August 2005, Washington, D.C., 4pp.

Zupanski, D., A. Y. Hou, S. Q. Zhang, M. Zupanski, C. D. Kummerow, and S. H. Cheung 2007: Information theory and ensemble data assimilation. Quart. J. Roy. Meteor. Soc., (in print). [Available at http://www.cira.colostate.edu/projects/ensemble/publications.php].

Presentations supported partly or fully by this project:

Hou, A. Y., 2004: "Ensemble Data Assimilation for Clouds and Precipitation", Presented at The CloudSat Science Team meeting, 24-25 May 2004. (INVITED)

Zupanski, D., 2005: “A General Ensemble-Based Approach to Data Assimilation, Model Error and Parameter Estimation”. LSCE, CEA/Saclay, October 19, Gif-sur-Yvette, France. (INVITED)

Zupanski, D., 2005: “Ensemble data assimilation and prediction: Applications to environmental science. Presentation at The Ewha Womans University, May 26, 2005, Seoul, South Korea. (INVITED)

Zupanski D., A. Y. Hou, S. Q. Zhang, M. Zupanski, and C. D. Kummerow, 2005: Ensemble data assimilation: Experiments using NASA’s GEOS column precipitation model. AMS Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 9-13 January 2005, San Diego, CA.

Zupanski D., A. Y. Hou, S. Q. Zhang, M. Zupanski, and C. D. Kummerow, 2005: Assessing the impacts of observations and model errors in the ensemble data assimilation framework. Fourth WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography, 18-22 April 2005 Prague, Czech Republic.

Zupanski, D. 2006: "Ensemble Based Estimates of Information Content in Observational Data Extractable by Data Assimilation Methods". NOAA/EMC Predictability Meeting, Camp Springs, MD, January 24, 2006. (INVITED)

Zupanski, D., 2006: Ensemble data assimilation applications to model bias estimation and information content analysis. The 25th Anniversary CIRA & CG/AR Spring Science Symposium, 16-17 May 2006 in Fort Collins, CO [ftp://ftp.cira.colostate.edu/Grames/CIRAScienceSymposiumMay2006/D.Zupanski_CIRA_Sci_May2006.ppt].

Zupanski, D., 2006: Ensemble Kalman filter. Advanced Numerics Seminar, March 8, 2006, Langen, Germany. (INVITED)

Zupanski D. L. Grasso, M. DeMaria, M. Sengupta, and M. Zupanski: Evaluating the Impact of Satellite Data Density within an Ensemble Data Assimilation Approach, The 86th AMS Annual Meeting, 14th Conference on Satellite Meteorology and Oceanography. 29 January - 2 February 2006, Atlanta, GA.

Zupanski D., S. Q. Zhang, A. Y. Hou, A.S. Denning, M. Uliasz,, L. Grasso and M. DeMaria, 2006: An ensemble-based approach for information content analysis. The 2006 AGU Fall Meeting, A13 Data Assimilation session. 11-15 December 2006, San Francisco, CA.

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 XXIV General Assembly of IUGG. MS008: Ensembles and Probabilistic Forecasting, July 2- 13, 2007, Perugia, Italy.

<u>NCAR</u> – CIRA-NCAR/MMM WRF-Var Collaboration Work Plan

Principal Investigators: A. Jones and S. Fletcher

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:

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:

Research project start late April 2007.

Participated in the WRF User's Workshop at Boulder, CO, June 12-15, 2007.

Participated in the WRF-Var DA Working Group Meeting at Boulder, CO, June 11, 2007.

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

This is a new project start. Initial kickoff meetings have been held, and research activities are underway.

4. Leveraging/Payoff:

This is a collaborative CSU/CIRA-NCAR/MMM WRF-Var work plan and leverages WRF-Var development activities with that which 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 Dr. Zhiquan Liu.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

NPS – Air Quality Research

Principal Investigator: Douglas G. Fox

NOAA Project Goals: Weather and Water, specifically the Air Quality component under the Goal

Key Words: Air Quality Research, Visibility Research; Visibility Monitoring; Aerosol Research, Aerosol Monitoring; Rural Air Quality; Air Quality Modeling.

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

The long-term objectives of the team are to understand the causes of all air pollution, including impaired visibility, in National Parks and other pristine lands in the United States. Since the early 1980s, CIRA has supported the National Park Service visibility research program directed by Dr. Bill Malm. Through these years, this group has conducted research that has helped in formulating and implementing the Clean Air Act mandate to protect the visual resources of National Parks and Wilderness, so-called Class I areas. In April 1999, the 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, 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.

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. Recently the group has been *simulating regional air quality* using an assortment of regional air quality models. 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:

Initiation of the ROMANS special study (see reports in the publications list);

Implementing regional air quality modeling (the regional air quality models have been installed on a new Linux cluster and are currently being tested);

Completion of a review of the science behind relating ambient aerosol concentrations to visibility, the so-called IMPROVE equation (see publications list);

Continuing work on developing and implementing improved QA/QC for IMPROVE data (A multiyear IMPROVE progress report has been drafted);

Completion of an analysis of data from a preliminary set of studies on forest fire emissions and their impact on visibility and initiated planning for further studies (ongoing activity).

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 Regional Planning Organizations (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 (USDA and other agencies in 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, Characterization of Aerosol Physical, Chemical, and Optical Properties at National Parks: Implications for Visibility Estimates. Seminar presented at the University of Texas-El Paso, November, 2005.

Jenny Hand, Research Scientist, Radiative effects of atmospheric aerosols: From visibility to climate change. Seminar presented at the University of Kansas, Lawrence, September, 2005.

Jenny Hand, Research Scientist, summer 2006, serves as a SOARS (Significant Opportunities in Atmospheric Research and Sciences) Science Mentor at NCAR.

From the SOARS website:

SOARS is a four-year program for undergraduate and graduate students interested in pursuing careers in the atmospheric and related sciences. It includes a 10-week summer program at the National Center for Atmospheric Research (NCAR).

The main role of a science research mentor is to identify and structure a research project appropriate for a SOARS protégé for the summer. The science research mentor and protégé collaborate to create a research plan, and work together to monitor progress and interpret results as the project progresses. On average, a science research mentor spends about 10 hours per week with his or her protégé, discussing the project, guiding research practices, teaching processes and methods, and assisting the protégé in the creation of his or her research paper and presentation.

(e) Public awareness.

Each year the group produces a high quality calendar reviewing the IMPROVE program, including highlighting selected field operators. This year we partnered with CIRA, including CIRA science outreach activities.

