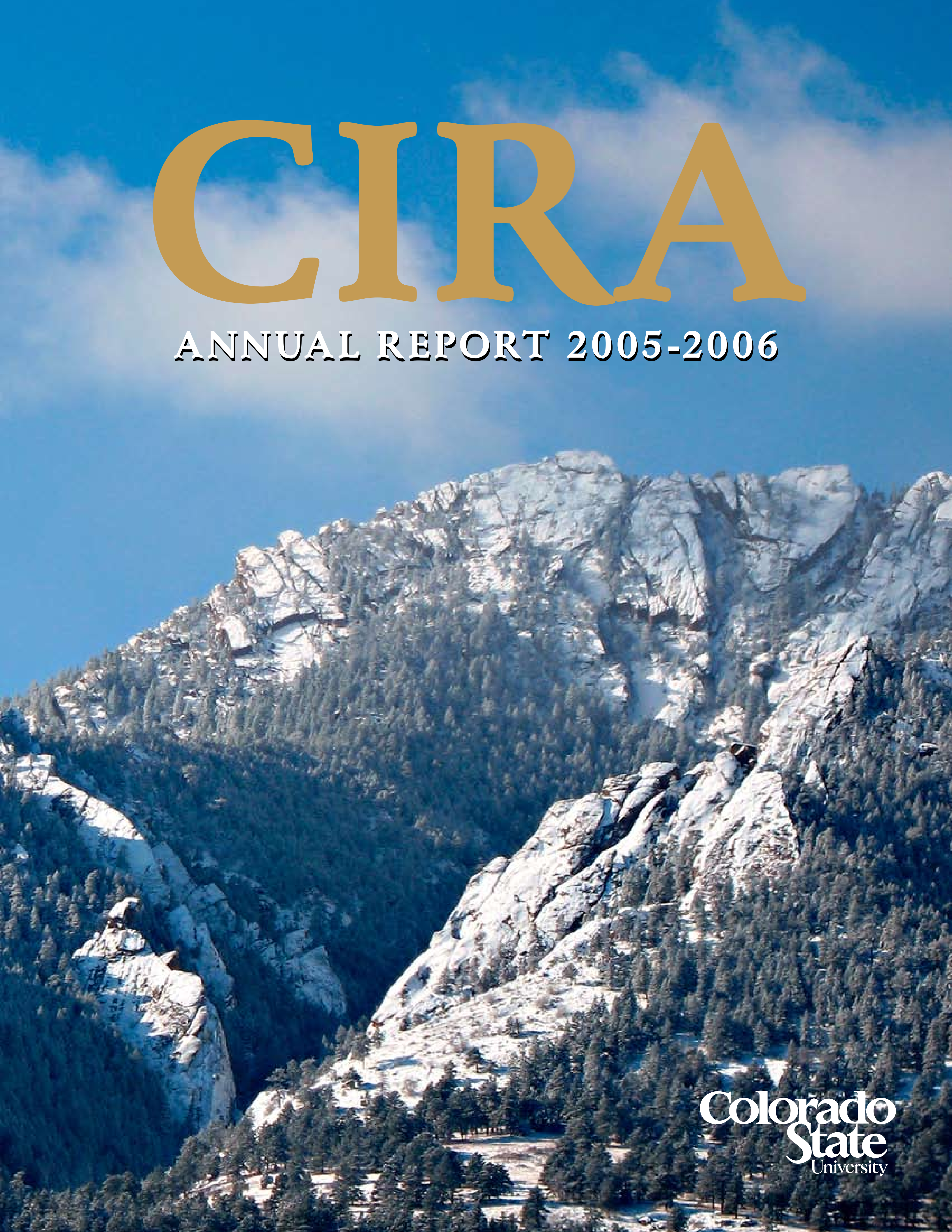
CIRA

ANNUAL REPORT 2005-2006



Colorado State University

CIRA ANNUAL REPORT FY 05/06

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE

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INTRODUCTION

This report describes research funded in collaboration with NOAA's cooperative agreement and the CIRA Cooperative Institute concept for the period July 1, 2005 through June 30, 2006. 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

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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

AHPS
CIRA continues to work with the National Weather Service in support of the efficient and effective implementation and development of NWS's Advanced Hydrologic Prediction Service program (AHPS). This project involves social research and analysis to understand the information needs of various user groups for the presentation, understanding, and training of using hydrologic information in a variety of decision-making and risk-based situations involving uncertainty. http://weather.gov/rivers.tab.php

Air Quality Education and Outreach
The National Park Service Visibility Research group at CIRA is using interactive technology to tell visitors how human activities impact environmental systems within the national parks and in our every day lives. They also have prepared information about ongoing research efforts in the area of sulfur and nitrogen compounds.

- A public outreach and educational kiosk program was created to make visitors to Sequoia Kings Canyon National Park aware of a growing air pollution problem and its effects on people and resources. Each presentation makes extensive use of rich media (graphics, animation and video), employs an interactive user interface, and creates activities that challenge users to test their knowledge of energy conservation practices. These features will capture the attention of visitors who span a range of age and education levels. In order to appeal to a growing population of Spanish-speaking visitors, there are Spanish and English versions of the program.

- A web-based learning activity is being developed that seeks to educate the general public about energy conservation practices that can be applied to our everyday lives. A special recycling activity challenges the user to make choices about what is trash and what can be recycled. The activity will relate the user choices to a visibility level or possible ozone event.

- In support of research to determine the origin and effects of nitrogen and sulfur compounds on visibility and natural ecosystems, a brochure has been prepared that will provide a quick explanation of the problem and summarize research goals, objectives, and measurement approaches. The ROMANS Study Brochure will be used to educate air quality managers, field operators, and the general public about ongoing research efforts.

Air Toxics Website
This website continues to provide online access to air toxic archive data about toxic substances in the air. Analyses of these data provide information about spatial patterns, temporal profile, and general characteristics of various air toxic compounds, and continues to be part of the ongoing work to support the deployment of a national air toxics monitoring system. http://vista.cira.colostate.edu/atda.

AMSU Outreach
With the launch of NOAA 15 in 1998, a new era of microwave remote sensing began. We developed a website (http://amsu.cira.colostate.edu) to offer AMSU information and products to interested people. The site includes:

- a description of AMSU's capabilities,
- raw and mapped data,
- browse images of AMSU products,
- real-time loops of blended AMSU and SSM/I (and GPS) precipitable water (useful for forecasting heavy rain),
- information on the status of AMSU data flow,
- algorithms (courtesy of our NESDIS collaborators), and
- publications.

CloudSat (An "A-Train" Formation Satellite) Education and Outreach
In the early morning hours of April 28, 2006, NASA launched the CloudSat satellite into space--the first ever vertical cloud profiling system designed to peer into and measure the moisture content of clouds. Orbiting at 428 miles above the earth's surface in the A-Train formation, CloudSat will enable scientists to not only improve their accuracy on quantifying the moisture content of clouds, but to provide data relative to global warming and climate change. The CloudSat Data Processing Center (DPC) at CIRA is responsible for the assimilation of the CloudSat data and its conversion into usable products for scientists and eventually the general public. As part of its ongoing educational outreach, the CloudSat DPC provides information at the following websites:

- On this website there is a wealth of instructional information about the CloudSat mission, its primary instrument - the Cloud Profiling Radar (CPR), and examples of meteorological phenomenon that CloudSat is designed to investigate.
  http://www.cloudsat.cira.colostate.edu

- CloudSat DPC description
  http://www.cloudsat.cira.colostate.edu/cloudsat_documentation/html/index.html

- CloudSat science data products
  http://www.cloudsat.cira.colostate.edu/dataHome.php

- Interesting CloudSat case studies
  http://www.cloudsat.cira.colostate.edu/CaseStudies.php

- Near-real-time "quick look" images
  http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php

CoCoRaHS Education and Outreach
In 1998 a small group of weather volunteers in northern Colorado under the direction of the Colorado Climate Center at Colorado State University began measuring rainfall and hail at their homes to help track local precipitation patterns from summer thunderstorms.

Since that time, the project has grown into a multi-state network of well over 2000 citizens measuring and reporting precipitation amounts year round.

There are no electronic measurement devices in CoCoRaHS. Volunteers use clear plastic rain gauges to manually measure the quantity of precipitation and send this data to a data website. During the winter months, the depth of snow is measured using rulers and "snow boards." Quantitative measurements of hail are taken using "hail pads," squares of Styrofoam wrapped with aluminum foil. Altogether, this suite of instruments provides measurements which create a very comprehensive assessment of the moisture falling from the sky.

Many teachers are getting students involved in CoCoRaHS to learn how scientists collect and analyze scientific data. Most importantly, volunteers of all ages and backgrounds are learning about their local climate and the importance of precipitation in daily life. CIRA continues to sponsor a science teacher internship program where teachers work directly with CoCoRaHS scientists to develop and test educational materials and lesson plans. This year's focus was on developing a course to involve more minority students in the study of weather. To learn more about CoCoRahs access the following website: http://www.cocorahs.org.

GLOBE Education and Outreach

The Global Learning and Observations to Benefit the Environment Program (GLOBE) continues to evolve and expand as the most extensive educational and outreach program with which CIRA is involved. The GLOBE Systems team, comprised of 8 CIRA researchers, continued to provide website, database, and data acquisition support to the Program's worldwide users now located in 109 countries. There are now more than 15 million observations in the GLOBE database collected by students in over 18,000 schools since the Program's inception in 1995. Visit the GLOBE website at http://www.globe.gov/globe_flash.html for additional information.

FXC-TMU Outreach

Research was completed on National Convective Weather Forecast (NCWF2) product integration into the AWIPS FXC Traffic Management Unit (TMU) 2.30 system and the TMU Website was upgraded to handle the NCWF2 Graphics used in Fort Worth. SID and STAR map backgrounds were created for the Dallas-Ft Worth airspace. The TCHP animation page was redesigned and the TMU home page was redesigned to fit the display. Version 2.2 of the TMU Website that contained the NCWF2 graphic products was released for evaluation.

FXC-VACT Outreach

During the past year, a major release of the FX-Collaborate (FXC) Volcanic Ash Coordination Tool (VACT) software, version 2.30 was implemented and the new system provided support of volcanic eruptions for the Anchorage VAAC. The FXC VACT was used in operations during the eruptions of Mt. Augustine and for four other events along the Aleutian chain and the Kamchatka peninsula. Refer to http://www-ad.fsl.noaa.gov/asdad/projects/vact/ for additional information on the project.

IMPROVE Education and Outreach

The Interagency Monitoring of PROtected Visual Environments (IMPROVE) research is focused on identification of particulate pollutants and the mechanisms by which they are transported. Details on this program are located at the following website: http://vista.cira.colostate.edu/improve/. This website was designed to provide federal, state, and local air quality regulatory agencies, as well as the general public, access to visibility data. This information includes monitoring a site's location, topography, air quality measurements over time, and pictures of the site and surroundings. A special feature is photographs documenting the spectrum of visibility conditions at each site. For the public there is an educational section that will guide people through the visibility science and regulatory information at their own pace. Animations, voice, and still images convey the basic concepts of visibility science, air quality data analysis and haze.

IMPROVE Education and Outreach Calendar

An annual calendar is created in support of the IMPROVE (Interagency Monitoring for Protected Visual Environments) Program (see above). The calendar targets field operators with the primary purpose of increasing the quality and consistency of data collection. As an outreach tool, the calendar provides information pertaining to monitoring protocols, providing operators a reliable tool for meeting data collection and maintenance requirements. Operators are introduced and their accomplishments acknowledged in a special section of the calendar which recognizes individual efforts. The education section provides background information on the IMPROVE program, its monitoring mission, measurements and measurement technology, laboratory processes, data results and applications, and descriptions of special research projects that cooperate with the IMPROVE monitoring effort. To view the complete calendar for 2006 please visit: http://vista.cira.colostate.edu/IMPROVE/Publications/Calendars.htm.

Joint Hurricane Testbed Training

The months of June through November are critical for the development of "tropical cyclones" a phenomena which begin as tropical disturbances, grow to tropical depressions, mature into hurricanes (typhoons in the western North Pacific Ocean), and normally die out as tropical storms over land. A new model which gives the probability of a storm's center being within 75 statute miles from a given location has been developed as part of the CIRA JHT project. This new model estimates the probability of experiencing tropical storm or hurricane conditions using a Monte Carlo Probability (MCP) model, where a large set of plausible tracks and intensities are determined by randomly sampling historical forecast error distributions. CIRA staff continue to train weather forecasters on the use of this new model as an outreach forecast for the general public including wind probabilities for specific areas within the tropical cyclone path.

Microwave Remote Sensing Training Module

CIRA staff, with expertise in remote sensing parameters (water vapor and clouds), have reviewed and commented on COMET's Training Module on "Microwave Remote Sensing" for the University Corporation for Atmospheric Research (UCAR). The goal of this module is to educate NWS/DoD forecasters about the variety of uses of microwave products from satellite, and help prepare them for the NPOESS era. For further information on this module see: http://deved-in.comet.ucar.edu/npoess/microwave_topics/overview/

RMTCs Training and Outreach
RMTCs are international Regional Meteorological Training Centers located in Costa Rica and Barbados. Continued activities with these RMTCs have focused on building case studies of heavy rain events associated with hurricanes, tropical waves, and the incursion of mid-latitude systems during the northern hemisphere winter. Assistance has also focused on convection and severe weather, fire detection, volcanic ash detection, satellite rainfall estimation, and satellite cloud climatologies. CIRA has helped organize and complete several World Meteorological Organization (WMO) sponsored two-week satellite training courses in these regions. At a 2005 training event in Costa Rica, CIRA provided electronic notebooks for participants to use during the training event and subsequently take back to their respective countries for the students/trainers to continue the training of others. Those notebooks have proven to be a valuable asset for continued training as well as the formation of a regional focus group where participants meet via Internet on a three-week basis to discuss satellite meteorology and local weather. In 2006, Argentina became the most recent RMTC to join the process, with Brazil currently being proposed as an RMTC for Portuguese speaking countries. See http://www.cira.colostate.edu/RAMM/TRNGTBL.HTM#vlab for more information on various RMTC activities.

Science on a Sphere Education and Outreach
CIRA personnel continue to partner with NOAA's Earth Science Research Laboratory in the design and implementation of an exciting project to visualize the wonders of the Earth, other planets and moons, and even the sun via a six-foot sphere suspended in space. Called "Science on a Sphere™ (SOS)" the visual impact of SOS will stimulate one's imagination and the desire to learn more about our living planet and its surrounding space. Customized software provides the magical look of projected data onto a seamless animated globe. Global infrared satellite imagery, sea surface temperatures, climate models, X-ray sun imagery, earth bathymetry, and surface elevation data are among the NOAA datasets displayed on the screen.

Science On a Sphere™ was installed at six new permanent public venues this past year—Nauticus National Maritime Museum in Norfolk, VA, Bishop Museum in Honolulu, HI, The Tech Museum in San Jose, CA, Science Museum of Minnesota in St. Paul, MN, NASA Goddard Space Center in Greenbelt, MD, and the Maryland Science Center in Baltimore, MD. Five-projector display architecture was implemented and demonstrated. This new projector arrangement reduces shadowing by viewers and eliminates polar regions where no data is displayed in our older four-projector arrangement. An enhanced software-based projector alignment method was developed, eliminating tedious mechanical projector alignment, while improving image registration. Finally, several new data visualizations were developed, along with enhancements to existing data sets. More information on Science on a Sphere can be found at: http://www.fsl.noaa.gov/sos/.

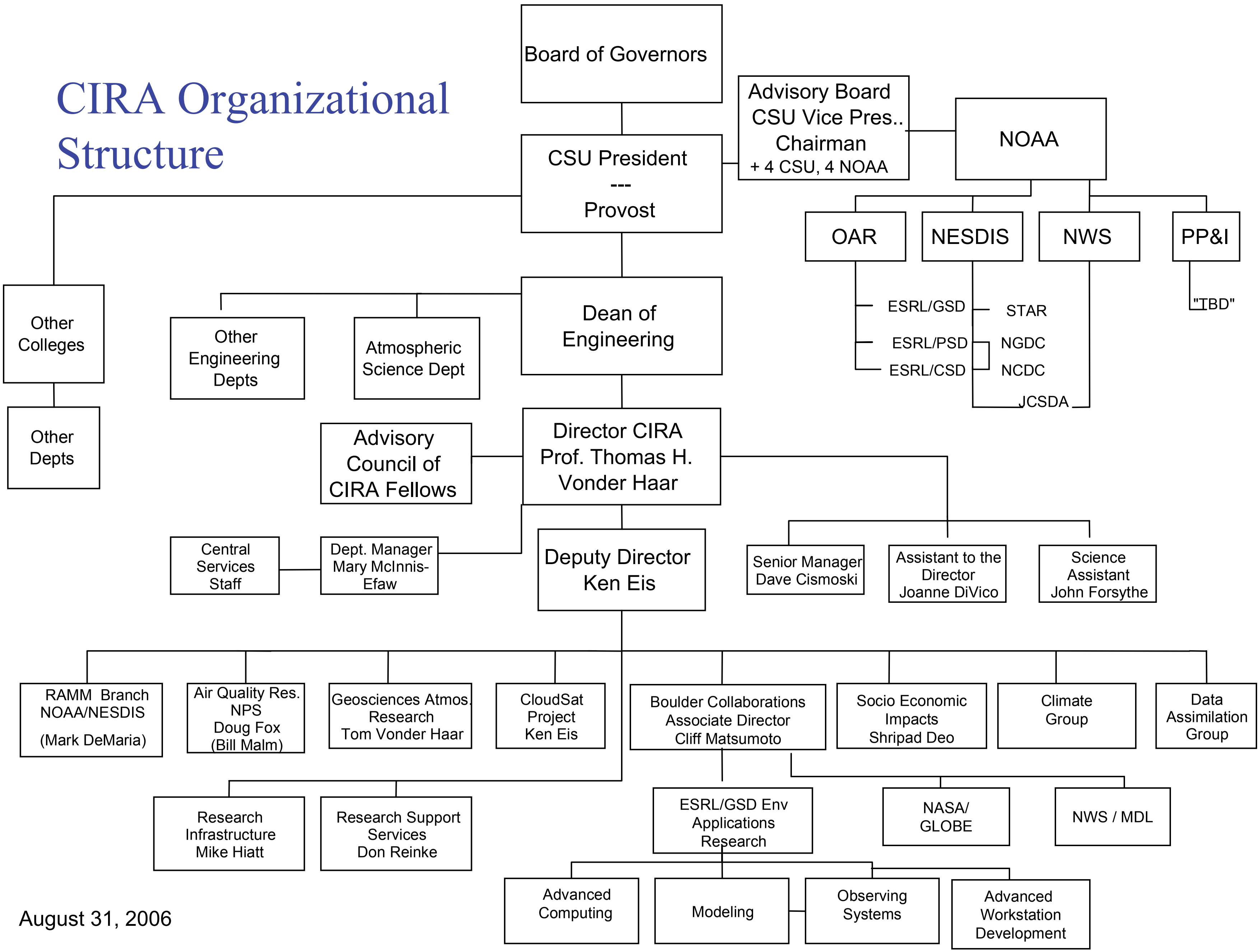
SHyMet Training and Outreach
The Satellite Hydrology and Meteorology Training Course is designed to cover the basics of Geostationary and Polar orbiting satellites including their instrumentation, orbits, calibration, navigation, and associated radiation theory. The course includes the remote sensing basics necessary for the correct interpretation of satellite imagery, identification of atmospheric and surface phenomena, and the integration of meteorological techniques with satellite observing capabilities. For additional information on this new course dedicated to operational satellite meteorology please visit the following website: http://rammb.cira.colostate.edu/training/shymet/.

VIEWS Education and Outreach
The Visibility Information Exchange Web System (VIEWS) is an online exchange of air quality data, research, and ideas designed to understand the effects of air pollution on visibility and to support the Regional Haze Rule enacted by the U.S. Environmental Protection Agency (EPA) to reduce regional haze and improve visibility in national parks and wilderness areas. Public access to this site is encouraged, as here one will find a living inventory of distributed air quality data resources for the western U.S.: http://vista.cira.colostate.edu/views/.

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.

Virtual Library and WMO Global Outreach
The Virtual Laboratory for Satellite Training and Data Utilization (VL) continues to maximize the exploitation of satellite data across the globe. It is a collaborative effort joining the major operational satellite operators across the globe (USA, Europe, China, Japan) with the World Meteorological Organization (WMO) “centers of excellence” (COEs) in satellite meteorology located in Costa Rica, Barbados, China, Australia, Kenya and Niger. These “centers of excellence” serve as the satellite-focused training resource for WMO members where trainers from different countries come to learn, and then return home to train others. Last year, CIRA introduced a new concept in training at the COE in Costa Rica. The success of this activity is helping CIRA meet an international outreach goal of advancing the utilization of satellite data. To learn more about the VL, and to tour CIRA’s Virtual resource Library visit the CIRA website (http://www.cira.colostate.edu/WMOVL/index.html).

CIRA Organizational Structure



August 31, 2006

CIRA RESEARCH HIGHLIGHTS
July 1, 2005 – June 30, 2006

Global and Regional Climate Dynamics

- We are developing a physically-based micrometeorological model (MicroMet) that will serve as an interface between current course-resolution meteorological models and the fine-resolution hydrological and ecological models. The preliminary version is completed.

- Performed the first climate sensitivity experiment using a GCM with explicit representation of clouds.

- Created the longest RCM summer climatology to date for the contiguous US and Mexico using RAMS which effectively produced a down-scaled NCEP-NCAR reanalysis in this region. One of the insights of this analysis was that the time varying SST modes in the Pacific affect the onset of the North American Monsoon System.

- Developed and tested a method for extrapolating surface-layer CO2 measurements at flux towers to atmospheric mixed-layer values under convection conditions.

- Developed several methods for estimating continental carbon budgets from CO2 mixing ration observations.

- Found that CO2 variations are predominantly driven by horizontal advection rather than changes in vertical mixing and can be well modeled.

- Identified smoke aerosols as having two different effects on cumulus development: absorption and local heating by biomass burning aerosols as it modifies atmospheric stability and the dynamical feedback of absorbing aerosols as they block solar radiation causing surface heat fluxes to fall.

- Our North American Monsoon (NAM) to Soil Moisture study has demonstrated the sensitivity of the NAM to soil moisture, SSTs and vegetation.

- Completed a multiscale variability study of the flow during NAME. QuickScat data was used to study Gulf surges.

- A preliminary plan for a network of global Unmanned Aerial System (UAS) observations has been designed and tested against past observations. Twelve ground stations for UAS operations have been selected using archived hourly surface observations to screen the stations for optimal conditions for takeoff of the UAS. The flight paths and routing of the UAS between fixed observational points have been screened for reliability of the network using reanalysis data. In addition to the global network of UAS, a concept of operations for an intensive UAS program over the Arctic to study climate change is under development.

- Six animated demonstrations from three different climate models have been created for Science on a Sphere™ (SOS) using model output from the fourth IPCC results. Three animations display surface temperature changes from the year 1870 to 2200; two animations show sea ice and ocean temperatures/currents; one additional animation shows precipitation changes.

- Project entitled Regional Transport Analysis for Carbon Cycle Inversions was initiated this past year to provide influence functions for selected CO_2 measurement towers in North America. Portion of this effort will be to provide Rapid Update Cycle (RUC) analyses as input to a Lagrangian model to calculate backward trajectories of particles reaching these observation sites. The winds obtained from the analyses are adjusted to conserve mass with a minimization technique with constraints using a Lagrangian multiplier. During the past year, data sets of hourly meteorological analyses generated by the RUC assimilation system on the 13-km grid over North America were obtained. Sub-setting software to extract only the transport fields from these analyses was developed and tested, and the CSU Lagrangian Particle Dispersion Model (LPDM) was adapted to read the 13-km RUC fields. The ability to calculate adjoint, or backward-in-time, transport influence functions for specified sampling stations has been verified to quantify 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.

- Regional climate simulations were performed for June 2004 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. Convection was parameterized in simulations on a 20-km resolution grid and cloud resolving simulations were performed on a 1.7-km resolution grid. The default parameterization of convection is an ensemble of closures based on varying assumptions. Turbulence is parameterized with a 2.5-order closure, and a land surface model by Smirnova et al. was used. Initial conditions for the atmospheric and the land surface models were obtained from the RUC analysis. Differences in hourly characteristics of precipitation in different simulations were obtained and some results of this effort were presented at the Conference on Applied Climatology in Ljubljana, Slovenia in September 2006.

- A one-year comparison is made of mean monthly values of cloud fraction and cloud optical depth over Barrow, Alaska between 35 GHz radar-based retrievals, the TOVS Pathfinder Path-P product, the AVHRR APP-X product, and a MODIS-based cloud retrieval product from the CERES-Team. The data sets represent largely disparate spatial and temporal scales; however, for this research effort, the focus is to provide a preliminary analysis of how the mean monthly values derived from these different data sets compare and to determine how they can best be used separately, and in combination, to provide reliable estimates of long-term trends of changing cloud properties.

Mesoscale and Local Area Forecasting and Evaluation

- Developed correction algorithms for the Judd and Campbell snow depth sensors that improved their error to +/-0.4 inches for 6-hour averages and to within 0.23 inches absolute error.

- Developed a special version of JTWC's Statistical Typhoon Intensity Prediction Scheme STIPS tool which included AOML's tropical cyclone heat potential TCHP. The average intensity forecast error improvement was significant.

- A webpage of landfall probabilities for 2004-5 hurricanes is at http://rammb.cira.colostate.edu/projects/tc_wind_prob. This was done in association with improved error statistics, and included in TPC's training sessions. 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 in the immediate future that will be distributed to the public.

- Completed the AMSU algorithm for the estimation of tropical cyclone maximum winds and wind structure. The fully operational version was implemented in June 2006 at NCEP/NCO, NTWC and NHC in Miami.

- In the "Stratocumulus Role in Modification of Pollution Plume Transported to the North American Continent" study, we successfully identified the smoke plumes documented by Wotawa and Trainer. No false positives were made; and, based on the success of this study, the method was applied to the historical database to develop estimates of annual frequency of occurrence of transport of smoke from wild fires to the eastern and southeastern US. These ranged from 5 to 15% of the aerosol samples being influenced by long-range transport of smoke.

- In support of an operational evaluation of the second version of the Graphical Turbulence Guidance product (GTG-2) produced by the FAA's Turbulence Product Development Team, the CIRA team designed and developed a verification data processing system for turbulence forecasts. The system produces statistical plots and graphical displays, which are available via a powerful web interface, using reports of turbulence from aircraft pilots as observations. NOAA collaborators intend to use the system as the primary verification tool in the upcoming formal assessment. In addition, CIRA researchers continue to deploy upgrades and new verification capabilities to an RTVS configuration at 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. This capability, a significant upgrade, aligns very well with the recently elevated NOAA priorities regarding performance evaluation of weather forecasts.

- The Developmental Testbed Center (DTC) Winter Forecast Experiment (DWFE) was run from 15 Jan to 31 Mar 2005 as a test of two 5-km numerical models with explicit convection run on the continental United States (CONUS) scale. One of the models was run out of ESRL/GSD, and the other at NCAR (the location of the DTC), with one run of each per day, out to 48 h over the CONUS scale. This was the first time that these perspective models of the future were run in real-time on such a large scale. CIRA researchers participated in the DWFE by providing subjective assessment of the forecasts of the high-resolution NMM and ARW versions of the WRF model for winter forecasting. Papers were presented at the AMS conference on Numerical Weather Prediction and Weather Analysis and Forecasting in August 2005. One of the unique products that was output from the DWFE models was model-simulated radar reflectivity, which allowed for a better depiction of the structures within winter storms, as well as a direct comparison of the model output with observations in real-time.

  To aid in evaluation of the model output, graphical representations of model output parameters were generated for 30-day study periods in each of the four seasons. The scripts used to generate the images, as well as the website for access and display, were created through modification of those used in the DTC Winter Forecast Experiment (DWFE) from FY05. Capabilities of the website were expanded to include display of images from the RUC-13 and the ability to compare WRF ARW- and NMM-based images in a side-by-side or tiled fashion. Numerical modelers and other meteorolgists were able to use the images to easily locate anomalies and closely scrutinize differences in the ARW and NMM cores and make definitive determination as to the most accurate choice for ultimate inplementation. The web-site may be viewed by pointing to http://bolas.fsl.noaa.gov/mab/wrfrr .

- Two major new advances were made in the suite of modeling capabilities at GSD. First, the NCEP WRF model, NMM, was modified to permit Local Analysis and Prediction System (LAPS) diabatic initialization. This required modifying initialization codes of the WRF source. This modified code has been run in real-time over the Colorado region, and it has been shared with the NWS/SOOs. Second, multiple mesoscale models (WRF-ARW, WRF-NMM, MM5, RAMS) have been pulled together in order to generate ensemble forecasts. Scripts were written to ensure that each model is run in real time and initialized with LAPS diabatic initialization. Probabilistic output is generated by combining the forecasts from this group of models and by including past forecasts. Ensemble forecasts have been generated in real-time and displayed on AWIPS for the NWS Boulder office.

- A full evaluation of ensemble forecasts produced in support of the Hydrometeorological Testbed has been conducted, and the results have been formed into an ensemble composition that will be run in real-time and distributed to Monterrey WFO, Reno WFO, and Sacramento WFO during next year's Hydrometeorological Testbed field project (Dec 2006 - Mar 2007).

- TAMDAR data is currently being evaluated at ESRL/GSD and elsewhere for quality, utility for forecasting various types of weather, and impact on numerical weather prediction model forecasts (via the RUC model). CIRA researchers at GSD have been involved in all of these aspects of the TAMDAR assessment. An extension of the Great Lakes Fleet Experiment into FY06 allowed for further analysis of the impact of TAMDAR observations on RUC model forecasts. Examination of errors in temperature, relative humidity and winds for model runs with and without TAMDAR data show improvement (i.e., smaller errors) in these parameters for the TAMDAR-inclusive model runs for the Midwest United States.

Applications of Satellite Observations

- Completed the WMO/TD No. 1267 "Implementation Plan for Evolution of Space and Surface-based sub-systems of the GOS". The plan is part of an effort to improve the utilization and future development of satellite-based weather observations.

- Developed a hurricane/cyclone surface wind field estimate from a combined GOES imagery, microwave, and model assimilation. The development of the components of the satellite tropical cyclone wind algorithm is complete. Real-time analysis is on schedule for the operational centers and evolution.

- Code for generating the three-dimensional wind field for Polar Regions from temperature profiles derived from AMSU radiance has been completed.

- Conducted numerous impact studies in support of GOES-R NPOESS and specific sensor technologies on weather forecasting systems. This included a study of AMSR-E and AMSU hurricane measurements. AMSU cloudy radiance assimilation showed large positive impacts on upper level wind divergence. AMSR-E cloudy radiance improved lower level wind circulation.

- VIIRS proxy data is being collected from MODIS to develop new maximum intensity algorithms for hurricanes.

- Synthetic HES imagery has been produced in support of GOES-R risk reduction using AIRS data as a proxy.

- Demonstrated that significant NOAA MEM bias errors exist on the order of 5-10%.
  --Identified AMSU-B Antenna Pattern Correction errors. After correction, the result was a 10-15% improvement in bias error for upper-water vapor profiles.
  --The demonstration allowed NESDIS/ORA to request the operationalization of the MSPPS microwave emissivity products already developed.

- Several new products have been developed under the GIMPAP project including -- a new cloud-top temperature differencing product that measures increases in temperature above the tropopause likely due to water vapor absorption above the clouds. These rare increases are associated with severe thunderstorms.

--A new Oklahoma centered fire hotspot image loop using the 3.9 micron channel for wild fire detection was produced.
--Confirmed CIMSS detection of a thermal foldover of certain GOES pixels when detecting fires (sources>342 deg C)

Cloud Physics

- In our studies of Secondary organic aerosols (SOA) it has been determined that properties of aerosol populations (number concentrations, size distributions) and accuracy of the CCN instruments are most crucial for CCN closure, whereas detailed knowledge of the aerosol composition plays only a minor role.

- The role of smoke aerosol in modifying the microphysics and dynamics of cumulus cloud fields in biomass burning regions such as Brazil was investigated. We have identified two primary reasons for the absence of clouds in heavy smoke regimes. The first is related to absorption and local heating by biomass burning aerosol and its modification of atmospheric stability. The second is based on a dynamical feedback due to the absorbing aerosol, and follows from the fact that heavy aerosol cools the earth's surface by blocking incoming solar radiation. The reduction in net surface radiation results in a commensurate reduction in surface fluxes, which suppresses convection and cloud formation.

Numerical Modeling

- The ensemble work has demonstrated that the MLEF method is better during the first few days of a forecast period. Additionally it improves the 48-hour forecast more than the 6-hour demonstrating the benefit of ensembles in creating balanced initial conditions.

- A visible radiative transfer model and its adjoint have been developed. This new model is 5 times faster than the previously used DISORT model. This code has been transferred to JCSDA.

- 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). Refer to the www.wrfportal.org website for additional information.

- The journal article on "An hourly assimilation – forecast cycle: The RUC" by S. Benjamin, D. Devenyi, S. Weygandt, K. Brundage, J. Brown, G. Grell, D. Kim, B. Schwartz, T. Smirnova, T. L. Smith, *Mon. Wea. Rev.,* 132, 495-518 (Feb 2004) was recognized a 2005 OAR Outstanding Scientific Paper. 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 assimilation/model system ingests a wide variety of meteorological observations each hour (a frequency much higher than is generally done) and produces short-range (up to 12-h) gridded weather forecasts. Significance: RUC analyses and short-range forecasts (initialized from the analyses) are used extensively within the aviation and severe weather communities as well as by National Weather Service forecasters. As such, the RUC forecast system is a vital component of the NOAA mission to provide weather information to society and to support a safe and efficient transportation system.

- A time-phased, multi-model ensemble forecast system was successfully developed. This system has now been adopted by NOAA/OAR and applied to the OAR's hydrometeorological testbed (HMT) field experiment in the American River Basin of California. It has also been made as a forecast product on NOAA/GSD's AWIPS. Coupled with the Local Analysis and Prediction System, this time-phased, multi-model ensemble forecast system is very useful for short-range Quantitative Precipitation Forecast (QPF) and Probabilistic QPF (PQPF).

- The WRF model was used to conduct idealized simulation of interaction among upper-level jet, gravity waves, and turbulence. During the past year, a PV inversion package was successfully developed, and this PV inversion package was used to simulate an upper-level jet and generation of gravity waves associated with this jet.

Education, Training, and Outreach

- The NOAAPort data ingest system and AWIPS-linked components are now functional and will be used in the next year to make improvements in the AWIPS' current NWSFO minimal satellite data capabilities. Using standard AWIPS configurations to port technology into NWS operations will greatly improve their acceptance of CIRA's training topics.

- A SHyMet funded Satellite Meteorology and Applications course has been developed for NWS interns. CIRA developed three of the learning modules: Orientation, GOES Imaging and Sounding including area coverage, resolution, and frequency, Satellite Applications to Tropical Cyclones, and revisions to Cyclogenesis-Analysis utilizing satellite imagery,

- The VISIT program has awarded over 16,000 training certificates and has received very positive student feedback.

- GLOBE Systems team comprised of 8 CIRA researchers continued to provide website, database, and data acquisition support to the Program's worldwide users now located in 109 countries. There are now more than 15 million observations in the GLOBE database collected by students in over 18,000 schools since the Program's inception in 1995. Visit the GLOBE website at www.globe.gov.

- During the past year, a major release of the FX-Collaborate (FXC) Volcanic Ash Coordination Tool (VACT) software, version 2.30 was implemented and the new system provided support of volcanic eruptions for the Anchorage VAAC. The FXC VACT was used in operations during the eruptions of Mt. Augustine and for four other events along the Aleutian chain and the Kamchatka peninsula. Refer to http://www-ad.fsl.noaa.gov/asdad/projects/vact/ for additional information on the project.

- Research was completed on National Convective Weather Forecast (NCWF2) product integration into the AWIPS FXC Traffic Management Unit (TMU) 2.30 system and the TMU Website was upgraded to handle the NCWF2 Graphics used in Fort Worth. SID and STAR map backgrounds were created for the Dallas-Ft Worth airspace. The TCHP animation page was redesigned and the TMU home page was redesigned to fit the display. Version 2.2 of the TMU Website that contained the NCWF2 graphic products was released for evaluation.

- Science On a Sphere™ was installed at six new permanent public venues this past year—Nauticus National Maritime Museum in Norfolk, VA, Bishop Museum in Honolulu, HI, The Tech Museum in San Jose, CA, Science Museum of Minnesota in St. Paul, MN, NASA Goddard Space Center in Greenbelt, MD, and the Maryland Science Center in Baltimore, MD. A five-projector display architecture was implemented and demonstrated. This new projector arrangement reduces shadowing by viewers and eliminates Polar Regions where no data is displayed in our older four-projector arrangement. An enhanced software-based projector alignment method was developed, eliminating tedious mechanical projector alignment, while improving image registration. Finally, several new data visualizations were developed, along with enhancements to existing data sets.

- 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 most recent version of the fielded software and the latest version of Linux, Enterprise, v. 3.0. This new version of the FX-Net system was considered a major upgrade by the NWS regional offices in Western, Southern, Alaska and Pacific regions. New high-resolution forecast models and additional data sets were added to the system. Data added included the long range GFS model out to 380 hrs, the new high-resolution CONUS ETA model, RAWS data utilizing MADIS, and the planning process to add US Forest Service dispersion models was begun. 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.

- In support of AWIPS enhancement, several efforts and activities occurred during the past year including:
  --development of data access techniques for displaying Multi-sensor Precipitation Estimate (MPE) and NOAA/NESDIS sea surface temperature data
  --integration of the Graphical Forecast Editor (GFE)
  --evaluation of AWIPS workstation usage
  --investigation of new data delivery paradigm
  --investigation into using AWIPS to disseminate hazard event information

- The successful implementation of Valid Time Event Codes (VTEC) in warning and advisory products for severe weather and flooding continues to be one of the most important near-term goals of the NWS. During FY04/05, CIRA researchers helped the NWS successfully implement VTEC for severe convective warnings and some marine warnings. During FY05/06, CIRA researchers aided in the implementation of VTEC in many hydrologic (flood) warnings and advisories. Upgrading and maintaining the VTEC's capability within AWIPS continues to require substantial changes both to AWIPS warning generation software and the text workstation component of AWIPS.

- During the past year, the 3-year project to implement NWS MDL's SCAN on Korean Meteorological Administration's (KMA) Forecast Analysis Station (FAS) was successfully completed. Project completion was demonstrated by hosting 12 KMA weather forecasters to a training exercise at NOAA ESRL/GSD (formerly NOAA/FSL). Two full days of training were provided.

Societal and Economic Impacts

- Professor Cochrane has completed an econometric model that models weather-induced natural disasters and their economic impacts. The model also computes the inter-segment impacts of these disasters. This accounts for such things as a local economy actually being stimulated by post-disaster building activity, government sector activities, and many other cross-sector economic couplings.

- Conducted training workshops, focus groups, and developed new prototype designs for NWS's Central Region's hydrology warning web system. The improved interface design that is based on detailed customer interactions, and not just what IT can do, has received a NOAA Administrator's Award and is being actively considered by the Climate Services Division and the National Integrated Drought Information System (NIDIS) for their new information portal.

- For the first time NWS has incorporated US Census data into the development of its severe weather watches and warnings product development. Coupled with GIS data, the database will allow the emergency management community to know the demographic and socio-economic details of the areas under threat. This will allow for better evacuation, vulnerability, and threat assessments. This kind of information, for example, would have immediately shown that the Ninth Ward in New Orleans needed buses for evacuation since most did not have cars.

- Joint collaboration with the National Renewable Energy Laboratory (NREL) continued to support applications of the RUC model in wind energy planning. Effort is now concentrated in application of ensemble forecasting methods to produce probability distribution functions for potential wind energy production, detection of nocturnal low-level jet, and improved near-surface wind forecasts through variation in surface roughness.

- Seven air quality models were run to provide forecasts of surface ozone concentrations over the eastern U.S. and southern Canada. Accuracy of these forecasts was assessed against hourly ozone measurements at over 350 locations. The ensemble of these air quality models was used to issue deterministic and probabilistic forecasts of maximum daily 8-hr and 1-hr averaged ozone concentrations. The economic value of forecasts, which is calculated using Richardson's cost-loss decision model was evaluated for both deterministic and probabilistic cases. Results indicated that deterministic forecasts obtained with the ensemble of models provide a greater benefit to decision-makers than forecasts issued with individual models. Probabilistic forecasts demonstrated similar advantages over the deterministic forecasts.

- 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 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 forecasts as they have all atmospheric and chemical data integrated into one system.

- FX-Collaborate (FXC) is currently being implemented and/or evaluated for the *Geo-targeted Alerting System (GTAS)* sponsored by NOAA and the Department of Homeland Security. The objective of the project is to develop a prototype public notification system to be used by NOAA and the DHS operations centers in the event of a biological, chemical or radiological release in the National Capital Region. The key system components of the GTAS system are FXC and the HYSPLIT dispersion model. The concept is to use FXC as the technology for controlling the execution of the HYSPLIT model, collaborating between the offices, and for creating the alert information that is sent to the selected vendor for notifying the public. During the past year, the HYSPLIT model was installed on the FXC session controller and software developed to convert the output of the model into a format that is usable by FXC. The FXC code was modified to allow easy customization of the FXC user interface to generate the appropriate control parameters and to view the dispersion model output. Also, the format of the alert information message (XML) was defined and tested with two different vendors using secure https communications.

Infrastructure

- CIRA's satellite storage now exceeds 100TBytes. This includes all GOES/GVAR data, GMS, CloudSat, and parts of AVHRR and GMS.

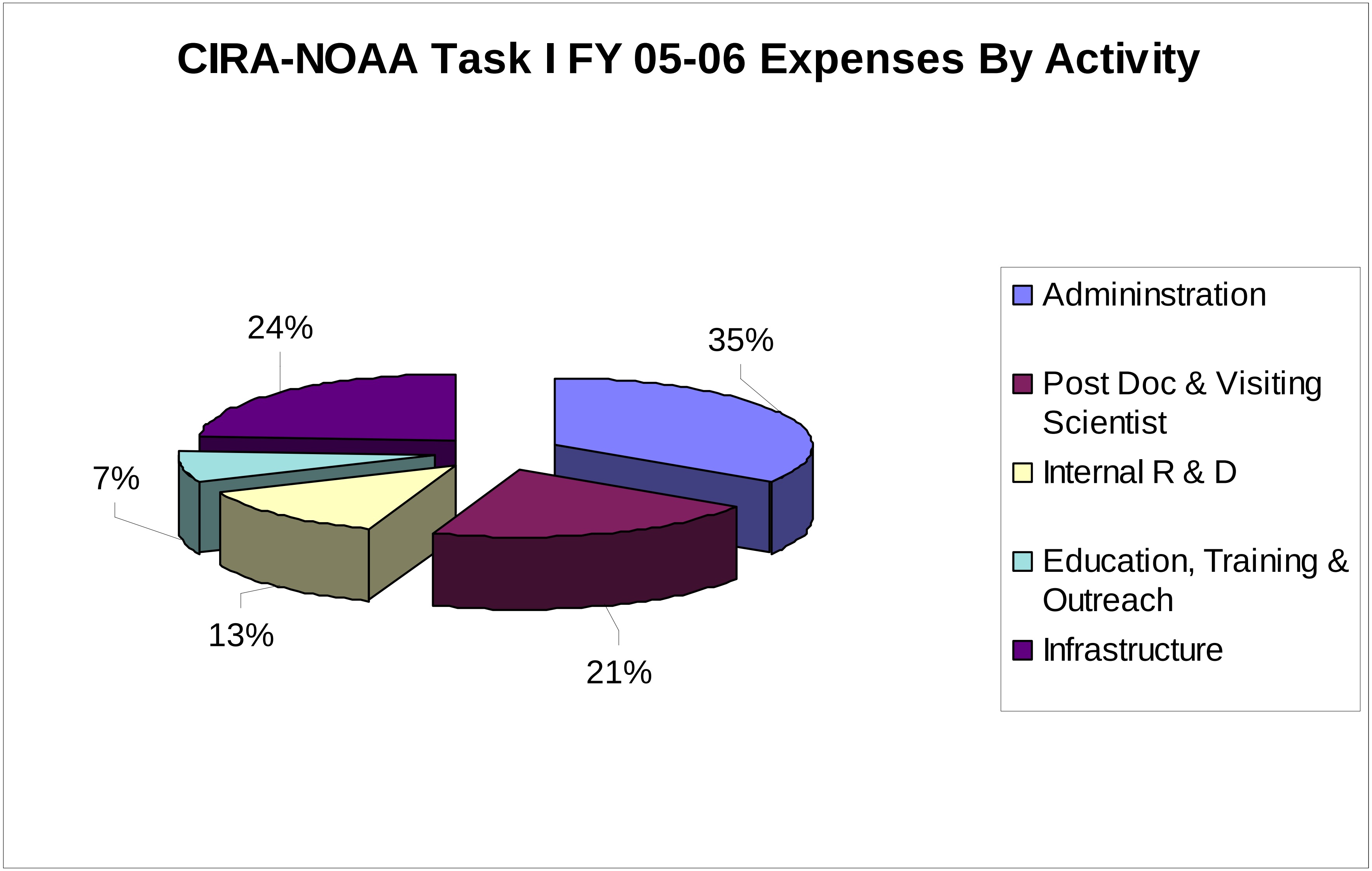
- We are nearing completion of the migration of our 8mm and DLT data to DVDs. We have also completed a major database indexing system that makes finding and exploring our holdings easier for the scientists.

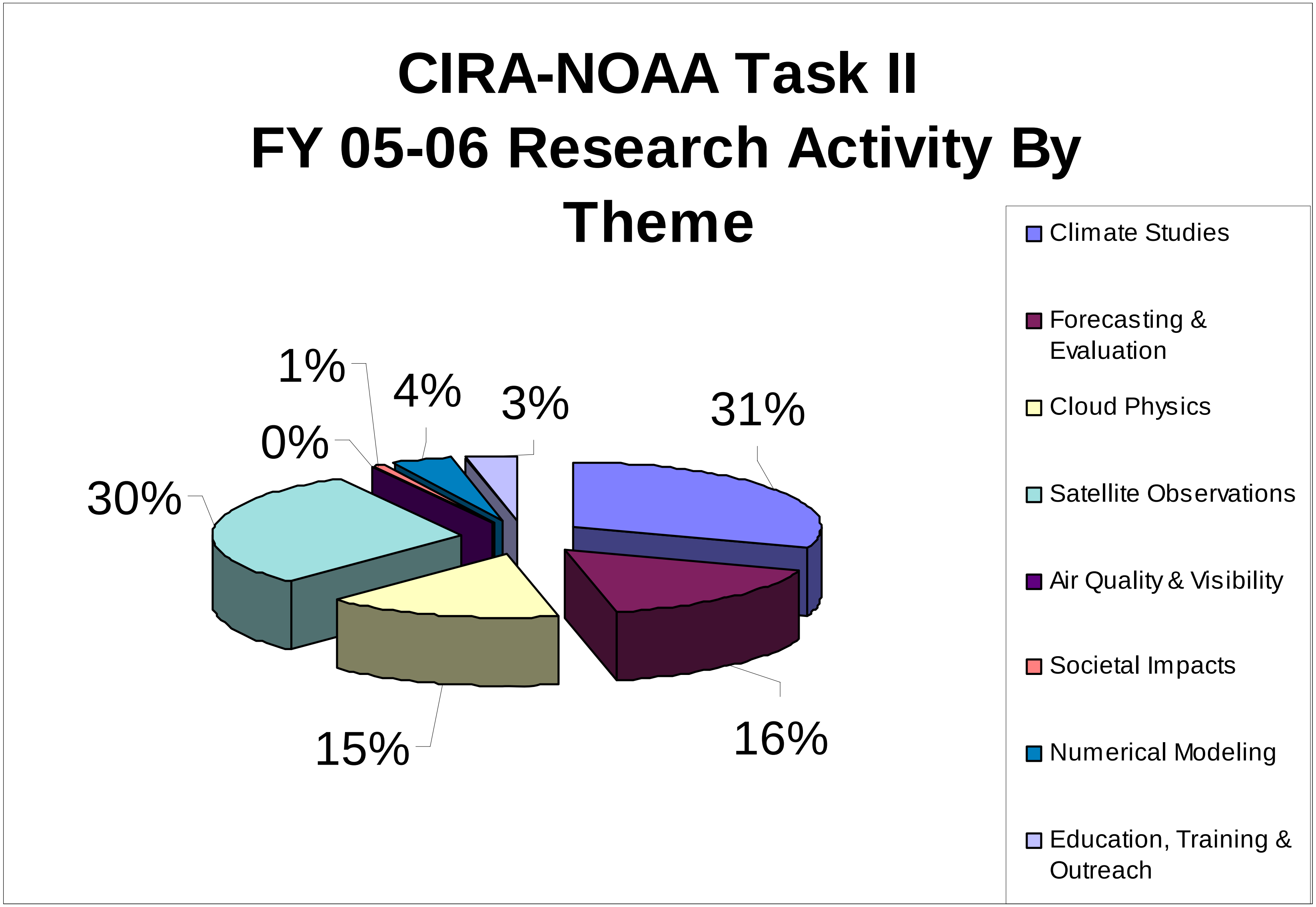
- The CloudSat Data Processing Center (DPC) is now fully functional with the launch of CloudSat on 28 April 2006. We were able to distribute the first light imagery in a mater of days after the launch.

- Our NOAAPort installation is complete.

- Successfully demonstrated DPEAS software within NESDIS/OSDPD on their PC network. This technology has maximized GRID technology in their offices with a savings of $600K and the creation of over $7M in benefits due to increased computer throughput.

- Our CIRA researchers in the Data Systems Group at GSD continued to collaborate with GSD scientists and developers to assemble and maintain a state-of-the-art meteorological data center. They continued their research into the design and development for new and modified datasets. Use of Object Data System (ODS) applications and methods continue to expand as legacy translators and product generation methods are replaced by new, more flexible techniques. Design and development continued toward creating an automated "archive search" system. This will facilitate the retrieval of data sets for use by researchers studying interesting weather events. Data acquired, decoded and processed by DSG have been vital to the success of projects and programs such as MADIS, RTVS, and FSL's X-window workstation (FX-Net). Additionally, data delivery systems developed for the programs such as DTC and RUC have also been vital to their success. Development of new metadata handling techniques is ongoing. This facilitates the use of real-time and archived data sets.


CIRA-NOAA Task I FY 05-06 Expenses By Activity
24%
35%
7%
13%
21%
Admininstration
Post Doc & Visiting Scientist
Internal R & D
Education, Training & Outreach
Infrastructure


CIRA-NOAA Task II
FY 05-06 Research Activity By Theme
1%
4%
3%
31%
0%
30%
15%
16%
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: 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 are developing 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 our research effort we have completed a preliminary version of the MicroMet model and published a paper summarizing its performance (see below).

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

All of our objectives are being met at the rates indicated in our original proposal. This is the second year of a three-year project, and the work is still "in progress". This includes both our model development and data assimilation efforts.

4. Leveraging/Payoff:

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

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

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

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

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., 2005: Characterizing local-scale Antarctic ice sheet processes within large-scale climate-system models. IPY Norwegian-US Antarctic Troll-South Pole Traverse Planning Meeting, May 8-10, Tromø, Norway.

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.

Liston, G. E., and K. Elder, 2004: A meteorological distribution system for high resolution terrestrial modeling (MicroMet). American Geophysical Union, Fall Meeting, December 13-17, San Francisco, California.

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.

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*, in press.

Liston, G. E., D. L. Birkenheuer, C. A. Hiemstra, D. Cline, and K. Elder, 2006: NASA Cold Land Processes Experiment (CLPX): Atmospheric analyses data sets. *J. Hydrometeorology*, in review.

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.

ADVANCED ENVIRONMENTAL SATELLITE RESEARCH SUPPORT

Principal Investigator: James F.W. Purdom

NOAA Project Goal: Weather and Climate

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

1. Long-term Research Objectives 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:

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

--WMO/TD No. 1267 "Implementation Plan for Evolution of Space and Surface-based Sub-systems of the GOS" adopted by WMO Commission on Basic Systems

--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

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

--Advisor to General Kelly, U.S. Permanent representative to World Meteorological Organization (WMO) at WMO Executive Council

--WMO Commission on Basic Systems Management Group

--GOES I/M Technical Advisory Committee

--GOES R Risk Reduction Technical Advisory Committee

--THORPEX International Implementation Team

8. Publications:

<u>Refereed Publications</u>

Chapter “Environmental Satellites” for Handbook on Weather, Water and Climate (this chapter was written at the request of the co-editors after they had received strong criticism in a review by Dr. Rick Anthes, President of UCAR, in the Bulletin of the American Meteorological Society (BAMS) for the omission of such a chapter. The chapter is to be placed in electronic version on the publisher's web site so that readers can view satellite imagery animations;

Internationally Invited Presentations with paper/presentation

Keynote address opening EUMETSAT User's Conference in Dubrovnik, "Polar and Geostationary Satellite System Synergy: Toward Optimum Utilization";

Lectures on "Mesoscale Convection" and "Hyperspectral/Multispectral Imagery" in Moscow, Russian Federation at SRC Planeta Third Joint Training Workshop. In lieu of paper, PowerPoint lectures with extensive imbedded notes provided to conveners.

Invited Presentations at workshops and conferences

Invited speaker and panelist at University of Wisconsin Space Science and Engineering Center (SSEC) Silver Anniversary, presented "Satellite Meteorology: Past, Present and Future"

Invited presentation to National Academy Panel reviewing "Earth Science and Applications from Space: A Community Assessment and Strategy for the Future," on the topic "Opportunities for International Partnerships in the Development of Future Space-based Global Observing Systems."

Invited presentation to International Winds Workshop in Beijing: "Satellite Derived Winds In The Severe Storm Environment: Now And In The Future"

Chaired and presented at SPIE Panel: "Three-Pillar Partnership in Remote Sensing: the Roles of Government, Industry, and Academia".

ADVANCED HYDROLOGIC PREDICTION SERVICE

Principal Investigator: Shripad D. Deo

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

Key Words: Social Science, Communication, Education

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

To infuse new understanding of science and technology to enhance the quality of water resources information,

To improve the understanding of how that information is used by diverse user groups served by NOAA's National Weather Service, and

To improve usability of information and make it socially robust by providing context in which information is developed and used.

The producers of 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.
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 explaining 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.

The comments and feedback from forecasters and users will enable us to refine or re-conceptualize these tools.

2. Research Accomplishments/Highlights:

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

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

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 six training workshops, ten focus groups, new prototype designs, and new operational information tools.

4. Leveraging/Payoff:

The work done with water resources information has provided a template for including a social science perspective 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 the interest of the National Integrated Drought Information System (nidis) in using similar approaches to develop this new information portal.

6. Awards /Honors:

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

7. Outreach: None as yet

8. Publications: None as yet

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 NOAAPORT data ingest system has been procured, installed, and is currently operational. Hardware and software for the AWIPS components of the project have also been procured and installed. The AWIPS components are functional, successfully ingesting and displaying data from the NOAAPORT receiver. Efforts are underway to test and verify the system before it is made available for researcher use.

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

The project is on schedule for its goal to have an operational NOAAPORT/AWIPS configuration at CIRA by fall 2006.

4. Leveraging/Payoff:

The current AWIPS configuration used in NWSFOs provides a minimal satellite data set and no advanced analysis capabilities. Improved forecaster training with advanced satellite data will provide better forecasts and better utilization of NOAA satellite data. In addition, CIRA hopes to beta test satellite capabilities of early AWIPS releases prior to release into the field.

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

This project leverages funds obtained from NWS to facilitate data ingest. Collaborators will include NWS, COMET, CIMSS, and FSL.

6. Awards/Honors: None as yet

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.

<u>Presentations</u>

D. Lindsey, August, 2005: Using satellite imagery to improve forecasts and nowcasts. *34th Conference on Broadcast Meteorology*, Washington, DC.

8. Publications: None as yet

AN EVALUATION OF ULTRASONIC SNOW DEPTH SENSORS FOR ESTIMATING 6- AND 24-HOUR SNOWFALL TOTALS

Principal Investigators: Roger A. Pielke, Sr. and Nolan J. Doesken

NOAA Project Goal: Climate; Climate Observations and Analysis

Key Words: Ultrasonic Sensors; Snowfall; Snow Depth; Campbell Scientific; Judd

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

In the 1990s the National Weather Service deployed automated surface observing systems at hundreds of airport locations across the country. Prior to the automation, human observers made snow observations every six hours. Once the automated systems were deployed, snow measurements ceased due to the lack of an automated sensor to measure snow. This project explored how well ultrasonic snow depth sensors compared to manual snow observations at nine sites across the country. This study had four objectives: 1.) Develop a method of quality assurance and quality control 2.) Identify factors which affect sensor performance 3.) Compare automated sensors to manual observations of snow depth 4.) Derive an algorithm to estimate sixhour snowfall from automated sensor snow depth. A reliable data smoothing/processing technique was achieved using filtering of large variability and smoothing with a moving average to smooth small variations in snow depth.

2. Research Accomplishments/Highlights:

Factors found to affect sensor performance included: snow crystal type, wind speed, blowing/drifting snow, uneven snow surface, extremely low temperatures, and intense snowfall. The Judd and Campbell sensors both did a satisfactory job measuring snow beneath the sensor within ±0.4 inches. Two separate algorithms were created due to differing degrees of precision between the two sensors. It was found that the Campbell sensor did a better job at estimating six hour snowfall than the Judd using an algorithm that calculated snowfall over 5 minute periods and applying a temperature based compaction model to the estimated snowfall. The Campbell agreed with the manual data with an average mean absolute error between measurements of 0.23 inches. The Judd sensor results improved by using an algorithm which calculated snowfall using the change in snow depth over sixty minutes; however, the Campbell results were better using the five minute snowfall algorithm. Overall, both sensors accurately depicted the snow depth on the ground; however the Campbell sensor was more accurate at predicting six hour snowfall using the algorithms presented in this research.

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

a) Develop a method of quality assurance and quality control – complete
After investigating different methods of data QA/QC, a reliable method was developed and worked favorably at all locations. The large amplitude variability was easily filtered and removed, and accounted for a very small amount of the data, 0.4% with the Judd

and 0.04% with the Campbell. The small amplitude variability was the most problematic characteristic of the snow sensor data because it affected snowfall estimation procedures and caused many "false alarms" in 6-hour snowfall totals. It was found that at most locations a one hour moving average smoothed the Campbell sufficiently to give reliable results with both depth comparisons as well as the five minute snowfall algorithm. The Judd sensor usually needed a three hour moving average in order to give reasonable estimates of six hour snowfall; however depth comparisons were accurate with both sensors using either moving average.

b) Identify factors which affect sensor performance -- complete
The main causes included: snow crystal type, presence of blowing/drifting snow, intense snowfall, wind speeds in excess of 15 mph, uneven snow surfaces and extreme cold temperatures (colder than -10º F for the Judd). Most of these factors can be substantially alleviated with proper siting and regular maintenance of the site and sensors.

c) Compare automated sensors to manual observations of snow depth – complete
Both sensors measured the depth of snow beneath them with reasonable accuracy and reliability. On average both sensors measured within ±0.4 inches, with some larger problems due to siting, blowing snow, drifting, melting, etc. In order to achieve an accurate measurement of snow depth, proper siting is most important. Both sensors tended to underestimate the total snow depth measurement taken at each site's historical snow measurement location. This was due to the point-nature of sensor measurement, and spatial variability of snow depth due to blowing, drifting, differential settling, melting, etc.

d) Derive an algorithm to estimate six hour snowfall from automated sensor snow depth– in progress
Two algorithms were created to test how well the sensors could estimate six hour snowfall. The five minute snowfall algorithm worked best with the Campbell. The extra small amplitude variability seen in the Judd sensor usually caused overestimation of the six hour snowfall and did not accurately represent the manual data pattern. The Judd sensor did provide more accurate results when the 60 minute snowfall algorithm was used. The 60 minute snowfall algorithm removed more of the small amplitude variability in the Judd and provided more accurate estimates of the manual data. However, the results for the 60 minute snowfall algorithm were not always in favor of one sensor over the other and the results differed by site. There were no climate trends found which explained the degree of smoothing or sensor which gave more accurate results for the snowfall algorithms. There may be climate factors that exist, however the differences in site setup seem to have more of an effect on the degree of smoothing needed at each site. Continuing work on the algorithm is needed, and a combination of siting, signal processing and integrating other meteorological parameters (temperature, wind, etc.) may be needed to improve snowfall estimation.

4. Leveraging/Payoff:

Snow impacts society and economic activity in the U.S., and reliable, long-term snow observations are surprisingly limited. This project provides an affordable solution for the very near future to collect snow data needed by the country at the growing number of automated weather measurement sites. This could improve NWS credibility for snowfall monitoring, mapping and dissemination as well as forecasting and verification. This study also suggests that properly installed and sited snow depth sensors could be included in other observing networks.

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

This project has been carried out in partnership with the USDA NRCS which has provided instrumentation on loan to assist in this effort. Our research findings and papers are posted on our research website at http://ccc.atmos.colostate.edu to provide prompt and broad dissemination of the current snow research.

6. Awards/Honors: None at this time

7. Outreach:

(a.) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree): Wendy Brazenec, M.S. degree in Natural Resources, Fall 2005 and continued on project as non-student hourly to complete draft of refereed journal article.

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

30th Annual Meeting of National Weather Association, 15-20 October 2005, Saint Louis, MO.

10th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 30 Jan – 2 Feb, Atlanta, GA.

(c) Fellowship programs;

None

(d) K-12 outreach;

Instrumentation and data are being shared with K-12 students and educators via visits and field trips to several of the test facilities where comparative data have been collected.

(e) Public awareness.

NWS offices are collaborating on this project and have had many opportunities to share their enthusiasm for this new way to measure snow. The Grand Rapids, MI NWS office has publicized this new observing system and is providing real-time snow depth sensors on their NWS website.

8. Publications:

Brazenec, W.A., 2005: Evaluation of ultrasonic snow depth sensors for automated surface observing systems (ASOS). Dept of Forest, Rangeland, and Watershed Stewardship, M.S. Thesis, Colorado State University, Fort Collins, CO, (N. Doesken, Committee member), Fall 2005, 134 pp.

Brazenec, W.A., N. J. Doesken and S. R. Fassnacht, 2006: Ultrasonic snow depth sensors for measuring snow in the U.S. 10th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 30 Jan – 2 Feb, Atlanta, GA, Paper 4.4.

Doesken, N.J., W. Brazenec, S. Fassnacht, 2005: Ultrasonic Snow Depth Sensors - Can they help us measure snow? 30th Annual Meeting of National Weather Association, 15-20 October 2005, Saint Louis, MO, paper P2.9.

Ryan, W.A., N.J. Doesken, and S.R. Fassnachet, 2006: Evaluation of ultrasonic snow depth sensors for automated surface observing systems (ASOS). AMS Journal of Technology, in progress.

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:

a) 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.

b) Create a merged, quality-controlled reflectivity product from all available radars (SMN and S-Pol) that can 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.

c) 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.

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

e) 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:

a) Version 1 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 accepted for publication in the *Journal of Climate*.

b) We have completed processing of Version 2 of the NAME radar composites, and will release them to the NAME community in July 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.

c) We are examining selected high-resolution satellite rainfall estimates using the field campaign precipitation observations from NAME. This study, when completed, will form a major contribution to the Pilot Evaluation of High Resolution Precipitation Products (PEHRPP), which is sponsored by the International Precipitation Working Group. Preliminary 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. We will be investigating this further with analysis of ground-based (S-Pol) and satellite (TRMM precipitation radar) products over the region.

d) We are using lightning data 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. Preliminary 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.
--The association among these moisture buildups, which are on the synoptic time scale, gulf surges, which are on mesoscale time scales, and mesoscale convective systems, are a topic for future study.

e) Using the NAME radar composites, 15-minute, 60-minute, and 24-hour rainfall accumulations were computed at each grid point. These totals were binned into 5-mm increments, as well as divided into three elevation groups: 0-1000m, 1000-2000m, and 2000-3000m. Plots of the cumulative distribution functions for each time interval were created, similar to those created using the NERN data. From the 24-hour results, the majority of the rainfall totals for the highest elevation group are on the lower end, with 70% of the totals less than 10mm/24hr and greater than 99% of the totals being less than 50mm/24hr. The lower elevation groups have higher fractions of larger rainfall amounts in comparison to the areas above 2000m with almost 5% of the accumulations greater than 50mm/24hr. These findings are qualitatively similar to those from the NERN data in that the larger accumulations are more restricted to the lower elevations. Also similar to their findings, the 15-minute and 60-minute totals reveal distributions with the highest elevations having the greatest fraction of low accumulations, although the separation between elevation bands is not nearly as large in comparison to the 24-hour totals.

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

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

a) Complete - Data quality control and radar intercomparisons are complete for Version 2 of the data, which will be distributed to the NAME community shortly. No further QC work is planned.

b) In Progress – Version 2 merged radar composites are now available. For Version 3, we will seek to merge the radar-based rainfall estimates with rain gauge measurements during the same time period. This will provide a high-quality rainfall product, with better spatial resolution and larger areal coverage than either network could provide on its own. Version 3 will become available at the termination of this grant in 2007.

c) In Progress – We currently are publishing a journal article on the initial findings of these analyses. The Ph.D. student on this grant is continuing this work.

d) In Progress – The M.S. student on this grant is continuing this work.

e) In Progress – Analysis of the lightning and environmental data taken during NAME continues.

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:

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

Lang, T. J., D. A. Ahijevych, S. W. Nesbitt, R. E. Carbone, S. A. Rutledge. And R. Cifelli, 2006: Radar-observed characteristics of precipitating systems during NAME 2004. *Journal of Climate*, In Press.

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

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

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

Nesbitt, S. W., 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., 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.

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: Surface and Satellite Measurements of Arctic Environment

Project has just started. Nothing to report for this year.

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:

None, project just started.

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

None, project just started.

4. Leveraging/Payoff:

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

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

None, project just started.

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, which is directly related to the Algorihtm Working Group effort.

7. Outreach:

None, project just started.

8. Publications:

None, project just started

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

Principal Investigator: John 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 Acheieve 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 had three parts.

To use a 12-year climatology of tropical cyclone heat potential (TCHP) developed at the NOAA Atlantic Oceanographic and Atmospheric Laboratory (AOML) to ascertain the likely impact of this information to tropical cyclone forecasts. This is accomplished by utilizing these data within the framework of the Statistical Typhoon Intensity Prediction Scheme (STIPS) that is used by JTWC in operations. This involved the development of a special version of the STIPS model that made use of predictors created from the TCHP. From the developmental dataset created during model development, a potential impact was estimated. The TCHP version of STIPS has also been running in parallel to the operational version of STIPs to assess the impact of TCHP on real-time tropical cyclone forecasts in the western North Pacific.

The second task was to use the operational version of the Statistical Hurricane Prediction Scheme to assess the impact of Ocean Heat Content on operational hurricane forecasts in the Atlantic Basin.

The third task was to evaluate the impact of ocean heat content in a 2-D coupled hurricane model developed at MIT. This portion of the work is to be performed at MIT.

2. Research Accomplishments/Highlights:

The STIPS intensity model that was run during 2005 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 the dependent sample when TCHP is added as a predictor.

AOML set up a system to run their THCP analysis system in real time, and the method was developed in cooperation with NRLMRY to deliver the products for real-time testing of the parallel version of the STIPS model. CIRA delivered the parallel version of the STIPS model, which was implemented at NRLMRY in real time. The intensity forecasts from the real-time runs of the parallel STIPS model are output in the standard Automated Tropical Cyclone Forecast (ATCF) system. This real-time runs began in late September of 2005 with West Pacific Typhoon number 17.

The parallel version of the JTWC operational STIPS model with THCP input is being run in real time. The impact of the THCP data will be evaluated when a large enough sample is available for a meaningful statistical evaluation. The parallel version will continue to run during the 2006 season, which should provide this sample.

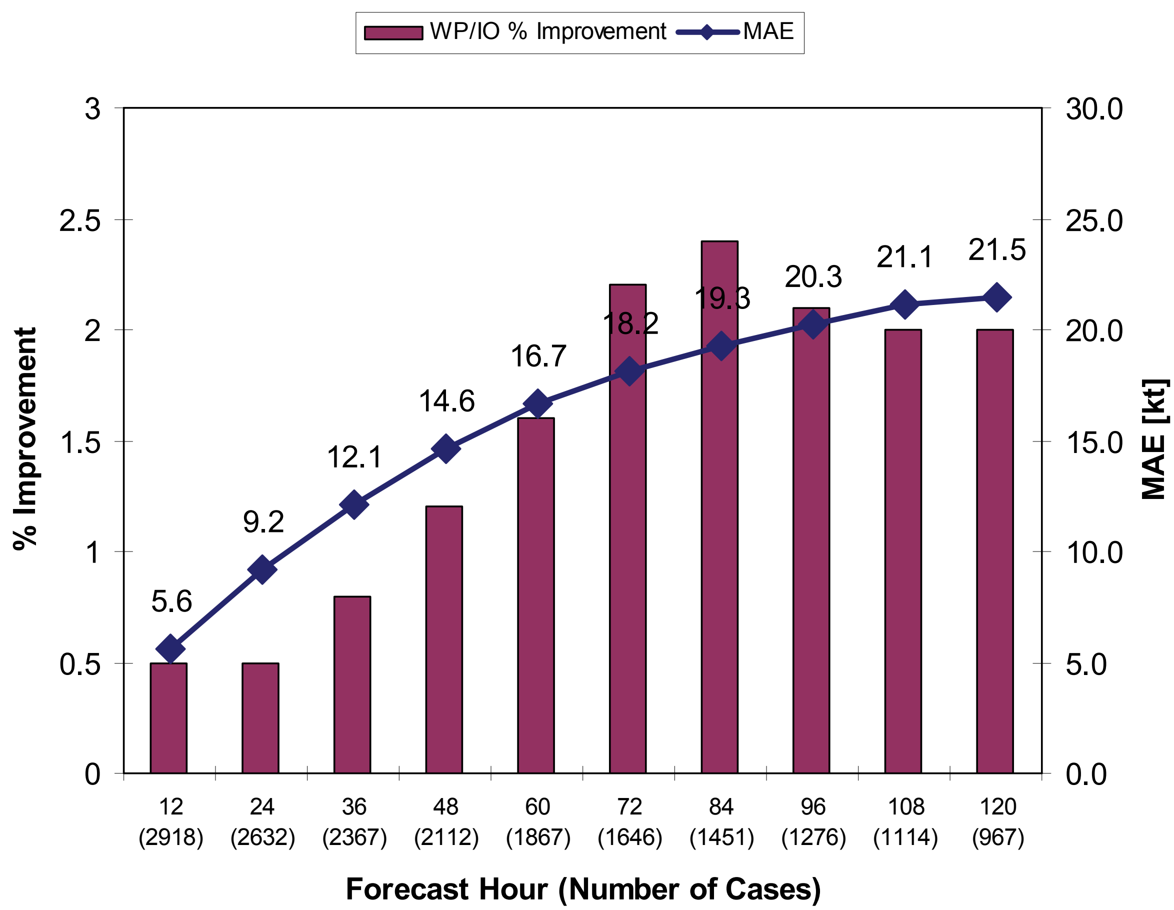


Figure 1. The percent improvement in the dependent version of the STIPS model at each forecast interval (purple bars) when TCHP is added as a predictor. The sample size is shown along the bottom of the diagram and the blue line indicates the mean absolute intensity error of the dependent sample (kt).

An evaluation of the 1995-2004 sample indicated that the TCHP reduces the SHIPS intensity forecasts by only about 1%. However, a further analysis showed that this predictor only influences a small percentage of forecasts where the TCHP is more than one standard deviation above the mean basin value. In these cases, the influence is much higher. To further investigate this sensitivity, the impact of the TCHP on the operational SHIPS forecasts of all the category 5 hurricanes (Isabel 2003, Ivan 2004, Katrina, Rita, Wilma 2005) since the NCEP/TPC product was implemented in 2002 was evaluated. To isolate the effects of the TCHP, only the over-water part of the forecasts were evaluated, and the version of SHIPS that does not include land effects was verified.

Figure 2 shows the percent improvement of the SHIPS forecasts for these five storms. The errors at all time intervals were reduced for 4 of the 5 storms. The average improvement for all storms was up to 6%, and the improvements at 72-120 h were statistically significant at the 95% level. For individual storms, the improvement was up to about 20%. These results show that even though the TCHP has only a minor impact on the total sample of Atlantic storms, it can have a much greater impact on those in the regions with very high TCHP values. These results appear in a manuscript that will soon be submitted to an AMS Journal (either Weather and Forecasting or BAMS).

A simple 2-D coupled ocean atmosphere model developed by Kerry Emanuel at MIT is also being used to evaluate the sensitivity of hurricane intensity forecasts to the upper ocean structure. The funds for that part of the project finally arrived at MIT, and a student has been identified to work on that study.

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

All tasks except the evaluation of the real-time impact of TCHP on STIPS performance and the sensitivity studies using a coupled 2-D hurricane model have been accomplished. This STIPS evaluation will be completed once a large enough sample exists for a comprehensive evaluation, which should occur at the end of the 2006 Typhoon season. The 2-D modeling work has started now that a student has been identified to do the work and the funding has arived at MIT.

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

6. Awards/Honors: None as yet

7. Outreach:

(a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); This Project is funding a graduate student at MIT via a subcontract

(b) Seminars, symposiums, classes, educational programs; See section 8

8. Publications:

Refereed Journal Articles

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, Submitted.

Conference Proceedings

DeMaria, M., 2006: Application of Oceanic Heat Content Estimation to Operational Forecasting of Recent Atlantic Category 5 Hurricanes. *AGU Ocean Sciences Meeting.* 20-23 February, Honolulu, HI.

Presentations

Application of Ocean Heat Content to Operational Forecasting during the 2004 and 2005 Hurricane Seasons by Ms. Michelle Mainelli (TPC/NHC), Dr. Mark DeMaria (NESDIS), presenting, et. al., 60th Interdepartmental Hurricane Conference, Mobile, AL, 22 March 2006.

ATMOSPHERIC CO2 INVERSION INTERCOMPARISON PROJECT (TRANSCOM3)

Principal Investigator: Scott Denning

NOAA Project Goal: Climate

Key Words: Carbon cycle, greenhouse gases, inverse modeling

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

--Dissemination of TransCom results via peer-reviewed literature and through web
--Provision of all TransCom code and model output via web to broader community

2. Research Accomplishments/Highlights:

We have completed the TransCom website, incorporating the new interannual inversion results. This includes both the results from individual models and the various data files that would allow interested investigators to reproduce the control estimates. We have further provided code and data that would allow interested investigators to perform independent inversion work.

We have further updated the website to reflect recent results from a TransCom meeting in Paris. This includes all the PowerPoint presentations, agenda, progress reporting, and future issues.

The website has now been ported to Purdue University, where Kevin Gurney has taken a faculty position

We have continued to publish results and analysis, including 5 major articles since the original grant terminated (see below), and have organized a number of follow-on activities at the international level.

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

We have completed the objective on including all interannual results and supporting materials.

Our ongoing support of workshops results is in progress.

We have completed the reorganization of the ftp server to provide researchers with all the model output, input files, code, and manuals for global scale inverse modeling.

We've accomplished both major objectives, in spades.

4. Leveraging/Payoff:

The maintenance of the database and website for the TransCom experiment continues to provide researchers with all the ingredients needed to perform global scale inversions with a full suite of model transport realizations. The aim of much of this work is the characterization of carbon sources and sinks which is a critical component of accurate projections of climate change over the coming decades. The importance of such projections to public policy and decision making is recognized by a large community..

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

--North American Carbon Program (interagency program involving contributions of 9 US agencies)
--Ocean Carbon and Climate Change (OCCC)
--CarboEurope
--CarboOceans

6. Awards/Honors:

7. Outreach:

Continuing leadership in inverse modeling through annual workshops and coordinated experiments.

8. Publications:

Baker, D. F., R. M. Law, K. R. Gurney, P. Rayner, P. Peylin, A. S. Denning, Bousquet, L. Bruhwiler, Y.-H. Chen, P. Ciais, I. Y. Fung, M. Heimann, J. John, T. Maki, S. Maksyutov, K. Masarie, M. Prather, B. Pak, S. Taguchi, and Z. Zhu, 2005. TransCom 3 inversion intercomparison: Impact of transport model errors on the interannual variability of regional CO2 fluxes, 1988–2003. Global Biogeochem. Cycles, 20, GB1002, 10.1029/2004GB002439.

Gurney, K.R., R.M. Law, A.S. Denning, P.J. Rayner, B. Pak, and the TransCom 3 L2 modelers, “Transcom 3 Inversion Intercomparison: Control results for the estimation of seasonal carbon sources and sinks,” Global Biogeochemical Cycles,18, GB1010, doi:10.1029/2003GB002111, 2004.

Gurney, K.R. “Towards robust regional estimates of carbon sources and sinks using atmospheric transport models - the TransCom 3 Experiment,” World Resource Review, 16 (2), 243-258, 2004.

Gurney, K.R., Y.H.Chen, T. Maki, S.R. Kawa, A. Andrews, Z. Zhu, “Sensitivity of Atmospheric CO2 Inversion to Potential Biases in Fossil Fuel Emissions,” J. Geophys. Res. 110 (D10), 10308, 2005.

Patra, P. K., K. R. Gurney, A. S. Denning, S. Maksyutov, T. Nakazawa, and TransCom Modelers. 2006, Sensitivity of inverse estimation of annual mean CO2 sources and sinks to ocean-only sites versus all-sites observational networks, Geophys. Res. Lett., 33, L05814, doi:10.1029/2005GL025403.

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

Principal Investigator: Tom Vonder Haar

NOAA Project Goal: Weather and Water

Key Words: GOES, Imager, Sounder, Product Development

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

In early 1994, NOAA introduced a new geostationary satellite series, GOES-I/M. Recognizing the need to ensure 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 ensure integration of the results into NESDIS operations.

The GIMPAP program at CIRA will help ensure that 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 will be received both directly for analysis using CIRA unique software and processing systems as well as over Internet. Two basic type products validation activities will be 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 will be 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 Branch 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

Tropical Cyclones

Characteristics of Atlantic Intense Hurricanes, 1995-2005: Final changes are underway following internal review on a paper by Zehr and Knaff. Additional computations have been completed with the seven 2005 Atlantic intense hurricanes. For example, Hurricane Wilma’s intensification rate (FigureA.1.1) of 97 hPa/day in terms of 24-h change of minimum sea-level pressure using Best Track data, stands out dramatically in comparison with other 1995-2004 Atlantic intense hurricanes. (R. Zehr)

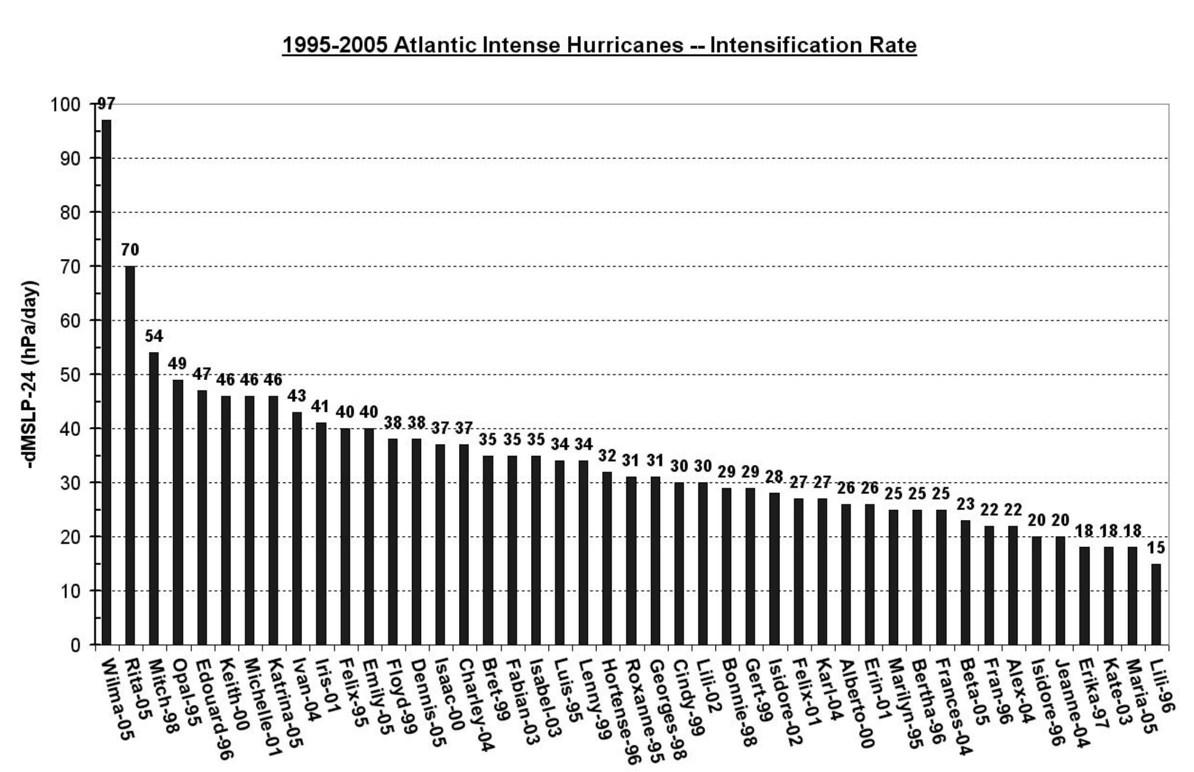


Figure A.1.1: Greatest 24-h decrease of minimum sea-level pressure with each of the 45 Atlantic intense hurricanes since 1995.

Severe Weather/Mesoscale

Another experimental product is now available on RAMSDIS Online. This product uses the 3.9 μm albedo along with solar geometry information to obtain ice cloud effective radius from a series of lookup tables. These lookup tables were created by performing more than 1000 model runs with an observational operator. Smaller values of effective radius are generally associated with higher-based thunderstorms with relatively strong updrafts. In Figure A.2.1, note how the storms in Oklahoma have smaller effective radii than the cirrus clouds further north in Kansas. (D. Lindsey, D. Hillger, L. Grasso)

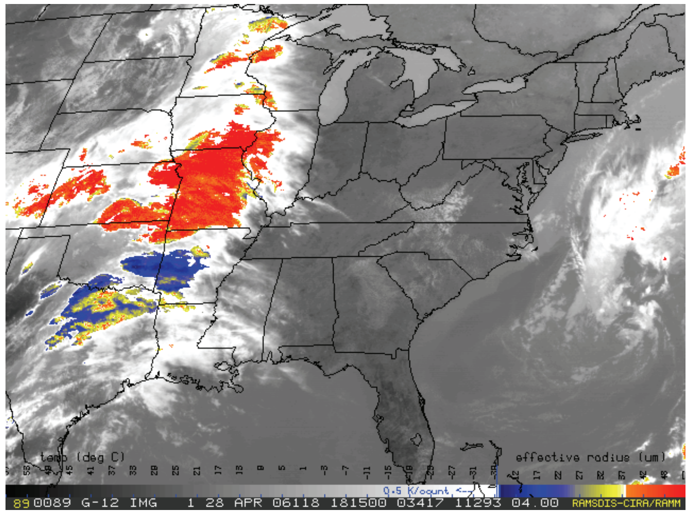


Figure A.2.1: GOES-12 ice cloud effective radius from 28 April 2006. Colors correspond to effective radii of cloud tops colder than -40ºC.

Winter Weather/Mid-latitude applications

A new cloud-top image product is being generated using real-time GOES imagery and displayed on RAMSDIS at CIRA. The product is the temperature difference between the GOES band-4 (10.7 µm) and band-3 (6.7 µm) images. Negative temperature differences are rare, but are found on the tops of thunderstorms, and are associated with the increase in temperature above the tropopause. The difference is likely due to water vapor absorption above the cloud tops, as was found by model simulations of the two GOES bands that are used in this product. In Figure A.3.1, a color table is used to indicate negative temperature differences, possibly associated with the most severe thunderstorms. This product will continue to be studied during daily satellite/weather discussions at CIRA. (D. Hillger, L. Grasso, D. Lindsey)

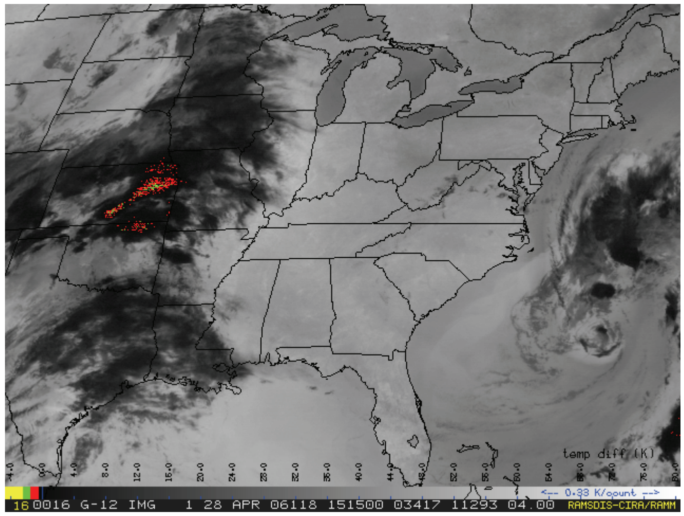


Figure A.3.1: An example of the temperature difference between the GOES infrared window band-4 (10.7 μm) and the water vapor band-3 (6.7 μm). Colors are used to emphasize negative temperature differences seen on cloud tops. Each color change represents a 1 K change in the temperature difference: red = -1 K, green = -2 K, and yellow = -3 K or more.

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

<u>National Weather Service (NWS) request for support for Oklahoma Fires:</u> In response to a request from the NWS Southern Region headquarters and the Norman, OK NWSFO, a GOES-12 full-resolution 3.9 μm loop covering Oklahoma was added to RAMSDIS Online. This product shows the hot spots associated with wildfires. See Figure A.4.1 for a sample image showing three fires in Northern Texas. This request was to provide Internet access to the GOES channel 2 data for use by responders in the field. (D. Watson)

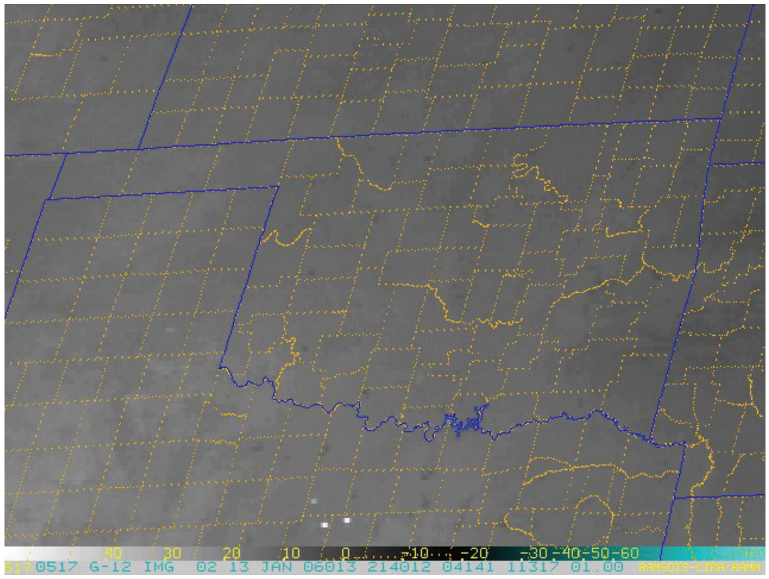


Figure A.4.1: Sample image showing three fires in Northern Texas.

Cloud Climatologies

Work on the new cloud climatology project with Eureka, CA continues. Data processing for the Eureka sector for July 1999-2005 is complete and August 1999-2005 nearly complete. Three time series of cloud composites (low, high and all) have been derived from the 10 µm channel for July 1999-2005. Examples from the results have been shared with the Eureka, CA National Weather Service (NWS) office (Figures A.5.1 and A.5.2). (C. Combs)

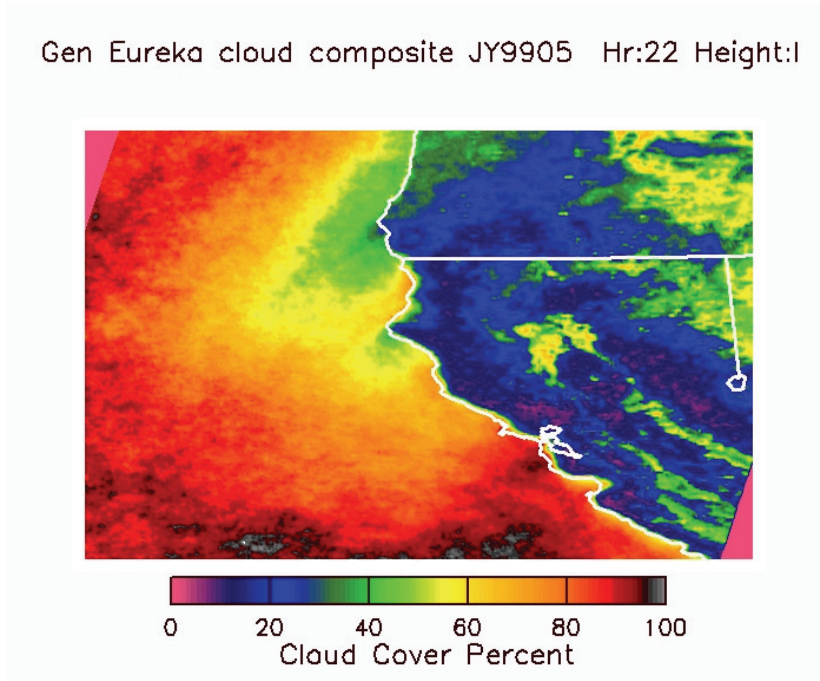


Figure A.5.1: Low cloud composite for July 1999-2005 for 2200 UTC (3 pm local)

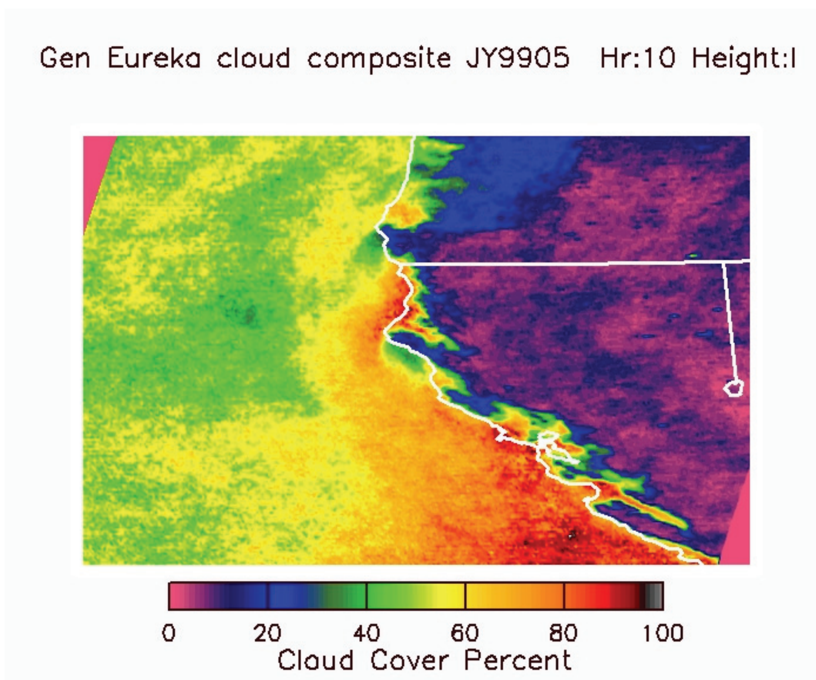


Figure A.5.2: Low cloud composite for July 1999-2005 for 1000 UTC (3 am local)

B. Calibration/Validation

UW/CIMSS/ASPB asked for help to confirm or deny a problem with GOES-12 band-2 (3.9 μm) hot pixels associated with range fires in Texas and Oklahoma. The problem, noticed for at least 7 pixels in one image, was that the hottest pixels appear cold when the GVAR counts reach maximum values, associated with temperatures over 342 K. (Figure B.1) CIRA confirmed that the values for those pixels were folded over to low counts, whereas they should have been at the top end of the scaled radiances. After getting our feedback, CIMSS forwarded the details of the problem to Satellite Operations. (D. Hillger; S. Kidder)

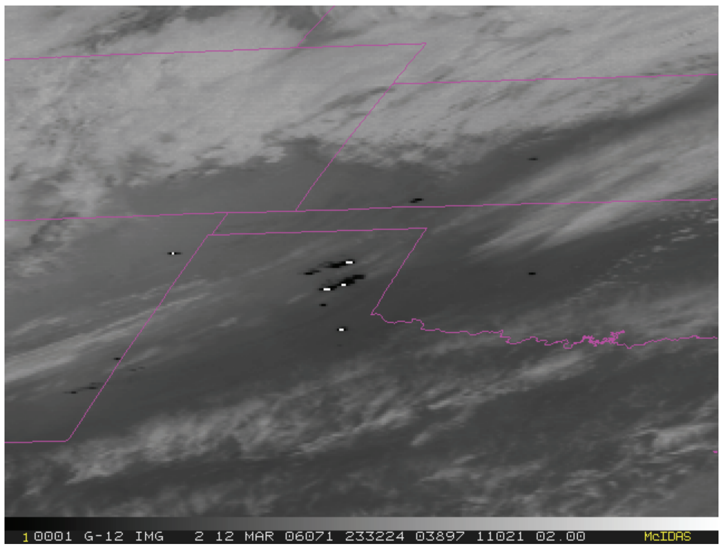


Figure B.1: GOES-12 band-2 (3.9 μm) image for 12 March 2006 at 2332 UTC, centered over the Texas Panhandle, showing hot spots that appear cold.

C. Training

GOES-12 imagery for March 2006 through May 2006 were processed for the Regional Meteorological Training Centers (RMTCs) in Costa Rica and Barbados. The archives are being used to study 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 1997-2006 by 10.7 μm temperature threshold technique for Costa Rica are presented in Figure C.1. (B. Connell)

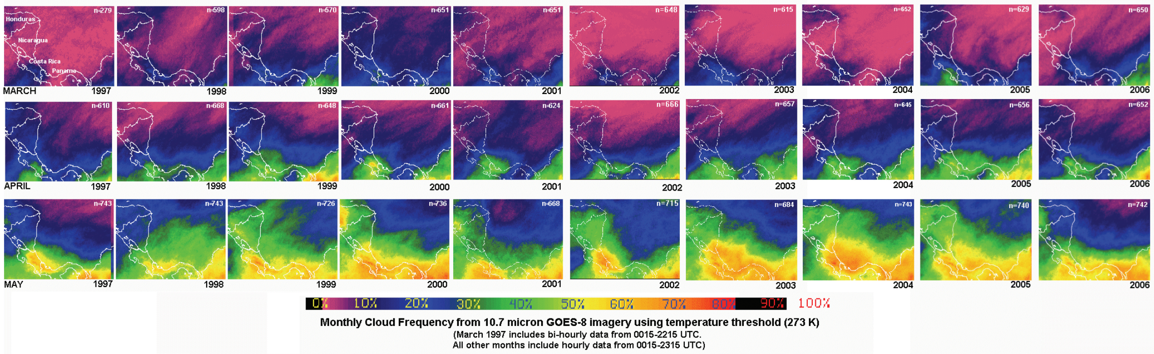


Figure C.1: Monthly cloud frequency composites for March through May 1997-2006 by 10.7 µm temperature threshold technique for Costa Rica.

GOES-12 imagery for December 2005 through February 2006 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 December 1996-2005, January and February 1997-2006 by 10.7 µm temperature threshold technique for Costa Rica are presented in Figure C.2.

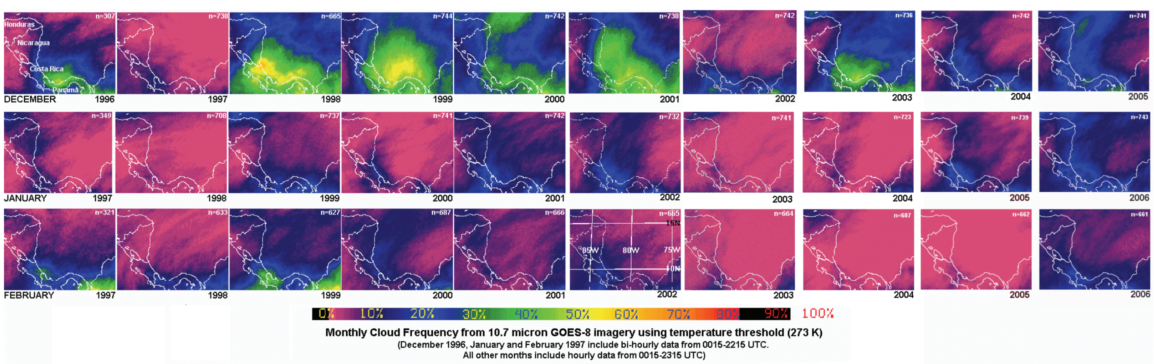


Figure C.2: Monthly cloud frequency composites for December 1996-2005, January and February 1997-2006 by 10.7 µm temperature threshold technique for Costa Rica.

A comparison of cloud frequency derived by temperature threshold of 10.7 µm imagery for December 1998-2005, January and February 1999-2006 for Barbados is shown in Figure C.3.