Each year the group produces public awareness materials for the National Park Service. This year we have initiated work with Sequoia Kings Canyon National Park in California to develop a computer-based learning and awareness program that has been installed in their visitor center and has received many commendations from the Park Service public information specialists and the general public as well.

8. Publications:

Ames, R. B., McClure, S. E., Schichtel, B. A., and Fox, D. G. 2005. The Visibility Information Exchange Web System (VIEWS), Air Toxics, and IMPROVE web sites: Database driven internet sites for access, inter-comparison, and on=line analysis of air quality data. Presented at the Air & Waste Management Association Specialty Conference: Environmental Data Analysis: Assessing Health and Environmental Impacts, Developing Policy and Achieving Regulatory Compliance, Oak Brook IL.

Barna, M. G. and Knipping, E. M. 2005. Using sulfur predictions from a global model to specify boundary conditions in a regional air quality model. Submitted to Atmospheric Environment, in press.

Barna, M. G., Schichtel, B. A., Gebhart, K. A., and Rodriguez, M. A. 2005. Evaluating the linearity of sulfate formation in response to change in sulfur dioxide emissions within a regional air quality model. Presented at the NOAA/EPA Golden Jubilee Symposium on Air Quality Modeling and Its Applications, Durham NC.

Barna, M. G., Gebhart, K. A., Schichtel, B. A., and Malm, W. C. 2006. Modeling regional sulfate during the BRAVO study: Part 1. Base emissions simulation and performance evaluation. Atmospheric Environment, 40, 2436-2448.

Barna, M. G., Schichtel, B. A., Gebhart, K. A., and Malm, W. C. 2006. Modeling regional sulfate during the BRAVO study: Part 2. Emission sensitivity simulations and source apportionment. Atmospheric Environment, 40, 2423-2435.

Barna, M. G., Rodriguez, M. A., Schichtel, B. A., and Gebhart, K. A., 2006. Simulating sulfur and nitrogen deposition at western national parks. Presented at the Air and Waste Management Annual Conference, New Orleans, LA, June 20-23.

Carreras-Sospedra, M., Rodriguez, M., Brouwer, J., and Dabdub, D. 2006. Air quality modeling in the South Coast Air Basin of California: What do numbers really mean? Accepted by the Journal of the Air & Waste Management Association.

Carrico, C. M., Malm, W. C., Kreidenweis, S. M., Collett Jr., J. L., Day, D. E., McMeeking, G. R., Hand, J. L., Herckes, P., Engling, G., Lee, T., and Carrillo, J. 2005. The Yosemite Aerosol Characterization Study of 2002 (YACS). CIRA report ISSN 0737-5352-65.

Collett Jr., J. L., Raja, S., Lee, T., Xiao-Ying, Y., Carrico, C. M., Kreidenweis, S. M, Hand, J. L, Schichtel, B. A., Day, D. E., Gebhart, K. A., and Malm, W. C. 1-4-2006. Preliminary Report of Findings from the 2005 Rocky Mountain National Park Pilot Study.

Collett, J. L., Jr., Raja, S., Lee, T., Xiao-Ying, Y., Carrico, C. M., Kreidenweis, S. M, Hand, J. L, Schichtel, B. A., Day, D. E., Gebhart, K. A., and Malm, W. C. 2006. Findings from the 2005 Rocky Mountain National Park Pilot Study.

Copeland, S. A. 2005. A statistical analysis of visibility-impairing particles in federal Class I areas. Journal of the Air Waste Management Association, 55, 1621-1635.

Day, D. E., Hand, J. L, Carrico, C. M., Engling, G., and Malm, W. C. 2006. Humidification factors from laboratory studies of fresh smoke from biomass fuels. Journal of Geophysical Research, under review.

Engling, G., Herckes, P., Kreidenweis, S. M, Malm, W. C., and Collett Jr., J. L. 2006. Composition of the fine organic aerosol in Yosemite National Park during the 2002 Yosemite Aerosol Characterization Study. Atmospheric Environment, 40, 2959-2972.

Fox, D. G., Riebau, A., Fisher, R. W. 2005. Critical Loads and Levels: Leveraging existing monitoring data. Presented at the USDA Forest Service Monitoring Symposium, Denver, September.

Fox, D. G., Riebau, A., Crow, T. 2005. Climate Variability: a new USDA Forest Service research initiative. Poster Presentation Number: 223 at the National Climate Change Workshop, Washington, DC, November.

Fox, D. G., and Riebau, A. 2005. Mountain air quality in the USA, with particular attention to contributions from wildfire. Proceedings International Open Science Conference on Global Change in Mountain Regions. Perth, Scotland, UK. October.

Fox, D. G., Riebau, A., and Lahm, P. 2005. A Review of Wildland Fire and Air Quality Management. Invited presentation at EASTFire Conference, George Mason University, Fairfax, VA, May 11-13 (Submitted for publication as a chapter in the conference book.).

Fox, D. G., and Riebau, A. 2005. Emissions from Wildfires and Effects on Air Quality and Human Health. Invited presentation at the USGS Workshop on Fire Effects, Tucson, AZ, December.

Gebhart, K. A., Malm, W. C., and Ashbaugh, L. L. 2005. Spatial, temporal, and interspecies patterns in fine particulate matter in Texas. Journal of the Air & Waste Management Association, 55, 1636-1648.

Gebhart, K. A., Schichtel, B. A., and Barna, M. G. 2005. Directional biases in back-trajectories due to model and input data. Journal of the Air & Waste Management Association, 55, 1649-1662.

Gebhart, K. A., Schichtel, B. A., Barna, M. G., and Malm, W. C. 2006. Quantitative back-trajectory apportionment of sources of particulate sulfate at Big Bend National Park, TX. Atmospheric Environment, 40, 2823-2834.

Green, M., Farber, R., Lien, N., Gebhart, K. A., Molenar, J., Iyer, H., and Eatough, D. 2005. The effects of scrubber installation at the Navajo generating station on particulate sulfur and visibility levels in the Grand Canyon. Journal of the Air & Waste Management Association, 55, 1675-1682.

Hand, J. L. and Malm, W. C. 2005. Review of the IMPROVE equation for estimating ambient light extinction coefficients, report, available at http://vista.cira.colostate.edu/improve/Publications/GrayLit/016_IMPROVEeqReview/IMPROVEeqReview.htm.

Hand, J. L., Malm, W. C., Day, D. E., Lee, T., Carrico, C. M., Carrillo, J., Collett, J., Jr., Laskin, A., Wang, C., Cowin, J. P., and Iedema, M. J. 2005. Optical, physical and chemical properties of tar balls observed during the Yosemite Aerosol Characterization Study. Journal of Geophysical Research, 110, doi:10.1029/2004JD005728.

Malm, W. C., Day, D., Carrico, C. M., Kreidenweis, S. M., Collett, J., McMeeking, G, Lee, T., and Carrillo, J. 2005. Intercomparison and closure calculations using measurements of aerosol species and optical properties during the Yosemite Aerosol Characterization Study. Journal of Geophysical Research, 110, doi:10.1029/2004JD005494.

Malm, W. C. and Hand, J. L. 2006. An examination of aerosol physical and optical properties of aerosols collected in the IMPROVE program. Submitted to Atmospheric Environment.

Malm, W. C., Pitchford, M. L., McDade, C. E., and Ashbaugh, L. L. 2006. Coarse particle speciation at selected locations in the continental United States. Submitted to Atmospheric Environment.

McMeeking, G. R., Kreidenweis, S. M., Lunden, M., Carrillo, J., Carrico, C. M., Lee, T., Herckes, P., Engling, G., Day, D. E., Hand, J., Brown, N., Malm, W. C., and Collett, J. L. 2006. Smoke-impacted regional haze in California during the summer of 2002. Agricultural and Forest Meteorology, 137, 25-42.

McMeeking, G. R., Kreidenweis, S. M., Carrico, C. M., Lee, T., Collett, J. L., and Malm, W. C. 2005. Observations of smoke-influenced aerosol during the Yosemite Aerosol Characterization Study: Size distributions and chemical composition. Journal of Geophysical Research-Atmospheres, 110, doi:10.1029/2004JD005389.

Medrano, M., Brouwer, J., Carreras-Sospedra, M., Rodriguez, M. A., Dabdub, D., and Samuelson, G. S. 2005. A methodology for developing distributed generation scenarios in urban areas using geographical information systems. Submitted to the International Journal of Energy Technology and Policy.

Pitchford, M. L., Schichtel, B. A., Gebhart, K. A., Barna, M. G., Malm, W. C., Tombach, I. H., and Knipping, E. M. 2005. Reconciliation and interpretation of the Big Bend National Park light extinction source apportionment: Results from the Big Bend Regional Aerosol and Visibility Observational study - Part II. Journal of the Air & Waste Management Association, 55, 1726-1732.

Rodriguez, M. A., Barna, M. G., and Schichtel, B. 2006. Using CAMx to model the potential impacts of a proposed power plant in the Four Corners region, presented at the 99th AWMA Annual Conference and Exhibition, New Orleans, LA, June20-23.

Rodriguez, M. A., Barna, M. G., Schichtel, B. A., and Gebhart, K. A. 2006. Poster: Regional modeling using CAMx: Evaluation of the air quality in the western national parks, CIRA Science Symposium, Fort Collins, May 16-17.

Rodriguez, M. A. and Dabdub, D. 2006. Air quality impacts of distributed generation in the South Coast Air Basin II: Uncertainty and sensitivity analysis. Accepted by Atmospheric Environment.

Rodriguez, M. A., Medrano, M., Carreras, M., BrouwerJ., Samuelson, G. S., and Dabdub, D. 2006. Air quality impacts of distributed generation in the South Coast Air Basin I: Scenario development and modeling analysis. Accepted by Atmo Environment

Samuelson, G. S., Dabdub, D., Brouwer, J., Medrano, M., Rodriguez, M. A., and Carreras-Sospedra, M. 2005. Air Quality Impacts of Distributed Generation, Final Report. California Energy Commission Contract # 500-00-033.

Schichtel, B. A., Pitchford, M. L., Gebhart, K. A., Malm, W. C., Barna, M. G., Knipping, E., and Tombach, I. H. 2005. Reconciliation and interpretation of Big Bend National Park's particulate sulfur source apportionment-Results from the BRAVO study Part I. Journal of Air & Waste Management Association, 55, 1709-1725.

Schichtel, B. A., Barna, M. G., Gebhart, K. A., and Rodriguez, M. A. 2006. Poster: Integrating air quality data and modeling results to refine source apportionment estimates, CIRA Science Symposium, Fort Collins, May 16-17.

Schichtel, B. A., Gebhart, K. A., Barna, M. G., and Malm, W. C. 2006. Association of airmass transport patterns and particulate sulfur concentrations at Big Bend National Park, Texas. Atmospheric Environment, 40, 992-1006.

Schichtel, B. A., Malm, W. C., Gebhart, K. A., Barna, M. G., and Knipping, E. M. 2006. A hybrid source apportionment model integrating measured data and air quality model results. Journal of Geophysical Research-Atmospheres, 111, doi:10.1029/2005JD006238.

Schichtel, B. A., Malm, W. C., and Pitchford, M. L. 2006. Critique of "Precipitation in light extinction reconstruction". Journal of the Air & Waste Management Association, 56, 539-546.

Vukovich, J. M., Shankar, U., Xiu, A., Adel, H., Fox, D. G., and McNulty, S. 2005. Preliminary assessment of the impact of climate change and variability on biomass and forest fires, the impact of forest fires on ozone and PM air quality, and the regional climate response to these changes in the southern U.S. EASTFire Conference, George Mason University, Fairfax, VA, May 11-13.

Wang, J., Christopher, S. A., Nair, U. S., Reid, J. S., Prins, E. M., Szykman, J., and Hand, J. L. 2005. Mesoscale modeling of Central American smoke transport to the United States, Part I: "Top-down" assessment of emission strength and diurnal variation impacts. Journal of Geophysical Research, 111 (D05S17), doi:10.1029/2005JD006416.

White, W. H., Ashbaugh, L. L., Hyslop, N. P., and McDade, C. E. 2005. Estimating measurement uncertainty in an ambient sulfate trend. Atmospheric Environment, 39, 6857-6867.

Yu, X. Y., Lee, T., Ayres, B., Kreidenweis, S. M, Malm, W. C., and Collett, J. L., Jr. 2006. Loss of fine particle ammonium from denuded nylon filters. Atmospheric Environment, 40. 4797-4807.