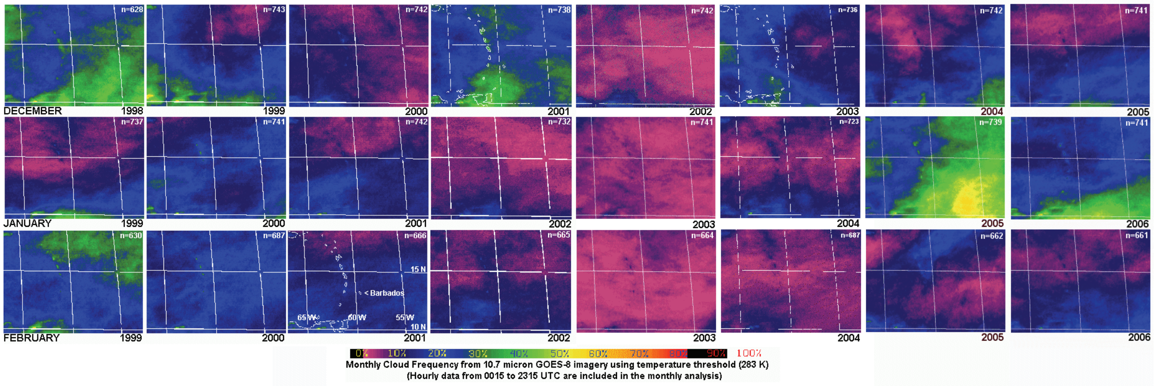


Figure C.3: Comparison of cloud frequency derived by temperature threshold of 10.7 µm imagery for December 1998-2005, January and February 1999-2006 for Barbados.

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

Most of the objectives for 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/Collaborators, Communications and Networking:

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

6. Awards/Honors:

Don Hillger gave an hour-long presentation to the *22nd Rocky Mountain Chinese Society of Science and Engineering (RMCSSE) Annual Conference* held in Aurora/Denver CO on 17 July. The presentation consisted of general NOAA/NESDIS slides, slides related to weather satellite history, and slides on GOES-R Risk Reduction activities. The presentation was very well received by about 70 attendees, and Dr. Hillger was awarded a plaque in recognition of his “outstanding” presentation.

7. Outreach:

(a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); Kate Maclay is an M.S. student in the CSU Department of Atmospheric Science and is supported by this project. An undergraduate student (Daniel Coleman) at Colorado State University is helping with the GOES data processing.

(b) Seminars, symposiums, classes, educational programs; See Section 8

(e) Public awareness; Real-time GOES data and products are made available online improve public awareness of the utility of GOES data

8. Publications:

<u>Refereed Journal Articles</u>

Bikos, D.E., J.F. Weaver, and J. Braun, 2006: The Role of GOES Satellite Imagery in Tracking Low-Level Moisture. *Wea. Forecasting*, **21**, 232-241.

DeMaria, M., M. Mainelli, L.K. Shay, J.A. Knaff , J. Kaplan, 2005: Further Improvement to the Statistical Hurricane Intensity Prediction Scheme (SHIPS). Wea. and Forecasting, **20**:4, 531–543.

Ferraro, R.R., Pellegrino, M.Turk, Chen, Qui, R.J., R.J. Kuligowski, S.J. Kusselson, Irving, S.Q. Kidder, J.A. Knaff, 2005: The Tropical Rainfall Potential (TRaP) Technique. Part 2: Validation. *Wea. and Forecasting,* **20**:4, 465-475.

Hillger, D., S.Q. Kidder, 2005: A simple GOES skin temperature product. *National Weather Digest,* **29:**4, (December), 25-31.

Kidder, S.Q., S.J. Kusselson, J.A. Knaff, R.R. Ferraro, R.J. Kuligowski, M. Turk, 2005: The Tropical Rainfall Potential (TRaP) Technique. Part 1: Description and Examples. *Wea. and Forecasting*, **20**:4, 456-464.

<u>Conference Proceedings</u>

Connell, B.H., and F. Prata, 2006: Detecting volcanic ash and blowing dust using GOES, MODIS, and AIRS imagery. *AMS 14th Conference on Satellite Meteorology and Oceanography, 29 January-3 February, Atlanta, GA.*

Cram, T., J.A. Knaff, and M. DeMaria, 2006: Objective Identification of Annular Hurricanes Using GOES and Reanalysis Data. *AMS 27th Conference on Hurricanes and Tropical Meteorology.* 24-28 April, Monterey, CA.

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. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA, 5 pp.

DeMaria, M., 2006: Statistical Tropical Cyclone Intensity Forecast Improvements Using GOES and Aircraft Reconnaissance Data. *AMS 27th Conference on Hurricanes and Tropical Meteorology.* 24-28 April, Monterey, CA.

Grasso, L.D., and D.T. Lindsey, 2006: Analysis of a hook echo and RFD from a simulated supercell on 8 May 2003. *AMS Symposium on the Challenges of Severe Convective Storms.* 29 January-3 February, Atlanta, GA.

Hillger, D.W., T. Schmit, D.T. Lindsey, J.A. Knaff, and J. Daniels, 2006: An Overview of GOES-N Science Test. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

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

Lindsey, D.T., 2006: A Climatological Study of Ice Cloud Reflectivity over the Continental US. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Maclay, K., 2006: Tropical Cyclone Inner Core Energetics and Its Relation to Storm Structural Changes. *AMS 27th Conference on Hurricanes and Tropical Meteorology.* 24-28 April, Monterey, CA.

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. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA. 6 pp.

Zehr, R.M., 2006: Atlantic Tropical Cyclogenesis - Satellite Analysis. *AMS 27th Conference on Hurricanes and Tropical Meteorology.* 24-28 April, Monterey, CA.

Newsletters

Fryer, M.K., and M. DeMaria, 2006: Daily weather discussions at CIRA, *CIRA Magazine,* 25, Spring, 4.

Presentations

D. Lindsey, January, 2006: 3.9 µm reflectivity work described in the *Monthly Weather Review.* StAR Seminar, Washington, DC.

M. DeMaria, October 16, 2005: Satellite wind algorithms developed by RAMMB. GOES-R Algorithm Working Group Meeting, VA.

M. DeMaria, October, 2005: Theory of equatorial waves. AT601 class (Atmospheric Dynamics) in the Department of Atmospheric Science at Colorado State University, Fort Collins, CO.

D. Lindsey, August, 2005: Using satellite imagery to improve forecasts and nowcasts. *34th Conference on Broadcast Meteorology*, Washington, DC.

D. Hillger, July, 2005: An overview/summary of CIRA calibration/validation activities. *CoRP Second Annual Science Symposium on Satellite Calibration and Validation,* Madison, WI.

CIRA RESEARCH COLLABORATION WITH THE NOAA NATIONAL GEOPHYSICAL DATA CENTER (NGDC) FOR SUPPORT OF THE NATIONAL GEODETIC SURVEY CORS PROJECT

Principal Investigator: Rob Prentice

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

Key Words: GPS Continuously Operating Reference Stations

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

The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, coordinates two networks of Continuously Operating Reference Stations (CORS): the National CORS network and the Cooperative CORS network. Each CORS site provides Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories. The CORS system enables positioning accuracies that approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically. Experimental forecast models for the space and terrestrial environment also use CORS data.

The National Geophysical Data Center (NGDC) is responsible for supporting continuing operations (COOP) of the CORS network in the event that the primary NGS site (in Silver Spring, MD) is brought down for any reason. In addition, NGDC supplies CORS data in a near real-time manner to NOAA's Space Environment Center and the Earth System Research Lab/Global Systems Division (ESRL/GSD) for use in ionospheric and weather model forecast models. These responsibilities, along with a rapid rise in the number of supported CORS sites has led to the need for several steps to be taken to design, develop, and implement an enhanced and more robust system for providing accurate CORS data.

Objectives include:

Development of quality control techniques that simplify the process of finding and correcting anomalies in CORS data holdings.

The transition of CORS data acquisition from numerous site-specific scripts to a database-driven acquisition method that is capable of acquiring data from all sites and raising appropriate alerts in the event that data from any site becomes unavailable.

Automation of the CORS archival process at NGDC and the creation of monitoring and reporting processes that are capable of notifying personnel of significant events related to data acquisition and reporting relevant statistics regarding archival holdings.

Specific tasks include:

Development of quality control techniques to better manage the CORS data holdings.

Design, development, and implementation of state-of-the-art automated GPS data ingest, quality control, and archival system.

Development of optimum online tools to make CORS data available to the public.

Development of experimental, near real-time models of the ionospheric and tropospheric environment.

Evaluation of the tropospheric and ionospheric experimental model outputs for integration in spatial data systems.

2. Research Accomplishments/Highlights:

Development of quality control tools for NGS to use in managing their GPS data holdings was completed. A high-level design of an automated archival system for CORS GPS data was also completed.

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

The first objective to develop quality control techniques to better manage CORS data holdings was completed. Significant progress was made on the second objective, but it was determined that a redesign of the existing software was necessary for production stability. A new design was created, but an automated data ingest, quality control, and archival system was not yet implemented at the time CIRA funding for the project ran out.

4. Leveraging/Payoff: None as yet

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

None as yet

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

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:

<u>Climate sensitivity experiment</u>

An 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

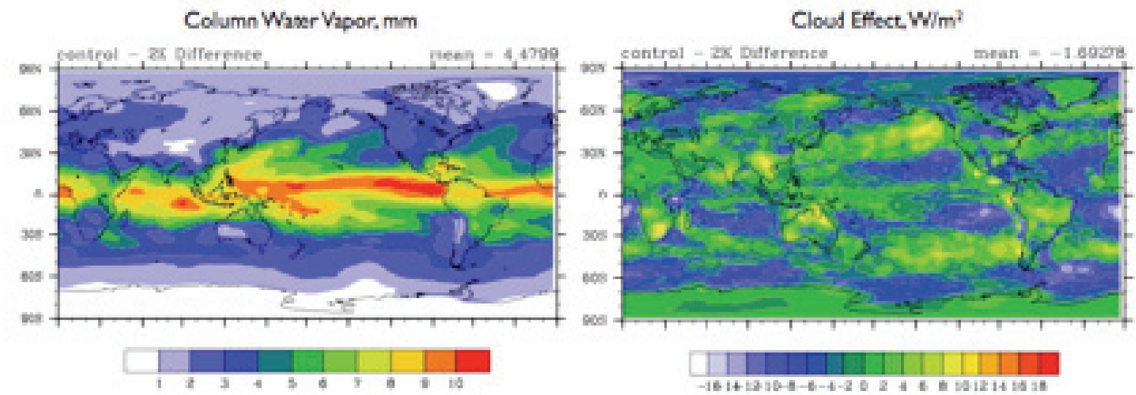


Figure 1. Perturbation of annual mean column water vapor (mm; left) and cloud effect (W m^{-2}; right), as simulated by the CSU MMF in response to a uniform SST increase of 2 K.

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 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.

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 and hence penetrate deeper as demonstrated by the joint probability distribution function of cloud size and several in-cloud variables (Fig. 2). The

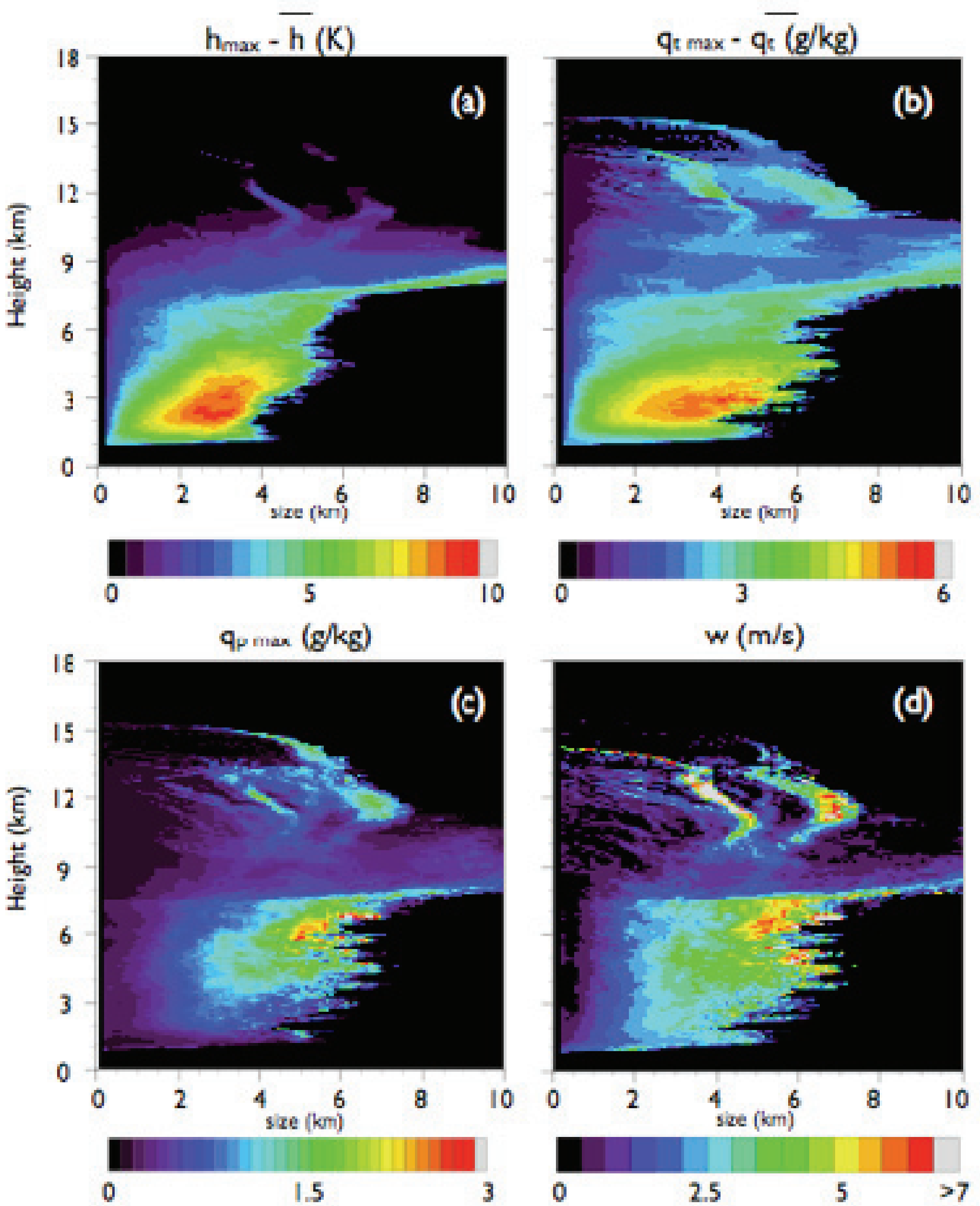


Figure 2. Joint PDF of cloud size and several in-cloud characteristics: maximum deviation from the mean of (a) moist static energy and (b) total water content; (c) precipitating water content; and (d) vertical velocity.

results suggest that there is close coupling between the boundary layer processes and convection which should be incorporated into improved parameterizations.

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.

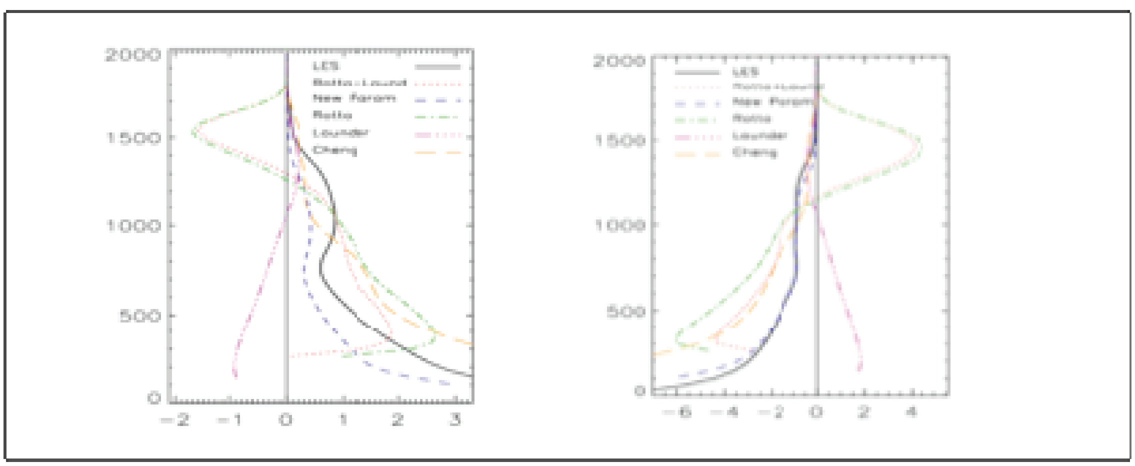


Figure 3: Comparison of the simulated pressure terms in the uu (left) and ww (right) equations for a fully-developed clear convective boundary layer

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).

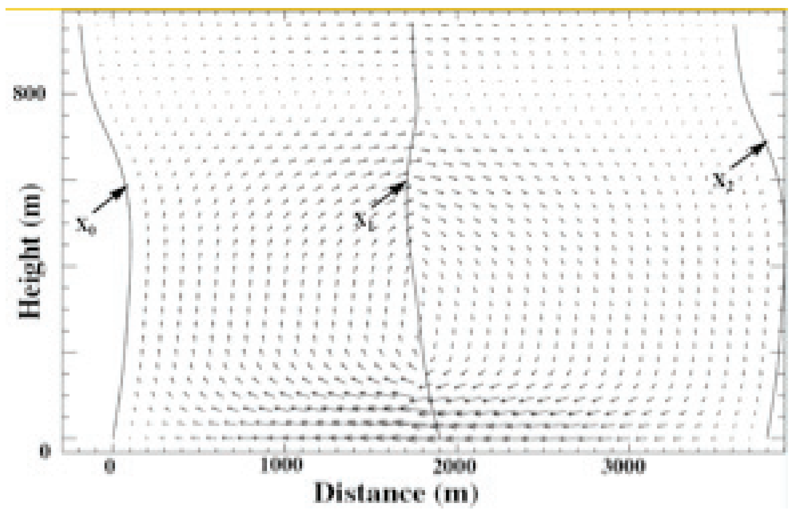


Figure 4: A sheared roll that is 100% parameterized by ADHOC2

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).

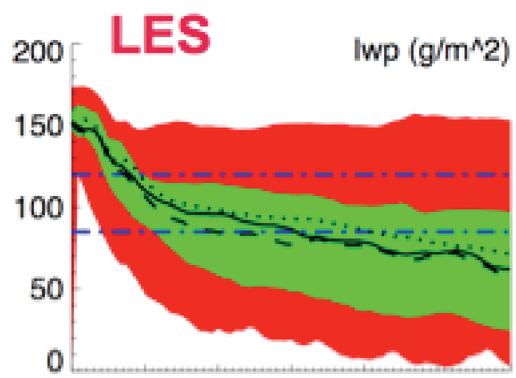
For the cloudy cases, the results showed that more unified schemes (ADHOC, Golaz) seemed to better handle getting LWP and entrainment correct at the same time, something that has been difficult for PBL models in general. For the Sc-topped PBLs, all schemes aggressively tried to decouple, whether or not 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



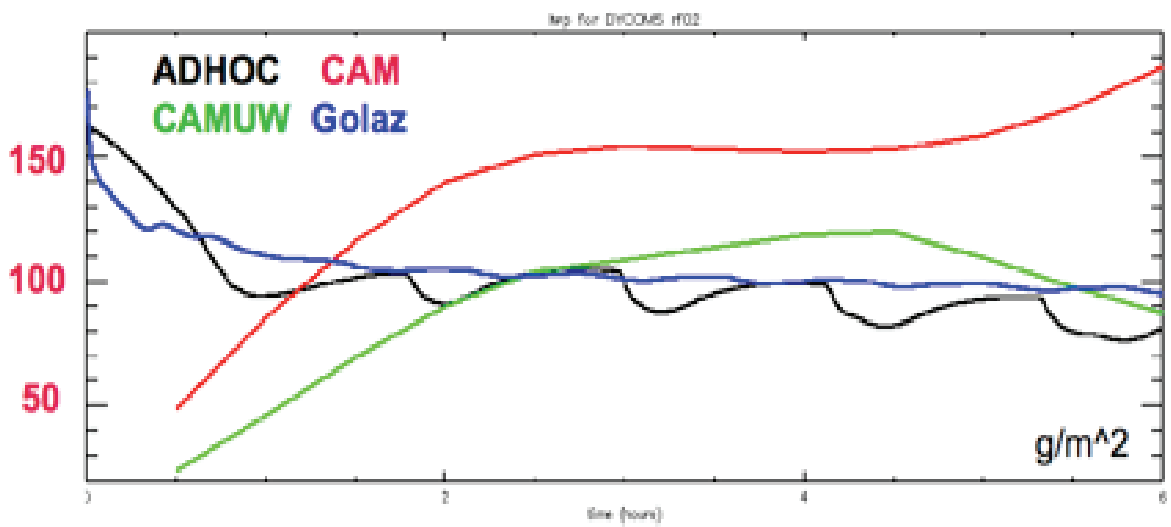


Figure 5: Comparison of the integrated LWP simulated by LES models (top-green) and observed (top-black line) with that simulated by models tested in CAM3 (lower panel).

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

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.

5. Research Linkages/Partnerships/Collaborators:

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.

CONTINUED DEVELOPMENT OF TROPICAL CYCLONE WIND PROBABILITY PRODUCTS

Principal Investigator: J.A. Knaff

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 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 the 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 the use of 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 project specifically funds 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:

During the first year of this project several tasks have been completed. These include:

Feedback on training sessions offered by TPC on the probablity product.

Updated error statistics.

A webpage of probabilities associated with landfalling Atlantic hurricanes in 2004 and 2005 at http://rammb.cira.colostate.edu/projects/tc_wind_prob.

Work has begun on the verification package.

A preliminary verification of the probabilities at coastal breakpoints was conducted and is described below.

An evaluation of the probabilities associated with hurricane warnings from the 2004 and 2005 seasons was conducted. Table 1 lists all the storms that had a warning issued for at least one time period. The probability program was adapted so that it provides probabilities directly at the same set of coastal breakpoints that are used to issue warnings. This set includes 195 points along the U.S. coastline from Brownsville, Texas to Eastport, Maine. The distance between these points is fairly irregular with spacing ranging from about 5 to 50 nmi. To provide more even coverage, the official breakpoints were supplemented by additional coastal points, so that the difference between points is no more than 15 nmi. The final set includes 342 coastal points. The MC model runs at the supplemented breakpoint set for all 14 storms in Table 1 were completed.

Table 1. Atlantic Storms with at Least One Hurricane Warning

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

A program to match the points with a hurricane warning with the probability output has also been developed. Results show that for all the coastal points for which a warning was issued for these 14 storms, the average 5-day cumulative probability was 28%. This is consistent with previous analysis of the warning regions which suggests that when a warning is issued there is actually only about a 1 in 4 chance of the point experiencing hurricane winds. This data will be further analyzed to determine the distribution of probabilities and the values at the end points of the warning areas. This work may lead to a new application of the MC probability program, which would provide objective guidance for issuing hurricane watches and warnings.

The 14 storm cases in Table 1 are also being used as a test dataset for the development of the verification program. There were 375 times when a warning was issued or hurricane winds were observed along the coast for at least one breakpoint for these 14 storms, which provides 128250 points (375 x 342) for development of the verification program.

Three methods were proposed for evaluating the probabilities, including a bias check, a Brier Skill Score, and a Relative Operating Characteristic (ROC) skill score. The results suggest that the wind probability product is skillful as measured by the Briar Skill Score and the ROC skill score and a bit biased toward underestimating wind probabilities. Closer examination of the biases show that Hurricane Wilma with the unanticipated growth of its wind field accounted for almost all of the biases.

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

This project is on schedule. The verification code is the final remaining task and will build off of the verification of warning break points. It should be noted that funding was late and the project did not start on schedule.

4. Leveraging/Payoff:

This project has a direct connection with the public interest. Coastal evacuations and other preparations for tropical cyclones are extremely expensive. The 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 within NOAA and the university community, including the NOAA/NESDIS Office of Research and Applications, the NOAA/NCEP TPC, the NOAA/OAR Hurricane Research Division, Colorado State University and the Unversity of Miami.

6. Awards/Honors: None as yet

7. Outreach:

(b) Seminars, symposiums, classes, educational programs; See Section 8

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

(e) Public awareness; 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:

Conference Proceedings

Knaff, J.A., and M. DeMaria, 2006: Continued Development of Tropical Cyclone Wind Probability Products: A Joint Hurricane Testbed Project Update. *60th Interdepartmental Hurricane Conference*. 20-23 March, Mobile, AL.

Presentations

DeMaria, M., June 2006: An update on CIRA Joint Hurricane Testbed projects, Tropical Prediction Center, Miami, FL.

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

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

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

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

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

Warm season precipitation in North America and its variability is strongly influenced by the North American Monsoon System (NAMS). Two hypotheses exist to explain NAMS variability: 1) remote sea surface temperature (SST) forcing, and 2) local surface influence. NAMS onset is influenced by time-evolving Pacific SST teleconnection patterns related to the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), as shown by Castro et al. (2006a,b). Presumably, local surface influences of snow cover, soil moisture, and vegetation become more important as the summer proceeds. The role of soil moisture, particularly in the central U.S., has been investigated using both GCMs and RCMs. More unknown is the possible role of vegetation on NAMS variability. NAMS-focused RCM investigations have thus far been limited to diagnostic or sensitivity studies. To systematically test each hypothesis of NAMS variability in an 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 an 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). An 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 an 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:

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://blue.atmos.colostate.edu/ to provide prompt and broad dissemination of our current research. Both Dr. Castro and Dr. Beltrán will present research results at the First CPPA Meeting at Tucson, AZ, in August 2006 and Dr. Castro participated in the Monsoon Region Climate Applications Binational Workshop in Guaymas, Sonora, Mexico, May 8-11, 2006.

6. Awards/Honors: None as yet

Christopher Castro successfully defended his Dissertation on June 22, 2005 and the Ph.D. was conferred Fall Semester 2005. Dr. Castro has accepted a professorship at the University of Arizona in Tucson and has 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

Castro, C.L., and R.A. Pielke Sr., 2004: Diagnosing the Climatology and Interannual Variability of the North American Monsoon Using the Regional Atmospheric Modeling System (RAMS): An Update. *GAPP Principal Investigators Meeting*, Boulder, Colorado, 30-31 August 2004.
http://blue.atmos.colostate.edu/presentations/PPT-25.pdf

Castro, C.L., and R.A. Pielke Sr., 2004: Diagnosing the Climatology and Interannual Variability of North American Summer Climate with the Regional Atmospheric Modeling System (RAMS). *NOAA Climate Diagnostics and Prediction Workshop*, Madison, Wisconsin, 18-22 October 2004. http://blue.atmos.colostate.edu/presentations/PPT-26.pdf

Castro, C.L., and R.A. Pielke Sr., 2004: Dynamical Downscaling: Assessment of Value Retained and Added Using the Regional Atmospheric Modeling System (RAMS). AGU Fall Meeting, San Francisco, CA, December 13-17, 2004.
http://blue.atmos.colostate.edu/presentations/PPT-31.pdf

Castro, C.L., R.A. Pielke Sr., and J. Adegoke, 2006: Investigation of the Summer Climate of North America: A Study with a Regional Atmospheric Model (Investigación del Clima del Verano en Norteamérica: Un Estudio con un Modelo Atmosférico). Monsoon Region Climate Applications: a Binational Workshop. Instituto Tecnológico de Sonora (ITSON), Guaymas, Sonora, Mexico, May 8-11, 2006.
http://blue.atmos.colostate.edu/presentations/PPT-63.pdf

Castro, C.L., A. 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. First Climate Prediction Program for the Americas (CPPA) PIs Meeting, 14-16 August 2006, Tucson, Arizona.

8. Publications:

Castro, C.L., Ph.D. Dissertation, 2005: Investigation of the Summer Climate of North America: A Regional Atmospheric Modeling Study. Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523.
http://blue.atmos.colostate.edu/publications/pdf/castrophd.pdf

Castro, C.L., R.A. Pielke, Sr., and G. Leoncini, 2005: Dynamical Downscaling: Assessment of Value Retained and Added Using the Regional Atmospheric Modeling System (RAMS). J. Geophys. Res. - Atmospheres, 110, No. D5, D05108, doi:10.1029/2004JD004721.
http://blue.atmos.colostate.edu/publications/pdf/R-276.pdf

Castro, C.L., R.A. Pielke Sr., and J. Adegoke, 2006a: Investigation of the summer climate of the contiguous U.S. and Mexico using the Regional Atmospheric Modeling System (RAMS). Part A: Model climatology (1950-2002). J. Climate, submitted.
http://blue.atmos.colostate.edu/publications/pdf/R-306.pdf

Castro, C.L., R.A. Pielke Sr., J. Adegoke, S.D. Schubert, and P.J. Pegion, 2006b: Investigation of the summer climate of the contiguous U.S. and Mexico using the Regional Atmospheric Modeling System (RAMS). Part B: Model climate variability. J. Climate, revised.
http://blue.atmos.colostate.edu/publications/pdf/R-307.pdf

Castro, C.L., A. Beltrán-Przekurat and R.A. Pielke Sr., 2006c: Statistical characterization of the spatiotemporal variability of soil moisture and vegetation in North America for Regional Climate Model applications. First Climate Prediction Program for the Americas (CPPA) PIs Meeting, 14-16 August 2006, Tucson, Arizona.

Chase, T.N., R.A. Pielke Sr., and C. Castro, 2003: Are present day climate simulations accurate enough for reliable regional downscaling? Water Resources Update, 124, 26-34. http://blue.atmos.colostate.edu/publications/pdf/R-275.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:

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 means 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:

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 the first objective.

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 the first and fifth objectives.

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:

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

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., 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.

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:

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

b) Using a combination of model analyses, GOES water vapor imagery, and historical tropical cyclone formation datasets and algorithms 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.

c) The long term research objectives are to aid in the improvement 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:

a) The development of the AMSU algorithm is completed. The global version of the algorithm for estimating tropical cyclone maximum winds and wind structure was developed and implemented at NCEP Central Operations (NCO). The fully operational version began in June of 2006, and is now supplied to tropical prediction forecast centers including the National Hurricane Center in Miami, the Joint Typhoon Warning Center (JTWC) in Honolulu, and the NESDIS Satellite Analysis Branch in Camp Springs. The operational tropical cyclone intensity and structure estimates for global storms are available from ftp://ftpprd.ncep.noaa.gov/pub/data1/amsu/ .

b) The tropical cyclone formation parameter for the Atlantic and eastern North Pacific was successfully transitioned to NESDIS operations. The fully operational version of the product is available at http://www.ssd.noaa.gov/PS/TROP/genesis.html .

This project is continuing by generalizing the formation parameter to the western North Pacific. In coordination with JTWC, the product will be developed in five sub-regions, as shown in Fig. 1. These regions are based on the experience of JTWC forecasters and the types of tropical cyclone genesis that typically occur in that region.

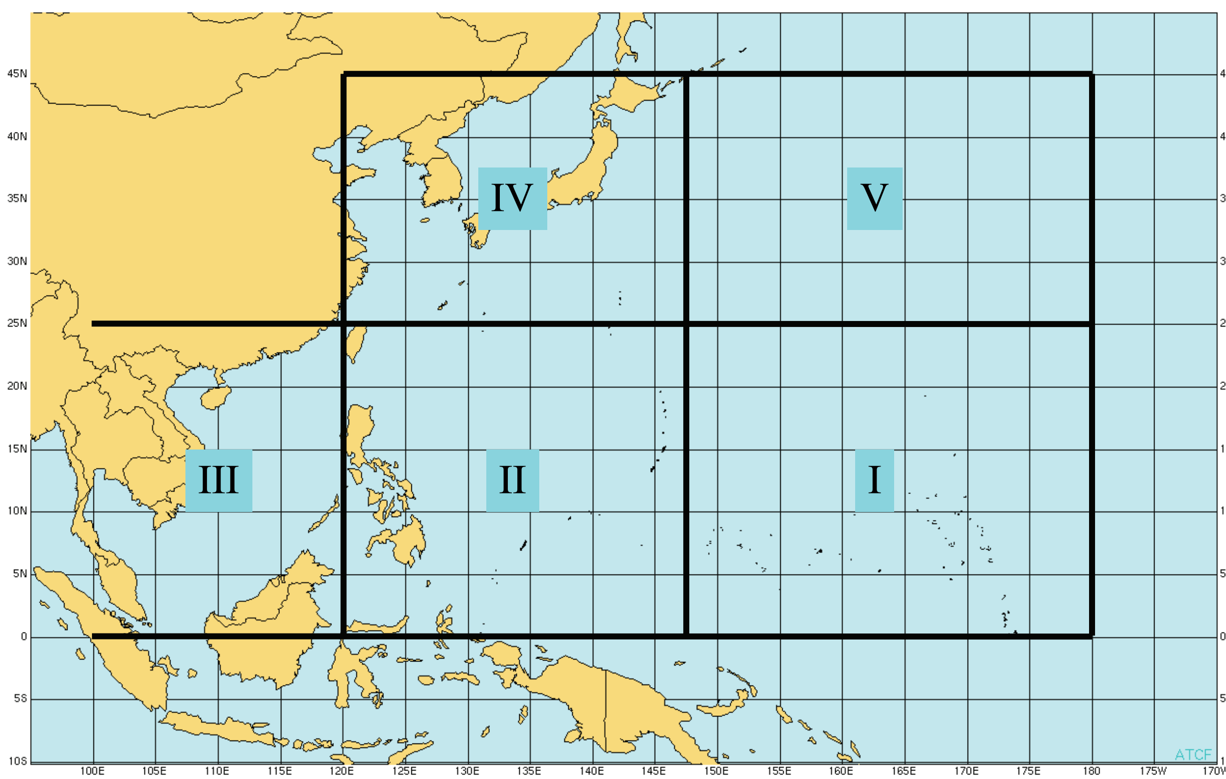


Figure 1. The five regions of the western North Pacific where the tropical cyclone formation probabilities will be summed.

c) The precipitation part of this project is completed. The numerical simulations and simulated satellite imagery were provided to Bob Kuligowski of NOAA/NESDIS and are being used to investigate possible improvements to the hydro-estimator.

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:

There are several payoffs that affect both operational forecasting and the general public. There has long been a need for aditional satellite-based methods for tropical cyclone intensity algorithms. An AMSU-based algorithm offers estimates that are completely independent of the operational standard developed by Dvorak in the 1970s. Operational forecasters at NHC and JTWC are required to forecast the likelihood of tropical cyclone formation in the next 24 hours. Currently there is little objective guidance for tropical cyclone formation. The algorithm developed in this project offers a truely objective guidance method to aid in these forecasts. An improved Hydroestimator product will result in better forecasts and warning associated with rainfall, which will benefit the public and industry.

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 as yet

7. Outreach:

(a) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); 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. An undergraduate student (Daniel Coleman) at Colorado State University is helping with the GOES data processing.

(b) Seminars, symposiums, classes, educational programs; See Section 8

8. Publications:

Refereed Journal Articles

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

Ferraro, R.R., Pellegrino, M.Turk, Chen, Qui, R.J., R.J. Kuligowski, S.J. Kusselson, Irving, S.Q. Kidder, J.A. Knaff, 2005: The Tropical Rainfall Potential (TRaP) Technique. Part 2: Validation. *Wea. and Forecasting,* **20**:4, 465-475.

Kidder, S.Q., S.J. Kusselson, J.A. Knaff, R.R. Ferraro, R.J. Kuligowski, M. Turk, 2005: The Tropical Rainfall Potential (TRaP) Technique. Part 1: Description and Examples. *Wea. and Forecasting*, **20**:4, 456-464.

Conference Proceedings

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

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

Principal Investigator: John Knaff

NOAA Project Goal: Weather and Water, Commerce and Transportation

Key Words: Tropical Cyclone, Hurricane, GOES data, Microwave satellite data

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

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

2. Reseach Accomplishments/Highlights:

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

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

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

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

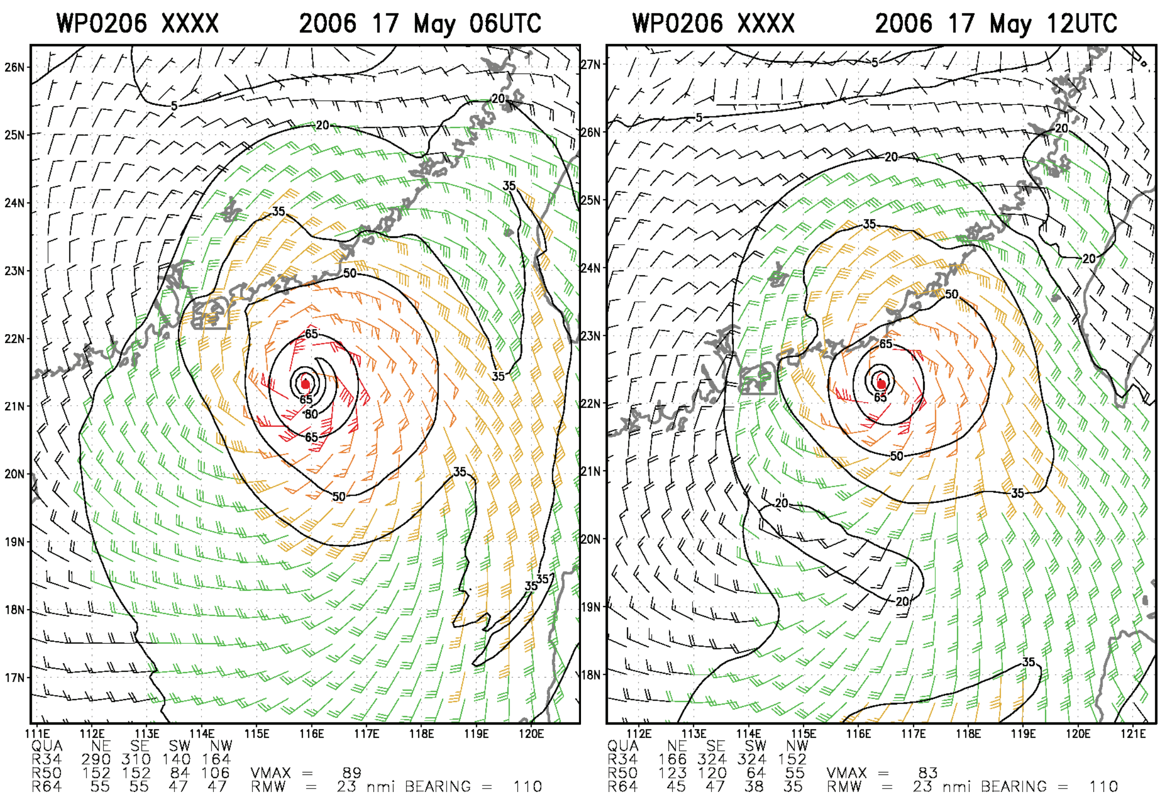
The longer term goal is to transition the final process to operations.

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

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

4. Leveraging/Payoff:

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



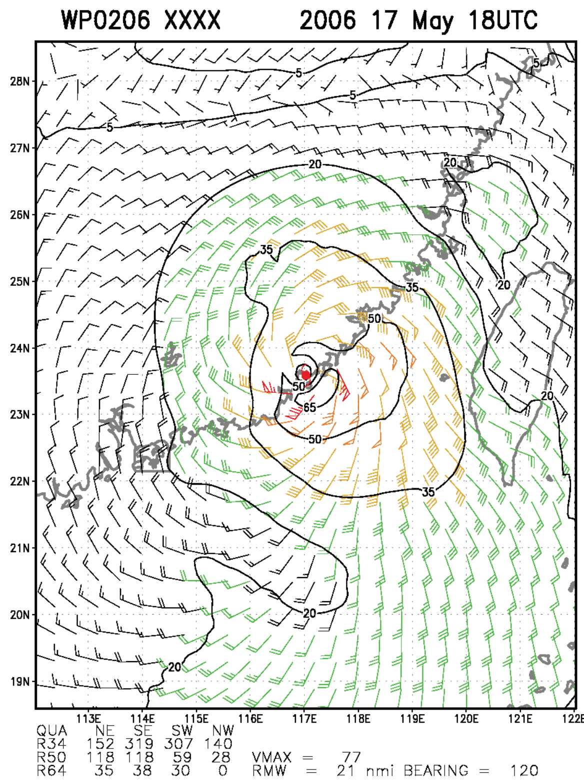


Figure 1: Six-hourly surface wind analyses for Typhoon Chanchu on May 17, 2006 as it makes landfall in China just east of Hong Kong. These were created in real-time and displayed on the web.

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

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

6. Awards/Honors: None as yet

7. Outreach:

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

(b) See Section 8

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

8. Publications:

Refereed Journal Articles

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

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

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

Conference Proceedings

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

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

Principal Investigator: John 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, 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 latter half of the 2006 hurricane season.

2. Research Accomplishments/Objectives:

As described in Knaff et al. (2003), annular hurricanes occur in specific environmental conditions, characterized by a combination of weak easterly or southeasterly vertical wind shear, easterly flow and relatively cold temperatures at 200 mb, sea surface temperatures ranging between 25.4C and 28.5 C, and relatively small 200-mb relative eddy flux convergence due to environmental actions. Furthermore, the presentation of annular hurricanes in GOES IR imagery is quite different than that of the larger population of non-annular hurricanes.

An index that objectively determines whether a tropical cyclone is an annular hurricane or not was developed using GOES IR data with the environmental diagnostic information derived from the NCEP GFS model. This index was derived using a two-step approach. The first step was to prescreen the cases that are extremely unlikely to be Annular (i.e., storms that are of tropical storm strength, storms encountering strong westerly shear, storms that do not have eyes in the IR imagery etc.). Once the data were prescreened, a linear discriminant analysis was used to determine the likelihood a storm is annular or non-annular. From the developmental data and the discriminant function, an index in terms of a probability can be estimated. Figure 1 shows this relationship.

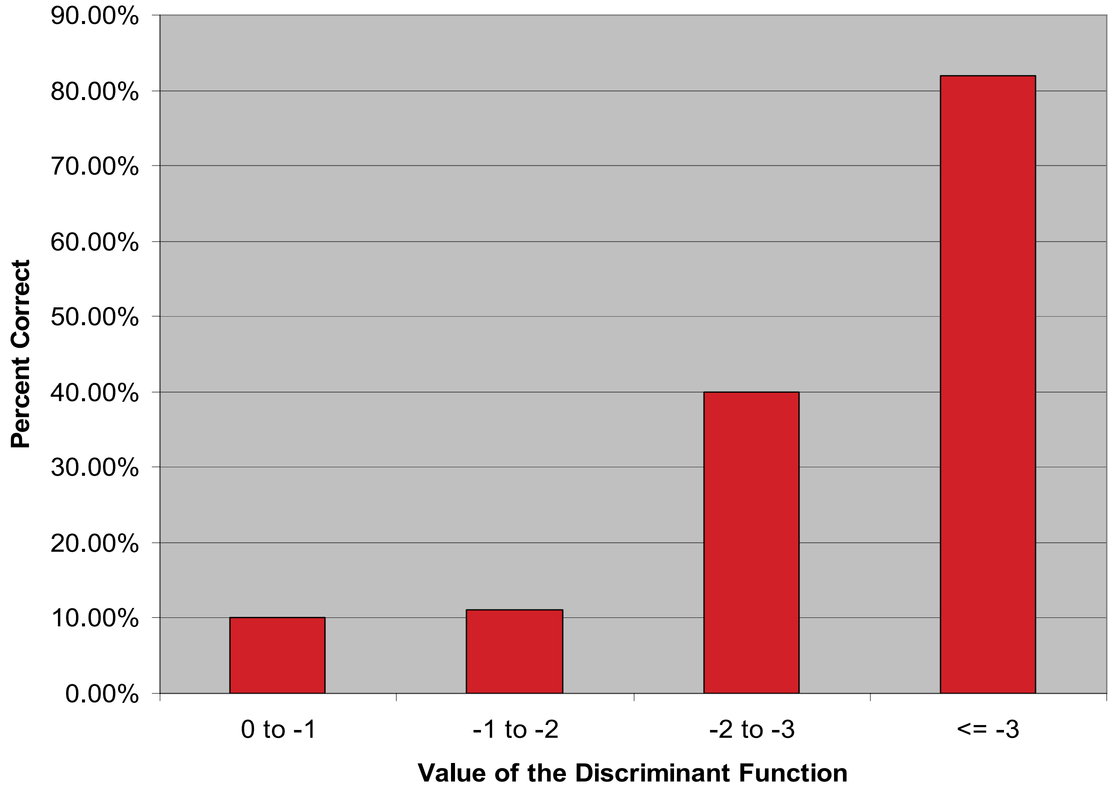


Figure 1. The probabilities associated with the Annular Hurricane discriminant function.

The annular hurricane index algorithm has been developed and is awaiting a transition to NOAA/TPC operations. This index will be tested during the 2006 Hurricane season.

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 Lonkages/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, Colorado State University and the University of Wisconsin.

6. Awards/Honors: None as yet

7. Outreach:

(b) Seminars, symposiums, classes, educational programs; See section 8

8. Publications:

Cram, T., J.A. Knaff, and M. DeMaria, 2006: Objective Identification of Annular Hurricanes Using GOES and Reanalysis Data. *AMS 27th Conference on Hurricanes and Tropical Meteorology.* 24-28 April, Monterey, CA.

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

Principal Investigator: T. 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 nonlinear balance equation is then solved for the stream function, from which the u and v components of the nondivergent wind may be calculated. These retrievals will be referred to as sounder nonlinear 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.
--Near real-time generation of sounder nonlinear balance winds to get a larger dataset for validation against radiosondes and comparison to other techniques.
--Coordination with other groups to determine if a multi-platform method can be used to more accurately estimate polar winds.

2. Research Accomplishments/Highlights:

Research accomplishments of the past year include:

--Temperature Comparison Statistics: The temperature profiles derived from AMSU radiances during the period 2-17 December 2004 were compared to temperatures measured by radiosondes. The bias and root mean square error (rmse) are shown as a function of pressure in Figure 1. The comparisons were made at the mandatory levels, except for 925 hPa, which is not a pressure level for which temperature is retrieved by the AMSU algorithm. The magnitude of the bias and the rmse of temperature are both within 4 K from 850 hPa to 10 hPa, with typical values of the bias being -2 K to 2 K and typical values of the rmse at 2-3 K. The errors increase near the surface (1000 hPa), but this is not unexpected for a satellite retrieval technique.

--Code Development: Code for generating the three-dimensional wind field from temperature profiles derived from AMSU radiances was developed in the context of a rotated polar-stereographic projection. Figure 2 shows a typical swath over the North Pole and Figure 3 shows the associated analysis domain for the swath. The nondivergent wind field was solved under the assumption of geostrophic, linear, and nonlinear balance. Figure 4 shows the bias and rmse of the geostrophic-, linear-, and nonlinear-balance wind speeds derived using the AMSU technique when compared to the actual wind speeds measured by radiosondes launched from Arctic stations. The bias and rmse are minimized at the levels where the wind is approximately in geostrophic balance. The two areas where this occurs are in the middle troposphere and in the stratosphere. Near the surface and near the jet level, the geostrophic wind is not as good an approximation, and the bias and rmse are increased. These two areas are also regions of the atmosphere where the retrieval of temperature by satellite is less accurate. For the free atmosphere, the magnitude of the bias is generally under 2 m s^{-1} and a typical rmse is below 6 m s^{-1}. The linear balance shows an overall improvement over the geostrophic balance. Except near the surface where there is an improvement in both the bias and rmse of around 1 m s^{-1} over the linear balance, the use of the nonlinear balance does not result in improvement over the linear balance. In fact, at most levels, it performs worse than the linear balance. On one hand, this is a bit surprising, as the nonlinear balance is a more accurate approximation than the linear balance. On the other hand, for flows of small Rossby number, where the Earth's vorticity dominates over the relative vorticity, the nonlinear balance will not result in increased accuracy.

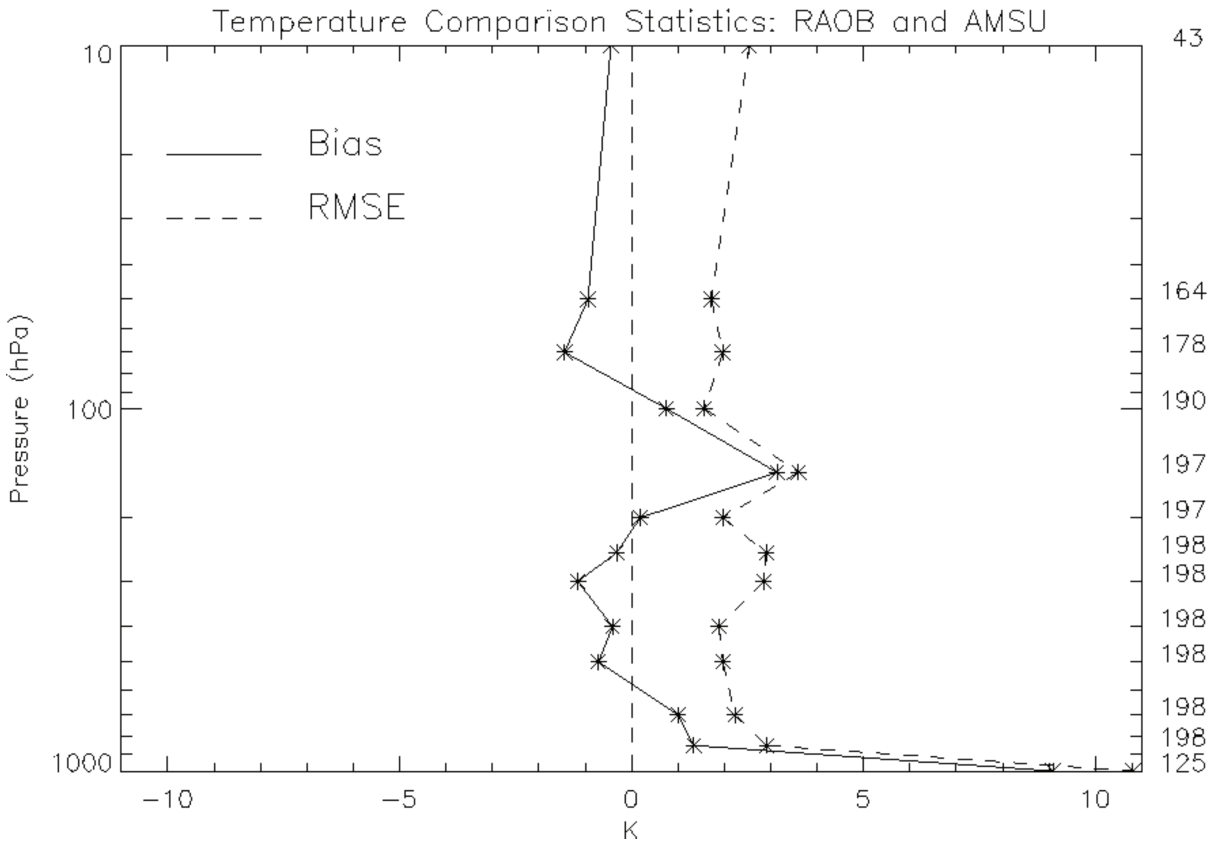


Figure 1. Bias and rmse of temperature comparisons between radiosondes and the satellite retrieval technique. The number of comparisons at each level is given on the right hand side of the figure.

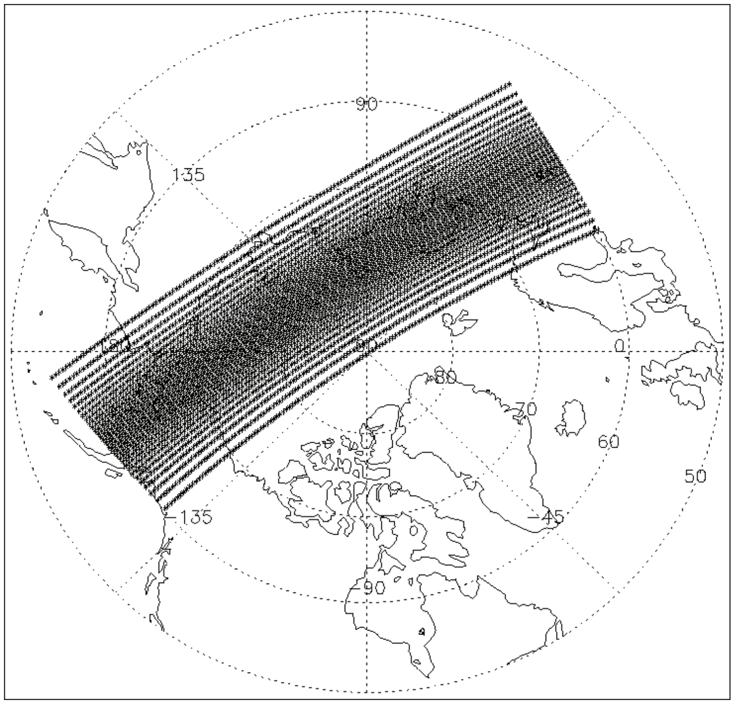


Figure 2. Locations of the AMSU footprints for a typical polar data swath. This example is from 0015 UTC on 17 December 2004.

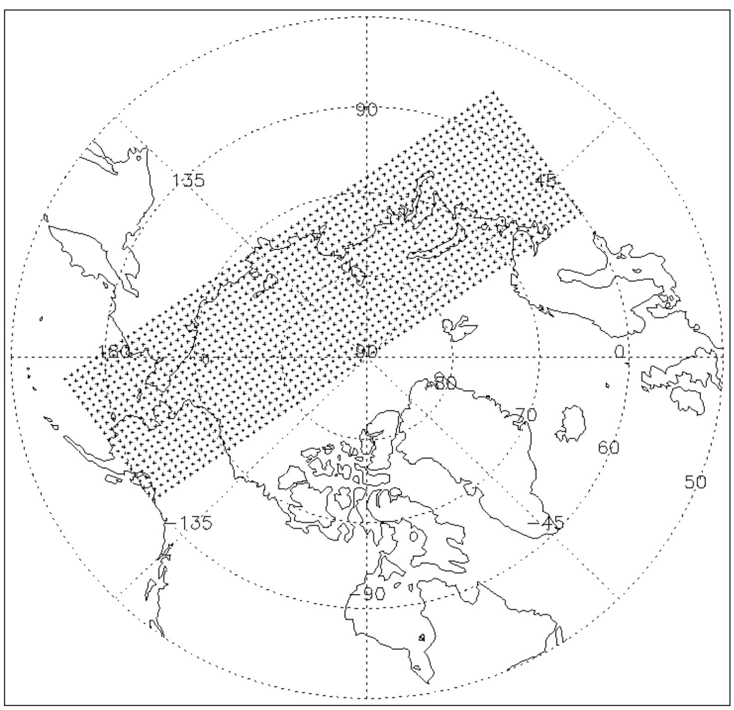


Figure 3. Analysis domain corresponding to Fig. 1.

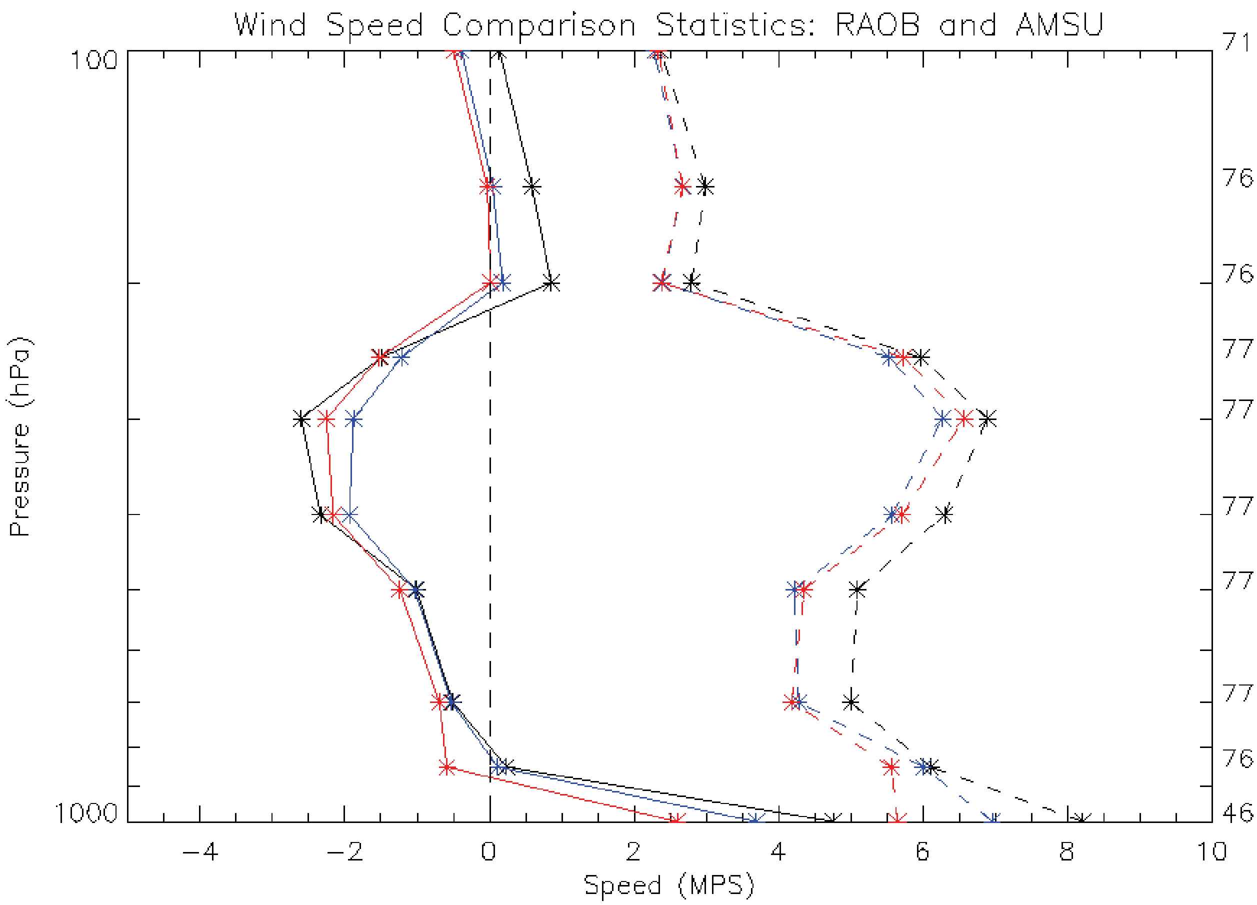


Figure 4. Comparison statistics for wind speed. Solid lines are the bias, dashed lines are the rmse. The colors correspond to the different balance approximations: black-geostrophic, blue-linear, red-nonlinear. The number of comparisons at each level is given on the right hand side of the figure.

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

The primary objectives were accomplished for the reporting period. These were to develop the nonlinear balance solver on a rotated polar-stereographic projection, and to compare the temperature and wind retrievals using the developed method with radiosonde data.

The other goals of comparing wind retrieval techniques, generating near real-time winds, and investigating the possibility of a multiplatform retrieval were not performed, as the primary PI decided not to perform these tasks.

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 the Cooperative Institute for Meteorological Satellite Studies located at the University of Wisconsin – Madison.

6. Awards/Honors: None as yet

7. Outreach:

8. Publications:

Dostalek, J.F. and M. DeMaria, 2006: Polar wind retrievals using the Advanced Microwave Sounding Unit. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

DOCUMENTING HISTORICAL CLIMATE NETWORK STATIONS IN COLORADO

Principal Investigators: Roger Pielke and Nolan Doesken

NOAA Project Goal: Climate and Climate observations and analysis

Key Words – HCN, NERON, Metadata, Field Survey

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

Modernization of the Historical Climate Network (HCN) is the next coordinated step for unambiguously detecting long-term climate signals in the US at regional scales. In preparation for this next step, a better knowledge of the current status, locations and possible problems associated with existing HCN stations is required. Poor siting, uncertainty in future ownership stability, and variations and changes in land cover types around an existing HCN will compel the selection of a nearby location for continuity of the climate record into the future. To make such assessments, field surveys of existing sites and potential future sites are required. Preparation of a review document summarizing these efforts will be delivered to NERON.

Objective 1. Evaluate 22 HCN in Colorado including a desk audit of existing metadata resources, site survey and photography of each site and at least one alternative. Before conducting field surveys, all HCN stations' metadata will be examined. At least two HCN stations in close proximity to Colorado State University will be surveyed first, and the results of these preliminary surveys will be shared with NCDC to make sure that mutually satisfactory data are being collected. Then, the remainder of the HCN stations will be visited in a series of two to three "sweeps." Upon completion of field data surveying, the remainder of the project will be completed in office.

Objective 2. A summary report will be compiled and submitted to NOAA's National Climatic Data Center (NCDC) at the close of the project that includes surveys for 22 HCN sites and alternative sites. This report will include recommendations for site selection and implications for filling in the NCDC-provided grid for measuring regional long-term climate signals for temperature and precipitation.

2. Research Accomplishments/Highlights:

See #3 below.

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

Objective 1 -- in progress
The first round of field surveys was completed in August 2005. Additional HCN proposed sites were added to the list of 22. Five sites out of 30 need to be revisited because of equipment and weather delays. Currently, it's anticipated that these surveys will be completed in 2006.

Objective 3 -- in progress
An excel file was completed and approved by the NERON program office. The rest of the stations will be completed by the end of 2006 and sent to the NERON group when final surveys are complete.

Some changes to the NERON (National Environmental Real-time Observation Network) are currently taking place and the unfinished work of Objectives 1 and 3 have been placed on hold until a clearly defined direction for HCN modernization has been achieved.

4. Leveraging/Payoff:

The HCN was in response to a need for accurate, unbiased, modern historical climate record for climate variability and change research which is currently in the forefront of the federal government, state and local government and public eye. Documentation on existing long-term weather observing sites is the first step in creating this network.

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

Collaborations exist within NOAA, NCDC and Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory and also with the American Association of State Climatologists.

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.

Temperature and Precipitation data are made available by NCDC at the following web site: http://lwf.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html.

8. Publications:

None

ENVIRONMENTAL APPLICATIONS RESEARCH

Principal Investigator: T.H. Vonder Haar

NOAA Project Goals: Various

Keywords: Various

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

Various. See following reports

2. Research Accomplishments/Highlights:

See following reports

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

See following reports

4. Leveraging/Payoff: See following reports

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

See following reports

6. Awards/Honors: See following reports

7. Outreach: See following reports

8. Publications: See following reports

I. Research Collaborations with the ESRL/GSD Office of the Director and the Senior Scientist (formerly the FSL Director's Office)

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

Principal Researcher: Nikki Prive

NOAA Project Goals/Programs: 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 preliminary plan for a network of global UAS observations has been designed and tested against past observations. Twelve ground stations for UAS operations have been selected using archived hourly surface observations to screen the stations for optimal conditions for takeoff of the UAS. The flight paths and routing of the UAS between fixed observational points have been screened for reliability of the network using reanalysis data. An animated demonstration of the operation of the UAS observing network for Science on a Sphere has been created. In addition to the global network of UAS, a concept of operations for an intensive UAS program over the Arctic to study climate change is under development.

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

--Objective: Developing software to test operations concepts, including routing of up to 20 aircraft over a global domain, with several months of realistic wind data as input. Use knowledge of global weather and climate observational requirements to determine optimal aircraft observing strategies.

Status: A preliminary phase of this objective is complete. Thirty six aircraft routes across the globe have been screened using several years of reanalysis data to achieve at least 97% on-schedule flights. The ground stations for the UAS have also been screened using hourly surface observations; twelve ground stations with greater than

97% reliability year-round have been selected. Fig. 1 illustrates the screening results for Eielson AFB in Alaska.

--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. Discussions with the forecasting / observing system simulation experiment community have been held, with plans to begin intensive work late in 2006.

--Objective: Participate in the instrument design part of the UAS program, including how the instruments are optimally integrated into the UAS.

Status: This objective has yet to be started.

5. 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.

6. Awards/Honors:

7. Outreach:

A poster was presented at the CIRA Science Symposium on May 17 presenting the Observing System Simulation Experiment concept for the global UAS observing network.

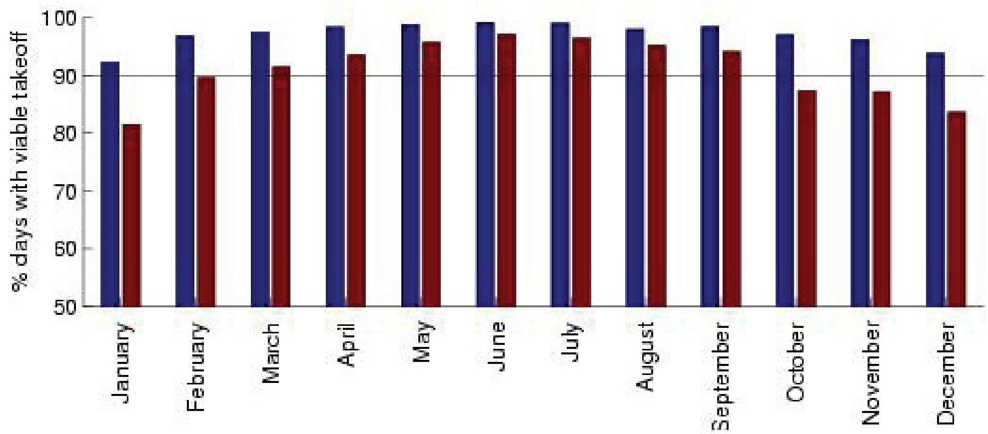


Fig. 1. Graph illustrating an example of screening results for a UAS ground station at Eielson AFB in Alaska. The screening procedure accounted for winds, visibility, ceiling, temperature, and icing conditions to determine how often takeoff and landing of the UAS was possible at the airfield. The percent of days with surface conditions acceptable for ground operations and takeoff/landing of the Global Hawk UAS at 00Z (red bars) or in a two-day timeframe (blue bars) are shown.

Project Title: <u>IPCC Climate Model Demonstrations for Science on a Sphere</u>

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 priority of promoting environmental literacy

Key Words: Climate model projections, Science on a Sphere^{TM}

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^{TM} to increase understanding of climate change science. [See Section VI. C. for additional information on the SOS Development project.]

2. Research Accomplishments / Highlights:

Six animated demonstrations from three different climate models have been created for Science on a Sphere (SOS) using model output from the fourth IPCC results. Three animations display surface temperature changes from the year 1870 to 2200; two animations show sea ice and ocean temperatures/currents; one additional animation shows precipitation changes.

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

In progress.

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.

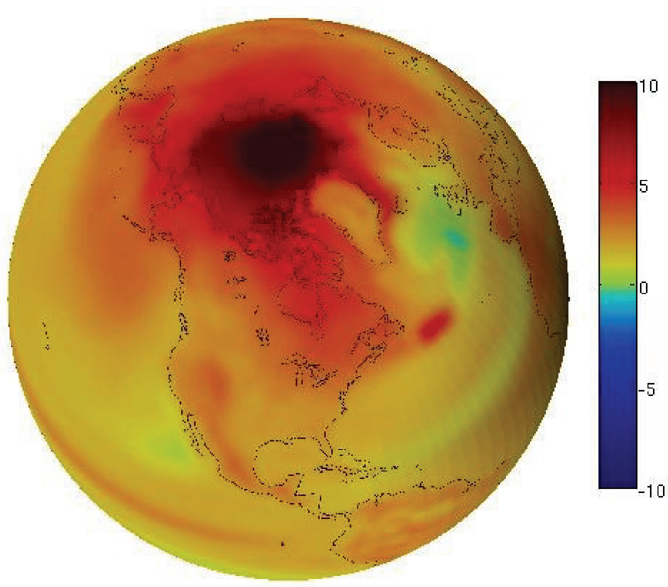


Fig. 1. A visualization of surface temperature change in the year 2100 from the NCAR CCSM model such as used in one of the SOS demonstrations.

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

Principal 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: 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/). Examples of the products are given in Figs. 1 and 2.

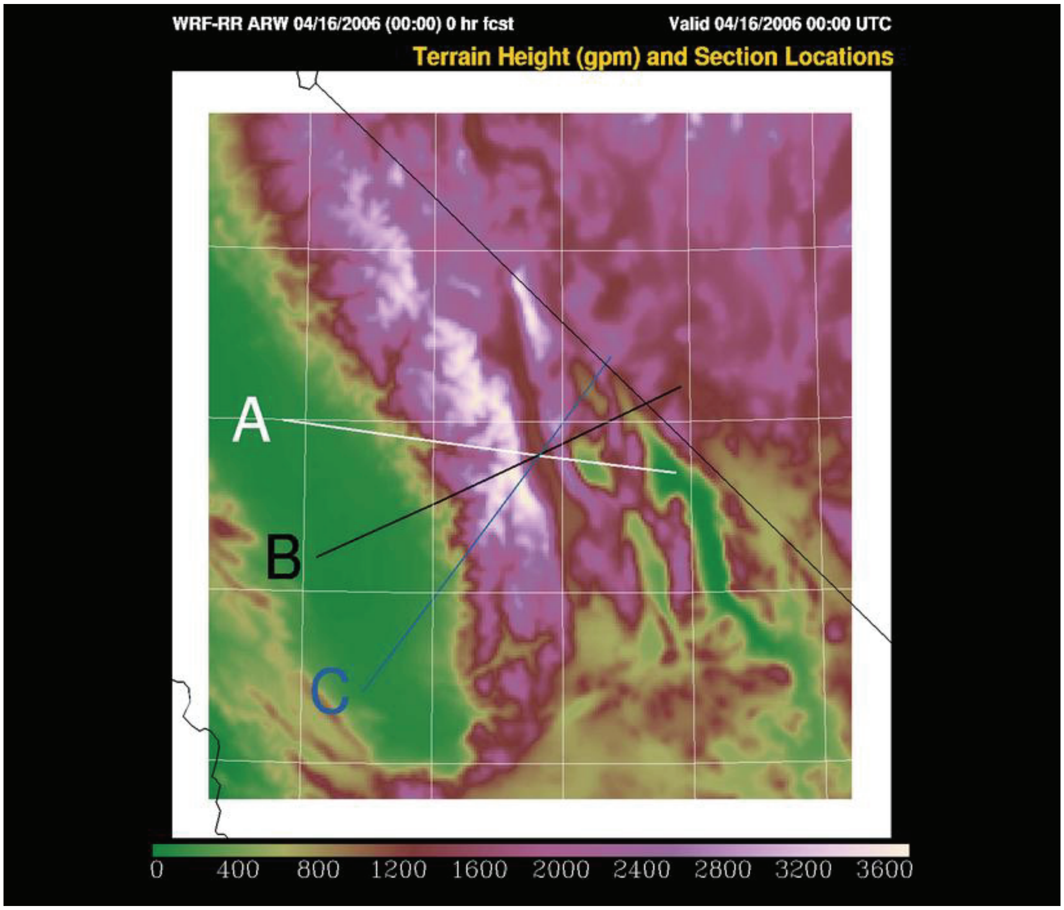


Fig. 1. WRF Rapid Refresh ARW model terrain height and locations of cross sections for T-REX.

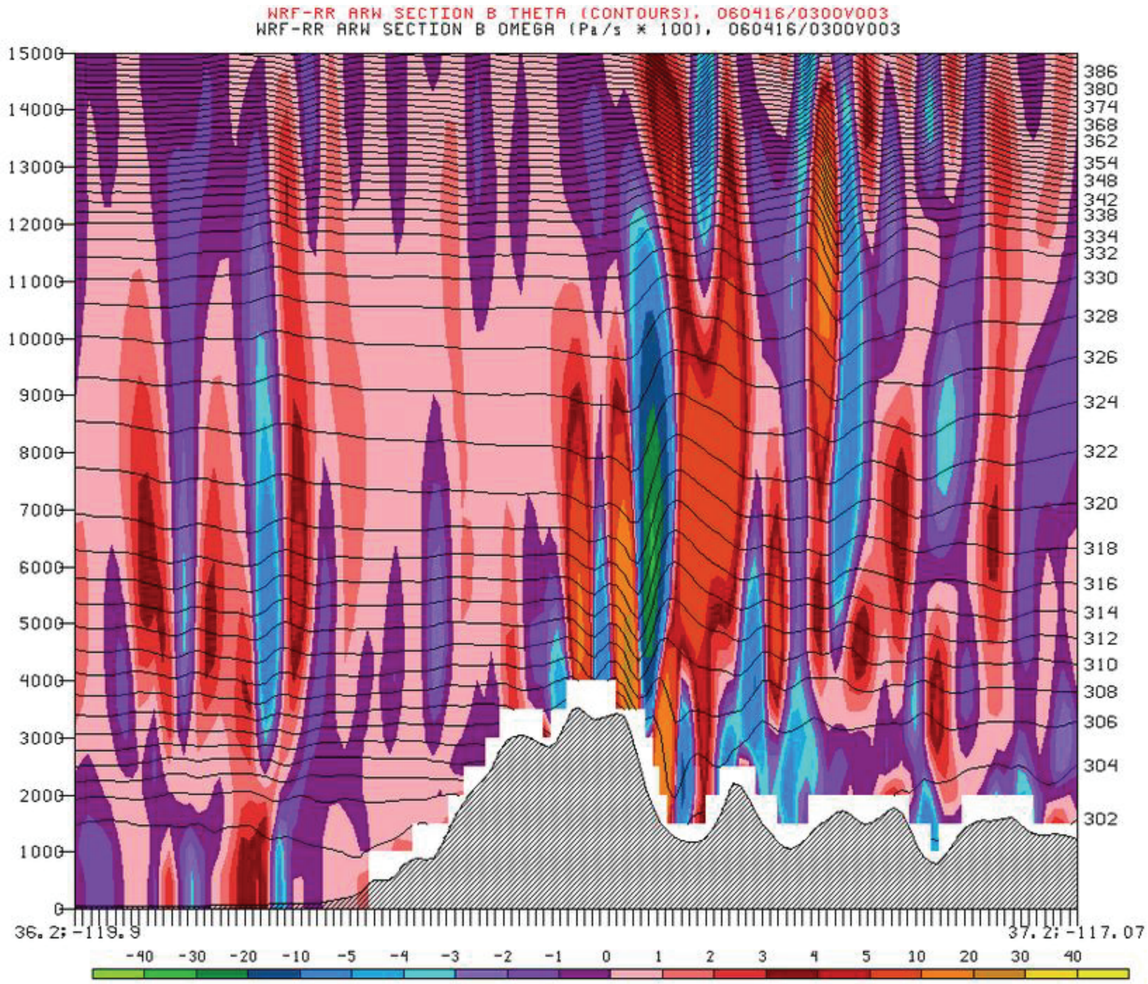


Fig. 2. Cross section "B" plot of omega and theta for a 3-hour forecast valid at 0300 UTC 16 April 2006 from the WRF Rapid Refresh ARW model.

Once final parameter settings for the two models and final revisions for the graphic products are agreed upon, the observed gravity wave cases will be redone and the graphics products will be submitted to the official T-REX online catalog, where they can be utilized by any of the researchers involved in the T-REX project.

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

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

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:
7. Outreach:
8. Publications:

II. Research Collaborations with the GSD Aviation Branch (formerly the FSL Aviation Division)

A. High Performance Computing-Advanced Computing

Project Title: Advanced High-Performance Computing

Principal Researchers: Jacques Middlecoff and Dan Schaffer
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.

Key Words: Computational Grid; TeraGrid; Gridpoint Statistical Interpolation; Model Parallelization; WRF Portal

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

a) CIRA researchers would continue to explore the feasibility of combining geographically distributed computing resources into a single virtual resource (a computational grid). In FY04-05, a prototype grid was constructed consisting of nodes at the Pacific Marine Environmental Laboratory (PMEL), the Geophysical Fluid Dynamics Laboratory (GFDL) and at ESRL. With continued funding in FY05-06, this grid would be made operational for systems at the afore-mentioned laboratories as well as at NCEP.

b) For the MAPP project, CIRA researchers would continue their collaboration with meteorologists to develop a simplified and centralized portal for running and monitoring various atmospheric models, including WRF NMM, WRF ARW, and GFS on a variety of computers.

c) For the MAPP project, CIRA researchers would improve NOAA code interoperability by porting the WRF, GSI, and GFS codes to the three major NOAA supercomputers. In addition to porting these codes and their supporting software, regression tests would be developed to facilitate testing, and the codes would be integrated into the portal program (see #2 above) for ease of use.

d) CIRA researchers would assist in verifying that the newly procured supercomputer meets requirements, would assist the user community in learning to use the new supercomputer, and would port SMS and the MAPP codes to the new system.

e) 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). During FY05-06, CIRA researchers would provide support to the Taiwan Central Weather Bureau (CWB) for the SMS version of the Non-hydrostatic Forecast System (NFS). This support would include optimization of SMS NFS and assistance to vendors that submit proposals to the CWB high performance computer system procurement.

f) The Global Systems Division of the new ESRL will be moving into global and coupled modeling. CIRA researchers would support this effort by using the Earth Systems Modeling Framework super-structure to couple models together. Ocean, weather and other models would be made "ESMF compliant" to facilitate the coupling process.

2. Research Accomplishments/Highlights:

a) CIRA researchers continued to explore the feasibility of creating a NOAA-wide computational grid.

b) 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 poster at the WRF Workshop in Boulder, co-authored a paper presented at AMS, presented a poster at AMS, and wrote an article on WRF Portal for the CIRA Magazine (Volume 25, Spring 2006).

c) The GFS code was successfully ported to the Jet supercomputer for both the Portland Group, Inc and Intel Fortran compilers. This work provides one of the underpinnings for work underway to use GSI and GFS to analyze the utility of observations from Unmanned Aerial Vehicles.

In addition to porting the GSI to Jet, CIRA researchers fixed bugs in, and made improvements to, GSI. Most importantly, CIRA researchers collaborated with Russ Treadon at NCEP to make these changes to GSI a permanent part of the NCEP GSI code so GSD would not have to re-port GSI each time a new version came out, and so other users with Linux clusters could more easily use the GSI. As a result, Dezso Devenyi was able to download the latest (June) version of GSI from the NCEP web page and get it running on Ejet in a few hours.

d) This goal has been postponed until next year because the procurement was postponed.

e) This proposed work was accomplished to the degree needed by the CWB. Support was provided to vendors submitting proposals for the new CWB computer system. This support enabled the vendors to port SMS NFS to their specific systems. The ultimate winner, IBM, was one of the vendors to which CIRA researchers provided support.

In addition to the CWB work, CIRA researchers embarked on a new effort to provide SMS as an alternative (to the Runtime System Library - RSL) implementation of the communication/decomposition functionality needed by the WRF model. The ultimate objectives are:

--To provide a more efficient implementation of the cross-processor communication needed by the WRF model.

--To add the SMS COMPARE_VAR capability to the WRF model. COMPARE_VAR greatly simplifies the debugging of parallel models such as WRF.

--To eliminate the need for NCAR and NOAA to maintain two separate implementations (RSL and SMS) of largely the same functionality.

f) Further analysis of ESMF revealed that it does not yet provide the kinds of capabilities needed by GSD. However, the use of ESMF to provide a coupling framework for the new FIM model is under discussion and could be investigated in detail by the end of next year.

An opportunity arose which allowed CIRA researchers to support the GSD global modeling effort more directly than by using the ESMF. Working with Drs. Sandy MacDonald and Jin Lee, CIRA researchers helped develop the Finite-element Flow-Following Icosahedral Model (FIM). FIM is a global model that will be able to perform as both a weather model and a climate model. FIM 1.0 was developed and CIRA researchers became part of the newly formed FIM group.

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

a) Unfortunately, the effort was not ultimately successful for two reasons.

--Software packages associated with the Globus toolkit that could have been used to create the computational grid were found to be incapable of doing the job.

--The existing security infrastructure at the various NOAA labs was found to be lacking. Thus, the respective lab security administrators did not have sufficient confidence in the infrastructure to make them feel comfortable opening up computational resources in a cross-lab fashion.

b) In progress.

c) Successfully completed.

d) Postponed.

e) The CWB effort was successfully completed; the WRF/SMS project is still in progress.

f) In progress.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

<u>Conferences</u>

Devenyi, D., S.G. Benjamin, J.M. Middlecoff, T.W. Schlatter, and S.S. Weygandt, 2005: Gridpoint statistical interpolation for Rapid Refresh. *17th Conf. on Numerical Weather Prediction*, 1-4 August, 2005, Washington, D.C., Amer. Meteor. Soc.

8. Publications:

Govett, M. and J. Smith, 2005: A WRF Based Portal for WRF. *WRF/MM5 Users' Workshop*, 27-30 June 2005, Boulder, CO.

Govett, M. and J. Smith, 2006: Developing Distributed Data Access Capabilities for the WRF Portal and Beyond. *22nd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology*, 29 January-2 February 2006, Atlanta, GA., Amer. Meteor. Soc.

Smith, J. and M. Govett, 2006: WRF Portal: A GUI Front End for WRF. *22nd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology*, 29 January-2 February 2006, Atlanta, GA., Amer. Meteor. Soc.

Smith, J., 2006: WRF Portal: The Graphical Front End to WRF, *CIRA Magazine,* Volume 25, Spring 2006.

B. Aviation Systems—Development and Deployment

Project Title: FXC VACT (Volcanic Ash Coordination Tool) Project

Principal Researcher: Jim Frimel
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. FX-Collaborate investigative research will focus on the following areas for the VACT project:

--Use of the FX-Collaborate systems to facilitate research collaboration between forecasters and researchers at separate locations

--Investigate the use of volcanic ash products for the Anchorage VAAC, CWSU and the AVO with FXC enhancements for sharing these products between these offices.

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 2005/2006 research year, CIRA researchers 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 VACT software, version 2.30 and providing support of volcanic eruptions for the Anchorage VAAC.

Creating the FXC VACT 2.30 release of the software was a major task and has taken almost a year to complete. The main focus of this release was to migrate the core ASDAD 5.2.2 AWIPS and FXC 2.0.0 software to AWIPS OB6 and the FXC 4.0.0 code base. This also required an Operating System upgrade from running the older Red Hat 7.2 platform to the new Red Hat Enterprise 3 (RHE3). Porting and merging all previous ASDAD software to the new platform required lots of planning and coordination. This was a major upgrade to the ASDAD software/systems infrastructure. While the overview and concept of migrating to a new code base is simple, the process is a very large undertaking under AWIPS. It was quite involved with many hurdles, roadblocks, and problems that had to be understood and resolved. An additional requirement while migrating all ASDAD systems was to maintain access to the previous development environment. This was needed in order to continue development and provide support for the current operational systems and software. The major difficulty in this was the current software would not run or build on the new platform and we only had available our current set of systems. Working within ASDAD's five-tiered software systems environment from development to primary operational systems, we are performing final integration testing on the tier four systems as of July 2006. Once final Acceptance Testing is completed, we will upgrade the primary operational systems, to RHE3 running the FXC VACT 2.30. This migration is planned to be complete and released operationally in the July/August 2006 timeframe.

During July of 2005, the decision was made to migrate ASDAD software to the latest AWIPS build that was moving to operations and the next generation of the FXC code base. This decision was based on the fact we were running on core 5.2.2 AWIPS software that was several generations old and older FXC technology that was based on RMI. We needed to take advantage of core AWIPS fixes, enhancements, and plan to be able to meet the ever-growing NOAA security requirements. For example, this included support for exported image processing within AWIPS, new decoder and data support, and FXC remote process communication based on TCP/IP sockets.

The first step in this process was to learn and understand the AWIPS OB6 build environment and requirements so we could define and upgrade our ASDAD systems to RHE3 running AWIPS OB6. We then configured a tier 1 development system and compiled the AWIPS OB6 software within the ASDAD environment. After resolving compiler and system dependencies and creating a successful build, we ran a BOU localization. We then resolved the issues we encountered with running a localization. Next, we created an AWIPS OB6 snapshot and setup an ASDAD source tree called FAA-awips-ob6. The FAA-awips-ob6 source tree would be the software the ASDAD team would merge and port its VACT enhanced code base with. Within the ASDAD environment, we compiled the FAA-awips-ob6 software and ran a BOU localization. After successfully building the FAA-awips-ob6 software on the ASDAD development system, we compared our system with the operational OB6 AWIPS. This test included configuring, creating, and testing the data ingest and data display of the BOU localization in the ASDAD environment. At this point, no ASDAD software or enhancements were migrated; we were only running and testing the core AWIPS OB6 code.

Once a completed AWIPS OB6 software build and environment under ASDAD was setup and tested, we needed to learn and understand the new AWIPS software architecture to be able to port and merge all current AWIPS ASDAD code developed for VACT projects to OB6. In this context, porting involved reengineering previous ASDAD solutions to work within the new AWIPS software architecture while merging involves more of just moving previous ASDAD solutions to the new AWIPS code base. At this point, we began the arduous task of porting and merging all ASDAD code and successfully creating the VACT localization. After the ASDAD VACT code base was migrated to FAA-awips-ob6, we then began porting and merging all ASDAD FXC VACT enhancements from FXC 2.0.0 RMI architecture to FXC 3.0.0 TCP/IP architecture. The AWIPS “localdev” software development environment was successful at meeting specific requirements of the original AWIPS development project but it is not a Software Configuration Management (SCM) system that is capable of managing trees of source code gracefully. This was never a requirement of the original specification. As such, it affects the efficiency of the merge process with other projects using the AWIPS code base. What we learned from this process is invaluable and will help in the next port and investigation into hopefully implementing an environment using an open source SCM solution that will streamline future merging with AWIPS core trees. What follows is a high level list of issues, in no specific order, encountered during the process of initial testing to merging of the ASDAD AWIPS enhanced code to the AWIPS code base: ldmAcqserver data acquisition, notification, data purging, Machine Endianness, Shp2bcd problems, NOAA1 database, postgreSQL table requirements, system load, decoder memory leaks, new models and names, satellite changes and GOES9 decommission, Hi Res satellite display exporting, localdev environment rework, Grib2decoder, METAR decoder, Maritime decoder and the FXC CLOSE_WAIT socket deadlocks.

The FXC VACT 2.30 builds continue to be tested and bugs and problems are being addressed. We have kept current with the required security patches to Red hat Enterprise 3. NOAA security required us to perform Harris scans of all of our systems and address any items flagged as High or Medium level threats. This was a big effort and took three weeks of the team’s time to comply with the new security standard. HP-UX machines were decommissioned.

In addition to the above port to the new FXC VACT 2.30 system, the following software maintenance and enhancements were accomplished. We updated the Volcanoes database. We developed FXC and AWIPS release scripts for the TMU and VACT projects that will make releasing the FXC software to our operational systems more efficient and less prone to error. We started development of the volcanic ash SIGMET decoder. The first guess software and output to VACT users was demonstrated. We extended the first guess software to include an ensemble first guess advisory derived from the MesoEta, AVNGBL, and UKMET runs of PUFF. We made changes to the text output for the first guess. In August 2005, fax software was installed on the FXC VACT system. The FXC VACT systems now provide End-to-End capability. The Alaska Center Weather Service Unit had sent out a TEST FAX to all clients on the FAX pool. We started defining the Volcanic Ash SIGMET text message that will be generated using the VACT system in version 3.0. We collaborated regularly using the FXC VACT systems with the Alaskan participants to keep the users active on the systems and help define requirements for the VACT SIGMET tool.

Over the past year, the ASDAD team provided FXC VACT support to the VAAC during volcanic episodes. The FXC VACT was used in operations during the eruptions of Mt. Augustine and for four other events along the Aleutian chain and the Kamchatka Peninsula.

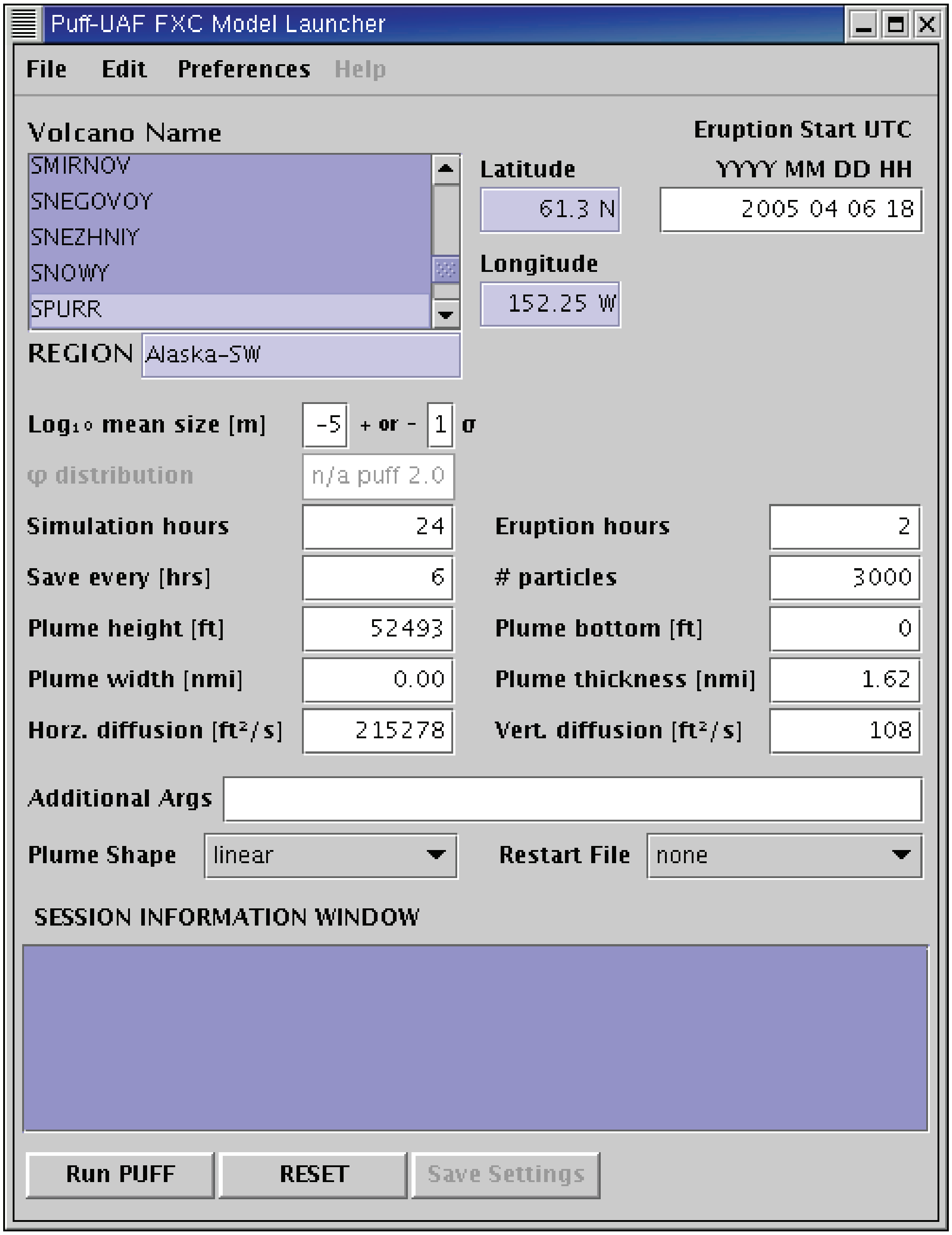


Fig. 1. A view of the Puff-UAF FXC Model Launcher interface.

FXC VACT participants collaborated on their own to monitor the Sheveluch eruption on 9/22/05 @ 05:15 ZULU. The AVO initiated a collaborative effort with the CWSU, and AAWU when AVO noticed that if the Kamchatkan Volcanic Eruption Response Team (KVERT) was wrong with their height estimate, the volcanic ash from the eruption could flow into jet route areas. AVO was able to determine this by using the PUFF model runs from the FXC VACT system. This case has been archived to DVD.

The Mt. Cleveland eruption was archived and used for the collaboration monthly test with the FXC VACT participants. Using the FXC VACT tool with the Mt. Cleveland archived data sets, participants were able to enhance satellite imagery to identify volcanic ash clouds and follow the ash for 12 – 14 hours. The participants were also able to run the PUFF dispersion model, which overlaid nicely on the satellite imagery so that a forecast could be issued. Participants were also able to get height information using RAOB sounding information that was captured as part of the archive. The CWSU could also have created an MIS product for their users, if the event had warranted. Two more volcanic ash events—a wind blow case resulting in a volcanic ash cloud over the Katmai peninsula and the Bezymianny eruption—were also archived.

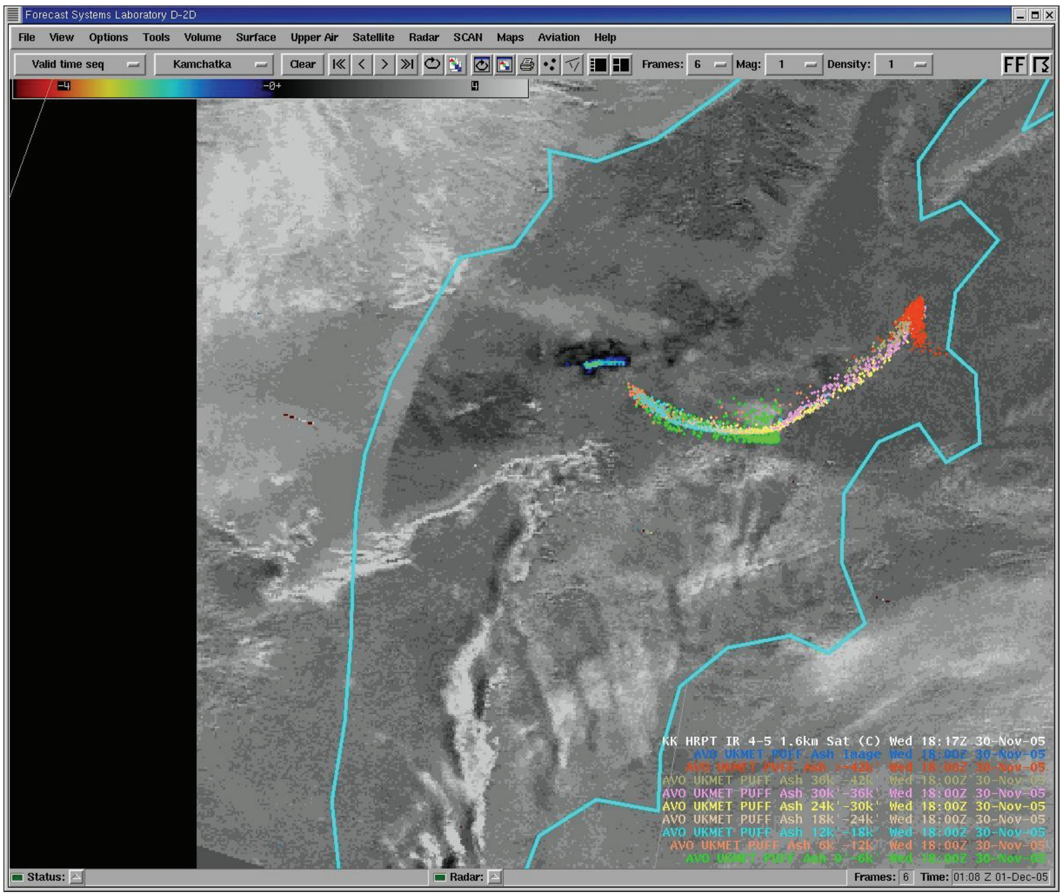


Fig. 2. The November 30, 2005 eruption of Bezymianny, Kamchatka, Russia is shown as ash cloud with HRPT IR 4/5 enhanced and UKMET PUFF Model output are captured.

Mt. Augustine erupted on the 11th of January and continued to erupt throughout the month. We have archived the FXC VACT data sets for all of the different eruptions throughout the month. While we were in Alaska, Mt Augustine erupted again on the 17th of January and we were able to see how the VACT was used during a live event. We have archived several eruptions for Mt. Augustine spanning the month of January. We were also successful at upgrading the polar satellite imagery on the VACT system so that volcanic ash is easily discernable in the 4-5 imagery without user intervention.

During the week in Alaska for system installs and training, we were able to take notes on new requirements based on operational collaboration efforts during an actual volcanic ash event.

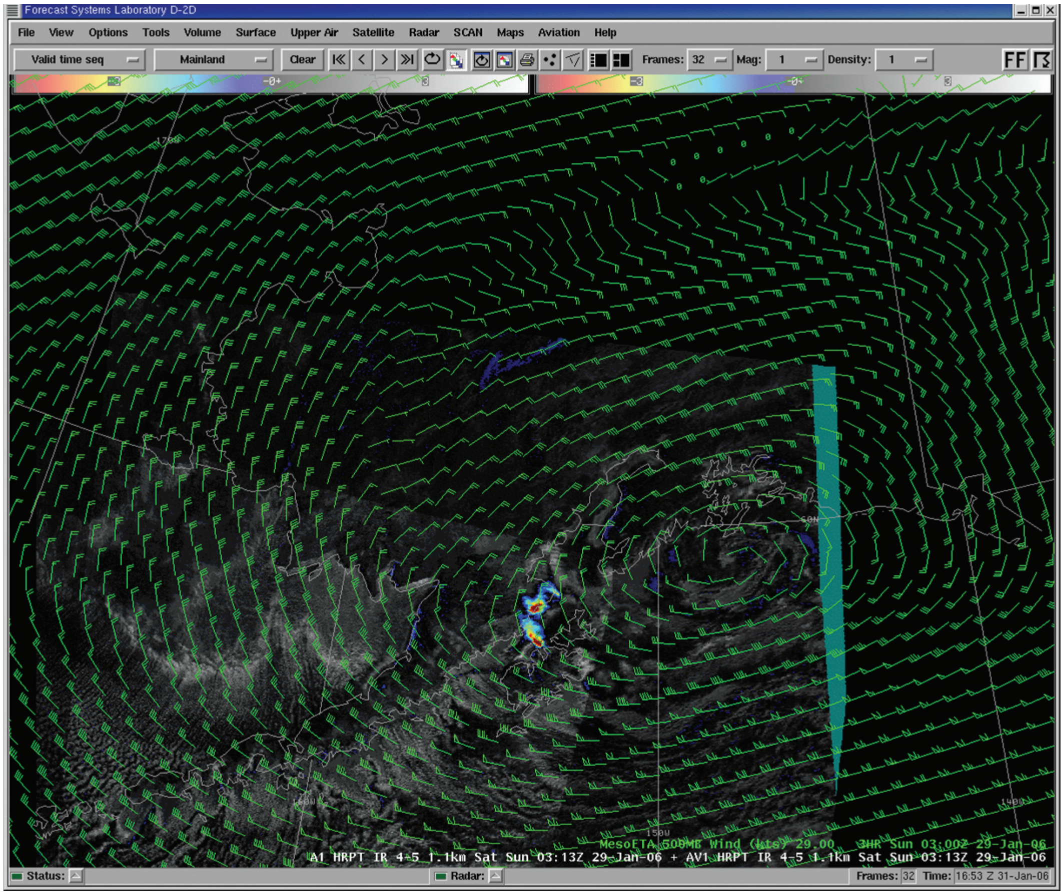


Fig. 3. This figure shows the January 29, 2006 eruption of Mt. Augustine with captured ash cloud with combined HRPT IR 4/5 enhanced satellite and MesoETA 500 MB winds.

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.

Objective: The AWIPS/FXC/VACT system will be enhanced with meteorological datasets to improve the detection and prediction of aviation hazards. The range and focus of this research includes volcanic map displays, model and dispersion model data, enhanced maps, GIS, impact databases, and product Generation tools and investigation of interagency collaboration.

Status:
(Completed)
--Major core AWIPS software upgrades and ASDAD ports ver 522 to OB6
--Major core FXC software upgrades and ASDAD ports ver 200 to 400

--Research and Develop Volcanic ASH SIGMET display
--New FAA CD map backgrounds

(In progress)
--Hysplit (VAFTAD) dispersion model
--VACT archival playback
--Research and Develop Volcanic ASH Creation Tool.
--Research and Develop impacts based on volcanic ash
--CANERM dispersion model
--Develop international SIGMET displays

(Yet to be started)
--Research and Develop interface for displaying URLs based on types
(Weather CAMS, VAAC Images ...)
--Research and Develop approach for adding FXC language translation tools
--Cloud top interrogation database

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

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

6. Awards/Honors:

7. Outreach:

Due to the activity of Mt. Augustine in the Cook Inlet of Alaska and the successful May 2005 operational exercise, the FXC VACT Project has had a highly visible year within the NWS, the FAA, and NOAA as mentioned in NOAA news below:

Jan 2006 Weekly Message: NOAA news
From the Under Secretary, VADM, Conrad C. Lautenbacher, Jr.
“Although the area of the Anchorage Volcanic Ash Advisory Center is one of the smallest areas, it covers air routes over some of the most active volcanic areas in the world. Life-threatening and costly damages can occur to aircraft that fly through an eruption cloud, and volcanic ash clouds can cause jet engines to stall. On January 11, when Augustine Volcano erupted to 30,000 feet, NOAA's Alaska Aviation Weather Unit/Volcanic Ash Advisory Center in Anchorage signaled that the eruption had occurred. The Anchorage Weather Forecast Office issued Marine and Public Ashfall Advisories soon after. The Federal Aviation Administration put NOAA’s information to work, giving air traffic managers and controllers a heads-up to ensure airspace safety around the volcano and along the forecast trajectory of the ash plume. The volcano's eruption had already automatically alerted the West Coast and Alaska Tsunami Warning Center of seismic activity. Since January 11, there have been seven more eruptions, including an eruption to 45,000 feet on January 17.

An Experimental Volcanic Ash Collaboration Tool, developed by NOAA Research's Global Systems Division, was used in real-time by NOAA and U.S. Geological Survey staff to evaluate the location, extent and movement of ash. With over 100 volcanoes, Alaska has 80 percent of all active U.S. volcanoes and eight percent of active volcanoes world-wide. Our thanks to Sam Albanese in Anchorage, who coordinated the emergency response before and during the eruptions and facilitated the creation of the NWS Augustine website (http://www.volcano.gov). This one-stop site has become a popular resource for local, state and federal officials and the media. Many thanks also to Joey Carr, Tony Hall, Bob Hopkins, Kristine Nelson, Jeffrey Osiensky, Greg Pratt, and Barbara Stunder. http://aawu.arh.noaa.gov/vaacdesc.php"

8. Publications:

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
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. FX-Collaborate investigative research will focus on the following areas for the TMU project:

--Use of the FX-Collaborate systems to facilitate research collaboration between forecasters and researchers at separate locations.
--Research, design and development of a java-based tool for creating CWAs.
--Research into the collaborative spatial and temporal ARTCC boundary aspects of CWAs.

2. Research Accomplishments/Highlights:

During the 2005/2006 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, version 2.30. The FXC FAA, TMU and FXC VACT projects all share a common code base. For a complete description of what was involved in the creation of the FXC TMU 2.30 release, please refer to the FXC VACT project description.

In addition to the above port to the new FXC TMU 2.30 system, the following software maintenance and enhancements were accomplished. All of our Web services were moved behind the new Application Shield system. This was installed at GSD to protect against Internet Web site attacks. All of the AWIPS 5.2.2 TMU code base and FXC TMU 2.0.0 code has been successfully ported to AWIPS OB6 and FXC 4.0.0. Research was completed on NCWF2 product integration into the AWIPS FXC TMU

2.30 system and the TMU website was upgraded to handle the NCWF2 Graphics used in Fort Worth. SID and STAR map backgrounds were created for the ZFW airspace. Logic was added to automatically enable/disable the CCFP product since this is only available seasonally. The TCHP animation page was redesigned and the TMU home page was redesigned to fit the display.

Version 2.2 of the TMU website that contained the NCWF2 graphic products was released for evaluation. The BufrDriver (responsible for decoding NCWF BUFR products), Flight Message Decoder was continually restarting. ASDAD developers had found problems with the AWIPS BUFR decoder during our development efforts on integrating the NCWF products into AWIPS for the TMU project. ASDAD was able to convince the AWIPS development team that changes were required to the baseline AWIPS code in order to handle the NCWF product suite. After merging our code base into the AWIPS OB6 baseline, we found that the BUFR decoders would fail during the NCWF decoding process. We found that AWIPS developers at NWS had commented out the code and weren't testing or verifying that the BufrDriver could still successfully decode NCWF. We worked with NWS developers to get our fixes back into the AWIPS baseline code.

A localization problem where our map backgrounds for our TMU scales were not being generated properly was corrected. Currently, all AWIP map background files reside on the NOAA1 database.

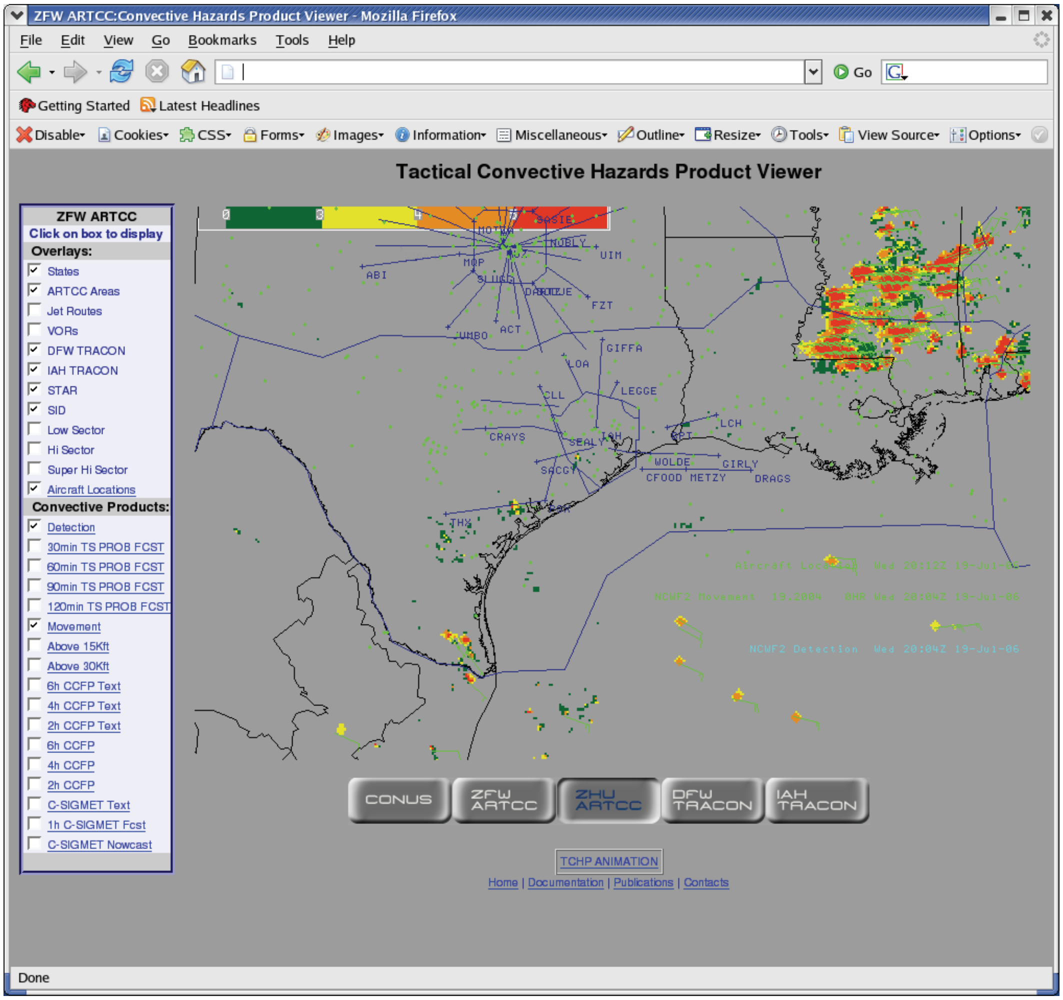


Fig. 4. Figure shows some of the enhancements to the TCHP web page; NCWF2 Detection, Movement, Aircraft Location Data with STAR and SID Maps.

These added capabilities, along with general software maintenance, hardening, bug fixes and enhancements, describe the changes to the FXC FAA and TMU project software during 2005/2006.

The goal of the TMU website is to consolidate all tactical aviation weather hazards information into a suite of products for presentation to TMU decision-makers in an easily understood format. (Much like what was done for the TCHP). The TMU project will capitalize on development of advanced products from the AWRP and optimize the use of conventional advisories. Feedback from the ZFW Traffic Management Unit and Center Weather Service Unit participants will help refine the content and presentation. The Demonstration and Evaluation (D&E) will expedite fielding of advanced products by obtaining operational input early in the process. When there is agreement between the participants that a satisfactory product has been created, specific recommendations will be made for national implementation on FAA operational systems such as the Volpe National Transportation Systems Center Enhanced Traffic Management System.

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.

Objective: The AWIPS/FXC/TMU system will be enhanced with meteorological datasets to improve the detection and prediction of aviation hazards. The range and focus of this research includes model data, enhanced maps, GIS, impact databases, and product Generation tools and investigation of interagency collaboration.

Status:
(Completed)
--Major core AWIPS software upgrades and ASDAD ports ver 522 to OB6
--Major core FXC software upgrades and ASDAD ports ver 200 to 400
--TCHP products with NCWF2 and related development-- New FAA CD map backgrounds

(In Progress)
--TMU archival playback
--Research and Develop TS CWA Creation Tool.
--Geographic on/off impact databases of runways, jet routes and sectors.
--Research and Develop Red/Green light grid approach to TMU Web site
--Extend TMU Web presence to include Alaska and Chicago
--Research and Develop application approach to TMU web capabilities.
--Continued Research on CWA Creation tool
--Develop international SIGMET displays.

(Yet to be started)
--Research and Develop interface for displaying URLs based on types (Weather CAMS, VAAC Images ...)
--Research and Develop TS CWA display.
--Automated TMU Products for icing. (CIP/FIP, PIREPs, AIRMETs, SIGMETs, CWA's, RUC 40km, IIFA)
--Research and Develop approach for adding FXC language translation tools
--Cloud top interrogation database

4. Leveraging/Payoff:

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

6. Awards/Honors:

7. Outreach:

8: Publications:

C. Forecast Verification

Project Title: Real-Time Verification System (RTVS)

Principal Researcher: Sean Madine
Team Members: Dale Betterton, Nick Matheson, Melissa Petty, and Chris Steffen

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.

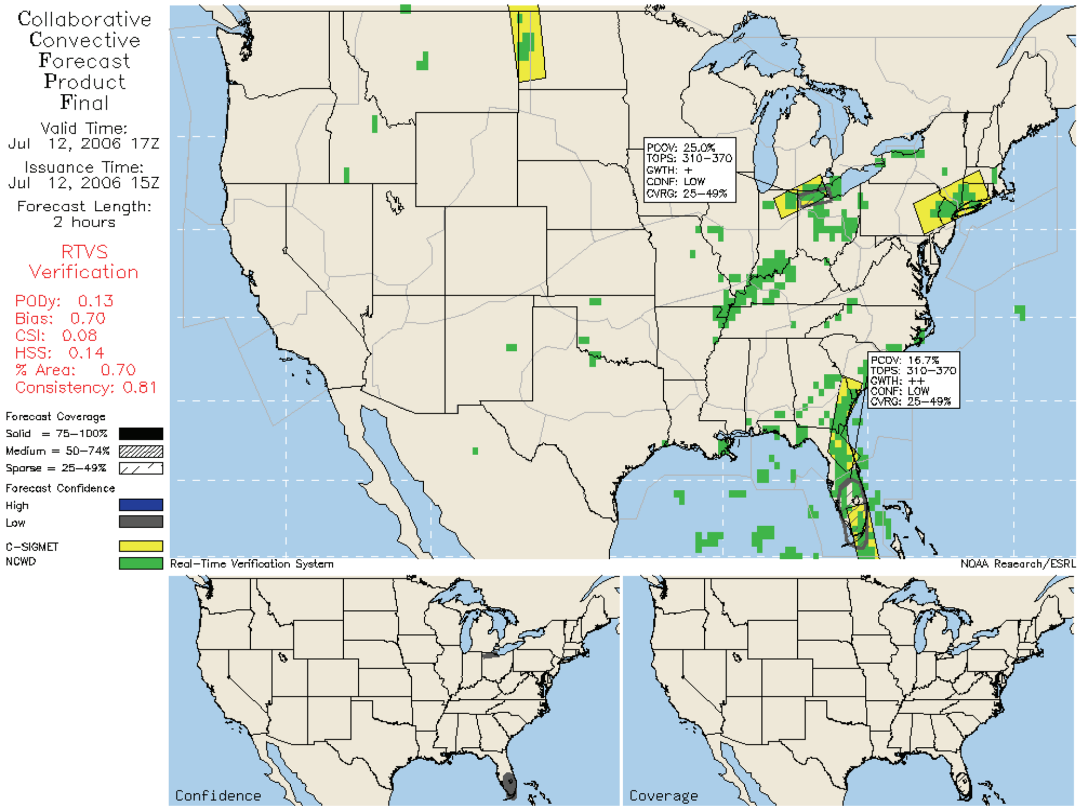


Fig. 1. Example of RTVS verification of the Collaborative Convective Forecast Product (CCFP), a human-generated strategic forecast issued by the NWS/AWC. This is just one of many forecast and analysis products evaluated by RTVS.

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) Quality Assessment of the National Convective Weather Forecast Version 2 (NCWF2)

The CIRA team significantly contributed to the quality assessment of the latest tactical convective forecast product (NCWF-2) developed by the FAA's Convective Product Development Team. The evaluation report, presented to a formal technical review panel, provided an inter-comparison of NCWF-2 with other operational convective forecast products. In addition to the traditional measures, the analysis included a probabilistic assessment of the products. Based strongly on the results of the collaborative analysis, the FAA technical reviewers decided to make the NCWF-2 product available in formal operations, improving the information accessible by tactical decision makers.

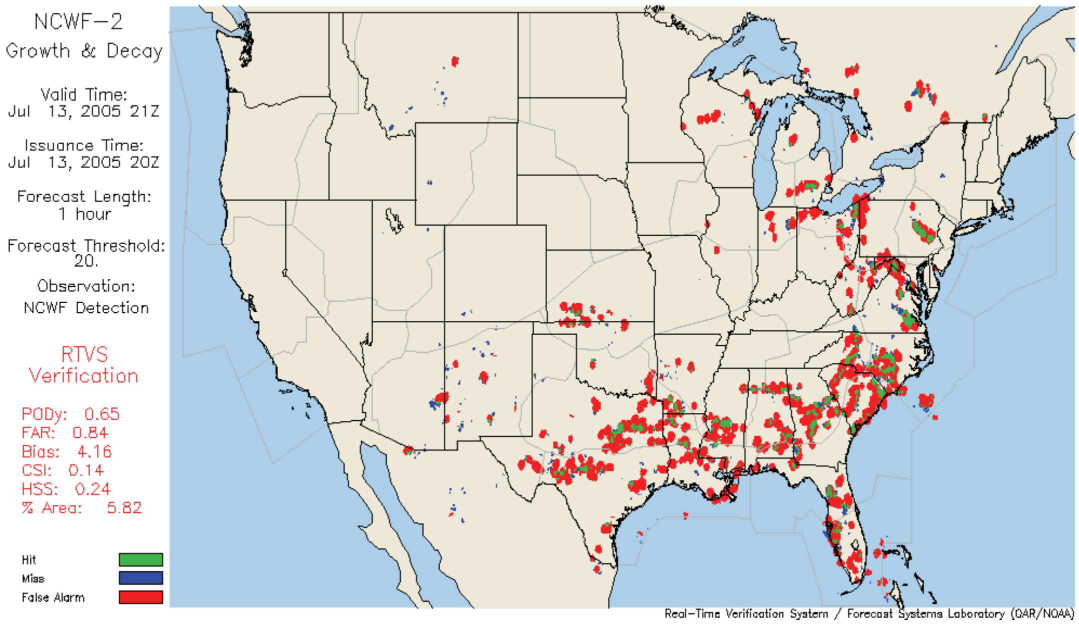


Fig. 2. Example of the verification of NCWF-2, a product that was assessed by CIRA researchers and subsequently moved to evaluation in an operational setting.

b) Design and Development of Processing System for Verification of Turbulence Forecasts

In support of an operational evaluation of the second version of the Graphical Turbulence Guidance product (GTG-2) produced by the FAA's Turbulence Product Development Team, the CIRA team designed and developed a verification data processing system for turbulence forecasts. The system produces statistical plots and graphical displays, which are available via a powerful web interface, using reports of turbulence from aircraft pilots as observations. NOAA collaborators intend to use the system as the primary verification tool in the upcoming formal assessment.

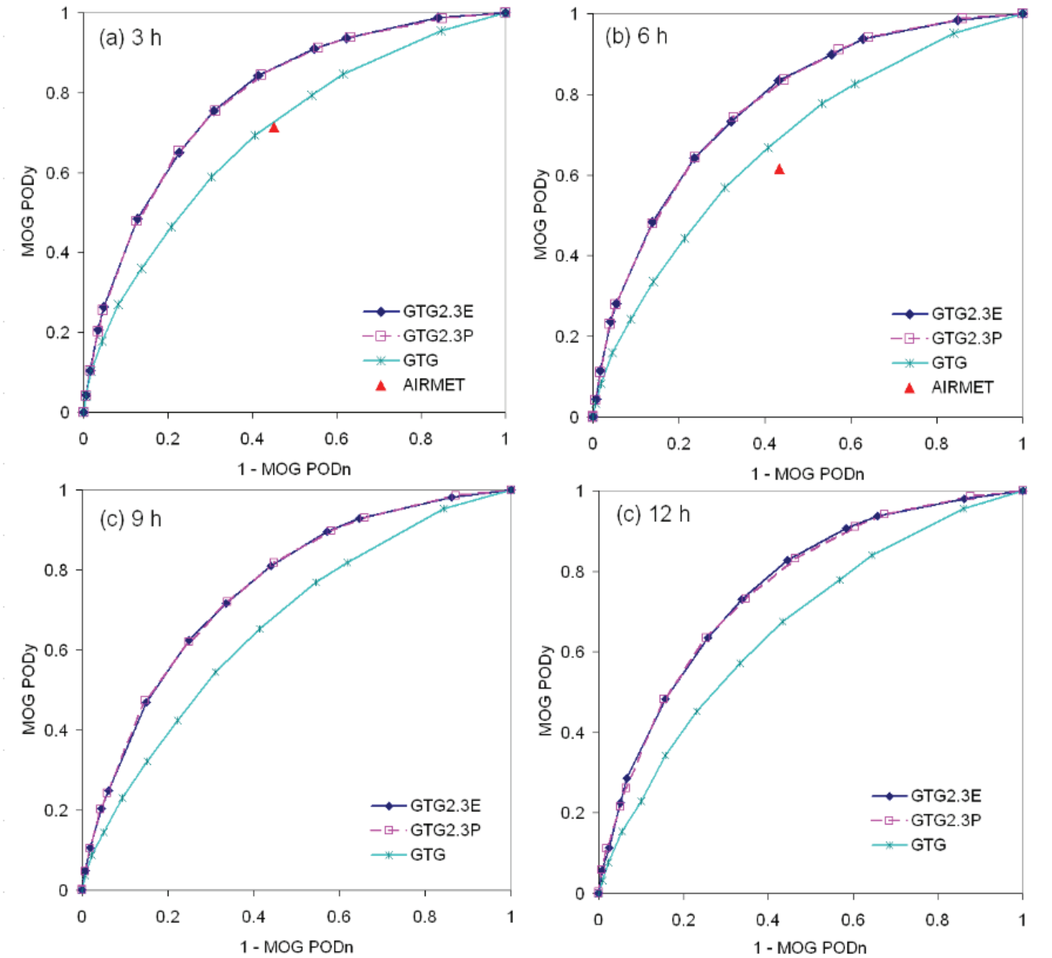


Fig. 3. Examples of ROC curves derived from the turbulence verification processing system, which are used to compare the performance of operational and experimental products.

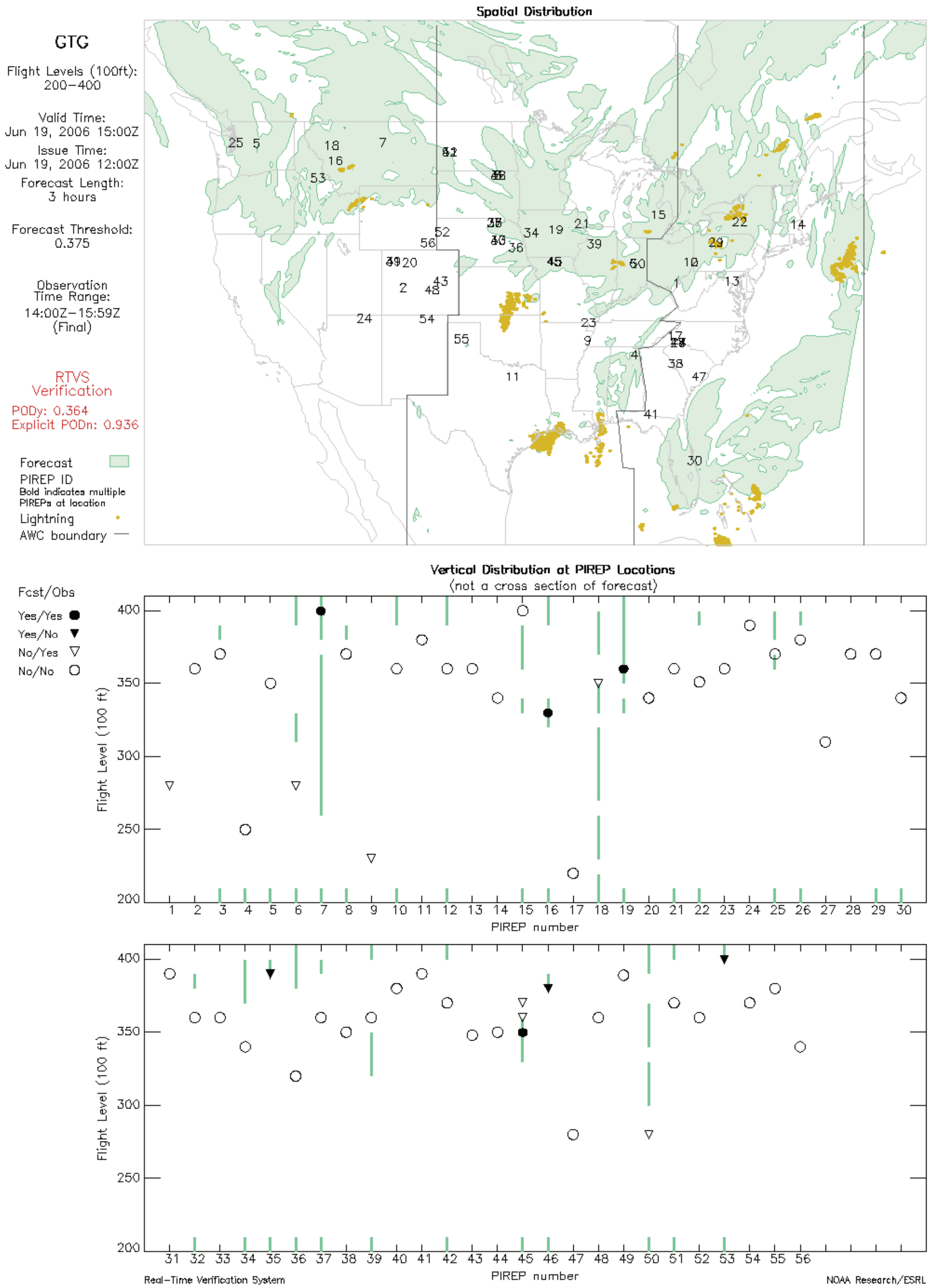


Fig. 4. A graphical display from the RTVS web site providing information about a turbulence forecast (GTG) and associated pilot reports of turbulence.

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 are collaborating with NOAA to develop a lead-time metric for the ceiling and visibility attribute of the Terminal Aerodrome Forecast (TAF). Meaningful computations will be developed that will effectively capture the timeliness of the forecast of a categorical flight rule shift relative to the observed occurrence.

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

CIRA researchers continue 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. This capability, a significant upgrade, aligns very well with the recently elevated NOAA priorities regarding performance evaluation of weather forecasts.

e) User-Based Verification of Convective Forecasts for Aviation

Current verification efforts attempt to include measures reflecting the value of the forecast to the consumers of that information. The CIRA team continued to study the user-based verification of the Collaborative Convective Forecast Product (CCFP) by incorporating the Aircraft Situational Display (ASD), information about the flight tracks of air traffic in the National Airspace System (NAS), into the quantitative skill scores. Researchers gained an understanding of the air traffic flow around important terminals based on historical ASD data from the 2005 and 2006 convective seasons. This will be combined with meteorological metrics to create an overall evaluation of the usefulness of the forecast from the consumer's point of view, ultimately leading to better use of meteorological forecast tools by the strategic air traffic decision community.

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 have tested some aspects during the development of the turbulence verification processing system.

--Objective: Evaluation of system optimization in the context of large geophysical data set processing and research of strategies for data management of geophysical observations, diagnostics and forecast products

Status: In Progress. CIRA researchers have created strategies for managing and optimizing access to verification data sets related to turbulence, and ceiling and visibility.

--Objective: Research of verification methodologies related to probabilistic forecast products

Status: In Progress. The CIRA team has effectively evaluated probabilistic convective forecasts such as NCWF-2 and CCFP for the FAA decision makers.

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

Status: In Progress. Researchers have examined the potential use of CloudSat products for verification of aviation products.

--Objective: Research of operationally relevant verification measures that incorporate Aircraft Situational Display (ASD) data

Status: In Progress. The CIRA team gained an understanding of the air traffic flow around important terminals based on historical ASD data from the 2005 and 2006 convective seasons.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

CIRA researchers in the RTVS group collaborated and/or partnered with the following organizations during the 2005-2006 fiscal year:

--Federal Aviation Administration (FAA)
--National Weather Service (NWS)
--National Center for Atmospheric Research (NCAR)
--National Environmental Satellite, Data, and Information Service (NESDIS)
--Cooperative Institute for Research in the Environmental Sciences (CIRES)

6. Awards/Honors:

7. Outreach:

8. Publications

Madine, S., M. Kay, and J.L. Mahoney, 2006: Comparing the FAA Cloud Top Height product and the NESDIS/CIMSS Cloud Top Pressure product in oceanic regions. *12th Conf. on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, P1.22.

Seseske, S.A., M.P. Kay, S. Madine, J.E. Hart, J.L. Mahoney, B. Brown, 2006: Quality Assessment Report National Convective Weather Forecast 2 (NCWF-2). *NOAA Technical Memorandum OAR GSD-33*, Forecast Systems Laboratory, Boulder, CO, 23pp.

III. Research Collaborations with the GSD Information & Technology Services

Project Title: Data Systems Group (DSG) Research Activities

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

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, computer services, and on-line storage.

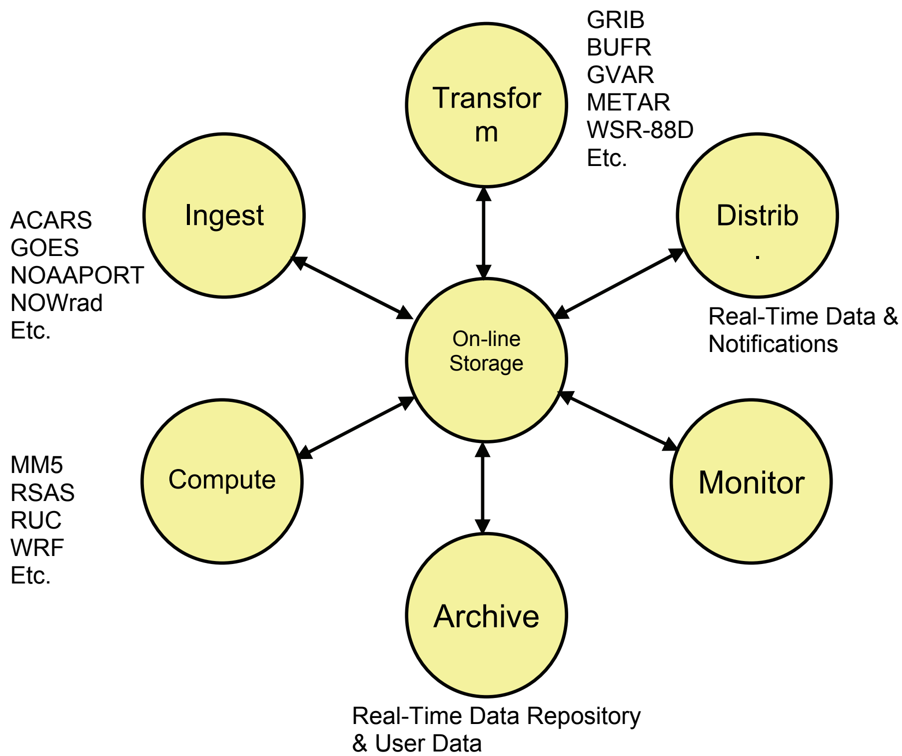


Fig. 1. Central Facility Services Provided by ODS

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

Design and development for new and modified 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:

--Replaced 16 Central Facility end-of-life servers with systems that will provide better reliability and scalability
--Implemented new Unidata Local Data Manager (LDM) farm
--Implemented new Central Facility LDM hub
--In support of the GPS Meteorology (GPS-MET) project, added monitoring, documentation, and data distribution
-- In support of the Science on a Sphere (SOS) project, added monitoring and documentation for the MTSAT data set from the Taiwan Central Weather Bureau, and added data ingest for a global precipitable water data set from the National Environmental Satellite, Data, and Information Service (NESDIS)
--In support of the FX-Net project, implemented a data ingest and transport method to acquire Fire Weather products
--Implemented Geostationary Operational Environmental Satellite-11 (GOES-11) data acquisition
--Assisted the Rapid Update Cycle (RUC) modeling team in transitioning resolution from 20 km to 13 km
--Data transformation
- Updated rawinsonde observation (RAOB) decoder
- Updated METAR decoder to handle global METARs
- Developed Java version of the Man-computer Interactive Data Access System (McIDAS) to Advanced Weather Interactive Processing System (AWIPS) compatible netCDF decoder
- Updated Terminal Aerodrome Forecast (TAF) decoder

-- Real-Time Verification System (RTVS)
- Configured Advanced Regional Prediction System (ARPS) model data ingest and distribution
- Updated configurations to handle new turbulence and ceiling/visibility data sets.
- Configured ingest and processing for National Convective Weather Forecast-6 (NCWF-6) products from the National Center for Atmospheric Research (NCAR)

--Meteorological Assimilation Data Ingest System (MADIS)/ RUC Surface System (RSAS)
- Transitioned the Cooperative Agency Profiler (CAP) data ingest and processing from the NOAA Profiler Network (NPN) environment into the Central Facility.
- Implemented new MADIS hardware (see Figure 2)
- Implemented Lightweight Directory Access Protocol (LDAP) server to manage data distribution accounts
- Added University of Alabama, Huntsville radiometer data
- Upgraded monitoring for the Polar Operational Environmental Satellite (POES) data
- Updated NOSPORTS/NOS-NWLON mesonet processing
- Updated MOComAgNet mesonet processing
- Implemented new HADS mesonet processing

○ Added new Mesonets
- AFA
- CoCoRaHS
- CODOT2
- CWOP-snow
- GADOT
- GLOBE
- Georgia DOT
- MDDOT
- MesoWest snow data
- MQT-Meso
- NEDOR
- NonFedAWOS network
- OHDOT
- PCDINPE
- VADOT
- VTDOT
- SFWMD
- WYDOT

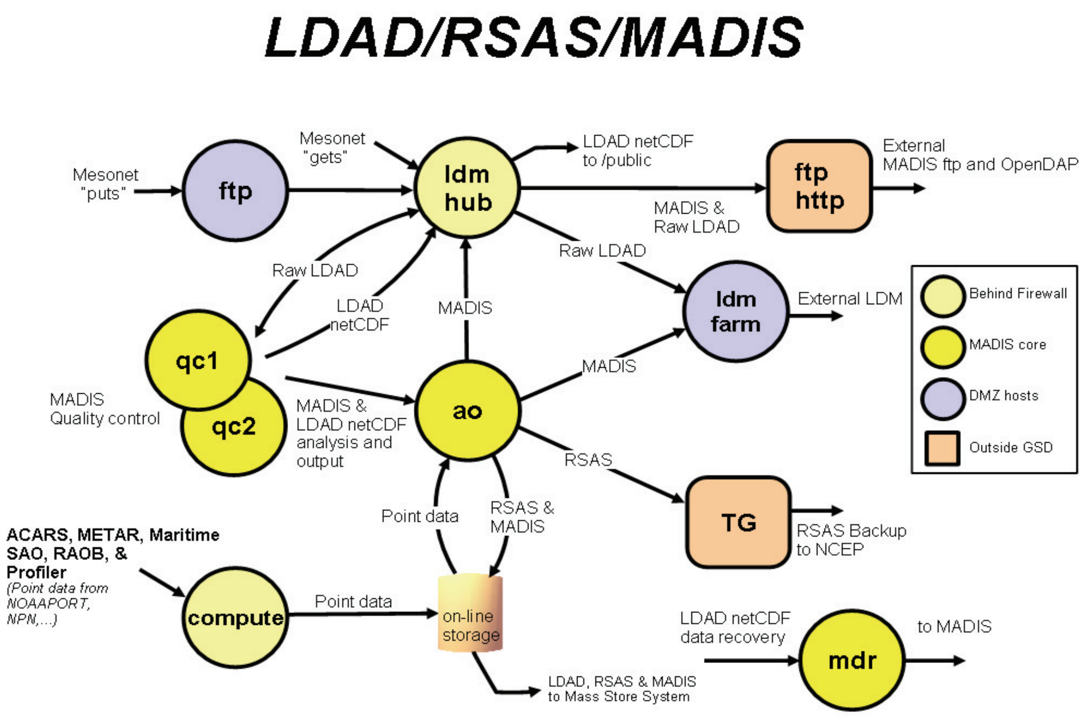


Fig. 2. Local Data Acquisition and Dissemination (LDAD)/RSAS/MADIS Data Flow

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:

6. Awards / Honors:

2005 GSD Web Award for best internal use - GRIB Data Viewer, Glen Pankow

7. Outreach:

8. Publications:

MacDermaid, C. and R. Lipschutz, 2006: Recent updates of the architecture of MADIS data processing and distribution at GSD. *NOAATech 2006.*

IV. Research Collaborations with the GSD Forecast Applications Branch (formerly the FSL Forecast Research Division/Local Analysis and Prediction Branch)

A. Special Projects

Project Title: Forecasting Enroute Turbulence

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

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

All of the following efforts in collaboration with the Senior Scientist Office support NOAA goal to "Serve Society's Needs for Weather and Water Information/Local Forecasts and Warnings." The aircraft turbulence detection and the Great Lakes Fleet Experiment/TAMDAR projects also support NOAA's goal to "Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation." In addition, the Hourly Precipitation Data Quality Control and the Atmospheric Trend Analysis of Rawinsonde Data projects also support NOAA goal to "Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond/Climate Observations and Analysis."

Key Words: Aircraft turbulence detection

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

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.

The Bow Echo and MCV Experiment (BAMEX) was conducted May 20 - July 6, 2003 in the Great Plains. Highly mobile observation platforms were used to examine the life cycles of mesoscale convective systems and represented a combination of two related programs to investigate bow echoes, principally those which produce damaging surface winds and last at least 4 hours and larger convective systems which produce long-lived mesoscale convective vortices (MCVs).

The Graphical Turbulence Guidance (GTG) Situation-Dependent Turbulence program examines the performance of the GTG turbulence predictors from the RUC model in various synoptic situations. CIRA researchers are part of this ongoing project to try to improve the GTG algorithm. GTG is actually a collection of many different algorithms developed over the years at ESRL/GSD, NCAR, and other centers. The current effort is examining the possibility of using an assessment of the synoptic conditions to determine more advantageous weights for the various algorithms within GTG. Eventually, the hope would be to codify the synoptic environments so that the determination of weighting factors could be done automatically.

2. Research Accomplishments / Highlights:

Preliminary results from BAMEX case studies were presented at the American Meteorological Society's 2006 Annual Meeting in a paper entitled: "Turbulence in MCS anvils: Observations and analyses from BAMEX" as part of the 12th Conf. on Aviation, Range, and Aerospace Meteorology.

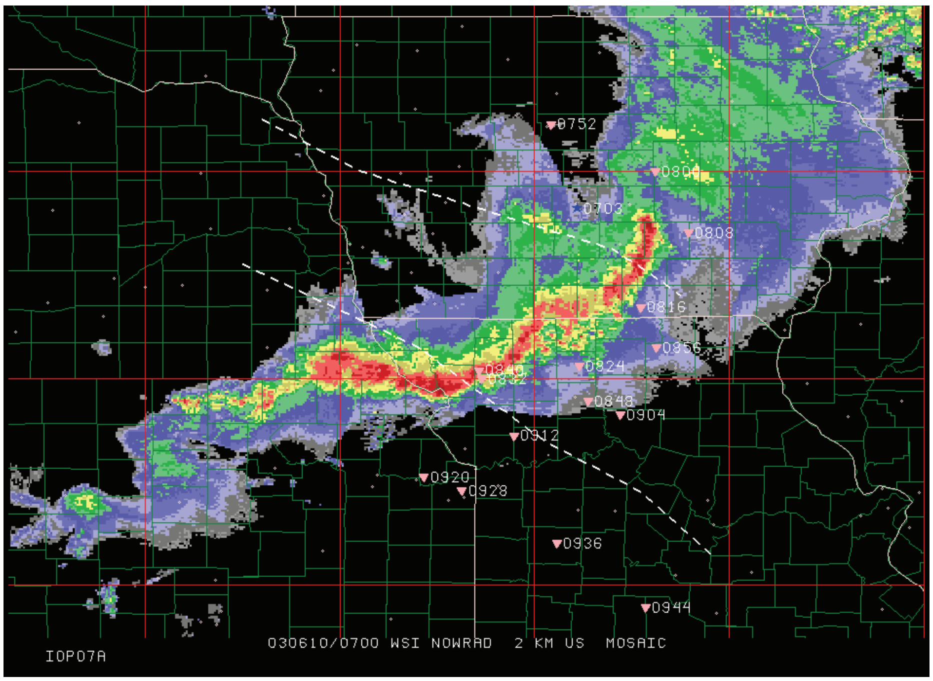


Fig. 1. Radar image of 10 June 2003 squall line.Triangles indicate location of research aircraft dropsonde observations.

Specifically, the capability to reformat and quality control research aircraft data was completed, along with development of diagnostic techniques and display visualizations that permitted detailed examination of the BAMEX data set. The BAMEX analyses yielded a better understanding of the meteorological environment in the vicinity of convection that may be indicative of turbulent regions. Examination of the 10 June 2003 case suggests both the feasibility and the potential value of quadrant analyses toward the development of knowledge and schemes leading to improved forecasts of turbulence near and within upper and mid-tropospheric MCS anvils.

The GTG tasks are multi-year in nature and substantial results are expected in FY07.

3. Comparison of Objectives:

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Collander, R.S., E.I. Tollerud, B.D. Jamison, F. Caracena, C. Lu, and S.E. Koch, 2006: Turbulence in MCS anvils: Observations and analyses from BAMEX. *12th Conf. on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, P7.1.

Project Title: <u>WRF Developmental Testbed Center (DTC)</u>

Principal Researcher: Randy Collander

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

Key Words: Weather Research and Forecast Model, Rapid Refresh, Gridpoint Statistical Iinterpolation

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

The Weather Research and Forecasting Rapid Refresh (WRF-RR) numerical model will be implemented in 2007, and went through preliminary testing from 2003-2005 with twice-daily real-time testing of the WRF-ARW model using RUC initial conditions. In FY06, testing began with the WRF-NMM as another possible alternative for the Rapid Refresh model. The Rapid Refresh will use a version of the NCEP-developed Gridpoint Statistical Interpolation (GSI), with RUC-specific enhancements (e.g., cloud analysis, use of surface observations) but also take advantage of the extensive capability for satellite radiance assimilation in the GSI. The domain is about 2.6 x larger than the RUC CONUS domain, expanding to include coverage of Alaska, Puerto Rico, the Caribbean, and most of Canada. It will provide a common, hourly updated mesoscale analysis and model forecast over the full North American area, and a common basis for subsequent aviation products over this larger region. The horizontal resolution will be about 13 km, the same as the current RUC. While the Rapid Refresh will use a version of the WRF model, its physical parameterizations will be similar to those used successfully with the RUC, including the mixed-phase cloud microphysics parameterization developed largely by NCAR for improved depiction of supercooled liquid water. The Rapid Refresh, like the RUC, will continue hourly cycling of full 3-d hydrometeor fields correcting previous 1-h forecasts with satellite cloud and METAR cloud observations and adding radar reflectivity.

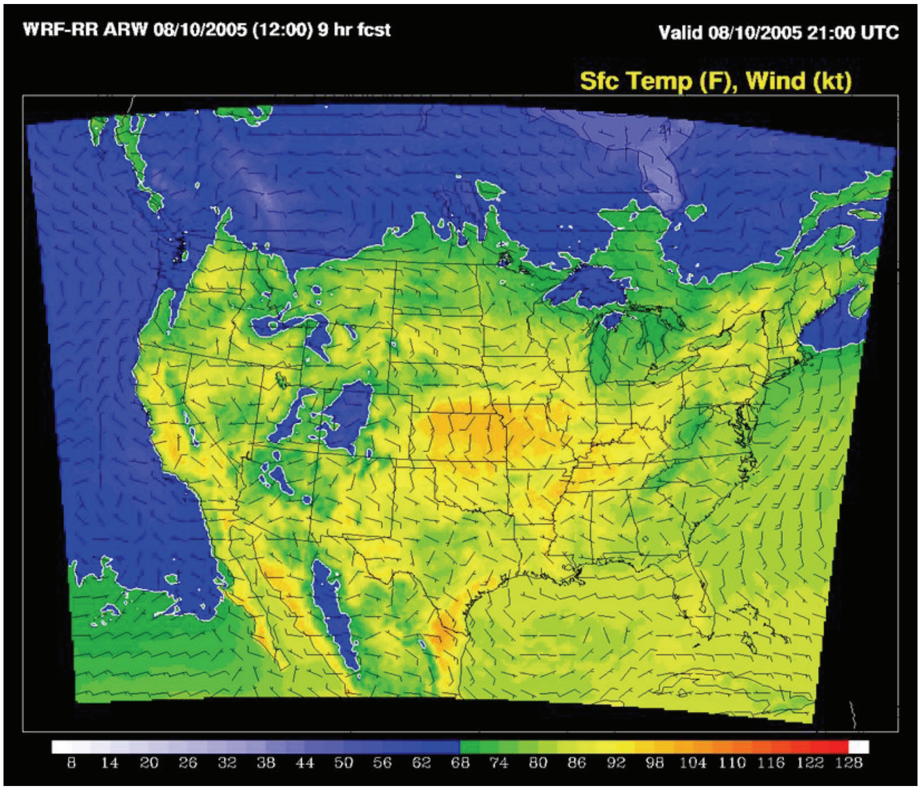


Fig. 2. 9-hour WRF-RR temperature forecast valid at 2100 UTC 10 August 2005 from the WRF-RR model using the ARW parameterization.

2. Research Accomplishments / Highlights:

To aid in evaluation of the model output, graphical representations of model output parameters were generated for 30-day study periods in each of the four seasons. The scripts used to generate the images, as well as the web site for access and display, were created through modification of those used in the DTC Winter Forecast Experiment (DWFE) from FY05. Capabilities of the web site were expanded to include display of images from the RUC-13 and the ability to compare ARW- and NMM-based images in a side by side or tiled fashion. Numerical modelers and other meteorolgists were able to use the images to easily locate anomalies and closely scrutinize differences in the ARW and NMM cores and make definitive determination as to the most accurate choice for ultimate inplementation. The web site may be viewed by pointing to http://bolas.fsl.noaa.gov/mab/wrfrr .

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

In progress.

4. Leveraging/Payoff:

5. Research Links:

6. Awards/Honors:

7. Outreach:

8: Publications:

Project Title: <u>Atmospheric Trend Analysis</u>

Principal Researcher: Randy Collander

NOAA Project Goal / Program: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings; Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate observations and analysis

Key Words: Climatological Temperature Trends, North American Rawinsonde Network

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

Quantifying current atmospheric temperature trends is key to identifying and understanding potential future global climate changes. Scientists in the ESRL Global Monitoring Division (formerly Air Resources Laboratory) perform extensive studies of temperature trends seen in observational data over North America (and globally). One data set of particular interest is the North American Rawinsonde network data that dates from approximately 1948 to the present.

2. Research Accomplishments / Highlights:

Using extensive experience in the development and analyses of high-quality data sets, specifically for upper-air observations, statistical and other analyses were performed in collaboration with Dr. Betsy Weatherhead and others to further our understanding of climate change and humanities role in these changes.

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

In progress.

Project Title: Hourly Precipitation Data Quality Control

Principal Researcher: Randy Collander

NOAA Project Goal / Program: Weather and Water—Serve society's needs for weather and water information / Local forecasts and warnings; Climate—Understand climate variability and change to enhance society's ability to plan and respond / Climate observations and analysis

Key Words: Precipitation observation quality control

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 scrutinization during daily manual evaluation and case studies. Fig. 1 provides an example of a daily quality-controlled hourly rainfall gauge reports.

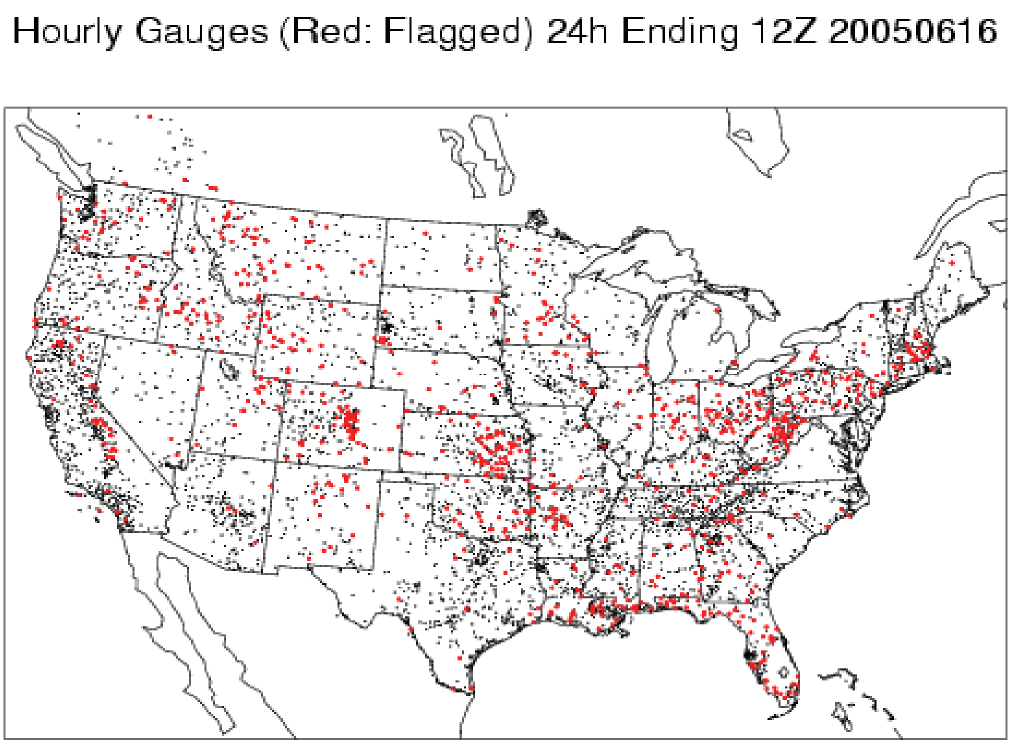


Fig. 1. Good (black) and bad (red) hourly gauges determined by the automated QC system for 16 June 2005.

2. Research Accomplishments/Highlights:

In FY06, consultations with the EMC continued on a limited basis. The refined criteria was applied to individual observations and daily totals as well as subjective evaluation of station performance during the preceeding 30 day period. Listings of stations which passed or failed the criteria were used in the Real Time Verfication 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 (report 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:

In progress.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Tollerud, E.I., R.S. Collander, Y. Lin, and A. Loughe, 2005: On the performance, impact, and liabilities of automated precipitation gauge screening algorithms. *21st Conference on Weather Analysis and Forecasting*, 1-5 August 2005, Washington, D.C., Amer. Meteor. Soc.

Tollerud, E., T. Fowler, B. Brown, and R. Collander, 2005: Assessing the impact of systematic observation errors on climate and operational precipitation analyses. *Preprints, 15th Conference on Applied Climatology*, 19-23 June 2005, Savannah, GA., Amer. Meteor. Soc.

B. Forecast Applications

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 #3, 6, 11, 12, 15, and 16)
- Coasts, Estuaries, and Oceans (for activity #4)
- Hydrology (for activity #12)

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

- Surface Weather (for activity #8)

Key Words: Local Analysis and Prediction, High Resolution Modeling

1. LAPS / WRF Improvements

Participating CIRA Scientists: Steve Albers, Chris Anderson

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. This is outlined in detail below for surface and upper air observations.

Surface Observations

A check was added for identical surface observation station names in subroutine 'check_for_dupes'. If the name is identical, they will be flagged even if the provider or location is different. A code section was correspondingly added to remove stations flagged as identical via a call to subroutine 'init_station', effectively rendering all fields for such stations as missing. Subroutine 'init_station' now sets the expected accuracy to 0, instead of the 'badflag' value to better fit in the intermediate observation file ASCII format.

Additional testing was done ingesting METAR observations from the MADIS datastream and this was found to work well. This should help our users such as the Spaceflight Meteorology Group (SMG).

QC thresholds for SST observations were tightened to help eliminate erroneous data. Soil Moisture observations (in terms of percentage) are now being read in from the LDAD files so we can evaluate their usage further along in LAPS. QC checks were improved for observation time information.

Upper Air Observations

Documentation was updated to explain that boundary profiler data are no longer available via the Demonstration Branch's FTP server. A new set of modules is being developed and tested to access the related Multi-Agency Profiler (as well as RASS) data via MADIS. Some of the RSA ingest routines are being employed for this in the interest of developing more generalized software. Profiler ingest file format is now determined dynamically for greater user flexibility. RASS ingest was enhanced so we can process the NetCDF files supplied via FTP from the Demonstration Branch.

We reworked into separate variables the categorization of ACARS input file format as distinguished from filename format. This helped in the modification of an on-the-fly check of filename convention to cover the situation where we have MADIS ACARS files. In this case, we have WFO style filenames with the NIMBUS file format. Modifications were completed to LAPS ingest software that allow adjustment of the aircraft observation assimilation time window. This supports the PADS (see below) and other projects.

RAOB ingest has been tested and shown to work with the MADIS data feed. Software was streamlined to ensure that empty output files are not written.

We collaborated with former CIRA researcher Brent Shaw (now at WNI) to add the capability to ingest cloud-drift winds from MADIS.

POES satellite sounding ingest has been implemented as requested by our CWB collaborators. Soundings are tagged with a label representing the nearest surface station to each sounding.

Surface Analysis

Space-Time Mesoscale Analysis System (STMAS)

CIRA researchers helped with the high-frequency variational surface analysis development for the Space-Time Mesoscale Analysis System (STMAS) project. Pre-generated analysis web images were improved to facilitate side-by-side comparisons between the experimental and operational versions of the STMAS software. This includes viewing animations as well as customized fields such as surface divergence and vorticity. We conducted tests collaborating with Dr. Yuanfu Xie and John Smart, setting up the STMAS analyses with a large CONUS sized domain. We were able to improve the efficiency of the background model processing allowing the CONUS domain to run in real-time on a 15-minute cycle. A separate LAPS build was set up on EJET that will allow us to freeze the STMAS software during the summer operational period.

We now apply separate QC thresholds for surface dewpoint that are lower than those for temperature. The gross error check now allows values between 120K and 350K for dewpoint. This may help for a case that Brent Shaw showed us for a model background (LGB) file created at Weather News Incorporated (WNI).

Radar Processing

We have worked towards more efficiency and other functional improvements for radar remapping and mosaicing. Various scripts were reworked and integrated providing a new capability for the real-time conversion from WSR-88D Archive-II format to our polar NetCDF files for subsequent LAPS processing. This was done in a way that allows easy switching between real-time and retrospective LAPS runs that utilize Level-II radar data. The radar remapping program is in the process of being cleaned up so that it can properly function on EJET.

Wind / Temperature Analyses

A subroutine called 'calc_qced_obs' was set up to help handle the observation data structures for the parallelized SMS version. This has an added benefit of making the software more modular. Inner (time-consuming) loops of the analyses were streamlined in the hopes of improving LAPS execution times, even for the serial version. A few wind analysis changes were made to simplify the SMS parallelization constructs.

The 'max_obs' parameter was doubled to allow 80000 observations in the data structure. In collaboration with Dr. Yuanfu Xie, the vertical coordinate of observations is now being expressed in fractional values to allow greater accuracy in support of the GSI analysis software testing.

Variable initialization and declaration was cleaned up in the wind analysis in general and in the CWB multiple-Doppler routine in particular.

Cloud / Precipitation Analyses

Array initialization was cleaned up in the derived products subroutine. We split off cloud type and mean volume diameter (MVD) calculations into a separate loop allowing greater flexibility in the setting of cloud layer cover thresholds. In this context, the 'thresh_cvr' variables and 'ibase/top' arrays were renamed to two separate names each, one for each cloud layer loop. These are for the respective loops that work with cloud top / vertical velocity as well as cloud liquid / ice (LWC). This will help allow the cloud fraction threshold for cloud type assessment to be set differently from that used by the microphysical fields as appropriate for downstream "hot-start" purposes.

The Icing Severity Index output file comment info was modified to be consistent with the description of the index values in the subroutine where it is calculated (ISI3).

General Software Improvements & Portability

Scripts were improved that manage the execution of LAPS in a parallel machine environment, using the SMS software package. Purge time of wideband radar data was increased to facilitate real-time radar evaluation. Purging strategy was improved for various other LAPS situations.

LAPS documentation was improved with information about soil moisture and ground temperature analyses. The README was updated to better describe the data flow within LAPS, including a new analysis flowchart provided by the Finnish Meteorological Institute. Radar ingest documentation was improved along with new module diagrams for profiler and RASS ingest. There is now better guidance for users in how to utilize various MADIS data sources as input for LAPS. Use of raw NIMBUS data as well as dropsonde usage is now also better described. Other improvements were made to documentation, error messages, software logging, diagnostics and comments. Some obsolete software was removed as a streamlining effort. Timing routines in the library were reorganized to improve their user friendliness.

Software configuration and portability were improved for newer machines, including those with 64-bit processors. In relation to this, we added C_OPT and F_OPT configuration flags allowing greater compiler flag flexibility; for example, we can set separate optimization flags for C and FORTRAN on 64-bit machines. This mostly supersedes the OPTIMIZATION flag and the new flags can be set depending on tests for the FORTRAN and C compilers. Some LAPS configure changes were made in support of the LAPS Graphical User Interface (GUI) implementation that Paula McCaslin is working on. In relation to this localization, paths were changed to reflect our new disk structure. Other software build scripts were updated to keep in sync with changes in LAPS software, domains, and platforms.

Default settings will now provide model initialization files for the WRF model instead of MM5. The case rerun script was made more generic allowing the passing in of options for various types of cluster machines.

LAPS Implementation

As part of a collaboration with Dr. Isidora Jankov, a real-time domain having 30-km resolution is being run experimentally on a mercator projection covering almost the entire globe (Fig. 1).

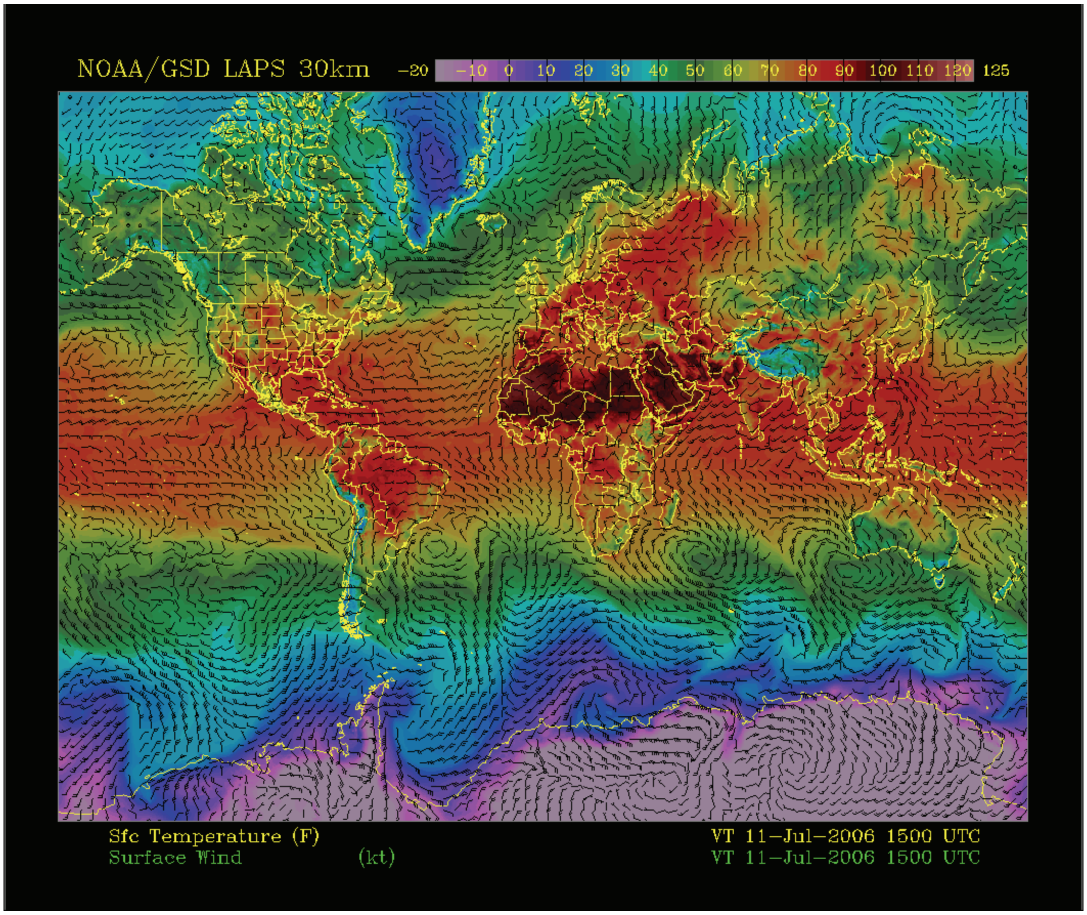


Fig 1. Analyzed surface temperature and wind on a "G-LAPS" 30-km global domain.

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.

WWW LAPS Interface

Individual levels can now be plotted for the soil moisture field while soil temperature and moisture observation plots were cleaned up a bit. Improved ground temperature plotting options (F/C + contour/image) and streamlined the logic along with that for the surface air temperature. Pressure contouring was adjusted and some cross-section station labels were improved. Labeling was improved to be more robust for various kinds of model background, model forecast, and other plots. Plotting labels and other documentation were changed from "FSL" to "GSD" reflecting the lab reorganization. Contour ranges were improved for omega plots. Contour scaling (e.g. logarithmic), plot labeling and logging information were all improved.

Plotting software was refined in several ways to function on the large STMAS CONUS domain. Image generation changes include an option within 'lapsplot' that can make raster image plots, greatly speeding up the STMAS and other images that we've seen taking a long time. Wind barb plots now have more flexible color capability depending on the image background. We also added a surface vorticity image option.

Zoom capability was added to plan view cloud type plots. Plots of analyzed precipitation concentration as well as forecast rain/snow concentration were added. We added forecast fields for cloud microphysical variables and radar reflectivity (plan view). Further adjustments were made on plan view plots of cloud condensate, both analyzed and forecast. Cross-sections were improved to generalize the hydrometeor plots. These now comprise rain, snow, and precipitating ice concentrations. Image displays of various microphysical variables were improved.

For the pre-generated analysis plots, we now use balanced heights for the 'H5B' product to accompany the balanced winds.

Scripts that manage the creation of pre-generated analysis web images were given added functionality so that they can work on our EJET cluster. The on-the-fly web page scripts were updated in the repository.

Mesoscale NWP Model Initialization and Evaluation

Two major new advances were made in the suite of modeling capabilities at GSD. First, the NCEP WRF model, NMM, was modified to permit LAPS diabatic initialization. This required modifying initialization codes of the WRF source. This modified code has been run in real-time over the Colorado region, and it has been shared with Bob Rozumulski who provides WRF software to NWS/SOO.

Second, we have pulled together multiple mesoscale models (WRF-ARW, WRF-NMM, MM5, RAMS) in order to generate ensemble forecasts. Scripts were written to ensure that each model is run in real time and initialized with LAPS diabatic initialization. Probabilistic output is generated by combining the forecasts from this group of models and by including past forecasts. Ensemble forecasts have been generated in real-time and displayed on AWIPS for the NWS Boulder office. Example of the ensemble forecasts, of both mean ensemble and ensemble probability are shown in Figs. 2a and 2b.

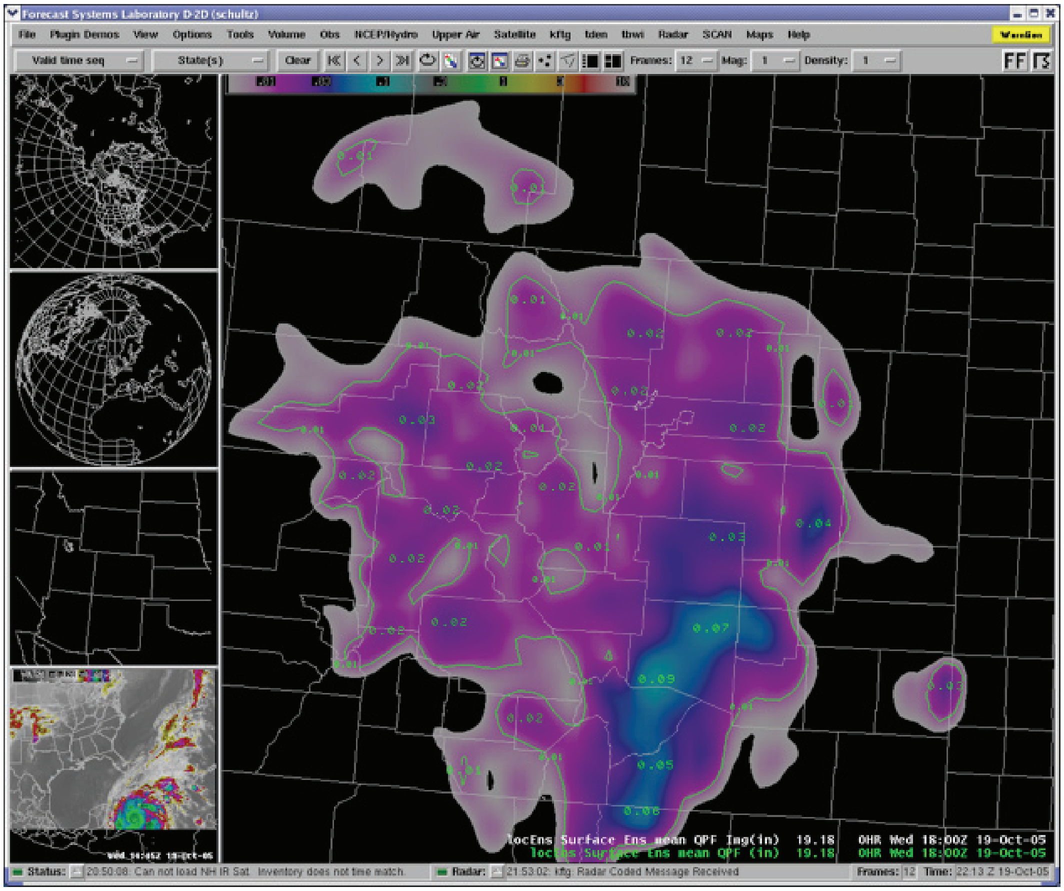


Fig. 2a. Example of ensemble mean precipitation product displayed on AWIPS over the Colorado domain.

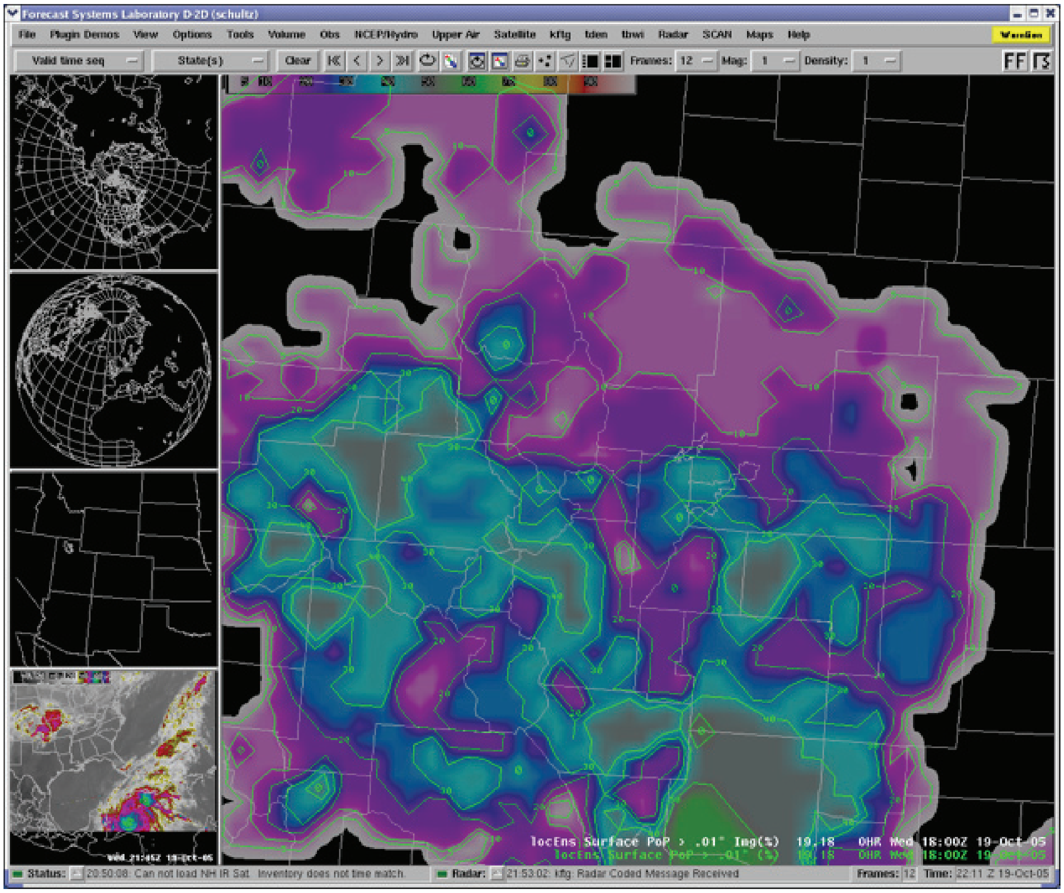


Fig. 2b. Fraction of ensemble members exceeding 0.01" displayed on AWIPS over the Colorado domain.

A full evaluation of ensemble forecasts produced in support of the Hydrometeorological Testbed has been conducted, and the results have informed an ensemble composition that will be run in real-time and distributed to Monterrey WFO, Reno WFO, and Sacramento WFO during next year's Hydrometeorological Testbed field project (Dec 2006 - Mar 2007).

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

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. Accepted by *Wea. and Forecasting.*

Koch, S., Y. Xie, J.A. McGinley, and S. Albers, 2005: Nowcasting applications of the Space-Time Mesoscale Analysis System. *21st Conf. on Weather Analysis and Forecasting*, 1-5 Aug 2005, Washington, D.C., Amer. Meteor. Soc., CD -ROM, P1.44.

Xie, Y., S.E. Koch, J.A. McGinley, S. Albers, and N. Wang, 2005: A sequential variational analysis approach for mesoscale data assimilation. *21st Conf. on Weather Analysis and Forecasting*, 1-5 Aug 2005, Washington, D.C., Amer. Meteor. Soc., CD-ROM, 15B.7.

2. Geostationary Orbiting Environmental Satellite (GOES) Project

There was no specific funding to carry out GOES activities during this past fiscal year. Other analysis runs relating to IHOP are discussed in Section 10.

3. Range Standardization and Automation (RSA) Project

Participating CIRA Scientists: Chris Anderson and Steve Albers

We continued to support the LAPS/MM5 shadow runs at GSD. This included assisting with software installation testing during GSD visits by Lockheed-Martin (LM). To facilitate the new testing methods, we developed a strategy to restore our developmental LAPS shadow-run following LM's installation checkout. We also gave support both remotely and on-site for Eastern and Western Range LAPS/MM5 runs.

Software testing was done on our shadow runs to assess coastal surface analysis artifacts related to the land/sea observation weighting function. Based on this we are returning to the strategy of using the nearest grid-point to determine the land fraction associated with a given station. Fig. 3 shows one of our hourly analysis fields.

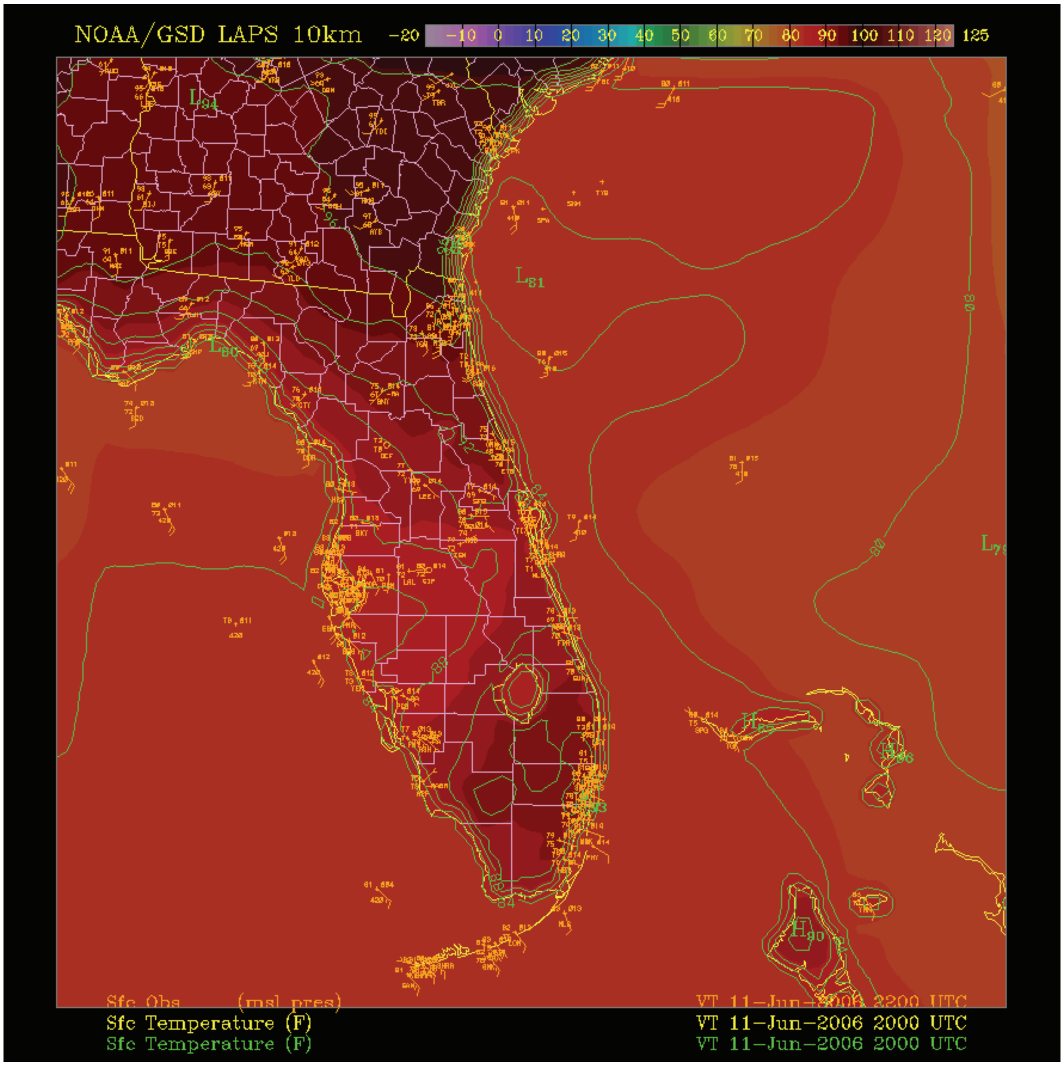


Fig. 3. Surface temperature as shown in an hourly LAPS analysis of the Eastern Range.

Discussions are underway about how to incorporate soil moisture observations into LAPS analyses and forecasts. One aspect of this is that LAPS sounding ingest is being enhanced so that it can process soil moisture observations from the meteorological towers.

We improved the MM5 code for compatibility with upgrades to OS and cluster communication software. We also contributed to a white paper describing new weather forecasting capabilities that could be obtained by upgrading the weather forecast model to WRF. We gave a presentation on RSA LAPS/MM5 status at the annual Technical Interchange Meeting (TIM) held during June in Boulder.

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

Awards/Honors: Project accomplishments were recognized with the 2005 NOAA Technology Transfer Award.

4. <u>Coastal Storms Initiative</u>

Participating CIRA Scientist: Chris Anderson

The Coastal Storms Initiative (CSI) is a project sponsored by the National Ocean Service and managed by the NWS Office of Science and Technology to perform a proof-of-concept for local data assimilation and NWP within a NWS Forecast Office. CIRA staff set up, configured, and tested the new Weather Research and Forecast (WRF) model on a Linux cluster installed at the Jacksonville, FL, forecast office in early 2003. During the past year, we continued to provide support on an as needed basis to keep the runs functioning properly. We also provided software to Bob Razamulski to allow his SOO distribution of WRF-NMM to couple with LAPS diabatic initialization.

This is pretty much in line with the stated goals given the level of funding that was realized.

5. <u>WINDPADS (Precision Airdrop)</u>

Participating CIRA Scientist: Steve Albers

Research has continued to make the LAPS aircraft data time windows more flexible to accommodate the PADS requirements. We also supplied an updated set of LAPS software to the Draper Laboratory that they were able to port to a Windows environment. They have sent us back a modified version for study and possible merging back into the LAPS software repository.

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

6. <u>Taiwan Central Weather Bureau (CWB)</u>

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

We performed some initial staging of the parallelized version of the LAPS wind analysis both at GSD and on a CWB Linux cluster using SMS. We tested newly developed software to ingest MADIS POES satellite soundings into the intermediate LAPS sounding database. We also evaluated how the new Japanese weather satellite MTSAT is performing within the LAPS cloud analysis.

We consulted with Shiow-Ming Deng (from CWB) and Dr. Yuanfu Xie on several aspects of setting up the Gridpoint Statistical Interpolation (GSI) option for the LAPS analysis. This included making the raw CWB observational data available to our large cluster computer (EJET) and setting up test domains on that machine, including a comparison of the GSI and operational LAPS versions. In connection with this, the LAPS real-time scheduling script was enhanced to more easily allow the GSI analysis option. A Makefile was updated to help allow the GSI software to be integrated into LAPS.

We collaborated with the CWB to add improved flexibility of the tropical cyclone bogusing software in handling both real-time and archived datasets. LAPS timing scripts were improved based on CWB recommendations. We also added the ability to ingest wind data from CWB rawinsondes into LAPS analyses. Updates were made to ensure that the surface synoptic observations from mainland China can be ingested into LAPS. We collaborated with Wen-ho Huang of the CWB to incorporate a new version of the dropsonde ingest software into LAPS.

We worked closely with Yun-Tsai Lin to develop a streamlined methodology for retrospective forecasts and case studies (including analyses). This required building a directory structure separate from the real-time shadow forecasts, and updating scripts so that they could accommodate multiple data sets simultaneously. Yun-Tsai Lin proceeded with examination of 6 case study events to determine the optimal parameterization suite for QPF over Taiwan. We followed up with another study examining the computational speed of the parameterization packages. After all was said and done, we were able to determine an optimal combination for their operational demands.

We supplied Taiwan CWB with a copy of the WRF-NMM code, coupled to LAPS, prior to its general release by NCAR. We also set-up and maintained 5-km WRF shadow forecasts.

This year's training activities with the CWB involved a visit by three CWB meteorologists to GSD in early December (one is the head of the CWB operational forecast branch). The training consisted of two days at GSD with an overview of various projects, but the main theme was their desire to learn more about operational marine and tropical forecasting in the United States. With this in mind, the remaining part of their visit was spent in Miami, Florida, visiting the following NOAA sites: the Hurricane Research Division, the Tropical Prediction Center, and the local Miami Weather Forecast Office (WFO).

We also showed them the Integrated Forecast Preparation System (IFPS). This system is being used at all Weather Forecast Offices in the National Weather Service to create gridded and text forecasts, and may be implemented in the future at the CWB. The CWB meteorologists spent two weeks at FSL in extensive training.

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

7. AWIPS Support to the NWS

Participating CIRA Scientists: 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 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. The graphical product monitor was made more robust and was configured to operate on-site at LAPS/AWIPS installations. Our observation blacklist was 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 joint presentation on the March 2003 massive winter storm at UCAR/COMET for the Sixth Winter Weather Forecasting Course in December organized by the Meteorological Service of Canada (MSC).

Although funding for the experimental infrasound system (developed by Dr. Al Bedard of the NOAA/Environmental Technology Lab in Boulder) was trimmed during the last fiscal year, the Boulder WFO continued to serve as one of the test sites, and we continue to interact with Dr. Bedard in searching for interesting cases. The system is able to detect infrasound signals from phenomena that include tornadoes and developing tornadoes. The hope is that it could provide a significant enhancement to Doppler radar in both detection of tornadoes and reducing false alarm, both critical National Weather Service goals.

CIRA researchers continue to give GSD weather briefings several times per month. Guest briefings were given in June by some of the students working on various ESRL projects during the summer.

c) D3D Activities

Formal funding for D3D has ended, at least for the time being, but we continue to support NWS WFOs that are interested in testing the software, and occasionally answer technical questions from sites that have D3D. Some interest in D3D remains across the NWS, although officially the software is restricted to use on the NWS case review workstations (known as the WES systems). Additionally, D3D is used at UCAR/COMET during some of their training workshops.

Our overall achievements for AWIPS/D3D Support compare favorably with the goals projected in the statement of work.

8. Federal Highways Road Weather Modeling

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 funding was unavailable for this effort during this period.

9. United States Forest Service (USFS)

Participating CIRA Scientist: Steve Albers

Funding was very limited this year, although we did make our real-time LAPS analyses and web products over the Colorado domain available to the USFS. Given these circumstances, our accomplishments compare favorably with the stated goals.

10. IHOP

Participating CIRA Scientists: Chris Anderson and Steve Albers

We continued evaluation of simulations of LLJ cases from IHOP. We conducted WRF simulations with grid point spacing of 4-km to better understand the ability of WRF to simulate the details of spatial fluctuations of wind and water vapor. The results showed that not only was WRF unable to simulate the observed spatial power spectra and cospectra of these variables, but also was unable to capture the persistence of the peak LLJ wind speed for forecast lead times exceeding two hours. We hypothesize this is due to inadequacies in the boundary layer parameterization.

We collaborated with Dr. Isidora Jankov in rerunning the June 12, 2002 LAPS IHOP case (see Fig. 4) in the interest of assessing and improving the hot-start for eventual publication. We learned some interesting things about how previous software written by one of our CWB collaborators handles the diagnosed vertical motion in various sectors of a developing convective storm. Some adjustment of the visible satellite normalization was needed to allow this to run smoothly on the large 600x600 gridpoint domain.

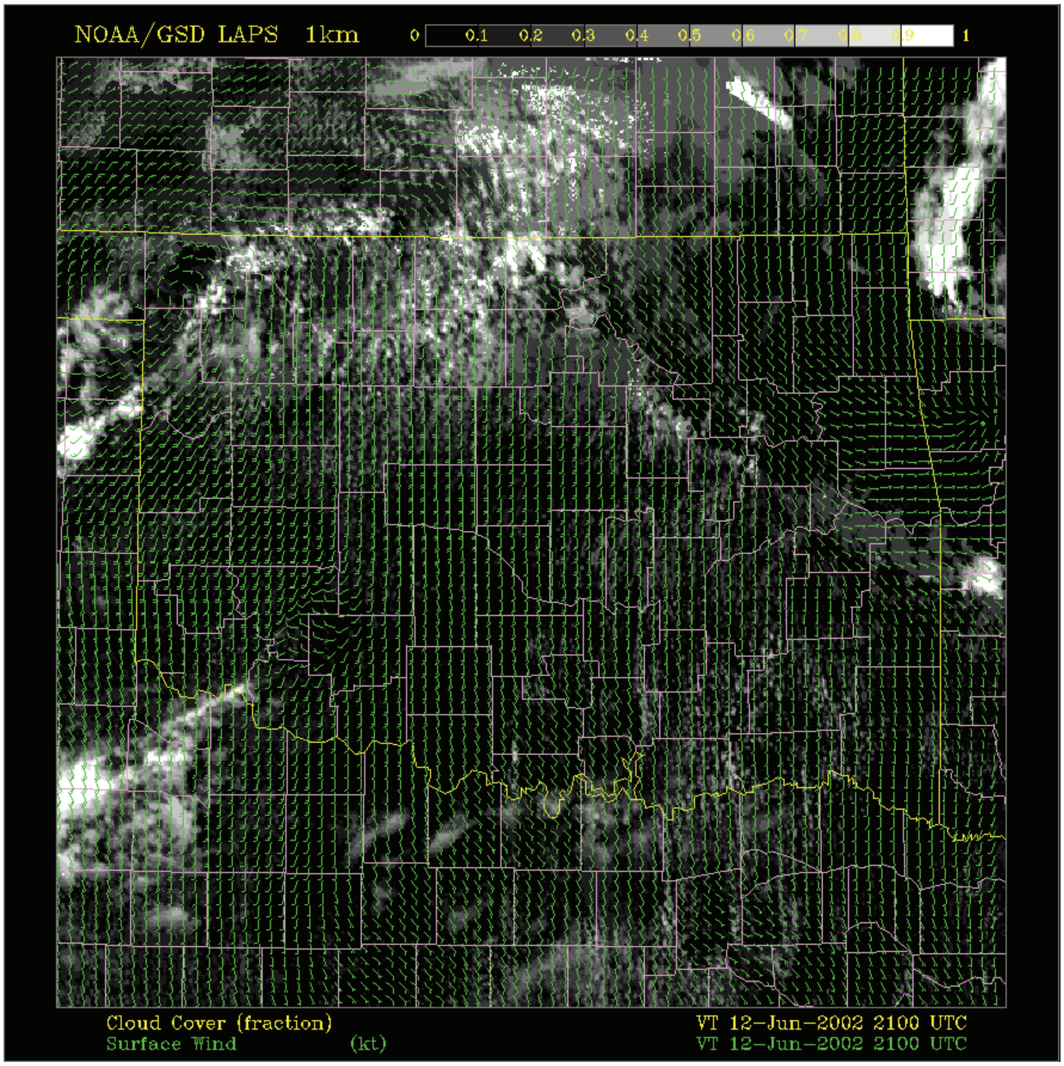


Fig. 4. Analyzed surface wind and column cloud cover are shown on the LAPS 1-km domain for an IHOP rerun case.

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

Publications:

Tollerud, E.I., F. Caracena, D.L. Bartels, S.E. Koch, B.D. Jamison, R.M. Hardesty, B.J. McCarty, W.A. Brewer, R.S. Collander, S. Albers, B. Shaw, D. Birkenheuer, and C. Kiemie, 2005: Mesoscale moisture transport by the low-level jet during the IHOP field experiment. *11th Conf. on Mesoscale Processes*, 24-28 Oct 2005, Albuquerque, NM, Amer. Meteor. Soc., CD-ROM, J6.6.

11. Weather Research and Forecast Model (WRF)

Funding and personnel were unavailable for any significant efforts this year.

12. Hydrometeorological Testbed (HMT)

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

The Hydrometeorological Testbed is a well-funded, multi-year project (www.hmt.noaa.gov) designed to improve the use of research quality observations and modeling in operational forecasts of precipitation and streamflow. A large field campaign was held December 2005 to March 2006 in the American River Basin of the Central Sierra Mountains. GSD provided high-resolution model forecasts in support of field operations and NWS operational forecasting.

By the beginning of the field campaign, a single forecast was operational. The forecast was generated by the WRF-ARW with a nest of two high resolution domains, an outer domain with 3-km grid point spacing covering northern and central California and an inner domain with 1-km grid point spacing covering only the American River Basin Domain. Soon after the beginning of the field project, an ensemble of forecasts was implemented. The ensemble was composed of MM5, WRF- ARW, and RAMS, each using the forecast domain described above. The models were initialized with LAPS diabatic initialization fields (including wide-band radar data) and integrated to a forecast lead of 12-hours. The forecast cycle was 3- hours, producing 8 forecasts from each model per day. Late in the project, it was determined that forecast lead times of 24-hours were desirable, and the ensemble was reconfigured to contain only one forecast grid (3-km) for which forecasts to 30-hour lead times were produced. Output from each model was available via a web page developed and maintained at NOAA/GSD.

Example 24-hr precipitation output from the 3-km grid of one of the ensemble members (WRF-ARW using the Thompson microphysics) is given below (Fig. 5a) for the heaviest precipitation event of the field project.

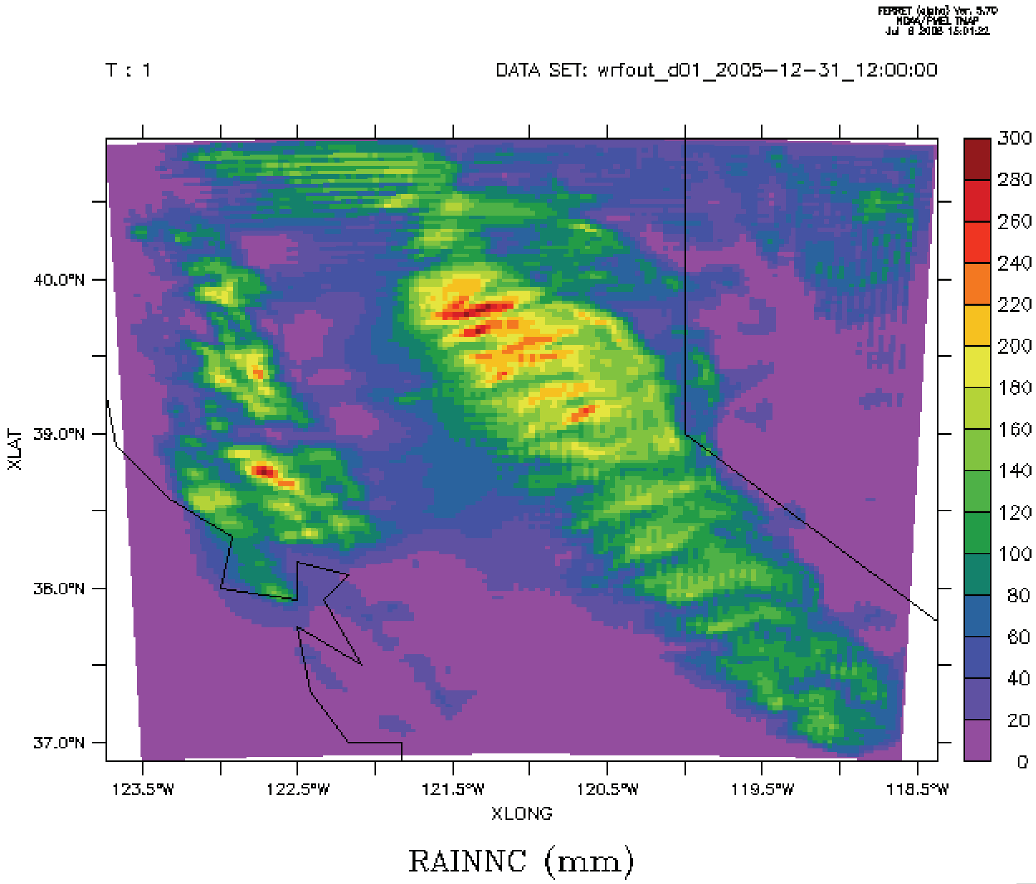


Fig. 5a. Evident in this plot are narrow regions of 24-hour precipitation accumulation exceeding 200 mm (~7.9 inches). These narrow regions correspond to peaks in the terrain. This information is not available in operational forecast models with larger grid point spacing. It is also not often evident 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).

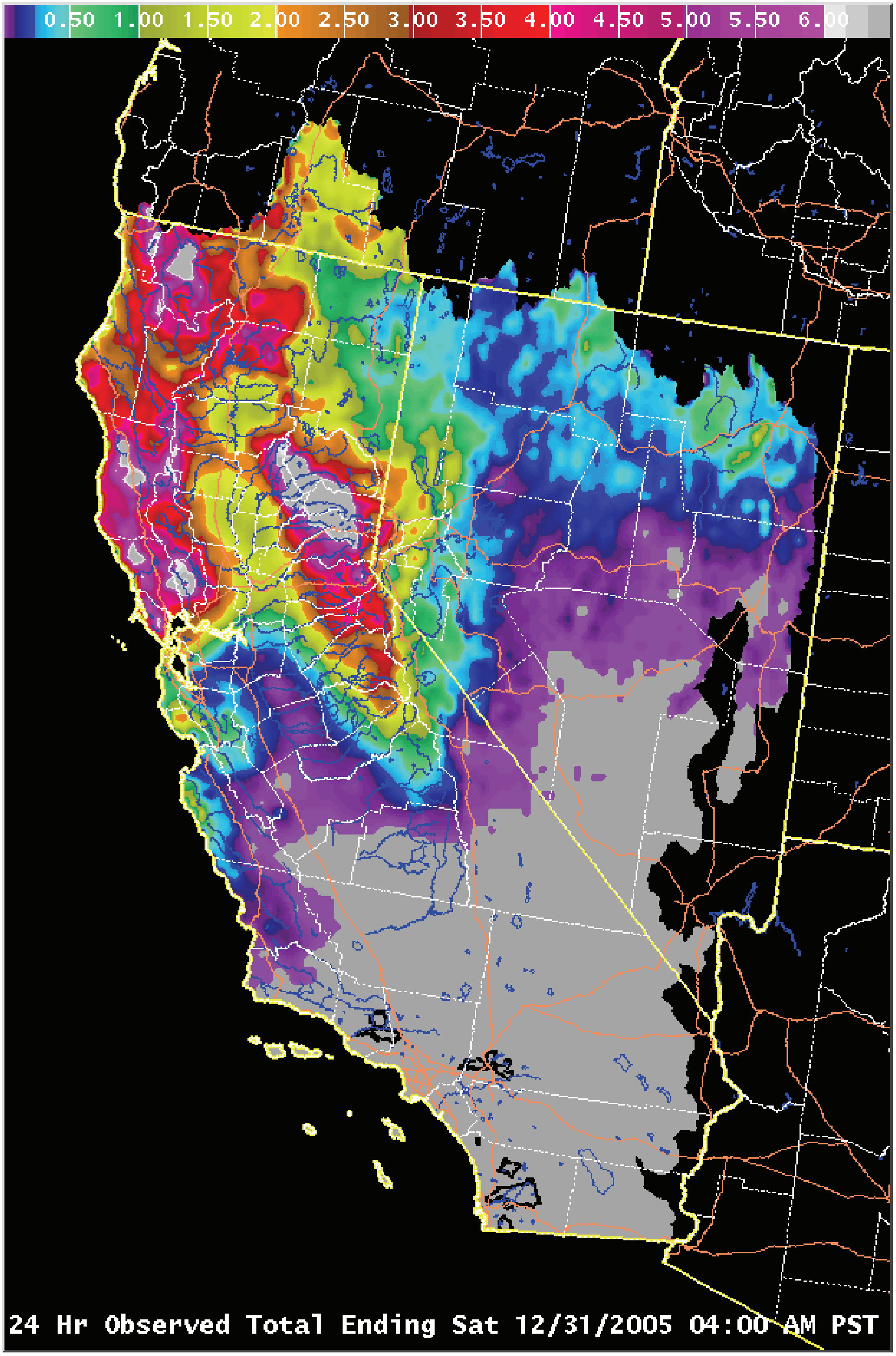


Fig. 5b. The gridded observations are produced by sending sparse rain gauge measurements through an interpolation routine. Thus, the spatial variability of the model runs, being unsmoothed, is much larger than observed. Nevertheless, the magnitudes of precipitation are similar. Where the observations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

Further examination of the model results at particular rain gauge locations reveals the model errors are very small. The Mean of the Absolute Error at Blue Canyon, a rain gauge along the North Fork of the American River, is about 0.2" out to a forecast lead time of 18 hours.

We have explored the possibility of decreasing forecast error and forecasting the expected error with ensemble forecasts. We found little improvement in forecast error within the first 24 hours, indicating the error growth is primarily due to synoptic scale errors that aren't manifested until forecast leads beyond 24 hours. However, there is value from the ensemble in that the spread of the ensemble is correlated with the error of the ensemble mean, suggesting it is reasonable to expect the ensemble to forecast the expected forecast error.

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.

CIRA researchers also 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.

During the forthcoming HMT field experiment Dec 2006 through Mar 2007, model forecasts will be provided directly to operational forecasters via ALPS. The products will include probabilistic displays of forecasted precipitation.

Publications:

Anderson, C., P. Schultz, and C. Lu, 2006: Examination of high-resolution NWP model QPF and PQPF for the American River Basin from time-lagged and multiple model ensembles during HMT-WEST 2006. *The AGU Joint Assembly,* 23-26 May 2006, Baltimore, MD, H22B-02, CD-ROM.

Anderson, C., P. Schultz, and C. Lu, 2006: Comparison of cold season QPF and PQPF from time-lagged and multiple model ensembles. *The 2nd* International *Symposium on Quantitative Precipitation Forecasting and Hydrology,* 5-8 June 2006, Boulder, CO, No. 4.5.

Lu, C., J. McGinley, P. Schultz, H. Yuan, B. Jamison, L. Wharton, and C. Anderson, 2006: Short-range quantitative precipitation forecast (QPF) and probabilistic QPF using time-phased, multi-model ensembles. Submitted to *J. Hydrometeorology*.

McGinley, J., S. Albers, C. Anderson, C. Lu, P. Schultz, and L. Wharton, 2005: Short Range (0-3hr) Quantitative Precipitation Forecasting: a futuristic vision. *11th Conf. on Mesoscale Processes*, Amer. Meteor. Soc., 24-28 Oct 2005, Albuquerque, NM, CD-ROM.

Yuan, H., J. A. McGinley, C. Lu, C. J. Anderson, and P. J. Schultz, 2006: Extreme precipitation events and bias correction of PQPF during the HMT 2005 -2006 winter campaign. *The AGU Joint Assembly,* 23-26 May 2006, Baltimore, MD, H22B-04, CD-ROM.

Yuan, H., J. A. McGinley, C. Lu, C. J. Anderson, and P. J. Schultz, 2006: Evaluation and bias correction of high-resolution QPF and PQPF during the HMT 2005-2006 winter campaign. *The 2nd* International *Symposium on Quantitative Precipitation Forecasting and Hydrology,* 5-8 June 2006, Boulder, CO, P. 4.31.