<u>NPS</u> – Characterizing Pollutant Deposition to Rock 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, sponsored by the National Park Service, is designed to investigate the transport and fate of airborne nitrogen and sulfur species in Rocky Mountain National Park (RMNP) and upwind areas. We also continued development and maintenance of the NPS mobile air quality laboratory and publication of findings from previous NPS-sponsored investigations, including the IMPROVE nitrate study and Yosemite 2002 Air Quality Study.

Rocky Mountain National Park is experiencing a number of deleterious effects due to atmospheric nitrogen and sulfur compounds. These effects include visibility degradation and changes in ecosystem function and surface water chemistry from atmospheric deposition. The nitrogen compounds include both oxidized and reduced nitrogen. Emissions of both nitrogen and sulfur compounds will need to be reduced to alleviate these deleterious effects. A large field campaign and modeling effort is planned by NPS to further our understanding of what will be needed in the longer term to address effects at the park, and to reduce uncertainties for future planning efforts. The focus of this project is on sample and data analysis from the 2006 field campaigns in order to improve understanding of pollutant sources, transport pathways, and deposition mechanisms.

2. Research Accomplishments/Highlights:

Aerosol, trace gas, and precipitation samples were analyzed from sites within and outside of RMNP, stretching across the state of Colorado. Wet deposition fluxes of sulfur and nitrogen species were quantified at sites inside and outside the park. Deposition within RMNP was dominated in spring by a single upslope snow storm that drew air from the east. Deposition fluxes in summer were split across numerous convective precipitation episodes. Wet deposition fluxes were much larger than dry deposition fluxes of the same pollutant species. Important wet inputs of organic nitrogen were observed, in addition to nitrate and ammonium. Concentrations of nitrogen air pollutants were higher to the east of RMNP than to the west. Nitrogen pollutant concentrations within RMNP generally increased when transport was from the east.

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

Complete conduct of the ROMANS summer field campaign and chemical analysis of samples collected during the two 2006 ROMANS field campaigns. Create a project results database and QC data. *Complete.*

Analyze and interpret findings from the ROMANS study.

Determine deposition fluxes for key species types. Compare importance of dry vs. wet deposition pathways for key sulfur and nitrogen species. Examine spatial variations in deposition within and outside RMNP. *In progress.*

Examine relationships between periods of high concentration/deposition and various transport patterns. *In progress.*

Work with NPS/CIRA modelers to validate model predictions and to better understand observed spatial and temporal patterns in species concentrations and deposition fluxes. *In progress.*

Continue to operate the NPS Mobile Air Sampling Lab in support of NPS special studies. *In progress*

Complete publications still in progress for recent studies in the various IMPROVE Nitrate Study sites (San Gorgonio, Grand Canyon, Bondville, Brigantine, and Great Smoky Mountains). Begin work on publications from the RoMANS studies. *In progress.*

4. Leveraging/Payoff:

Findings from the study are being used by air quality regulators, policymakers, and other stakeholders to improve understanding and consider mitigation of sources contributing to elevated levels of N deposition in RMNP.

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

Partners in the study included the National Park Service, USEPA, CDPHE, RMNP research staff, and Air Resource Specialists.

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), Ali Bote (BA).

Public presentations of findings from this work were made to the Colorado Livestock Association, the Colorado Department of Public Health and Environment (CDPHE), the

Air and Waste Management Association, the American Geophysical Union, and the National Acid Deposition Program.

8. Publications:

Engling, G., Herckes, P., Kreidenweis, S., Malm, W. C., and Collett, Jr., J. L. (2006) Composition of the fine organic aerosol in Yosemite National Park during the 2002 Yosemite Aerosol Characterization Study. *Atmos. Environ.*, 40, 2959-2972.

Engling, G., Carrico, C. M., Kreidenweis. S. M., Collett, Jr.., J. L., Day, D. E., Malm, W. C., Hao, W. M., Lincoln, E., Iinuma, Y. and Herrmann, H. (2006) Determination of levoglucosan in biomass combustion aerosol by high performance anion exchange chromatography with pulsed amperometric detection. *Atmos. Environ.*, 40, S299-S311.

Herckes, P., Engling, G., Kreidenweis, S. M., and Collett, Jr., J. L. (2006) Particle size distributions of organic aerosol constitutents during the 2002 Yosemite Aerosol Characterization Study. *Environ. Sci. Technol.,*40, 4554-4562.

Lee, T., Yu, X.-Y., Ayres, B., Kreidenweis, S. M., Malm, W. C., and Collett, Jr., J. L. (2007) Observations of fine and coarse particle nitrate at several rural locations in the United States. *Atmos. Environ.*, in press.

McMeeking, G. R., Kreidenweis, S. M., Lunden, M., Carrillo, J., Carrico, C. M., Lee, T., Herckes, P., Engling, G., Day, D. E., Hand, J., Brown, N., Malm, W. C., and Collett, Jr., J. L. (2006) Smoke-impacted regional haze in California during the summer of 2002. *J. Agric. Forest Meteor.*, 137, 25-42.

Yu, X-Y., Lee, T., Ayres, B., Kreidenweis, S. M., Malm, W. and Collett, Jr., J. L. (2006) Loss of fine particle ammonium from denuded nylon filters. *Atmos. Environ*., 40, 4797-4807.

NPS – Development of Improved Methods for 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 developed and validated simplified techniques for the quantification of concentrations of levoglucosan, a biomass combustion tracer, in filter samples of smokes. 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 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. We found significant differences in optical characteristics: smokes from fuels that were dominated by flaming combustion were much more light-absorbing, but also frequently contained significant concentrations of soluble inorganic material. Smoldering combustion produced light-colored smokes primarily composed of organic carbon species.

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 are beginning the process of planning activities for Year 3, when we will conduct a field study to apply the source profile information we have gathered in the laboratory.

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

Development of optimized techniques for smoke marker measurement*. Complete.*

Year 1 burn experiments at Fire Science laboratory. *Complete (May/June 2006).*

Sample analysis from Year 1 FSL burn experiments. *Complete.*

Data analysis from Year 1 FSL burn experiments. *In progress.*

Year 2 burn experiments at Fire Science laboratory. *Complete (note, delayed from planned January 2007 date to May/June 2007).*

Sample analysis from Year 2 FSL burn experiments. *In progress.*

Data analysis from Year 2 FSL burn experiments. *In progress.*

Peer-reviewed journal article describing inexpensive smoke marker measurement approaches. *Complete.*

Peer-reviewed journal articles describing smoke source profiles measured at FSL. *In progress.*

4. Leveraging/Payoff:

Findings from the study are being communicated to air quality regulators, policymakers, and other stakeholders to improve understanding of the characteristics of smokes from various fuels.