13. Space Flight Meteorology Group (SMG)

Participating CIRA Scientists: Steve Albers and Chris Anderson

We assisted with LAPS installation for a newly funded project with the Space Flight Meteorology Group. This group gives meteorology support at the Johnson Space Center in Houston for missions such as Space Shuttle flights. They have sent us a sample of their raw observational data and we started to test the interfacing of LAPS ingest and analyses to this database. We also set up a real-time shadow run here at GSD to emulate the data sources this group will be using.

We sent them our LAPS analysis software and they have successfully compiled the software and are running LAPS with our default test dataset. LAPS scripts and documentation were improved to facilitate this process. We are having a continuing dialogue with SMG on how to set up various on-site datasets to be compatible with LAPS. This includes some testing (and improvements) with LAPS in relation to ingest of MADIS METAR and ACARS data. A web site was developed to keep an updated summary of this communication as it pertains to an itemized list of the observational datasets being used.

We also had some preliminary discussions with SMG on forecast model setup.

14. LAPS Ensemble Post-Processing (EPP)

Principal Researcher: Brian Jamison

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

The EPP project is directed towards incorporating a number of LAPS model forecasts valid for the same time, and combining them into an ensemble mean forecast. Because of differing initial conditions in each model run, the time it takes for a model to "spin-up" (i.e. come to an equilibrium state from the initial conditions), and the fact that models lose skill with time due to small errors in the initial conditions, ensemble mean forecasts will likely have more skill than an individual forecast. The EPP project is the first trial of an ensemble based LAPS product, and will focus initially on precipitation.

Research Accomplishments / Highlights:

Two periods were selected for initial trials of the mean ensemble forecasts: April 10-11, and April 28-29, 2005. LAPS output grids and Stage IV precipitation data were collected for these periods. Stage IV precipitation is a national scale mosaicked quantitative precipitation estimation, and is used here for verification. In order to valicate the precipitation forecasts using Stage IV, the Stage IV data were interpolated to the LAPS grid. The ensemble member forecasts were generated, and corrections for known model biases were applied. Mean ensemble forecasts were generated using the ensemble members. These forecasts were then compared with the interpolated Stage IV product.

Comparison of Objectives vs Actual Accomplishments for the Reporting Period:

In progress.

15. <u>LAPS WRF Static Initialization (WRFSI)</u>

Principal Researcher: Brian Jamison

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

The Local Analysis and Prediction System (LAPS) section of GSD / Forecast Applications Branch has developed a graphical user interface (GUI) to allow a user to define a particular domain and resolution to run the Weather Research and Forecasting (WRF) model using LAPS model initialization data. Part of this effort involves generating some graphical products of static initialization fields, including: average terrain elevation, annual minimum and maximum green fraction, top and bottom layer dominant category soiltype, terrain slope index, terrain adjusted mean annual soil temperature, and land use dominant category.

Research Accomplishments/Highlights:

Occasionally, the graphics generated have some problems with particular defined domains and projections which need to be corrected. This past year, the National Mesoscale Model (NMM) was a new addition which required the ability to plot in a rotated lat-lon projection. This projection is simply a cylindrical equidistant projection with the pole translated to a different point on the globe. The ability to recognize and plot this projection was added to the script that plots the static initialization fields.

Comparison of Objectives vs Actual Accomplishments for the Report Period:

Successfully completed.

16. Developmental Testbed Center (DTC) Winter Forecast Experiment (DWFE)

Participating CIRA Researcher: Ed Szoke

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

The DTC Winter Forecast Experiment (DWFE) was motivated by the needs of the National Weather Service (NWS) for improved model guidance to support their winter weather forecast and warning mission. The DWFE experiment uses high-resolution (5 km) NWP models with improved physics, in an effort to offer a solution.

Research Accomplishments/Highlights:

The Developmental Testbed Center (DTC) Winter Forecast Experiment (DWFE) was run from 15 Jan 05 to 31 Mar 2005 as a test of two 5-km numerical model with explicit convection run on the continental United States (CONUS) scale. One of the models was run out of ESRL/GSD, and the other at NCAR (the location of the DTC), with one run of each per day, out to 48 h over the CONUS scale. This was the first time that these perspective models of the future were run in real-time on such a large scale.

CIRA researchers participated in the DWFE by testing high-resolution (5 km) CONUS scale models (NMM and ARW, two versions of the WRF model) for winter forecasting. We were involved with subjective assessment of the forecasts with papers to be presented at the upcoming AMS conference on Numerical Weather Prediction and Weather Analysis and Forecasting in August 2005.

One of the unique products that was output from the DWFE models was model simulated radar reflectivity, which allowed for a better depiction of the structures within winter storms, as well as a direct comparison of the model output with observations in real-time. An example of the banded structures that can be present in a winter storm is shown with the reflectivity time series in Fig. 1, for a Nor'Easter on 1 March 2005, with the various bands labeled. Forecasts of reflectivity from the two DWFE models, with the bands labeled for comparison with the observed reflectivity, are shown in Fig. 2, illustrating how the models were able to capture many aspects of the complex banding in this storm.

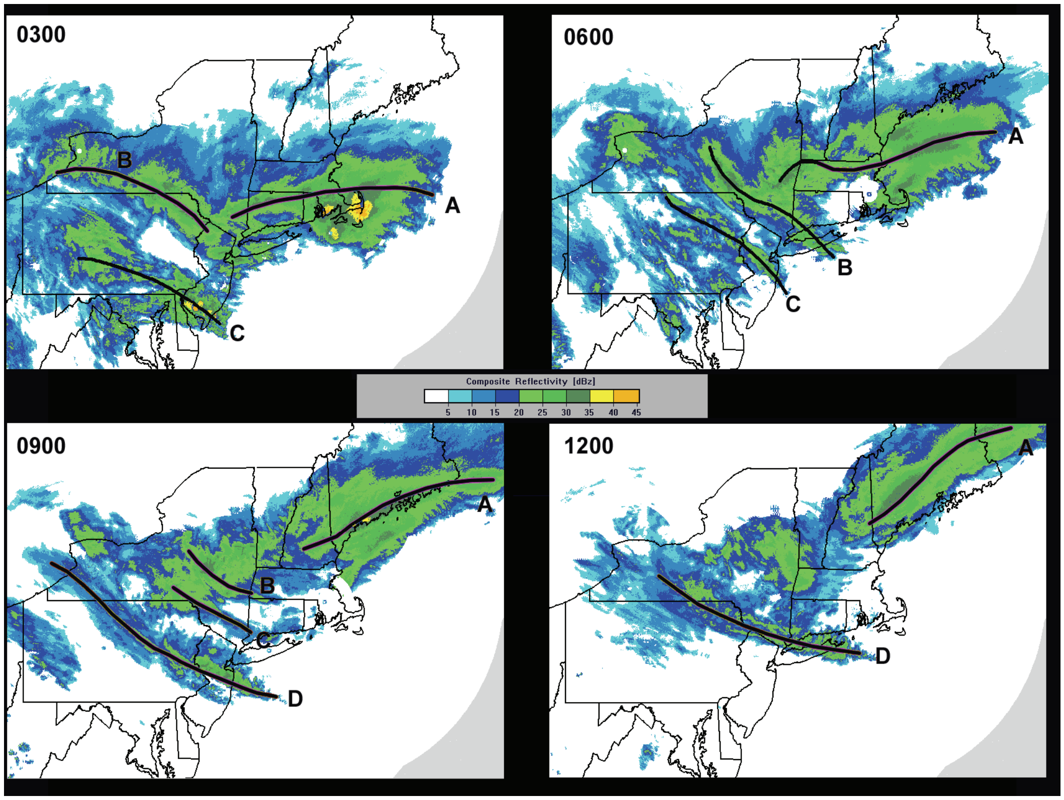


Fig. 1. Composite radar reflectivity displays at 0300, 0600, 0900, and 1200 UTC 01 March 2005 over New England (dBZ), showing snowbands A, B, C, and D, as determined from hourly displays.

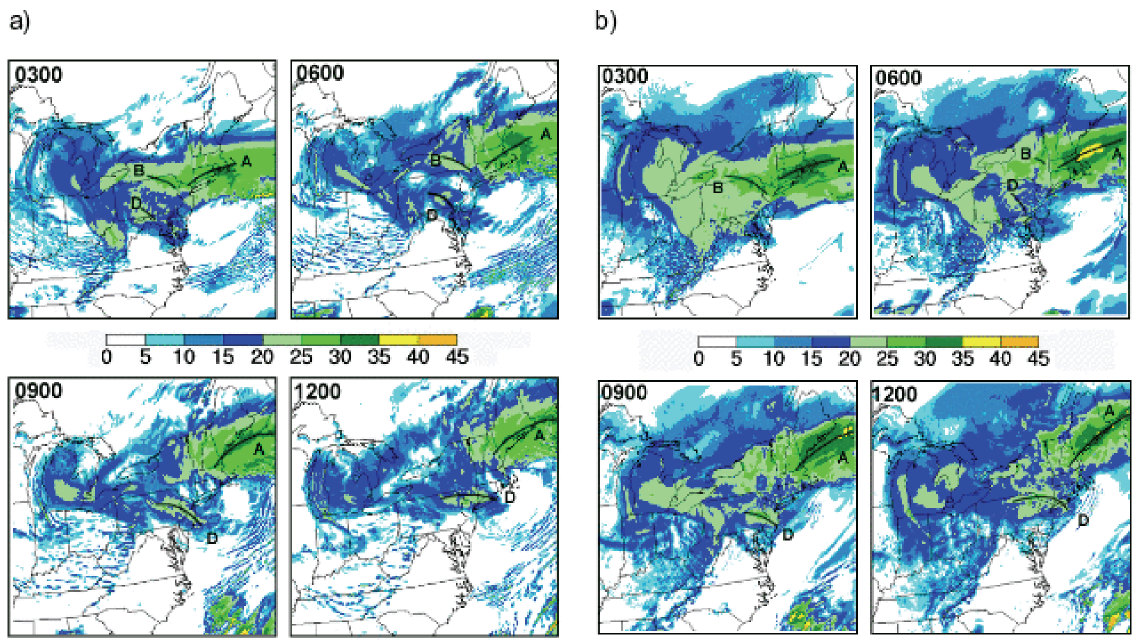


Fig. 2. Simulated composite radar reflectivity fields (dBZ) at 0300, 0600, 0900, and 1200 UTC 01 March over the northeastern U.S. forecast by a) the ARW model, and b) the WRF-NMM model, showing precipitation bands A, B, and D for comparison with the observed bands in Fig. 1.

GSD was not only involved in the running of one of the models, but also in the real-time assessment of the forecasts, and in post-DWFE research. The real-time assessment included an online website where NWS forecasters (the models were made available to the NWS through web displays, and in many cases on GSD's FXNet and/or AWIPS) could provide their evaluations. We are currently involved with the NWS in documenting this assessment along with some cases from the DWFE time period for an article to be published in *Weather and Forecasting*.

Publications:

Koch, S.E., R. Gall, G. DiMego, E. Szoke, J. Waldstreicher, P. Manousos, B. Meisner, N. Seaman, M. Jackson, R. Graham, A. Edman, and D. Nietfeld, 2005: Lessons learned from the DTC Winter Forecast Experiment. *17th Conf. on Numerical Weather Prediction*, 1-5 Aug 2005, Washington, D.C., Amer. Meteor. Soc., CD-ROM, 7.6.

Koch, S.E., B. Ferrier, M.T. Stoelinga, E. Szoke, S.J. Weiss, and J.S. Kain, 2005: The use of simulated radar reflectivity fields in the diagnosis of mesoscale phenomena from high-resolution WRF model forecasts. *11th Conf. on Mesoscale Processes*, 24-28 Oct 2005, Albuquerque, NM, Amer. Meteor. Soc., CD-ROM, J4J.7.

Szoke, E., S. Koch, and D. Novak, 2005: An examination of the performance of two high-resolution numerical models for forecasting extended snow bands during the DTC Winter Forecast Experiment. *21st Conf. on Weather Analysis and Forecasting*, 1-5 Aug 2005, Washington, D.C., Amer. Meteor. Soc., CD-ROM, 7.3.

Tardy, A.O., M. Jackson, and E. Szoke, 2005: Evaluation of high resolution model QPF performance in the complex terrain of the Great Basin as part of the DTC Winter Forecast Experiment. 1-5 Aug 2005, *21st Conf. on Weather Analysis and Forecasting*, Washington, D.C., Amer. Meteor. Soc., CD-ROM, 7.4.

V. <u>Research Collaborations with the GSD Assimilation and Modeling Branch (formerly the FSL Forecast Research Division/Regional Analysis and Prediction Branch)</u>

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

Principal Researchers: Tracy Smith and Kevin Brundage

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

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

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

The primary focus of the GSD Assimilation and Modeling Branch is the refinement and enhancement of the Rapid Update Cycle (RUC) and development of the Weather Research and Forecast (WRF) model. The RUC is a national scale 4-D data assimilation and forecast systems specifically designed to run at a high temporal frequency (1-hour cycle), taking advantage of a variety of special observations such as ACARS, RASS, profiler, radar, GPS integrated precipitable water vapor, and GOES soundings. It is run operationally at the NOAA/NWS National Centers for Environmental Prediction, and in various experimental configurations at the ESRL Global Systems Division. In addition to refinement and enhancements of the RUC, CIRA researchers collaborate on the development of the Weather Research and Forecast (WRF) model used by CIRA and GSD researchers and which will eventually replace the current hydrostatic forecast model now used in RUC. Overall goals are to continue the development work on the Weather Research and Forecast (WRF) model used by CIRA researchers and to improve the required visualization techniques for the RUC and WRF fields. Additionally, CIRA researchers would work on applications of the RUC to forecast problems, including forecasts of wind energy generation potential and anticipation and detection of significant vertical wind shear at wind-turbine levels. 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. A new version of the operational RUC was implemented at NCEP on 28 June 2005, with increased horizontal resolution, down to 13km, several new data sources, and improved surface, precipitation and cloud forecasts. 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, moisture observations.

Collaborations with the National Renewable Energy Lab continued to support research applications of the RUC model in wind energy planning. Current work is concentrated in application of time-lagged ensemble forecasting methods to produce probability distribution functions for potential wind energy production, detection of nocturnal low-level jet using the RUC, and improved near-surface wind forecasts through variation in surface roughness parameterization.

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

RUC13 implementation at NCEP was 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. At present, the wind energy applications are also in progress.

4. Leveraging/Payoff:

The RUC is an important forecasting tool for both aviation and severe weather forecasts, which ultimately impact public safety.

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

The journal article on “An hourly assimilation – forecast cycle: The RUC” by S. Benjamin, D. Devenyi, S. Weygandt, K. Brundage, J. Brown, G. Grell, D. Kim, B. Schwartz, T. Smirnova, T. L. Smith, *Mon. Wea. Rev.,* 132, 495-518 (Feb 2004) was recognized as one of the 2005 OAR Outstanding Scientific Paper Award. 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 assimilation/model system ingests a wide variety of meteorological observations each hour (a frequency much higher than is generally done) and produces short-range (up to 12-h) gridded weather forecasts. Significance: RUC analyses and short-range forecasts (initialized from the analyses) are used extensively within the aviation and severe weather communities as well as by National Weather Service forecasters. As such, the RUC forecast system is a vital component of the NOAA mission to provide weather information to society and to support a safe and efficient transportation system.

7. Outreach:

8. Publications:

Benjamin, S.B., D. Devenyi, T. Smirnova, S. Weygandt, J.M. Brown, S. Peckham, K. Brundage, T.L. Smith, G. Grell, and T. Schlatter, 2006: From the 13-km RUC to the Rapid Refresh. *12th Conf. on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc.

Koch, S. E., B. D. Jamison, C. Lu, T. L. Smith, E. I. Tollerud, C. Girz, N. Wang, T. P. Lane, M. A. Shapiro, D. D. Parrish and O. R. Cooper, 2005: Turbulence and gravity waves within an upper-level front. *J. Atmos. Sci.*, 62, 3885-3908.

Gutman, S.I., K. Holub, S. Sahm, T.L. Smith, S. Benjamin, D. Birkenheuer, D. Helms, J. Facundo, L. McMillin, J.G. Yoe, and J. Daniels, 2005: The meteorological role of the Global Positioning System in NOAA's integrated upper-air observing system. Preprint, *21st Conf. on Weather Analysis and Forecasting*, 1-5 Aug 2005, Washington, D.C., Amer. Meteor. Soc.

Project Title: <u>Great Lakes Fleet Experiment and TAMDAR</u>

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

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

Key Words: TAMDAR, Airborne Weather Sensors, Aircraft Data Impact on Model Forecasts

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

TAMDAR, for Tropospheric AMDAR (Airborne Meteorological Data Relay), is a new sensor flown on commercial aircraft that measures relative humidity, in addition to the parameters of wind and temperature that are currently available from standard AMDAR (formerly known as ACARS) data. Currently, TAMDAR is available on an experimental basis from a fleet of Mesaba Airlines commuter aircraft flown over the Great Lakes region and extending south to the lower Mississippi Valley that fly generally more local routes at lower altitudes than AMDAR flights. The Great Lakes Fleet Experiment (GLFE) involves the analysis of observations received from these TAMDAR instrumentations. Experiment goal is to design, build and fly an inexpensive instrument that would measure meteorological variables from commuter aircraft flying between small and medium-size airports. Tasks primarily involve examining the data for quality, and investigating the impact of the data on weather model forecasts. For these investigations, retroactive runs of the Rapid Update Cycle (RUC) 20 km model were used to compare runs with and without TAMDAR observations to determine the impact of TAMDAR in the Midwest United States.

2. Research Accomplishments/Highlights:

TAMDAR data is currently being evaluated at ESRL/GSD and elsewhere for quality, utility for forecasting various types of weather, and impact on numerical weather prediction model forecasts (via the RUC model). CIRA researchers at GSD have been involved in all of these aspects of the TAMDAR assessment.

An extension of the GLFE into FY06 allowed for further analysis of the impact of TAMDAR observations on RUC model forecasts. Examination of errors in temperature, relative humidity and winds for model runs with and without TAMDAR data show improvement (i.e., smaller errors) in these parameters for the TAMDAR-inclusive model runs for the Midwest United States region.

Simultaneous runs of the RUC development model ("dev") and the identical model including TAMDAR data ("dev2") are running in near real-time, and plots of field differences of temperature, humidity, and winds continue to be provided on a web page for review (http://www-frd.fsl.noaa.gov/mab/jamison/tamdar/devdiff/). Six isobaric levels (1000mb, 925mb, 850mb, 700mb, 500mb, and 300mb) are compared for the analyses and 3-hour forecasts out to 24 hours. This has been invaluable not only to examine TAMDAR data impact for singular forecasts, but also to examine the progression of the effect of the impact with time.

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. Some of these runs included: a run with all AMDAR data (including TAMDAR), a run excluding the TAMDAR data, a run with a correction for the relative humidity error characteristic, a run including the TAMDAR descent winds (previously omitted due to known problems with the data), a run with a correction to omit data that were included past the analysis time, and a run to properly utilize the data quality control flags.

Other efforts to examine the impact of the data on the model include comparing the dev and dev2 cloud analyses and forecasts with satellite data. Results were prepared and presented at a TAMDAR community meeting regarding RUC cloud and ceiling forecasts with and without TAMDAR data verified against satellite data. Conclusions were that there were certainly cases where the RUC benefitted from the inclusion of TAMDAR data, providing improved forecasts, though there were a few cases where this was not the case. This is typical for a new observing system which still has some data quality issues.

An example of the potential impact of the data on a RUC forecast is shown for a case of heavy precipitation in the Upper Midwest from last October. The TAMDAR coverage for the 6-h period leading up to the model initialization time of 0000 UTC on 5 October 2005 is shown in Fig. 1.

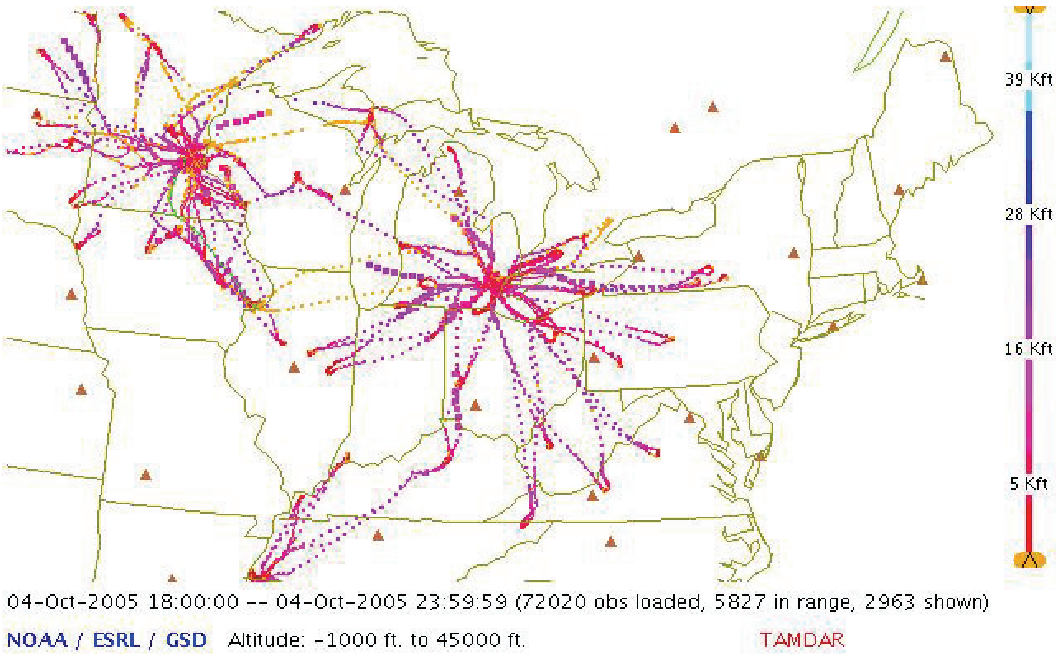


Fig. 1. Plan view of available TAMDAR data for 4 October 2005. Triangles indicate RAOB locations, while airports are located at the endpoints of the various routes. TAMDAR flight data shown is from 1800 UTC 4 October through 0000 UTC 5 October.

While many flights go into the main three hubs of Minneapolis, Detroit, and Nashville, many other small airports are also served that typically do not have any AMDAR data. In terms of the weather, heavy precipitation fell near a stalled front with over two inches in northwestern Wisconsin for the 6-h period ending 0600 UTC on 5 October, as estimated by the National Precipitation Verification Unit (NPVU) of NOAA (Fig. 2). This precipitation can be compared to the forecasts for the same 6-h period by the RUC model runs initialized at 0000 UTC shown in Fig. 3. The RUC model that included TAMDAR had a better 0-6 h forecast of total precipitation than the model without TAMDAR; note that the TAMDAR run (Fig. 3b) places the heavy precipitation maximum in northwest Wisconsin where it is observed, and also correctly has no precipitation in southern and central Wisconsin. Comparison of some forecast soundings from the 1800 UTC runs with the 0000 UTC RAOBS (not shown) indicated that the model forecast soundings from the RUC run with TAMDAR more closely matched the RAOB sounding for Green Bay and Detroit. In particular, a better resolution of the moisture in the atmosphere below ~500 mb likely led to the better forecasts for this case.

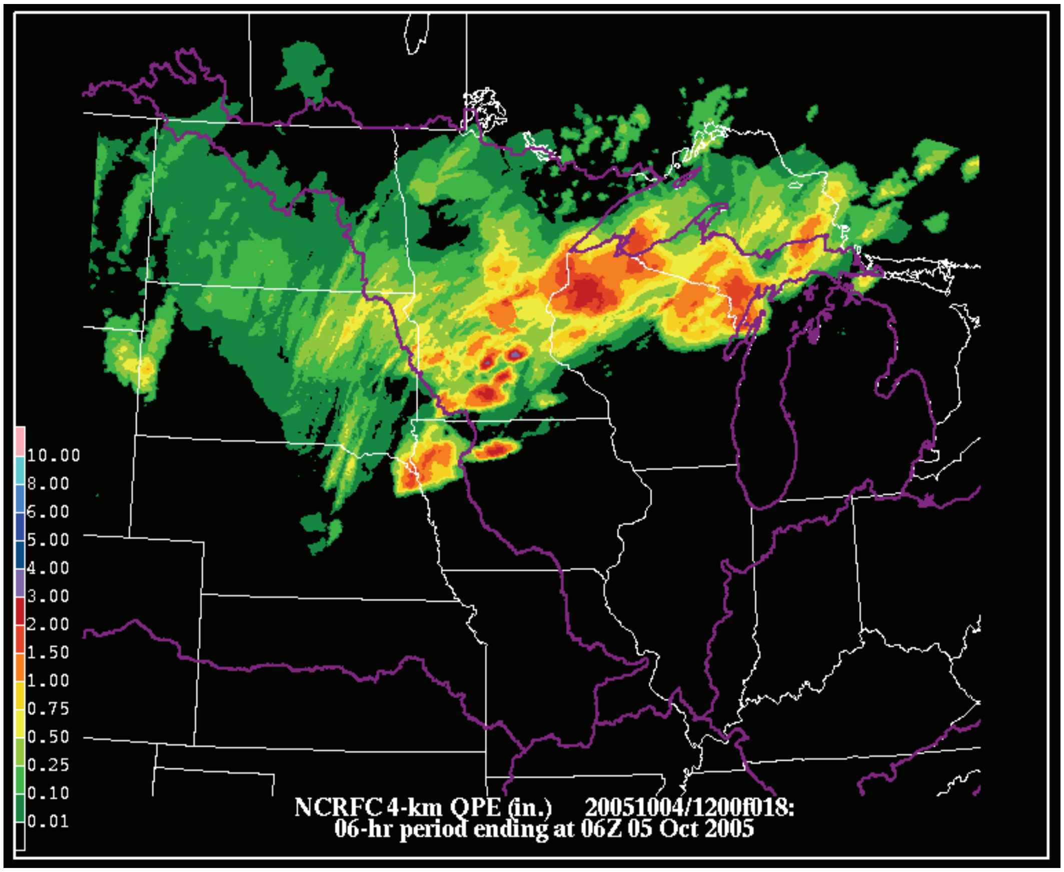


Fig. 2. NPVU precipitation analysis for the 6-h period ending 0600 UTC 5 October, in inches.

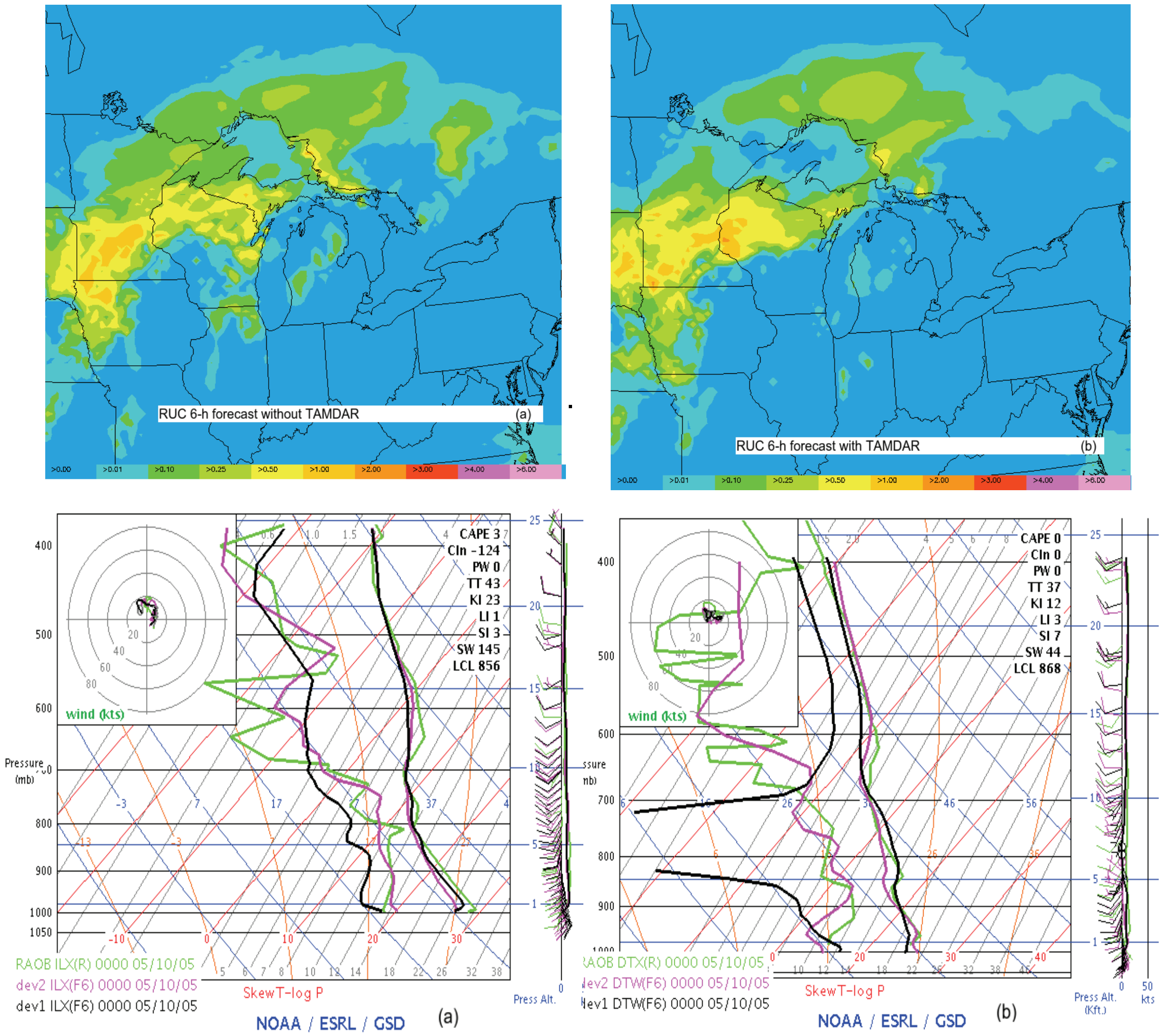


Fig. 3. RUC 6-h forecasts, ending 0600 UTC 5 October, of accumulated precipitation (in) without (a) and with (b) TAMDAR.

In addition to the impact of TAMDAR on numerical model forecasts (which the GSD group has also documented statistically), direct assessment of TAMDAR soundings can be very useful for a number of short-range forecast problems, from convective initiation and severe weather to rain vs. snow and the formation of fog, to name a few. Examples of such applications have been documented, through the perusal of various weather events as well as examination of forecast discussions from Weather Forecast Offices (WFOs) located within the TAMDAR region. The Green Bay WFO has been a focal point at the NWS level for this activity and we have closely coordinated with them to document TAMDAR examples and produce various training documents.

Studies of the ability for accurate turbulence and icing detection via the TAMDAR instruments proved less successful when compared to pilot reports (PIREPs), although the relatively small data set of PIREPs for comparison may be a contributing factor in the seemingly poor correlation.

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

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

4. Leveraging/Payoff:

5. Research Links:

6. Awards/Honors:

7. Outreach:

8. Publications:

Mamrosh, R.D., E.S. Brusky, J.K. Last, E.J. Szoke, W.R. Moninger, and T.S. Daniels, 2006: Applications of TAMDAR aircraft data reports in NWS Forecast Offices. *10th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 9.4.

Moninger, W.R., M.F. Barth, S.G. Benjamin, R.S. Collander, B.D. Jamison, P.A. Miller, B.E. Schwartz, T.L. Smith, and E. Szoke, 2006: TAMDAR evaluation work at the Forecast Systems Laboratory: An overview. *10th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 9.7.

Szoke, E.J., B.D. Jamison, W.R. Moninger, S.G. Benjamin, B.E. Schwartz, and T.L. Smith, 2006: Impact of TAMDAR on RUC forecasts: Case studies. *10th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 9.9.

Project Title: Development of Time-Phased Multi-Model Ensemble Forecast System and its Application to Short-Range QPF and PQPF

Principal Researcher: Chungu Lu

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

Key Words: Short-range QPF and PQPF, High-resolution Atmospheric Modeling, Rapid-updating Data Assimilation System, Ensemble Forecast System, Forecast Post-processing

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

The long-term research objectives and scientific plans are to research various data assimilation systems and ensemble forecast methods, and to develop and eventually transfer the optimum systems and method to NOAA forecast operations.

2. Research Accomplishments/Highlights:

In the past year, we have successfully developed a time-phased, multi-model ensemble forecast system. Fig. 1 schematically shows how ensemble members are generated from this system. This system now has been adopted by the NOAA/OAR and applied to the OAR's hydrometeorological testbed (HMT) field experiment in the American River Basin of California. It has also been made as a forecast product on NOAA/GSD's AWIPS.

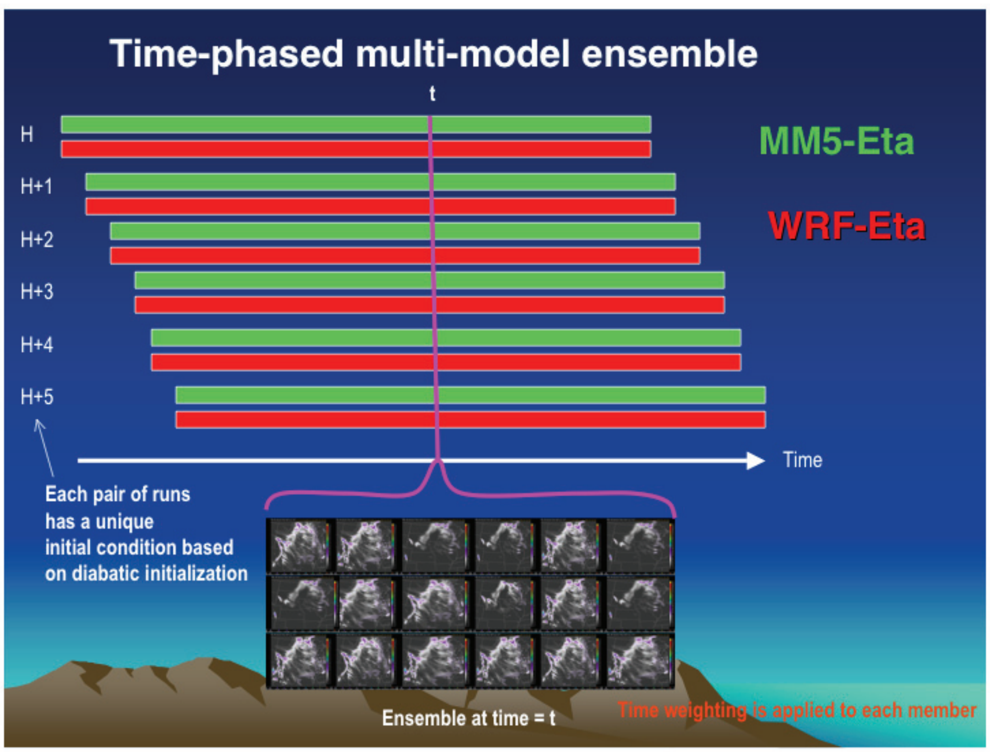


Fig. 1. Conceptual diagram for time-phased multi-model ensemble forecast system.

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

In progress.

4. Leveraging/Payoff:

Coupled with the NOAA Local Analysis and Prediction System, this time-phased, multi-model ensemble forecast system is very useful for short-range Quantitative Precipitation Forecast (QPF) and Probabilistic QPF (PQPF). Figs. 2a and 2b show a "spaghetti" diagram for the distribution of predicted precipitation greater than 0.254 mm (0.01 in) from each time-phased ensembles of two mesoscale atmospheric models for a synoptic weather event on 10-11 April 2005. The comparison of QPF from time-phased multi-model ensembles with NOAA Stage IV observations is plotted in Fig. 3. Fig. 4 shows the PQPF derived from this ensemble system. Statistical verification that was conducted shows that the ensemble-based QPF has reasonable skill in comparison with deterministic forecasts, while ensemble-based PQPF significantly outperforms deterministic forecasts.

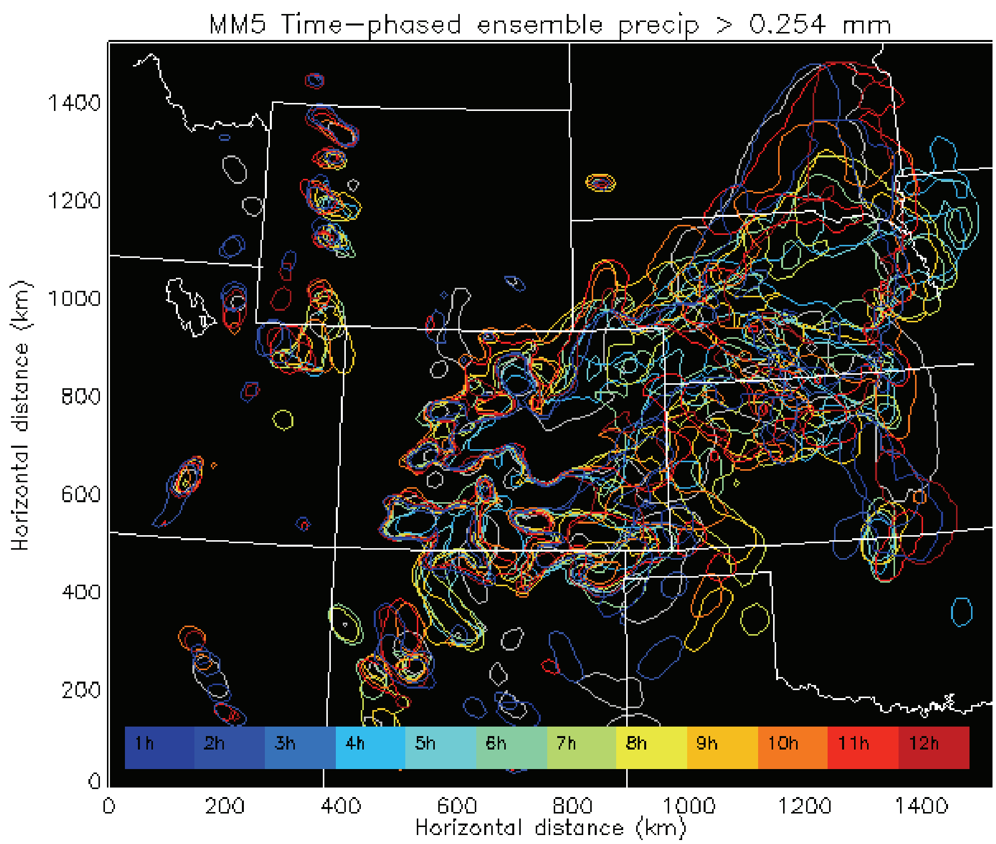


Fig. 2a. Spaghetti diagram for 12 time-phased forecasts of precipitation for 0.254 mm/hr from the MM5 model for 0300 UTC 11 April 2005.

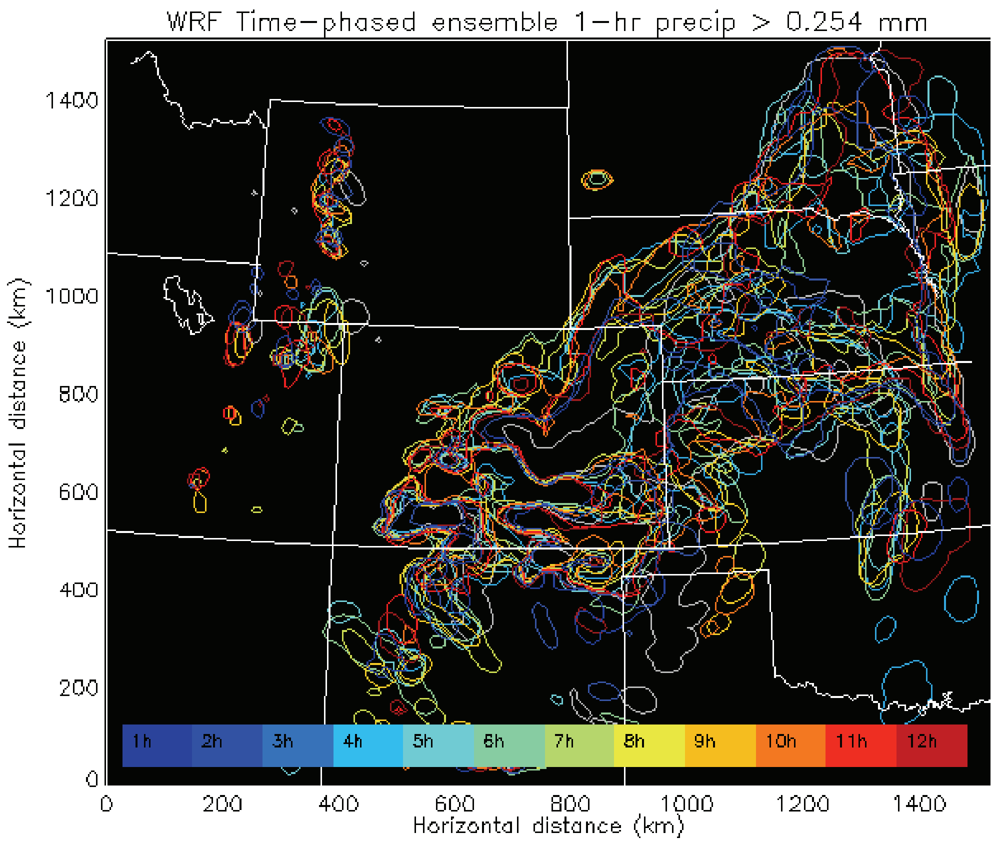


Fig. 2b. Same as Fig. 2a, except for 12 time-phased forecasts from the WRF model.

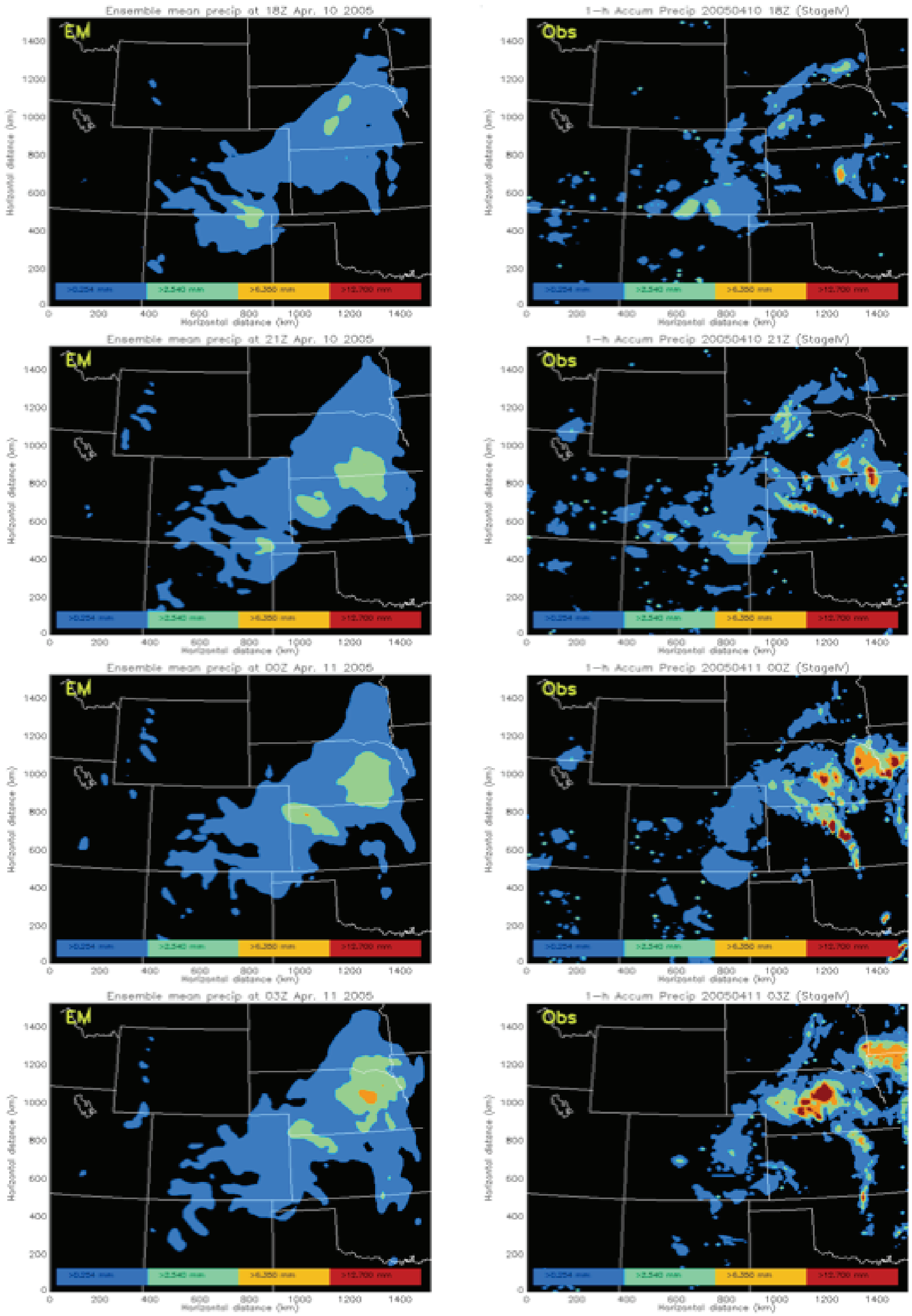


Fig. 3. Ensemble-mean QPF (left column) and Stage IV observations (right column) for a) 1800 UTC, b) 2100 UTC, c) 0000 UTC, and d) 0300 UTC 10-11 April 2005.

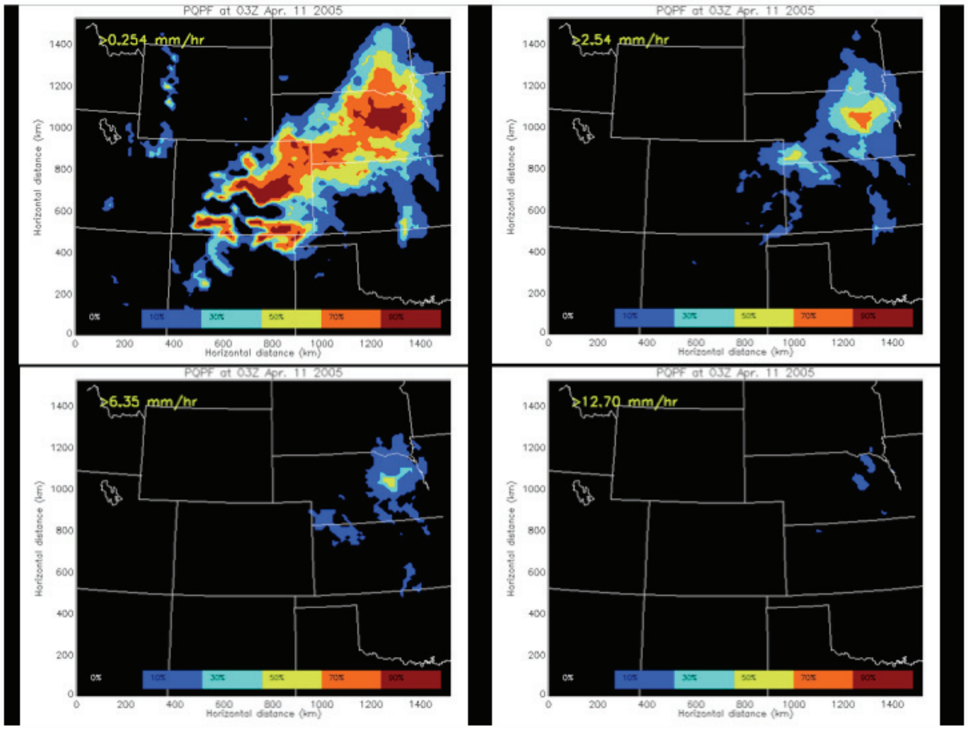


Fig. 4. Time-phased multi-model ensemble PQPF for a) 0.254, b) 2.54, c) 6.35, and d) 12.70 mm/hr rainfall thresholds at 0300 UTC 11 April 2005.

This system is highly applicable in the hydrological prediction operation, such as flash flood warning, transportation decision making, aviation terminal and highway operations, and fire weather forecasting. These applications may have a significant impact on public safety and society welfare. We are currently contacting some NOAA river forecast offices, to try to develop channels for this system to be used in operations.

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Anderson, C., P. Schultz, and C. Lu, 2006: Examination of high-resolution NWP model QPF and PQPF for the American River Basin from time-lagged and multiple model ensembles during HMT-WEST 2006. *The AGU Joint Assembly,* 23-26 May 2006, Baltimore, MD, H22B-02, CD-ROM.

Anderson, C., P. Schultz, and C. Lu, 2006: Comparison of cold season QPF and PQPF from time-lagged and multiple model ensembles. *The 2nd* International *Symposium on Quantitative Precipitation Forecasting and Hydrology,* 5-8 June 2006, Boulder, CO, No. 4.5.

Lu, C., J. McGinley, P. Schultz, H. Yuan, B. Jamison, L. Wharton, and C. Anderson, 2006: Short-range quantitative precipitation forecast (QPF) and probabilistic QPF using time-phased, multi-model ensembles. Submitted to *J. Hydrometeorology*.

Lu, C., H. Yuan, B. Schwartz, and S. Benjamin, 2006: Short-range numerical weather prediction using time-lagged ensemble forecast system. *Wea. and Forecasting,* accepted.

Lu, C., J. McGinley, P. Schultz, H. Yuan, B. Jamison, L. Wharton, and C. Anderson, 2006: Development of time-phased, multi-model ensemble forecast system. *The AGU Joint Assembly,* 23-26 May 2006, Baltimore, MD,. H22B-03, CD-ROM.

Lu, C., J. McGinley, P. Schultz, H. Yuan, B. Jamison, L. Wharton, and C. Anderson, 2006: Short-range QPF and PQPF using time-phased, multi-model ensembles. *The 2nd* International *Symposium on Quantitative Precipitation Forecasting and Hydrology,* 5-8 June 2006, Boulder, CO, P. 4.19.

McGinley, J., S. Albers, C. Anderson, C. Lu, P. Schultz, and L. Wharton, 2005: Short Range (0-3hr) Quantitative Precipitation Forecasting: a futuristic vision. *11th Conf. on Mesoscale Processes*, Amer. Meteor. Soc., 24-28 Oct 2005, Albuquerque, NM, CD-ROM.

Yuan, H., J. A. McGinley, C. Lu, C. J. Anderson, and P. J. Schultz, 2006: Extreme precipitation events and bias correction of PQPF during the HMT 2005 -2006 winter campaign. *The AGU Joint Assembly,* 23-26 May 2006, Baltimore, MD, H22B-04, CD-ROM.

Yuan, H., J. A. McGinley, C. Lu, C. J. Anderson, and P. J. Schultz, 2006: Evaluation and bias correction of high-resolution QPF and PQPF during the HMT 2005-2006 winter campaign. *The 2nd* International *Symposium on Quantitative Precipitation Forecasting and Hydrology,* 5-8 June 2006, Boulder, CO, P. 4.31.

Yuan, H., J. A. McGinley, C. J. Anderson, C. Lu, and P. J. Schultz, 2006: Short -range probabilistic quantitative precipitation forecasts from multi-model and time-phased ensembles. *The 2006 Boulder Laboratories Postdoctoral Poster Symposium,* 14 June 2006, Boulder, CO, No. 7.

Project Title: Idealized Simulation of Gravity Waves and Turbulence Interaction Associated with an Upper-Level Jet

Principal Researcher: Chungu Lu

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: Aviation Safety, Upper-levelJjet, Gravity Waves, Turbulence, Atmospheric Model Simulation.

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

This project is partly supported by the Federal Aviation Administration (FAA) and partly 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 turbulence generation in the upper troposphere, and to provide public aviation safety advisory based on the obtained scientific understandings.

2. Research Accomplishments/Highlights:

The Weather and Research Forecast (WRF) model is used to conduct idealized simulation of interaction among upper-level jet, gravity waves, and turbulence. Last year, we successfully developed a PV inversion package, and using this PV inversion package, we were able to simulate an upper-level jet and generation of gravity waves associated with this jet. Fig. 1a shows the simulated upper-level jet at 120 hour of model integration time. Figure 1b shows the simulated baroclinic wave system with a surface low and warm/cold fronts at 120 hours.

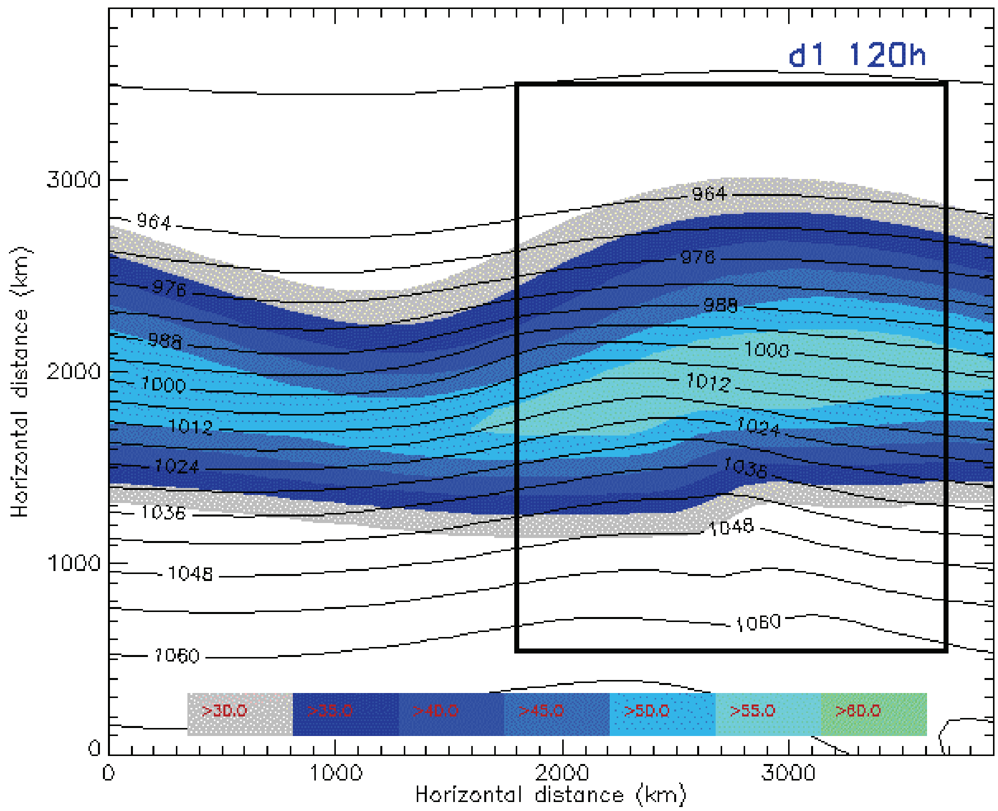


Fig. 1a. Simulated upper-level jet at 120 hours of model integration time. The contour is the geopotential height (in decameters), and the color shades are the isotach (in m/sec). The box indicates the next nested domain.

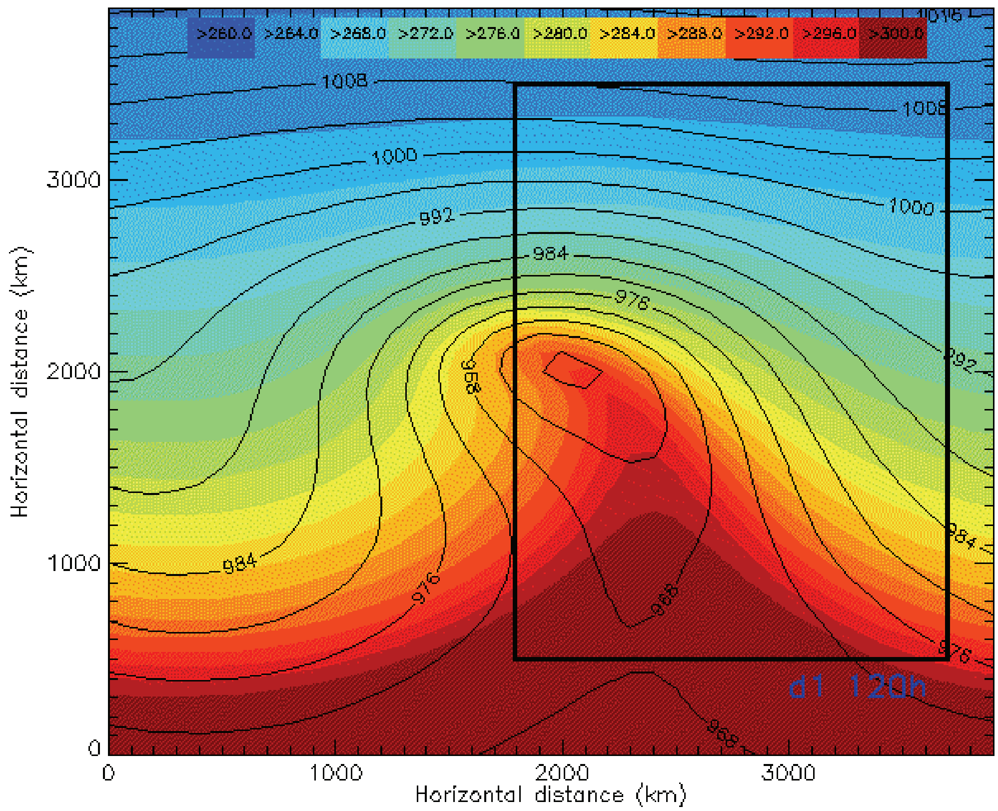


Fig. 1b. The simulated surface low and warm/cold fronts. The counters are pressure (in hPa), and the color shades are for temperature (in Kelvin). The box indicates the next nested domain.

We were able to nest the model domain from 100-km horizontal resolution down to 4-km resolution, and were able to simulate the process of gravity waves steepening and scale collapse. Figs. 2a and 2b show the developed gravity waves associated with the upper-level jet at 120 hours for the nested domain 2 (D2) with a horizontal grid spacing of 20 km at a horizontal view and a vertical cross-section, respectively.

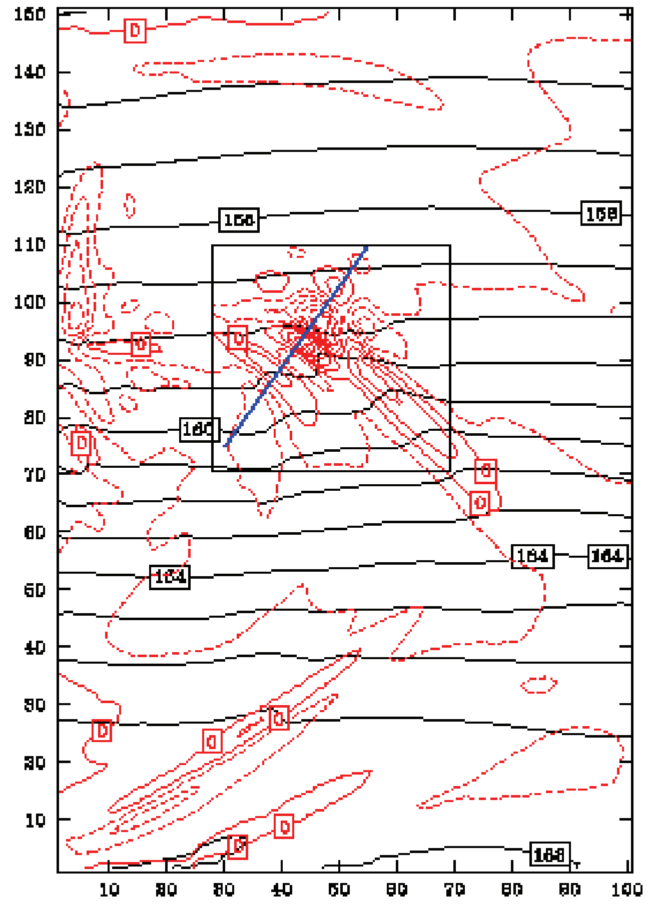


Fig. 2a. The nested domain 2 (D2) simulation at 120 h of model integration time, indicated a set of gravity waves is generated on the north side of upper-level jet, close to the jet ridge. The red contours are vertical velocity (in m/sec.), the black contours are pressure (in hPa), the blue line indicates that a cross-section analysis is taken in Fig. 2b, and the box indicates a finer nested domain for Fig 3.

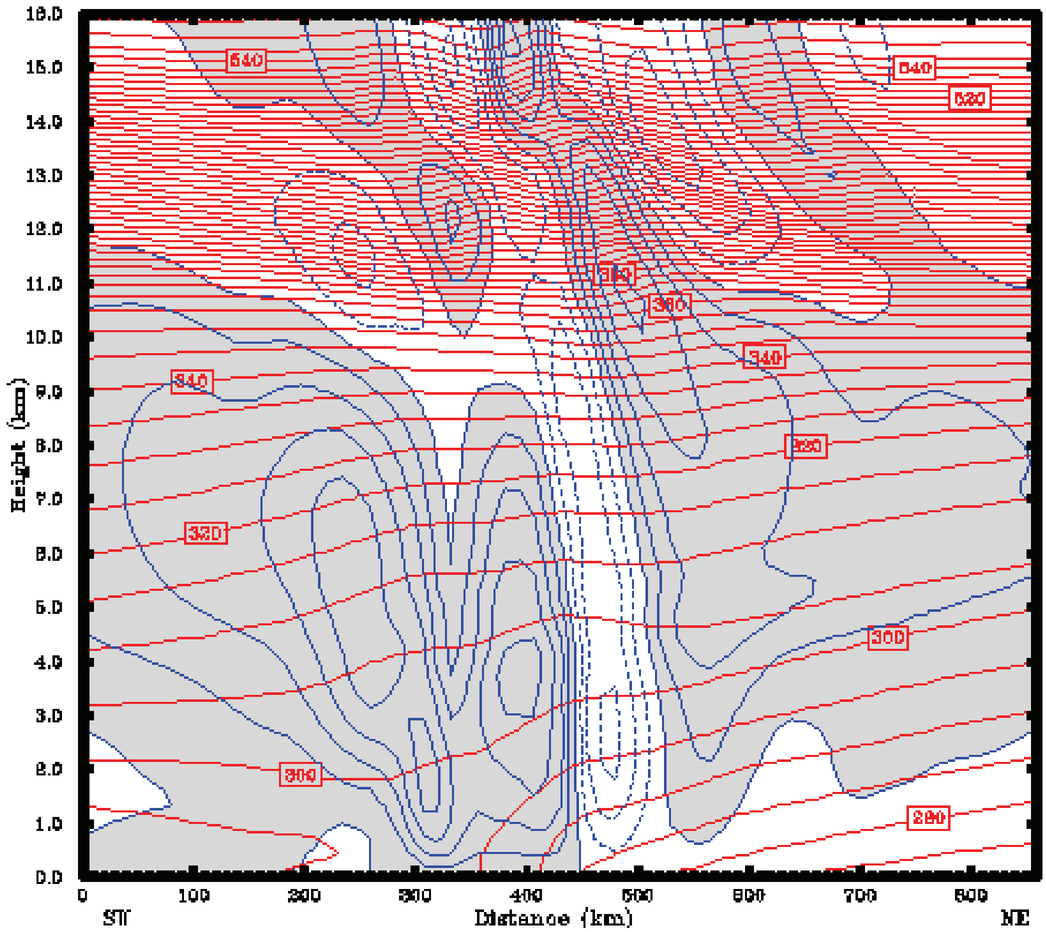


Fig. 2b. The vertical cross-section view of gravity waves along the blue line in Fig. 2a. The blue contours are vertical velocity, with values larger than 0.5 m/sec being shaded in grey. The red contours are potential temperature.

The finer-scale domain [nested domain 3 (D3) with a horizontal grid spacing of 4 km] simulations (Fig. 3a-b) indicate these gravity waves begin to steepen and experience a clear scale contraction. However, there are problems with the WRF model to continue down to finer scales. Currently, we are still in the process of trying to assess if the WRF model can work appropriately all the way to the turbulence scale.

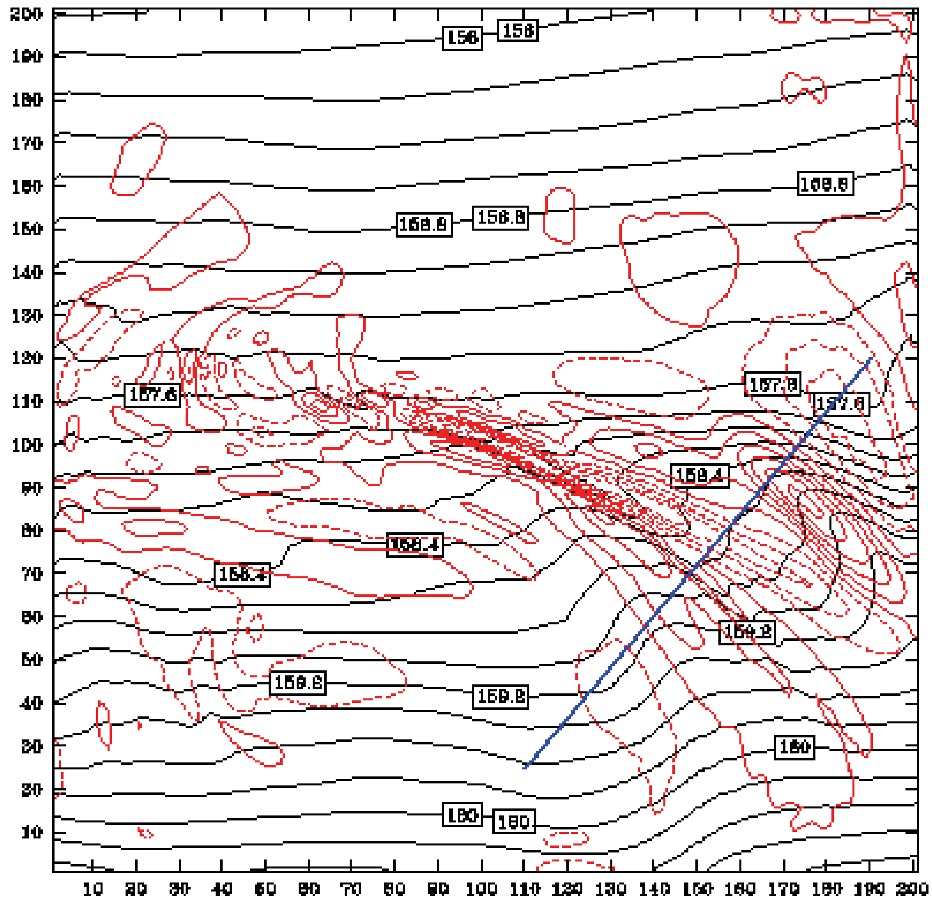


Fig. 3a: Same as Fig. 2a, except for nested domain 3 (D3) with a horizontal grid spacing of 4 km. This finer-domain simulation depicts gravity waves experience scale contraction. The blue line indicates a vertical cross-section is taken in Fig 3b.

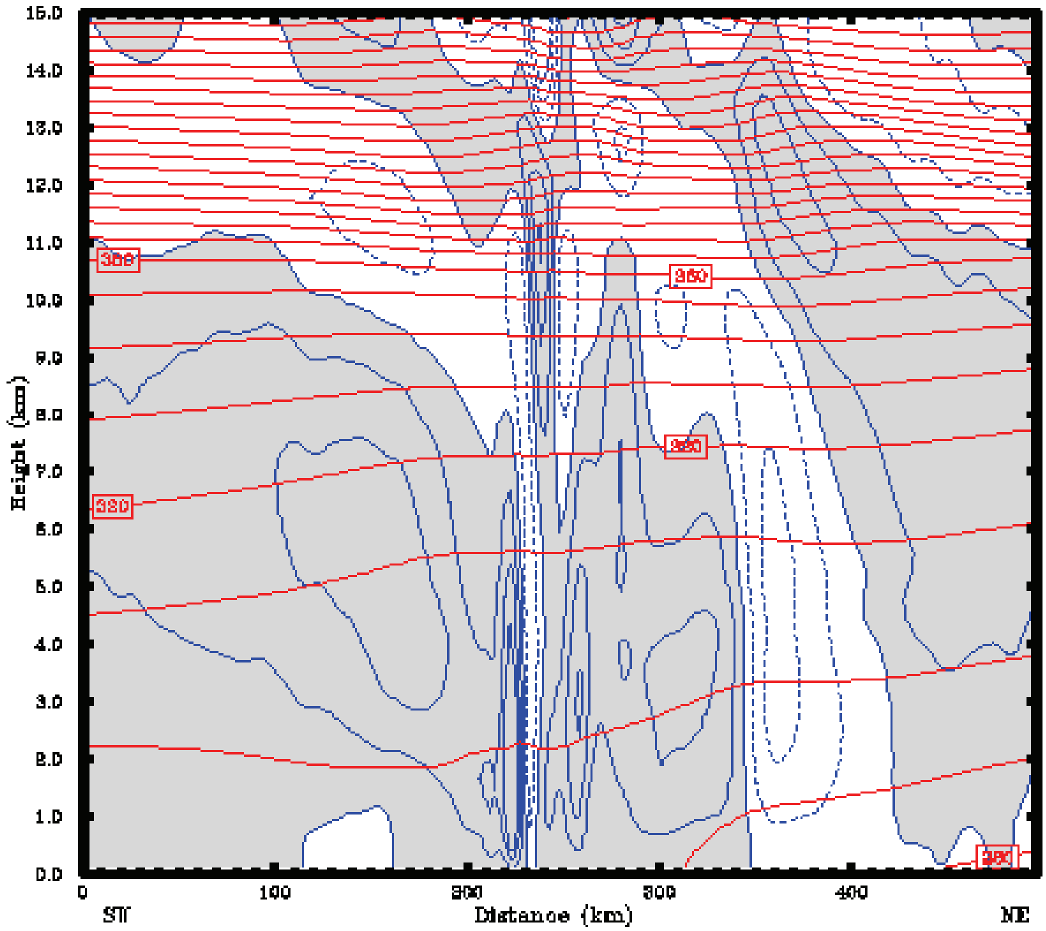


Fig. 3b. The vertical cross-section view of gravity waves in the finer domain.

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

In progress.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Collander, R.S., E.I. Tollerud, B.D. Jamison, F. Caracena, C. Lu, and S.E. Koch, 2006: Turbulence in MCS anvils: Observations and analyses from BAMEX. *12th Conf. on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc.

Koch, S.E., and C. Lu, 2006: The generation of gravity waves in unbalanced jet streams. *The 2006 European Geosciences Union Conference*, Vienna, Austria.

Koch, S.E., C. Lu, 2006: Turbulence generation by gravity waves within upper -level jet-front systems. *The Doug Lilly Symposium*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc.

Lu, C., and S. Koch, 2006: Interaction of upper-tropospheric turbulence and gravity waves as observed from spectral and structure function analysis. Submitted to *J. Geophys. Res.*

Lu, C., S. Koch, F. Zhang, and N. Wang, 2006: Modeled mesoscale gravity waves: continuous spectrum and energy cascade. *11th Conf. on Mesoscale processes*, 24-28 Oct 2005, Albuquerque, NM, Amer. Meteor. Soc., CD-ROM.

Lu, C., W. Hall, and S. Koch, 2006: High-resolution numerical simulation of gravity wave-induced turbulence in association with an upper-level jet system. *12th Conf. on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM.

Project Title: <u>Air Quality Forecasting</u>

Principal Researcher: Mariusz Pagowski

NOAA Project Goal/Programs: Weather and Water—Serve society's needs for weather and water information / Environmental Modeling and Air Quality

Key Words: Ozone Forecasts, Improvement, Economic Value

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

This research has the general objective to improve ozone forecasts. A study was undertaken to evaluate benefits of probabilistic forecasts compared to deterministic forecasts.

2. Research Accomplishments/Highlights:

In the summer of 2004, seven air quality models provided forecasts of surface ozone concentrations over the eastern U.S. and southern Canada. Accuracy of these forecasts can be assessed against hourly ozone measurements at over 350 locations. Simulation domain is shown in Fig. 1.

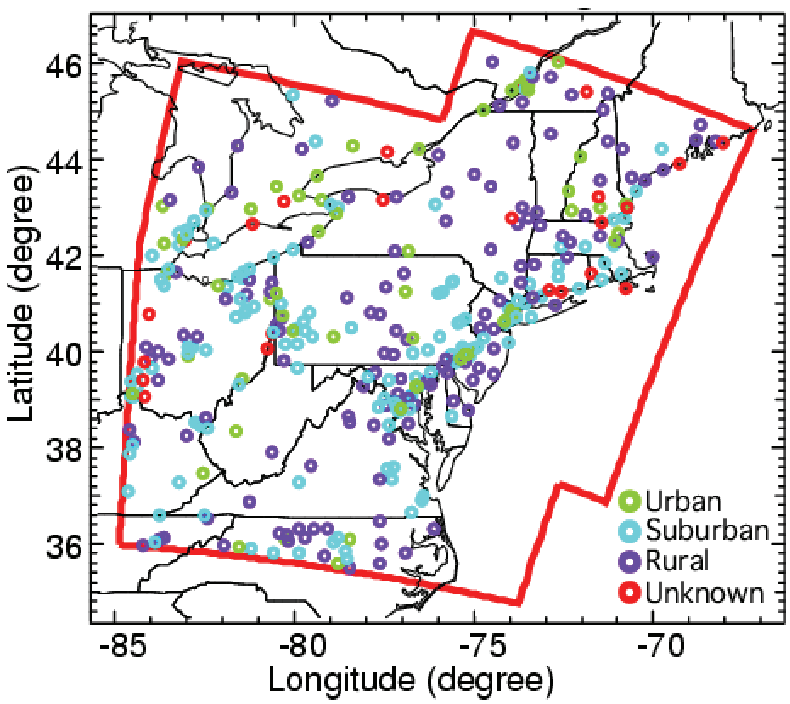


Fig. 1. Locations of the measurement sites, the AIRNow site classification, and outline of the domain of model overlap.

The ensemble of the air quality models is used to issue deterministic and probabilistic forecasts of maximum daily 8-hr and 1-hr averaged ozone concentrations. To remove the bias, the probabilistic forecasts are calibrated using a method described by Pagowski et al. (2006). The economic value of forecasts, which is calculated using Richardson's cost-loss decision model (Richardson 2000, Richardson 2003), is evaluated for both deterministic and probabilistic cases. As shown in Fig. 2, deterministic forecasts obtained with the ensemble of models provide a greater benefit to decision-makers than forecasts issued with individual models. Probabilistic forecasts demonstrate similar advantages over the deterministic forecasts. Further details are given in Pagowski and Grell (2006).

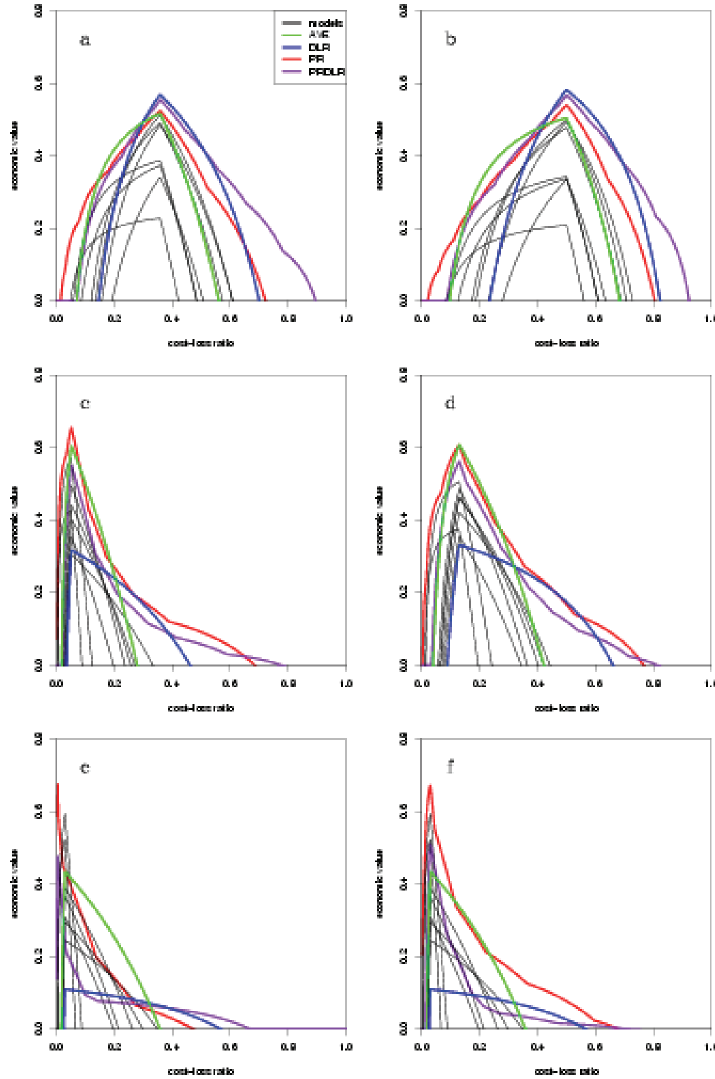


Fig. 2. Economic value of deterministic and probabilistic forecasts of maximum daily 8-hr (left) and 1-hr (right) averaged surface ozone concentration over 50 ppbv (a and b), 70 ppbv (c and d), and 85 ppbv (e and f) thresholds with single models (black), ensemble average (red), ensemble weighted with DLR (blue), uncalibrated probabilistic (red), and probabilistic calibrated with DLR (purple).

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

The research is considered successful and completed. Improvement of ozone forecasts is considered very relevant to public interest.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

Pagowski, M. et al., 2006: Application of dynamic linear regression to improve the skill of ensemble-based deterministic ozone forecasts. *Atmospheric Environment*, 40, 3240-3250.

Pagowski, M. and G. Grell, 2006: Ensemble-based ozone forecasts: skill and economic value. *J. Geophys. Res.*, in print.

Pagowski, M., G.A. Grell, S.A. McKeen, D. Devenyi, J.M. Wilczak, V. Bouchet, W. Gong, J. McHenry, S. Peckham, J. McQueen, R. Moffet, and Y. Tang, 2006: A simple method to improve ensemble-based ozone forecasts. *Geophys. Res. Lett.,* 32, L07814-1-4.

Richardson, D.S., 2000: Skill and relative economic value of the ECMWF ensemble prediction system. *Quart. J. Royal Meteorol. Soc*., 126, 649--667.

Richardson, D.S., 2003: Economic value and skill, in forecast verification. A practitioner's guide in atmospheric science, I.T Joliffe and D.R. Stephenson (eds.), J. Wiley & Sons, Chichester, England, 164--187.

McKeen, S., J. Wilczak, G. Grell, I. Djalalova, S. Peckham, E.Y. Hsie, W. Gong, V. Bouchet, S. Menard, R. Moffet, J. McHenry, J. McQueen, Y. Tang, G.R. Carmichael, M. Pagowski, A. Chan, T. Dye, G. Frost, P. Lee, and R. Mathur, 2005: Assessment of an ensemble of seven real-time ozone forecasts over eastern North America during the summer of 2004. *J. Geophys. Res.* 110, D21307-.

Project Title: <u>Regional Climate Modeling</u>

Principal Researcher: 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:

For this purpose, regional climate simulations are performed in June 2004 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. Convection is parameterized in simulations on a 20-km resolution grid and cloud resolving simulations are performed on a 1.7-km resolution grid (Fig. 1). The default parameterization of convection is an ensemble of closures based on varying assumptions (Grell and Devenyi 2002). Turbulence is parameterized with a 2.5 order closure, and a land surface model by Smirnova et al. (2002) is used. Initial conditions for the atmospheric and the land surface models are obtained from the RUC analysis.

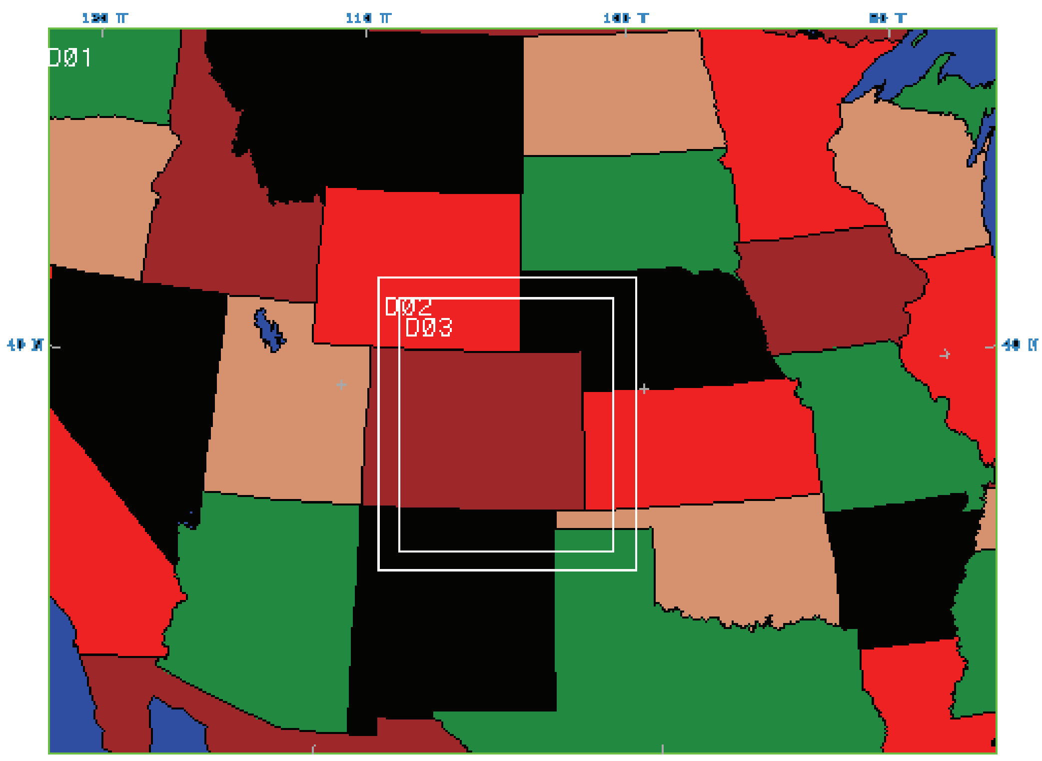


Fig. 1. Simulation domains: D01 - 20-km resolution grid, D02 – 5km resolution grid, D03 - 1.7-km resolution grid.

A comparison of simulated precipitation with a .25 degree resolution CPC analysis is shown in Fig. 2. Initial soil moisture obtained from the RUC analysis does not differ significantly from the minimum values allowed for a given soil type. Sensitivity of precipitation to the initial soil moisture is studied by assigning maximum soil moisture for a given soil type. The results are shown in Fig. 3.

A small high-resolution domain allows for the analysis of spatially averaged precipitation. Differences in hourly characteristics of precipitation in different simulations are illustrated in Fig. 4.

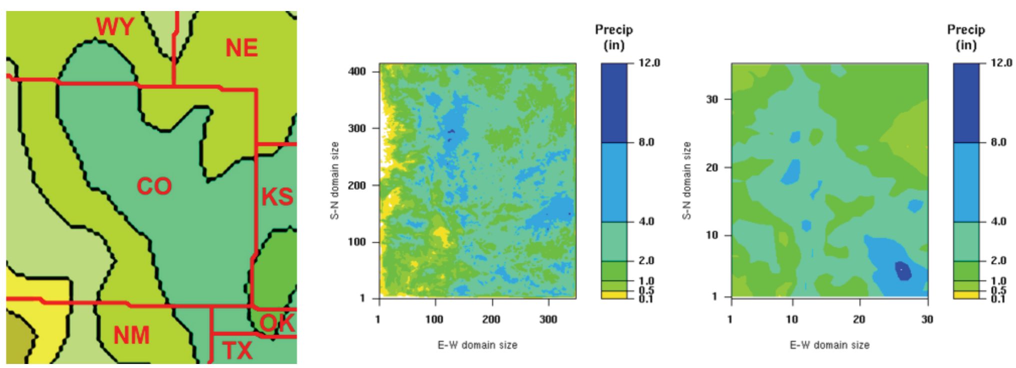


Fig. 2. Observed monthly accumulated precipitation in June 2004 from the Climate Prediction Center, simulated in high- and low-resolution domains.

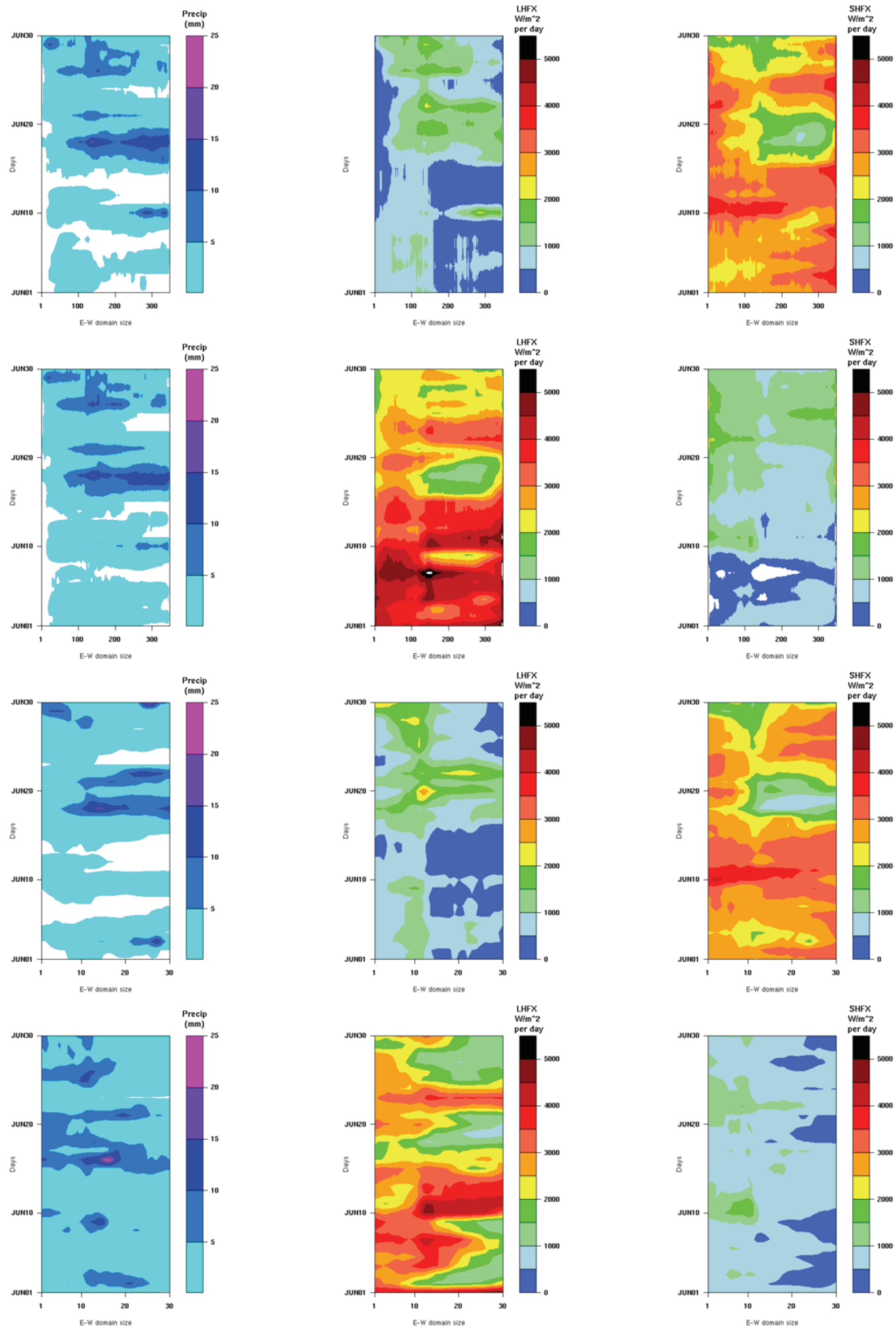


Fig. 3. Sensitivity to the initial soil moisture at different model resolutions. Columns from the left: N-S averaged precipitation, latent and sensible heat flux. From the top: 1.7-km model resolution: RUC derived soil moisture, maximum soil moisture, 20-km resolution: RUC derived soil moisture, maximum soil moisture.

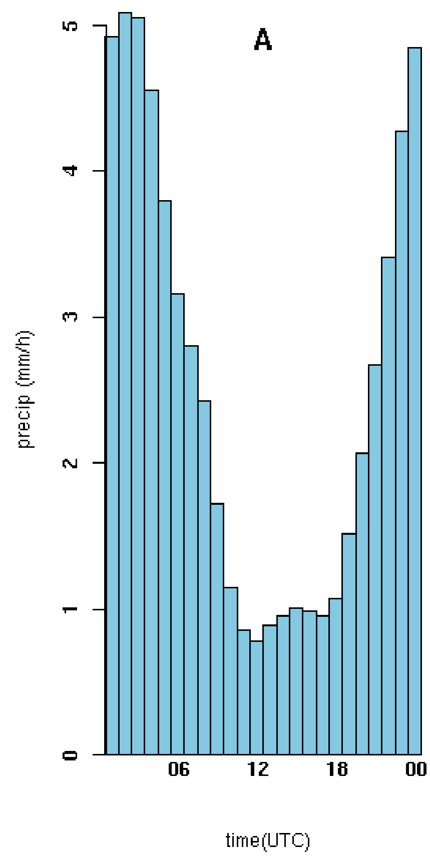


Fig. 4A. Hourly precipitation averaged spatially and temporally over one month, simulated in 1.7-km and 20-km domains with explicitly resolved convection.

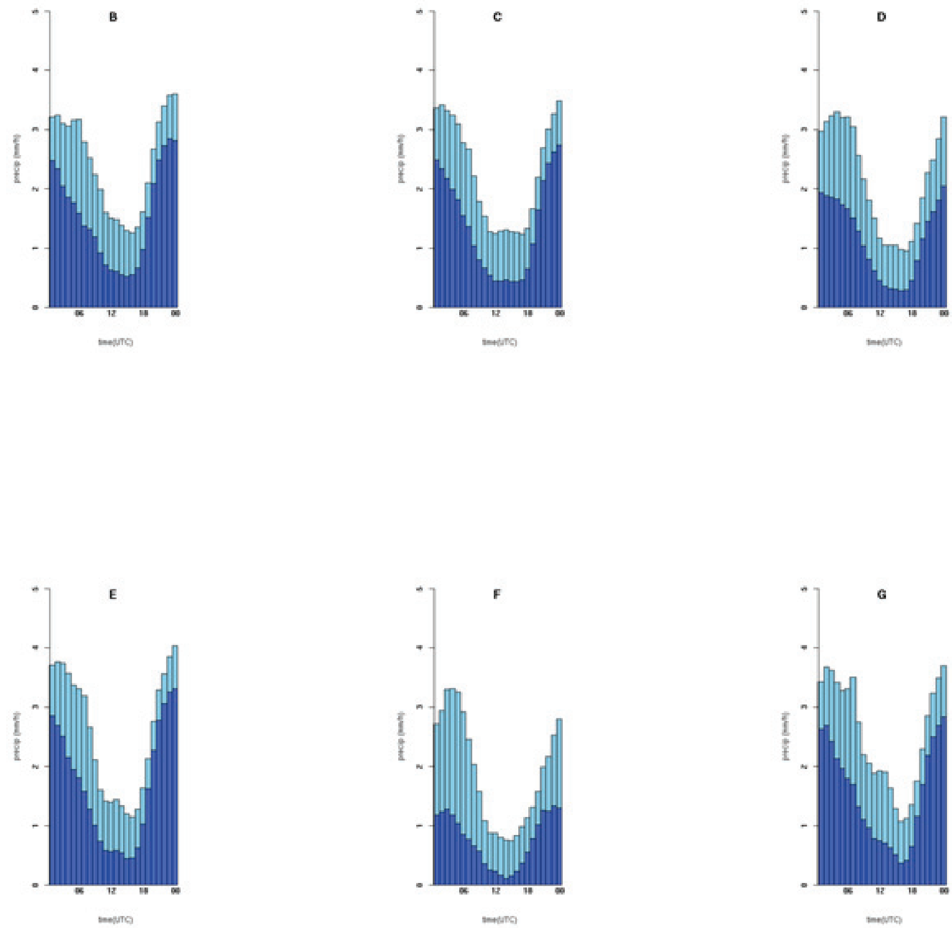


Fig. 4B-4G. Hourly precipitation averaged spatially and temporally over one month, simulated in 1.7-km and 20-km domains with parameterized convection. B - ensemble of closures, C - Grell, D - Frank-Cohen, E - Krishnamurti, F - Kain-Fritsch, G – Arakawa-Schubert.

Some results of this effort will be presented at the Conference on Applied Climatology in Ljubljana, Slovenia in September 2006. A journal publication is being planned for the next year.

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

The research is in progress and will be continued in year 2006/2007.

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Grell, A.G., and D. Devenyi, 2004: A generalized approach to parameterizing convection combining ensemble and data assimilation techniques. *Geophys. Res. Lett.*, Vol. 29, No. 12.

Smirnova, T. G., J. M. Brown, and S. G. Benjamin, 2000: Parameterization of frozen soil physics in MAPS. *J. Geophys. Res.* 105 (D3), 4077-4086.

Project Title: <u>Regional Transport Analysis for Carbon Cycle Inversions</u>

Principal Researcher: 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:

Objective of this research is to provide influence functions for selected measurement towers in North America. A portion of the effort will be to provide RUC analyses as input to a Lagrangian model to calculate backward trajectories of particles reaching these observation sites. The winds obtained from the analyses are adjusted to conserve mass with a minimization technique with constraints using a Lagrangian multiplier.

2. Research Accomplishments/Highlights:

During the past year, we obtained data sets 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 sub-setting 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.

Fig. 1 presents a series of influence functions [ppm/umol] calculated during testing of 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/m2/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.

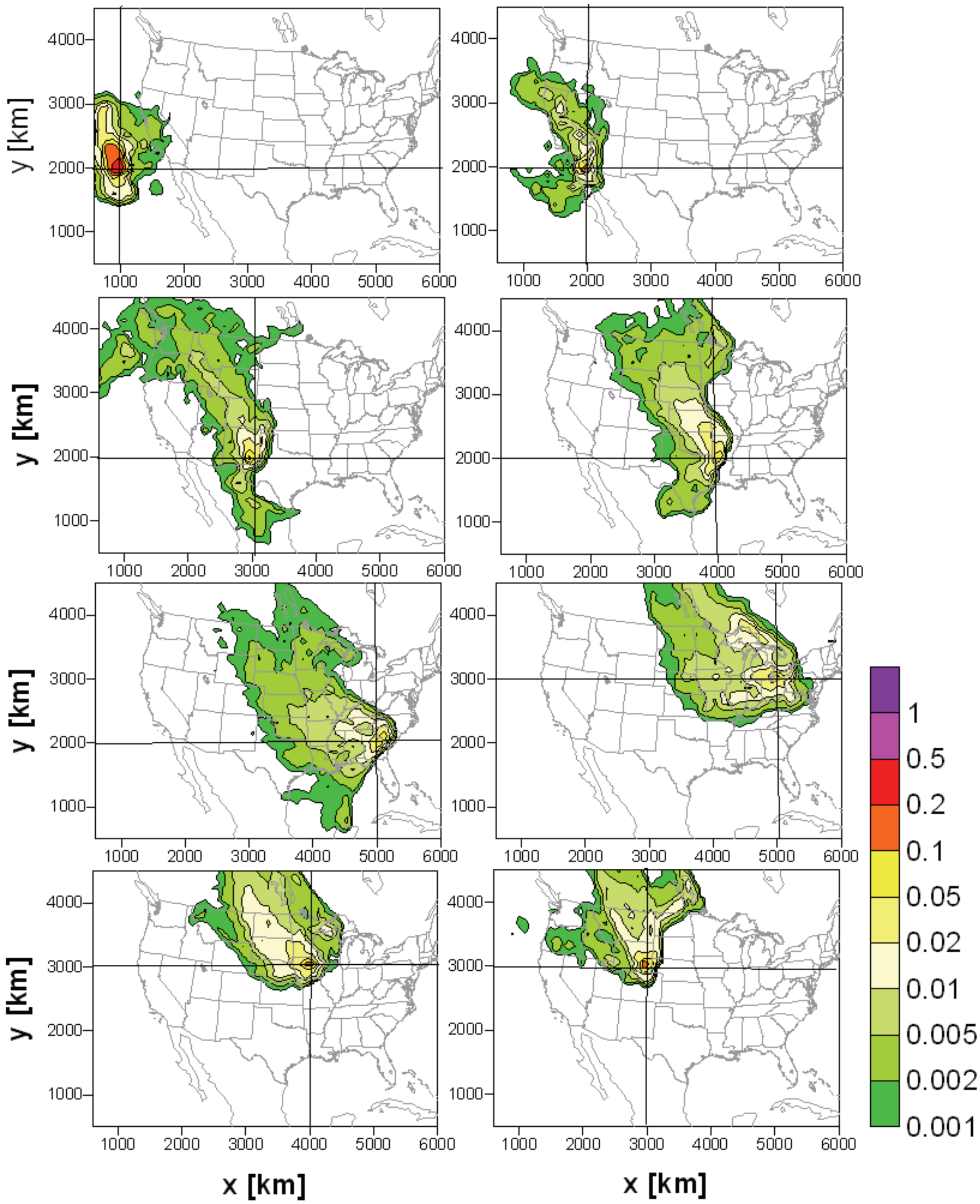


Fig. 1. A series of influence functions [ppm/umol] calculated during testing the prototype RUC/LPDM system. They are derived for the 10-day period of March

6-16, 2006 and hypothetical 400 m towers spaced every 1000 km across the RUC domain.

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 Report Period:

The research is in progress and will be continued in year 2006/2007.

Project Title: <u>FAA Turbulence Project</u>

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

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, the period of January-February 2005 was chosen as an initial test period. For simplification, the 300 hPa level was selected for the initial analysis. Plotted fields of the individual diagnostic algorithms were obtained for reference. Software was written to generate plots of some basic meteorological fields from analyses and forecasts of the Rapid Update Cycle (RUC) model, including isotachs, omega, shear, stability, temperature, vorticity, temperature advection and vorticity advection. Software was also written to plot satellite IR images and to plot pilot reports (pireps) of turbulence for verification. These plots were collated and organized on a webpage for easy analysis of the synoptic pattern and related variables.

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, and cases including those patterns were subjectively recognized and identified during the test period. The 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. The early results appear to be quite promising, with fields and combinations of fields correlating well to the observed turbulence. The performance of the individual diagnostic algorithms comprising the GTG is currently being investigated. 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.

Under the heading of diagnostic development, the Unbalanced Flow (UBF) algorithm currently used in the GTG was upgraded to include Duct Factor (which promotes gravity waves to advect downstream) and an advection scheme. The original upgraded UBF was produced in Interactive Data Language (IDL), however, and as such, was not able to be directly incorporated into the GTG. To accomplish this, the code was translated into Fortran, and delivered for testing. Results of the testing revealed that the new algorithm was not as accurate as the original UBF. The Fortran code was reviewed and some bugs were discovered and corrected. This corrected version is undergoing in-house testing and will be delivered to NCAR for testing in the near future.

A new task is being undertaken to examine out-of-cloud convectively induced turbulence (OCIT), or more simply, turbulence generated near convective clouds and storms. As an initial step, software was written to display pireps superimposed on a satellite infrared (IR) image. Since the IR data can be as frequent as every 15 minutes, only those pireps within 7.5 minutes of the image time are plotted. Scripts were written to automatically choose the proper satellite and pirep data, generate the plots, and move plots older than 48 hours to a storage repository. A web page was also developed to display the most current images in a thumbnail fashion for subjective case selection. Once an adequate number of cases are found, some statistics will be performed to identify any trends in the data. A recently developed RUC product dubbed RCPF (RUC Convective Probability Forecast) that uses an ensemble of forecasts to provide probability forecasts of convection may also be used to eventually provide forecasts of OCIT that could be included in a newer version of the GTG. Software was recently written to contour the RCPF probability values (Fig. 1) as an additional product in the satellite IR and pirep plots.

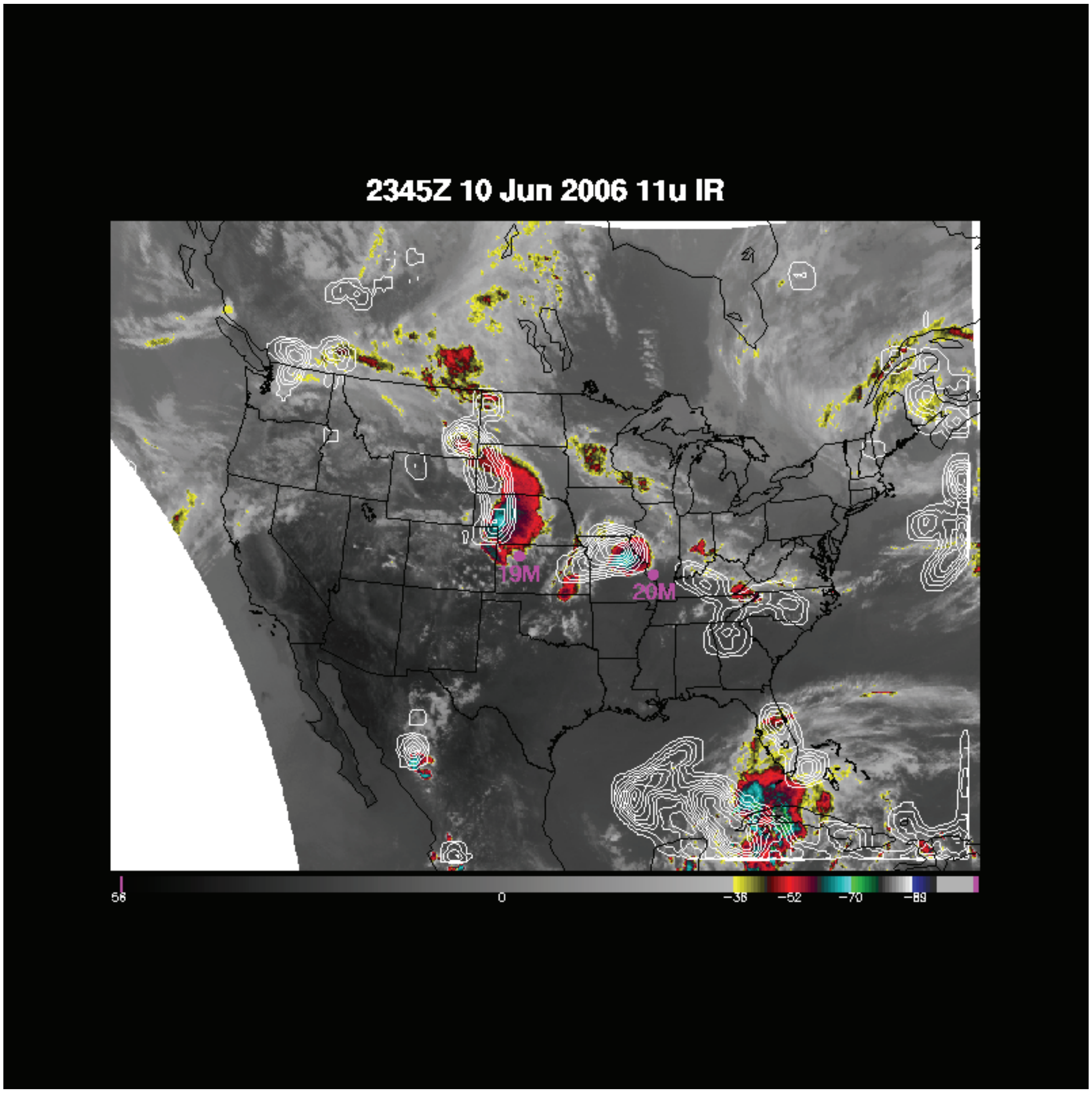


Fig. 1. A Satellite IR image for 2345 UTC, 10 June 2006 with superimposed pireps of moderate turbulence and contours of RCPF probabilities. The pireps are at 19,000 and 20,000 ft. altitude.

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/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Collander, R.S., E.I. Tollerud, B.D. Jamison, F. Caracena, C. Lu, and S.E. Koch, 2006: Turbulence in MCS anvils: Observations and analyses from BAMEX. *12th Conference on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta GA, Amer. Meteor. Soc.

Project Title: <u>AMDAR (Airborne Meteorological Data Reporting) Optimization</u>

Principal Researcher: Brian Jamison

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

Key Words: Airborne Weather Sensors, Model Sensitivity Study

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

The AMDAR Optimization Project is designed to determine what effect thinning of aircraft data has on a numerical model. Communication costs to provide aircraft data can be extensive, and if it can be shown that fewer observations have little impact on the model output, then the number of observations can subsequently be reduced.

2. Research Accomplishments/Highlights:

For this study, the Rapid Update Cycle (RUC) 20 km model was used, and the test period was selected to be April 22-28, 2005. The RUC model was run retroactively five separate times for this period, each time using different "data thinning" strategies which involved dividing the three dimensional RUC volume into sub-area boxes, and limiting the number of aircraft reports within those boxes. Plots of temperature, humidity, and wind differences were analyzed for the impact of the thinned data. Results were varied, showing that specific areas where active and rapidly changing weather conditions were occurring were affected more than quiescent areas. Because of this, attempts were made to potentially identify the active areas in an objective manner. The characteristics used to identify these areas included: the advection of the 1000-500 mb thickness by the 700 mb wind, the lifted index, the ground level and 850 mb relative humidity, and the 250 mb wind differences. Software was written to plot these characteristics independently and in combined plots, which were generated and analyzed.

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:

8. Publications:

Moninger, W.R., S.G. Benjamin, D. Devenyi, B.D. Jamison, B. Schwartz, T.L. Smith, and E.J. Szoke, 2006: AMDAR optimization studies at the Forecast System Laboratory. *12th Conference on Aviation, Range, and Aerospace Meteorology (ARAM)*, 30 Jan-2 Feb 2006, Atlanta GA, Amer. Meteor. Soc.

Moninger, W.R., S. G. Benjamin, D. Dévényi, B. D. Jamison, B. Schwartz, T. L. Smith, and E. Szoke, 2006: AMDAR optimization studies at the Earth System Research Laboratory / Global Systems Division. *10th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 6.11a.

Project Title: Science Quality Datasets - Radiosonde Data Web Page and Archive

Principal Coordinator: Brian Jamison

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: Archive of North America Radiosonde Data

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

A science quality archive of radiosonde data for North America began as a collaborative effort between FSL and NCDC in 1992, and continues to be a widely used baseline data set for weather researchers and climatologists nationwide. The archive exists as a CD-ROM set available from NCDC, and is complemented by a web page of global radiosonde data updated regularly. Tasks include: managing and updating the radiosonde data webpage, responding to users' questions and requests, and creating periodic CD-ROM updates to the archive.

2. Research Accomplishments/Highlights:

Tasks completed for the past year include moving the automated processes to run on another computer server due to the phasing out of the older computer, filling small data requests that cannot be filled via the website, responding to questions about the archive and radiosonde data in general, and providing in-depth technical information and references when necessary.

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.

VI. Research Collaborations with the GSD Technology Outreach Branch (formerly the FSL Technology Outreach Division)

A. FX-Net Forecaster Workstation Project

Principal Researcher: Sher Schranz
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, Weather water science, technology, and infusion. FX-Net is a cross-cutting solution provided to all of these program elements. FX-Net also supports NOAA's cross-cutting priorities of environmental literacy, outreach and education.

Keywords: PC Workstation, Fire Weather, Air Quality, Compression Algorithm

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

Background: 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 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.

Research Objectives: 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.

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.

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 while 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 and extended Java applications.

The Wavelet Compression (see project 2.0 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:

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 most recent version of the fielded software and the latest version of Linux, Enterprise, v. 3.0. This new version of the FX-Net system was considered a major upgrade by the NWS regional offices in Western, Southern, Alaska and Pacific regions.

Additional data analysis tools and an automated updating process were added to insure any product updates were immediately available to the FX-Net Client users. The capability to password-protect users accessing NWS FX-Net servers was also added.

New high-resolution forecast models and additional data sets were added to the system. Data added included the long range GFS model out to 380 hrs, the new high-resolution CONUS ETA model, RAWS data utilizing MADIS, and the planning process to add US Forest Service dispersion models was begun.

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.

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

All objectives are in progress.

4. Leveraging/Payoff (Benefits to the Public):

The FX-Net system is highly leveraged in terms of program funding and technology. The project is funded by the National Weather Service, the EPA, 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 Alaskan oil spill (See Fig. 1). 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 National Weather Service 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.

Fig. 1. September, 2005, New Orleans. NWS Incident Meteorologist (IMET) briefing HazMat crews in the aftermath of Hurricane Katrina using FX-Net.

5. Research Linkages/Partnerships /Collaborators and Technology Transfer

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 FY05-06, Predictive Services forecasters used FX-Net to view long-range forecasts to aid their fire potential forecasts and utilized real-time data to support NIFC fire suppression resource managers.

BLM users at the above locations provide long-range fire predictions, daily fire indexes, and drought outlook products for various BLM websites and for operational use by fire weather forecasters. 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 selected 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.

EPA users who participated in the pilot project who used this system as their primary forecast preparation system during significant air quality forecasting seasons have recommended that the EPA continue the FX-Net project.

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. 4.0) 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.

Researchers from the U.S. Air Force, Boeing, NASA and the Weather Modification community have also used the system for model verification, field studies and experimental weather forecasting.

FX-Net and the Public Sector
In FY05-06, the ENSCO commercial version of the Met WiseNet system based on the FX-Net v. 4.0 system was released. The commercial evaluation period proved the commercial viability of the system. Via an agreement with ENSCO, the FX-Net development team added capabilities

6. Awards/Honors:

One member of the FX-Net development team was named “Employee of the Month” by FSL management in FY 05/06.

The FX-Net team received a Merit Award from the BLM/ National Interagency Fire Center's Predictive Services group for 'Outstanding Service in Support of BLM Predictive Services'.

7. Outreach / Education:

Presentations and demonstrations of FX-Net were given to visitors from China, Korea, the Finnish Meteorological Institute, Boeing Corp, ENSCO, Raytheon, Vaisala, UCAR, the Weather Modification Workshop, and various other interested individuals.

In addition:

● FX-Net was demonstrated to Adm. Lautenbaucher and other visitors to the exhibits at the Annual AMS Conference and Exhibit in Atlanta in January, 2006.

● FX-Net training was held at the Annual Incident Meteorologist's (IMETS) training meeting in March in Boise, Idaho.

● An FX-Net forecasting seminar for state and local air quality forecasters was given at the 2005 EPA Air Quality Conference in San Antonio in February 2006. An FX-Net status presentation was also given at the Conference.

Although a request for a Hollings scholar was not filled this year, the project will be hosting one during the summer of 2007 to work on compression algorithms.

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) Earth Day open house and talks with various elementary and secondary school groups.

8. Publications: None as yet.

<u>B. Gridded FX-Net or the World Wide Weather Workstation (W^4)</u>

Principal Researcher: Sher Schranz
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, Environmental modeling, Weather water science technology and infusion. FX-Net is a cross-cutting solution provided to all of these program elements.

Keywords: PC Workstation for Gridded Products, Wavelet Compression

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

Background: 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.

Research Objectives: 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 FY05-06 goals were to build a Phase II system demonstrating the ability to:

1) distribute additional observational, gridded and image data to multiple, remote D2D users from one AWIPS server;

2) improve the gridded data compression to maintain the NWS-approved maximum error while improving compression ratios and memory usage;

3) add more remote clients and measure data distribution performance; and

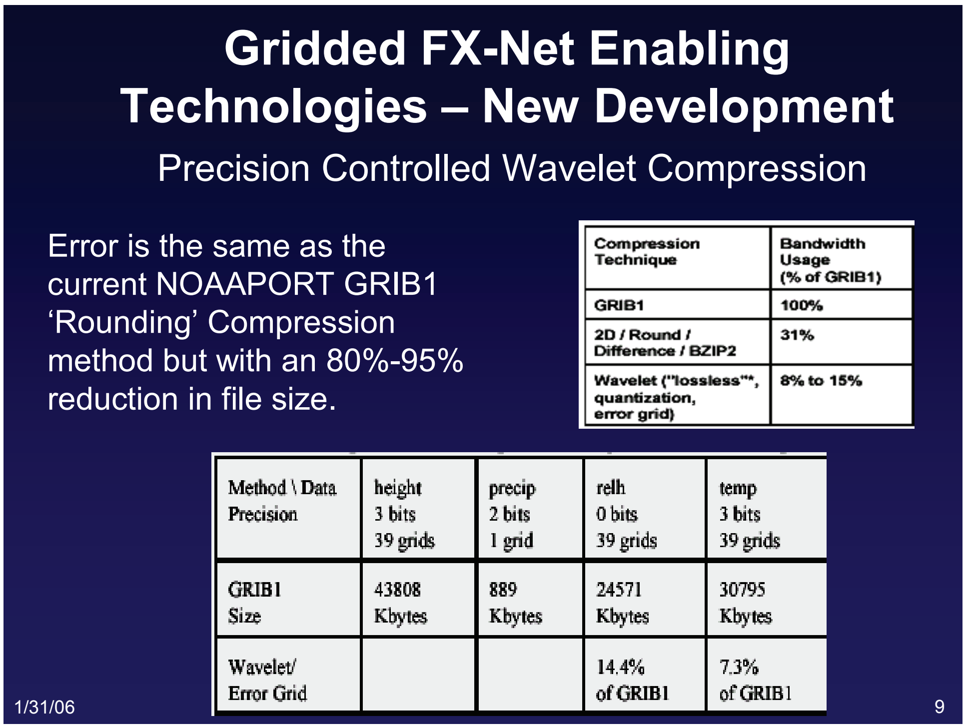
4) improve the robustness of the data distribution system.

2. Research Accomplishments/Highlights and Current Status:

Research in FY05-06 centered on improving compression, adding more distributed data sets and measuring performance when adding additional remote clients to the existing set of server systems.

Server software: 1) Developed the Compression Relay Management System (CRMS) to manage data compression, data distribution, arrival notifications and delivery mechanisms; 2) Added new compression algorithms which included new quantization scheme to handle higher-resolution gridded data sets.

Wavelet Compression: 1) The new scheme compresses grids from models that range from global 180 km to CONUS 12 km resolutions; 2) More robust code optimizes memory usage; 3) See Fig. 2 for a comparison of the Wavelet Compression in Gridded FX-Net vs. other compression methods.



Compression Technique	Bandwidth Usage (% of GRIB1)
GRIB1	100%
2D / Round / Difference / BZIP2	31%
Wavelet ("lossless"*, quantization, error grid)	8% to 15%

Method \ Data Precision	height 3 bits 39 grids	precip 2 bits 1 grid	relh 0 bits 39 grids	temp 3 bits 39 grids
GRIB1 Size	43808 Kbytes	889 Kbytes	24571 Kbytes	30795 Kbytes
Wavelet/ Error Grid			14.4% of GRIB1	7.3% of GRIB1

Fig. 2. Gridded Wavelet data compression vs. other gridded data compression.

Clients: During FY 05-06, Gridded FX-Net Clients were installed at three test sites. The test users reported to NIFC management that the system was approved and working up to expectations. Based on the success of the prototype system, NIFC management determined that additional prototype systems should be delivered to the sites that were not scheduled for delivery until Phase II was implemented. As a result, five additional systems were built and installed at GACC offices across the country. See Fig. 3 for the Gridded FX-Net basic architecture.

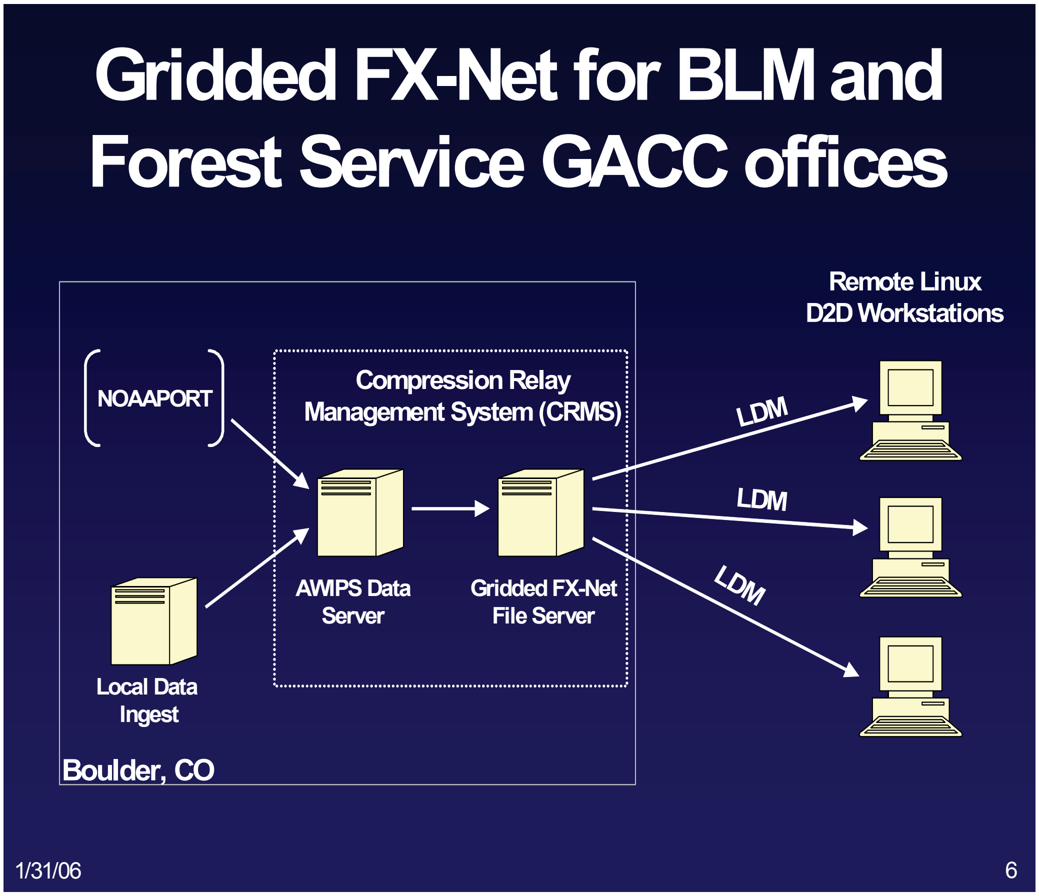


Fig. 3. Gridded FX-Net architecture.

As a result of these installations, meteorologists at the predictive services units and GACC offices have the opportunity to execute fire prediction algorithms that require the use of atmospheric model grids. They did not have this capability before the Gridded FX-Net systems were installed.

The next phase of the project will include research and development to add:

1) “pull” technology to allow users to request data not already ‘pushed’ to the system;
2) expanded high-resolution gridded data, observations and the AWIPS ‘pull’ text data base;
3) capability to the compression algorithms for a lossless capability for radarimagery;
4) evaluation of LDM distribution system and identifying potential alternatives.

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

All of the objectives are in progress.

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/Collaborators 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 National Weather Service regional headquarters offices in the Alaska and Pacific regions are developing new operational concepts for their remote Weather Service Offices that do not currently have AWIPS systems.

6. Awards/Honors:

7. Outreach:

8. Publications:

Schranz, S., 2006: The gridded FX-Net Prototype Project for the National Interagency Fire Center. *22nd Conf. on Int. Conference on Interactive Information Systems (IIPS) for Meteorology, Oceanography, and Hydrology: Aviation Meteorology, Safety, and the Future Aviation Weather System*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 6.8.

Stewart, J., N. Wang, and E. Polster, 2006: Compression and Relay Management System (CRMS) architecture and use of wavelet compression. *22nd Conf. on Int. Conference on Interactive Information Systems (IIPS) for Meteorology, Oceanography, and Hydrology: Aviation Meteorology, Safety, and the Future Aviation Weather System*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 10.8.

Wang, N. and C. Matsumoto, 2005: A comparison study of data compression techniques for the Battle-scale Forecast Model grids. *BACIMO 2005 Conference,* 12-14 Oct 2005, Monterey, CA, P.6.04.

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^{TM} 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^{TM} (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 five-projector display architecture was implemented and demonstrated. This new projector arrangement reduces shadowing by viewers and eliminates polar regions where no data is displayed in our older four-projector arrangement.

--An enhanced software-based projector alignment method was developed, eliminating tedious mechanical projector alignment, while improving image registration.

--SOS was installed at six new permanent public venues—Nauticus National Maritime Museum in Norfolk, VA, Bishop Museum in Honolulu, HI, The Tech Museum in San Jose, CA, Science Museum of Minnesota in St. Paul, MN, NASA Goddard Space Center in Greenbelt, MD, and the Maryland Science Center in Baltimore, MD.

--Several new data visualizations were developed, along with enhancements to existing data sets.

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

Objective: CIRA proposes to continue the development of new capabilities and data sets for the Science on a Sphere (SOS) global visualization system.

Status: In progress. A number of improvements were made to the McIDAS global IR satellite data processing. GFS forecast animations for 500mb height and precipitable water can now be processed via IDL and displayed on the SOS. A new animation for the oceanic depth of the 26C isotherm was produced to help in assessing the 2005 hurricane season. Steve Albers presented a poster at the American Geophysical Union conference in San Francisco describing his various SOS efforts (reference below). Steve reports on his data set enhancements:

“The software that processes the real-time global IR satellite imagery is being reworked so that it can also process and save archive data cases. One of the first uses of this was to set up a dataset featuring an animation of the 2005 hurricane season, for use at the AMS conference. I helped organized this and several other hurricane related datasets into the SOS playlist that was used at the conference.”

Several improvements were made to the real-time global IR satellite animations. Experiments were conducted to add (by reprojecting) MTSAT IR satellite data into our existing global IR mosaic. This has the potential to improve the temporal frequency of the animation over a region including Japan. The datasets from the Aviation Weather Center are thus being augmented by our quality control and overlayed with MTSAT data obtained from the CWB in Taiwan. New IDL software is being used to combine the augmented satellite animations with the NASA Blue-Marble with several options for more vivid color enhancements. These newly enhanced versions are now viewable in real-time on SOS. See Fig. 1 below.

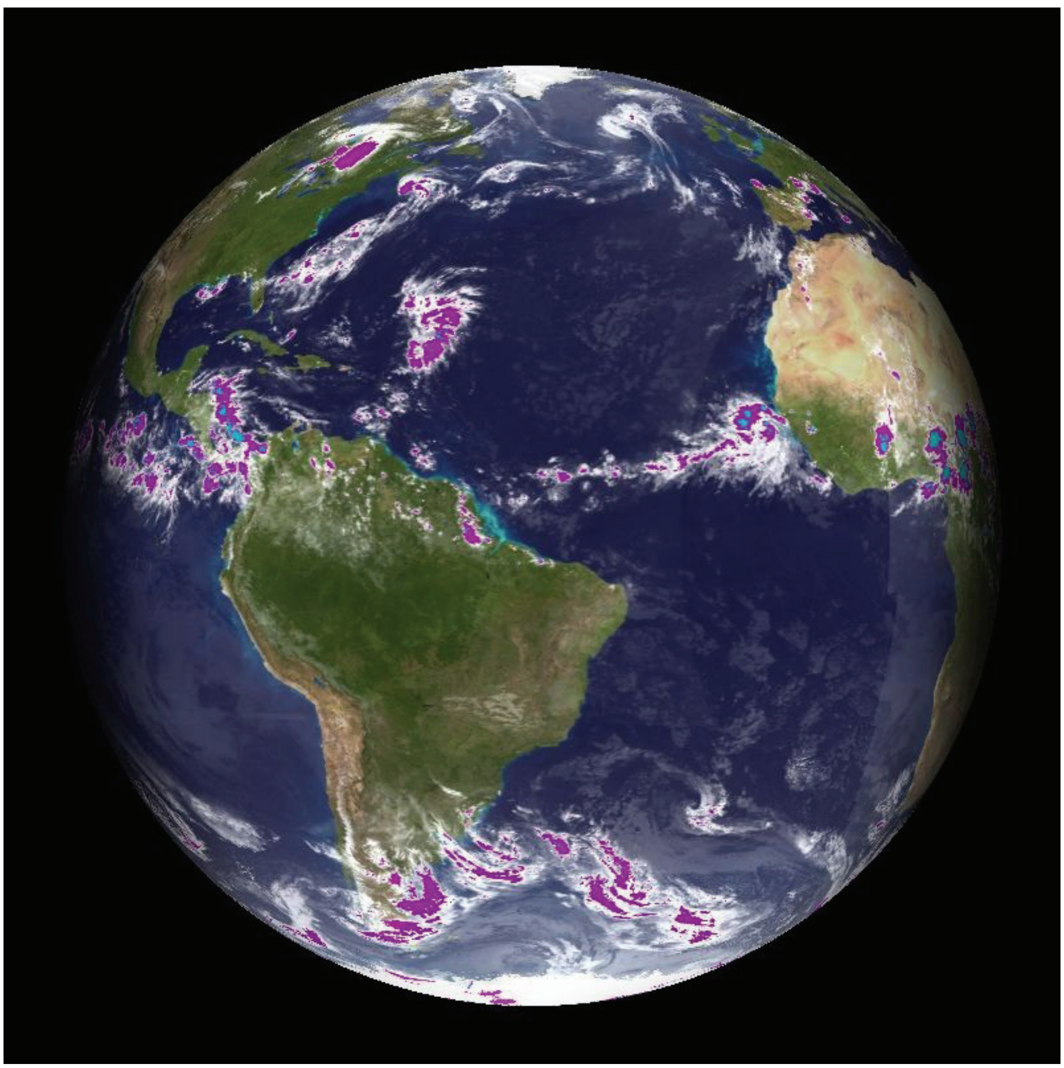


Fig. 1. A projector's eye view of the enhanced McIDAS / Blue Marble animation.

Some datasets were reprocessed so that they can now be rendered on SOS with different projector configurations, including the NCDC 20-year SST animation, as well as their 20-year land temperature animated dataset. This encompasses for each movie frame the conversion from four projector viewpoint images into single global cylindrical projection images.

Discussions were held with personnel from NESDIS in the hopes of adding a real-time polar-orbiter global precipitable water animation to SOS. A preliminary version of this is now being shown on SOS in real-time.

An astronomy oriented SOS demonstration for a group from the Space Science Institute was performed as well as an oceanic-oriented SOS demonstration for the GHRSST-PP workshop—a gathering of experts on global sea surface temperature analyses, including scientists from the UK Met Office.

A number of planetary datasets were updated to include newly available imagery, including Jupiter, its satellites and several satellites of Saturn, Uranus, and Neptune. The map created for Neptune's moon Triton was utilized (and credited) in the graphic artwork featured on the cover of the journal Nature for May 11, 2006. Other improvements were made to our global mosaic for Saturn's satellite Iapetus (see Fig. 2 below). A new map of Pluto was added showing current low-resolution knowledge of its surface.

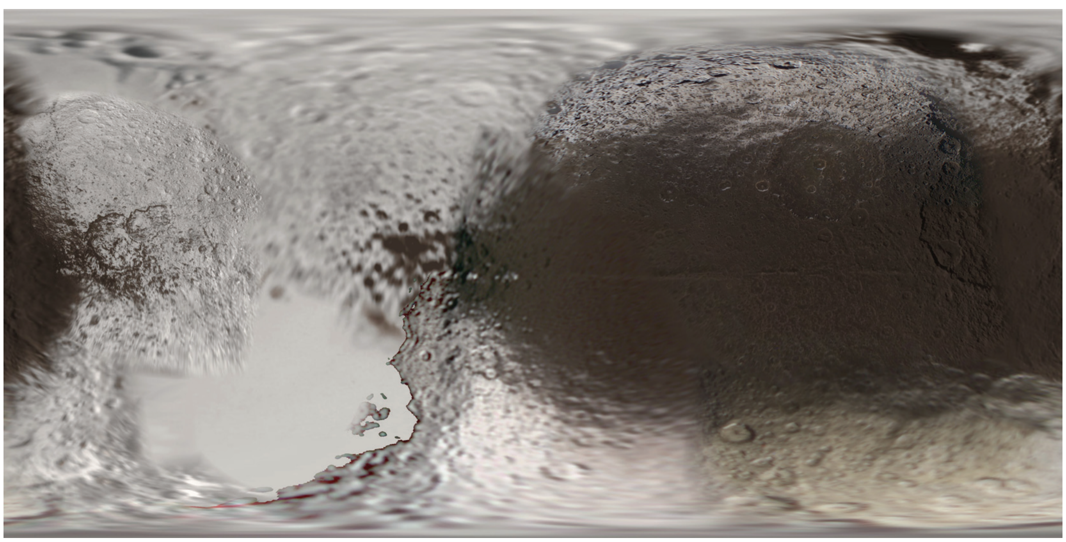


Fig. 2. Cylindrical map of Iapetus that was developed for projection on SOS.

Objective: New arrangements of projectors will be developed and evaluated, including raising the positions of the four current projectors, possibly adding a fifth projector to fill a missing data region at the bottom of the sphere. A new eight-projector arrangement will be developed using either short-throw projectors or mirror bounce to shrink the required footprint of the system. The eight-projector architecture is being developed for installation at the Smithsonian Ocean Hall exhibit.

Status: In progress. Elevating the position of the four projectors was designed and successfully demonstrated at two sites: the ESRL Planet Theater in Boulder and the new Bishop Museum site in Hawaii. This projector elevation was necessary at the Bishop site to avoid excessive shadowing by observers, due to unusually low ceilings in the room. At the ESRL Planet Theater, the fifth (bottom) projector was added and demonstrated, although only a few of the many SOS data sets have been re-rendered for the bottom projector. The eight-projector arrangement was implemented in the display software (see Fig. 3), although demonstration of this capability has been indefinitely deferred due to the additional projector purchase and maintenance costs. The five-projector architecture has adequately addressed the shadowing and data coverage issues, which were the impetus for the eight-projector objective.

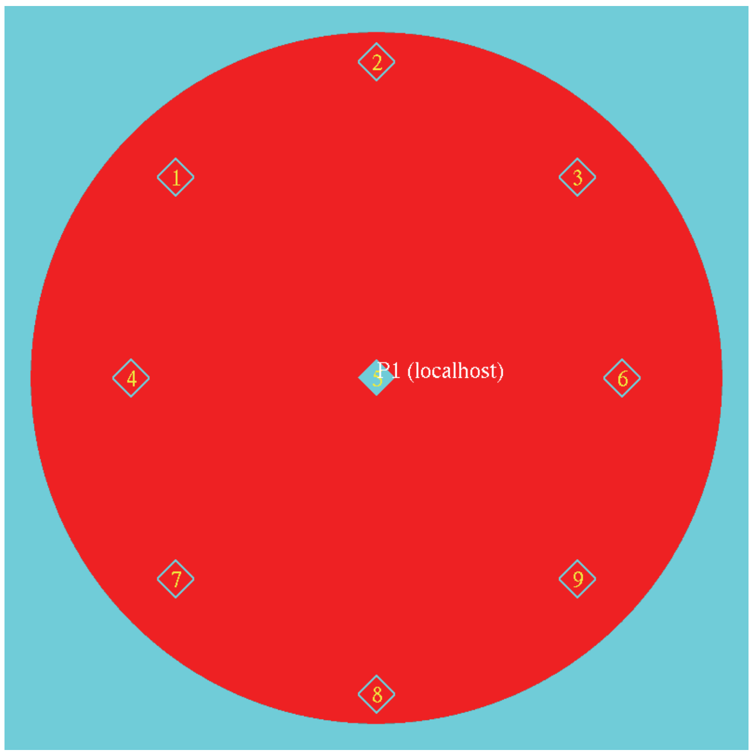


Fig. 3. With the new SOS software alignment process, the user can interactively warp the position of any one of nine target points, without affecting the registration of the other eight. This dramatically improves the quality and speed of projector alignment. The user's view of this process for a single projector is shown here.

Objective: CIRA staff will continue to extend and improve the software and user interface of the existing version of SOS in new and existing venues. For example, interactive highlighting of features and control of the sphere will be developed for a planned SOS installation at the Stennis Space Center museum.

Status: While the Stennis installation has been shelved in the aftermath of Hurricane Katrina, significant other software and user interface enhancements were completed. The most significant of these is a new projector alignment method, using software image warping techniques rather than manual projector alignment adjustments. The new alignment is accomplished using the SOS remote control, and is much more accurate and less time consuming than mechanical projector adjustment was. Some other enhancements to the system include fade transitions between clips, more flexible interactive tilting of imagery, and the first rudimentary display of data exported from an ALPS workstation.

Objective: CIRA researchers will also be providing support for SOS installation, training and operation at other new SOS installations including the Nauticus Maritime Museum, the NASA Goddard Visitor Center, and new sites to be awarded by the NOAA Environmental Literacy Grant program.

Status: SOS was successfully installed at the Nauticus Maritime Museum, the NASA Goddard Visitor Center, and four sites that were awarded NOAA Environmental Literacy Grants: Maryland Science Center (Baltimore), Science Museum of Minnesota (Saint Paul), Tech Museum (San Jose), and Bishop Museum (Honolulu).

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

Albers, S., D. Himes, and A. E. MacDonald, 2005: Displaying Planetary and Geophysical Datasets on NOAA's Science on a Sphere^{TM}. *AGU Fall 2005 Conference*, San Francisco, CA, 5-9 December 2005, Poster session.

VII. <u>Research Collaborations with the GSD Information Systems Branch (formerly the FSL Modernization Division)</u>

Project Title: <u>WFO-Advanced</u>

Principal Researcher: MarySue Schultz
Team Members: Joanne Edwards, Tom Kent, and Leigh Cheatwood

NOAA Project Goal/Program: Weather and water--serve society's needs for weather and water information / Local forecasts and warnings

Key Words: Data Processing and Visualization, Advanced Meteorological Workstation Development

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

The WFO-Advanced project is responsible for developing and evaluating new techniques for weather data processing and visualization, in support of the Advanced Weather Interactive Processing System (AWIPS). 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 United States. CIRA, in cooperation with the Information Systems Branch (ISB), is responsible for conducting research and experimenting with new techniques in the areas of real-time programming, database access, data decoding, data distribution and visualization in support of the AWIPS objective.

2. Research Accomplishments/Highlights:

In support of AWIPS enhancement, the following efforts and activities occurred during the past year:

--Developed data access techniques for displaying Multi-sensor Precipitation Estimate (MPE)
--Developed data access techniques for displaying NOAA/NESDIS sea surface temperature data
--Integrated the Graphical Forecast Editor (GFE)
--Evaluated AWIPS workstation usage
--Investigated new data delivery paradigm
--Investigated using AWIPS to disseminate hazard event information

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

Objective: Explore new technologies to address the rapid increase in existing meteorological data, the introduction of new datasets, and the integration of these data into the development of the next generation of forecaster workstations based on Linux.

This objective is in progress; research has been on-going for several years.

Accomplishments: CIRA researchers were responsible for the introduction of two new datasets last year—one into AWIPS and one into ALPS, a prototype system that will provide evolutionary changes to AWIPS. The Multi-sensor Precipitation Estimate (MPE) grids were integrated into AWIPS. These are useful for predicting precipitation and flash flood conditions. The grids are produced locally at each WFO, and are not delivered to the sites via the standard AWIPS distribution networks. CIRA staff successfully developed a capability for displaying this dataset on the AWIPS workstations. The second dataset, introduced into ALPS, was sea surface temperatures produced from satellite data. This is a global-scale dataset produced by NOAA/NESDIS twice a week, and it includes information on sea surface temperature anomalies and hotspots, where the temperatures are higher than the maximum monthly climatology.

CIRA investigated the concept of combining existing Emergency Management (EM) technology with AWIPS to collect and disseminate hazard event information (for example, Avalanche Warnings and Hazardous Materials Warnings) to the public. The EM software selected for the project was the Disaster Management Interoperability Services (DMIS) tool kit, developed by Battelle Laboratories. The DMIS tool kit was already in use for interaction and coordination within the emergency management community. AWIPS already had the capability of sending weather warnings to the public via NOAA Weather Radio and the NOAA Weather Wire Service. CIRA, ISB, Battelle, Northrup Grumman and NWS personnel developed the HazCollect system to test the project's primary concept. Each group developed software and participated in extensive end-to-end testing of the system. The test results showed that emergency management and weather warning technology can be used together successfully to disseminate non-weather emergency warnings to the public. The overall system design worked well; communications between components were stable and reliable, and messages that were created by EM technology could be integrated successfully into the AWIPS systems.

Another important contribution CIRA made to this objective was the evaluation of existing AWIPS capabilities. During the past year, CIRA staff members conducted research on the operational use of the AWIPS and Graphical Forecast Editor (GFE) software at a number of WFOs. The objective was to determine which datasets, visualization tools and forecasting tools were most heavily used. Data were collected on a daily basis and analyzed once a month. The results were reported to NWS headquarters and to the AWIPS developers, and were also presented to the larger AWIPS community at the 2006 IIPS/AMS conference in Atlanta, GA. The evaluation results provided feedback on which capabilities are used at the WFOs, influencing the development of the next generation of forecaster workstations.

Objective: Enhance the workstation interface for accessing data to introduce new capabilities such as drawing.

This objective is in progress.

Accomplishments: CIRA researchers developed a new data access technique for AWIPS, for displaying grids produced by the GFE. The GFE grids can be modified interactively through the GFE Editor. Developing the data access technique for this dataset is a step towards introducing a drawing capability to AWIPS, which would also involve interactively modifying data.

Objective: A new distributed data schema will be investigated that will make data available on demand to Weather Forecast Offices, as well as to other organizations. The workstation interface for accessing data will be enhanced to make use of the new data system.

This objective is in progress and will be accomplished over a number of years.

Accomplishments: In the current AWIPS design, all available data is delivered to each WFO, where it is stored locally. This design puts a heavy load on the data delivery network and on the data servers and databases at the WFOs. The new paradigm involves storing model output and satellite data on a central server, delivering it to the WFOs only when needed. Other data types will continue to be distributed to each WFO. The load on the AWIPS network and at the WFOs will be reduced, which should result in faster data access to the local data, and should allow the NWS to continue expanding the available datasets without upgrading the hardware at the WFOs. The design calls for data on the central server to be stored in a standard format so that it can be made available to other organizations. The new paradigm will also allow WFOs to share locally generated gridded data (for example forecast grids from the GFE), which will not be available over standard AWIPS distribution networks.

Last year, CIRA researchers led a team that constructed a Statement of Need for research on the new data paradigm. The Statement of Need was accepted by AWIPS management. CIRA also conducted research of off-the-shelf database software, to evaluate its usefulness in the distributed data paradigm. CIRA staff designed and developed prototype software for the remote access of gridded data, and conducted several demonstrations of the prototypes for NWS management to prove that the new paradigm is feasible.

4. Leveraging/Payoff:

New meteorological datasets, including global scale data, are becoming available frequently. Each new dataset contains improved information, such as greater resolution, more accurate measurements, or more sophisticated derived products. It is important to provide forecasters at the WFOs with these state-of-the-art datasets. Data analysis is an important component of forecasting, and any improvements in the data will also improve the analysis phase of forecasting. For AWIPS to continue incorporating new datasets, the development of the new data paradigm is very important. The existing software and hardware become overloaded as new datasets are added, resulting in the need for hardware upgrades at the WFOs. If a subset of the data can be stored on central servers, this will help alleviate the problem, reducing the cost of maintaining the WFOs. The new central server idea will also make it easier for forecasters to share local data and forecasts. It is expected that this capability will result in more accurate forecasting, especially in locations where forecasts from different offices overlap. It should also be easier to track storms moving from one forecast area to another. Integrating the hazard event warnings into AWIPS provides a reliable way to disseminate this information to the public. AWIPS has been successfully disseminating weather warnings for years, and can be expected to do the same with this information. Integrating the GFE with AWIPS provides a number of important capabilities. Prior to the addition of the GFE, forecasters using AWIPS were able to produce forecasts and warnings in text format only. Gridded forecasts can be more comprehensive and accurate, and the gridded forecast output is now required by an increasing number of NWS customers.

5. Research Linkages/Partnerships/Collaborators:

CIRA collaborated with NOAA/NESDIS for the acquisition of sea surface temperature data. CIRA, ISB, the National Centers for Environmental Prediction (NCEP), and the Office of Climate, Weather, and Water Services (OCWWS) collaborated on constructing and submitting the Statement of Need for the new data paradigm research. CIRA, ISB, NWS, Northrup Grumman and Raytheon collaborated on the hazard event distribution research.

6. Awards/Honors:

7. Outreach:

8. Publications:

Cheatwood, L.K., and W.F. Roberts, 2006: Forecaster usage patterns of AWIPS D2D and GFESUITE during 2005. *22nd Int. Conference on Interactive Information Systems (IIPS) for Meteorology, Oceanography, and Hydrology: Aviation Meteorology, Safety, and the Future Aviation Weather System*, 30 Jan-2 Feb 2006, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, P1.7.

VIII. Research Collaborations with the GSD Information Systems Branch (ISB) / Information Presentation Section (formerly the FSL Systems Development Division)

Project Title: Two-dimensional Display (D2D) Development and AWIPS Support

Principal Researchers: Jim Ramer, Jim Fluke, 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:

Research objective is to conduct continued research 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:

Last year, the merging of the RSA changes into AWIPS was completed. Thus, RSA has simply become part of AWIPS, with the goal that any future RSA changes would be AWIPS changes. This will provide useful RSA features to AWIPS users, and will keep RSA much more up to date. Also, since AWIPS changes are merged regularly into ALPS (AWIPS Linux Prototype System), the RSA changes will be in the ALPS system as well, thus providing the option of using ALPS for future RSA releases.

The successful implementation of Valid Time Event Codes (VTEC) in warning and advisory products for severe weather and flooding continues to be one of the most important near term goals of the NWS. During FY04/05, CIRA researchers helped the NWS successfully implement VTEC for severe convective warnings and some marine warnings. During FY05/06, CIRA researchers aided in the implementation of VTEC in many hydrologic (flood) warnings and advisories. Upgrading and maintaining the VTEC's capability within AWIPS continues to require substantial changes both to AWIPS warning generation software and the text workstation component of AWIPS.

CIRA also continued to provide AWIPS software enhancement support, as well as software configuration management (CM) support for local developers working on AWIPS. This includes: keeping the local GSD AWIPS baselines in sync 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.

The WFO-Advanced workstation software is the core of AWIPS display capabilities, as well as the display generating engine behind the FX-Net and FX-Collaborate (FXC) workstations. CIRA researchers continued to extend and maintain the WFO-Advanced workstation capabilities, mainly in conjunction with AWIPS and ALPS projects.

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. The focus this past year has been on distributed data and on an improved interface for user developed applications. The distributed data effort so far has been mostly exploratory. However, there has already been a great deal of prototype work done on the new applications interface, and this continues apace with the goal of having a usable first capability early next fiscal year. New applications are known as plugins and can be written in different languages. They can be easily integrated into ALPS by simply placing the code into a predefined directory and restarting the workstation. An example of a plugin that illustrates the new graphic API is shown in Fig. 1. below.

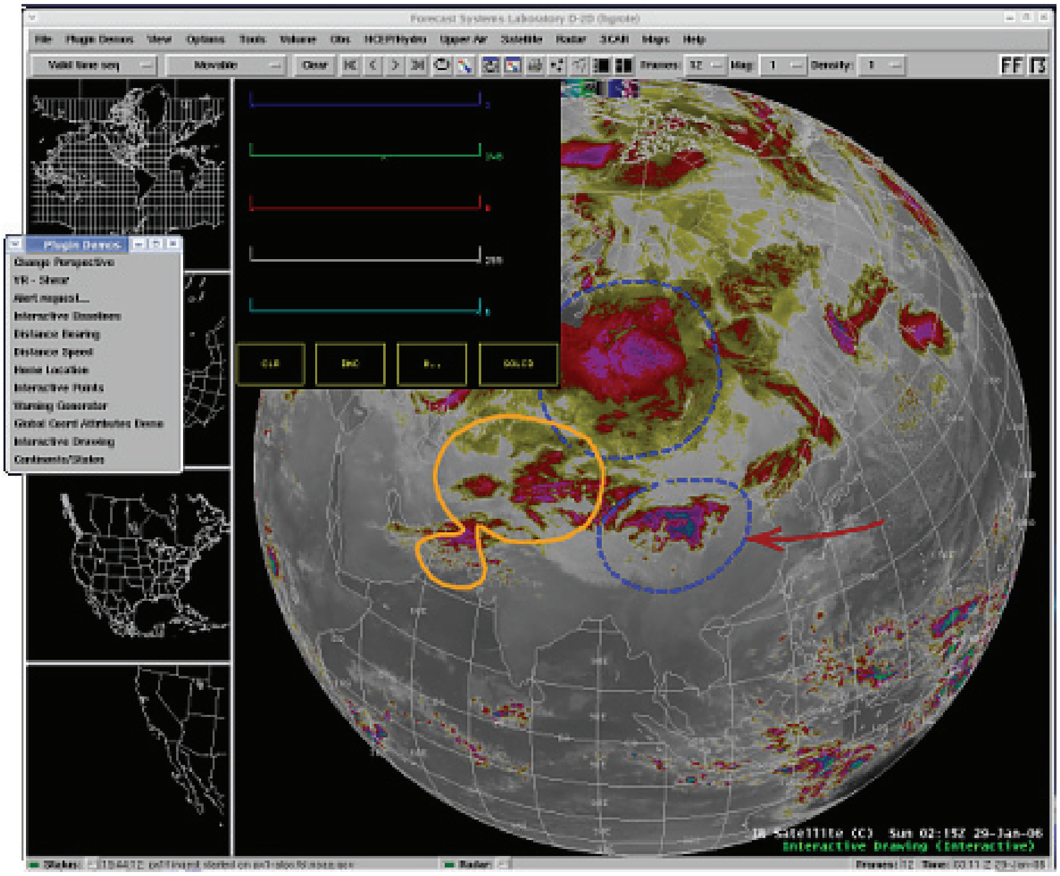


Fig 1. An example of a plugin that illustrates the new graphic API.

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

In progress.

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:

6. Awards/Honors:

7. Outreach:

8. Publications:

Grote, H., 2006: Expanding the power of AWIPS with plugins. *22nd Conf. On Int. Conference on Interactive Information Systems (IIPS) for Meteorology,Oceanography, and Hydrology: Aviation Meteorology, Safety, and the Future Aviation Weather System*, Atlanta, GA, Amer. Meteor. Soc., CD-ROM, 7.6.

Project Title: <u>Exploratory Development of a Real-time Collaborative Workstation.</u>

Principal Researcher: U. Herb Grote

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

Key Words: Forecaster Collaboration, Graphical Product Generation, FXC

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

The overall objective is to develop an interactive display system that allows remote forecasters/users to collaborate in real-time on a common forecast for a particular weather or weather-dependent event.

In order to prepare a common forecast, whether this be 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 will 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 can also run dispersion models to help predict movement of volcanic ash, smoke, or toxic chemicals and has a direct alert capability to 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 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. The concept is to use FXC as the technology for controlling the execution of the HYSPLIT model, collaborating between the offices, and for creating the alert information that is sent to the selected vendor for notifying the public.

2. Research Accomplishments/Highlights:

In collaboration with other GSD staff, the HYSPLIT model was installed on the FXC session controller and software developed to convert the output of the model into a format that is usable by FXC. The code was tested with different data sets and different control parameters and prepared for integration with FXC. The FXC code was modified to allow easy customization of the FXC user interface to generate the appropriate control parameters and to view the dispersion model output. Also, the format of the alert information message (XML) was defined and tested with two different vendors using secure https communications.

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

The work is progressing on schedule and all parts of the systems appear to be working as expected. The next step is to install FXC clients in several FEMA offices in the D.C. area and train users on the system.

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.

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 properly in the GTAS environment.

6. Awards/Honors: None as yet.

7. Outreach: There has been some interaction with private industry and other local governments on systems like GTAS for alerting the public to severe weather events, such as flash flooding.

8. Publications:

National Weather Service New Concept of Operation (CONOPS)

1. Background and Research Objectives:

The CONOPS project is a new activity that was recently initiated by the National Weather Service to evaluate the system and operational impact of a proposed change in the way forecast office operations are performed in this country. The concept is based on defining clusters of forecast offices that can respond to weather or other events occurring within the cluster domain by reassigning individual office responsibilities.

The NWS AWIPS system with its Graphical Forecast Editor (GFE) are the key systems components that need to be evaluated under this concept. Currently, each office creates forecast grids only for its particular spatial domain and the various grids are exchanged with neighboring office to minimize boundary idiosyncrasies. Under the new concept, it is possible for one office to create all grids for the entire cluster. Also, a collaboration capability, such as FXC, is required to ensure that all offices are aware of the weather events occurring within the cluster domain and to decide how the workload is to be divided among offices.

2. Research Accomplishments/Highlights:

Since this is a relatively new activity, much of the work has been in planning the work and defining the system architecture to be used for the evaluation. Several coordination meetings have been held with key NWS representatives to ensure that the management and technical details of the project are well defined and understood. The two offices for the “Laboratory Experiment” will be at GSD and at the NWS Central Region Headquarter at Kansas City. The FXC software has been modified to allow more dynamic domain reassignment, and the communications software (specifically the message repeater) has undergone more rigorous testing. The repeaters allow a larger number of forecast offices to communicate over a relatively low bandwidth by implementing repeaters at key communication hubs and offices.

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

All planned tasks have been completed on time. The communications tests identified some software bugs in the FXC code which have been corrected. Additional work is required to ensure all necessary data sets are available on FXC and additional code needs to be developed to track and identify FXC usage patterns. A major enhancement will be the development of a cluster management tool that allows offices to view and record office responsibilities within the cluster.

4. Leveraging/Payoff:

The CONOPS project is leveraging past developments by CIRA and GSD on AWIPS, GFE, and FXC. The successful completion of the CONOPS project can lead to improved weather forecasts by the NWS and more efficient forecast office operations.

5. Research Linkages: The primary collaborators on this activity are NWS forecast office and NWS management staff.

6. Awards/Honors:

7. Outreach:

8: Publications

Graphical Product Generation

1. Background and Research Objectives:

FXC has an extensive graphic capability for meteorological product generation that is being used by a number of different customers that include the USAF, NASA, the Central Weather Bureau in Taiwan, private companies, and possibly as many as fifty NWS forecast offices. These graphical products are posted to the web for public use, included in presentations, and used in briefings to various customers. Examples of these types of products can be found on the web (http://fxc.noaa.gov/screenshots.html). The objective of this activity is to work with government and private companies to enhance the utility of FXC for communicating weather information to the public and specific groups of users (such as aviation).

2.. Research Accomplishments/Highlights:

FXC graphical products continue to be posted on the web site.

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:

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:

--Processing all volumetric radar data collected during EPIC-2001 while the R.V. Ronald H. Brown 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; and

--Attempt to reconcile differences between the time-mean rainfall rate inferred from the radar with those derived from other in-situ (profiler, rain gauge, disdrometer, ocean freshwater budget) and satellite (TRMM PR and passive microwave) data. This task will include providing collaborates on this proposal (Dr. Christopher Bretherton of University of Washington) a short report on whether the current EPIC Z-R relationship used by CSU needs to be modified. If it does, files containing surface rain maps for each scan based on the corrected Z-R relationship will be provided.

The plan for addressing the first objective includes interpolating the data to a Cartesian grid and constructing radar reflectivity histograms for all radar data collected within a specified area of the nominal location of the R.V. Ronald H. Brown during EPIC. The histograms will be generated for the height range 1.5-19 km AGL for all radar volumes that were collected (~2,900). In order to accomplish the second objective, an algorithm will be written to correlate rain intensity data from the NOAA TAO buoy with the radar reflectivity data for all rainfall events observed during EPIC. The correlation will be done over time periods ranging from 10 minutes (one radar volume) to one hour. The coincident TAO buoy and radar data will then be used to determine an optimal Z-R relationship for EPIC. A comparison of the performance between the optimal Z-R and the current default EPIC Z-R will be made using rainfall data from the R.V. New Horizon. Based on the results of the comparison, new rainfall maps will be generated that can be used by the EPIC community.

2. Research Accomplishments/Highlights:

The start date for the grant award was May 2006; the work is still in the preliminary stage. At this point, we have determined the dimensions and resolution for the interpolated Cartesian grid and have begun some sensitivity tests to calculate radar reflectivity distributions and rainfall parameters. We hope to have concrete results for the first objective by fall, 2006 and to test the optimal Z-R by the end of 2006.

It is hoped that the results of this work will serve as a validation tool for numerical models that attempt to simulate the climate statistics in the EPIC region. Such validation is necessary in order to improve the models and their ability to make reliable seasonal forecasts.

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

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors:

7. Outreach:

8. Publications:

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, SCAN, KMA, Radar, NCAR Autonowcaster, AWIPS, GIS

There were two primary projects during this past year—the port of MDL's SCAN to KMA's FAS and the alpha-test of implementing NCAR's Autonowcaster convection forecasting tool to AWIPS.

<u>The KMA SCAN Implementation Project</u>

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

The Decision Assistance Branch (DAB) of the NWS Meteorological Development Lab (MDL) is collaborating with the Korean Weather Administration (KMA) to help them improve their short-term weather forecasting capabilities on AWIPS-like workstations. Supporting this partnership, CIRA continues this collaborative effort transferring MDL's AWIPS SCAN (*System for Convection Analysis and Nowcasting*) application to KMA's AWIPS-like FAS (*Forecaster Analysis System*) workstation. Related activities to accomplish this task include the ingest of KMA radar data, generation and storage of the radar products required by SCAN, and the development of an operational SCAN-oriented geographic database.

2. Research Accomplishments/Highlights:

During this year, the 3-year project to implement MDL's SCAN on Korean Meteorological Administration's (KMA) Forecast Analysis Station (FAS) was successfully completed. The project required solutions in three general software areas: Data Acquisition, Data Preparation, and Application Modifications.

Data Acquisition
Because KMA did not previously have an automated data ingest system in place, I designed and implemented a process to receive KMA raw radar reflectivity data from KMA's 10 radar sites and notify the local system of the arrival of each data file. The implementation was required to operate continuously, in real-time, without human interaction or failure, with minimal data latency, and trigger subsequent processing of the newly received data.

Data Preparation
In addition to SCAN's extensive static data requirements (configuration tables and GIS related data); SCAN requires several real-time radar products to generate its graphical and tabular guidance products, specifically, Reflectivity (Z), Composite Reflectivity (CZ),

Volume Integrated Liquid (VIL), and Storm Tracking Information (STI). None of these radar products were being produced by KMA. I designed and implemented the “front-end” processing shared by each of the radar product generators. This included the “trigger” code to automatically start processing upon receipt of new 'raw' radar products.

This is followed by decoding and structuring of the 'raw' radar data, establishing the protocol and methods for radar product generation. This portion of the code was designed by me and implemented by a KMA Visiting Scientist. Involvement at this level provided him with expert knowledge of the application. The expectation was that he would extend and expand the KMA SCAN on his return home, adding Korean language characters, adapt for new radars, and prepare for future AWIPS upgrades.

After radar product generation, I provided the “back-end” data storage and notification software using signal radar product updates and additional 'downstream' processing.

Application Modifications
The SCAN application required a variety of modifications. To begin, AWIPS uses a series of scripts to process meteorological metadata and GIS data to prepare the forecast workstation's background and menu displays. This preprocessing is commonly referred to as “localization.”

Much of the SCAN-required metadata and GIS data (localization data) needed to be created for KMA's SCAN, because it was not otherwise available. The localization scripts required extensive modification to remove the US-specific references and tailor them to the available (and created) KMA data sets. The metadata files used by the localization scripts required modifications to incorporate the Korean textual symbols that were preferred by the Korean forecasters in workstation menus and map labels.

The KMA radars differed significantly from the US-employed NEXRAD radars, software adjustments were made to accommodate theses differences. Because Korea covers a small area, KMA's SCAN displays required incorporating multiple radar analysis, something omitted in the earlier NWS implementation.

Project completion was demonstrated by hosting 12 KMA weather forecasters at a training exercise at NOAA ESRL/GSD (formerly NOAA/FSL). Two full days of training were provided. The training sessions were divided between short lectures of how to use SCAN and understand its displays, followed by hands-on, real-time SCAN exercises at one of four KMA-staged workstations using archived KMA radar data sets to simulate the KMA operational forecast setting. The hands-on training exercises were designed to demonstrate and elaborate upon the lecture topics.

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

Completed and tech transferred.

4. Leveraging/Payoff:

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

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications: None as yet

The Autonowcast Prototype Project

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

The Autonowcast Interface Project is conducted in cooperation with the NCAR Autonowcast (AN) development team and progressed at the same time as the KMA SCAN project. The project requirements are generally to provide an AWIPS interface to the AN displays and NWS forecaster interactions required by the AN system. The longer term goals, provided we successfully execute our initial goals, are to move much of the user interface and display software in a phased plan; migrating from NCAR's AN display system (CIDD) to AWIPS' D2D, providing a familiar 'look-and-feel' to the NWS forecasters, and allowing the NCAR scientists to focus on the science in the Autonowcaster.

NCAR has installed an AN system at the Fort Worth-Dallas WFO to demonstrate to the forecasters the types of products that AN provides and to assist in their situational awareness, thus improving NWS forecasts. The AN system, to be most effective, requires a forecaster to provide initial convective boundaries and periodically update the AN modeled output. The AN is a stand-alone system (co-located with, but detached from, AWIPS). This requires a forecaster to leave the AWIPS workstation to use it.

The forecaster defines or modifies convection boundaries on CIDD. These are sent to NCAR (in Boulder) for analysis. The new or modified boundaries generate new AN model output, which the forecaster can display on CIDD. After reviewing the AN data, the forecaster returns to their AWIPS workstation with an improved sense of the weather situation. While this interaction works, it is inconvenient, especially during severe weather when the AN system can provide the greatest benefit.

Our initial project goals are to display AN products on the AWIPS workstation and allow forecaster interaction (boundary definition and editing) on AWIPS' D2D.

2. Research Accomplishments/Highlights:

As the Technical Lead on this project, I see the task broken down into several subtasks: Data Acquisition, Data Display, Forecaster Interaction (boundary editing), and Data Dissemination.

Data Acquisition

The approach to satisfying this subtask utilizes the AWIPS' LDAD (Local Data Acquisition and Dissemination) technique for exchanging data between non-NWS data providers and AWIPS.

I am responsible for the Data Acquisition task, providing the communications software necessary to *import* AN data in a “secure” manner from the 'external' user (NCAR) into AWIPS.

After acquiring the NCAR data (there are ten (10) unique data sets), the binary data files are converted (in real-time) and stored in NETCDF data files configured for easy display on AWIPS. On completion of the decode and storage processing, the AWIPS system is notified of the new data availability for subsequent processing and display updates.

Using the directory architecture I specified, I implemented an Object-Oriented design to decode and store all the data used by this application in real-time. By processing these data in real-time, the AWIPS forecasters can use these data in their operational duties.

Data Display
The AWIPS was 'localized' by another team member using my directory architecture and the new NetCDF data files to display the AN data products on AWIPS' D2D.

Forecaster Interaction (Boundary Editor)
A third team member has developed an AWIPS 'extension' application to provide the forecaster interaction. My data acquisition software provides her 'extension' with a general, simple convective boundary format which is used to exchange data between the AWIPS and AN.

Data Dissemination
The convective boundaries defined or modified by the Boundary Editor must be returned to the AN for further processing. I have provided a “secure” LDAD method to *export* these data through the AWIPS firewall, allowing NCAR to retrieve these files for additional AN processing.

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

This project is currently being tested and evaluated at MDL, prior to operational *alpha*-testing at FWD WFO. Operational testing is expected during the late severe storms season later this year.

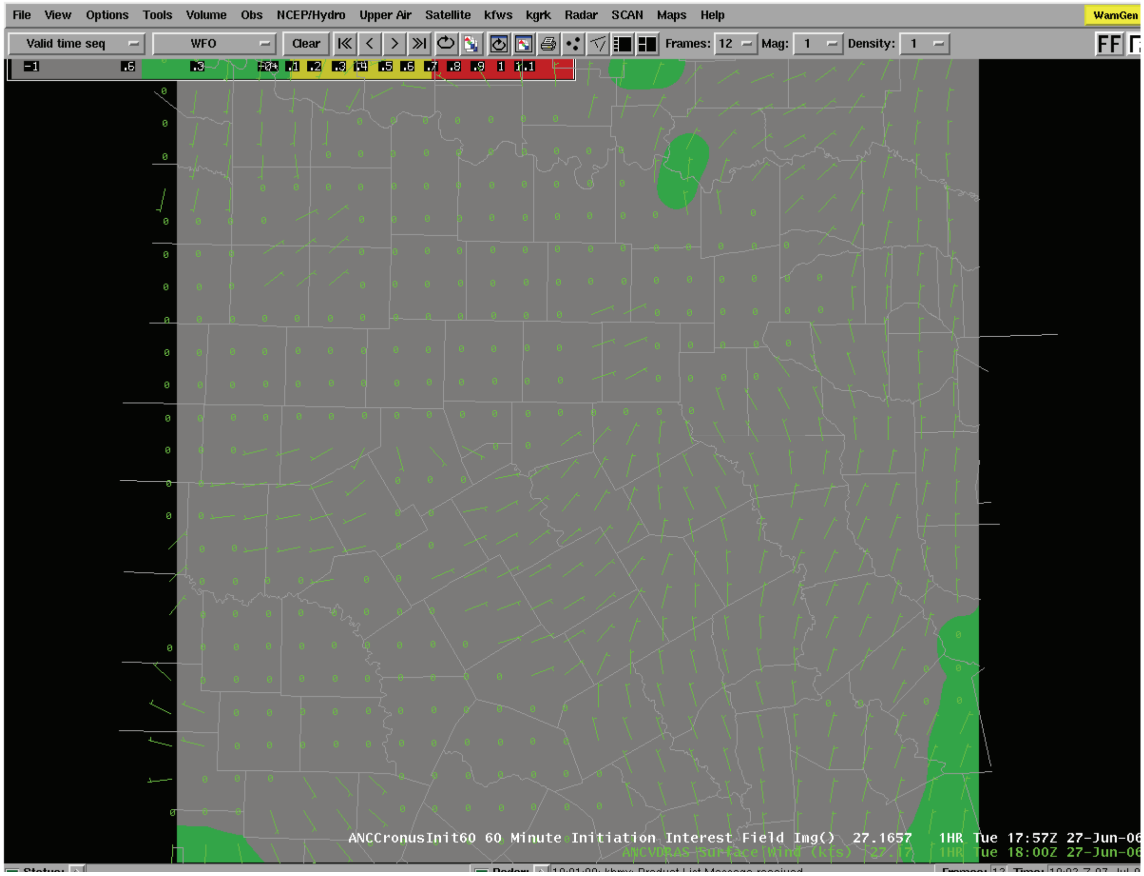


Fig. 1. This is an example of NCAR's Autonowcaster (AN) data displayed on a FWD AWIPS (Fort Worth/Dallas WFO) localization. Here, surface winds are overlayed on the AN 60-minute forecast Convective Initiation field.

4. Leveraging/Payoff:

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

NCAR

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

Principal Investigators: T. Vonder Haar

NOAA Project Goal: Various

Keywords:

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

2. Research Accomplishments/Highlights:

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

4. Leveraging/Payoff:

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

6. Awards/Honors:

7. Outreach:

CIRA conducted various tours for corporations and local public and private schools.

Seminars

August 26, 2005, T. Nakajima (Univ. of Tokyo). A Study of Aerosol Climate Effects Using Model and Satellite Remote Sensing.

September 15, 2005, D. Atlas (NASA). Contrails to Cirrus – Morphology, Microphysics, and Radiative Properties.

September 22, 2005, K. Gurney. Global Carbon Sources and Sinks: Estimates and Links to Climate Variability from the Inverse Approach.

September 29, 2005, G. Holland (NCAR). Tropical Cyclone Genesis as a Scale Interaction Process.

October 6, 2005, E. Holland (NCAR).

October 11, 2005, H. Xiang-Yu Huang (NCAR). The Weather Research and Forecasting Model Based 4-dimensional Variational Data Assimilation System.

October 13, 2005, H. Cochrane. Valuing Improvements in Weather and Climate Forecasts: Retro and Prospective Views.

October 27, 2005, Q. Li (JPL). Trapping of Deep Convective Pollution by Upper Level Anticyclones: Implications for Global Climate.

October 28, 2005, O. Popovicheva (Moscow St. Univ.). General Physico-Chemical Properties of Aircraft Engine and Laboratory-Made Soots: Some Atmosphere Implications.

November 9, 2005, S. Nigam (Univ. of Maryland). Hydroclimate Variability over the Great Plains in Observations, Reanalyses and Model Simulations.

November 10, 2005, K. Shell (NCAR ASP). Climate Sensitivity to Airborne Mineral Dust in a Simple Model.

November 17, 2005, R. Bleck (NOAA/NASA/GISS). Putting Models to Use: Simulation of Oceanic CO2 Sequestration.

November 18, 2005, M. Cai (Florida St. Univ.). 40-70 Day Meridional Propagation of Global Circulation Anomalies.

November 22, 2005, H. von Storch (GKSS). Hockeysticks, The Tragedy of the Commons and Sustainability of Climate Science.

December 6, 2005, T. Lee (NRL). NPOESS Satellite Training Online Through COMET.

December 13, 2005, X. Wang (ESRL). A Comparison of Hybrid Ensemble Transform Kalman Filter-3DVAR and Ensemble Square-Root Filter Analysis Schemes.

January 19, 2006, F. Stratmann (Leipzig). LACIS: New Facility for Cloud Studies at the Institute for Tropospheric Research, Leipzig.

January 23, 2006, T. Nakajima (Univ. of Tokyo). Atmospheric particles Observed by ADEOS2 Global Imager.

January 26, 2006, P.W. Chan (Hong Kong Observatory). Windshear and Turbulence at the Hong Kong International Airport – Observation, Warning and Modeling.

January 26, 2006, O. Liechti (A&K, Switzerland). Meteorological Flight Plans for Soaring and Their Verification.

February 9, 2006, R. Cohen (Berkeley ASC). Atmospheric Nitrogen Oxides: Observational Challenges to Conventional Wisdom.

February 22, 2006, J. Brown (ESRL). WRF from a NOAA-Boulder Perspective: Physics and Core Comparisons.

February 23, 2006, R. Martin (Dalhousie Univ.). Interpretation of Satellite Observations of Tropospheric Aerosols and Trace Gasses.

March 7, 2006, J. Hand. Individual Particle Analysis of Biomass Burning Aerosols from Young and Aged Smoke.

March 9, 2006, R. Korty (CIT). The Eocene Paradox.

March 24, 2006, R. Anthes (UCAR). GPE Radio Occultation Sounding of Earth's Atmosphere – Recent Results and the COSMIC Program.

April 12, 2006, G. Brasseur (NCAR). The Response of the Upper and Middle Atmosphere to Solar Variability and Anthropogenic Perturbations.

April 13, 2006, D. Vimont (Univ. of WI). Mid-latitude Influences on Tropical Pacific Climate Variability.

April 20, 2006, O. Pauluis (NYU). Water Vapor and the Maintenance of the Atmospheric Circulation.

April 25, 2006, I. Jankov. The Role of Physical Schemes Interactions on Warm Season Rainfall Forecasts.
April 27, 2006, D. Wesley (UCAR/COMET). Mechanisms for Extreme Snowfall Variations in the Front Range Heavy Snowstorm of 17-20 March 2003, and a few other Winter Front Range Forecast Issues.

May 1, 2006, J. Hack (NCAR). Modeling the Climate System Across Scaled.

May 1, 2006, S. Kusselson (NOAA, NESDIS, OSDPD). NOAA/NESDIS/Satellite Analysis Branch Collaboration with CIRA/CSU.

May 4, 2006, W. Rossow (NASA GISS). Evaluating and Testing Model Representations of Cloud-Climate Relations.

May 11, 2006, J. Steppleler (German Weather Service). Developments Concerning a Next Generation Model.

May 19, 2006, G. Goodge (NCDC). The Climate Reference Network (CRN): What Is It? Where Is It? And, What Can It Do For Me?

June 8, 2006, E. Raschke (ZMAW, Germany). Some Controversial Results on the Radiative Forcing of Our Climate System as Extracted from Model Results for the AMIP-2 and IPCC-FAR and for the Radiation Climatologies of the ISCCP-FD and GEWEX-SRB.

Fellowship Program

Isidora Jankov - CIRA Post Doc

Project Title: Development of an optimal ensemble configuration for rainfall forecasting in support of the new Hydrometeorological Testbed (HMT): an investigation and improvement of the Hot Start technique within the Local Analysis and Prediction System (LAPS).

Principal Investigator: Tom Vonder Haar

NOAA Project Goal / Program: Weather and water—Serve society's needs for weather and water information / Hydrology and 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:

a) Continuation of work toward improvement of the Quantitative Precipitation Forecast;

b) Post-processing of global to local scale models' output using the Factor Separation method;

c) Exploring maximum likelihood ensemble filtering as a method for ensemble optimization; and

d) Expanding the Local Analyses and Prediction System (LAPS) initialization to global scales.

2. Research Accomplishments/Highlights:

a) Events selected during the winter of 2005-2006 field experiment located over California (as one of the projects supported by the HMT) were rerun using the Weather Research and Forecasting (WRF) model with both different physical schemes and various horizontal grid spacing. An evaluation of impacts that different physical schemes and their interactions have on simulated, mainly orographically forced, precipitation was performed by following the Factor Separation methodology. The results were used in design of an optimal mixed-physics ensemble for rainfall forecasting. Furthermore, impact of different horizontal grid spacing on error in simulated rain volume was evaluated.

Based on previously discussed results, the ensemble for the 2006-2007 HMT field phase will be reconfigured. Also, these two studies resulted in a manuscript submitted to Journal of Hydrometeorology and a manuscript is in preparation for submission to Weather and Forecasting.

b) In collaboration with Steve Albers, for the purpose of expanding a publication which explains/discusses the hot start technique, necessary reruns of the event that occurred during the International H_2O Project (IHOP) were performed. The simulations were performed over the stretched domain (600x600 points) and with high-resolution, 1-km grid spacing. In order to carry out these simulations, various code adjustments were necessary. In addition, changes in the LAPS balance code were made for specific experiments related to the publication.

c) As the first step of the long term objective iv) listed above, in collaboration with Steve Albers, LAPS code has been exercised over the expanded domain covering most of the globe with 60-km grid spacing. Recently, the horizontal grid spacing has been increased to 30 km (Fig. 1).

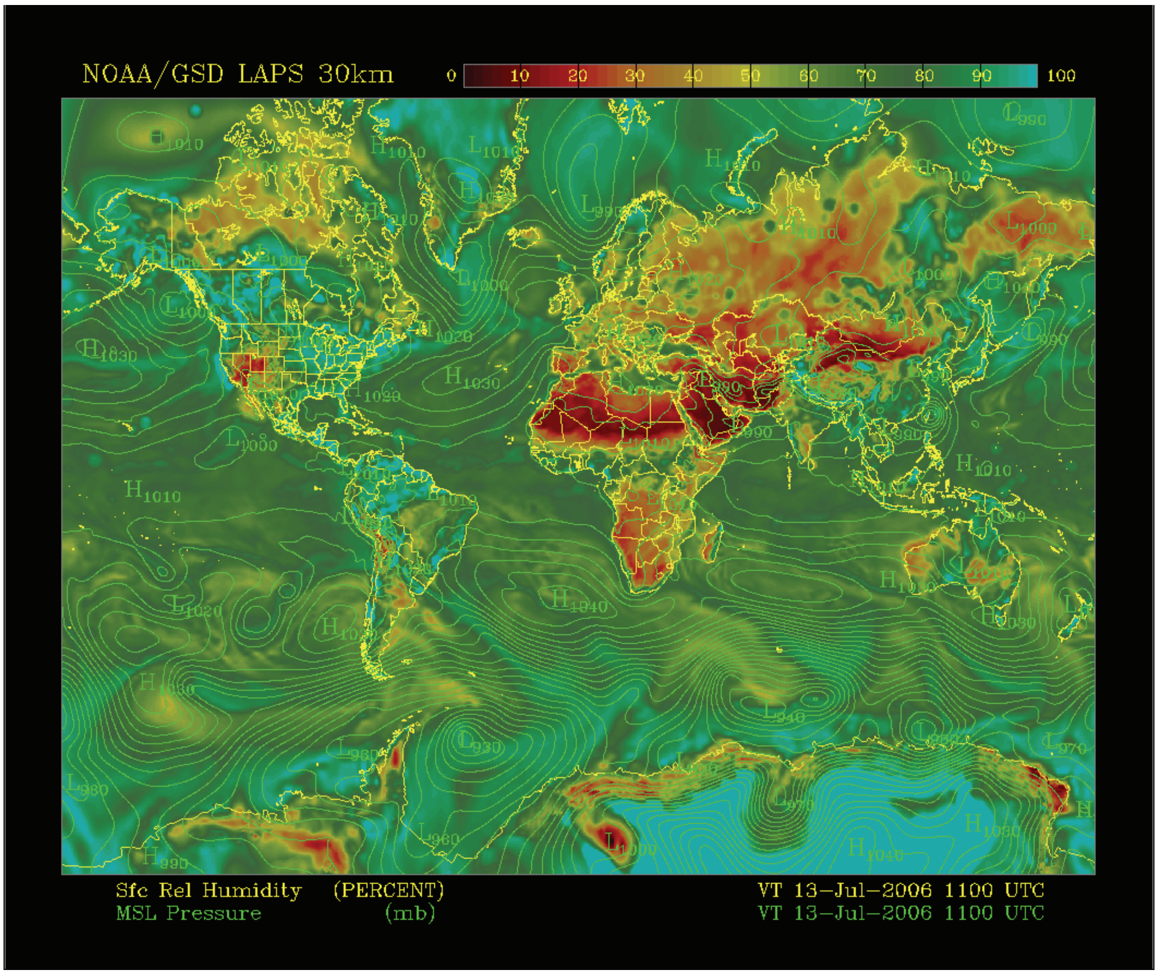


Fig. 1. 30-km grid spacing LAPS analyses of surface relative humidity (image) and mean surface level pressure (contours) for July 13, 2006 at 1100 UTC.

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

The objectives related to the design of an optimal ensemble for rainfall forecasting to support HMT have been fully accomplished. The experience with LAPS gained through the reruns of archived events will be used for future long-term objectives.

All of the other objectives are in progress.

4. Leveraging /Payoff:

Results from the HMT-related projects will be used to optimize the ensemble for 2006-2007 HMT field phase.

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), Steven Albers (CIRA/ESRL/GSD) Christopher Anderson (CIRA/ESRL/GSD), and Steven Koch (NOAA/ESRL/GSD). In addition to these collaborators, future work will involve collaborations and communications with Dusanka Zupanski (CIRA) and Milija Zupanski (CIRA).

6. Awards/Honors: Not as yet

7. Outreach:

8. Publications:

Jankov, I., W.A. Gallus, Jr., M. Segal, and S.E. Koch, 2005: Influence of initial conditions on the WRF-ARW model QPF response to physical parameterization changes. *Wea. and Forecasting* (submitted).

Jankov, I., P.J. Schultz, C.J. Anderson, and S.E. Koch, 2006: The impact of different physical schemes and their interactions on cold season QPF. *Journal of Hydrometeorology* (submitted).

Jankov, I. and P.J. Schultz, 2006: An optimal ensemble for cold season QPF (to be submitted to *Wea. and Forecasting)*.

Jankov, I., W.A. Gallus, Jr., M. Segal, and S.E. Koch, 2006: The role of physical scheme interactions in design of a mixed-physics ensemble for warm season MCS rainfall forecasting. Preprints, *2nd Quantitative Precipitation Forecast and Hydrology Symposium*, 4-8 June 2006, Boulder, CO.

Jankov, I., C.J. Anderson, P.J. Schultz, and J.A. McGinley, 2006: An optimal high-resolution ensemble for cold season QPF. Preprints, *2nd Quantitative Precipitation Forecast and Hydrology Symposium*, 4-8 June, 2006, Boulder, CO.

Jankov, I., P.J. Schultz, C.J. Anderson, and J.A. McGinley, 2006: The impact of different physical parameterizations and their interactions on cold season QPF, *CIRA Science Symposium*, 16-17 April, 2006, Fort Collins, CO.

Yoo-Jeong Noh – CIRA Post Doc

Project Title: Development of a snowfall retrieval algorithm 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:

a) Develop a snowfall retrieval algorithm utilizing high-frequency satellite microwave measurements based on Bayesian Theorem - snow cases in US

b) Improve the retrieval over land by using microwave surface emissivity data

2. Research Accomplishments/Highlights:

a) Chosen several snow cases during December 2004 over the continental US.

b) Obtained AMSU A/B data for these cases.

c) Calculated snowfall profiles from NEXRAD Level II data by using NCAR radar programs (SPRINT/CEDRIC) and applying Ze-S relationship.

d) WRF modeling to understand snow cloud structures and get liquid water information in the clouds.

--ETA, NARR, and NCEP/NCAR reanalysis data have been tested to initialize the WRF model, and finally ETA data with 12km resolution was used.

--Model simulations done for three snow cases in TX and NC using one way nesting.

--Validation using radar data and analyses of the results in progress.

e) To calculate land surface emissivity, NOAA microwave emissivity Model (MEM) will be used. Now data acquisition is in progress. Discussion with Dr. Jones and Mr. Forsythe about related works will be continued.

f) Programming to make appropriately formatted input data from WRF simulations, radar data, and MEM results for the radiative transfer model is continuing.

3. Comparison of Objectives vs. Actual Accomplishments

Project has just begun

4. Leveraging/Payoff:

5. Research Linkages/Partnerships/Collaborators:

6. Awards/Honors: None as yet

7. Outreach:

8. Publications. None as yet.

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8. Funds for CIRA Publications:

Vonder Haar, T.H., 2006. *Annual Report on the Cooperative Institute for Research in the Atmosphere 01 July 2005 – 30 June 2006*, Cooperative Institute for Research in the Atmosphere, Colorado State University, Ft. Collins, CO.

GETTING READY FOR NOAA'S ADVANCED REMOTE SENSING PROGRAMS: A SATELLITE HYDRO-METEOROLOGY (SHyMet) TRAINING AND EDUCATION PROPOSAL

Principal Investigator: B.H. Connell

NOAA Project Goal: Weather and Water; Programs: Local Forecasts and Warnings

Key Words: Training, Outreach, Collaboration

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

The overall objective of the SHyMet program is to develop and deliver a comprehensive distance-learning course on satellite hydrology and meteorology. This is being done in close collaboration with experts from CIRA, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison, the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, the National Weather Service (NWS) Training Center (NWSTC) in Kansas City, Missouri, and the NWS Warning Decision Training Branch (WDTB) in Norman, Oklahoma. The challenge is to provide necessary background information to cover the many aspects of current image and product use and interpretation as well as evaluate data and products available from new satellite technologies and providing new training on the these tools to be used operationally.

The (SHyMet) Course will cover the necessary basics of remote sensing, satellite instrumentation, orbits, calibration, and navigation, and will focus heavily 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 on this project, 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 outline has gone through revisions to reflect feedback from the Science and Operations Officers of various National Weather Service offices.

The specific plans for this past year of the project included:

Organize course material for the intern training track

Within NOAA's e-Learning Management System (LMS), set up a learning path to track the various levels of the course, and set up pre- and post-course testing to track the progress of the participants throughout the course.

Deliver the intern track of the course.

Prepare a web page featuring training highlights for managers.

Further Plans for the longterm include:

Evaluate feedback from the first course offering to make appropriate modifications.

Select the outline and content for a second course offering under SHyMet and put this second course together.

2. Research Accomplishments/Highlights:

It was recognized last year that the SHyMet outline with its extensive range of topics was a very ambitious project. A need was also recognized for a basic course on Satellite Meteorology and Applications for the NWS Intern. During the past year, nine modules for an Intern Course were chosen and assembled. The course consists of 5 online modules and 4 teletraining modules representing about 16 hours of total training hours. The sessions are:

SHyMet Intern Orientation (Online only)

GOES Imaging and Sounding Area Coverage, Resolution, and Image Frequency (Online only)

GOES Channel Selection (Online only)

POES Introduction (Polar Satellite Products) (Online only)

GOES Sounder Data and Products (Teletraining and Online)

GOES High Density Winds (Teletraining and Online)

Cyclogenesis (Teletraining and Online)

Severe Weather (Teletraining and Online)

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 is being met by utilizing the already established Virtual Institute for Satellite Integration Training (VISIT) program. (http://www.cira.colostate.edu/ramm/visit/visithome.asp)
Of the above mentioned modules, CIRA created three new modules: 1) Orientation, 2) GOES Imaging and Sounding area coverage, resolution, and image frequency, and 3) Satellite Applications to Tropical Cyclones. Revisions were made to the following two modules: 1) Cyclogenesis: Analysis utilizing satellite imagery and 2) Introduction to satellite interpretation for severe weather.

SHyMet Intern officially kicked off Monday April 3, 2006 (although registration had been ongoing through the month of March) with the first teletraining session, “SHyMet Intern Cyclogenesis”, held April 4, 2006. The final teletraining session of the year, “GOES Sounder”, was held on June 29, 2006. Several SHyMet Intern participants continue the SHyMet Program utilizing the on-line versions (e-learning) in lieu the four teletraining sessions (1. GOES Sounder Data and Products, 2. GOES High Density Winds, 3. Cyclogenesis, and 4. Severe Weather). Registration is completed through contact with the SHyMet administrators here at CIRA and also, for NOAA personnel, through DOC/NOAA’s Learning Management Site (LMS).

There are 76 “registered” NOAA participants representing about 45 different NOAA/NWS offices.

Of the 76 registered, 26 have completed the entire SHyMet Intern Course. There are 6 registered non-NOAA participants. Of the 6, 5 are Department of Defense and one is civilian. Of the 6 registered, the civilian has completed the entire course. The first NOAA participant to complete the course did so on April 19, 2006. The first (and only) non-NOAA participant to complete the course did so on June 27, 2006.

Four of the SHyMet Intern Course sessions were offered as teletraining sessions for a three-month period starting in April and ending in June. The four sessions were:

GOES Sounder Data and Products
GOES High Density Winds
Cyclogenesis
Severe Weather

GOES Sounder Data and Productions along with GOES High Density Winds were administered and facilitated by Scott Bachmeier (CIMSS – University of Wisconsin). Cyclogenesis and Severe Weather were administered and facilitated by both Dan Bikos and Jeff Braun (CIRA – Colorado State University). There were a total of 29 SHyMet teletraining sessions held between the April through June time period with a total of 157 offices participating (many more than once). There were 211 total training participants taking part in these teletraining sessions (many more than once). Of the 211, 180 participants were “registered” with SHyMet. The others were just “visiting.”

In addition to the SHyMet course, CIRA hosted the SHyMet meeting in Ft. Collins in September 2005.

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

Objectives 1-3 have been fully met. Because of the extensive preparations involved with items 1-3, item 4 has been delayed.

4. Leveraging/Payoff:

NOAA needs to view as tool for justifying public investment in science initiatives). The training materials being developed will help the user (the weather forecaster) better utilize current satellite products that are available. This will in turn lead to better weather forecasts for the public.

5. Research Linkages/Partnerships/Collaborators, Communications 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. The Department of Defense (DOD) has expressed interest in incorporating this satellite training course into their programs. Because of CIRA's, VISIT's and COMET's close links with the World Meteorological Organization (WMO), the training courses will be included in the WMO's Virtual Laboratory for Education and Training in Satellite Meteorology. This interest indicates that the training research and development activities at CIRA have wide-ranging applications.

6. Awards/Honors: None as yet

7. Outreach:

(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.

CIRA has participated in monthly VISITview weather briefings using GOES satellite imagery (http://hadar.cira.colostate.edu/vview/vmrmtcrso.html) and voice via Yahoo messenger between the US and WMO designated RA III and RA IV countries. This past year has seen explosive participation in sessions with the recent month of April experiencing a record attendance of 40 concurrent users logged on to the VISITview server and 34 concurrent users logged into YAHOO messenger. Each month there is an English/Spanish bilingual session and a Spanish-only session. 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.

(e) Public awareness; The SHyMet training is available on-line to increase public awareness of the importance to satellite data

8. Publications:

<u>Conference Proceedings</u>

Connell, B.H., 2006: Preparing for GOES-R: old tools with new perspectives. *4th GOES-R Users' Conference,* 1-3 May, Broomfield, CO.

Presentations

Connell, B., November 14, 2005: GOES and the characteristics of its channels. Remote Sensing class at the Metropolitan State College of Denver, CO.

Lindsey, D., October, 2005: Invited lecture. AT351, an undergraduate laboratory for Introduction to Weather and Climate, for the Department of Atmospheric Science at Colorado State University, Fort Collins, CO.

Lindsey, D., August, 2005: Using satellite imagery to improve forecasts and nowcasts. *34th Conference on Broadcast Meteorology*, Washington, DC.

Newsletters

Connell, B. and Hillger, D. Preparing for GOES-R: old tools with new perspectives. CIRA Newsletter, Vol. **21**, Spring 2006, p 1-3. http://www.cira.colostate.edu/newsletter/spring2006.pdf

Training

B. H. Connell (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 a 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.

B. Connell attended the GOES-R User Conference 1-3 May in Broomfield, CO. A poster on satellite tools for training activities was displayed.

GLOBAL MICROWAVE SURFACE EMISSIVITY ERROR ANALYSIS

Principal Investigator: Andy Jones

NOAA Project Goal: Weather and Water

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

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

The NESDIS Microwave Land Emissivity Model (MEM) is used as an important radiative boundary condition for 3DVAR satellite data assimilation within the NCEP Global Data Assimilation System (GDAS). The purpose of this project is to develop advanced techniques to validate the MEM using satellite data sources and other ancillary data sets such as water vapor profiles and land surface temperature fields, and to create new general procedures for analysis of the (observational versus model) innovation vector errors. The work is funded by the Joint Center for Satellite Data Assimilation (JCSDA).

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. Coincident MEM model output is then intercompared with the direct 1DVAR emissivity retrievals to validate the MEM results. In addition to the MEM model output, the experimental MSPPS microwave emissivities were also compared to the 1DVAR emissivity retrievals.

Previously planned emissivity collaborations with NRL JCSDA participants were made especially difficult due to funding shortfalls by the JCSDA for that effort. The project “Assimilation of Passive Microwave Radiances over Land: Use of JCSDA Common Microwave Emissivity Model (MEM) in Complex Terrain Regions” was not fully funded. The emphasis however remains on identification of continued improvements necessary for accurate global microwave emissivities for accurate MEM utilization. Final science conclusions and recommendations are listed in the results section.

The following project goals have been met:

--Improve atmospheric profiling capabilities (advanced data assimilation, 1DVAR)
--Conducted needed error analysis work related to the MEM versus independent observations
--Generalize the error characterization approach to future Observational Operator (OO) and Data Assimilation (DA) needs
--Improve understanding of existing MEMs

2. Research Accomplishments/Highlights:

The main achievement of this work was a demonstration of significant NOAA MEM bias errors on the order of 5-10%. A geographical spatial distribution of the errors was generated with a channel-by-channel diagnosis being provided to NESDIS/ORA.

In addition, detailed error contribution estimates were made regarding the contribution of the AMSU data relative to the background error field. Examples of these results were also provided to NESDIS/ORA. Due to the large statistical output of the system examples were provided to demonstrate the magnitude of the MEM errors, and to provide full statistical details of the results.

Conversely, the results for the MSPPS microwave emissivity intercomparison faired much better with errors on the order of 3-5%. Thus these new results were used by NESDIS/ORA to request the operationalization of the MSPPS microwave emissivity products. This occurred in the summer of 2006. The operationalization of the existing experimental product (MSPPS emissivities) was a consequence of our global emissivity validation research efforts.

This work also identified errors in the AMSU-B Antenna Pattern Correction. The correction of which results in 10-15% bias improvements to AMSU-B upper-water vapor profiles. While research activities are essentially complete, a journal manuscript of that work remains in progress (Nielsen et al., 2006).

Several publications were created or are in progress that contain summaries and application of the new global microwave emissivity results toward water vapor retrievals over ocean and land surfaces (Jones et al., 2006a; Nielsen et al., 2006; Forsythe et al., 2005, 2006a, 2006b, Jones et al., 2005, 2006b, 2006c;).

Conclusions and Recommendations:

This project has created the first detailed global all-microwave emissivity retrieval capabilities for use in microwave emissivity validation studies. The creation of this data set was a key objective of the project. Much technical work remains to be performed in terms of analysis of the results and in performing additional intercomparisons. We recommend that instantaneous emissivities be generated and used in a new and more complete global analysis of microwave emissivities in conjunction with ongoing JCSDA emissivity research activities. This work will also improve the quality of other microwave land surface products.

Future Work and Plans:

Follow-on activities should focus on implementing near-real time microwave emissivity generation capabilities. We have already demonstrated the feasibility of such an approach within this work (CIRA currently runs regional microwave emissivity sectors in near real-time for water vapor profile research activities). However, current JCSDA approaches are emphasizing the use of climatological microwave emissivities and thus will likely continue to be a source of large radiometric boundary condition errors within the operational 3DVAR applications. This is primarily because rapidly changing surface conditions can quickly overwhelm the historical microwave surface emissivity estimates. Thus timely information would be of most value to existing weather data assimilation systems.

We have also identified future performance improvements through our most recent research activities. This includes vertical discretization improvements needed within the radiative transfer model, and in identifying the need for better emissivity band selection and handling within the 1DVAR emissivity retrieval. These improvements should be incorporated into the next generation emissivity retrieval system.

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

The research activities are now complete. Some publications remain in progress (Jones et al., 2006a, Nielsen et al., 2006), but primary goals are now complete.

4. Leveraging/Payoff:

This work has identified MEM model biases on the order of 5-10% (some locations have even greater biases). This translates to regional radiometric errors on the order of 10-20K. This is a substantial error source that can be removed by advanced microwave emissivity analysis work. This in turn will improve the NWP model performance. As a result, this work will increase the use of global microwave satellite data by 25% (land regions are currently omitted in microwave radiance data assimilation systems). In related work, we are using the new microwave emissivities to perform global microwave water vapor retrievals over land. Thus this project's high quality microwave surface emissivities will be able to extend the atmospheric profiling capabilities of existing microwave satellite sensors. This is an important new research topic within the satellite meteorological community.

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

This work was funded by the Joint Center for Satellite Data Assimilation (JCSDA). NOAA collaborators include: Dr. Fuzhong Weng, and Dr. Banghua Yan (NESDIS/ORA). NRL collaborators include: Dr. Ben Ruston, and Dr. Nancy Baker (NRL).

6. Awards/Honors: None as yet

7. Outreach:

8. Publications

<u>Journal Papers</u>

Jones, A. S., P. S. Shott, J. M. Forsythe, C. L. Combs, T. H. Vonder Haar, 2006a: Retrieval of global microwave surface emissivity over land using AMSU, In preparation.

Nielsen, M., P. J. Stephens, A. S. Jones, J. M. Forsythe, R. W. Kessler, T. H. Vonder Haar, 2006: AMSU-B antenna pattern corrections, In preparation.

Technical Reports and Conference Papers

Forsythe, J. M., K. M. Donofrio, A. S. Jones, C. L. Combs, and T. H. Vonder Haar, 2006a: Atmospheric profiles from the AMSU instrument using CIRA 1-dimensional variational optimal estimator, *CIRA Science Symposium,* May 16-17, Fort Collins, CO.

Forsythe, J. M., K. M. Donofrio, R. W. Kessler, A. S. Jones, and T. H. Vonder Haar, 2006b: Atmospheric profiles over land and ocean from AMSU, *14th Conference on Satellite Meteorology and Oceanography,* January 29 - February 2, Atlanta, GA.

Forsythe, J. M., M. J. Nielsen, A. S. Jones, R. W. Kessler, K. Donofrio, 2005: Water vapor and temperature profile retrievals from satellite microwave sounding instruments over land and ocean. *BACIMO 2005,* October 12-14, Monterey, CA, P5.03.

Jones, A. S., J. M. Forsythe, C. L. Combs, and T. H. Vonder Haar, 2006b: Masking effects of surface features – How 1DVAR microwave emissivities place bounds on the problem, *CIRA Science Symposium,* May 16-17, Fort Collins, CO.

Jones, A. S., P. C. Shott, J. M. Forsythe, C. L. Combs, R. W. Kessler, M. J. Nielsen, P. J. Stephens, T. H. Vonder Haar, 2005: Global microwave surface emissivity error analysis, *BACIMO 2005,* October 12-14, Monterey, CA, P5.02.

Jones, A. S., P. C. Shott, J. M. Forsythe, C. L. Combs, and T. H. Vonder Haar, 2006c: Error analysis of global microwave surface emissivity over land, *14th Conference on Satellite Meteorology and Oceanography,* January 29 - February 2, Atlanta, GA (poster only).

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT SECTOR PROCESSING AND ANALYSIS

Principal Investigators: G. Garrett Campbell, T.H. Vonder Haar, J. A. Kankiewicz

NOAA Project Goal: Climate Observations

Keywords: Climate, Observations, Cloud

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

The International Satellite Cloud Climatology Project collects and processes operational satellite data to establish a climatology of observations of cloudiness and cloud properties. CIRA acts as the Sector Processing Center and is funded by the Atmospheric Research Center of NOAA. Our prime responsibility is the collection of GOES satellite data for the project. In the last year we have collected 99% of the time slots available from GOES West, processing more than 1 terabyte of raw data in total. This provides full disk imagery every 3 hours for use in the cloud analysis.

2. Research Accomplishments/Highlights:

We began GOES data collection at the start of the project in 1983 and now have more than 20 years of global cloud analyses available for the general scientific community.

Those attending the July 2006 GEWEX Cloud Assessment workshop agreed to begin publishing well understood and observed trends in satellite-based cloud climatologies (e.g., diurnal, seasonal and regional trends) so that the climate modeling community can begin to realistically model known climate variations. ISCCP data was extensively used and reported on by many attendees during this workshop.

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

The basic objective of the project is collection of satellite data. This was achieved at CIRA with 99% of potential data collected.

ISCCP data collection code at CIRA has been successfully rewritten to allow the archival of 10-bit data versus the 8-bit data collected in the past. This will improve the radiance resolution of the ISCCP archive.

CIRA successfully transitioned ISCCP data processing from GOES 10 to GOES 11 after NOAA switched out the GOES-WEST satellites in June 2006. ISCCP data deliveries continued uninterrupted during this timeframe.

4. Leveraging/Payoff:

NOAA has the responsibility for collecting climate records to lead to the understanding of climate processing and to provide base line records for detecting changes. ISCCP provides a valuable “Climate Data Record” but estimating its accuracy has been greatly improved upon in the last year. An improvement in the understanding of the error inherent to ISCCP data has opened the door for ISCCP's use as a valuable climate observation tool.

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

ISCCP is an international effort under the World Meteorological Organization. Within the U.S. there is substantial collaboration between NOAA and NASA on this project.