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

Partners in the study included the National Park Service, University of Nevada Desert Research Institute, and USDA / USFS Fire Sciences Laboratory. Separately-funded collaborative participants in the field studies included Aerodyne Research Inc., University of Colorado, Pacific Northwest Laboratory, Lawrence Berkeley Laboratory, USEPA, Academica Sinica Taiwan, and Montana State University.

6. Awards/Honors: None 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

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NSF – Collaborative Proposal to NSF: Ensemble Data Assimilation Based on Control Theory

Principal Investigator: Milija Zupanski

NOAA Project Goal: Weather and Water, Climate, Environmental Modeling
Climate Observations and Analysis, Climate

Key Words: Non-Gaussian, Non-differentiable, Minimization, Ensemble Assimilation/Prediction, Maximum Likelihood Ensemble Filter, Shallow-water

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

Long -rm 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 Colorado State University global shallow-water model is used with the Maximum Likelihood Ensemble Filter (MLEF), in an effort to explore the use of control theory in ensemble data assimilation. Two important issues naturally arising in geophysical problems are addressed: (i) non-Gaussian probability distribution assumption, and (ii) non-differentiability of prediction model and observation operator. The main accomplishments of this research are:

MLEF system with shallow-water model is developed and tested in two important scenarios: zonal flow over an isolated mountain and Rossby-Haurwitz waves.

MLEF system with lognormal observation errors is developed (Fletcher and Zupanski 2006a),

Hybrid Normal-lognormal MLEF system allowing both the initial conditions and observation non-Gaussian errors is developed (Fletcher and Zupanski 2006b),

MLEF system as a non-differentiable minimization algorithm is developed, and a manuscript is in preparation,

Method for adaptive ensemble size reduction and inflation is developed and tested with shallow-water model (Uzunoglu et al. 2006),

A spin-off research focusing on data assimilation for extreme events has been initiated,

Relevance of this research to adaptive observation strategy has been recognized and is considered to be applied within the T-PARC (Thorpex Pacific Asian Regional Campaign) experiment.

2. Research Accomplishments/Highlights:

This research is successfully completed, with all goals achieved. Due to the spin-off work, and the time needed to complete several manuscripts, this research is under consideration for an extension by the National Science Foundation.

Although this research is sponsored by the National Science Foundation, the results of this research are being transferred to related projects using the MLEF algorithm, including NOAA, NASA, and DoD projects. The personnel working on this project includes Prof. David Randall (CoPI - CSU Atmospheric Science), Steven Fletcher, and the collaborating group from Florida State University (Prof. Michael Navon - PI, Bahri Uzunoglu), as well as Prof. Dacian Daescu (CoPI - Portland State University). The results of this work were presented at many workshops and conferences, including the American Geophysical Union (AGU) Assembly (December 2006, San Francisco, CA), the SIAM Conference on Computational Science and Engineering (February 2007, Costa Mesa, CA), and at the XXIV General Assembly of the International Union of Geodesy and Geophysics (IUGG) (July 2007, Perugia, Italy).

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:

Fletcher, S.J., and M. Zupanski, 2006a: A data assimilation method for lognormally distributed observation errors. Q. J. R. Meteorol. Soc., 32, 2505-2520.

Fletcher, S.J., and M. Zupanski, 2006b: A hybrid multivariate Normal and lognormal distribution for data assimilation. Atmos. Sci. Let., 7, 43-46.

Uzunoglu, B., S.J. Fletcher, I. M. Navon, and M. Zupanski, 2007: Adaptive ensemble size reduction and inflation. Q. J. R. Meteorol. Soc., in print.

Zupanski, D., M. Zupanski, A. Y. Hou, S. Q. Zhang, and C. D. Kummerow, 2007: Information theory and ensemble data assimilation. Part I: Theoretical aspects. Q. J. R. Meteorol. Soc., in print.

Zupanski, M., and I. M. Navon, 2007: Predictability, observations and uncertainties in geosciences. Bull. Amer. Meteor. Soc., in print.

NSF – Collaborative Research: Norwegian-United States IPY Scientific Traverse: Climate Variability and Glaciology

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:

Planning for our 2007-2008 Antarctic field expedition is proceeding 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. "Yet to be started."

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. “Yet to be started.”

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 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.

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

<u>NSF</u> – IPY: Collaborative Research: A Prototype Network for Measuring Actic Winter Precipitation and Snow Cover (Snow-net)

Principal Investigator: Glen E. Liston, Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO 80523.

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:

Plans are in place to install our field sites and instrumentation during summer 2007.

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

Install instrumentation at our field-measurement sites. “In progress.”

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

<u>NSF</u> – 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> – 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 (ζ) equals precipitation (P) minus sublimation (S). These three terms, ζ, 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., D. L. Kane, and G. E. Liston, 2006: Determining solid precipitation on Alaska's Arctic Slope. American Geophysical Union, Fall Meeting, December 11-15, San Francisco, California.

Berezovskaya, S., G. E. Liston, and D. L. Kane, 2007: Snow cover distribution: 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.

Liston, G. E., and M. Sturm, 2003: Improving Arctic snow-related features within regional climate models. SEARCH Open Science Meeting, October 27-30, Seattle, Washington.

Liston, G. E., and M. Sturm, 2003: The role of winter sublimation in the Arctic moisture budget. Proceedings of the 14th Northern Research Basins International Symposium and Workshop, August 25-26, Kangerlussuaq, Sondre Stromfjord, Greenland, pp. 91-98.

Liston, G. E., M. Sturm, L. J. Mahrt, and R. A. Pielke, Sr., 2004: Winter precipitation, sublimation, and snow-depth in the Pan-Arctic. NSF CHAMP Freshwater Initiative All-Hands Meeting, May 4-7, Woods Hole, Massachusetts.

Liston, G. E., 2004: Merging observations and models to describe snow-related land-atmosphere interactions at local to global scales. Civil and Environmental Engineering Department, Duke University, 12 October, Durham, North Carolina. Invited presentation.

Liston, G. E., and K. Elder, 2004: A distributed snow evolution modeling system (SnowModel). American Geophysical Union, Fall Meeting, December 13-17, San Francisco, California. Invited presentation.