6. Awards/Honors: None as yet

7. Outreach: None

8. Publications: None

IMPACT OF FUNDAMENTAL ASSUMPTIONS OF PROBABILISTIC DATA ASSIMILATION/ENSEMBLE FORECASTING: CONDITIONAL MODE VS. CONDITIONAL MEAN

Principal Investigator: Milija Zupanski

NOAA Project Goal: Weather and Water

Key Words: Probabilistic Assimilation/Prediction, Ensemble, Maximum Likelihood Ensemble Filter, Global Forecasting System

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

The long-term objective of this research is to explore the possibility for NOAA operational use of the ensemble assimilation/prediction system, by designing a double-resolution system, with a high-resolution model used as a control, and a low-resolution model used in ensemble forecasting. The system includes NCEP operational observations.

The Maximum Likelihood Ensemble Filter (MLEF) with the NCEP Global Forecasting System (GFS) at resolution T62L28 is used in this study, with special algorithmic design in order to facilitate the use of NCEP operational codes. In particular, the GFS spectral model and the Spectral Statistical Interpolation (SSI) data assimilation codes are used as modules in the MLEF algorithm. Main accomplishments are:

MLEF system with GFS and SSI (standard observations only, satellite and radar next year) 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 100-200 ensemble members used,

Model bias and parameter estimation is also developed. The results, however, show that the impact of bias correction is not as important as initially thought,

Comparison between SSI and MLEF shows that MLEF is better during first few days, deteriorating afterwards. There is also a clear signal that 48-hour forecast is generally much more improved than 6-hour forecast, suggesting the benefit of ensembles in creating balanced initial conditions,

Comparison with other ensemble algorithms (LETKF, ENSRF) shows that MLEF is performing better in the Tropics, but is not as well in the extratropical 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.

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:

The results were presented at the NOAA THORPEX PI meeting held at NCEP in Washington, DC, January 17-19, 2006. [Presentation available at http://wwwt.emc.ncep.noaa.gov/gmb/ens/THORPEX/PI-workshop/Zupanski_NOAA_THORPEX.ppt]

8. Publications:

IMPROVED STATISTICAL INTENSITY FORECAST MODELS

Principal Investigator: John Knaff

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:

The new decay model was implemented in SHIPS at the beginning of the 2005 season. This new model reduces the decay rate over islands and other narrow landmasses to eliminate a bias that was prevalent in the original version. The new decay model was included in the operational SHIPS in 2005, based upon re-runs of the 2001-2004 seasons, all of which showed neutral or positive impact. To determine the impact on the real-time runs, the 2005 Atlantic and east Pacific forecasts were re-run with the new and old versions of the decay model. The re-runs were needed to make the comparison exact because it is not always possible to exactly reproduce everything that can happen in real time. The 2005 Atlantic season was ideal for this evaluation because of the large sample size, and the large number of storms impacted by land.

Figure 1 shows the improvement (reduction in mean absolute error) of the 2005 Atlantic SHIPS forecasts for the entire sample of storms. The new decay model improved the forecasts at every forecast internal, with the maximum impact at 96 hours. The improvement at most time periods was statistically significant at the 95% level.

The east Pacific storms were also re-run with the new and old decay model. The new decay model had little impact on the east Pacific forecasts because so few cases were impacted by land. The differences in the forecast errors with the new and old decay models were less than 0.7% at all forecast intervals, and none of the differences were statistically significant.

The new decay model has been implemented on the NCEP IBM for the 2006 hurricane season. Thus, the part of the project is essential completed.

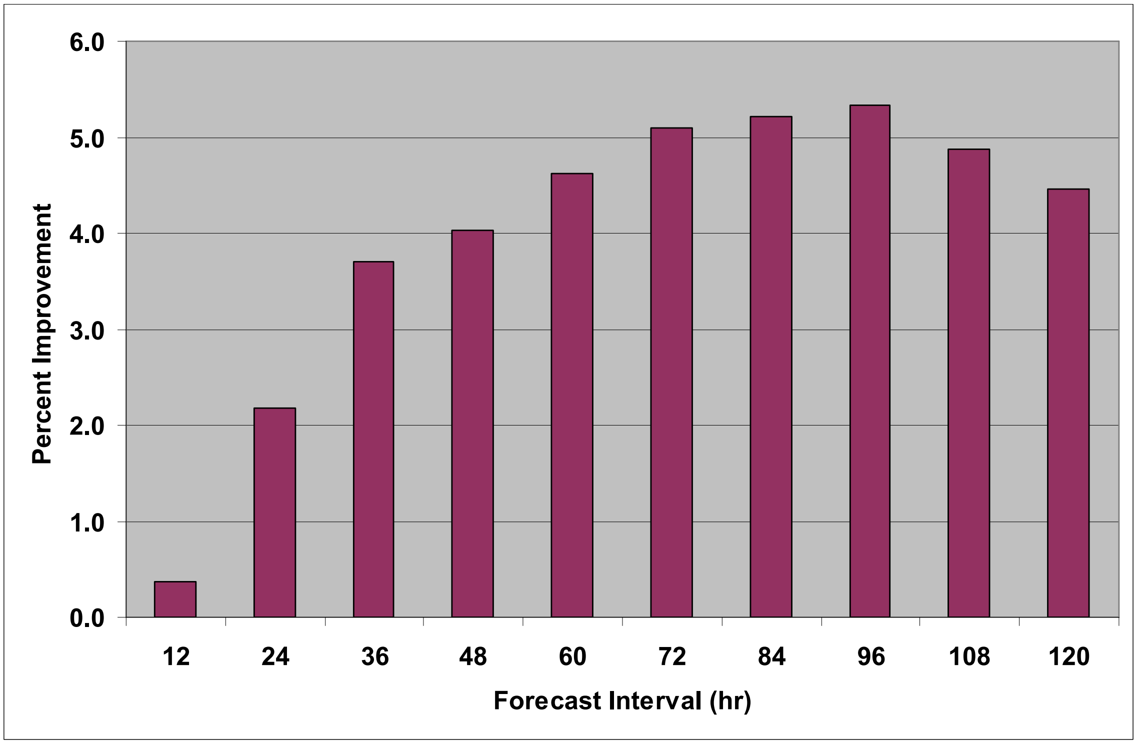

Figure 1. The improvements in the 2005 Atlantic SHIPS forecasts due to the inclusion of the new decay model. The sample includes all of the 2005 SHIPS forecasts, including those not affected by land.

2) 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 are being tested. The first 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 $\Lambda^2 u = \Lambda^2 v = 0$. Preliminary testing of the vortex removal methods has begun, and this code is being incorporated into the part of the SHIPS routine that performs the model diagnostics. This work will continue through the 2006 hurricane season.

3) Improved Rapid Intensity Index

This work is a collaborative effort with John Kaplan from the NOAA/OAR Hurricane Research Division. John visited CIRA in mid-April and considerable progress on the discriminant analysis (DA) version of the RII was made. The DA software available from the IMSL library was adapted to the RII development code, and the performance relative to the operational RII was evaluated for the dependent sample. In the operational RII, the seven scaled inputs are equally weighted, while the DA chooses optimal weights that best separate the rapid intensifying cases from the non-rapid intensifiers. The new version of the RII has been implemented at NCEP/TPC and is being evaluated in real time by NHC forecasters. A post-season evaluation will be performed to determine if the new method provides more accurate forecasts. If so, it will be transitioned to NCEP/TPC operations.

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

This project is on schedule. One of the three algorithms has already been transitioned to NCEP/TPC operations and the other two are being tested in real time during the 2006 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%, which contribued to more accurate watches and warnings. The NHC intensity forecasts will continue to benefit as this project continues.

5. Reseach 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, the NOAA/OAR Hurricane Research Division, and Colorado State University.

6. Awards/Honors:

M. DeMaria, a NOAA contributor to this project, received a Department of Commerce Silver Medal for improvements to the SHIPS model under the Joint Hurricane Testbed program.

7. Outreach:

(b) Seminars, symposiums, classes, educational programs; See section 8

(d) K-12 outreach; 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>

DeMaria, M., J.A. Knaff, and J. Kaplan, 2006: On the decay of tropical cyclone winds crossing narrow landmasses, *J. Appl. Meteor.*, 45:3, 491-499.

DeMaria, M., M. Mainelli, L.K. Shay, J.A. Knaff, J. Kaplan, 2005: Further Improvement to the Statistical Hurricane Intensity Prediction Scheme (SHIPS). *Wea. and Forecasting*, 20:4, 531–543.

Knaff, J.A., C.R. Sampson, M. DeMaria, 2005: An operational statistical typhoon intensity prediction scheme for the Western North Pacific. *Wea. and Forecasting,* 20:4, 688-699.

Conference Proceedings

DeMaria, M., 2006: Statistical Tropical Cyclone Intensity Forecast Improvements Using GOES and Aircraft Reconnaissance Data. *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

Presentations

DeMaria, M., June 2006: An update on CIRA Joint Hurricane Testbed projects, Tropical Prediction Center, Miami, FL.

INCORPORATION OF CENSUS DATA IN SEVERE WEATHER WATCHES AND WARNINGS (Applied Social Science Research in Collaboration with National Weather Service (NWS) for Incorporation of Census Data in Severe Weather Watches and Warnings)

Principal Investigator: Shripad D. Deo

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

Key Words: Social Science, Hazards Communication, Local Watches and Warnings

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

(a) To add a new understanding of social science data to enhance the quality of natural hazards 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 weather and water information to make it socially robust by providing the context in which information can be used.

We have started developing a database with Geographic Information Systems (GIS) and census information to support various watches and warnings developed and issued by NWS in graphical and text formats. This database will enable the NWS to provide a better understanding of population (age, sex, density, etc), communities (metropolitan, urban, rural, etc.), their socio-economic attributes (income, education, linguistic proficiency, etc.), physical structures (schools, churches, stadiums, fairgrounds, etc), disabilities, etc. of a region under a weather watch or warning. This information will allow the emergency management community to know the demographic and socio-cultural details of the area under threat. By knowing the scope and nature of the threat, they can assess the vulnerabilities, plan, and match the available resources accordingly.

The producers of information (such as, NWS) need to have a better 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 also need to cultivate socio-technical networks, develop appropriate information tools, and understand the context in which these tools are used.

2. Research Accomplishments/Highlights:

a) Increased awareness and appreciation of user information needs to enable them to make better decisions through social science research methods.

b) 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 will be achieved by making weather forecasting offices aware of the potential through training workshops, new prototype designs and new operational information tools.

4. Leveraging/Payoff:

The work on this project will provide a template for social science perspective to be included in climate information regarding other weather-related events (resources, climate change, and drought).

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

The initial social science collaborative research work in water resources has attracted the interest of the National Integrated Drought Information System (NIDIS) to use similar approaches for their work.

6. Awards/Honors: The project is still in its initial development phase.

7. Outreach:

8. Publications:

INTERACTIONS OF THE MONSOON AND ANTICYCLONES IN THE COUPLED ATMOSPHERE-OCEAN SYSTEM

Principal Investigator: David A. Randall

NOAA Project Goal: The goal of our PACS project is to reduce uncertainty in models that predict climate change by better representing the processes that affect cloud feedbacks.

Key Words: Clouds, Climate, Models

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

The goal of our PACS project is to reduce uncertainty in models that predict climate change by better representing the processes that affect cloud feedbacks.

2. Research Accomplishments/Highlights:

The mixed-layer approach to modeling the planetary boundary layer (PBL) is particularly well suited to inversion-topped PBLs, such as the stratocumulus-topped boundary layer found off the continental American coasts in the subtropical Pacific Ocean. However, a strong temperature inversion near 850 hPa (the trade-wind inversion) is not confined to the stratocumulus regimes, but has been observed over most parts of the subtropical-tropical Pacific Ocean. Over the past year, we have tested a simple mixed-layer model's (MLM) ability to diagnose PBL depth, entrainment velocity and cumulus mass flux velocity from monthly mean re-analysis data (both from the National Centers for Environmental Prediction (NCEP) and the European Center for Medium-Range Weather Forecasts (ERA-40)). Part of this test involved a comparison between the Colorado State University's General Circulation Model (CSU GCM) and the MLM run with input data from the CSU GCM. The results were also compared to some available observations (soundings from the East Pacific Investigation of Climate).

The MLM succeeds in diagnosing positive PBL depths and entrainment velocities on the order of hundreds of meters and mm s^{-1}, respectively (Fig. 1). Convective regions are marked by deep PBLs in the MLM's output, and entrainment is generally large where the PBL is deep. The cumulus mass flux velocity is large in the convective areas and small in the stable regions (Fig. 2).

Comparison with the CSU GCM shows that neglecting temporal covariances, as is done in the MLM, changes the diagnosed PBL depth by several hundred meters (Fig. 3). However, the temporal covariances in the GCM are significantly larger than in the re-analysis data (a weakness of the GCM), and the effect of the covariances on the PBL depth is much smaller when the MLM is run with the re-analysis data.

Observations with similar spatial and temporal coverage as the model output are as yet unavailable. However, the PBL depth can be estimated from available soundings in the stable regions of the domain by locating the height of the temperature inversion. The MLM's PBL is shallow compared to the inversion base height from EPIC soundings, particularly over the cold tongue. The MLM's PBL depth does mimic the general behavior of the observed inversion, though, whose base is low over the cold tongue and lifts toward the north until the inversion disappears in the convection associated with the intertropical convergence zone (ITCZ). There is a conflict between the MLM's PBL depth and the picture of the PBL depth obtained from other models (CSU GCM, ERA-40), where the PBL is shallowest in the convective areas and deep in the stable areas of the domain. In contrast, the MLM's PBL depth is deepest (unreasonably so) in the deep-convective areas.

The difference in the MLM results from the NCEP and ERA-40 re-analyses is quite remarkable. The runs with ERA-40 data provide a much better output. In particular, the cumulus mass flux velocity, a rather elusive quantity, appears to be reasonably well diagnosed and marks the areas of deep convection clearly with large velocities.

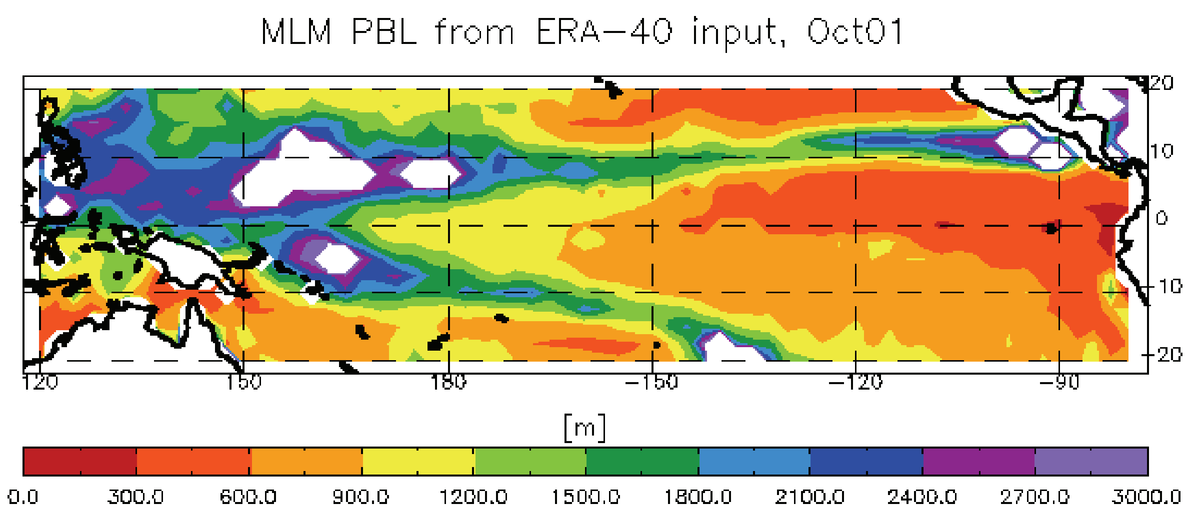

Fig. 1: PBL depth diagnosed by the MLM from ERA-40 monthly mean re-analysis data for October 2001. White areas indicate above-scale values.

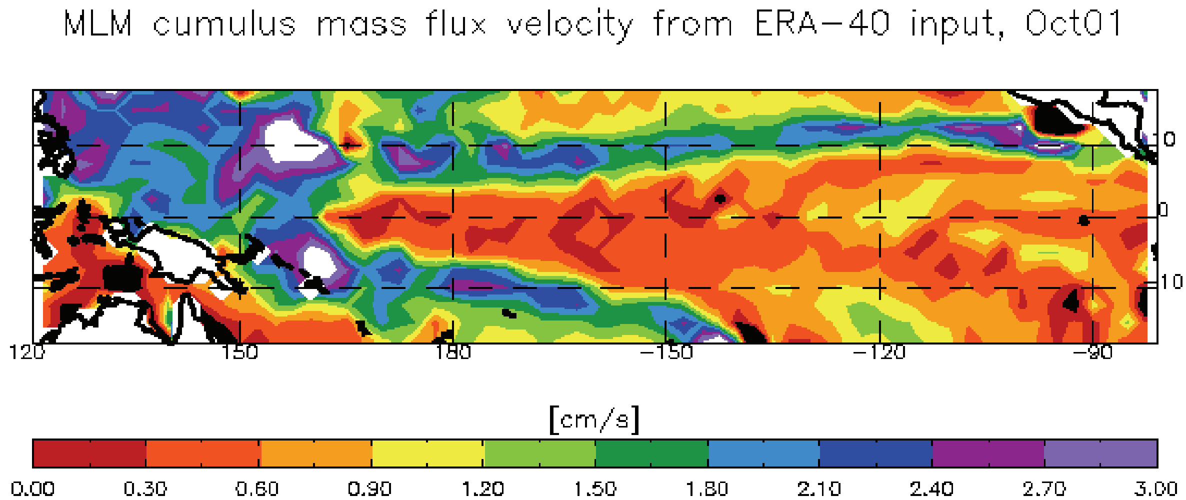

Fig. 2: Cumulus mass flux velocity diagnosed by the MLM from ERA-40 monthly mean re-analysis data for October 2001. White areas indicate above-scale values, black below-scale values.

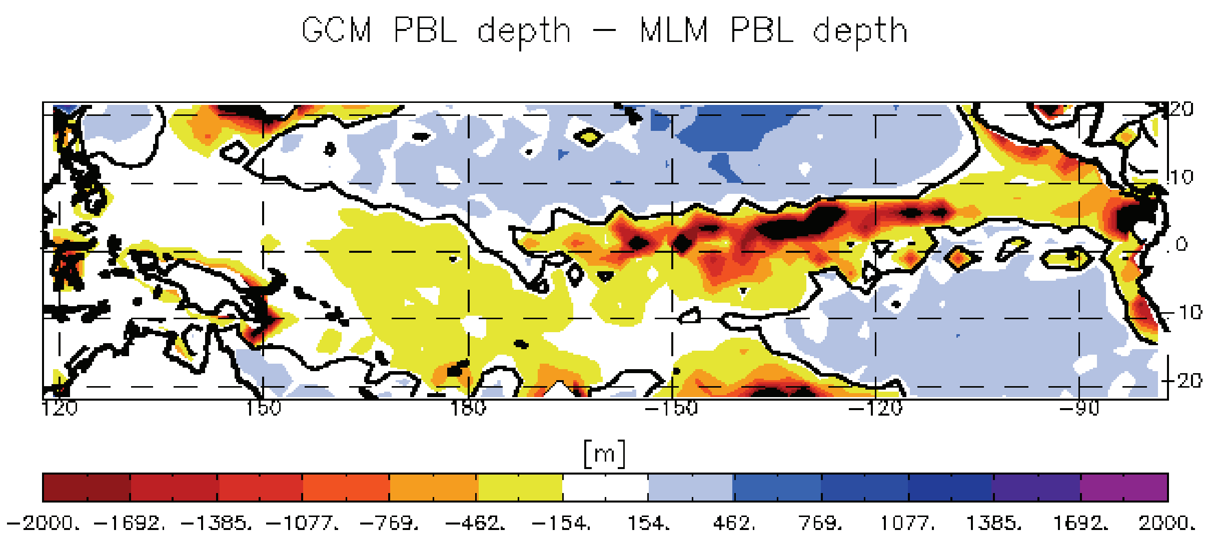

Fig. 3: Difference plot between PBL depth from CSU GCM run and MLM run with GCM input data (i.e. model run with temporal covariances minus model run without temporal covariances). Run for climatological April conditions.

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

The work reported above deals with PBL and cloud processes over the Pacific, on which we proposed to work.

4. Leveraging/Payoff:

Our research will lead to more accurate weather forecasts and predictions of climate change.

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

We have been collaborating with Martin Kohler and Anton Beljaars of the European Centre for Medium Range Weather Forecasts.

6. Awards/Honors:

David Randall received CSU's Scholarship Impact Award for 2005.

7. Outreach:

8. Publications:

Ahlgrim, M., 2004: M. S. Thesis, Colorado State University.

Ahlgrim, M., and D. A. Randall, 2005: Diagnosing monthly mean boundary-layer properties from re-analysis data using a bulk boundary-layer model. *J. Atmos. Sci.* (in press).

DeMott, C., D. A. Randall, and M. Khairoutdinov, 2006: In preparation for *J. Atmos. Sci*.
Khairoutdinov, M., and D. A. Randall, 2006: A high-resolution simulation of TRMM-LBA. In preparation for *J. Atmos. Sci.*

Randall, D. A., and W. H. Schubert, 2005: Dreams of a stratocumulus sleeper. In *Atmospheric Turbulence and Mesoscale Meteorology*, Cambridge University Press.

Yamaguchi, T., 2005: *Entraining cloud-topped boundary layers*. M.S. Thesis, Colorado State University.

Yamaguchi, T., and D. A. Randall, 2006: Large-eddy simulation of evaporatively driven entrainment into cloud-topped mixed layers. Submitted to *J. Atmos. Sci*.

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 the effects of aerosol on rainfall, cloud fraction, and cloud lifetime with a large eddy model and to evaluate the relative importance of the various processes to modification of cloudiness in clean and polluted air over smoke area, urban area, and over ocean.

2. Research Accomplishments/Highlights:

The role of smoke aerosol in modifying the microphysics and dynamics of cumulus cloud fields in biomass burning regions such as Brazil was investigated. We have identified two primary reasons for the absence of clouds in heavy smoke regimes. The first is related to absorption and local heating by biomass burning aerosol and its modification of atmospheric stability. The second is based on a dynamical feedback due to the absorbing aerosol, and follows from the fact that heavy aerosol cools the earth's surface by blocking incoming solar radiation. The reduction in net surface radiation results in a commensurate reduction in surface fluxes, which suppresses convection and cloud formation.

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

We have completed our study in the Smoke area with two peer-reviewed publications. Some of these effects will be further investigated in the Houston, TX area during the summer of 2006 field campaign (Texas Air Quality Study / Gulf of Mexico Atmospheric Composition and Climate Study: TexAQS / GoMACCS).

4. Leveraging/Payoff:

Case studies in the Houston, TX area during the summer of 2006 field campaign will improve understanding on how aerosol and other chemical species are transported from the surface to the upper troposphere, and modify cloudiness and air quality in the Houston area.

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

Research was conducted in collaboration with:

Feingold, G: NOAA/ESRL

Levin, Z. and A. Teller: Tel Aviv University, Israel.

Xue, H. Beijing University, China.

6. Awards/Honors: None as yet

7. Outreach: None as yet

8. Publications:

Jiang, H., H. Xue, A. Teller, G. Feingold, and Z. Levin, 2006: Aerosol Effects on the Lifetime of Shallow Cumulus. *Geophys. Res. Lett.*, in press.

Jiang, H. and G. Feingold, 2006: Effect of aerosol on warm convective clouds: Aerosol- cloud-surface flux feedbacks in a new coupled large eddy model. *J. Geophys. Res.*, 111, D01202, doi:10.1029/2005JD006138.

MAXIMIZING THE USEFULNESS OF GRID TECHNOLOGY ON NOAA OFFICE PCs

Principal Investigator: A. Jones

NOAA Project Goal: Supporting NOAA's Mission
Related Programs: Satellite Services, Information Technology Services

Key Words:

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

This is a collaborative project with NESDIS/OSDPD (OSDPD lead: Ms. Limin Zhao) to maximize the usefulness of grid technology on NOAA Office PCs for satellite data processing. The work is funded by the NOAA High Performance Computing and Communications (HPCC) Program and by matching funds from NESDIS/OSDPD.

Approach:

A typical office PC can be idle more than 80% of the time. This work uses an innovative PC-based grid computing system developed at CIRA called the Data Processing and Error Analysis System (DPEAS). The new system enables the previously wasted computing cycles to be used for NOAA data processing efforts in a secure and efficient manner. A technology transition cost/benefit analysis was performed on the DPEAS software framework technologies as used in three case study examples. The software framework uses advanced shared libraries and software systems that speed the transition of software technology from research into NOAA operations. Out of the three case studies that were analyzed, a total of 4 years of effort was saved. This resulted in a cost savings of $600K, with the creation of more than $7M in benefits due to the improved technology transition speed. Blended products are also identified to have proportionally larger benefits from the possible time improvements. The average ROI of the new software framework method is 3,167%. The lowest ROI analyzed was 2,981%. These transition method benefits are in addition to an earlier reported cost/benefit result of $1M over a 5 year period based on hardware and software considerations alone. Thus the software framework approach for satellite processing has great potential for NOAA.

2. Research Accomplishments/Highlights:

a) Previous accomplishments included extensive on-site testing of the DPEAS software within the NESDIS/OSDPD office PC network environment. This included a series of successful technology demonstrations and completion of a cost/benefit analysis.

b) The cost/benefit analysis and final report was completed (Jones et al., 2005).

c) The DPEAS software framework training guide publication series was completed (Jones and Shott, 2005; Shott and Jones, 2005a, 2005b).

d) A training trip visiting OSDPD at Suitland, MD was completed (3rd of a series of 3 training trips) (Sep. 16, 2005).

e) Publication of project scientific results related to the blended TPW algorithms was completed (Kidder and Jones, 2006).

Conclusions and Recommendations:

The technology transition process is now simplified and improved. This results in faster transition times measured in a few days to mere hours. Total benefits from this work (primarily from process time improvements) amounted to more than $7M. The method has substantial cost savings in its implementation, and the average ROI using the new software framework is 3,167%.

We recommend that NOAA take advantage of existing computational platforms (AIX/Linux/Windows) by implementing a common satellite processing software framework. Such a framework should leverage existing successful satellite processing models such as the DPEAS CPE example of this work, and other successful systems within NESDIS. As NPOESS Data Exploitation (NDE) and GOES-R activities proceed, they should be implemented in such a manner to leverage a common software framework for more efficient transition of technology from the research community to the operational community (and vice-versa). Such a system would be highly mobile, scalable, configurable, and also provide a common training and educational asset for NOAA, while improving technology transition and reducing costs.

Future Work and Plans:

Future efforts will be to implement an AIX-specific implementation of DPEAS for operational use at OSDPD. This work will become part of a foundational set of tools for the NESDIS collaborative computing environment for OSDPD, ORA, and the NOAA Cooperative Institutes. Proposals to continue the formal operationalization and AIX activities are being actively planned (Ms. Limin Zhao is the OSDPD contact for that work).

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

All goals were successfully completed. The DPEAS Software Framework Technology was successfully transitioned to OSDPD in several stages and then analyzed for cost/benefit results. The Blended TPW Algorithm is currently providing 24/7 experimental products from OSDPD to operational NOAA users.

4. Leveraging/Payoff:

This work resulted in a ROI of 3,167%. Accrued estimated benefits amount to more than $7M in process improvements for this particular series of analyzed case studies. If concepts from this work are successfully applied to more satellite processing systems in the future, software framework benefits to NOAA and the Nation could easily exceed $350M (e.g., application to the NPOESS 55 EDRs = 55 * $7M = $385M).

We expect substantially easier and less costly science transitions with the adoption of the new collaborative environment framework. As it is currently envisioned, we anticipate that all NESDIS and University Linux/AIX/Windows systems will be able to use the software system in its final form.

5. Research Linkages/Partnerships/Collaborators:

This work was jointly funded by the NOAA High Performance Computing and Communications Program and NESDIS/OSDPD. NOAA Collaborators include: Ms. Limin Zhao (OSDPD), Dr. Ivan Tcherednitchenko (Computer Sciences Corporation), Dr. Ralph Ferraro (ORA), Mr. Carl Karlburg (OSDPD). Ms. Ingrid Guch (formerly with OSD, now with ORA) has also been helpful in the initial creation and guidance of the project. The end-user Blended TPW testing is in collaboration with Mr. Sheldon Kusselson (OSDPD/SAB), Ms. Jianbin Yang, and Mr. John Paquette (OSDPD/SSD).

6. Awards/Honors: None as yet

7. Outreach:

Presentations
Jones, A.S.: "DPEAS Usage and Programming", NOAA/NESDIS HPCC Training Seminar, Camp Springs, MD, September 16, 2005.

8. Publications:

Journal Papers
Kidder, S.Q., and A.S. Jones, 2006: Blended satellite products for operational forecasting, J. Atmos. Oceanic Technol. (accepted).

Technical Reports and Conference Papers
Jones, A.S., and P.C. Shott, 2005: DPEAS *Usage and Programming Document,* Fort Collins, CO, July 2005, 46 pp.

Jones, A.S., P.C. Shott, L. Zhao, I. Tcherednitchenko, R.R. Ferraro, C. Karlburg, S.Q. Kidder, 2005: *Maximizing the Usefulness of Grid Technology on NOAA Office PCs*: Communications Program and NOAA/NESDIS/OSDPD, July 2005, 39 pp.

Shott, P. C., and A. S. Jones, 2005a: *DPEAS CPE Process Document NOAA-16 AMSU-A Processing,* July 2005, 7 pp.

Shott, P. C., and A. S. Jones, 2005b: *DPEAS CPE Process Document MEM Processing,* July 2005, 8 pp.

MICRO RAD ’06: MICROWAVE RADIOMETRY AND REMOTE SENSING SPECIALIST MEETING

Principal Investigator: Steven C. Reising

NOAA Project Goal: Weather and Water

NOAA Programs: Local Forecasts and Warnings; Coasts, Estuaries and Oceans; Environmental Monitoring; Weather Water Science, Technology and Infusion.

Key Words: Microwave Radiometry, Radiometer Calibration, RFI Mitigation, Ocean Salinity Mapping, Sea Surface Winds and Waves, Hurricanes, Sea Ice, Snow Cover, Soil Moisture, Radiance Assimilation into NWP Models, Temperature and Humidity Sounding, Clouds and Precipitation Measurement.

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

The Specialist Meeting on Microwave Radiometry and Remote Sensing Applications, commonly referred to as MicroRad or simply “μrad,” was conceived to provide a common international forum to report and discuss recent achievements in the field of microwave radiometry for remote sensing of the environment. The topics of these meetings include instrument design, calibration and RFI mitigation, as well as applications to weather forecasting through radiance assimilation, to coastal and ocean remote sensing, and to monitoring the hydrological cycle through global, all-weather remote sensing of sea ice, snow cover, clouds and precipitation. The meetings are also intended to facilitate interaction between the scientific community and industry, and to foster the benefits to society of microwave and millimeter-wave radiometry, both through the application of data products in weather prediction, climate analysis, and environmental management, and through economic gain. The first MicroRad specialist meeting was held in Rome at “La Sapienza” in 1983, and the second in Florence in 1988. Since then, MicroRad has been held approximately every 2.5 years, alternating in venue between the United States and Italy.

The specific plan to accomplish these objectives is to plan and hold the MicroRad ’06 conference in San Juan, Puerto Rico, from February 28 to March 3, 2006. The purpose of this grant is to provide partial funding for the conference, in the form of a grant to cover conference management (in part), registration assistance and final program production.

2. Research Accomplishments/Highlights:

This year 125 MicroRad attendees from 15 different countries convened in San Juan, Puerto Rico, USA. They presented 130 technical papers in 16 sequential sessions over 4 full days, with 5 oral papers per session. These included 34 invited talks, half from Europe and half from the U.S. Posters associated with each session were introduced by session chairs preceding each 40-minute coffee break, allowing plenty of time for interacting with poster presenters and for renewing aquaintances. This format continued the successful structure of the MicroRad conferences to date.

The final program, containing abstracts of the papers presented, was distributed at the MicroRad symposium. Copies of the full proceedings on CD-ROM, which included both full papers and presentation slides from authors who gave their approval, were mailed to all participants by July 15, 2006. All full papers on the CD-ROM are fully citable and will appear on the IEEE Xplore web site (http://www.ieee.org/ieeexplore) in the near future. In addition, digital audio recordings of 20 presentations, along with the corresponding slides, will be provided as online educational lectures by the IEEE Geoscience and Remote Sensing Society (GRSS). Those lectures processed to date are available at http://www.grss-ieee.org/menu.taf?menu=Conferences&detail=Audio. Membership in IEEE GRSS is required to download the educational lectures except for one “teaser,” which is freely available to the public.

Finally, a Special Issue of the *IEEE Transactions on Geoscience and Remote Sensing* (TGRS) consisting of peer-reviewed full papers on the topics of this meeting is scheduled for publication in May 2007. The manuscript deadline was June 1, 2006, and 45 manuscripts were received. The Guest Editors for the Special Issue of TGRS are Steven C. Reising, Frank S. Marzano, Eni G. Njoku, and Ed R. Westwater.

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

The tasks of this project have been completed, including conference management, registration assistance and final program production. The MicroRad ’06 specialist meeting was successfully held at the Condado Plaza Hotel in San Juan, Puerto Rico, on the scheduled dates. The final program and CD proceedings have been published. The last step of the overall effort is for the Guest Editors of TGRS to complete their work on the Special Issue on MicroRad ’06. However, this special issue is not sponsored by this grant, so the activity on this project has been completed.

4. Leveraging/Payoff:

Improvements in weather prediction and monitoring of the global water cycle provide many benefits to society. These goals are advanced by improving the opportunities for communication and collaboration among international experts in the field of microwave radiometry. The MicroRad ’06 specialist meeting and its publications clearly provided such opportunities.

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

As a co-sponsor of this workshop, NOAA has partnered with IEEE, NASA, and the National Center for Atmospheric Research (NCAR) to make possible the MicroRad ’06 Specialist Meeting.

6. Awards/Honors:

None.

7. Outreach:

At least 18 of the 125 attendees of the MicroRad ’06 specialist meeting were students. This meeting contributed to their education in the field of microwave radiometry and remote sensing applications.

8. Publications:

Reising, Steven C., 2006*: 2006 IEEE MicroRad Proceedings*, CD-ROM, OmniPress, IEEE Copyright 2006.

Reising, Steven C., 2007: Special Issue on Microwave Radiometry and Remote Sensing Applications, *IEEE Transactions on Geoscience and Remote Sensing*, to appear in May 2007.

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: Thomas H. Vonder Haar

NOAA Project Goal and Programs: Weather and Water, Local forecasts and warnings, hydrology

Key Words: Community Radiative Transfer Model (CRTM), Integration and 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.

--Integrate new atmospheric absorption models into the current CRTM model. Redesign the current CRTM framework to handle different atmospheric absorption models.

--Compare the different models' output and make recommendations as to which one is the best for specific satellite sensors.

2. Research Accomplishments/Highlights:

--Be familiar with the current CRTM framework.

--Be familiar with the UMBC Stand Alone Radiative Transfer Algorithm (SARTA) forward model.

--Integrate the SARTA forward model into the CRTM, and compare the results with SARTA.

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

--Integration of SARTA forward model into CRTM has been completed (from 3/23/06-06/20/06).
--The SARTA tangent-linear model and adjoint model are in progress (from 06/20/06-now).

Prasanjit Dash – NESDIS Post Doc

Project Title: An improved SST Product from AVHRR/3 sensor to be flown onboard MetOpA"

Principal Investigator(s):
Postdoctoral Scientist: Dr. Prasanjit Dash
Supervisor: Prof. Thomas H. Vonder Haar, CIRA
Principal Technical Advisor: Dr. Alexander Ignatov, NESDIS/STAR
Team Members : John Sapper (NESDIS/OSDPD), Yury Kihai, Alexander Frolov (QSS contracto), Andy Heidinger (NOAA/Wisconsin)

NOAA Project Goal: Climate; Long-term Environmental Data Record (EDR)—primarily Sea Surface Temperture (SST) will be derived, archived, and used for climate studies

Key Words: Sea Surface Temperature (SST), MetOp, AVHRR, Radiative Transfer Modeling (RTM), Cloud Detection, QC/QA tools for SST, Split Window Technique (SWT)

Reporting period: Mar-20-2006 to Aug-10-2006:

MetOp-Background:
The EUMETSAT's Polar System (EPS) will operate a series of Meteorological Operational (MetOp) satellites the first of which will be launched in the near future (postponed 3 times and EUMETSAT is looking for next suitable launch window). Among other sensors, Metop-2 (after launching MetOp-A) will carry AVHRR-3 onboard provided by the US (manufactured by ITT aerospace/communications industries). This is a major collaborative step between NOAA and EUMETSAT towards data continuation from AVHRR sensors. Among various applications of AVHRR data, sea surface temperature (SST) determination is crucial and NOAA provides SST using the 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. The processor will be based on previous heritage but will be greatly tuned for a dedicated SST processor and will be improved based on rigorous statistical analysis (QC/QA). 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 radiative transfer modeling in the thermal infrared in order to analyze the information content of the channels and formulate the optimal form/s of SWT. CIRA plays a crucial role by supporting the postdoc program in collaboration with NOAA NESDIS.

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

NOAA AVHRRs' data have been routinely used for the SST estimation employing the SWT, along with generation of other Environmental Data Record (EDR). Most of the operational SST processors are based on SWT which takes advantage of the differential absorption in two different nearby channels in atmospheric window channels. NOAA polar-orbiters' SST products have been based on linear SWT since 1970 and nonlinear SWT since 1990. The current NOAA Main Unit Task (MUT) 24/7 operational processor has SST as one of the products and uses 9 different SW-equations applicable under different conditions. Another processor CLAVR-x is an advanced processor with more features; however, it is not ready to be operational.

Surface temperature is an indicator of the energy balance at the earth's surface and its long-term estimates are for climatological studies. The SST and land surface temperature (LST) retrievals from passive radiometric measurements have similar basis (see [1]Dash et al., 2002 for a review of passive radiometric measurements), however, the implementation and choice of algorithms are different depending on target and observation conditions. Set-up of an optimal processor dedicated to SST determination from MetOp AVHRR is currently underway, which will be based on physical-statistical method and forms a major part of this project. This will also ensure the continuation of SST products that have been archived for over 20 years at NESDIS and will be valuable for climatological studies in the future.

Objective: Optimal SST processor for MetOp-A and extend them to other AVHRR like processors.

Plans:
-- Extensive radiative transfer modeling to analyze the information content and usefulness of the available channels. The tools have to fully automated to make global simulations possible within limited time in order to be able to use analysis/forecast data, e.g. from ECMWF, NCEP. Useful radiative transfer models: MODTRAN, CRTM

--Develop highly automated robust statistical tools for operational *Quality Control / Quality Assurance*. The tools will be employed using scripts to routinely produce statistical outputs and plots and post them at a central location (operational division) in order to enable the monitoring of algorithm and sensor performance. Also, comparison is made with climate data (e.g., BAUER-ROBINSON climatology or PATHFINDER data to check for consistency of the satellite products.)

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[1] Land Surface Temperature and emissivity estimation from passive sensor data: theory and practice; current trends. Dash, P., F.-M. Göttsche, F.-S. Olesen, and H. Fischer International Journal of Remote Sensing,Vol. 23, No. 13, 2563-2594, 2002.

--Analyze archived products from currently operational MUT system for long time-series (e.g., a few years) to check their performance and investigate possible improvements (using the tools from above).[*if desired or necessity is identified, plan to reprocess the data for improved products*]

--Work on the heritage of MUT, CLAVR-x, APOLLO etc. to use the available wisdom by peers who developed these techniques a few decades earlier, keeping in mind the opportunity to make them faster, more reliable and robust. Also, the final products will have larger spatial resolution than MUT which can be interpolated later on to desired low-resolution products.

--Investigate Bulk-to-Skin conversion problem [long-term or the task to be shared]

--Investigate emissivity variation with angle, wind-speed [long-term or the task to be shared]

--Publish the results in the community and be open to newer ideas/suggestions from experts around the world.

2. Research Accomplishments/Highlights:

Progress in Radiative Transfer Modeling :
Prior to the operational phase of the MetOp-A SST processor, which currently is in the developmental stage, it is required to perform an information content analysis of the channels. Also, RT Modeling is necessary to investigate the best form of SWT with large amounts of simulated data. Another additional improvement would be (subject to investigation) determination of SWT coefficients based on RTM for global long-term atmospheric data (ECMWF, NCEP fields etc.) in addition to bulk temperatures derived from buoys.

MODTRAN 4.2 was installed successfully. After thorough checking with different compilers for optimized performance and highest obtainable accuracy, it was installed to work with double precision accuracy. Part of the 'drivers' in the original MODTRAN code were modified to provide tailored output for RTM suitable for satellite sensors. Wrapper code was designed to work effectively with not-so-user-friendly MODTRAN code. The wrapper code takes into account the need for simulation conditions (scan angle variation, temperature variation etc) and creates Tape5 MODTRAN input, invokes the MODTRAN, and collects the Tape6 output.

Subsequent programs take into account to convolve the Tape6 data for specific sensor response functions. Around 4000 simulations were performed for each of the cases for 6 model atmospheres, and varying zenith angles and surface temperatures:

- MetOp-2 bands 3B, 4, 5 channels
- quasi monochromatic MetOp 3B, 4, 5 channels
- quasi monochromatic Aqua-MODIS 20, 22, 23, 31, 32 channels
- quasi monochromatic GOES-R 9, 8, 7, 3 channels

Figure 1 shows an example simulation of temperature deficit in MetOp-A channels 3B, 4, and 5 for different MODEL atmospheres in nadir-only data acquisition.

Figure 2 shows an example simulation of temperature deficit in MetOp-A channels 3B, 4, and 5 for different zenith angles and one given atmosphere (Mid-Latitude Summer).

All the codes are developed in FORTRAN and compiled with INTEL FORTRAN compiler. The programs are employed through CONTROLS FILES and COMMAND LINE INTERPRETERS to make the processing easier for large amounts of data. The package is also fully capable of simulating the NOAA series of AVHRR sensors (NOAA-09 till NOAA18), MetOp-2, MetOp-1, and quasi monochromatic channels of Aqua MODIS, GOES-R. Utility tools are also fully completed to accommodate any satellite to the package as soon as the response functions are available. Part of these utility rarely-used standalone tools are in IDL code unlike the main S/W package which is in FORTRAN. UNIX scripts are also being developed to fully automate the already semi-automatic set-up. Once the scripts are fully developed, it will be convenient to perform simulations for global datasets.

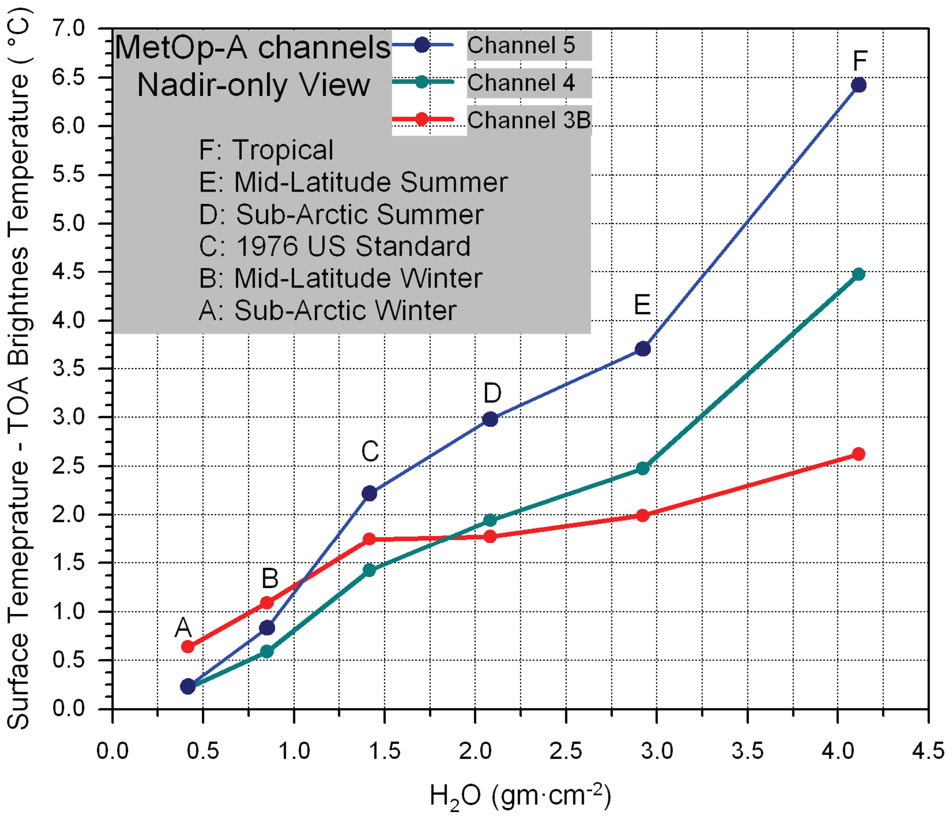


Figure 1: T-deficit (Surface Temperature – TOA brightness temperatures) in MetOp-A top-of-atmosphere measurements vs. water content. Simulations performed with MODTRAN 4.2 at 1cm^{-1} spectral resolution.

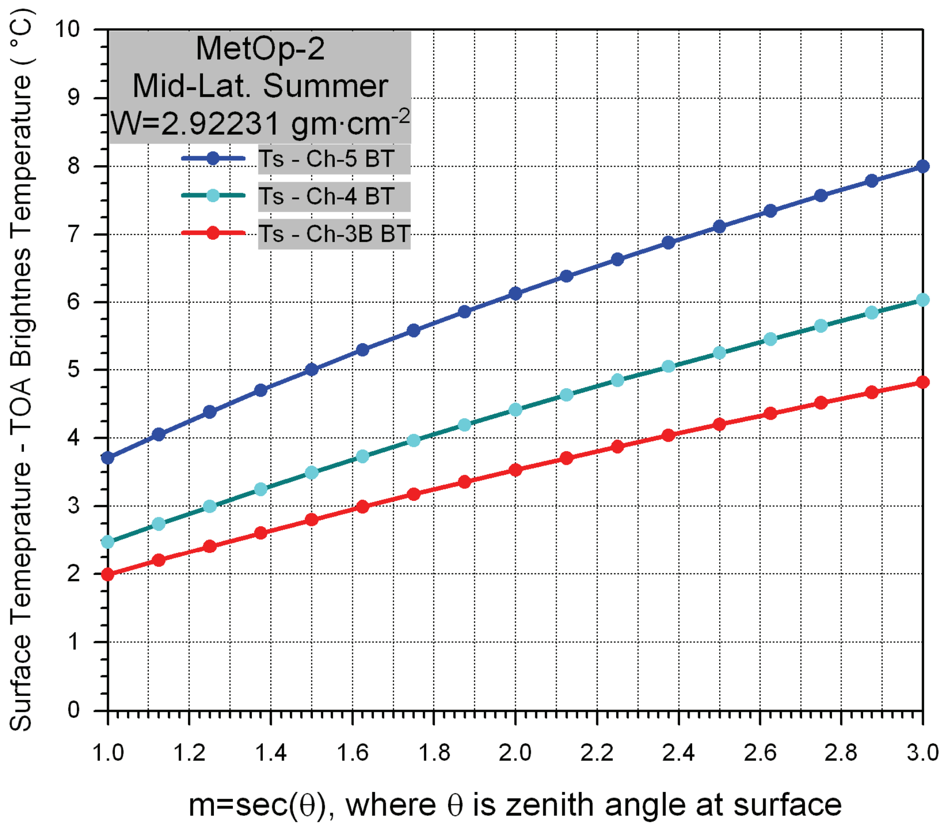
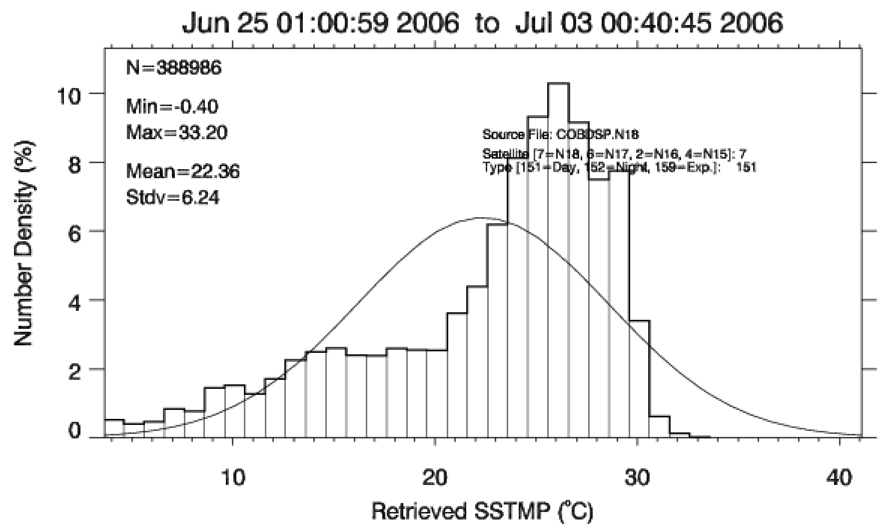
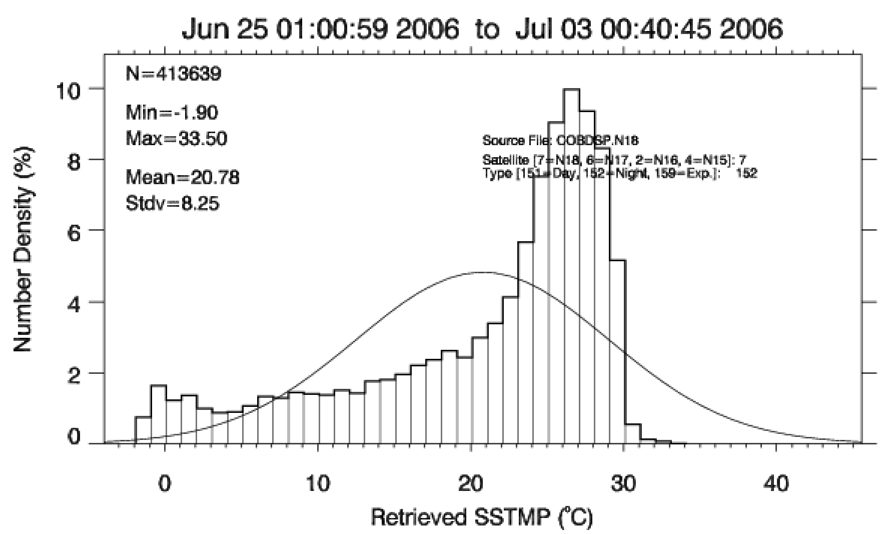


Figure 2: temperature deficit in MetOp-A channels 3B, 4, and 5 for 17 different zenith angles (corresponding to θ, where θ is zenith angle at surface) and one atmosphere (Mid-Latitude Summer).

Progress in statistical analysis based QC/QA tools:
Robust, Flexible, and semi-automated IDL tools were developed for this purpose. The tools will check for intra-consistency of the Global SST products and can also inter-compare products from different processors/platforms/origin. The tool automatically generates statistics and outputs as ASCII text to a designated file. Also variation of anomaly (w.r.t. climate data) is stored for time-series analysis and will allow checking the temporal trend once the processing is complete. Development of code for offline processing is complete, and it is also used through a CONTROL FILE system. Ways to automate them using scripts is being investigated. In the coming months, it is expected to have the processing of archived SST products for at least a year using this tool. Figures 3 (a, b) show the global distribution of the MUT generated SST products [3a: Daytime, 3b: Night-time]. The statistics and plots are generated using the newly developed IDL tool and is planned to make it operational for routine checking of SST products.



(a)

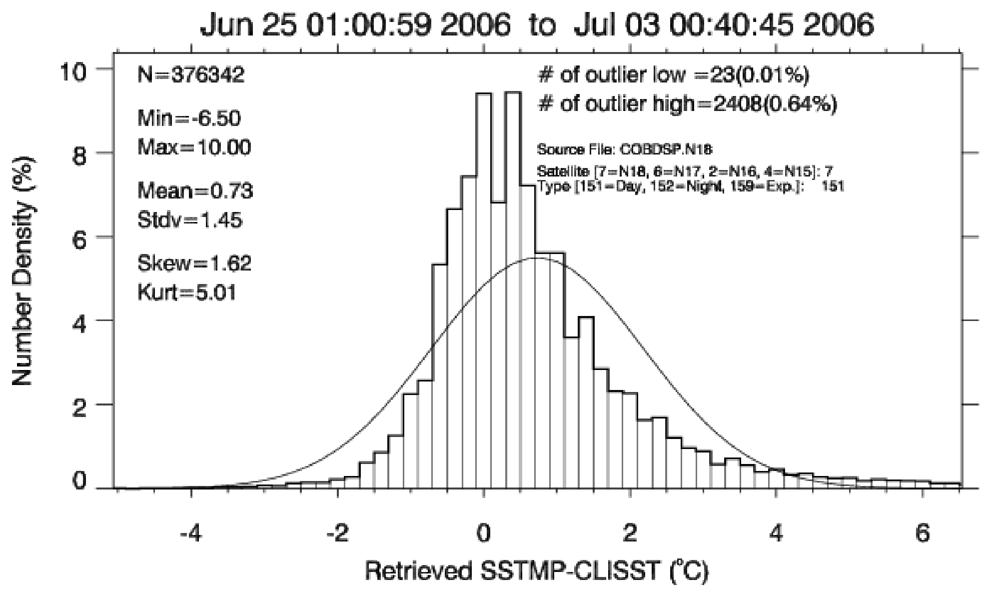


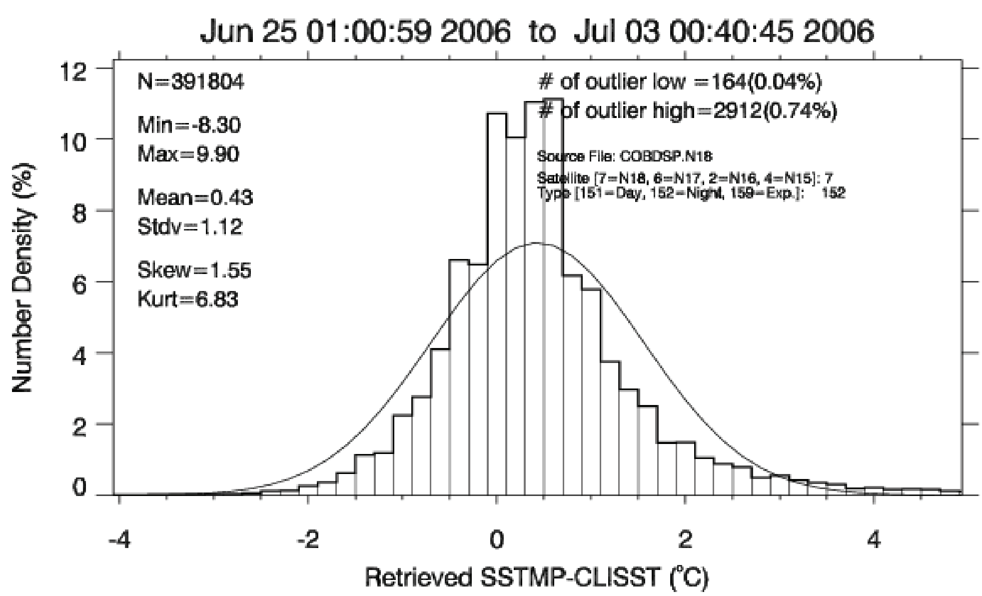
(b)

Figure 3: Global distribution of MUT SST products. Satellite: NOAA 18. (a) daytime, (b) Night-time

Figures 4 (a) and (b) show the global distribution of anomaly (w.r.t. Bauer-Robinson climatological SST) of MUT generated SST products [4a: Daytime, 4b: Night-time]. The statistics and plots are generated using the newly developed IDL tool and plans are to make it operational for routine checking of SST products. The tool will be operationally implemented for the MetOp-A once in orbit.

(a)





(b)
Figure 4: Global distribution of SST anomaly (MUT SST product – Bauer-Robinson SST). Satellite: NOAA 18. (a) daytime, (b)Night-time. Ideal Gaussian PDF constructed using the actual Mean and Standard Deviation is annotated over the actual distribution.

3. Comparison of Objectives vs. Actual Accomplishments:

RTM:

Completed for basic atmospheric analysis using MODTRAN
Needs extension to global atmospheric fields (in progress)
Investigate other RTMs, e.g., OPTRAN (yet to be started)

Quality Control / Quality Assurance Tools

Completed for stand-alone applications
Needs some more programming for operational real-time processors.

Analyze products from current MUT system for time-series (e.g., 1 year)

In progress …
Archived data is being obtained slowly from archives- Administrative issues need to be solved (point of contact, ftp-server etc.)

Work on the heritage of MUT, CLAVR-x

In progress …

Investigate Bulk-to-Skin conversion problem [long-term or to be shared]

yet to be started or decide upon who/how to start

Emissivity variation with angle, wind-speed [long-term/to be shared]

yet to be started or decide upon who/how to start

Publish the results in the community

In progress …

4. Leveraging/Payoff:

To understand the global temperature patterns, predict changes in the pattern and quantify its effects and conserve and manage marine resources by providing proper input to global and local models

5. Research Linkages:

Collaborations: CIRA; Partnership: None; Linkages, Communication, Networking: EUMETSAT

6. Awards/Honors: Not during the reporting period

7. Outreach: Not during the reporting period

8. Publications:

Conference/Symposium
Ignatov, A., P. Dash, and YI Kihai, 2006: Model analyses towards a robust and accurate physical-statistical SST algorithm for use with current and future infrared sensors. 3rd Symposium on NPOESS, AMS 2007 (submitted).

Journal
Dash, P., et al. Analysis of information content in window channels based on radiative transfer for model atmospheres: a step towards SWT based MetOp-A SST processor, Dash et al., [*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
Office of Research & Applications, NOAA/NESDIS
USGS National Center for EROS

NOAA Project Goal: Climate – climate observations and analysis

Key Words: Land Use/Land Cover Change, Temperature, Urbanization, Deforestation, NDVI, Land Cover Trends Project

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 over a multi-decadal time period. The Land Cover Trends Project at the USGS National Center for EROS is currently analyzing land use/land cover 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 land use/land cover change and trends in local or regional climate are being studied. Comparisons will also be made with satellite-derived Normalized Difference Vegetation Index (NDVI) data from the locations of the Normals stations to determine relationships between NDVI and the observed temperature trends and land use/land cover change.

2. Research Accomplishments/Highlights:

To date, the Land Cover Trends Project has completed analysis on 31 of 84 ecoregions, encompassing 829 sample blocks. These 829 sample blocks 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 land cover/land use change type, amount, and time period of change have been determined for each of these 526 stations.

Examination of trends in minimum, maximum, and average temperature at those Normals stations with buffer zones intersecting Trends sample blocks in 23 ecoregions has been completed. Results of these statistical analyses were presented at the 16th William T. Pecora Memorial Symposium and the annual meeting of the Association of American Geographers. Further, potential associations between the observed temperature trends and nearby changes in land use/land cover in these 23 ecoregions were 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 results were recently published in *Geophysical Research Letters*.

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 23 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 ecoregions newly completed by the Land Cover Trends Project – In progress

--Exploration of methods for separating land use/land cover 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:

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 at this time

7. Outreach: None at this time

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 (2006), Documentation of bias associated with surface temperature measurement sites for climate change assessment, submitted to *Bulletin of the American Meteorological Society*.

<u>Tong Zhu – NESDIS Post Doc</u>

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, Hurricane Modeling.

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

For the development of operationally-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:

We performed an impact study of AMSU and AMSR-E Measurements on Hurricane Prediction. The assimilation of AMSU cloudy radiances produces large positive impacts on hurricane upper warm core structures and therefore upper level divergence. The assimilation of AMSR-E cloudy radiances can improve lower level wind circulation. The analyzed mass and wind fields show reasonably asymmetric structures.

We developed and delivered some GOES-R proxy data to the GOES-R Algorithm Working Group (AWG) users. We designed an Observation System Simulation Experiments (OSSE) framework to assess the impact of GOES-R measurements on hurricane prediction.

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

The project is going well. We are now3 developing a GOES-R proxy data system. We are going to develop the GOES-R ABI proxy data using SEVIRI and MODIS. We will coordinate with other teams to archive all matched data and develop a tool to display MODIS retrieved aerosol optical depth and aeronet data.

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.

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.

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, A. Huang, D. Zhou, M. Sengupta, B. Ruston, M. Goldberg, and J. Yoe 2006: GOES-R Proxy Data Management System. Fourth GOES Users' Conference, Broomfield, CO, May 1-3, 2006.

Zhu, T. and F. Weng, 2006: Impact of AMSU and AMSR-E Measurements on Hurricane Prediction. AMS 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, April 23-28, 2006.

Zhu, T. and F. Weng, 2006: GOES-R Observation System Simulation Experiment Framework, Fourth GOES Users' Conference, Broomfield, CO, May 1-3, 2006.

NPOESS APPLICATIONS TO TROPICAL CYCLONE ANALYSIS AND FORECASTING

Principal Investigator: J.A. Knaff

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:

Proxy VIIRS tropical cyclone datasets are being collected from MODIS and AVHRR data. Figure 1 shows an example of infrared data from MODIS from Hurricane Wilma (2005) near the time of its maximum intensity. The MODIS imagery has a resolution comparable to what will be available from VIIRS, and is being used to develop new methods for estimating tropical cyclone intensity, and to determine the impact of the resolution on storm structure analysis.

Combined AIRS/AMSU data from the NASA AQUA mission are being used as a proxy for ATMS/CrIS data. A dataset of AIRS/AMSU temperature soundings from hurricane eyes is being collected to develop a new method for hurricane intensity monitoring. So far, six soundings have been obtained, and a prototype algorithm has been developed. The method uses a downward integration of the hydrostatic equation to estimate the minimum surface pressure, which is a measure of the storm intensity. Figure 2 shows the minimum pressure from Hurricanes Isabel and Lili in comparison with ground truth estimates from aircraft. Results show that the method worked extremely well for Isabel, which was a large storm, but was inadequate for Lili, which was a smaller storm. This should be less of a problem for the NPOESS data from ATMS/CrIS, since the resolution will be improved. A much larger dataset is being collected to obtain more reliable statitics.

Numerical model simulations of Hurricane Lili (2002) and Wilma (2005) are being performed to further investigate the improvements that the increased resolution of ATMS/CrIS will provide.

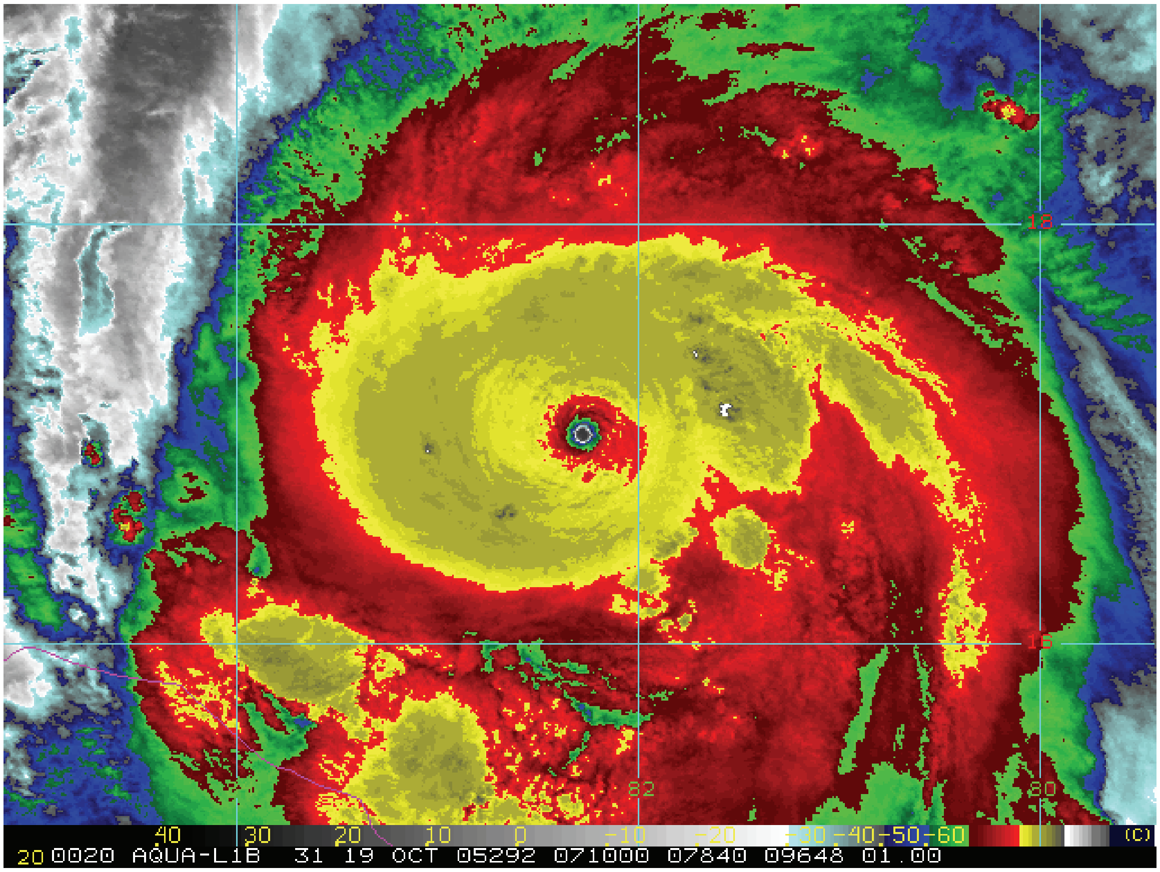


Figure 1. MODIS IR (window channel) image of Hurricane Wilma on 19 October 2005 at 0710 UTC. Wilma was a category 5 hurricane at this time.

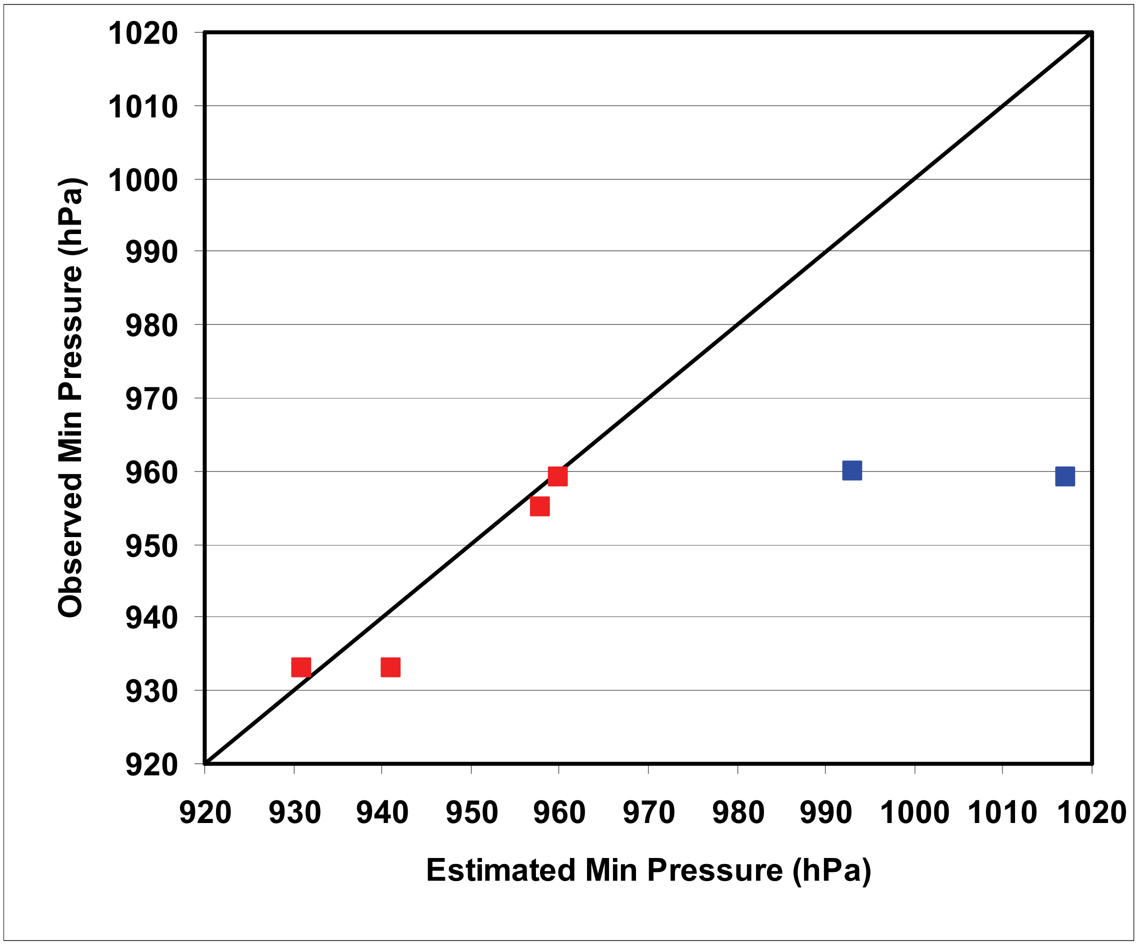


Figure 2. The minimum central pressure estimated from AIRS/AMSU soundings versus the observed minimum central pressure for Hurricanes Isabel (red) and Lili (blue).

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

The funding for this project arrived at CIRA in the second half of the CSU fiscal year. Despite this lag, many results have already been obtained. The primary objectives of the first part of year 1 have been accomplished.

4. Leveraging/Payoff:

What NPOESS will recieve for resources invested is:
--Advanced product development
--Extended operational use of the satellite
--Greater utilization of NPOESS data for tropical cyclone analysis

5. Research Linkages/Partnerships/Collaborators, Communication 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

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) Robert DeMaria, an undergraduate student in the CSU Computer Science Department was partially supported by this project.
(b) See section 8
(c) None
(d) A high school student is being supported as part of this project
(e) A web site is under development to illustrate the utlility of NPOESS with proxy data

8. Publications:

Conference Proceedings

DeMaria, M., D.W. Hillger, C. Barnet, R.T. DeMaria, 2006: Tropical Cyclone Applications of Next-Generation Operational Satellite Soundings. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Grasso, L.D., M. Sengupta, J.F. Dostalek, and M. DeMaria, 2005: Synthetic GOES-R and NPOESS imagery of mesoscale weather events. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Grasso, L.D., M. Sengupta, J.F. Dostalek, and M. DeMaria, 2006: Synthetic GOES-R and NPP imagery of mesoscale weather events. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

Hillger, D.W., 2006: GOES-R Product Development Risk Reduction Activities. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Presentations

Grasso,L., October 19, 2005: Synthetic GOES-R and NPOESS imagery. *Desert Research Institute (DRI) Seminar* in Reno, NV.

DeMaria, M., May 2006: NPOESS Applications to Tropical Cyclone Analysis and Forecasting, NPOESS Workshop at COMET, Boulder, CO

ORA IT INFRASTRUCTURE OF THE FUTURE

Principal Investigator: A Jones

NOAA Project Goal: Supporting NOAA's Mission
Related Programs: Satellite Services, Information Technology Services

Key Words:

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

This is a collaborative multi-institutional study panel review of NESDIS/ORA IT infrastructure (ORA lead: Ms. Susan Callis). The study panel provides guidance and makes recommendations to optimize and improve ORA's effectiveness as it relates to satellite data processing and technical research capabilities. Due to the institutional synergies, the impact of future satellite program components (NPOESS, GOES-R, and NPOESS Data Exploitation) and collaboration technologies are critical to the research-to-operations transfer path and are vital to future CIRA collaborative research activities with NOAA. Activities of the Study Group are detailed in the ORA document entitled "ORA IT Infrastructure of the Future Study Group, Proposal for Study Group" (March 15, 2005). This work represents the participation of Drs. A. S. Jones and S. Q. Kidder within the review study panel. The work was funded by NESDIS/ORA.

Approach:

Drs. Jones and Kidder are members of the ORA IT Infrastructure Study Group. Participation in the study panel activities includes an on-site visit to ORA, and detailed report generation following the visit. The on-site review was held in mid-May 2005, the report was completed in late summer of 2005.

2. Research Accomplishments / Highlights:

Final report containing review conclusions and recommendations was completed (Callis, et al., 2005).

Conclusions and Recommendations:

A comprehensive list of panel recommendations have been submitted to ORA senior management (Callis et al., 2005). ORA management is in the process of implementing those recommendations to streamline and reorient their IT services, science project management activities, and restructure their current IT business practices. Several new initiatives were identified for significant improvements in the future manageability of the ORA IT Infrastructure.

Future Work and Plans:

Future efforts will be to assist ORA in the implementation of components of the future IT infrastructure as it pertains to the CIRA mission. This could include joint software framework initiatives, and other topics as determined by ORA in collaboration with CIRA. This work is in the early formative stages at this time.

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

All objectives were completed on schedule.

4. Leveraging/Payoff:

This work is critical to several large satellite programs including NPOESS, GOES-R, and the NPOESS Data Exploitation (NDE) program. The study group expects the streamlining of the ORA IT infrastructure to generate substantial new research capabilities by reducing duplication of efforts and leveraging joint research assets through a more coordinated and targeted management approach.

5. Research Linkages/Partnerships/Collaborators:

This work includes participation by CIRA, Cooperative Institute for Meteorological Satellite Studies (CIMSS, Univ. of Wisconsin), Scripps Institute of Oceanography (Univ. of CA, San Diego), and private contractors from SP Systems Inc., QSS Group Inc., and ERT, Inc.

6. Awards/Honors:

7. Outreach:

8. Publications This Year:

Technical Report:

Callis, S., J. Brust, P. Chang, J. Daniels, A. S. Jones, S. Q. Kidder, D. Molenar, T. Schreiner,J. Simpson, R. Sinha, W. Wolf, 2005, J. Huie, and C. A. Meetre: ORA IT Infrastructure of the Future, 114 pp.

PILOT PROGRAM TO IMPROVE SATELLITE SYSTEM UTILIZATION THROUGH EDUCATION, TRAINING AND OUTREACH

Principal Investigator: T. Vonder Haar/J. Purdom

NOAA Project Goal: Weather and Climate

Key Words: Satellite Systems, Data Utilization, Education, Training

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

In realizing its goals, the Institute emphasizes research, graduate education, and mentoring newly graduated professionals in science areas related to NOAA's mission. The Institute has three major objectives:

a) To enhance the effectiveness of research and graduate-level teaching efforts through close collaboration between CSU and NOAA.

b) To serve as a focal point for research in the atmosphere and specified programs by scientists from Colorado, the nation and the world, and

c) To train personnel for research in the atmospheric sciences and to accumulate experience with multifaceted research programs.

In recent years, our collaborative research has involved NOAA's OAR Research Laboratories, OGP, the NESDIS Office of Research Applications, and the National Weather Service.

Consistent with the original NOAA/CSU Memorandum of Understanding (MOU) this support for administrative and clerical personnel for general operations is related to activities associated with the Director's Office and management of CIRA. In addition to this management support, provision is made for Post Doctoral Fellows and Graduate Research Assistants who collaborate with CIRA and NOAA personnel on new and exciting research activities.

In accord with the MOU and based upon periodic review by NOAA and the CIRA Advisory Board, the research collaborations are focused upon seven (7) theme areas:

a. Global and Regional Climate Studies
b. Local and Mesoscale Area Weather Forecasting and Evaluation
c. Cloud Physics
d. Applications of Satellite Observations
e. Air Quality and Visibility
f. Societal and Economic Impacts
g. Numerical Modeling
h. Education, Training, and Outreach

Specific research projects under the theme areas are each proposed and staffed to meet specific objectives. Research teams of faculty, students, and staff work with NOAA program leaders and scientists to accomplish the objectives.

2. Research Accomplishments: Research supported by equipment

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

Objective obtained.

PROCESSING OF ORGANIC AEROSOLS BY HETEROGENEOUS AND MULTIPHASE PROCESSES

Principal Investigator: Barbara Ervens and Sonia M. Kreidenweis

NOAA Project Goal: Climate. *Programs*: Climate Observations and Analysis; Climate Forcing; Climate Predictions and Projections.

Key Words: Aerosols; carbonaceous aerosols; direct aerosol climate effects; indirect aerosol climate effects; secondary organic aerosol (SOA); tropospheric chemistry

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

Uncertainties in estimating the climate effects of aerosols arise due to the complexity of aerosol properties and the diversity in their chemical and physical source and sink processes. Most importantly, particulate organic carbon has been shown to be an important component of the global aerosol system, and yet the sources and mechanisms for its formation in the troposphere by chemical and physical processes remain largely unknown. Our long-term objective is to contribute toward improvements in the representation of organic aerosols in chemical and climate models, including their role in aerosol indirect forcing. We plan to accomplish this through a combination of literature data evaluation and parameterization, development of new models for proposed chemical processes that are shown to be important to capture, and modeling of the interactions between organic aerosols and clouds. Evaluation of the relative importance of various proposed processes is an important component of our work at each step.

Specific plans include the following. Through support from this project, we have now compiled a new data set based on literature studies that takes into account physical and chemical processes leading to formation of secondary organic aerosols (SOA). Application of this comprehensive data set to global models, and evaluation through comparison with observations of what processes may still be missing or misrepresented, are expected to lead to a better understanding of sources of organic aerosol mass in the troposphere. This database will continue to be updated as new results are reported.

In addition, we perform model studies in order to explain measured number concentrations of cloud condensation nuclei (CCN) and to identify aerosol properties that are most crucial in order to obtain CCN closure. This work contributes to elucidation of the role of organic aerosols in aerosol-cloud interactions by evaluating the relative importance of composition in affecting CCN and cloud properties. Similar studies will continue through the project period as new observations are reported and are reconciled with current understanding through modeling.

2. Research Accomplishments/Highlights:

During Year 1, we focused on the description of SOA formation by chemical processes. We performed an extensive evaluation of studies that have appeared in the literature and compiled a consistent set of data for potential SOA precursors, namely biogenic compounds and aliphatic carbonyl compounds. The parameterized formation rate expressions can be easily implemented into other models and allow an estimate of the extent to which chemical reactions – in addition to physical processes – can contribute to SOA formation and might explain (part of) the gap between modeled and measured SOA mass in the fine fraction of tropospheric aerosol particles. This compilation and some first estimates for typical atmospheric conditions are being summarized in a publication (Ervens and Kreidenweis, 2006).

The second focus of our work is the continuation of CCN closure studies that were started in the previous year. Using observations of CCN and aerosol composition that were acquired during ICARTT 2004, we conclude that properties of aerosol populations (number concentrations, size distributions) and accuracy of the CCN instruments (critical supersaturation measurements) are most crucial for CCN closure, whereas detailed knowledge of the aerosol composition plays only a minor role. At other locations where the particles have a different mixing state due to different histories, this conclusion might change, as suggested by first analyses of aerosol / CCN data from the SOAR campaign (Riverside, CA).

In addition, we were involved in the application of the chemical mechanism we developed in 2004 (Ervens et al., 2004) that addresses organic aerosol (oxalate) formation in clouds. Particulate oxalate mass concentrations that were measured during ICARTT 2004 could be explained for different scenarios with our combined chemistry / microphysics cloud model. We performed some additional model calculations with new mechanistic data for oxalate formation from laboratory studies which have become available during the last year. However, it seems that our original mechanism is robust for most scenarios and the changes in oxalate formation due to the newly suggested reaction pathways are usually small. This work will be reported in the July 2006 Ph.D. dissertation of Dr. Ann Marie Carlton of Rutgers University, and in a manuscript submitted by A. Sooroshian et al. of Caltech, who have collaborated with us on these aspects of the model evaluation and application.

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

We have completed all project objectives, including publications. Specifically, our Year 1 objectives were:

--Compilation of an experimental database for SOA formation from isoprene, α--pinene and aldehydes.

--Initial evaluation of role of above reactions in global SOA production.

--Participation in ICARTT data analyses, specifically aerosol-CCN closure.

--Preparation of at least two manuscripts (one on SOA data base, one on aerosol-CCN closure).

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 aerosols. Our work will also help elucidate the relative roles of biogenic and anthropogenic secondary organic aerosol precursors, which have implications for regulatory policies, visibility, and health impacts.

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

We are collaborating with Dr. Graham Feingold, NOAA/ESRL, on this project. Dr. J. Ogren and Dr. E. Andrews (NOAA/ESRL), Dr. J. Jimenez and Dr. M. Cubison (University of Colorado) provided the data sets for CCN closure acquired at the Chebogue Point ground station in Nova Scotia, Canada (International Consortium for Atmospheric Research on Transport and Transformation; ICARTT, 2004) and at Riverside, California, during the SOAR (Study of Organic Aerosol in Riverside, 2005).

Further discussion and tests of the oxalate reaction mechanism have been conducted in collaboration with Barbara Turpin and Ann Marie Carlton (Rutgers University). The application of the oxalate model has been performed by collaborators Armin Sorooshian and John Seinfeld (Caltech).

We have also contributed to NOAA programs by participating in science team meetings and in the analysis of data from community-supported field studies, namely ICARTT 2004.

6. Awards/Honors: None as yet

7. Outreach:

(a) None as yet

(b) Ervens has served on the Ph.D. committee of Dr. Ann Marie Carlton (Rutgers University, NJ, July 2006).

We have reported results from our work at the following conferences and workshops during 2005 / 2006 (titles and authors listed below in Section 8):

AGU Fall Meeting, San Francisco, USA, 2005

AAAR Annual Conference, Austin, USA, 2005

INTROP/EUROCHAMP/ACCENT Joint Workshop: *"The routes for organics oxidation in the atmosphere and its implications to the atmosphere"*, Alpe d'Huez, France, 2006.

ICARTT 2005 Data Analysis Workshop, University of New Hampshire, 2005

8. Publications:

Refereed Journal Articles

Ervens, B., and S. M. Kreidenweis, Chemical SOA formation: Data evaluation and application, *Environmental Science and Technolog*y, to be submitted.

Ervens, B., M. Cubison, E. Andrews, G. Feingold, J. Ogren, J. Jimenez, and A. Nenes, Prediction of CCN number concentration using Measurements of Aerosol Size Distributions and Composition and Light Scattering Enhancement due to Humidity, *Journal of Geophysical Research, submitted March 2006*.

Sorooshian, A., F. J. Brechtel, B. Ervens, G. Feingold, V. Varutbangkul, R. Bahreini, S. Murphy, J. S. Holloway, E. L. Atlas, K. Anlauf, G. Buzorius, H. Jonsson, R. C. Flagan, and John H. Seinfeld, Oxalic acid in clear and cloudy atmospheres: Analysis of data from ICARTT 2004, *Journal of Geophysical Research*, *submitted,* 2005.

Ervens, B., G. Feingold, and S. M. Kreidenweis, The influence of water soluble organic carbon on cloud drop number concentration*, J. Geophys. Res.*, 110, D18, D18211, doi: 10.1029/2004 JD005634, 2005.

Koehler, K. A., S. M. Kreidenweis, P. J. DeMott, A. J. Prenni, C. Carrico, B. Ervens, and G. Feingold, Cloud condensation activity of atmospheric aerosols. Part II: Application to organic species, *Atmos. Chem. Phys.*, 6, 785-809, 2006.

Conference Proceedings

Cubison, M., B. Ervens, E. Andrews, P. DeCarlo, G. Feingold, J. Ogren, and J. Jimenez, Aerosol-CCN measurements at Chebogue Point during ICARTT 2004, ICARTT 2005 Data Analysis Workshop, University of New Hampshire, 2005.

Ervens, B., G. J. Frost, G. Feingold, and S. M. Kreidenweis, Organic aerosol formation in clouds: Production of oxalate, INTROP/EUROCHAMP/ACCENT Joint Workshop: *"The routes for organics oxidation in the atmosphere and its implications to the atmosphere"*, Alpe d'Huez, France, 2006.

Ervens, B., M. Cubison, E. Andrews, P. DeCarlo, T. Jobson, A. Laskin, G. Feingold, J. Jimenez, and J. Ogren, A closure study of aerosol-CCN measurements from recent field campaigns, AGU Fall Meeting, San Francisco, USA, 2005.

Ervens, B., G. Feingold, and S. M. Kreidenweis, Contributions of acid-catalysed processes to secondary organic aerosol mass – A modelling approach, AGU Fall Meeting, San Francisco, USA, 2005.

Ervens, B., Cubison, M. Andrews, E., DeCarlo, P., Feingold, G., Ogren, J., and Jimenez, J., On the Relationship between *f(RH)* (and *g(RH)*) and Cloud Condensation Nuclei, AAAR Annual Conference, Austin, TX, 2005.

PROPOSAL ON EFFICIENT ALL-WEATHER (CLOUDY AND Clear) OBSERVATIONAL OPERATOR FOR SATELLITE RADIANCE DATA ASSIMILATION

Principal Investigator: Tomislava Vukicevic

NOAA Project Goal: Weather and Water: Weather Water Science Technology and Infusion

Key Words: Radiative Transfer, Data Assimilation

1. Research Objective:

The goal of this project is to develop capabilities within the Community Radiative Transfer Model (CRTM) for assimilation of satellite visible radiance in both clear and cloudy atmospheres. To achieve this capability a radiative transfer algorithm capable of dealing with multiple scattering in clouds along with its adjoint needed to be developed. The plan was to develop such an algorithm and deliver it to the Joint Center for Satellite Data Assimilation (JCSDA) for incorporation in the CRTM.

2. Research Accomplishments/Highlights:

A visible radiative transfer model and its adjoint has been 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.

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

The objective of this proposal has been met and the code has been transferred to the JCSDA. The relevant codes are also available at http://nit.colorado.edu/shdomppda/index.html

4. Leveraging/Payoff:

The capability 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 capability to improve cloud prediction. This model will help NOAA assimilate GOES visible radiances in weather forecasting models. It is expected that such a capability will allow NOAA to use a large amount of satellite radiance data for data assimilation thereby leading to significant improvement in cloud prediction.

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

This model was developed in partnership with Dr. Frank Evans of the University of Colorado whose expertise has been helpful in the JCSDA fulfilling its goals.

6. Awards/Honors:

7. Outreach:

8. Publications:

Vukicevic, T., 2006: “SHDOMPPDA: A radiative transfer tool for cloud sky data assimilation” . *Journal of Atmospheric Sciences* (accepted)

RADAR REMOTE SENSING PROCESSES

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: Surface and satellite measurements of Arctic environment

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

At present, the only continuous measurements of Arctic surface radiation, clouds, aerosols and chemistry sufficient for detailed evaluation of interactive climate change processes in the lower atmosphere (0-15 km) are made in Barrow, Alaska. The Barrow facilities include the National Weather Service (with records from the 1920s), the National Oceanic and Atmospheric Administration (NOAA) Baseline Observatory (in operation since 1972), and the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) site (in operation since 1998). It is the intention of the Atmospheric Observatory Element of the NOAA/SEARCH program to mirror the Barrow atmospheric measurements, first in northeastern Canada, and at some later date in central Siberia.

In the existing and proposed Observatories, detailed measurements of clouds are necessary because a number of studies indicate that clouds have a major influence on the surface radiation budget (Intrieri et al, 2002). This in turn will impact surface temperatures, ice ablation/melt rates, and the onset of the annual snow melt season. Therefore, some of the ideal components for Atmospheric Observatories include cloud radar (35 GHz), cloud lidar, and IR/MW radiometers from which detailed cloud properties can be deduced. To determine effects, comprehensive measurements of upward and downward broadband radiation and albedo are (Barrow) and will (Canada/Russia) be made that allow calculations of radiation budgets at the surface. Finally, aerosol measurements both at the surface (e.g. nephelometers and condensation particle counters) and through the depth of the atmosphere (lidar) will potentially allow separation of anthropogenic from natural forcing.

My specific work includes using in-situ and satellite temperatures, cloud fraction and cloud optical depth at locations of interest. In the case of temperature, these locations are Barrow Alaska, Alert and Eureka Canada, and Tiksi Russia. For the other work, observations at Barrow Alaska are used.

Since the satellite temperatures measure surface temperatures and the in-situ measurements are air temperatures, the main comparison is the temperature trend of each over the same site and time. We are also investigating the spatial variability of these variables.

2. Research Accomplishments/Highlights:

A one-year comparison is made of mean monthly values of cloud fraction and cloud optical depth over Barrow, Alaska (71° 19.378' North, 156° 36.934' West) between 35 GHz radar-based retrievals, the TOVS Pathfinder Path-P product, the AVHRR APP-X product, and a MODIS-based cloud retrieval product from the CERES-Team. The data sets represent largely disparate spatial and temporal scales; however, for this research effort, the focus is to provide a preliminary analysis of how the mean monthly values derived from these different data sets compare, and to determine how they can best be used separately, and in combination to provide reliable estimates of long-term trends of changing cloud properties (e.g., Wang and Key, 2002). The radar and satellite data sets described here incorporate Arctic specific modifications that account for cloud detection challenges specific to the Arctic environment.

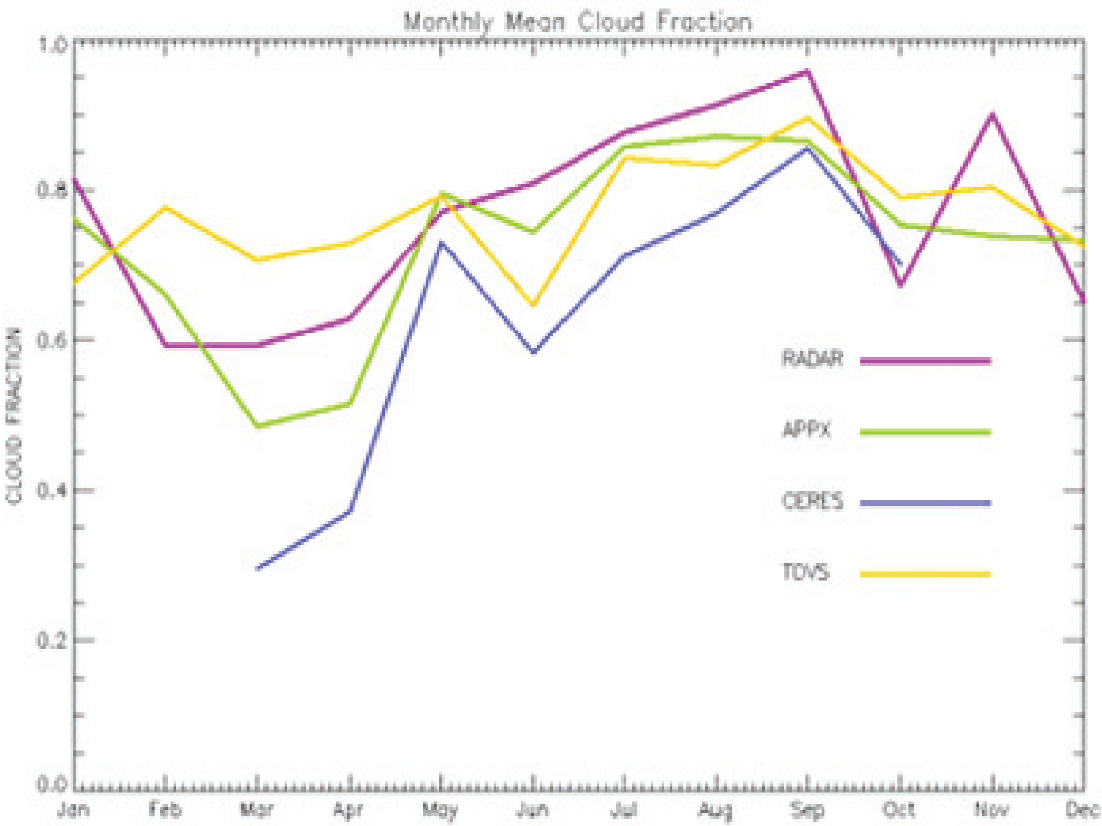


Fig. 1. Monthly Mean Cloud Fractions for Radar, APPX, CERES and TOVS

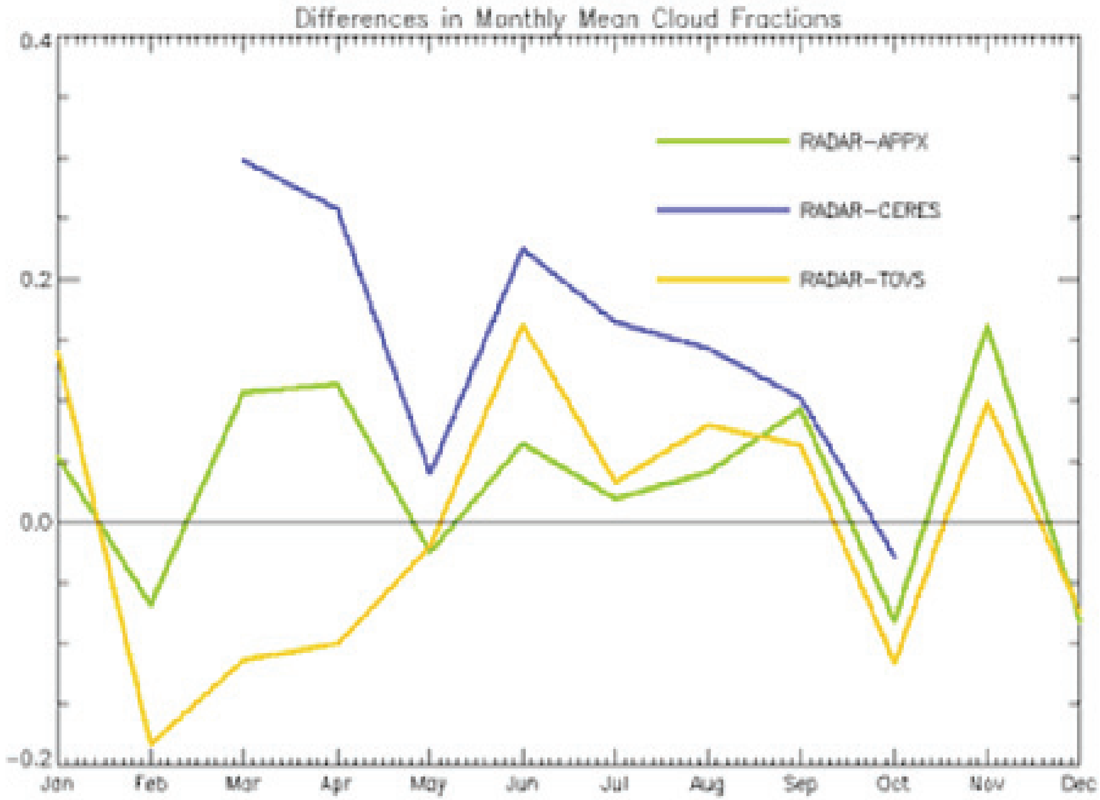


Fig. 2. Difference in monthly mean cloud fraction for Radar-APPX, Radar-CERES and Radar-TOVS. Positive values indicate that the satellite product has a lower estimate of cloud fraction and negative values indicate the satellite product has a higher estimate of cloud fraction.

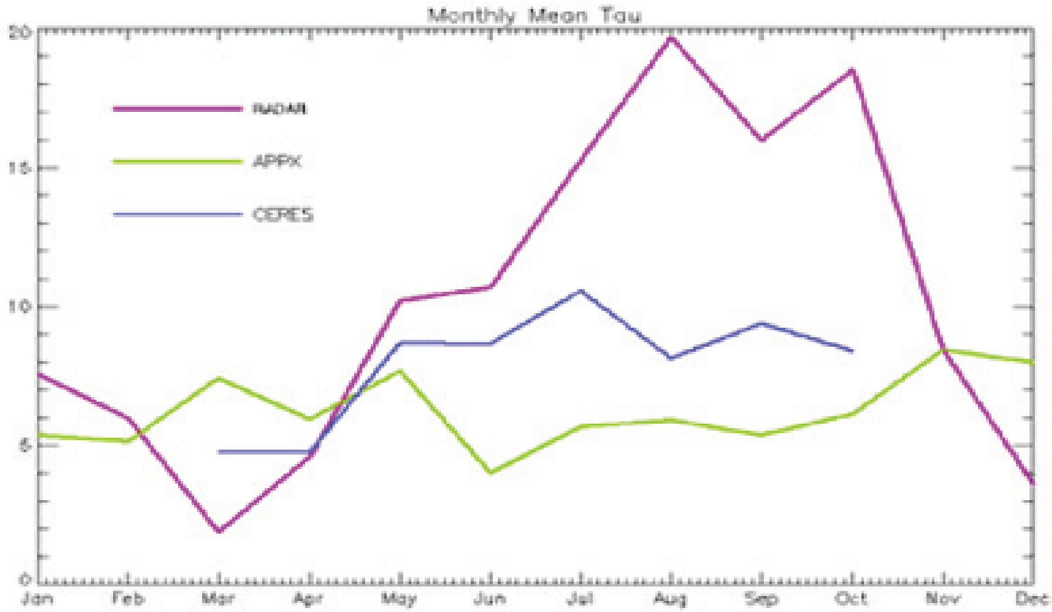


Fig. 3. Monthly Mean Cloud Optical Depth From Radar, APPX and CERES.

Another analysis which is in progress is to compare satellite surface temperature trends with the in-situ air temperature trends measured near the surface. We had data for 18 years for several sites. An example of this work is shown in the following figures.