Liston, G. E., M. Sturm, and L. J. Mahrt, 2005: Winter precipitation, sublimation, and snow-depth in the Pan-Arctic. NSF CHAMP Freshwater Initiative All-Hands Meeting, June 1-3, Seattle, Washington.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Rocky Mountain Research Station, USDA Forest Service, 8 December, Fort Collins, Colorado. Invited presentation.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Tsukuba University, October 18, Tsukuba, Japan. Invited presentation.

Liston, G. E., 2006: Simulating snow distributions using high-resolution atmospheric and snow modeling tools (MicroMet and SnowModel). Frontier Research Center for Global Change, October 13, Yokohama, Japan. Invited presentation.

Liston, G. E., 2006: How can we link large-scale atmospheric and climate features with small-scale alpine snow processes? Alpine Snow Workshop, University of Munich, October 5-6, Munich, Germany. Invited keynote address.

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.

Sturm, M., G. E. Liston, L. J. Mahrt, D. Vickers, S. Saari, J. Holmgren, W. Bogren, and C. Polashenski, 2006: Sublimation in northern Alaska. NSF CHAMP Freshwater Initiative All-Hands Meeting, 31 March – 2 June, Estes Park, Colorado.

8. Publications:

Liston, G. E., 2004: Representing subgrid snow cover heterogeneities in regional and global models. J. Climate, 17(6), 1381-1397.

Liston, G. E., and M. Sturm, 2004: The role of winter sublimation in the Arctic moisture budget. Nordic Hydrology, 35(4), 325-334.

Liston, G. E., and J.-G. Winther, 2005: Antarctic surface and subsurface snow and ice melt fluxes. J. Climate, 18(10), 1469-1481.

Liston, G. E., and K. Elder, 2006: A distributed snow-evolution modeling system (SnowModel). J. Hydrometeorology, 7, 1259-1276.

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, 241-251.

<u>WESTERN GOVERNORS ASSOCIATION</u> – Western Regional Air Partnership (WRAP) Technical Support System (TSS): A Web-based Air Quality Information Delivery System

Principal Investigators: Douglas Fox and 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 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 Western Regional Air Partnership's (WRAP) 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 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 inter-operability 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 the WRAP and other 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 comprised of 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.

1. Research Linkages/Partnerships/Collaborators, Communication 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. 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 submitted, and ongoing cooperation with the EPA is fostered to ensure the convergence and synergy of the TSS resources with those offered by the EPA.

2. Awards/Honors: None as yet

3. Outreach:

It is important that users be fully trained on the use of TSS resources and offered ample opportunities to ask questions, offer suggestions, and contribute to the ongoing refinement of the TSS. To facilitate this, TSS project members conduct monthly teleconference sessions with users to introduce new features, provide updates on status and progress, and conduct walkthroughs and tutorials on the use and application of TSS tools. To raise awareness of TSS resources within the larger air quality community, project members give frequent presentations to various organizations that might benefit from or be interested in using TSS resources. The TSS website is continuously advertised and listed with relevant online catalogs, indexes, and related web resources, and a responsive system for responding to user questions and feedback is followed.

4. Publications/Presentations:

Ames, R. B., McClure, S. E., Schichtel, B. A., Fox, D.G. 2006. Examples of Web-Based Reporting and Analysis Products from VIEWS and the WRAP TSS. AWMA 2006, New Orleans, LA.

Ehman, J., McClure, S. E., Moore, T. 2006. Developing an Integrated Mapping and Analysis Tool for an Online Decision Support System. Federal Geographic Data Committee (FGDC) Grant Proposal (Awarded).

McClure, S. E. 2006. The WRAP Technical Support System: An Integrated Architecture for the Management, Analysis, and Presentation of Monitoring, Modeled, and Emissions Data. WRAP Attribution of Haze Workgroup Presentation, Denver, CO.

McClure, S. E., Adlhoch, J. P., and Morris, R. 2007. Using the WRAP Technical Support System for the Development of State and Tribal Implementation Plans. WRAP Attribution of Haze Workgroup Training Workshop, Denver, CO.

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	Environmental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observations and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transportation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geostationary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services
5-31130	Funds for the Cooperative Institute for Research, Task 1	X			X												X		X	X	X
5-31133	Continued Investigation of the N.A. Monsoon Sensitvity to Boundary and Regional Forcing with a Focus on Land-Atmosphere Interaction				X	X	X		X		X	X									
5-31144	Environmental Applications Research	X	X	X	X	X	X		X					X				X	X		
5-31152	Satellite Data Reception and Analysis Support					X											X	X	X	X	X
5-31154	Climate Process Team on Low-Latitude Cloud Feedbacks on Climate Sensitivity		X						X	X	X		X		X						
5-31178	Data Fusion to Determine North American Sources and Sinks of Carbon Dioxide at High Spatial and Temporal Resolution			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										
5-31181	Impact of Fundamental Assumptions of Probabilistic Data Assimilation/Ensemble Forecasting: Conditional Mode vs. Conditional Mean	X			X	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			X						
5-31184	Proposal on Efficient All-Weather (Cloudy and Clear) Observational Operator for Satellite Radiance Data Assimilation	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	Environmental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observations and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transportation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geostationary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services
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															
5-31192	Continued Development of Tropical Cyclone Wind Probability Products	X								X		X			X						
5-31193	Improved Statistical Intensity Forecast Models	X			X	X		X				X	X		X						
5-31198	Investigation of smoke aerosol-cloud interactions using large eddy simulations				X																
5-31201	Applications of satellite altimetry data to statistical and simplified dynamical tropical cyclone intensity forecast models																				X
5-31203	Advanced Environmental Satellite Research Support					X											X			X	
5-31204	Regional Transport Analysis for Carbon Cycle Inversions			X							X	X									
5-31207	Incorporation of Census Data in Severe Weather Watches and Warnings		X													X					
5-31209	Expansion of CIRA research collaboration with the NWS Meteorological Development Lab	X	X																		
5-31210	GOES West ISCCP Sector Processing Center																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				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	Environmental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observations and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transportation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geostationary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services
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
5-31215	EPIC ITCZ Radar Data				X	X			X	X			X	X	X						
5-31218	Analysis of clouds, radiation and aerosols from surface measurements and modeling studies	X	X	X		X	X		X	X	X	X		X	X			X		X	X
5-31220	A satellite analysis of atmospheric rivers	X	X			X	X					X			X		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			
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									
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				
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5-31829	Assistance for Visibility Data Analysis & Image Display Techniques			X															X		
5-31897	Assistance for Visibility Data Analysis and Image Display Techniques			X																	
5-31920	The Role of Atmospheric Water Content in Climate and Climate Change (NASA)								X	X											
5-31927	Ensemble Data Assimilation of Precipitation Observations	X	X		X	X	X		X			X		X	X			X			X
5-31960	A-Train Data Depot: Integrating Atmospheric Measurements Along the A-Train Tracks Utilizing Data from the Aqua, CloudSat and CALIPSO Missions		X			X			X	X											X
5-31981	Parameterizing subgrid snow-vegetation-atmosphere interactions in earth-system models		X		X																
5-31983	Weak Constraint Approach To Ensemble Data Assimilation: Application To Microwave Precipitation Observations	X	X		X	X															
5-31988	Mesoscale Carbon Data Assimilation for NACP			X					X	X	X										
5-32704	CloudSat Artic Energy Budget Science and Data Processing								X	X	X										X
5-32730	GLOBE: Inspiring the Next Generation of Explorers (UCAR-NASA)					X															
5-32806	Characterizing pollutant deposition to Rocky Mountain National Park			X							X										
5-32832	Development of Improved Methods for Characterizing Wildland Fire Particulate Matter Emissions and their Air Quality/Visibility Impacts			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	Environmental Modeling	Weather and Water Science	Surface Weather	Coasts, Estuaries, and Oceans	Climate Observations and Analysis	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transportation System	Aviation Weather	Marine Weather	NOAA Emergency Response	Geostationary Satellite Acquisitions	Homeland Security	IT Services	Polar Satellite Acquisitions	Satellite Services
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 Tranverse: climate variability and glaciology								X	X	X										
5-33116	IPY: Collaborative Research: A prototype network for measuring arctic winter precipitation and snow cover (snow-net)		X				X		X		X										
5-33238	The White Arctic: A Snow-Impacts Synthesis for the Terrestrial Arctic		X		X		X					X									
5-33428	CIRA-NCAR/MMM WRF-Var collaboration Work Plan	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										
5-35004	Western Regional air partnership (WRAP) technical support system (TSS): a web-based air quality information delivery system			X							X	X						X			
5-36500	Development of Methods for Data Assimilation with Advanced Models & Advanced Data Sources	X	X		X	X	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
5-37404	Multi-Year C.A. for Center for GeoSciences/Atmospheric Research	X	X			X	X					X	X	X	X		X			X	X