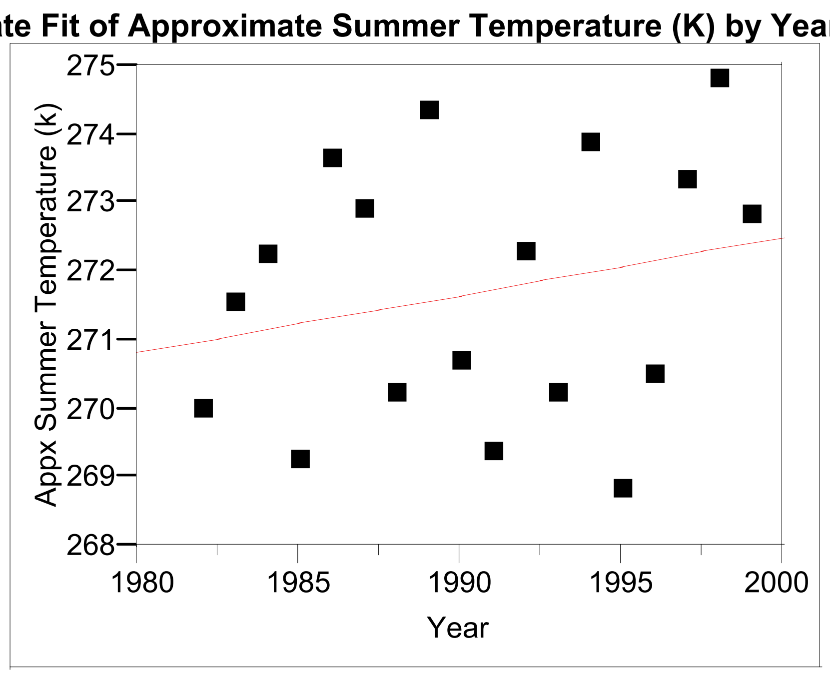
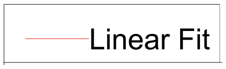


Fig. 4. Summertime Satellite Surface Temperatures for Eureka Canada.



Linear Fit

Approximate Summer Temperature (K) = 103.90139 + 0.0842962 Year

Summary of Fit

RSquare	0.056563
RSquare Adj	-0.0024
Root Mean Square Error	1.894465
Mean of Response	271.6929
Observations (or Sum Wgts)	18

Here, our linear fit shows a warming of about 0.8 degrees K per decade. However, the rsquared value is so poor, one should not say it is warming at this site during the summer. There is too much year to year variability to get a good measure of a trend.

Bivariate Fit of Eureka Summer Temperature(K) by Year

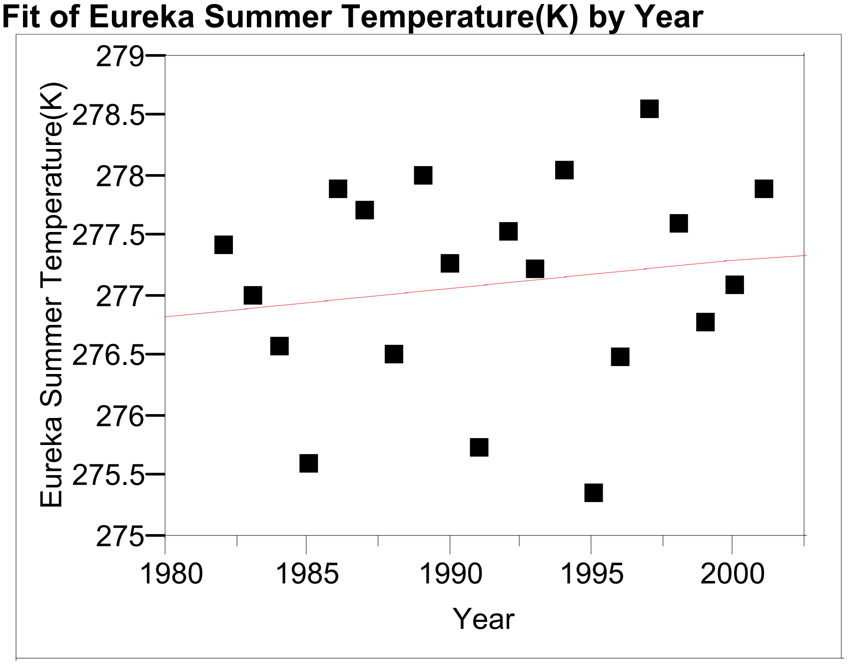


Fig. 5. In-situ Summertime Air Temperature.

We can compare the same time interval for the in-situ air temperatures to the satellite surface temperatures and compute a trend. As with the satellite, there is too much variation in this time interval to compute a trend.

Linear Fit

Linear Fit
Eureka Summer Temperature (K) = 231.84559 + 0.0227256 Year

Summary of Fit

RSquare	0.024078
RSquare Adj	-0.03014
Root Mean Square Error	0.879392
Mean of Response	277.1035

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

In progress; this is a multi-year program.

4. Leveraging/Payoff:

Results from this effort will help us understand the long-term impact of climate change on the Arctic.

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

NASA and DOE

6. Awards/Honors: None as yet

7. Outreach:

8. Publications and Presentations:

University of Toronto CANDAC Science Meeting, 18-20 April 2006

NASA Cloud Climatology Meeting, 5-7 April 2006

NASA CERES Science Team Meeting, 3-5 May 2006

NOAA Arctic Science Meeting

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:

a) Produce a library of influence functions based on mesoscale high-frequency RUC analyses
b) Evaluate the RUC-based influence functions
c) Store and disseminate the output to other researchers for use in carbon cycle inversions.

We will achieve the first objective by adapting the CSU Lagrangian Particle Dispersion Model (LPDM) to read meteorological fields from the RUC analyses. We will run the model backward in time from each continuous CO_2 observing tower site in the US 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 the second objective 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 data sets 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.

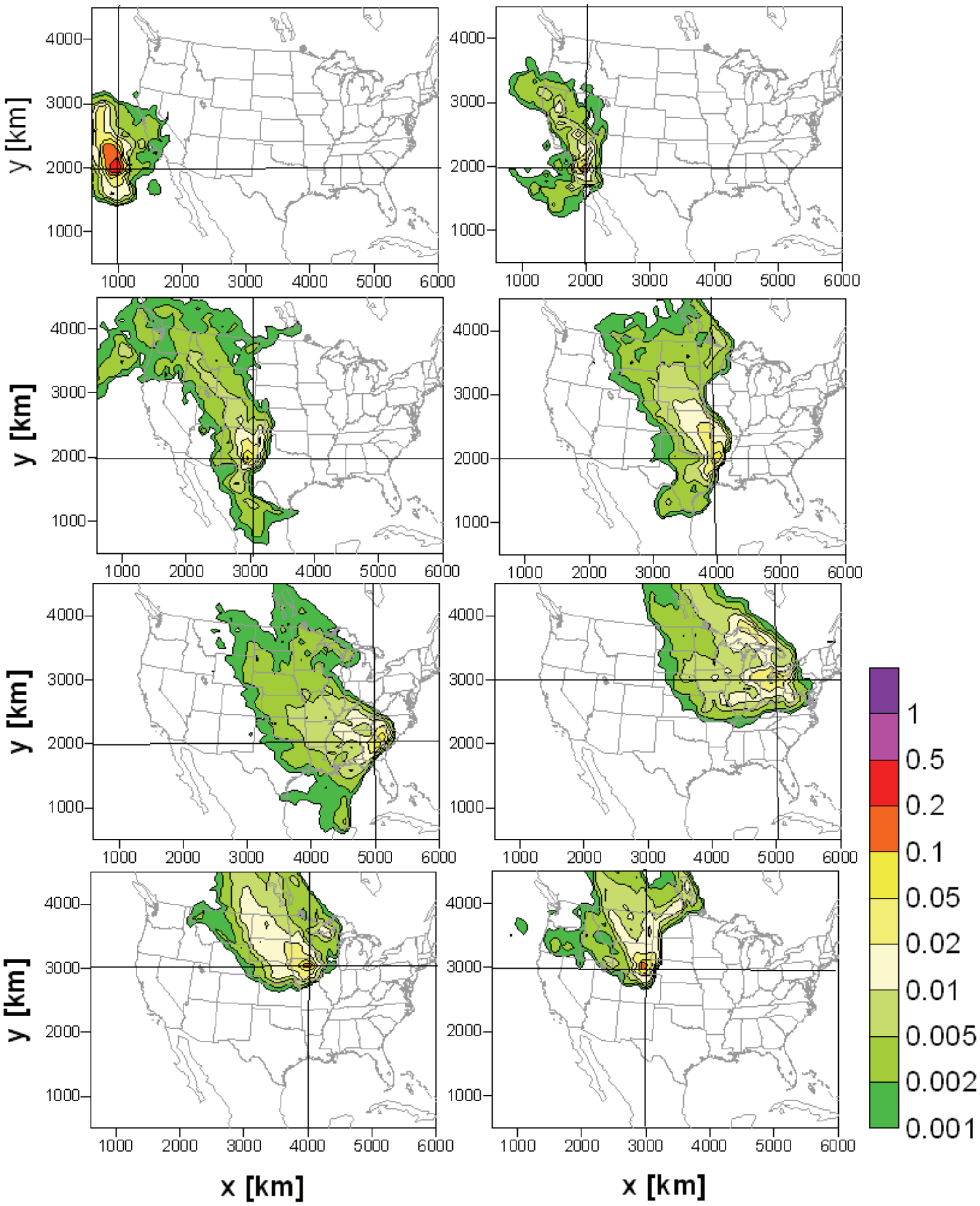


Figure 1 presents a series of influence functions [ppm/umol] calculated during testing the prototype RUC/LPDM system. They are derived for the 10-day period of March 6-16, 2006 and hypothetical 400 m towers spaced every 1000 km across the RUC domain. The influence functions are integrated with unit CO_2 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 with 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 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 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:

a) 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.

b) 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.

c) 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 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, 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:

RESEARCH & DEVELOPMENT FOR GOES-R RISK REDUCTION

Principal Investigator: 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:

Synthetic Images. This year, synthetic HES imagery was produced directly from observed soundings. That is, the discrete Fourier transform was applied to several soundings. During the inverse operation, specific vertical wavelengths were filtered out. This procedure demonstrated the added information that can be gained by increasing the vertical resolution of the GOES-R HES. In addition, considerable effort was spent making the observational operator run in parallel. This was necessary to produce synthetic GOES-R 3.9 μm imagery in a reasonable time. Synthetic 3.9μm imagery was produced for one case. Further, efforts have shifted a bit from producing data to writing the results for peer reviewed publication. Additional information may be obtained at our website: http://rammb.cira.colostate.edu/projects/goes_r

Data Collection. A new case was added to the Case Study Database: The eruption of the Volcano Reventador (Ecuador) that occurred on 3-5 November 2002. A multitude of satellite loops, images, and products are available which monitor the eruption and resulting ash plume, including those from GOES, MODIS, and AIRS. Further, a collection of full resolution (temporal, spectral, and spatial) Meteosat Second Generation data was collected over the tropical Atlantic 1 June – 3 December for future satellite applications.

Data Assimilation. Our data assimilation efforts focused on two areas. First, the impact of small (cloud resolving) scales within the MLEF approach. This was done in collaboration with G. Carrio and W. Cotton, from CSU/Atmospheric Science Department. Second, account for representativeness error in ensemble data assimilation methods. Representativeness error arises from different variability of the observed variables and model produced variables, and it is present even in experiments with simulated observations, since we have to impose an error, often in the form of Gaussian random noise, to simulated observations. Thus, in some cases, the errors of the observations and of the model-produced variables could be quite different, which is manifested in representativeness error. I have experimented with assimilation of simulated brightness temperature employing RAMS model, and have concluded that representativeness error could have a large impact on data assimilation results.

Tropical Cyclone Product Development. A study with Jack Beven, a hurricane specialist from the NCEP Tropical Prediction Center in Miami has been initiated to test the impact of GOES-R on tropical cyclone intensity estimation using our proxy database. Jack selected 12 cases of interest that span the Dvorak pattern types for analysis. He is manually running with Dvorak Enhanced IR technique on 1, 2 and 4 km imagery to test the sensitivity to resolution. These results will be presented at the upcoming GOES-R meeting in Boulder, CO in May.

The study of HES hurricane eye soundings using AIRS as a proxy has been expanded to include 6 cases. Figure 4.1 shows that the technique is very sensitive to the eye size and cloud contamination. This figure shows that the errors in the estimation of minimum surface pressure for the Isabel cases with a large eye were very small, but the errors for Lili with a small eye were large. AIRS soundings directly from the NASA site are being obtained and compared with the samples obtained from C. Barnett at NESDIS. Assuming these are comparable, a much larger sample size will be obtained from storms from the active 2005 hurricane season. These results were presented at the AMS Conference on Satellite Meteorology and Oceanography in Atlanta, in Feb. 2006.

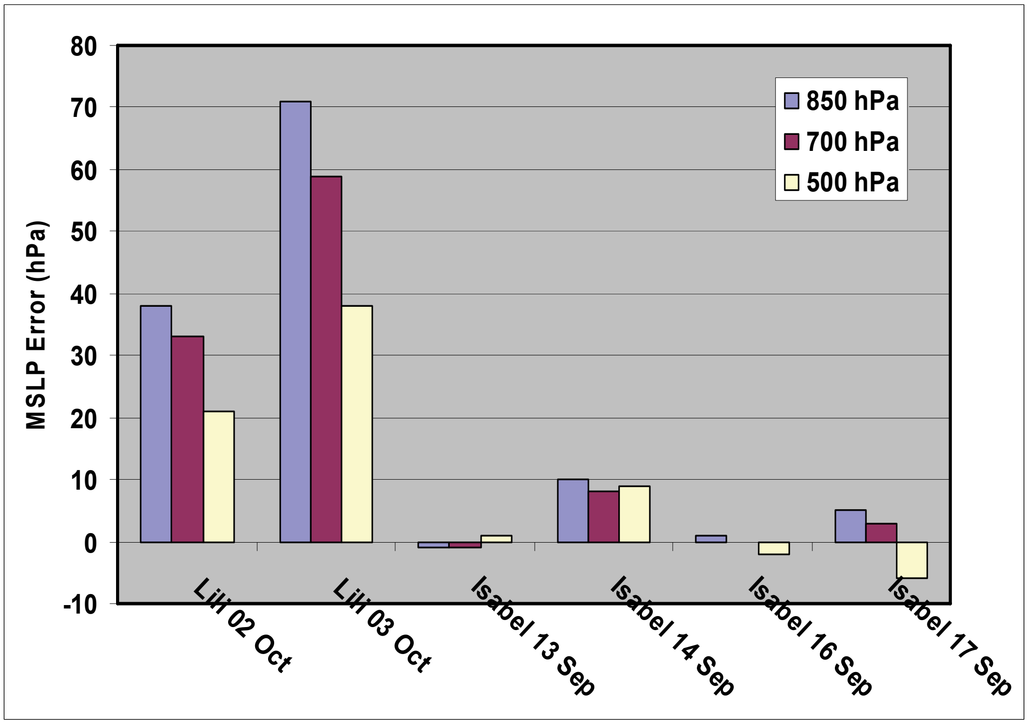


Figure 4.1 Errors in the minimum surface pressure estimated by a hydrostatic integration of an AIRS eye sounding from 100 hPa to the surface. To help correct for cloud contamination, three methods are compared, where a constant lapse rate is assumed from 850, 700 or 500 mb to the surface. The errors are very sensitive to eye size, relative to the AIRS footprint size.

Prototype product development for fog, smoke and volcanic ash analysis. A new daytime fog/stratus discrimination product has been under development for use with future GOES-R ABI bands. The product utilizes the ABI-equivalent MODIS bands in the visible and near-IR portions of the spectrum, and has as its basis the Shortwave Albedo Product, which discriminates fog/stratus through the reflective properties of water clouds in shortwave vs. longwave IR imagery. The new product also utilizes a three-color technique such as used in the MSG “natural color” (red: 1.6 μm, green: 0.86 μm, blue: 0.6 μm) product. In the new three-color fog/stratus product (Figure 1), the 1.6 μm band was retained, but the Shortwave Albedo replaces the 0.86 μm band, and the order of the bands/colors was switched.

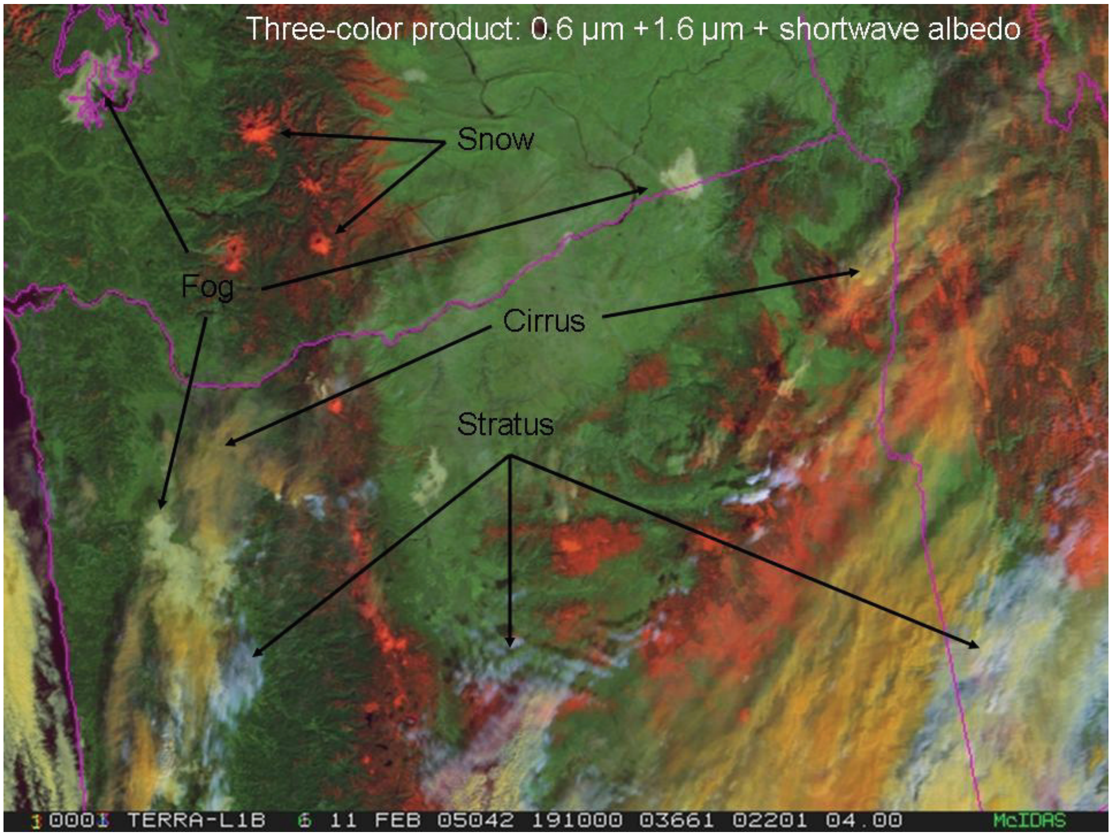


Figure 3.1: New Three-Color Fog/Stratus Product that better discriminates clouds from land, and between different levels and types of clouds, over southern Washington and Oregon on 11 Feb 2005 at 1910 UTC. Snow is orange/red; high-level cirrus/ice clouds are yellow/orange; low-level stratus/water clouds have a blue tint; and fog (on the ground) is whiter than stratus clouds that are off the ground. Most land surfaces are green, the color discrimination of land types sacrificed for cloud level and type discrimination.

Volcanic Ash Detection**.** GOES, MODIS, and AIRS data for the Reventador Volcanic eruption in Ecuador on 3-5 November 2002 have been added to the GOES-R Risk Reduction Activity database. Figure 2 shows an example of imagery and products from MODIS for identifying ash and aerosol compositions. Figure 2a is the standard 11.0 µm imagery and shows that the eruption cloud looks like a convective cloud. Figure 2b shows the typical “reverse absorption” product that has been used to identify ash from many satellite platforms (GOES, AVHRR). Figure 2c uses a combination of channels that will be available on GOES-R, which highlights ash and aerosol. Figure 2d highlights detection of SO_2. This case highlights the complicated nature of volcanic ash/aerosol in the design of optimal methods for detection.

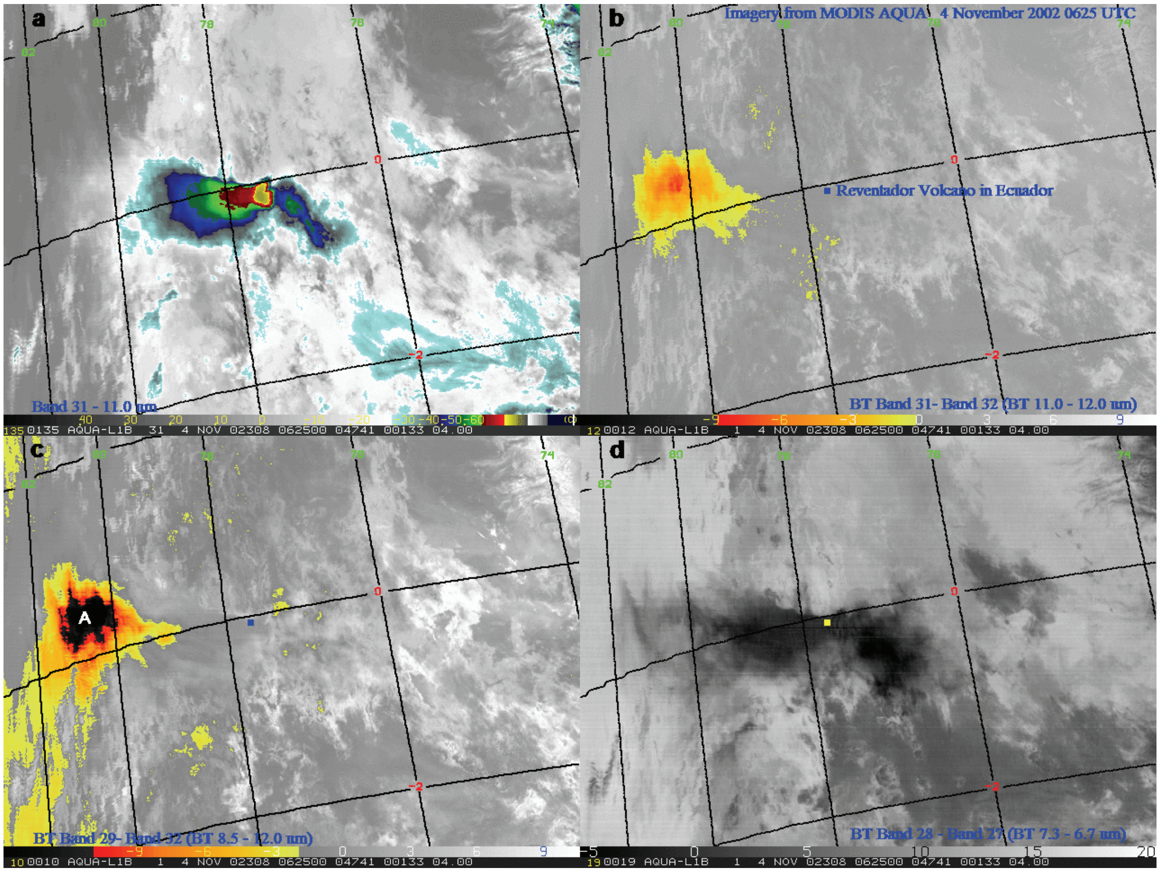


Figure 3.2: MODIS Aqua imagery and products for the Reventador Volcanic Eruption in Ecuador (4 November 2002, 0625 UTC) a) Band 31 (11.0 µm), b) Brightness Temperature (BT) difference Band 31-32 (BT11.0 – 12.0 µm), c) BT difference Band 29-32 (8.5 -12.0 µm), and d) BT difference Band 28-27 (7.3 – 6.7 µm).

<u>Severe Weather Applications</u>. A new investigation into the GOES-R ABI 6.185 - 10.35 µm difference has begun. An observational operator was used to simulate brightness temperatures from the 6.185 and 10.35 µm channels. The difference between these 2 channels has been observed over deep convection, so this investigation is meant to explain these observations, and to evaluate the utility of such a product when GOES-R is launched. Fig. 5.1 below shows this simulated product from the 8 May 2003 Severe Weather case; pixels colored red correspond to areas in which the 6.185 - 10.35 µm difference is positive.

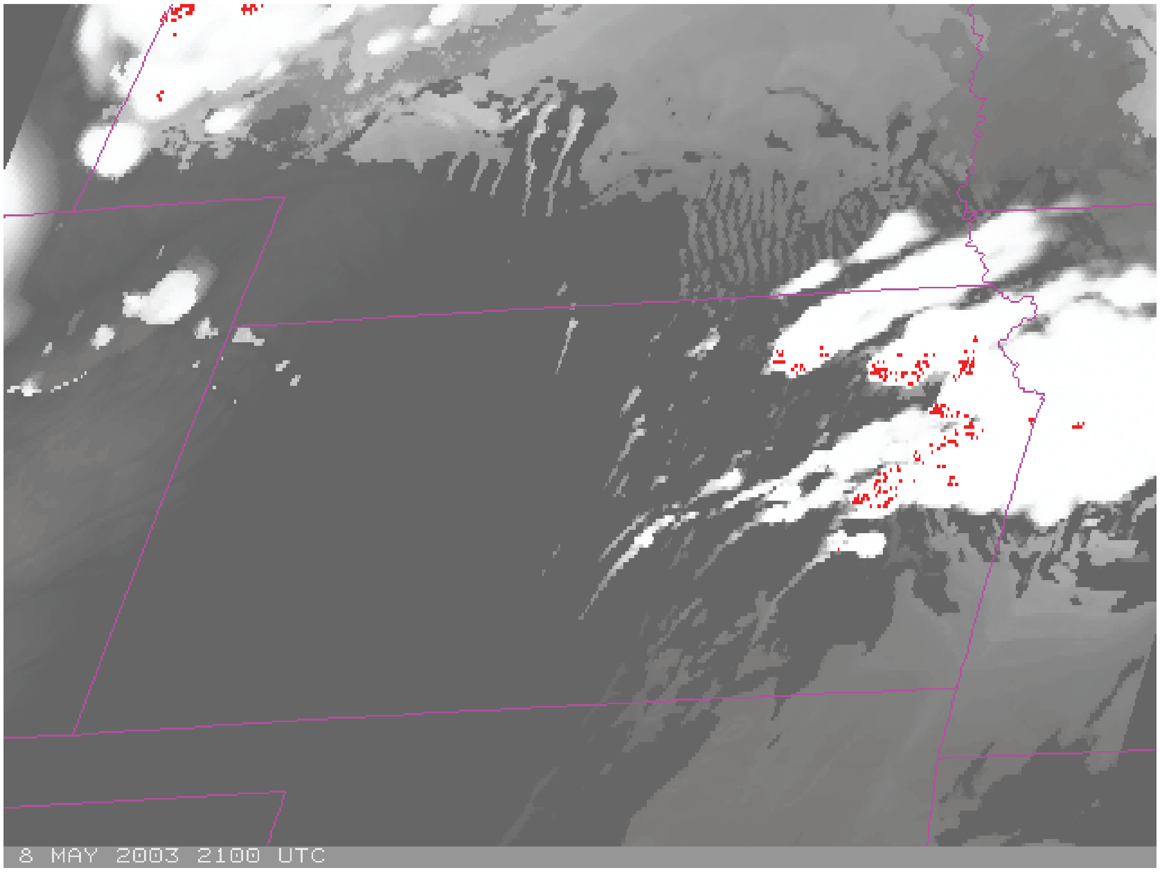


Fig. 5.1. Synthetic GOES-R ABI 6.185 - 10.35 μm brightness temperatures applied to the 8 May 2003 severe weather case. Pixels colored red have positive differences, and tend to be associated with thunderstorm overshooting tops.

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

In general all of the objectives have been met except one. Producing synthetic imagery at 3.9 μm required paralellization of the observational operator code. This took longer than expected. This was a result of trial and error deciding the best way to make the code run in parallel.

3. 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
--Improved products for fog, volcanic ash and fire detection

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

Our research linkage includes:

--Coordinating with CIMSS and the Joint Center for Satellite Data Assimilation. These groups are producing the required OPTRAN coefficients and code for radiative modeling of GOES-R ABI channels.
--Coordination with Dr. William Cotton, Dept. Atmos. Sci., Colorado State University. The coordination produces efficient production of a final product. That is, we can avoid duplication of work and 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) Robert DeMaria, an undergraduate student in the CSU Department of Computer Science is partially supported by this project.

(b) See Section 8

(c) None

(d) A summary of this project is available on a web site to increase public awareness of the GOES-R program

8. Publications:

<u>Conference Proceedings</u>

Connell, B.H., 2006: Preparing for GOES-R: old tools with new perspectives. *4th GOES-R Users' Conference,* 1-3 May, Broomfield, CO.

Connell, B.H., and F. Prata, 2006: Detecting volcanic ash and blowing dust using GOES, MODIS, and AIRS imagery. *AMS 14th Conference on Satellite Meteorology and Oceanography, 29 January-3 February, Atlanta, GA.*

DeMaria, M., 2006: Hurricane Intensity Estimation from GOES-R Hyperspectral Environmental Suite Eye Sounding. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

DeMaria, M., D.W. Hillger, C. Barnet, R.T. DeMaria, 2006: Tropical Cyclone Applications of Next-Generation Operational Satellite Soundings. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Grasso, L.D., and M. Sengupta, 2006: A technique for computing hydrometeor effective radius in bins of a gamma distribution. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

Grasso, L.D., M. Sengupta, J.F. Dostalek, and M. DeMaria, 2005: Synthetic GOES-R and NPOESS imagery of mesoscale weather events. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Grasso, L.D., M. Sengupta, J.F. Dostalek, and M. DeMaria, 2006: Synthetic GOES-R and NPP imagery of mesoscale weather events. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

Grasso, L.D., M. Sengupta, and D.T. Lindsey, 2006. A technique for computing hydrometeor effective radius in bins of a gamma distribution. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Hillger, D.W., 2006: GOES-R ABI New Product Development: Focus on Fog and Atmospheric Dust. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

Hillger, D.W., 2006: GOES-R Product Development Risk Reduction Activities. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Lindsey, D.T., 2006: A Climatological Study of Ice Cloud Reflectivity over the Continental US. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Sengupta, M., L.D. Grasso, D.T. Lindsey, and M. DeMaria, 2006: Statistical comparisons of model output with satellite observations: a severe weather case. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Zehr, R.M., 2006: Analysis of High Resolution Infrared Images of Hurricanes from Polar Satellites as a Proxy for GOES-R. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

Zupanski, D., L.D. Grasso, and M. DeMaria, 2006: Ensemble Data Assimilation of Simulated Brightness Temperature Observations. *4th GOES-R Users' Conference*. 1-3 May, Broomfield, CO.

Zupanski, D., L.D. Grasso, M. DeMaria, M. Sengupta, and M. Zupanski, 2006: Evaluating the Impact of Satellite Data Density within an Ensemble Data Assimilation Approach. *AMS 14th Conference on Satellite Meteorology and Oceanography.* 29 January-3 February, Atlanta, GA.

Newsletters

Connell, B.H., and D.W. Hillger, 2006: Preparing for GOES-R: Old tools with new perspectives, *CIRA Magazine,* 25, Spring, 1-3.

Presentations

D. Lindsey, January, 2006: 3.9 µm reflectivity work described in the *Monthly Weather Review.* StAR Seminar, Washington, DC.

L. Grasso, October 19, 2005: Synthetic GOES-R and NPOESS imagery. *Desert Research Institute (DRI) Seminar* in Reno, NV.

M. DeMaria, October 16, 2005: Satellite wind algorithms developed by RAMMB. GOES-R Algorithm Working Group Meeting, VA.

SATELLITE DATA RECEPTION AND ANALYSIS SUPPORT

Principal Investigator/Group Manager: 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.

<u>Computer Resources</u>

CIRA currently has approximately 200 systems that represent CIRA's core computer base. These systems are custom designed, assembled, and maintained by the group. The following list gives a brief overview of the infrastructure resources managed by this group:

Complete system management: Pentium-4 servers/workstations using the Microsoft Windows XP/2003 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 issues, and property accounting.

Security: firewall, NTFS, antivirus, and antispam.

Network: LAN, WAN, cabling, switches, firewall, IP control.

Infrastructure budget and expenditures: $160k/year hardware/software budget.

Technical group consulting: RAMM, NPS, Bacimo, AMSU, Geosciences, CHANCES,

CloudSat, Students, Visiting Scientists.

Linux cluster: 64-bit, 40 processor cluster for high throughput modeling.

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's archive contains complete GOES, AVHRR, and Meteosat data back to 1994. The earthstation currently collects, processes, distributes, and archives:

GOES-10
GOES-11
GOES-12
GOES-13 (experimental)
NOAA-16/17
Meteosat-5
MSG-1

All products are collected at full resolution and processed into McIDAS formatted files. These files are distributed to researchers on high-speed servers and archived on DVD for future use.

Special Projects

CloudSat

The group completed the CloudSat data processing computer infrastructure. This new infrastructure contains 45 individual workstations and 15 terabyte RAID storage systems all specified, acquired, assembled and deployed by the group. 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 of comparable “pizza box” servers. By consuming less power and generating less heat, the room requirements are much lower further saving the CloudSat project significant funds.

The CloudSat satellite successfully launched this year. The CloudSat Data Processing Center started full operational status and is performing well.

GOES-11/13

The group completed several computer and software upgrades to collect GOES-11 and GOES-13.

NOAAPort Receive System

The group purchased and installed a NOAAPort receive system. The installation included another antenna platform. The group now maintains 5 antenna systems.

Archive

CIRA has 7000 8mm tapes and 1000 DLT tapes that contain meteorological data from the past decade. These tapes are at risk since tape technology does not last and the tapes drives to read the tapes are no longer available. Using in-house developed software, automated systems, and student hourly’s, the tapes are slowly being converted to DVD. The group hopes to have converted all the tapes in the next year.

Telemetry Equipment Repairs

Two older RF down converters failed this year requiring either repair or replacement. These units cost $15000.00 to replace. Over the course of one month, the group was able to successfully repair both units in house.

Future Work

CIRA has literally run out of space for computer servers and clusters. Additionally, the old server room is over loaded and does not provide reliable power or air conditioning. Therefore, CIRA is building a new computer building by renovating the building just south of CIRA. The room will provide a more reliable environment for the Linux cluster as well as other Windows servers, and provide additional space for new systems.

The student hourly’s will continue to convert tapes to DVD.

Microsoft will release several new major products this next year including Windows Vista, Office 2007, and Exchange 2007. These products will be evaluated for function, maturity, and suitability into CIRA infrastructure.

SCIENCE STEWARDSHIP OF THEMATIC CLIMATE DATA RECORDS—A PILOT STUDY WITH GLOBAL WATER VAPOR

Principal Investigator: Thomas H. Vonder Haar

NOAA Project Goal: Climate

Key Words: Climate Data Records, CDR, Data Stewardship, NVAP, Water Vapor, AIRS, Satellite Meteorology, SSM/I, Data Rescue

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

2. Research Accomplishments/Highlights:

Water vapor is Earth's most important greenhouse gas and is a critical Climate Data Record (CDR). CIRA was the driving force behind the creation of the NASA Water Vapor Project (NVAP) dataset, a blended CDR used by hundreds of researchers worldwide, beginning in the early 1990's. NVAP provides total and layered precipitable water on a daily basis for 1988-2001 by merging satellite and radiosonde data. CIRA performed this pilot study in 2005 to examine the error in the NVAP components using the NASA Aqua spacecraft and in particular the AIRS sensor. AIRS is the most capable water vapor-observing satellite instrument flown to date. Aqua data was not available until mid-2002, so several test months of the NVAP dataset were created from 2003 and 2004 data to compare to Aqua results.

Science questions addressed by this research are:

--How do the NVAP heritage sensors compare with the NASA AIRS retrievals of precipitable water?
--Can scientific data stewardship of a CDR be demonstrated by extending a historical dataset forward in time to compare to more recent, powerful instruments?
--What recommendations for interpretation and reanalysis can be made from comparing NVAP inputs to AIRS results?

Principal Scientific Findings and Results are:

--Scientific stewardship of the water vapor CDR has been demonstrated by extending a historical dataset forward in time to overlap more capable instruments.
--A recreation of the NVAP total precipitable water (TPW) data from 2003-2004 shows that AIRS, SSM/I and TMI agree well. The loss of the HSB instrument on Aqua (February 2003) did not significantly affect the results.
--The ATOVS operational TPW product behaves as an outlier compared to AIRS, SSM/I and TMI (Figure 1). The use of this field in a blended satellite product is not encouraged. An alternative ATOVS retrieval is required for climate studies.
--The recovery and rescue of over 100 8mm tapes containing SSM/I antenna temperature data from 1987-1992 was successful. The data has been delivered on DVD to Dr. Fuzhong Weng at NESDIS for eventual inclusion into CLASS, to fill a gap in

the archive. The sensors and time period covered are shown in Figure 2. CIRA determined the format and physical units of the data.

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

Successful: Extension of NVAP TPW fields forward in time to compare to AIRS.

Successful: Delivery of rescued SSM/I data to NOAA.

In Progress: A journal paper summarizing the comparison of AIRS TPW with SSMI/, ATOVS, and TMI TPW.

4. Leveraging/Payoff:

Tom Karl (Director of NOAA's National Climate Data Center) has presented the time series of TPW anomalies with atmospheric temperature and sea surface temperature anomalies at scientific conferences. The time series of water vapor is a key companion to other metrics of global warming since the TPW in the atmosphere is expected to increase if Earth warms. Careful stewardship of the water vapor CDR will allow such planetary changes to be detected and studied.

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

There is a close linkage to NASA in that Aqua is a NASA spacecraft and NVAP was a NASA-sponsored CDR. Results gained from this NOAA effort may help guide creation of future years of NVAP, in terms of error characterization and reanalysis efforts. The findings have relevance for the use of the operational ATOVS sounding product for climate studies.

6. Awards/Honors: None at this time

7. Outreach: N/A

8. Publications:

Conference paper and poster (P2.28) " A Pilot Study of Scientific Data Stewardship with Global Water Vapor" presented at 14th AMS Conference on Satellite Meteorology and Oceanography, Atlanta GA, January 2006.

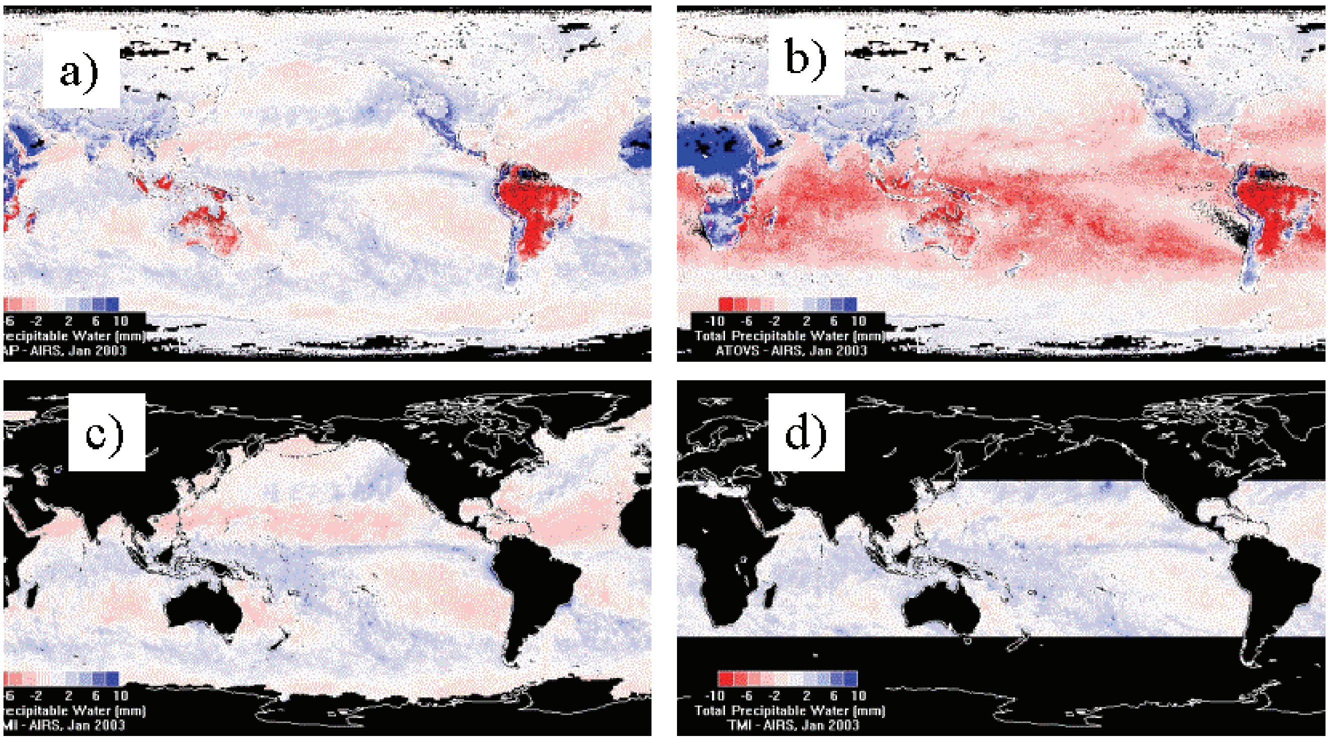


Figure 1: NVAP components minus AIRS TPW for January, 2003. Red areas are where AIRS is moister, blue is AIRS drier. Scale is from –10 to +10 mm. a) NVAP blended minus AIRS TPW. b) ATOVS (NOAA-15 and-16) minus AIRS. c) SSM/I (F-13 and F-14) minus AIRS. d) TMI minus AIRS.

Month/Year	F8	F10	F11
Jul, 1987	green	grey	grey
Aug, 1987	green	grey	grey
Sep, 1987	green	grey	grey
Oct, 1987	green	grey	grey
Nov, 1987	green	grey	grey
Dec, 1987	red *	grey	grey
Jan, 1988	green	grey	grey
Feb, 1988	green	grey	grey
Mar, 1988	green	grey	grey
Apr, 1988	green	grey	grey
May, 1988	green	grey	grey
June, 1988	green	grey	grey
Jul, 1988	green	grey	grey
Aug, 1988	green	grey	grey
Sep, 1988	green	grey	grey
Oct, 1988	green	grey	grey
Nov, 1988	green	grey	grey
Dec, 1988	green	grey	grey
Jan, 1989	green	grey	grey
Feb, 1989	green	grey	grey
Mar, 1989	green	grey	grey
Apr, 1989	green	grey	grey
May, 1989	green	grey	grey
June, 1989	green	grey	grey
Jul, 1989	green	grey	grey
Aug, 1989	green	grey	grey
Sep, 1989	green	grey	grey
Oct, 1989	green	grey	grey
Nov, 1989	green	grey	grey
Dec, 1989	green	grey	grey

Month/Year	F8	F10	F11
Jan, 1990	green	grey	grey
Feb, 1990	green	grey	grey
Mar, 1990	green	grey	grey
Apr, 1990	green	grey	grey
May, 1990	green	grey	grey
June, 1990	green	grey	grey
Jul, 1990	green	grey	grey
Aug, 1990	green	grey	grey
Sep, 1990	green	grey	grey
Oct, 1990	red	grey	grey
Nov, 1990	green	grey	grey
Dec, 1990	green	green	grey
Jan, 1991	green	green	grey
Feb, 1991	green	green	grey
Mar, 1991	green	green	grey
Apr, 1991	red	red	grey
May, 1991	green	green	grey
June, 1991	green	green	grey
Jul, 1991	green	green	grey
Aug, 1991	green	green	grey
Sep, 1991	green	green	grey
Oct, 1991	green	green	grey
Nov, 1991	green	green	grey
Dec, 1991	green	green	green

*Instrument powered off month of 12/87

Month/Year	F8	F10	F11
Jan, 1992	grey	green	green
Feb, 1992	grey	red	green
Mar, 1992	grey	green	green
Apr, 1992	grey	green	green
May, 1992	grey	green	green
June, 1992	grey	green	green
Jul, 1992	grey	green	green
Aug, 1992	grey	green	green
Sep, 1992	grey	green	green
Oct, 1992	grey	green	green
Nov, 1992	grey	green	green
Dec, 1992	grey	green	green

- green = Copied off tape and on to DVD
- red = Tape missing or corrupt
- grey = Satellite not in operation

Figure 2: Summary of the SSM/I data rescued from 8mm tape and written to DVD for the period 1987-1992.

SENSITIVITY OF THE NORTH AMERICAN MONSOON TO SOIL MOISTURE AND VEGETATION

Principal Investigators: 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, SSTs, and vegetation.

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:

NAM Generated Potential Vorticity Anomalies
Seasonal simulations have been carried out from June 1 – August 31 for the 1988, 1993, 1997, and 2000 warm seasons. These simulations cover the U.S., a portion of Canada, and most of Central America. Initially, a single grid configuration was used with 30km grid spacing, the Kain-Fritsch cumulus parameterization, and single-moment microphysics with both liquid and ice species. These seasons were chosen for simulation because of the availability of daily precipitation data over both the U.S. and Mexico. Dr. Art Douglas from Creighton University has been willing to collaborate with us via the provision of Mexico weather observations and daily rain gauge data. These data are used for the estimation of soil moisture and soil temperature that is needed for model initialization. Saleeby and Cotton (2005a, 2006a) have shown that accurate initialization of soil moisture is crucial when trying to improve predictability of warm season precipitation.

These simulated warm seasons were examined for the development of monsoon related potential vorticity anomalies associated with intense daily monsoonal convection that tends to occur along the Sierra Madre mountains of west-central Mexico. Averaged PV fields have shown a maximum generation of high values of PV over and along the western slopes of the Sierra Madres at several kilometers above the surface. There is a distinctive increase in the mid-level PV over much of the western U.S. between the months of June and August. The area of increased PV extends continuously from southern Mexico to Colorado, and is collocated with increased precipitation over the same region. Higher resolution simulations (7km grid spacing) were preformed for two individual week-long events that appeared especially coherent. In these events, anomalously high PV air was coherently advected northward into the southwest U.S. and impacted precipitation systems over Arizona and New Mexico. These systems tend to weaken over time, and the scale of their impact downstream from their source region has yet to be determined.

Model sensitivity to variation in SST data

Saleeby and Cotton (2005a) showed that variability in prescribed SST anomalies can impact coastal moisture flux and precipitation due to variability in latent heat flux from the ocean surface. The availability of low-level moisture is crucial for the development of deep moist convection along the core monsoon region of Mexico.

Recently, several higher resolution and more accurate SST datasets have been made available via improvement in satellite technology. As a part of this project, the Reynold's 1° x 1° Version 2 data, AVHRR 18-km data, and MODIS 4.63km data have been adapted for assimilation into the RAMS land surface model. RAMS does not contain an ocean model, so it relies upon accurate data for initializing and updating SSTs when running RAMS in a regional climate mode over a full North American warm season.

Simulations were run on a single 30km grid spacing domain from June 1 – August 31 for the 2002, 2003, and 2004 warm seasons, which included the season involving the NAME field campaign. These simulations used single-moment microphysics and the Kain-Fritsch cumulus parameterization to predict the resolvable and unresolvable precipitation at this scale. Shorter term simulations were also run for the Gulf of California monsoon surge event that occurred July 13-15, 2004 and was well-documented from the NAME observation network. For each case and season, we initialized and nudged the SSTs with each dataset mentioned above as well as the climatological mean data.

Preliminary results from the seasonal simulations reveal large differences in seasonal averaged moisture flux and accumulated precipitation with use of the different SST sources at the varying resolutions. The greatest variability occurs over the ocean areas and coastal zones, which does impact transport of moisture into the Sierra Madres of western Mexico. Hence, we also see precipitation variability far downstream from ocean areas. Precipitation variation occurs in a relatively coherent stream along the periphery of the warm season anti-cyclone. The greatest variability, however, occurs along coastal Mexico where differences in SSTs from the various datasets produce a change in precipitation of up to 1.5 mm/day! With such variability in model realizations, it becomes necessary to determine the most reliable and accurate SST data to use when trying to improve the predictability of warm season precipitation.

Analysis of this study is ongoing and results will be presented at the annual CPPA PI meeting in Tucson in August 2006.

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

Our research accomplishments are consistent with the stated objectives in the original proposal.

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

None.

6. Awards/Honors:

None.

7. Outreach:

(a.) Graduate/Undergraduate students (List by name, degree status and continuance after obtaining degree); This research supported Steve Saleeby who is a Ph.D. candidate in Atmospheric Science at CSU.

(b) Seminars, symposiums, classes, educational programs; Presentations given at 2005 Climate Diagnostics Meeting, 2006 Warm Season Precipitation Symposium, 2006 CPPA PI Meeting (see pub list below):

8. Publications:

Saleeby, S.M., and W.R. Cotton, 2005a: Sensitivity of wet and dry North American Monsoon seasons to variability in sea surface temperature and soil moisture. *85th AMS Annual Meeting*, San Diego, CA.

Saleeby, S.M., and W.R. Cotton, 2005b: Interseasonal Survey of Long-lived Positive Potential Vorticity Anomalies Generated from Monsoon Convection. *NAME Special Session, 30th Climate Diagnostics and Prediction Workshop*, State College, PA.

Saleeby, S.M., and W.R. Cotton, 2006a: Sensitivity of monsoon-related warm season precipitation to large and regional scale soil moisture anomalies. *Geo. Phys. Lett.*, (In preparation).

Saleeby, S.M. and W.R. Cotton, 2006b: 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.

SHIP-BASED OBSERVATIONS OF PRECIPITATION CONVECTION AND ENVIRONMENTAL CONDITIONS IN SUPPORT 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 plane 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.

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

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; *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:

(a.) Graduate/Undergraduate students (David Lerach, M.S. candidate)
(b) Seminars, symposiums, classes, educational programs: None as yet
(c) Fellowship programs: None as yet
(d) K-12 outreach: None as yet
(e) Public awareness. None as yet

8. Publications:

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,* accepted. (Pereira, L.G., and S.A. Rutledge).

Radar-Observed Characteristics of Precipitating systems during NAME 2004, *Journal of Climate, conditionally a*ccepted. (Lang, T.J., A. Ahijevych, S.W. Nesbitt, R.E. Carbone, S.A. Rutledge, and R. Cifelli).

Radar Observations During NAME 2004 Part I: Data Products and Quality Control. 32nd Conference on Radar Meteorology, Albuquerque, NM, 24-29 October 2005. (T.J. Lang, R. Cifelli, 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. (T.J. Lang, R. Cifelli, D. Lerach, L. Nelson, S.W. Nesbitt, G. Pereira, and S.A. Rutledge)

The North American Monsoon Experiment (NAME) 2004 Field Campaign and Modeling Study. *Bull. Amer. Meteor. Soc.,* **87,** 79-94. (W. Higgins et al.)

STUDY OF GULF SURGES USING QuikSCAT AND NAME OBSERVATIONS

Principal Investigator: Richard H. Johnson

NOAA Project Goal: Climate

Keywords: 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.

We have used QuikSCAT data for the 2000-2005 period to test the hypotheses that (i) QuikSCAT-derived surface winds can be used as an effective tool to monitor Gulf Surges, map their evolution and spatial variability, and determine their variability on seasonal to interannual timescales, and (ii) a source of cool air in Gulf Surges is from an acceleration of the flow across the strong SST gradient that exists at the southern tip of Baja. Candidate mechanisms for accelerating this flow are easterly waves, hurricanes, or mesoscale convective systems. Enhanced measurements from the 2004 North American Monsoon Experiment (NAME) field phase have been used to investigate these possible mechanisms. We also proposed to conduct a mesoscale modeling study to investigate the dynamics of monsoon surges.

2. Research Accomplishments/Highlights:

A study of the multiscale variability of the flow during NAME has recently been completed (Johnson et al. 2006). Characteristic of El Niño years, the monsoon onset in 2004 was slightly later than normal and precipitation over the southwestern U.S. was slightly below normal. The onset was accompanied by a strong surge on 13 July, which was linked to the westward passages of Tropical Storm *Blas* to the south and an upper-level inverted trough over northern Mexico.

QuikSCAT data have been used to investigate Gulf surges and their interannual variability for the period 1999-2003 (Bordoni et al. 2004) and more recently for the 2004 NAME season (Johnson et al. 2006; Rogers and Johnson 2006). Surges are well-documented by the QuikSCAT winds despite the narrowness (approximately 100-200 km) of the GoC. A large fraction of Gulf Surges are connected with tropical cyclone passages to the south of the GoC. Based on a detailed study of the 13 July 2004 Gulf surge, we hypothesize that the salient dynamics for this particular event involve an atmospheric Kelvin wave channeled along the GoC whose leading edge steepens into an atmospheric undular bore as it propagates up the Gulf (Rogers and Johnson 2006).

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. (2006), and Rogers and Johnson (2006). 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 salient 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. candidate, UCLA; Prof. Bjorn Stevens, UCLA; Dr. Michael Douglas, NSSL/NOAA; Dr. Wayne Higgins, NCEP/NOAA; and Dr. Kingtse Mo, NCEP/NOAA.

6. Awards/Honors:

PI Richard Johnson was elected to NAME Science Working Group and CPPA Science Panel.

7. Outreach:

Peter Rogers received the M.S. degree in Fall 2006 under this award. 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 NAME and NOAA CPPA by attending meetings of the NAME SWG and NOAA CPPA Science Panel in 2005 and 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., P. E. Ciesielski, B. D. McNoldy, P. J. Rogers, and R. K. Taft, 2006: Multiscale variability of the flow during the North American Monsoon Experiment. *J. Climate* (in press).

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*. (submitted).

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, three 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 16,000 training certificates have been awarded (Fig. 1), and most student feedback suggests a direct applicability to current forecast problems. Most NWS forecast offices have participated in VISIT teletraining since October 1, 2004 (Fig. 2). The VISIT 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.

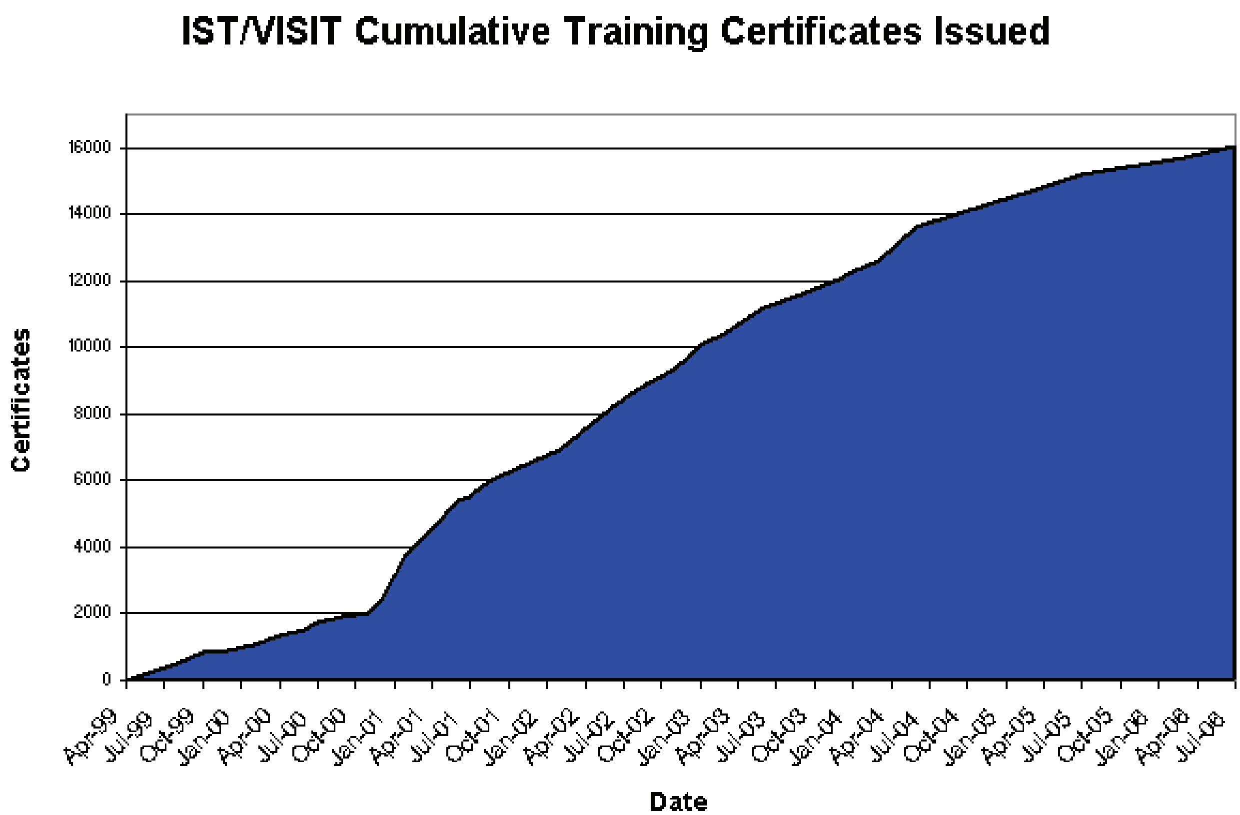


Figure 1. IST/VISIT Cumulative Training Certificates Issued.

Figure 2. Map showing the NWS forecast offices that have taken VISIT teletraining session(s), number of sessions attended given by the color.

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

In the last year, the VISIT team at CIRA has developed a new teletraining session titled “The GOES 3.9 μm Channel”. This was done in order to make the CIRA GOES 3.9 μm webpage tutorial subject matter more visible to all NWS forecast offices as teletraining. All other objectives of the proposal were also accomplished.

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. With travel costs increasing and budgets decreasing, 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/Partnerships/Collaborators, Communication and Networking:

The project involves considerable collaboration within the National Weather Service through contributions to training material, input on "beta-tests" of training sessions, and feedback following the delivery of the training. Coordination also occurs with other agencies involved in satellite training such as NESDIS ORA, DoD and COMET.

VISIT staff provided support for the development and implementation of the SHyMet (Satellite and Hydrology Meteorology) Intern Course Program which had 82 registered students(76 NOAA and 6 non-NOAA). We updated and appended some VISIT teletraining material to be used in this course, specifically, for the "Cyclogenesis: Analysis using Satellite Imagery" and "Introduction to Satellite Interpretation for Severe Weather" sessions taught by J. Braun and D. Bikos. Braun and Bikos gave 18 combined hours of course instruction for these sessions which was provided for 89 students (registered and non-registered). Support for the SHyMet Program includes such roles as sending and receiving evaluations and surveys; development and peer review of proposed sessions for the course; registration of prospective students; web page development; and student tracking and correspondence. The SHyMet Intern Course was administered to NOAA employees through the Department of Commerce E-Learning Management System (LMS). VISIT staff facilitated the course through the LMS, including the development of the "learning path" for both teletraining and audio playback versions of the SHyMet Intern Course as well as for metric statistics, record keeping and advertisement.

6. Awards/Honors: None as yet

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 and a college undergraduate student are supported by this project.

(b) D.E. Bikos, J.F. Weaver, J. Braun, and R.M. Zehr, Jul 1, 2005 – Jun 30, 2006: 117 VISIT teletraining sessions delivered to NWS offices, and others (2087 participants). CIRA, Fort Collins, CO.

B. H. Connell, 2006: Collaboration of and participation in monthly international weather briefings 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, as well as outside the U.S.: Antigua, Argentina, Bahamas, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Jamaica, Panamá, Peru, Paraguay, and Venezuela

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 a 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 2005: Basic Meteorology for science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, October 2005: Basic Meteorology for science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, November 2005: Basic Meteorology for science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, April 2006: Basic Meteorology for science, Boltz junior high school, Fort Collins, CO.

J.F. Braun, November 2005: Science fair judge, Boltz junior high school, Fort Collins, CO.

(e) VISIT training material is available to the public via the Internet.

8. Publications:

Newsletters

Braun, J., 2005: The VISIT Program. *CIRA Magazine*, **24**, Fall, 20-21.

Connell, B.H., and D.W. Hillger, 2006: Preparing for GOES-R: Old tools with new perspectives, *CIRA Magazine,* **25**, Spring, 1-3.

Presentations

B. Connell, November 14, 2005: GOES and the characteristics of its channels. Remote Sensing class at the Metropolitan State College of Denver, CO.

D. Lindsey, October, 2005: Invited lecture. AT351, an undergraduate laboratory for Introduction to Weather and Climate, for the Department of Atmospheric Science at Colorado State University, Fort Collins, CO.

D. Lindsey, August, 2005: Using satellite imagery to improve forecasts and nowcasts. *34th Conference on Broadcast Meteorology*, Washington, DC.

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

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Jeffrey Privette, NASA-Goddard Space Flight Center

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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 contemporary 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

a) 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.

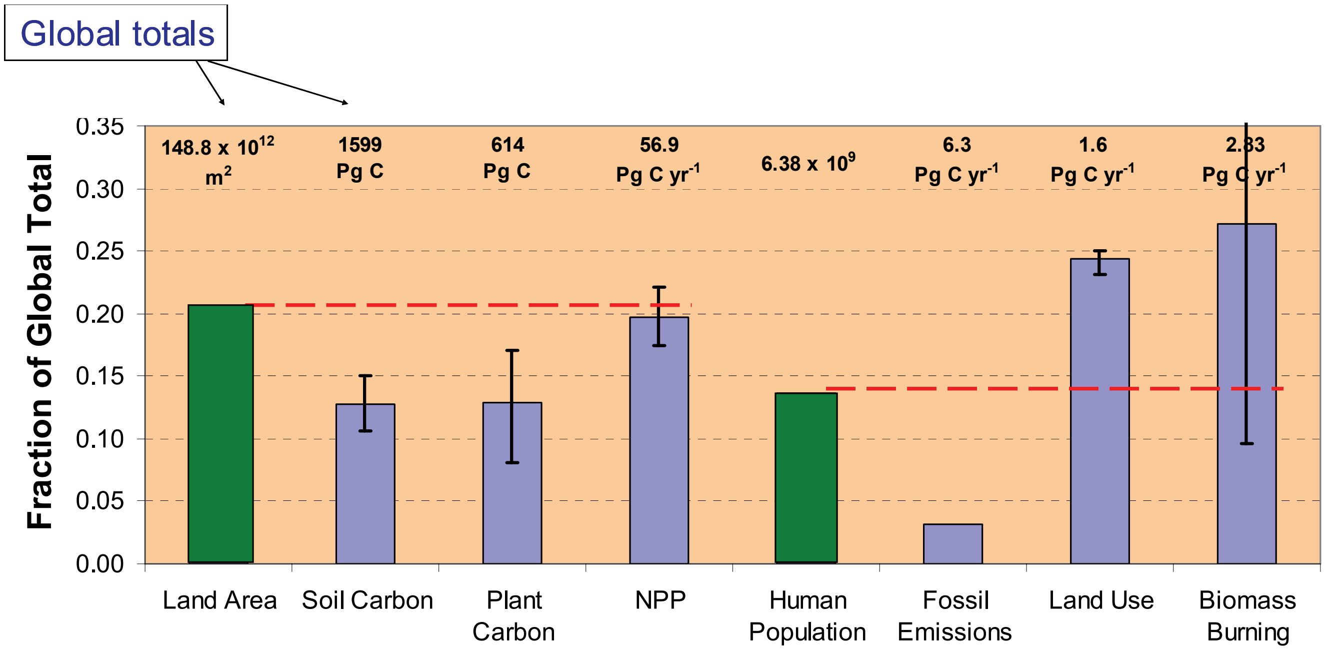


Figure 1. Carbon statistics for Africa expressed as fraction of global totals ('error bars' show range of published estimates). Land area and human population are shown as reference for Africa's fractional contribution to global carbon stocks and fluxes.

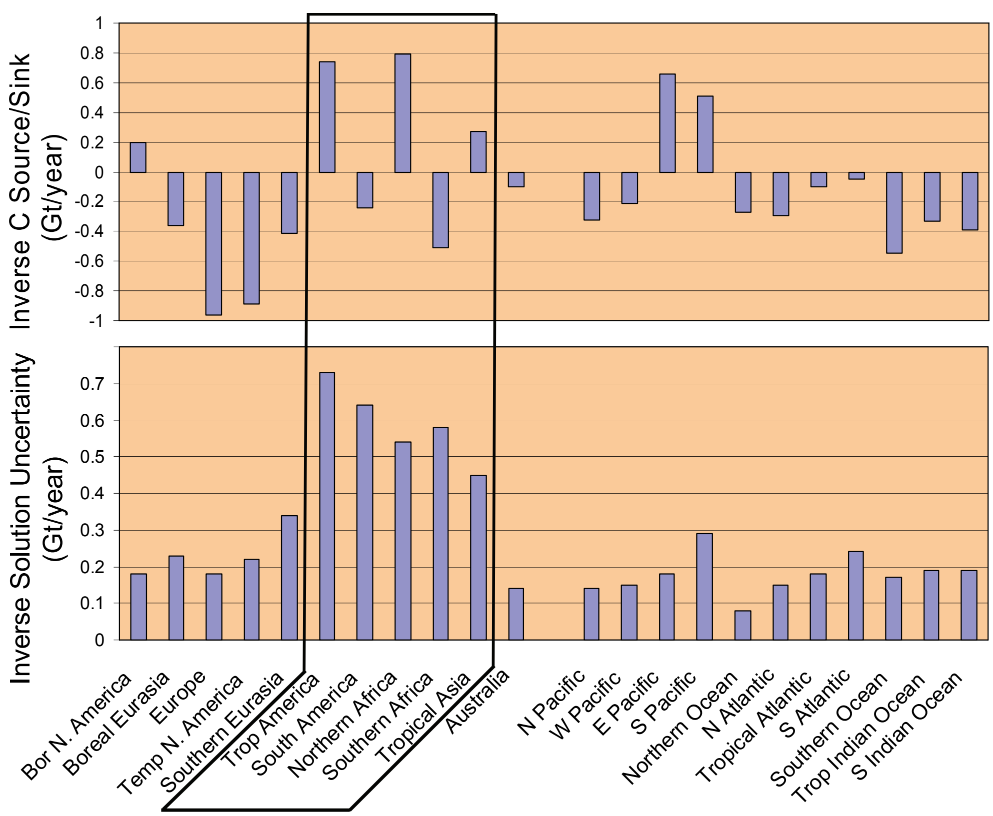


Figure 2. Inverse analysis results showing high levels of uncertainty for Africa and tropical terrestrial regions. (Data from TRANSCOM-2; Gurney et al., 2004).

b) 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

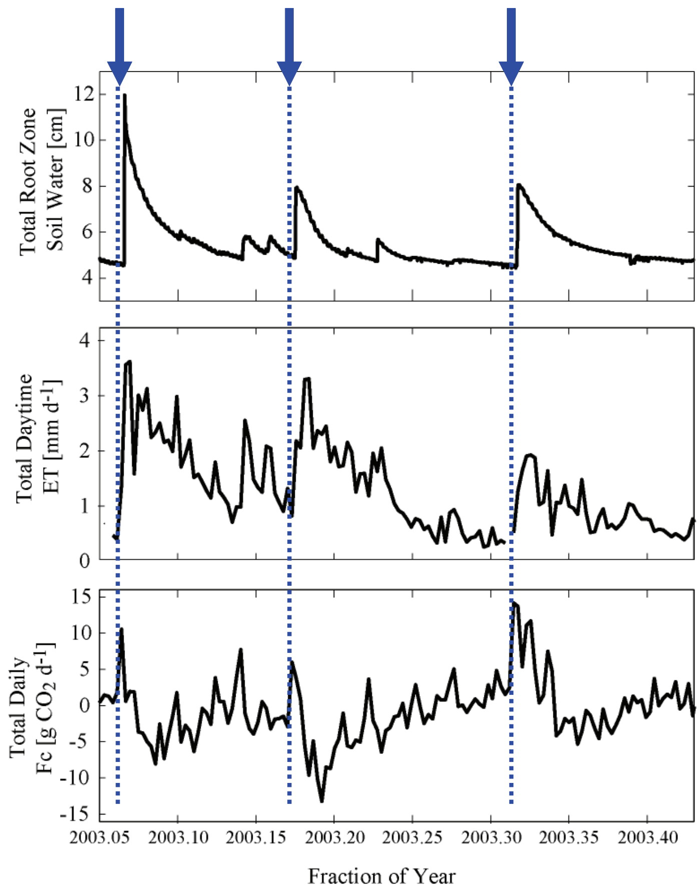


Figure 3. Pulse dynamics in tropical savannas. Measurements at the Kruger Park intensive research site during 2003 show the complex and non-linear response of savanna vegetation to rainfall events that depend not only on soil moisture, but also on phenological status and structural characteristics of the vegetation that impose lags and changing sensitivity to rainfall events through the growing season.

c) 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.

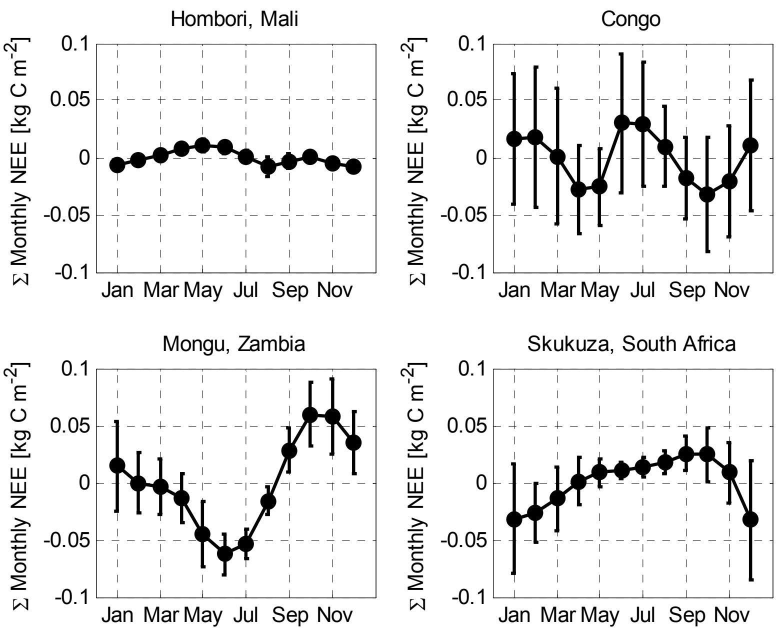


Figure 4. Monthly net ecosystem exchange (NEE) for 4 sample sites in Africa estimated using the Simple Biosphere Model (SiB3) and the long-term (1983-2000) AVHRR dataset. Climate data for the period were obtained from NCEP climate re-analysis fields. Hombori and Skukuza are active ACE field sites for 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.

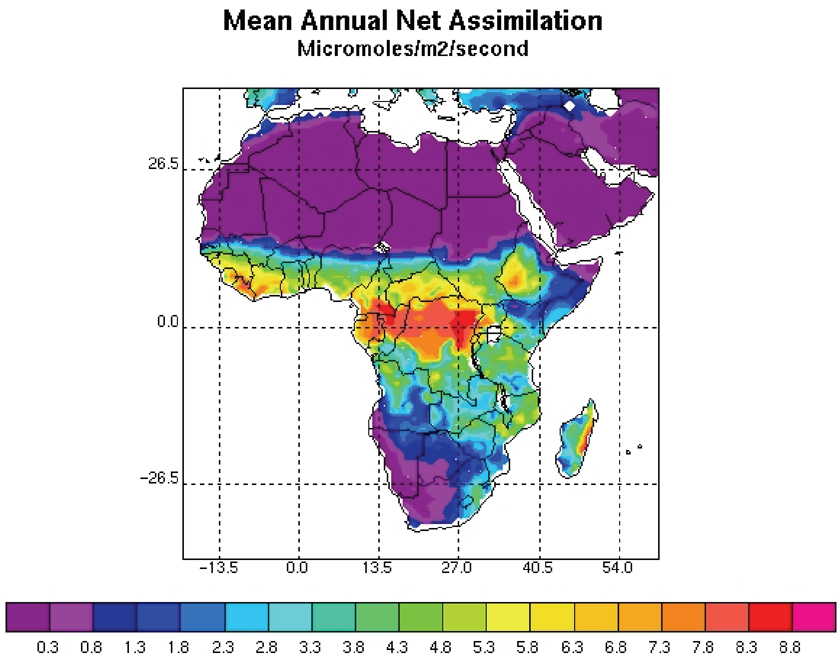


Figure 5. Annual average net assimilation rate (1983-2000) estimated using the SiB3 model, NCEP climate re-analyses and the long-term AVHRR data set.

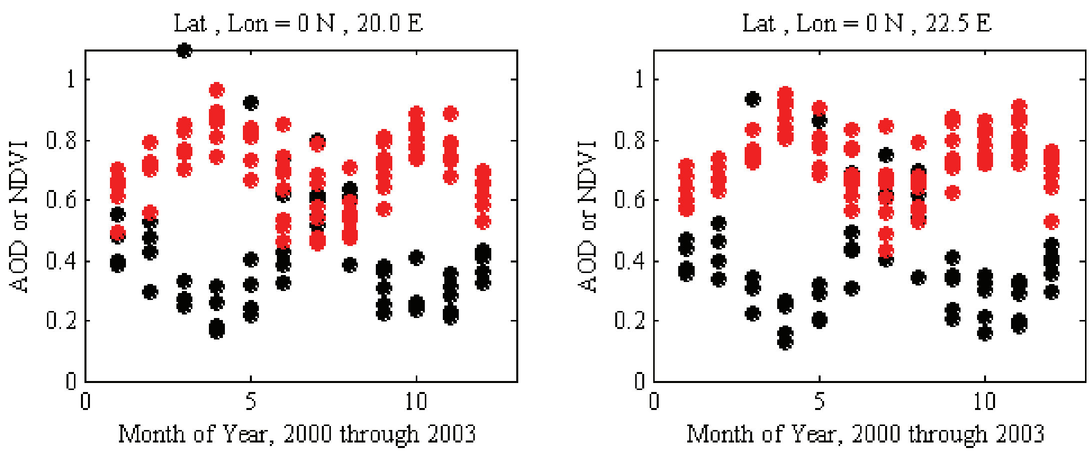
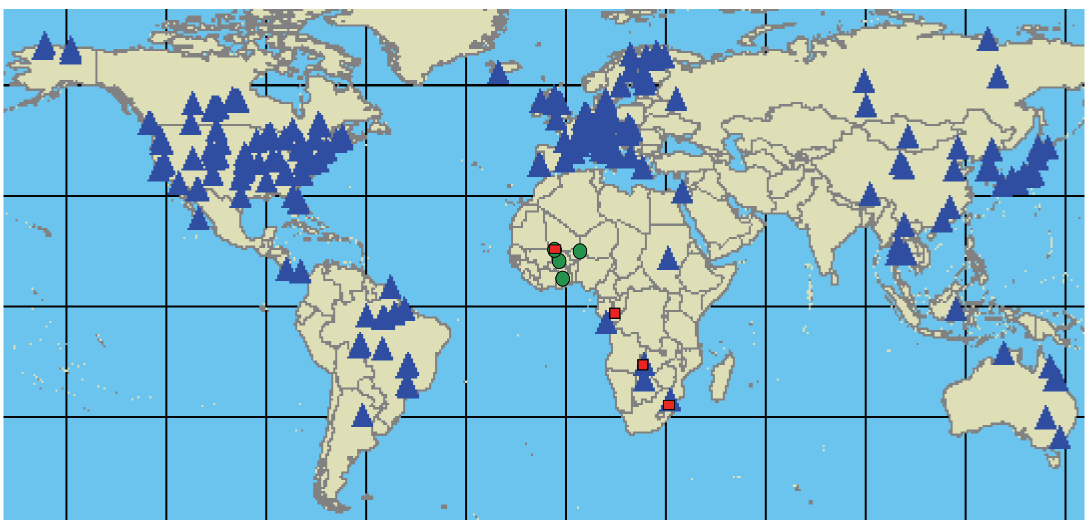


Figure 6. Monthly average AVHRR NDVI (red) and MODIS aerosol optical depth (black) in the moist tropics of Africa. Data are shown for two sites on the equator and for years with overlapping AVHRR and MODIS data availability (2000-2003). Note the strong seasonality in AVHRR NDVI that is negatively correlated with aerosol optical depth.

d) 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 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).



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

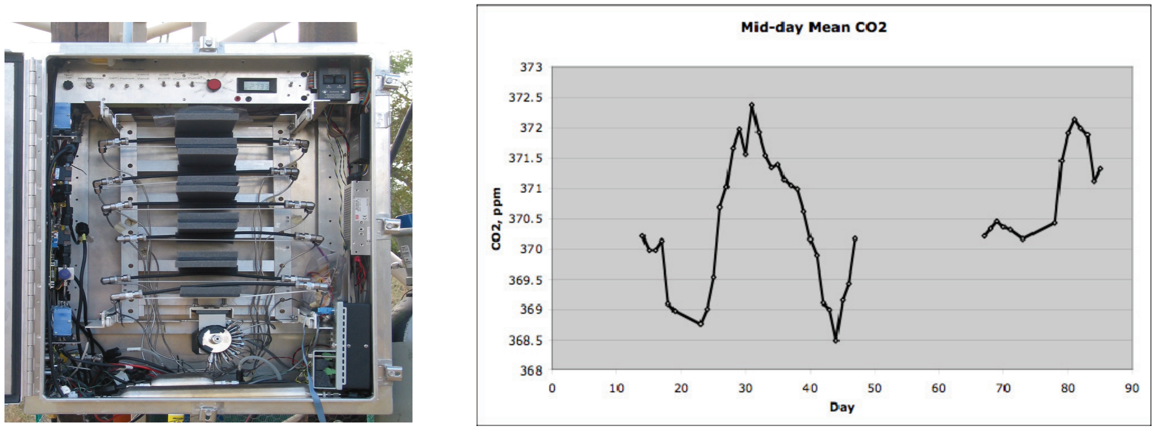


Figure 8. Precision carbon dioxide and flask sampling system (left) and midday atmospheric CO_2 concentration measurements (right) at the Skukuza eddy flux site in the Kruger National Park, South Africa. The system uses automatic calibration with WMO-traceable standards and a temperature controlled infrared gas analyzer to measure CO_2 concentration to an absolute precision of ~0.2 ppm.

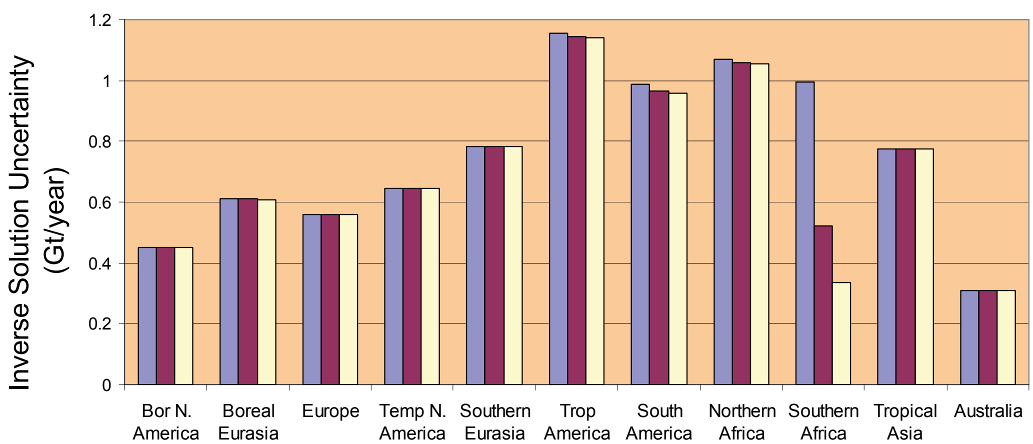


Figure 9. Effect of precision CO_2 sites in Southern Africa on atmospheric inversion uncertainty for Africa and other terrestrial regions (Blue: using existing flask network; Maroon: anticipated effect of adding a precision CO2 site in South Africa; white: adding a precision CO2 site in Zambia). Atmospheric 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.

e) 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.

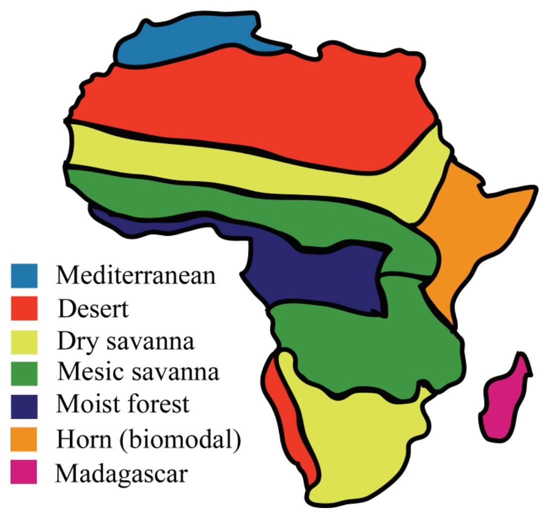


Figure 10. Bioclimate defined basis regions for new atmospheric inversion studies in Africa.

f) 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 solving 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.

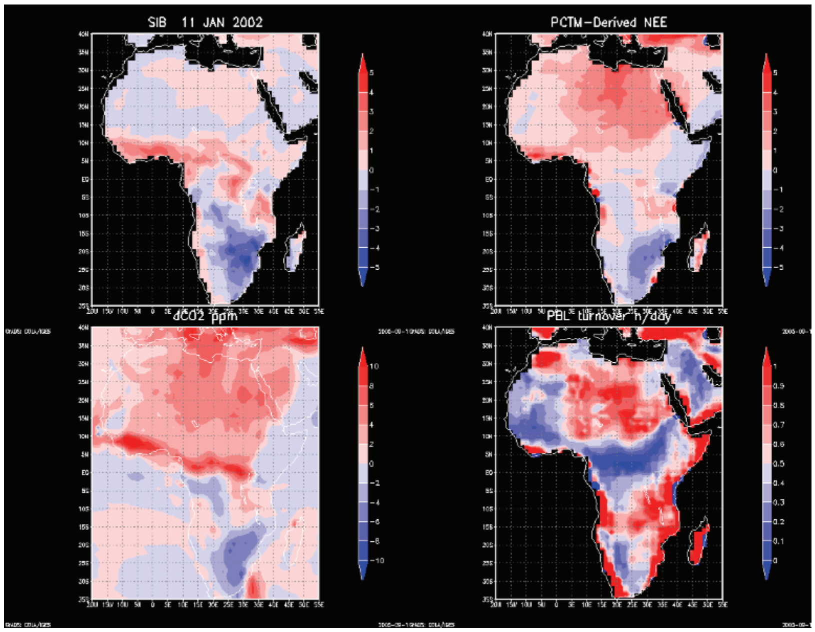


Figure 11. Regional Carbon Flux Estimation using a PBL-budget approach with near-surface [CO2] and atmospheric transport. This figure shows a snapshot (11 January 2002) of an annual simulation. The regional inversion method was described by investigator Berry and collaborators (Betts, Helliker, and Berry, 2004, Coupling between CO2, water vapor, temperature and radon and their fluxes in an idealized equilibrium boundary layer over land. JGR, 109, D18103).

g) 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.

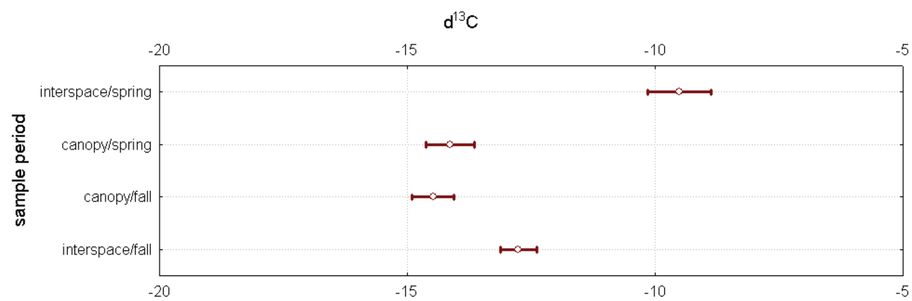


Figure 12. $d^{13}C$ of soil CO_2 flux by season and sampling location for 2006

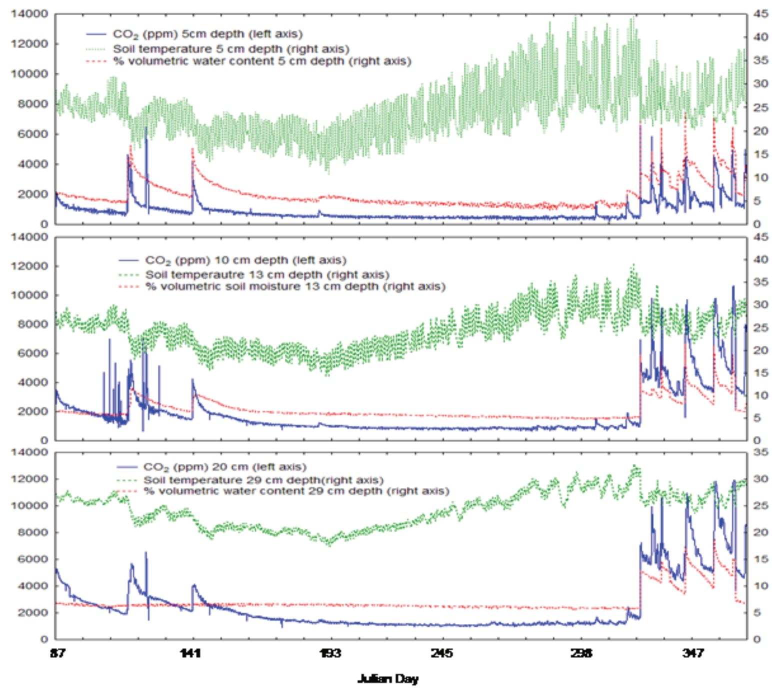


Figure 13. Soil CO_2 concentrations, water content and temperature during 2006 for an undercanopy sampling location. Note the close correspondence between soil CO_2 and water content through the year.

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*

THE ROLE OF STRATOCUMULUS CLOUDS IN MODIFYING POLLUTION PLUMES TRANSPORTED TO THE NORTH AMERICAN CONTINENT

Principal Investigator: Sonia M. Kreidenweis

NOAA Project Goal: Climate. *Programs*: Climate Observations and Analysis; Climate Forcing; Climate Predictions and Projections.

Key Words: Aerosols; Carbonaceous Aerosols; Direct Aerosol Climate Effects; Indirect Aerosol Climate Effects; Secondary Organic Aerosol (SOA); Tropospheric Chemistry

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

Our specific goals were to:

--analyze historical IMPROVE data for significant events of transport from Asia, Africa, Mexico and Central America, and Canada;

--participate in DYCOMS and ITCT 2K2 field studies, in data interpretation and in modeling of case studies of aerosol-gas-cloud interactions;

--perform theoretical modeling studies of aerosol processing pathways.

We used the database from the IMPROVE (Interagency Monitoring of Protected Visual Environments) network, a cooperative study between the National Park Service and a number of other agencies, that monitors aerosols in U.S. National Parks. The network began collecting data in 1988 and thus over a decade of twice-weekly, 24-hour integrated aerosol samples have been analyzed and recorded. We developed markers for smoke-impacted aerosols, as well as for Saharan dust. The accuracy of the proposed markers was tested via known long-range transport events before extrapolation of methodologies to the full data set.

In the aerosol-gas-cloud modeling effort, our modeling framework was made available for data interpretation for the DYCOMS-II and ITCT-Y2K projects, and we continue to stay in contact with the science teams for possible collaborative work. We continued work in theoretical exploration of aerosol-gas-cloud interactions using our models with initial and boundary conditions based on typical atmospheric conditions. We have extended the model capabilities by including a full description of gas-phase photochemistry, by expanding the aqueous-phase chemical mechanism to include formation of organic species, and by including a complete thermodynamic treatment of organic and inorganic aerosol species.

2. Research Accomplishments/Highlights:

Long-range transport of aerosol

We examined whether the Canadian smoke plumes responsible for episodic elevated CO during the 1995 Southeastern Oxidants Study (Wotawa and Trainer, 2000) can be detected in the IMPROVE aerosol database (1988-present). Data from four IMPROVE sites near or within the SOS95 region were used: Great Smoky Mountains National Park, TN (GRSM); Mammoth Cave National Park, KY (MACA); Sipsey Wilderness, AL (SIPS); and Shining Rock Wilderness, NC (SHRO). Data from three sites outside the SOS95 region were also examined: Jefferson/James River Face Wilderness, VA (JEFF); Shenandoah National Park, VA (SHEN); and Upper Buffalo Wilderness, AR (UPBU). Non-soil potassium was chosen as a tracer for biomass burning. The primary sources of potassium in aerosols are soil, sea salt, and smoke; with appropriate assumptions regarding the soil and sea-salt contributions, the potassium (K) associated with smoke can be isolated. We flagged samples as smoke-influenced if this smoke-derived K concentration exceeded a calculated background value. Backward isentropic trajectories were then used to identify source regions for the aerosols in each sample, and compared with available databases on fire locations and durations.

Our methodology successfully identified the smoke plumes documented by Wotawa and Trainer (2000), and did not falsely detect smoke impact at sites outside the main transport path. Based on the success of the methodology for this and a second 1998 case study, we applied it to the historical database to develop estimates of the annual frequency of occurrence of transport of smoke from wild fires to the eastern and southeastern U.S. These ranged from about 5% to up to 15% of the aerosol samples being influenced by long-range transport of smoke.

Our work showed that transport of smoke from Mexico and Central America occurs during springtime and can impact parks as far north as Shenandoah. Transport from Canada dominates later in the summer. Transport from fires in parks in the western U.S. was insignificant – almost no back-trajectories, for smoky or non-smoky conditions, could be traced to the intermountain west, so the transport of aerosols from this part of the country has minimal impact on the southeastern U.S. Finally, we confirmed that North African dust can be positively identified by increases in the ratio of Al/Ca in fine particles, as proposed by Perry et al. (1998).

Graduate student Elizabeth Zarovy was supported by this grant. She defended her M.S. thesis in November 2002.

Although this study showed that smoke-derived K can be a useful tracer for biomass burning, it must be emphasized that it cannot give a quantitative estimate for smoke contribution to total aerosol concentrations. Our analyses indicate that there is no simple relationship between smoke impact and elevated aerosol concentrations. Progress in this arena will require regional modeling of various aerosol sources and aerosol transport and transformation in the atmosphere.

Modeling studies of aerosol-gas-cloud interactions

Cloud processing of aerosol through both drop collision-coalescence and aqueous chemistry was simulated with the aid of a large eddy simulation model and fully coupled components that represent (i) size-resolved aerosol, (ii) size-resolved microphysics, and (iii) the conversion of SO_2 to sulfate via aqueous chemistry. Our prior work has shown that the outcome of processing in a stratocumulus-capped marine boundary layer depends strongly on the cloud liquid water content, aerosol concentrations, trace gas concentrations, and contact time with a cloud. The current model represents spatial and temporal variability of these parameters at large eddy scales on the order of a few hundred meters and time scales on the order of a few seconds. A number of scenarios were investigated: (i) a case with relatively low aerosol concentrations in which aqueous chemistry processing does not substantially affect drizzle; (ii) a case with intermediate aerosol concentrations of relatively large size in which drizzle is suppressed by aqueous chemistry; (iii) a case with intermediate aerosol concentrations of relatively small size in which drizzle is enhanced by aqueous chemistry. The simulations indicate that aqueous chemistry can modify the dynamics and microphysics of stratocumulus clouds and illustrate the complexity of the coupled system. This work suggests that parameterizations of the effects of cloud processing of aerosol require careful consideration of the myriad feedbacks in the cloudy boundary layer. The paper describing these findings appeared in 2002 in *J. Geophys. Res.*

We have expanded the gas- and aqueous-phase mechanisms used in our parcel model so that additional types of chemical processing, other than simply conversion of S(IV) to S(VI), can be considered. The model now includes full descriptions of gas-phase photochemistry and aqueous-phase production of organic species. We have applied this model to investigate processes leading to observed organic acid and formaldehyde concentrations in fogs from the San Joaquin Valley of California. We found that mass transport limitations can lead to chemical heterogeneities between large and small drops, that the aqueous-phase concentrations were not in equilibrium with the gas, and that chemical reactions producing organic species were also rapid enough compared with mass transport to help drive the concentrations from equilibrium. A manuscript describing this work appeared in *J. Atmos. Chem.*

In related work, we have coupled the chemical model to a thermodynamic model of inorganic and organic aerosol and aqueous species that was provided by colleague Dr. Simon Clegg. The model has been used to compute realistic bounds on aqueous-phase aerosol organic species production rates. To our knowledge this is the first model to include the full set of relevant reactions and thermodynamics and to have been applied to estimate aerosol mass addition by organic species in-cloud. We conducted a series of tests that examine the degree to which in-cloud production of organic species can enhance particulate mass concentrations, can generate mixed-composition particles, and can trigger modifications in cloud microphysical properties. This information is needed to complement the large body of work in the literature that focuses on similar effects, but only for inorganic species, which in some instances constitute less than half the total aerosol mass concentration. We also used a variant of this model to examine sensitivity of aerosol indirect effects to aerosol composition, and showed this sensitivity to be much smaller than the current large range reported in the literature, if parameter space is reasonably constrained.

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 have found application in reducing the current large uncertainty in estimates of radiative forcing of climate by aerosols. Our work will also help elucidate the relative roles of biogenic and anthropogenic secondary organic aerosol precursors, which have implications for regulatory policies, visibility, and health impacts. The aqueous-phase model that was developed has been used by at least two other groups, at Caltech and Rutgers, in the evaluation of laboratory and field data.

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

We collaborated with Dr. Graham Feingold, NOAA/ESRL, on this project.

6. Awards/Honors: None.

7. Outreach:

The project PIs presented aspects of this work at numerous conferences, workshops, and invited seminars (see partial listing below).

8. Publications:

Ervens, B., P. Herckes, G. Feingold, T. Lee, J. L. Collett, Jr., and S. M. Kreidenweis, “On the drop-size dependence of organic acid and formaldehyde concentrations in fog,” *Journal of Atmospheric Chemistry*, 46, 239–269, 2003.

Ervens, B., G. Feingold, G. L. Frost, and S. M. Kreidenweis, “A modeling study of aqueous production of dicarboxylic acids 1: Chemical pathways and speciated organic mass production,” *Journal of Geophysical Research*, 109, D15205, doi:10-1029/2003JD004387, 2004.

Ervens, B., G. Feingold, S. L. Clegg, and S. M. Kreidenweis, “Aqueous production of dicarboxylic acids 2: Implications for cloud microphysics,” *Journal of Geophysical Research,* 109, D15206, doi:10-1029/2003JD004575, 2004.

Ervens, B., G. Feingold, and S. M. Kreidenweis, The influence of water soluble organic carbon on cloud drop number concentration*, J. Geophys. Res*., 110, D18, D18211, doi: 10.1029/2004 JD005634, 2005.

G. Feingold, S. Clegg and S.M. Kreidenweis, “Modificaion of internally mixed organic/inorganic aerosols by cloud chemistry”, presented at the 22nd Annual American Association for Aerosol Research Conference, Anaheim, CA, October 20-24, 2003,.

Ervens, B., G. Feingold, S. M. Kreidenweis, and S. L. Clegg, “Organic aerosol mass production in clouds: Modification of the hygroscopic behavior of inorganic aerosols,” presented at the AGU Meeting, Nice, France, April 25–30, 2004.

Ervens, B., G. Feingold, P. Herckes, J. Collett and S. Kreidenweis, “Uptake of Organic Acids by Water Droplets,” presented at the AGU Fall Meeting, San Francisco, California, December 6–10, 2002.

Feingold, G. and S. M. Kreidenweis, “Cloud Processing of Aerosol as Simulated by a Large Eddy Simulation with Coupled Microphysics and Aqueous Chemistry,” *Journal of Geophysical Research*, 107(D23)6-1-6-15, 2002.

Feingold, G. and S. M. Kreidenweis, “Cloud Processing of Aerosol as Simulated by Large Eddy Simulation with Coupled Microphysics and Aqueous Chemistry,” presented at the 11th Conference on Cloud Physics, Ogden, Utah, June 3–7, 2002.

Feingold, G. and S. M. Kreidenweis, “Aerosol-Cloud-Chemistry Interactions in a Large Eddy Simulation,” presented at the 21st Annual AAAR Conference, Charlotte, North Carolina, October 7–11, 2002.

Feingold, G., S. M. Kreidenweis, H. Jiang and W. R. Cotton, “Large Eddy Simulations of Aerosol-Cloud-Chemistry Interactions,” presented at the AGU Fall Meeting, San Francisco, California, December 6–10, 2002.

Koehler, K., S. Kreidenssweis, A. Prenni, P. DeMott and C. Carrico, “Water Activity and Critical Supersaturations Estimated from Hygroscopicity Measurements. “presented at the 23rd Annual American Association for Aerosol Research Conference, Atlanta, GA. October 4-8, 2004.

Kreidenweis, S.M., C. J. Walcek, G. Feingold, W. Gong, M. Z. Jacobson, C. H. Kim, X. Liu, J. Penner, A. Nenes, and J. H. Seinfeld, “Modification of aerosol mass and size distribution due to aqueous-phase SO_2 oxidation in clouds: comparisons of several models,” *Journal of Geophysical Research,* 108, (D7), 4213, 10.doi:1029/2002JD002697, 2003.

Kreidenweis, K. Koehler, and P. J. DeMott, “Water activity estimates from hygroscopicity data, Part I: Theory and application to inorganic salts,” *Atmospheric Chemistry and Physics*, 5, 1-14, 2005.

Kreidenweis. S.M. and G. Feingold, “Modeling of Cloud Droplet Number Concentrations and Their Link to Aerosol and Cloud Chemistry,” presented at the AGU Fall Meeting, San Francisco, California, December 6–10, 2002.

Kreidenweis, S.M., “The Impact of North American Fires on Aerosol in the U. S.,” presented at the AGU Fall Meeting, San Francisco, California, December 8–12, 2003.

Zarovy, E.M., 2002: “Detection of Smoke Impact in Aerosol Samples in the Eastern and Southeastern United States During Late Spring and Summer,” M. S. Thesis, CSU,

Zarovy, E.M. and S. M. Kreidenweis, “Smoke Contributions to Summertime Aerosols in the Eastern and Southeastern U.S.,” presented at the 21st Annual AAAR Conference, Charlotte, North Carolina, October 7–11, 2002.