CIRA AWARDS

GSD Team Member of the Month – June 2007 – *Mike Biere*
The following nomination comes from Technology Outreach Branch Chief Bill Bendel.

"Mike Biere – Technology Outreach Branch/Science On a Sphere® Senior Software Engineer – is designated as GSD's Team Member of the Month for June 2007. He is receiving this in recognition for superb efforts in furthering the SOS mission. In particular: contributing innovative ideas on improving the current SOS system; continuing to support customers at many sites with real time answers; providing training during the installation of SOS systems at several museums and science centers; developing the software for the five projector configuration for SOS; and interacting with vendors, suppliers, and sphere builders to get the work done right and on time."

CIRA 2006 Research Initiative Awards – *Kevin Brundage, Louie Grasso and Manajit Sengupta*
Kevin received the award based on his significant participation on the NOAA Research and Development High Performance Computing System Procurement as well as his continuing superior performance on collaborative research with NOAA/RDTL GSD's Assimilation and Modeling Branch.

Louie Grasso and Manajit Sengupta received the award for their outstanding work on the GOES-R Project.

***Dr. Shripad Deo* Wins Regional Excellence Award**
Dr. Shripad Deo, a CIRA Research Associate based in Kansas City, MO with our National Weather Service Central Region Headquarters colleagues, was recently recognized with a Regional Excellence Award. The focus of Dr. Deo's research has been in trying to help the NWS communicate with the public more clearly and effectively. In this project, the goal was to develop a web portal that would allow the lay public access to NWS information without being overwhelmed. With help from the webmaster, the project was completed in June of 2006.

NOAA Environmental Heroes 2007– *Nolan Doesken*
The NOAA 2007 Environmental Hero Awards were presented by retired Navy Vice Admiral Conrad Lautenbacher, Ph.D., Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator, at the National Press Club in Washington, D.C., on April 20, 2007.

Nolan Doesken was one of ten recipients of the prestigious award. "Doesken organized a network of citizen volunteers to measure and report precipitation from their homes following a flash flood that killed five people in Fort Collins, Colorado in 1997. Starting with a few volunteers in 1998, the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network involves thousands of volunteers in 17 states, and enhances the forecasting and warning capabilities of the NOAA National Weather Service."

Distinguished Administrative Professional Awards go to *Jim Frimel* and *Don Reinke*

Congratulations go out to Jim Frimel for his selection as one of the recipients of this year's CSU Distinguished Administrative Professional Award. This annual award recognizes administrative professionals for continuing meritorious and outstanding achievement in outreach, teaching, administration and/or research at CSU.

Jim is being recognized for his key leadership of several high visibility research projects, including the FAA- and NWS-sponsored Volcanic Ash Coordination Tool project that recently received the 2006 NOAA Bronze Medal. He was presented his award at the Celebrate Colorado State! Luncheon on April 26 at the Lory Student Center.

Congratulations to Don Reinke on his selection as recipient of this year's College of Engineering Distinguished Administrative Professional Award for his exceptional performance as Leader of the CloudSat Data Processing activity since 2001. CloudSat is a NASA-managed cloud imaging satellite that has been making unique vertical structure measurements since June 2006.

Don was presented his award at the annual College of Engineering Visual Arts and College Awards Reception held April 12th.

Principal Investigator Richard Johnson has just finished a 3-year term on the NAME Science Working Group and was selected to serve on the CPPA Science Panel.

GSD Team Member of the Month – December 2006 - *Evan Polster*

Evan Polster was named GSD's December 2006 Team Member of the Month. Evan serves as the Technology Outreach Branch programmer Analyst for the FX-Net Technology. He was recognized for his outstanding efforts in furthering the FX-Net activities including: contributing innovative ideas on improving recent FX-Net Client updates; working hard to meet many development and software release deadlines; maintaining the Starteam software version control system and the FX-Net group Wiki site; and providing Java development leadership.
On the web: http://www-tod.fsl.noaa.gov/fxnet.html

***Sher Schranz and Jebb Stewart* Honored for FX-Net Project**

At the annual NWS Incident Meteorologist (IMET) Workshop in Boise, Idaho during the week of March 12, 2007, the National Weather Service Director, Brig. General D.L. Johnson, USAF (Ret.), presented 'Certificates of Recognition' to two members of the FX-Net project team. Sher Schranz, Project Manager, and Jebb Stewart, Development Lead, received the award.

"In Recognition of your leadership to ensure operational excellence via innovative development and maintenance of critical software for our IMETS."

The National Weather Service has implemented an All Hazards Onsite Meteorological Support System to provide data and communications to the NWS Incident Meteorologists (IMETS) at remote locations. The core component of the system is the

NOAA ESRL/GSD's FX-NET system. FX-NET provides AWIPS-like displays on the IMET laptop while retrieving real-time atmospheric data from remote data servers. FX-NET has been deployed to hundreds of fires during the last four fire weather seasons, and to other events such as Katrina clean-up support, oil spills and national political conventions. FX-Net delivers high-resolution satellite, radar, observational and weather prediction model data utilizing unique compression technology and state of the art, cross-platform display software.

Best New Site by *Jeff Smith*
CIRA Research Associate Jeff Smith was recognized at the NOAA/Global Systems Division (GSD) Christmas party this past December (2006) with a web award for "Best New Site." Jeff's creation, called "JavaZone" was created as a supplement to Jeff's Java class for the Earth Systems Research Laboratory (NOAA) in Boulder, CO. However, it has taken on a life of its own and become a valuable resource for many GSD developers who weren't able to take the class. The site is fun, clever and user-friendly. Power Point training slides, Java programming exercises, downloads, links and a "fun stuff" category are all provided on the site. Jeff's well-designed and well-coded site is GSD's Best New Site of 2006.
On the web: http://www-ad.fsl.noaa.gov/ac/javazone/

2007 AMS Poster Award – *Mark Govett and Jeff Smith*
Poster Award for Use of WRF Portal to Support the Developmental Testbed Center

Gold Medal and Paper of the Year Awards for *Tracy Smith*
The ESRL/Global Systems Division's GPS-Met team received the 2006 Department of Commerce Gold Medal for its development of Global Positioning System (GPS) meteorology, a new low cost, upper-air observing system that uses GPS to continuously measure the total amount of water vapor in the atmosphere. Although only Federal employees are eligible for this award, CIRA Research Associate Tracy Smith was a key member of the team that successfully demonstrated new applications for GPS meteorology that are essential to NOAA's Integrated Earth Observing System/Global Earth Observing System of Systems. Their efforts have advanced weather forecasting, climate monitoring, and atmospheric research by providing a new way to monitor atmospheric water vapor.

Tracy was also one of the coauthors on a paper selected as one of the 2005 OAR Outstanding Scientific Paper Awards announced in June. The award-winning paper, "An Hourly Assimilation-Forecast Cycle: The RUC," was published in Monthly Weather Review. This paper describes the analysis system utilized within the Rapid Update Cycle (RUC) and discusses some issues associated with high-frequency data assimilation cycling. The RUC is an operational NCEP weather forecast system Tracy helped develop as part of the GSD Assimilation and Modeling Branch.

On the web: the website for GPS-Met is http://gpsmet.noaa.gov/jsp/index.jsp
for the RUC (now known as Rapid Refresh) is http://rapidrefresh.noaa.gov/
A copy of the MWR paper can be found at:
http://www-frd.fsl.noaa.gov/pub/papers/Benjamin2004c/j.pdf

Prof. Tom Vonder Haar elected Chairman of the Interdisciplinary Section of the National Academy of Engineering

Dr. Tom Vonder Haar, University Distinguished Professor of Atmospheric Science and Director of CIRA, has been elected Chairman of the Interdisciplinary Section of the National Academy of Engineering. The Academies of Engineering and Science and the Institute of Medicine were founded by President Abraham Lincoln to serve as advisors to the Nation. The Interdisciplinary Section includes 140 Academicians from industry, research laboratories and the university community.

Vonder Haar was named to the Academy in 2003. He joined CSU faculty Larry Roesner, Civil Engineering, George Seidel, Jr., Biomedical Sciences, and Barry Beaty, Microbiology, Immunology and Pathology in this honor. CSU faculty emeritus Jack Cermack and A. Ray Chamberlain, Civil Engineering, with Albert Meyers and Marshall Fixman, Chemistry, are also active members of the Academy.

NASA Honor Award goes to SDPC Team

A NASA Group Achievement Award was presented to the CSU-CIRA Team comprised of ***Kenneth Eis, Phil Partain, Dale Reinke, Donald Reinke, and Laura Sample*** for "exceptional contributions to the CloudSat mission in the design, development and implementation of the CloudSat Data Processing System." CloudSat launched on April 28th, 2006 and the Data Processing Center has processed 100% of the data collected by the instrument since it became operational on June 2nd 2006.

A formal announcement of this award was made at the awards ceremony at JPL on June 21st. Phil Partain traveled to JPL to accept the Award for the DPC. Phil is an employee of Science Technology Corporation, METSAT Division and is working under a subcontract to CIRA as the CloudSat Data Processing Center System Engineering and Operations Manager.

	CI Lead Author					NOAA Lead Author					Other Lead Author				
	FY03	**FY04**	**FY05**	**FY06**	**FY07**	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**
Peer-Reviewed	~~~	29	70	42	61	21	20	14	30	27	78	40	25	71	63
Non Peer-Reviewed	~~~	82	128	40	98	32	48	52	91	35	44	53	46	64	65

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	0	0	0	0	0
Postdoctoral Fellows	12	0	0	12	0
Research Support Staff & Administrative Personnel*	65	32	20	8	5
Total	87	32	20	30	5
Employees who received less than 50% support		**Degree**			
Category	**Number**	**Bachelors**	**Masters**	**Doctorate**	**Non-Degreed**
Research Scientists	12	0	0	12	0
Visiting Scientists	1	0	0	1	0
Postdoctoral Fellows	0	0	0	0	0
Research Support Staff & Administrative Personnel*	39	17	12	0	10
Total	52	17	12	13	10
Supported Students		**Degree**			
Category	**Number**	**Bachelors**	**Masters**	**Doctorate**	
Undergraduate	0	0	0	0	
Graduate	7	0	6	1	
Total	7	0	6	1	
Employees located at NOAA Laboratories		**GSD**	**PSD**	**CSD**	**FSL/MDL**
Total	43	40	1	1	1
Obtained NOAA Employment within the last year					
Total	2				

***CIRA does not differentiate between Research Support Staff and Administrative Personnel**