ULTRASONIC DEPTH SENSORS FOR NWS SNOW MEASUREMENTS IN THE US: EVALUATION OF OPERATIONAL READINESS

Principal Investigator: Nolan Doesken

NOAA Project Goal: Climate and Climate observations and analysis

Key Words: Ultrasonic Sensor, Snowfall Algorithm, Snow Depth,

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 personnel there.

Objective 2: Evaluate instrument siting, exposure, installation and system engineering specifications prior to the 2006-2007 winter season. Recommend a standardized station configuration. Then 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 snowdepth 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. Canadian collaboration was initiated promptly culminating in a 3-day “Snow Measurement Workshop” held at Environment Canada in Downsview, Ontario in July 2006. This meeting produced several recommendations for instrument siting and measurement intercomparisons which will be conducted cooperatively in each country for the 2006-07 winter season.

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

Objective 1 is in progress with Environment Canada. Objective 2 , engineering evaluation and site configuration, is also well underway. Other objectives have yet to be started.

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 forecast and 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, Communication and Networking:

Environment Canada, National Weather Service, USDS website

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) Wendy Ryan was hired to continue ultrasonic snow depth sensor work as a natural extension of her Master’s Thesis.

8. Publications:

None

ADDITIONAL CIRA FUNDING

BERMUDA BIOLOGICAL STATION FOR RESEARCH INC. (RISK PREDICTION INITIATIVE)

Exploiting Infrared Satellite Data to Estimate Tropical Cyclone Wind Radii

Principal Investigator: J.A. Knaff

NOAA Project Goal: Weather and Water, Commerce and Transportation

Key Words: Tropical cyclone, Satellite, Winds

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

To develop and apply a method to estimate tropical cyclone wind structure from infrared (IR) imagery. This imagery is already routinely used around the globe to estimate tropical cyclone intensity. The algorithm will be developed from about 250 cases from 1995-2003 for which corresponding aircraft reconnaissance is available. This algorithm will then be applied to the extensive archive of IR data that resides at CIRA (more than 70,000 images from storms around the globe). The IR algorithm and the wind structure statistics from the algorithm will be created.

2. Research Accomplishments/Highlights:

This study used IR data to estimate the wind structure of a TC through estimates of the radius of maximum winds (RMAX) and the wind speed at 182 km (V182). The estimative algorithms were developed using 12-hourly analyses of 405 aircraft reconnaissance cases from the 1995-2003 Atlantic and Eastern Pacific hurricane seasons along with corresponding IR imagery. A multiple linear regression analysis technique was applied to develop a model to predict these two parameters. Independent tests were performed on 50 cases from the 2004 hurricane season. The RMAX and V182 estimates were subsequently used in conjunction with a modified combined Rankine Vortex wind model to estimate the symmetric tangential wind profile out to 202 km from storm center. Additionally, storm motion derived wind asymmetry was added to the symmetric wind profile to provide a reconstruction of the entire 2-D wind field, at each of 51 radial, and 16 azimuthal grid points. An example of the algorithm’s output is shown in Figure 1.

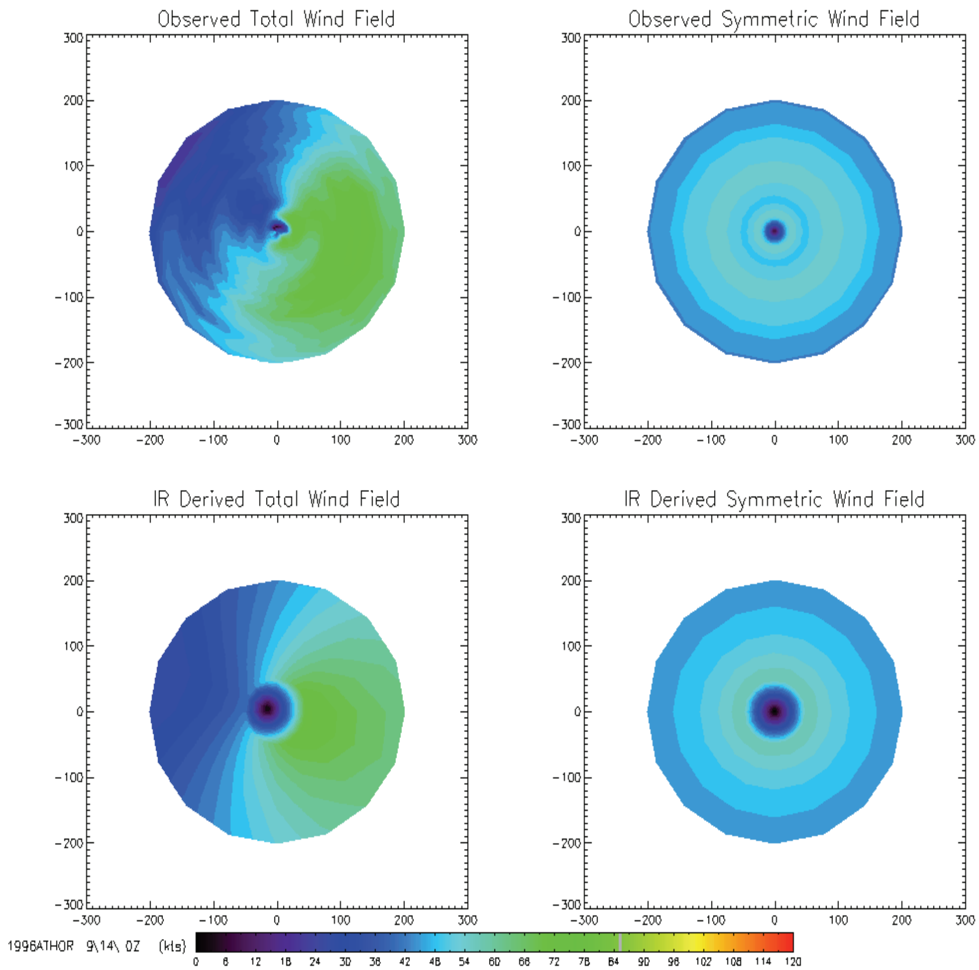


Figure 1. Four panel plot of the aircraft observed vs. IR-derived symmetric and total wind fields for Hurricane Hortense on September 14, 1996 at 00Z.

The formulation of the algorithm, fitting a modified Rankine vortex, results in biases that are a function of intensity. To rectify these biases, the algorithm was modified so that it better fit the observed wind radii for the cases with aircraft reconnaissance. This basically extended (contracted) the 34-kt wind radii outward (inward) for weaker (stronger) storms and contracted the 64-kt winds inward for storms with intensities greater than 95 kt. The final corrected wind radii algorithm was then run on the data in the IR archive and probability density function stratified by intensity were delivered to the sponsor.

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

All stated objectives were met during the 1-year reporting period.

4. Leveraging/Payoff:

This algorithm provides vital information concerning the inner core (within 150 km of the center) wind structure of the tropical cyclone that is typically available only from aircraft data. As a result, this algorithm can be used in conjunction with other satellite-derived data to create a satellite-only tropical cyclone wind analysis, which includes the inner core region. Such a product would be available globally. This is important as routine aircraft reconnaissance is available only in the N. Atlantic.

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

This work was funded by a consortium of re-insurance companies and the resulting algorithms are in the public domain. The algorithm can be applied to other applications such as combining the output with other wind datasets, monitoring the size of tropical cyclones etc which are important to NOAA, DOD and local emergency managers.

The statistics created from the output of this algorithm is expected to be useful information for the insurance industry allowing better estimates of the risks involved in their business.

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.-e) None, except (b), See section 8

8. Publications:

Refereed Journal Articles
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,* in press.

Conference Proceedings

Knaff, J.A., and C. Sampson, 2006: Reanalysis of West Pacific tropical cyclone intensity 1966-1987. *AMS 27th Conference on Hurricanes and Tropical Meteorology.* 24-28 April, Monterey, CA.

Presentations

Knaff, J., September, 2005: Exploiting Infrared Satellite Data to Estimate Tropical Cyclone Wind Radii. *The RPI Research Update Workshop*, 2005, St. George, Bermuda.

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

--Hydrometeorology
--Cloud Structure, Dynamics and Climatology
--N-Dimensional Data Assimilation and Data Fusion
--Boundary Layer Atmospheric Chemistry and Aerosols
--Derivation 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 is evident in the significant impacts CG/AR research has had 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 is a brief description of some of the CG/AR research highlights that have been completed or have made substantial progress in the last year by theme area.

Hydrometeorology

NOAA Project Goal: Weather and Water
Related Programs: Hydrology, Environmental Modeling, Local Forecasts and Warnings, Environmental Modeling, Weather Water Science, Technology, and Infusion

Summary - The military is interested in improved hydrology models for use in overland surface flows, as well as for predictive erosion and deposition models. This is highly applicable to environmental quality issues related to the DoD with monitoring and control of their various military training grounds, in addition to having Homeland Security implications.

Research Accomplishment/Highlights:

a. Completed a toxic transport for overland flows and streams. This model, based on the hydrological model CASC2D-SED and soil chemistry models that simulate leeching, solution, and precipitation of metallic ions has been developed to predict the movement and deposition of toxic metals such as cadmium, copper, and zinc. The model is clearly applicable to Homeland Security concerns.

b. We are in the advanced stages of work on a new first principles hydrologic hillside slope model called HYDOR. This model is comparing well with the CASC2D-SED network model and will be scalable to very fine scales (puddles) up to scales large enough to be directly congruent to atmospheric models (kilometers).

Hydrometeorology - Applications of WindSat for Soil Moisture Satellite Data Assimilation and DoD Impact Studies

NOAA Project Goal: Weather and Water
Related Programs: Local Forecasts and Warnings, Environmental Modeling, Weather Water Science, Technology, and Infusion Program

Summary - This work performs advanced soil moisture satellite data assimilation research and error analysis using newly available WindSat passive microwave data. This work will reduce risks associated with the NPOESS CMIS EDR scientific algorithms by using current heritage sensors and WindSat, and specifically lead toward objective performance levels (i.e., sensing of deep soil moisture) for the soil moisture EDR. The work is funded by the NPOESS IPO via the CIRA cooperative agreement with the Army Research Lab (ARL).

Approach - There are three main components of this work: 1) application of satellite data assimilation using a 4DDA system (RAMDAS) developed at CIRA in the DoD Center for Geosciences / Atmospheric Research (CG/AR) to the problem of profiling soil moisture to a depth between 10 and 100 cm, 2) Soil Moisture and Land Surface Temperature EDR application research exploiting WindSat and other available satellite data sets (e.g., AMSU and GOES) for masking phenomenology (e.g., vegetation and microwave surface roughness) studies, and 3) application and improvement of Backus-Gilbert techniques for use within RFI-contaminated environments.

The following project goals have been met:

- --Stand alone WindSat Soil Moisture EDR retrieval software.
- --An improved version of the CIRA 1-Dimensional Optimal Estimator (C1DOE WindSat SM EDR retrieval software.
- --WindSat-specific Discrete Backus-Gilbert spatial filter implementation.
- --Analysis of Army-relevant sensitivity tests using the CMIS data retrieval software at ARL (Rapp et al., 2007).

--Initial SM EDR masking phenomology case study preparations and preliminary research results.
--Creation of quality controlled ERDC data set archives used for validating the study results (Combs et al., 2007).

Research Accomplishment/Highlights:

a. The science team coordinates research activities with the NPOESS Soil Moisture Working Group which meets throughout the year. Meetings have been held at Silver Spring, MD.

b. Key Army-relevant sensitivity tests using the CMIS simulation system at ARL were successfully completed.

c. The stand-alone soil moisture retrieval system is now being used with the WindSat data sets with validation of the method underway.

d. We also continue work toward a substantial revision of that system toward a more sophisticated 1DVAR approach. The new 1DVAR work is in progress.

e. The new Backus-Gilbert spatial filter work has been completed. The software was delivered to the IPO, with several journal papers either submitted or in progress. A technical report detailing a recent 2D DBG implementation remains in progress.

Conclusions and Recommendations - This project is part of a larger national scientific effort (via the NPOESS Soil Moisture Working Group) to perform soil moisture remote sensing below the earth's surface and evaluate and overcome the inherent associated technical and scientific difficulties. This requires the use of more advanced satellite data assimilation techniques. The framework for using the WindSat satellite data as a surrogate for the CMIS EDR algorithm sensitivity tests, and the validation of current masking phenomenologies is a key objective of the project. All WindSat data preparation work necessary for the advanced 4DDA work has progressed well and is on schedule.

The new discrete Backus-Gilbert (DBG) method is an improvement over existing spatial filter methods, by allowing the method more flexibility while controlling the error propagation behaviors. Some of this work is fundamental to the use of Backus-Gilbert theory to the satellite application area. New publications on the 2D implementation of the DBG work demonstrate improved spatial filter behaviors in the presence of light RFI contamination. We recommend that the DBG be used as a method to improve NPOESS microwave sensor performance in the presence of RFI contamination.

Future Work and Plans - Future work includes 1) deep soil moisture analysis using WindSat in conjunction with 4DDA techniques, 2) Soil Moisture EDR masking phenomenology study results, 3) improvements to the stand-alone soil moisture EDR retrieval software, with final data analysis and conclusions.

Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

The second year of the project is complete and all second year goals were successfully met.

Leveraging/Payoff:

This work is a combined effort between CIRA, ARL, and the US Army Corps of Engineers (ERDC). Specialized DoD data sets are being provided by ERDC for the soil moisture validation efforts of this work, and the ARL facilities are being used to run the proprietary CMIS EDR simulation software. This allows CIRA to contribute to the next series of operational satellites focusing on the soil moisture EDR for NPOESS (NPOESS will generate the first operational soil moisture EDR product). Thus this work is a risk mitigation activity for the operational NPOESS program.

Research Linkages/Partnerships/Collaborators:

This work was funded by the NPOESS IPO via ARL. 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). The project team has routine telecoms approximately every two weeks. Our project also interacts with the NPOESS Soil Moisture Working Group.

Cloud Structure, Dynamics and Climatology

a. Our field program to collect data on complex layered non-precipitating clouds (CLEX-10) is scheduled to provide validation data for CloudSat this coming winter in Eastern Canada. This research has already provided insight into improvements in modeling ice, water, and mixed-phase clouds critical to aircraft icing and precipitation modeling.

b. A related paper titled “What determines altocumulus dissipation time?” has been accepted by JGR. This paper is written by Adam Smith, one of Prof. Vincent Larson’s students and funded by CG/AR.

N-Dimensional Data Assimilation and Fusion

NOAA Project Goal: Weather and Water
Related Programs: Environmental Modeling, Weather Water Science, Technology, and Infusion

Summary - Data assimilation technologies are used heavily within the CG/AR research program. The primary focus of the methods is to improve model initial conditions that allow for better prognostic weather forecasts. In addition to this emphasis, research opportunities abound for exploration of data information content, model physics parameterization insights and improvements, and quantitative model error analysis using the data assimilation techniques. Two primary techniques are in use at CG/AR: 1) a 4-dimensional variational technique using a fully coupled mesoscale atmospheric model and land surface model using the Regional Atmospheric Mesoscale Data

Assimilation System (RAMDAS), and 2) the Maximum Likelihood Ensemble Kalman Filter (MLEF).

These major research systems are critical to the next generation of data assimilation technologies for use by NOAA and the DoD. In particular, we are beginning to transition components of our DoD/DA research to the WRF community DA efforts. At this time, this primarily includes collaborations on the WRF-3DVAR and WRF-4DVAR efforts. However, as the advanced MLEF work matures, we expect additional transition possibilities to be explored as well.

The US Army is currently using the WRF-ARW framework, as is the USAF, while the US Navy is developing related WRF-COAMPS components. The WRF-ARW and WRF-NMM efforts are likewise mutually-related through the various national collaboration activities (some explicitly through JCSDA activities and in collaboration with the developers of Common Radiative Transfer Model (CRTM) components, and others through separate contacts with our DoD collaborators).

Research Accomplishments/Highlights:

a. Cloudy data assimilation using explicit microphysics resulted in several related publications. This work demonstrates the ability to use direct radiance assimilation within clouds in both the IR and VIS spectrum. Our sensor focus was on using the Geostationary Environmental Operational Satellite (GOES). Results demonstrated a reduction of the infrared brightness temperature cost function (a measure of system of error) from > 30 K to ~6 K. This is a large improvement for cloudy conditions, especially when the operational context is considered (all operational DA systems typically exclude cloudy conditions as being too difficult for existing DA techniques). This extension to cloudy environments is a major success of the RAMDAS research activities.

b. We are in the process of extending this GOES imager DA work toward GOES Sounder data as well. This has resulted in another publication which focuses on analysis of the GOES Sounder sensitivities as opposed to the GOES imager sensitivities. Initial sensitivity studies indicate the GOES Sounder channels contribute independent and potentially helpful information for clouds, in particular for the water vapor field which surrounds and supports the cloudy environment.

c. The MLEF was used in 2-dimensional large-scale eddy simulations (LES) using the CSU Regional Atmospheric Modeling System (RAMS). The emphasis of this work is arctic boundary layer clouds. Interactions with the various ice nucleation processes and other model cloud physics parameters are undergoing additional tests using the available arctic observational data sets.

d. We are performing model error covariance localization work using local influence functions to improve the model error estimation and have shown an ability to improve the overall MLEF system performance. This work used a Lagragian Particle Dispersion Model (LPDM) to estimate carbon fluxes using simulated observations of CO_2.

e. Modified the RAMS two-moment microphysics to work within the WRF-ARW dynamical framework. This provides WRF with its first two-moment cloud microphysics scheme. This has potential applications toward aerosol feedback studies, and more advanced ice nucleation studies for cirrus and arctic clouds, all of which are great importance for climate change research.

f.   Analyzed and published the potential vorticity impacts of the MJO. Understanding typhoon interactions within the wake of an MJO event could be important for medium to long-range forecasting of typhoons.

Boundary Layer Atmospheric Chemistry and Aerosols

NOAA Project Goals: 1) Climate. Related Programs: Climate Observations and Analysis, Climate Predictions and Projections, Regional Decisions Support
2) Water and Weather. Related Programs: Local Forecasts and Warning, Air Quality, Environmental Modeling
Key Words: Aerosols, Aerosol Forecasting, Dust, Long-range Transport, Visibility, Aerosol Optical Depth

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

The Navy Aerosol Analysis and Prediction System (NAAPS) is one of the first web-based aerosol forecast products to be made available to the community and to the general public. It finds extensive use in a variety of applications, including as an aid to military tactical decision-making. During the ongoing development of NAAPS, model predictions have been vetted against data in many parts of the world, but the continental U.S. (CONUS) has not been a focus until recently. Our objective is to evaluate model predictions for atmospheric dust concentrations over CONUS for a multi-year time period via comparison to available *in situ* aerosol data. We evaluate both the long-range transport of dust to CONUS from Asia and North Africa, as well as the production of dust from arid regions in North America.

Our methods involve the re-run of NAAPS for years 2001-2004, a task completed by our collaborator at the University of Warsaw. We also identify aerosol composition data from the IMPROVE (Interagency Monitoring of PROtected Visual Environments) network as the preferred *in situ* data set for comparisons (Figure 1). Aerosol data are available every third day, and protocols exist for using reported quantities to estimate the contributions of dust to total ambient aerosol mass concentrations. We compare these surface-based dust loading estimates with the predictions in the lowest model layer, and suggest model improvements based on the results.

Research Accomplishments/Highlights:

A comparison of the Navy Aerosol Analysis and Prediction System (NAAPS) predictions of surface soil dust to IMPROVE measurements throughout the continental U.S. from 2001-2004 allowed an examination of the impact of long-range dust transport from both

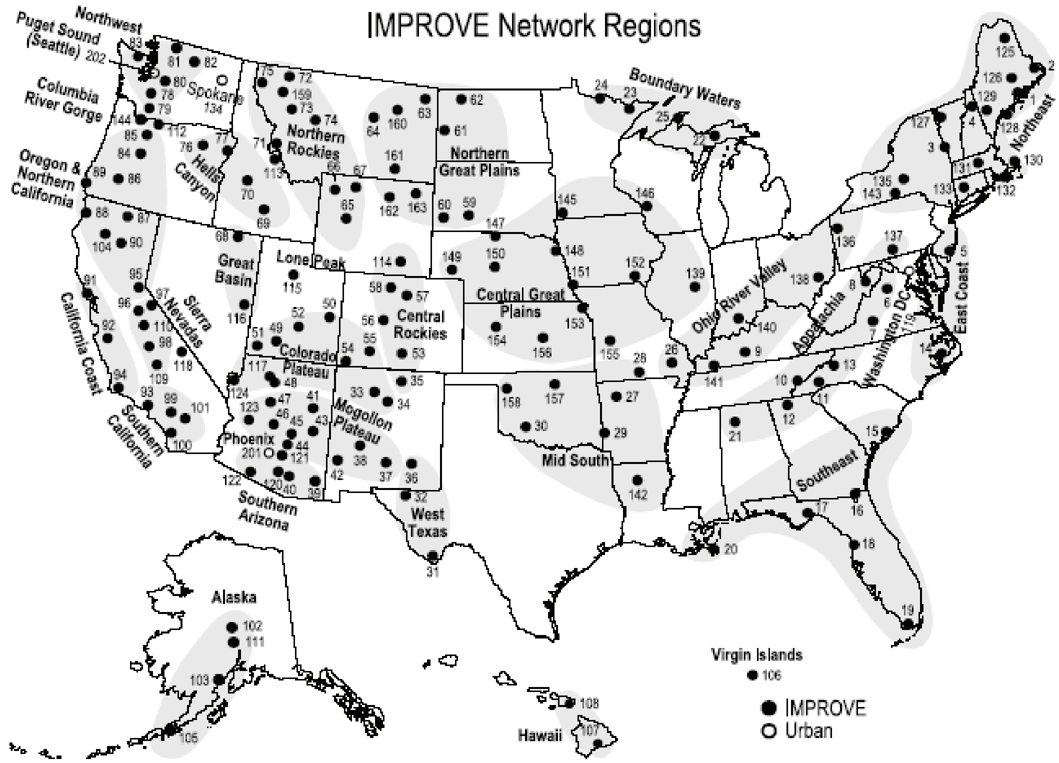


Figure 1. Locations of IMPROVE measurement sites.

Asian and North African sources over North America, since these processes tend to peak at different times of the year. We found that long-range dust in the model tracks well with IMPROVE soil amounts at many sites in the U.S., specifically Asian dust transport in springtime. Overall, comparisons indicated that the model reproduced a reasonable 4-year (2001-2004) long-range dust transport climatology over North America.

Figure 2 shows one example of seasonal model/data comparisons for Theodore Roosevelt National Monument in North Dakota. In springtime, the ratio of model/ observations is centered on 1, indicating good predictive agreement. In other seasons, the model has less skill, and especially in winter and fall overpredicts dust concentrations. North American sources in the model tended to be overactive in fall and winter 2001-2004, as compared to the soil mass measured by IMPROVE. These sources are being investigated and modified with the addition of snow cover information in the model and with an increased threshold friction velocity (Figure 3).

Comparisons to IMPROVE coarse aerosol fraction, which is assumed to contain only insoluble soil particles, have highlighted many uncertainties in the actual composition of this parameter at different U.S. sites. Some limited speciated PM_{10} measurements have revealed that over 60% of the aerosol coarse fraction is composed of species other than soil at coastal sites and those inland sites are frequently impacted by air masses of marine origin. These discrepancies lead to uncertainties in the model–to-observation comparisons.

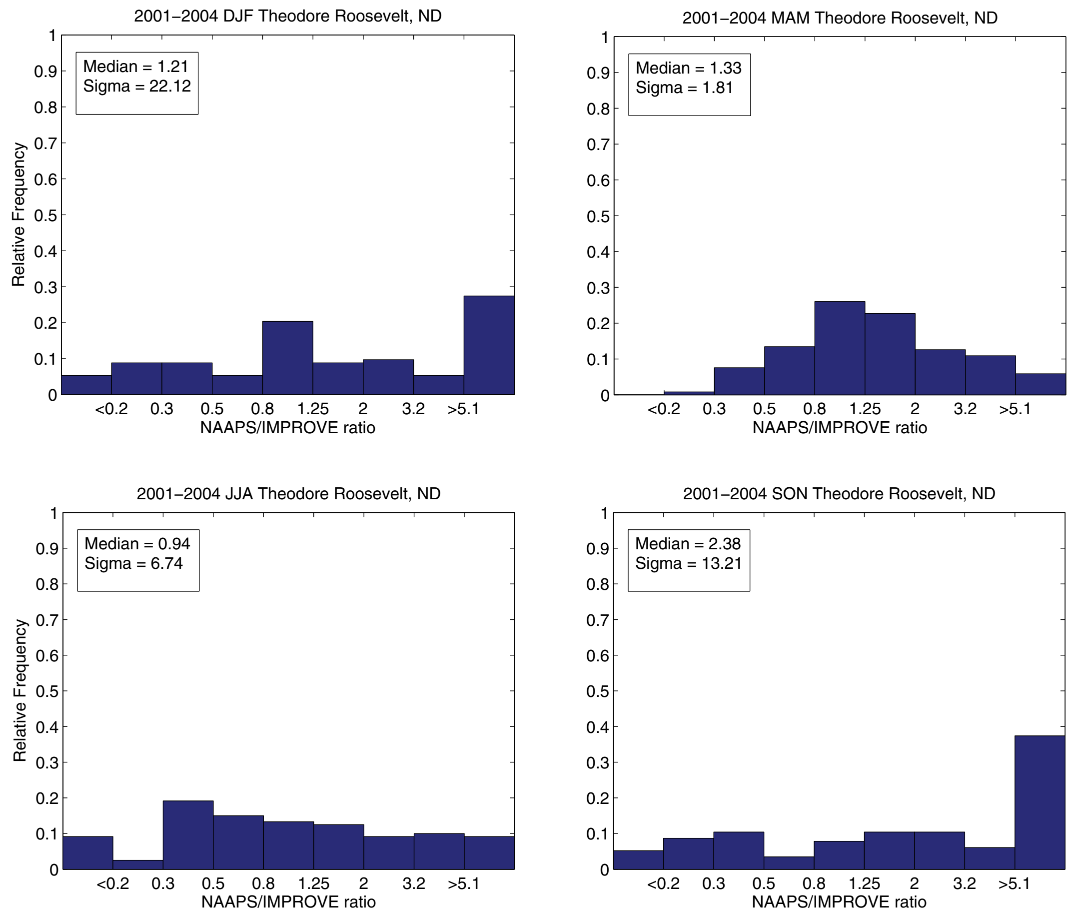


Figure 2. Frequency distributions of the ratio of modeled dust concentrations to observed dust concentration at Theodore Roosevelt National Monument.

Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

We have completed all project objectives, including completion of an M.S. thesis. Kelley Johnson successfully defended her thesis on this work on June 13, 2006. Specifically, our objectives during the reporting period were:

--Re-run of the NAAPS model to generate aerosol output fields for 2001-2004.

--Compilation and quality-control of IMPROVE data from multiple sites across the U.S. for 2001-2004.

--Selection of most appropriate aerosol dust proxy variable for model - *in situ* data comparison.

--Completion of comparisons of NAAPS output with IMPROVE data and analysis of reasons for discrepancies.

--Recommendation of model adjustments to improve dust forecast across the U.S.

Leveraging/Payoff:

The results of this work will be applicable to improvement of dust forecast models, for applications to visibility, climate, and military operations and decision-making.

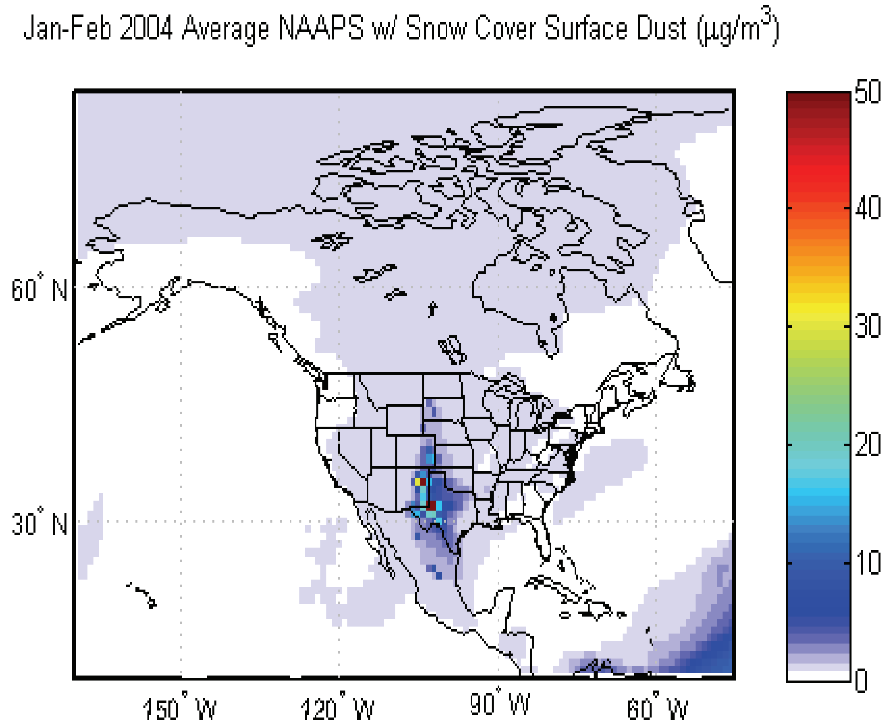


Figure 3(a). Average surface concentration with snow cover.

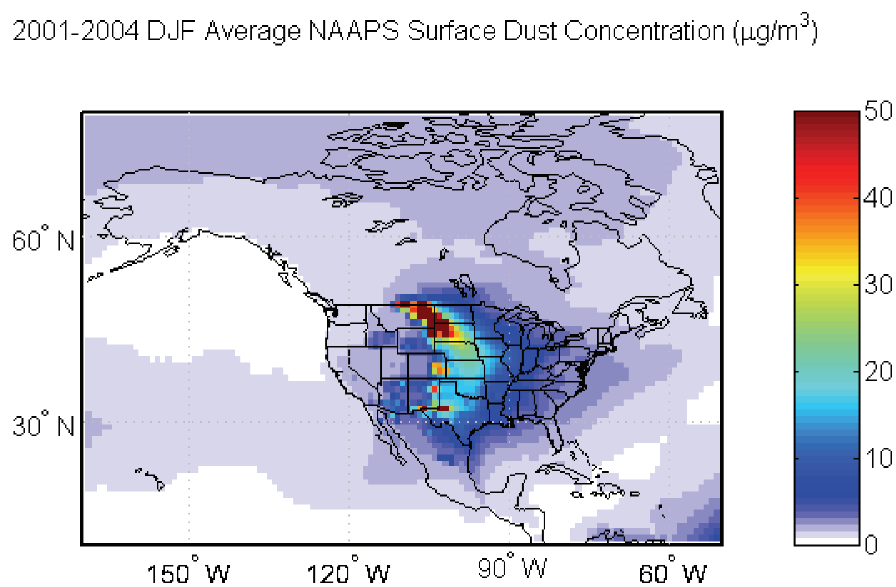


Figure 3(b). 2001-2004 average surface concentration without snow cover.

Research Linkages/Partnerships/Collaborators, Communication and Networking:

We are collaborating with Drs. Doug Westphal and Piotr Flatau at the Naval Research Laboratory in Monterey, CA. We are also collaborating with Ph.D. student Marcin Witek at the University of Warsaw (under Dr. Flatau's advisement), who is providing the NAAPS model re-runs. He has made extended visits to CSU as a visiting scholar in support of this collaboration.

Derivation of Battlespace Parameters

A. GOES Cloud Products for CLEX-10

NOAA Project Goal: Weather and Water, Climate, Commerce and Transportation
Key Words: GOES, CLEX-10, Mid-Level Clouds

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

CLEX-10 is the tenth in a series of Cloud Layer Experiments designed to study the characteristics of mid-level, mixed-phase clouds run by CIRA's Center for Geosciences/Atmospheric Research, and funded by the Department of Defense. CLEX-10 will be run in collaboration with the Canadian CloudSat CALIPSO Validation Project (C3VP) in the fall and winter of 2006. The purpose of this work is to prepare GOES imagery to aid meteorologists in locating the clouds of interest so that the aircraft can get to them, or so that the aircraft measurements can be better interpreted.

Research Accomplishments/Highlights:

A website has been set up with a variety of cloud products to aid CLEX-10 staff. The products currently include:

a. Day/Night Albedo (0.65 μm albedo, day; 3.9 μm albedo, night)
b. 10.7 μm Brightness Temperature ($T_{10.7}$)
c. Water Vapor (6.7 μm Brightness Temperature, $T_{6.7}$)
d. 3.9 μm Albedo ($A_{3.9}$)
e. 13.3 μm Brightness Temperature ($T_{13.3}$)
f. $T_{10.7}$ - $T_{13.3}$ [K, +40 (black) to -8 (white)]
g. Experimental $A_{3.9}$ Cloud Phase
h. $T_{10.7}$ 10-Day Background
i. $T_{10.7}$ Cloud Mask
j. Experimental $A_{3.9}$ Cloud Phase Using $T_{10.7}$ Cloud Mask

These products cover the area of southern Ontario, which is where CLEX-10 will take place. The products run in real time and can be viewed at: http://amsu.cira.colostate.edu/CLEX10.

Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

The objective at this point is to get the website running in preparation for CLEX-10, and that has been accomplished. As CLEX-10 approaches, modifications will take place.

Leveraging/Payoff:

This project, and CLEX-10 in general, are funded by DoD, yet many of the results will be of interest to NOAA.

Research Linkages/Partnerships/Collaborators, Communication and Networking:
NASA, DoD.

Outreach: Publicly available website: http://amsu.cira.colostate.edu/CLEX10.

B. An Assessment of AMSU-A Moisture Retrievals over Land and Ocean

NOAA Project Goal: Weather and Water
Key Words: Precipitable Water, AMSU, Retrievals over Land, Surface Emissivity

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

Microwave satellite observations have been used for many years to retrieve total precipitable water and cloud liquid water over the ocean—even in the presence of clouds—using AMSU-A or SSM/I data. The long-term goal of this project is to retrieve the same quantities over land using AMSU-B data. The purpose of the work outlined here is to determine how well this might be accomplished.

Research Accomplishments/Highlights:

I applied Rodgers (2000) maximum a posteriori (MAP) model to a simulated, simplified atmosphere (in which everything is known) to determine the best that one can hope for in moisture retrieval accuracy using AMSU-A channels and how various factors (especially surface emittance) influence this accuracy. The conclusions are:

--Atmospheric temperature is accurately retrieved over land or ocean
--Surface temperature is accurately retrieved over land, but poorly retrieved over ocean
--Liquid water is marginally retrieved over ocean, but lost in the noise over land
--Water vapor is accurately retrieved over ocean, but probably not retrievable over land with AMSU-A channels
--Retrieving surface emittances instead of treating them as model parameters is unlikely to help
--Adding AMSU-B channels would possibly help with land retrievals
--Experiments with a 1-D optimal estimator should be performed to see if they support these results and to set a course for future research.

Reference:

Rodgers, C. D., 2000: *Inverse Methods for Atmospheric Sounding: Theory and Practice.* World Scientific, 238 pp.

Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

The objectives were accomplished, and they have been incorporated in designing a research path to moisture retrievals over land using AMSU-B data.

Leveraging/Payoff:

NOAA doesn't currently run moisture retrievals over land using AMSU-B data. This research, funded by DoD, is a step in that direction.

Research Linkages/Partnerships/Collaborators, Communication and Networking: DoD

Outreach: Graduate students are involved in other aspects of this work.

C. Satellite Microwave Remote Sensing of Atmospheric Profiles over Land and Water

NOAA Project Goal: Weather and Water
Key Words: AMSU, SSMIS, 1DVAR, Microwave Remote Sensing, Antenna Pattern Correction, Microwave Surface Emissivity, GPS Precipitable Water

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

Microwave remote sensing of the atmosphere over land has lagged behind remote sensing over the ocean. Products which are available to forecasters and climate researchers over ocean are often not produced over land. This is due to the complex radiometric presentation of the surface in this spectral region. This challenging problem has hindered the ability of satellite microwave remote sensing instruments to realize their full potential in weather prediction and climate studies.

This work focuses on developing the science basis to remotely sense profiles of moisture, temperature and clouds over land and ocean from current and future satellite microwave sensors. Determination of surface emissivity is a key goal needed for progress. Work is underway on several fronts to develop tools and techniques to attack this problem.

A CIRA one-dimensional variational (1DVAR) optimal estimation microwave technique, named C1DOE, has been built and incorporated into the powerful Data Processing and Error Analysis (DPEAS) software system developed at CIRA. DPEAS builds a pathway to a wide variety of satellite sensors and supporting data (model fields etc.) to investigate this problem. Currently, the NOAA Advanced Microwave Sounding Unit (AMSU) A and B data is being investigated.

The objectives of this research are to retrieve temperature, moisture and cloud profiles from satellite over land and ocean and determine the errors in the retrieval. Results are being compared to Global Positioning System (GPS) and radiosonde measurements. Improvements upon current remote sensing techniques are also sought, such as numerical solution techniques and modeling of clouds. The ultimate goal of this research is to create algorithms which will be useful both in real-time analysis and weather prediction and in studies of Earth's atmosphere for climate.

A particular challenge of this work is to constrain the problem sufficiently through the determination of the microwave land emissivity. A science question of interest is how well must emissivity be known and whether it should be solved for explicitly in the retrieval or specified as a model parameter.

Research Accomplishments/Highlights:

The work requires the highest precision possible from the satellite measurements, to capture the weaker atmospheric signals over land. A first step in this direction was the development of an AMSU-B antenna pattern correction, which removed a bias of roughly 2- 4 K from the measurements (M. Nielsen, M.S. Thesis). Up to a 10 % impact may occur for water vapor mixing ratio in the upper troposphere.

A global radiosonde/satellite matchup dataset has been created from September 2003 to allow science experiments. There are about 6000 matchups in the dataset, with supporting ancillary data. The Global Data Assimilation System (GDAS) data from NCEP has been captured for this time period. Experiments are underway with this dataset to determine:

--What is the radiative transfer model bias?
--How well can water vapor profiles be retrieved with a variety of instrument and first guess errors?
--How well does C1DOE perform in cloudy atmospheres?

Kevin Donofrio (M.S. Student) is investigating these questions.

A near-realtime system has been created to demonstrate the current performance of C1DOE and to serve as an experimental testbed for science changes. Figure 4 shows an example of the output from June 8, 2006 for a NOAA-16 overpass over the CONUS, along with the GOES 11 μm data and GPS / AMSU / SSMI merged total precipitable water (TPW) product. Currently, clouds are not enabled in the retrieval, so no solution is the correct answer in cloudy regions. A research topic is understanding why the retrieval is non-convergent in some areas.

C1DOE is currently configured to retrieved temperature, moisture and clouds as 7 levels in the atmosphere, along with surface emissivity at 5 bands from 23 to 183 GHz.

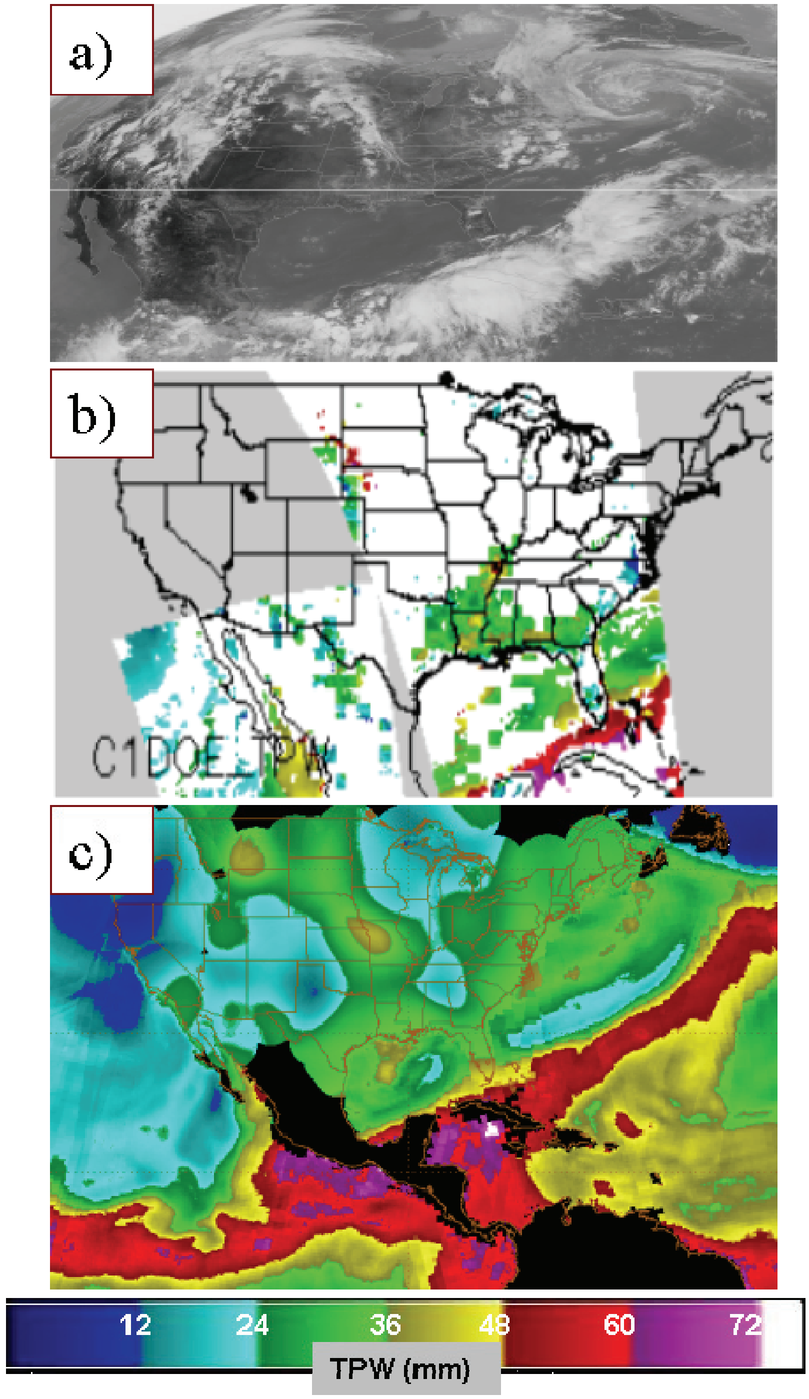


Figure 4. a) GOES Infrared image, June 8, 2006, 2030 UTC. b) The C1DOE total precipitable water retrieval (mm). c) The GPS/AMSU/SSMI merged satellite TPW retrieval used for comparison.

A research accomplishment to support this task was the incorporation of realtime GPS total precipitable water (TPW) vapor over land from NOAA Global Systems Division into a merged satellite product. This product mimics what we aspire to derive from passive microwave satellite sensors, except the microwave retrievals will also have vertical

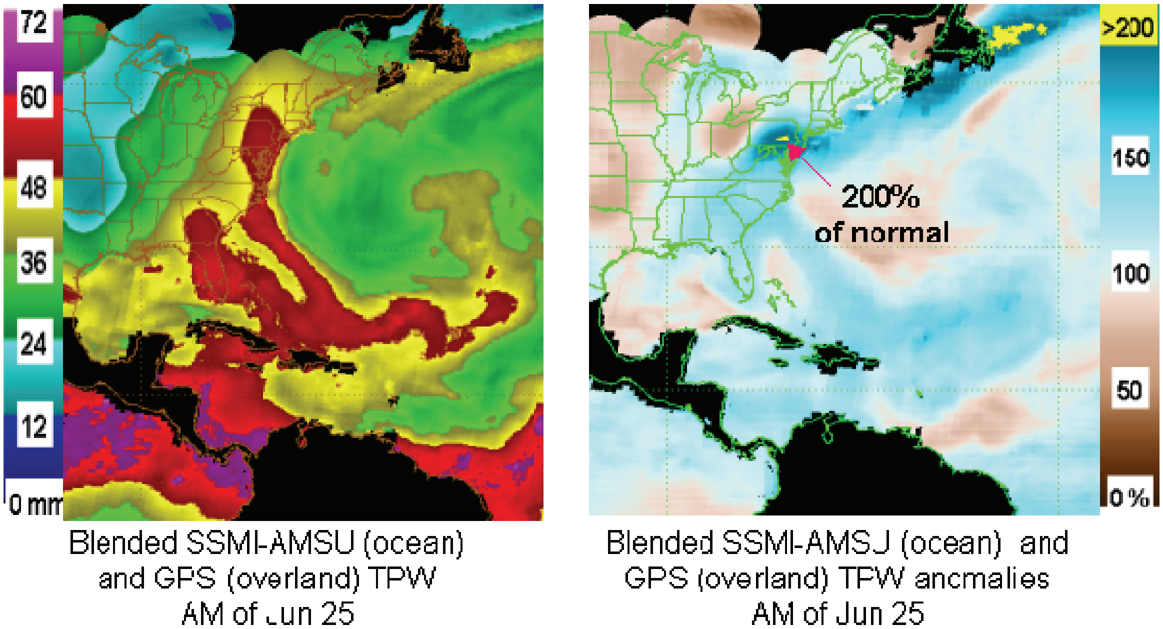


Figure 5. Blended AMSU / SSMI / GPS total precipitable water product on the morning of June 25, 2006. Notice the flux of tropical moisture up the east coast. Rainfall records were broken in the Washington, D.C. area and destructive flooding occurred.

profiles. The GPS measurements are extremely accurate and are of great use in validation of satellite retrievals.

Figure 5 shows an example of the merged product during a large flux of moisture into the U.S. East Coast in June 2006. The GPS fields were readily added to the realtime satellite data flow already running at CIRA in the Data Processing and Error Analysis (DPEAS) system and being used by NOAA forecasters. This product has received accolades from the NOAA Hydrometeorological Prediction Center and by Science Operations Officers (SOO's) in the NWS. We intend to use this product for validation and interpretation of the C1DOE retrievals, but it is a good spinoff from this DoD-sponsored research that shows value to forecasters now.
Comparison of Objectives vs. Actual Accomplishments for Reporting Period:

Complete: Development of an AMSU-B antenna pattern correction. Delivered to Fuzhong Weng, Ralph Ferraro (NOAA), and Ben Ruston - Naval Research Lab (Monterey).

Complete: Near-realtime retrieval system over CONUS using NOAA-16 data.

In Progress: Journal papers on validation of ocean and land atmospheric profiling performance in clear sky.

In Progress: Study of emissivity error impact and whether to make emissivity a model parameter or solve explicitly.

In Progress: Addition of liquid cloud parameterization and dynamic creation / destruction of cloud liquid water.

In Progress: Bias study of C1DOE radiative transfer model and comparison to the NOAA CRTM model.

Yet to be started: Inclusion of infrared data into retrieval.

Leveraging/Payoff:

Once microwave retrievals are realized over land, there should be a positive impact on products used to forecast the weather. Many current microwave products have “blacked out” regions over land. This will supply forecasters with more awareness of the entire weather situation. Figure 1 illustrates this using GPS as a proxy for AMSU retrievals.

One of the factors controlling hurricane intensity is entrainment of dry air from the environment. Water vapor profile retrievals from AMSU will capture these features and help provide information useful for intensity forecasts – the most challenging aspect of hurricane forecasting.

The AMSU instrument is a predecessor for planned instruments on the next generation of NOAA/DoD/NASA satellites. This research will transfer to the new instruments and allow users to benefit from the investment in these sensors.

Animations of the experimental merged GPS and satellite products are available on this website, updated every 6 hours:

http://amsu.cira.colostate.edu/GPSTPW

Research Linkages/Partnerships/Collaborators, Communication and Networking:

DoD is supporting this work; spinoffs will flow back to NOAA. The water vapor profile retrieval and land emissivity knowledge are very important to both DoD and NOAA to improve forecasting. This work has been discussed with Sid Boukabara (NOAA), who is developing a related system (Microwave Integrated Retrieval System (MIRS)).

Outreach:

Matthew Nielsen completed his M.S. thesis in Fall 2005.

Kevin Donofrio masters student, expects defense in Fall 2006.

GPS data used to support this project was employed in AT786 practicum class “GPS Remote Sensing.”

8. Publications:

Carey, L.D., L.R. Belcher, J.A. Kankiewicz, and T.H. Vonder Haar, 2005: MM-wave radar structure and microphysical characteristics of a mixed phase altocumulus cloud on 2 November, 2001. Preprint CD-ROM, 32nd Radar Conference, American Meteorological Society, October 24-29, Albuquerque, NM.

Carey, L.D., L.R. Belcher, J.A. Kankiewicz, and T.H. Vonder Haar, 2005: MM-wave radar structure and microphysical characteristics of a mixed phase altocumulus cloud on 2 November, 2001. Preprint CD-ROM, American Geophysical Union Annual Fall Meeting, December 5-9, San Francisco, CA.

Falcone, A.K., 2005: Canonical coordinate feature extraction for cloud classification and analysis. Masters thesis, Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado, 168 pp.

Falcone, A.K., M.R. Azimi, and J.A. Kankiewicz, 2005: Multi-satellite cloud product generation using temporally updated canonical coordinate features. *IEEE Trans. Geosci. Remote Sens.* (submitted).

Falcone, A.K., M.R. Azimi-Sadjadi, 2005: Multi-satellite cloud product generation over land and ocean using canonical coordinate features. 2005 MTS/IEEE Oceans Conference, September 18-23, Washington, DC.

Falk, M.J. and V.E. Larson, 2006: What causes partial cloudiness to form in multilayered midlevel clouds? A simulated case study. *J. Geophys. Res.* (submitted).

Falk, M.J. and V.E. Larson, 2006: A simulation of partial cloudiness in multilayered altocumuli. Preprint CD-ROM, Twelfth Conference on Cloud Physics, July 10-14, Madison, WI (AMS).

Forsythe, J.M., K.M. Donofrio, R.W. Kessler, A.S. Jones, and T.H. Vonder Haar, 2006: Atmospheric profiles over land and ocean from AMSU. Preprint CD-ROM, Fourteenth Conference on Satellite Meteorology and Oceanography, January 29-February 2, Atlanta, GA (AMS).

Fowler, L.D. and T.H. Vonder Haar, 2006: Implementation of the RAMS cloud microphysics parameterization in WRF-ARW. On web site, Seventh Annual WRF Users' Workshop, June 19-22, Boulder, CO.

Johnson, K., 2006: A comparison of the Navy Aerosol Analysis and Prediction System to in-situ aerosol measurements in the continental U.S.: transport vs. local production of soil dust aerosol. Masters Thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, CO.

Johnson, K., S.M. Kreidenweis, M. Witek, D.L. Westphal, P. Flatau, 2006: A comparison of the Navy Aerosol Analysis and Prediction System (NAAPS) to in-situ aerosol measurements in the continental U.S.: transport vs. local production of soil dust aerosol. Seventh American Association for Aerosol Research International Aerosol Conference, September 10-15, St. Paul, MN.

Jones, A.S., P.C. Shott, J.M. Forsythe, C.L. Combs, R.W. Kessler, M.J. Nielsen, P.J.Stephens, and T.H. Vonder Haar, 2005: Global microwave surface emissivity error analysis. On web site, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Jones, A.S., D. Rapp, G. McWilliams, M. Mungiole, G. Mason, N.S. Chauhan, C.L. Combs, S. Longmore, B. McKeown, T. Vukicevic, and T.H. Vonder Haar, 2006: NPOESS soil moisture satellite data assimilation and RFI mitigation: Use of WindSat data and a Discrete Backus-Gilbert technique. International Geophysics and Remote Sensing Symposium (IGARSS) 2006, July 31-August 4, Denver, CO (accepted).

Kang, D.H., 2005: Distributed snowmelt modeling with GIS and CASC2D at California Gulch, Colorado. Masters thesis, Department of Civil Engineering, Colorado State University, Fort Collins, Colorado, 195 pp.

Kankiewicz, J.A., T.H. Vonder Haar, and L. Carey, 2005: An overview of the next cloud layered experiment (CLEX-10). On web site, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Kankiewicz, J.A., S.Q. Kidder, and D.T. Lindsey, 2006: 3.9 micron albedo characteristics of midlevel mixed-phase clouds. 12th Conference on Cloud Physics, July 10-14, Madison, WI (AMS). (Abstract withdrawn).

Kotenberg, K.E., N.B. Wood, and V.E. Larson, 2006: Derivation and tests of the GCSS analytic longwave radiation formula. Preprint CD-ROM, Joint Twelfth Conference on Cloud Physics and Atmospheric Radiation, July 10-14, Madison, WI (AMS).

Koyama, T., T. Vukicevic, M. Sengupta, T.H. Vonder Haar, and A.S. Jones, 2006: Analysis of information content of IR sounding radiances in cloudy conditions. *Mon. Wea. Rev.,* (accepted).

Larson, V.E., J-Ch. Golaz, H. Jiang, and W.R. Cotton, 2005: Supplying local microphysics parameterizations with information about subgrid variability: Latin hypercube sampling. *J. Atmos. Sci.*, (62) 4010-4026.

Larson, V.E., K.E. Kotenberg, N.B. Wood, 2006: An analytic longwave radiation formula for liquid layer clouds. *Mon. Wea. Review* (accepted).

Larson, V.E., A.J. Smith, M.J. Falk, K.E. Kotenberg, J.C. Golaz, 2006: What determines altocumulus dissipation time? *J. Geophys. Res.* (accepted).

Larson, V.E. and B.M. Griffin, 2006: Coupling microphysics parameterizations to cloud parameterizations. Preprint CD-ROM, Twelfth Conference on Cloud Physics, July 10 14, Madison, WI (AMS).

Leoncini, G., and R.A. Pielke, Sr., 2005: Nonlinear or linear; hydrostatic or nonhydrostatic mesoscale dynamics. Preprint CD-ROM, AGU Fall Meeting, December 6-9, San Francisco, CA.

Masarik, M.T. and W.H. Schubert, 2006: Potential vorticity aspects of the MJO. Preprints, Twenty-seventh Conference on Hurricanes and Tropical Meteorology, April 23-28, Monterey, CA (AMS).

Nielsen, M.J., 2005: Remote sensing of water vapor over land using the advanced microwave sounding unit. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, CO, 87 pp.

Nielsen, M.J., and T.H. Vonder Haar, 2005: Remote sensing of water vapor over land using the advanced microwave sounding unit. CIRA Technical Report, Colorado State University, Fort Collins, Colorado, 87 pp. [ISSN: 0737-5352-70].

Nielsen, M.J., P.J. Stephens, A.S. Jones, J.M. Forsythe, R.W. Kessler, and T.H. Vonder Haar, 2006: Impact of AMSU-B antenna pattern corrections on physical profile retrieval methods. *J. Atmos. Ocean. Tech.* (submitted).

Nobis, T., and R.A. Pielke, 2006: Results and sensitivities of an urban parameterization coupled to the Regional Atmospheric Modeling System (RAMS) over Washington DC. Preprint CD-ROM, Sixth Symposium on Urban Environment, January 29-February 2, Atlanta, GA (AMS).

Nui, J., L. Carey, P. Yang, J.A. Kankiewicz, T.H. Vonder Haar, 2006: A common microphysical structure for midlevel mixed phase clouds in the mid-latitudes: Results from the Cloud Layer Experiment (CLEX-9). Twelfth Conference on Cloud Physics, July 10-14, 2006, Madison, WI (AMS).

Pielke, Sr., R.A., T. Matsui, G. Leoncini, T. Nobis, U. Nair, E. Lu, J. Eastman, S. Kumar, C. Peters-Lidard, Y. Tian, and R. Walko, 2005: A new paradigm for parameterizations in numerical weather prediction and other atmospheric models. *National Wea. Digest* (in press).

Rojas, R., and P.Y. Julien, 2006: Washload erosion modeling with CASC2D-SED. *J. Hydraul. Eng.* (submitted).

Sample, L.B., 2005: Sensitivity analysis for the retrieval of aerosol optical properties from measured reflectances. Masters thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 114 pp.

Schubert, W.H., and M.T. Masarik, 2006: Potential vorticity aspects of the MJO. *Dynam. Atmos. Oceans.* (accepted).

Seaman, C.J., J.A. Kankiewicz, J.M. Davis, and K.E. Eis, 2005: Simulated transmissivity of mid-level, mixed-phase clouds. On web site, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 11-15, Monterey, CA.

Seaman, C.J., T. Vukicevic, and T.H. Vonder Haar, 2006: Assimilation of GOES radiances to improve forecasting of mid-level, mixed phase clouds. Preprint CD-ROM, Fourteenth Conference on Satellite Meteorology and Oceanography, January 29-February 2, Atlanta, GA (AMS).

Smith, A.J., B.M. Griffin, J-Ch. Golaz, and V.E. Larson 2006: Comparison of large-eddy simulations with a single-column model: implications for mid-level cloud parameterization. Preprint CD-ROM, Twelfth Conference on Cloud Physics, July 10-14, Madison, WI (AMS).

Stephens, P.J., and A.S. Jones, 2006: Bounds on the variance in the pattern matching criteria. *IEEE Trans. Geosci. Remote Sensing* (in press).

Stephens, P.J., and A.S. Jones, 2006: Geometrical variations of gain patterns. *IEEE Trans. Geoscience and Remote Sensing* (in review).

Stephens, P.J., and A.S. Jones, 2006: Application of a discrete Backus-Gilbert spatial filter to microwave radiometer data. *J. Atmos. and Oceanic Tech.* (submitted).

Stokowski, D.M., 2005: The addition of the direct radiative effect of atmospheric aerosols into the regional atmospheric modeling system (RAMS). Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO, Paper No. 764.

Stokowski, D.M., 2005: The addition of the direct radiative effect of atmospheric aerosols into the regional atmospheric modeling system (RAMS). Masters thesis, Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO, 81 pp.

Velleux, M.L., 2005: Spatially distributed model to assess watershed containment transport and fate. Ph.D. dissertation, Department of Civil Engineering, Colorado State University, Fort Collins, CO, 261 pp.

Vonder Haar, T.H., J.M. Forsythe, J. Luo, D.L. Randel, S. Woo, 2005: Water vapor trends and variability from the global NVAP dataset. Preprint CD-ROM, Sixteenth Conference on Climate and Variability and Change, January 9-13, San Diego, CA (AMS).

Vonder Haar, T.H., J.M. Forsythe, R.W. Kessler, 2006: A pilot study of scientific data stewardship with global water vapor. Preprint CD-ROM, Fourteenth Conference on Satellite Meteorology and Oceanography, January 29-February 2, Atlanta, GA (AMS).

Vukicevic, T., M. Sengupta, A.S. Jones and T.H. Vonder Haar, 2006: Cloud resolving satellite data assimilation: Information content of IR window observations and uncertainties in estimation. *J. Atmos. Sci.*, 63(3)**,** 901-919.

Wang, N., and C. Matsumoto, 2005: A comparison study of data compression techniques for the battle-scale forecast model grids. On web site, Battlespace Atmospheric and Cloud Impacts on Military Operations Conference (BACIMO) 2005, October 12-14, Monterey, CA (NRL).

Wichern, G., 2006: Adaptive methods for rapid acoustic transmission loss prediction in the atmosphere. Masters thesis, Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado, 165 pp.

Wichern, G. and M.R. Azimi-Sadjadi, 2006: An environmentally adaptive system for rapid acoustic transmission loss prediction. Proceedings DVD-ROM, IEEE World Congress on Computational Intelligence Conference, July 16-21, Vancouver B.C., Canada.

Zupanski, M., 2005: Maximum likelihood ensemble filter: theoretical aspects. *Mon. Wea. Rev.,* 133, 1710-1726.

Zupanski, M. and D. Zupanski, 2006: Model error estimation employing an ensemble data assimilation approach. *Mon. Wea. Rev.*, 134(5), 1337-1354.

ENSCO

FX-Net Enhancements for Applications and Technical Transfer to ENSCO's METWise Net System

Principal Investigators: Cliff Matsumoto and Sher Schranz

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

Key Words: FX-Net, Gridded FX-Net, Environmental Information Systems

Background:

ENSCO, Inc. provides engineering, science, and advanced technology solutions for the defense, security, transportation, environment, aerospace, and intelligent automation industries. ENSCO supports government and industry organizations with a variety of information systems solutions. ENSCO plans to focus on expanding AWIPS and associated applications and applying the technology to commercial weather-related areas such as aviation services. To accomplish this, ENSCO is pursuing a collaboration with CIRA and CSURF to commercially license FX-Net (the embedded wavelet data compression technique, in particular) as the platform to support their commercial weather-related applications.

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

The following specific tasks were formulated as the initial requirements to transfer FX-Net features and capabilities to ENSCO's METWise Net system.

Task 1 - Password Implementation:

-- Implement and test the password interface on the FX-Net 4.1 Client and ENSCO's FX-Net file server.

--Provide consulting and training to ENSCO staff at a level that would allow them to customize their password scheme.

Task 2 – Build FX-Net 4.1 Servers and Client which would require at least one trip to their Florida facility.

--Built and tested FX-Net data and file servers using AWIPS OB6 and ENSCO's new AWIPS data server CONUS localization.

-- Implement and test Postgres database.

--Build FX-Net 4.1 client for the OB6 servers, to include selected ENSCO requests.

--Build second 4.1 Client to incorporate ENSCO Help file changes.

--Fix any client bugs that are directly related to the 4.1 FX-Net client build.

--Troubleshoot network and server issues over the phone and through email, as necessary.

2. Research Accomplishments/Highlights:

Password implementation was completed. The password interface on the FX-Net 4.1 Client and ENSCO's FX-Net file server was implemented and tested. Consulting and training for the ENSCO staff were provided at a level that would allow them to customize their password scheme.

FX-Net data and file servers were built using AWIPS OB6 and ENSCO's new AWIPS data server CONUS localization. This effort required one trip to their Florida facility. A Postgres database was also implemented and tested. An FX-Net 4.1 client for the OB6 servers was built to include select ENSCO requests as well as a second 4.1 Client to incorporate ENSCO Help file changes.

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

All planned objectives were met.

NASA - CloudSat

Report Provided by: Ken Eis/Don Reinke

CIRA provides the operational data processing center (DPC) for this NASA-sponsored satellite mission. NOAA relevance is illustrated by the mission's basic science products that fit into the NOAA Climate Goal (Fig 1).

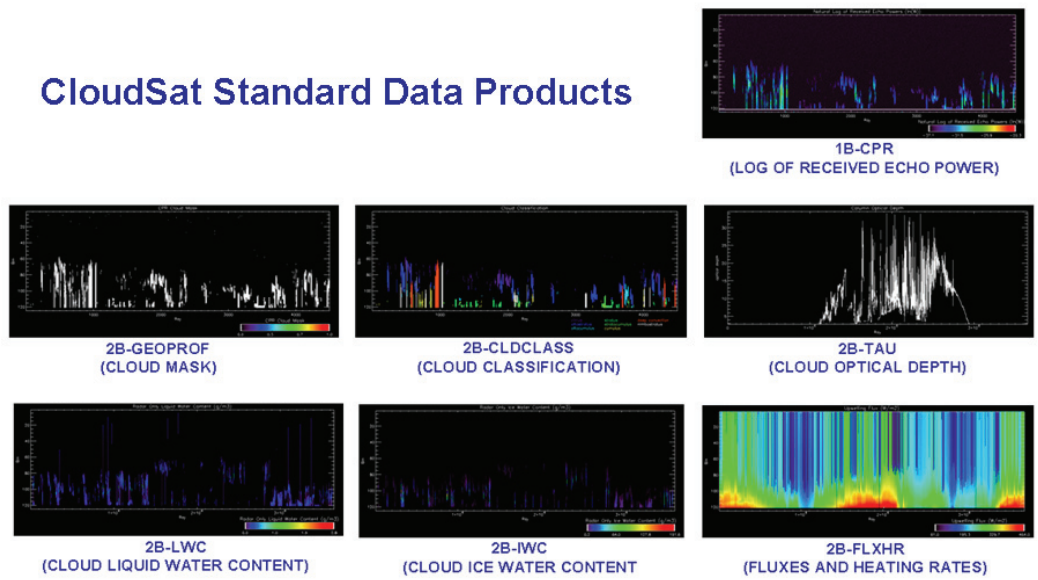


Figure 1. Examples of CloudSat Standard Data Products.

Cloud liquid and ice content cloud type and atmospheric heating and cooling rates are key to NOAA's climate, severe weather, aviation support, and precipitation research.

Additionally the DPC's computer software development technology has the potential to improve all science-to-operations software programming activities. CloudSat was launched April 28, 2006 and became operational June 2, 2006.

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). (Note: the NASA ESSP "CALIPSO" mission is a CloudSat launch partner).

A unique aspect of this mission is the fact that CloudSat will be flying in formation with other Earth Sciences missions dubbed the A-Train (Fig 2). CloudSat will be a 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).

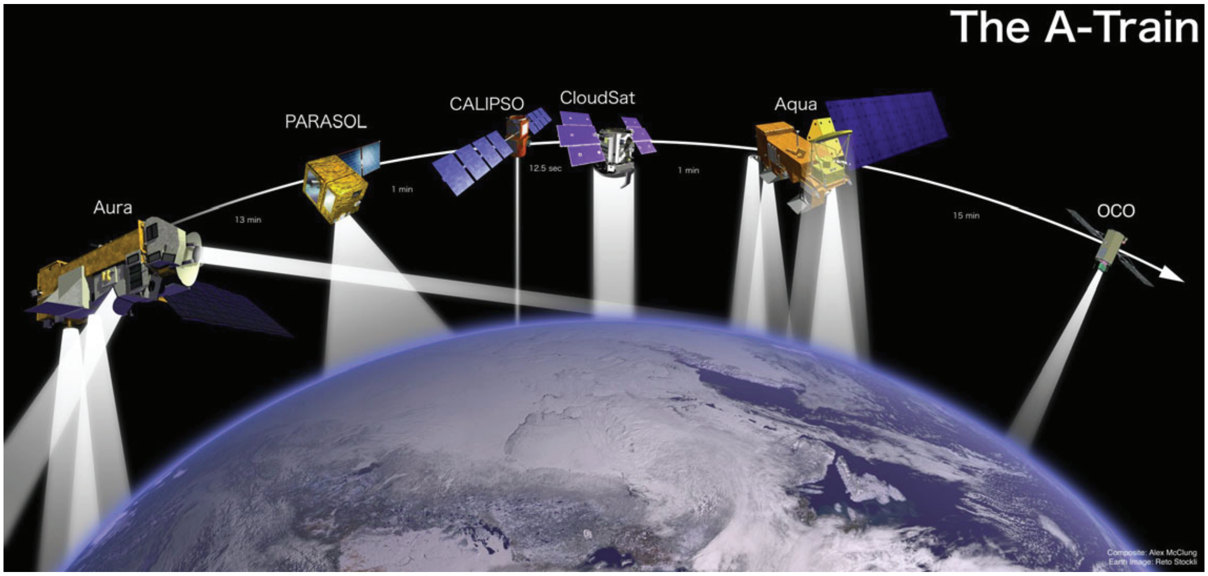


Figure 2. “A-Train” satellite constellation

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. All of the CloudSat standard data products will be produced at the CloudSat Data Processing Center in the new ATS-CIRA Research Center, located adjacent to CIRA and the Atmospheric Science Department.

CloudSat data is downlinked to the U.S. Air Force Satellite Control Network and transferred via the RTD&E Support Center (RSC), in Albuquerque NM, to the CIRA DPC. CIRA is responsible for the implementation of the hardware and software infrastructure that is necessary to produce the nine standard data products. Members of the CloudSat Science Team have developed the science algorithms and software for each of these products (figure 1). 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 students. More information about the DPC can be found at http://www.cloudsat.cira.colostate.edu

Progress During the Past Year:

CIRA turned on the automated CloudSat data processing system for the first live data transmission on May 20th. Within 10 minutes of the receipt of the first dump of CloudSat data, they were processed through the level 0 ingest system and the first CloudSat CPR data image was uploaded to the DPC website for access by the world (Fig 3).

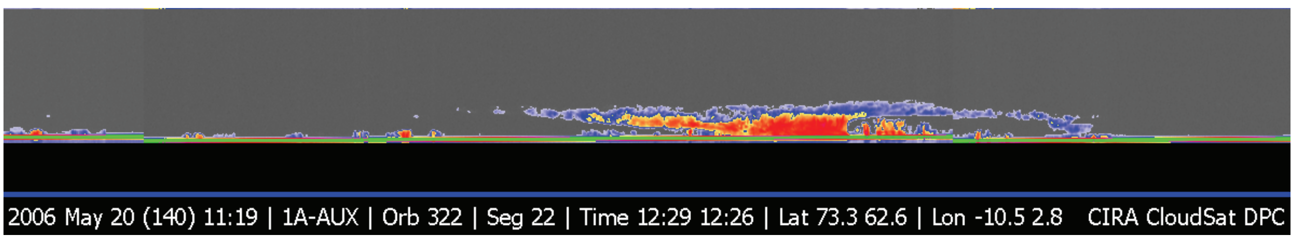


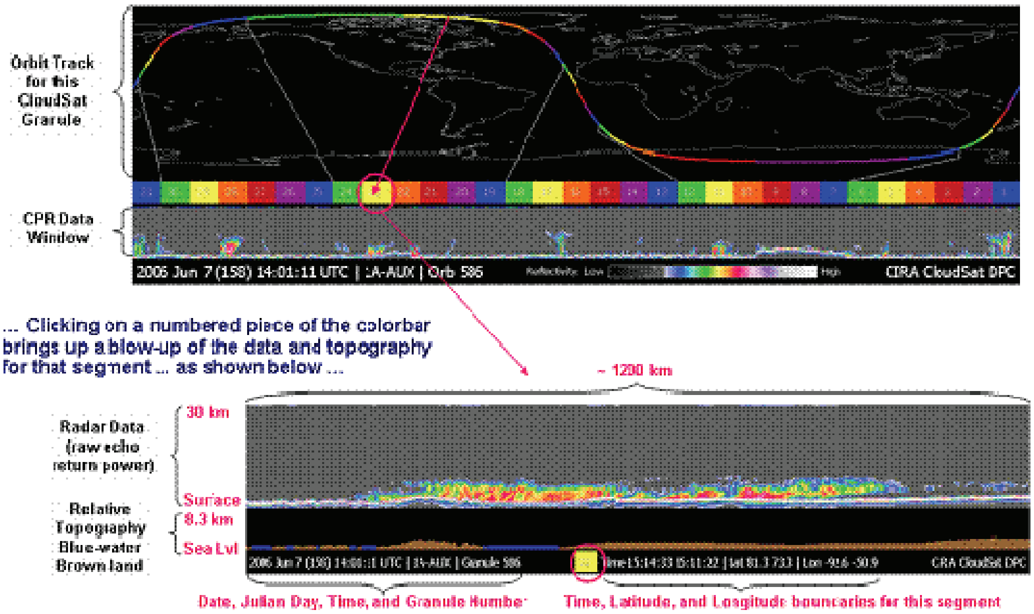
Figure 3. First CloudSat data collected May 20th 12:26–12:29 UTC. This segment represents an approximately 1200 km long data path and the scale on the data window is approximately 30-km of elevation above mean sea level.

To date, the system has been performing smoothly and the data product checkout has been progressing as scheduled.

As of July 15th, 99.62% of the CloudSat data have been collected from the spacecraft, and 100% of those data have been successfully processed through Level 1 (geo-located and calibrated data) by the CloudSat Data Processing Center at CIRA.

Initial CloudSat Imagery

Below are several examples of imagery produced from the CloudSat CPR data. The first figure is a description of the “Quicklook” images that are produced from the raw CPR (Level 0) data (Fig 4).



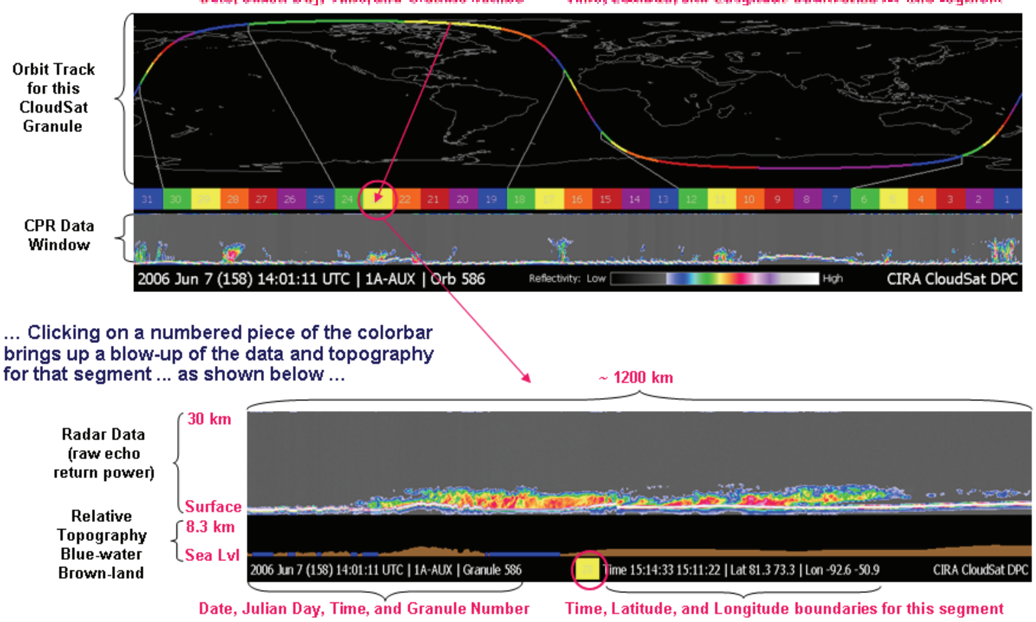


Figure 4. Description of the CloudSat "Quicklook" (Level 0) images. The data displayed on these images is the raw radar echo return power.

The following images are examples of some of the exciting features of this data set that will be of interest to NOAA researchers (Fig 5).

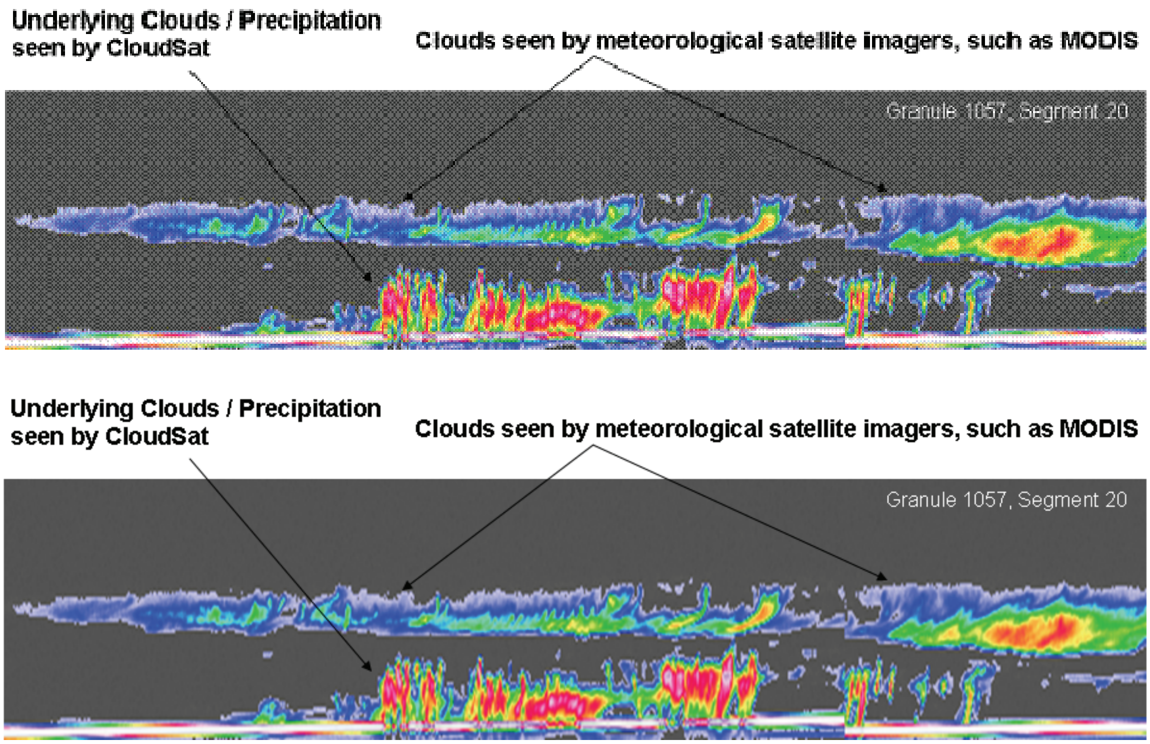


Figure 5. “Hidden” Clouds.

One of the most significant features of CloudSat CPR data is the ability to see “hidden” (lower) layers of cloud beneath the top cloud layer that is the only one that is detected by passive sensors. In addition, the cloud base of the top layer is also evident – again a feature that is not detected by conventional satellite sensors.

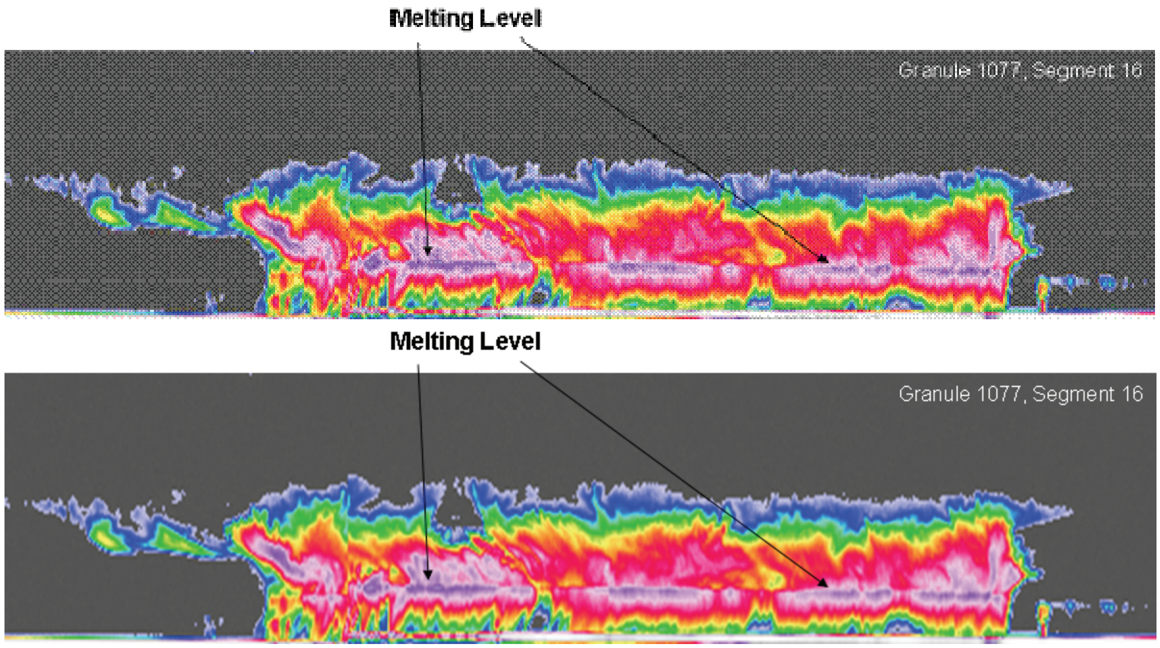


Figure 6. Detection of the “Melting Level”.

Another feature of the CPR data is the detection of the “Melting Level” (evident in Figure 6 as a horizontal line of brighter echo returns in the middle of the cloud layer).

This signature happens when snow / ice crystals fall below the freezing level (air temperature of $0^{O}C$) and begin to melt. At 94GHz, the water covered ice is highly reflective compared to the reflectivity of snow or ice. (The Melting Level is generally less than 1-km below the Freezing Level)

This provides a direct measurement of the potential for aircraft icing … a significant flight hazard that is impossible to measure directly with standard meteorological satellite sensors.

<u>NASA</u> – Fast Fluxes and Slow Pools: Integrating Eddy Covariance, Remote Sensing and Ecosystem Processes Data Within a Data Assimilation Framework

Principal Investigators: Rob Braswell, UNH/Tomislava Vukicevic CIRA

NOAA Project Goal:

Key Words: Carbon Cycle, Assimilation

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

Assessment of key processes in carbon cycle on inter-decadal time scales by estimation of model parameters from surface carbon flux data.

2. Research Accomplishments/Highlights:

Vukicevic worked on developing a variational data assimilation algorithm for a carbon cycle model SIPNET (Simplified PnET model, Braswell et al, 2005) using a well established and commonly used optimization procedure: least square with gradient evaluation (Crassidis and Junkins, 2004). The varaitional data assimilation algorithm was intended to provide a computationally efficient way to study the effect of different temporal scales in the observations and model on estimates of the ecosystem model parameters from surface flux observations. The variational algorithm was used successfully for similar purposes in a prior study by the collaborators on this project but with a significantly simpler ecosystem model (Vukicevic et al, 2001).

The implementation with SIPNET was not successful because of a disparity of parameter values over several orders of magnitude and poor knowledge of prior error covariance needed for scaling the optimization problem. There is no prior experience with the prior error covariance modeling in the ecosystem inverse modeling. The negative results in this study indicate that modeling of the parameter error covariances needs development in order to be able to use computationally efficient optimization procedures for estimation of the ecosystem model parameters. The inverse modeling or estimation of SIPNET parameters was done successfully using a much more computationally expensive procedure that is based on the Monte Carlo approach (Braswell et al, 2005).

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

The objective was to develop an efficient technique to identify processes in the exchange of carbon in the atmosphere-land system on different time scales, using assimilation of limited flux data into the model, such that the technique could be used for many sites. This objective was not achieved because the known efficient data assimilation technique could not be successfully applied to the problem due to limitation of poor knowledge of so-called prior error statistics needed for the application. More research is necessary to improve this aspect of the problem.

4. Leveraging/Payoff:

5. Research Linkages:

6. Awards/Honors:

7. Outreach:

8. Publications:

NASA – The GLOBE Program

Principal Researcher: Mike Turpin
Team Members: Travis Andersen, Matt Hansen, Mike Leon, Karen Milberger, Maureen Murray, Dave Salisbury, and Ali Zimmerman

NOAA Project Goal:

Key Words: International Education and Science Program; Observations and Reporting of Science Protocols; 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 the 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 15 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 17,000 GLOBE schools located in more than 100 countries.

In the spring of 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), E&O and NCAR are part of the GLOBE staff.

2. Research Accomplishments/Highlights for the GLOBE Program:

This was a transitional year for the GLOBE Program as it looked to shape the Next Generation GLOBE (NGG). In December 2005, NSF announced a new round of funding via an RFP designed to better connect scientists with science learning in the classroom. To accomplish this, new partnerships between GLOBE and scientists associated with Integrated Earth System Science Programs (IESSPs), which are major NSF or NASA-funded programs related to Earth system science, were pursued. This is a bit different than in the past when the NSF-funded individual PIs for individual protocols or groups of protocols. In keeping an eye toward this and the Next

Generation GLOBE (NGG), transition projects were formed focusing on various NGG elements. These, for example, included:

a. Regional Consortia: These were established to encourage and assist international regions to take on more leadership and responsibility for the implementation of GLOBE in their region. This project is helping GLOBE partner countries to form strong, self-sustaining regional infrastructures capable of working with IESSPs, communicate educational opportunities associated with the IESSPs to their schools and communities, as well as prepare and support schools for the projects.

b. GLOBE School Network: The GLOBE School Network focuses on a plan to build a collaborative, global network that links schools and communities to IESSPs and facilitates a conversation centered on student research studies with three goals in mind: to raise environmental awareness in GLOBE communities, to increase knowledge of the earth system and to promote successful student research experiences on the environment.

Members of the GLOBE International Advisory Committee (GIAC) have been selected. This group, consisting of members from each region, will provide a forum for representation, input, and advice from the international GLOBE community. Its first meeting will be at the annual GLOBE meeting in Phuket, Thailand in August 2006.

The GLOBE One field campaign concluded in December 2005. In February, 174 GLOBE students were able to share their research with scientists at a research symposia in Black Hawk County, Iowa. As part of this campaign, GLOBE students performed research on surface temperature, land cover mapping, hummingbirds, weather and climate, contrails, and incoming solar radiation. Also, throughout the campaign, Davis automated weather stations collected surface observations which were recorded to complement the data collected by the students. The automated data were quality controlled by NCAR/EOL. For more information on GLOBE One: www.globe.gov/globeone.

In October 2005, GLOBE facilitated a web forum for students to ask questions of scientists working with the CALIPSO and CloudSat satellite missions. The engaging aspect of these missions for students is that as they collect data about cloud observations, aerosols, precipitation and temperature, their data can be used to validate the observations made by the satellites. Hence, the students are helping the scientists to get as accurate a picture of the atmosphere as possible.

Then later that month, in honor of Earth Science week (October 2005), GLOBE hosted a contrail “count-a-thon.” Participants were asked to observe and report about the type and number of contrails they saw in their area at a certain time of day as they were learning about the contrails and clouds. For more information on this contrail count-a-thon, see: www.globe.gov/earthsciweek2005.

In late March, students, families and citizen-scientists from around the world participated in a campaign called GLOBE at Night to observe and record the magnitude of visible stars from all over the world. People from 96 countries made over 4500 observations. To learn more about this activity and what the results of the data showed, please see: www.globe.gov/globeatnight.

Two GLOBE schools reached a major milestone this past year by making and reporting their 100,000th observation to the GLOBE database. Congratulations to Norfork High School in Arkansas and Vang barne-og ungdomsskule (K-10) in Valdres, Norway.

Research Accomplishments / Highlights for the GLOBE Systems Team

The Systems 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.

Building on the approach of NGG, work is underway to re-design the website. The intent of the re-design is to organize content in such a way to make it easy to find. There will also be more focus on new technology approaches (e.g. Flash) for educational products in support of student research.

Another primary focus for the system team remains the development/maintenance of the GLOBE Partner Administration Web site. 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 a continuous effort to make more user-friendly pages, better tools to support the partners with their training and monitoring efforts, and a detailed partner administration manual.

The operational GLOBE website system is mirrored with hardware. The new mirror server outside of Bangkok, Thailand will be operational by late summer after the upcoming annual GLOBE conference. The GLOBE Program office and GLOBE Thailand are looking forward to this collaborative effort which is an example of a component of regional consortia.

As of November 2005, GLOBE data are now being ingested by the MADIS system developed by NOAA ESRL/GSD (formerly NOAA/FSL). The GLOBE datasets that MADIS can store include air temperature, precipitation, relative humidity and barometric pressure. To see the station data, visit: http://www-frd.fsl.noaa.gov/mesonet/.

In early 2006, a GLOBE partnership survey was distributed to the GLOBE Partners. As this survey was entirely online, the systems team was heavily involved in the technical design, operation, and data analysis of the results. The outcome of this survey was for the GLOBE office 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 Phuket, Thailand.

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.

The rollout of the 2005 Teacher's Guide was completed in early spring. This involved converting the documents into InDesign and then verifying the conversion worked. In addition to the conversion, changes needed to be made to the content of the 2003 guide. The current version, 2005, will be the last version before the selection of the Earth Science programs to be integrated into GLOBE.

All GLOBE data is freely available on the GLOBE website. Per the request of a partner who suggested that an alternative method be pursued to avoid the time it takes to download the complete dataset, the data for the first 10 years of the program (1995-2005) has been placed onto a set of 4 CD-ROMs for distribution on request.

Efforts are currently underway to look at a means by 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.

NASA – Mesoscale Carbon Data Assimilation for NACP

Principal Investigators: Scott A. Denning/Dusanka Zupanski

NOAA Project Goal: Weather and Water

NOAA Programs: Environmental Modeling, Weather Water Science, Technology, 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 major objective of this research is to develop a generalized framework for carbon flux estimation from multiple streams of carbon observations, in support of the North American Carbon Program (NACP). This will be accomplished by using ensemble-based data assimilation techniques applied to a fully coupled model of regional meteorology, ecosystem carbon fluxes, and biomass burning (SiB-CASA-RAMS). Terrestrial carbon fluxes over North America due to photosynthesis, autotrophic respiration, decomposition, and fires, and a "residual" time-mean source or sink will be simulated by the model. 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:

During the report period, we have aggressively pursued the development of both the forward and inverse algorithms to be used in the research. Forward model development has included major improvements in the ecophysiology model SiB, the introduction of a new biogeochemistry module based on CASA, and continuing experimentation with the coupled SiB-RAMS model. We have analyzed real observations of CO2 from a suite of six tower sites in the domain, and found that the forward model is successful in reproducing some of the observed synoptic variability. Excessive midsummer stress over the central and western US degrades the quality of the simulated CO2 when transport carries air from those regions to the tower locations.

The most significant innovation has involved application of the Maximum Likelihood Ensemble Filter (MLEF, Zupanski 2005; Zupanski and Zupanski 2006) to the carbon inversion problem using an offline Lagrangian Particle Dispersion Model (LPDM). We have developed a system for separate optimization of photosynthesis and respiration fluxes in the coupled SiB-RAMS model that involves estimation of multiplicative biases in each component flux on a spatially-distributed grid every 10 days, based on errors in simulated CO2 mixing ratio at a suite of observing stations. The system also includes estimation of spatial covariance of the flux biases.

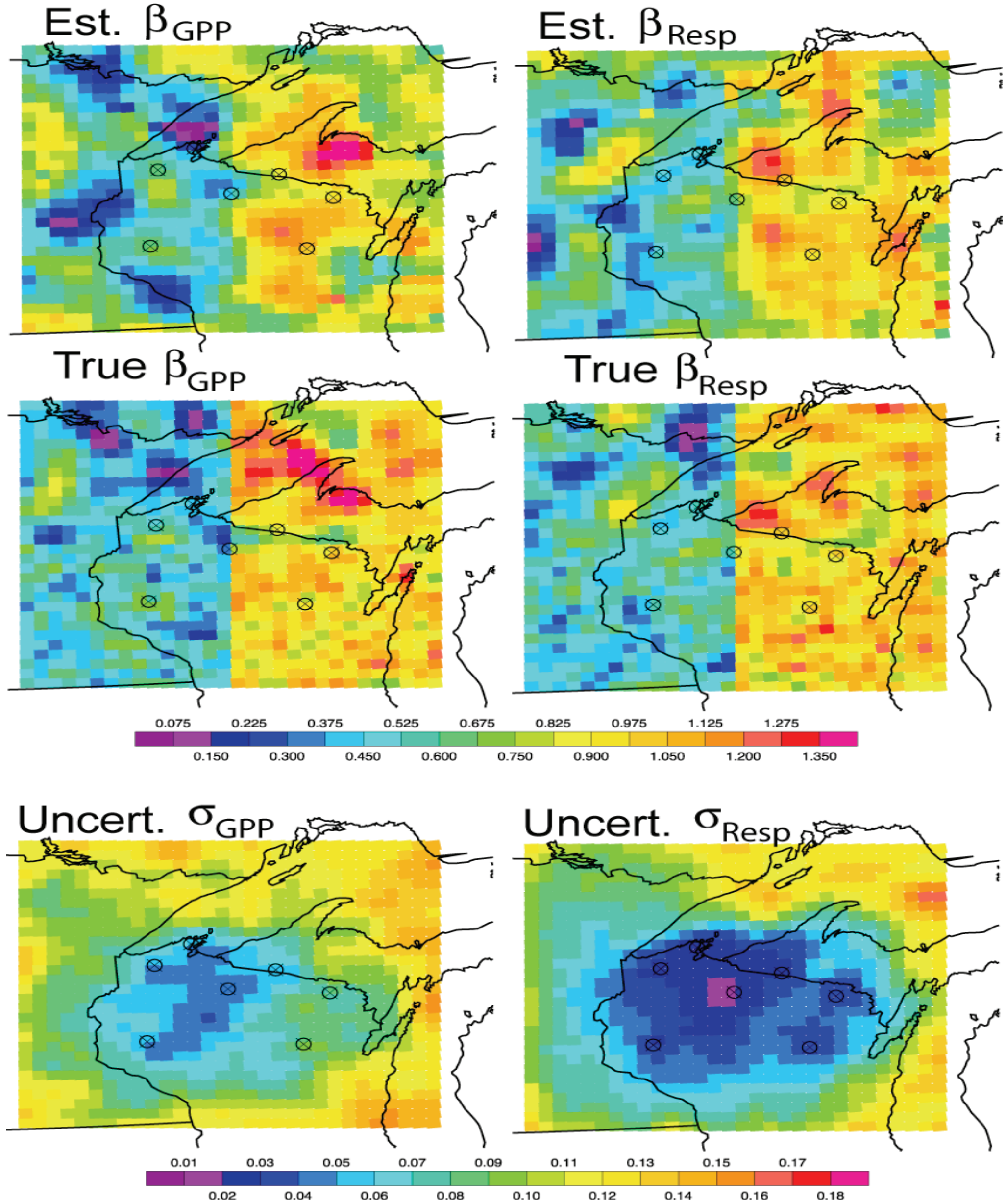


Fig. 1: Assimilation of synthetic Ring [CO_2] using SiB-RAMS-LPDM-MLEF. Top panels show gridded estimates of biases in GPP $ß_{GPP}$) and ecosystem respiration ($ß_{Resp}$) on a 20-km grid after 7 assimilation cycles of 10 days each. Small circles with X's indicate sampling sites. Prior guesses for both biases are defined using a uniform value of 0.75. Middle panels show the prescribed "true" distribution. The lower panels show the estimated uncertainty (1σ).

We have evaluated the ability of the MLEF to estimate biases in SiB-RAMS fluxes given influence functions generated by the LPDM using synthetic observations for the Ring of Towers experiment in the summer of 2004. A forward simulation of a 70-day period starting on 1 June 2004 was performed in SiB-RAMS on a domain somewhat larger than the conterminous USA on a grid of *Dx*=40 km. A finer nest was run on a 1000 km x 1000 km subdomain centered on WLEF with *Dx* =10 km. Influence functions were generated by running the LPDM backward in time for two-hour mean “samples” from six surface layer towers in the Ring, plus five levels on the WLEF tower (all but the 11 m level). We then sought to estimate the bias factors every 10 days (seven assimilation cycles) on a 20-km grid over a 600 x 600 km area centered on the tall tower. The bias estimation results shown in Fig. 1 indicate remarkable capability of the MLEF approach to recover the true bias and to significantly reduce uncertainty of the estimated bias in the well-observed area of the Ring interior. The estimated biases clearly distinguish the east-west structure in the “true” field, and also capture much of the random finer variations, including the smoother patterns in the south than the north. The constraint is weak over the Great Lakes, because both GPP and Resp are zero there. Overall uncertainty in the model bias is less than 5% over most of the interior of the Ring.

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. This research is most directly applicable to the NACP.

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

Main investigators working on this research project include S. A. Denning, D. Zupanski, J. Collatz, M. Uliasz, M. Zupanski, and I. Backer. Collaborators include K. Gurney, R. Lokupitiya, N. Suits, L. Prihodko, and K. Schaefer. This research is in synergy with other CIRA research projects. These projects include: (i) NOAA/NESDIS research project titled “Research and Development for GOES-R Risk Reduction” (PI: Prof. T. Vonder Haar). (ii) NOAA/THORPEX research project titled “Impact of Fundamental Assumptions of Probabilistic Data Assimilation/Ensemble Forecasting: Conditional Mode vs. Conditional Mean” (PI: Dr. M. Zupanski). (iii) NASA research project titled “Weak Constraint Approach to Ensemble Data Assimilation: Application to Microwave Precipitation Observations” (PI: D. Zupanski). (iv) NSF project titled “Collaboration in Mathematical Geosciences: Ensemble Data Assimilation Based on Control Theory” (PI: M. Zupanski). All these research projects employ the MLEF approach.

6. Awards/Honors:

7. Outreach:

Andrew Schuh and Nicholas Parazoo, graduate students at CSU/Atmospheric Science Department are collaborating on this research project, supervised by Prof. A. S. Denning.

Presentations supported partly or fully by this project

Baker, I.T., D. Zupanski, L. Prihodko, K. Schaefer, K., J. Berry, and A.S. Denning, 2005: Leaf-to-Canopy Scaling Biosphere Model (SiB). *AGU Fall Meeting, 5-9 December 2005*, San Francisco, CA.

Denning, A. S., S. Conner Gausepohl, S. R. Kawa, I. T. Baker, Z. Zhu, M. Brown, S. Vay, S. C. Wofsy, A. Philpott, G. J. Collatz, K. Schaefer, and J. Kleist, 2005: Simulation and Observation of Global Variations in Surface Exchange and Atmospheric Mixing Ratios of CO2. *AGU Fall Meeting, 5-9 December 2005*, San Francisco, CA. (*INVITED*)

Denning, A. S., Dusanka Zupanski, Marek Uliasz, Andrew Schuh, and Milija Zupanski, 2005: Regional carbon flux estimation using the Maximum Likelihood Ensemble Filter. *The Seventh WMO International CO2 Conference*, September 26-30, 2005, Broomfield, CO.

Lokupitiya, R. S., A. S .Denning, D. Zupanski, K. Gurney, and M. Zupanski, 2005: Application of Maximum Likelihood Ensemble Filter (MLEF) With a Parameterized Chemistry Transport Model (PCTM) to Optimize Surface CO2 Fluxes□. *AGU Fall Meeting, 5-9 December 2005*, San Francisco, CA.

Lokupitiya, R. S., A. S. Denning, D. Zupansaki, K. R. Gurney, and M. Zupanski, 2006: An application of maximum likelihood ensemble filter (MLEF) to carbon problems. *The 25th Anniversary CIRA & CG/AR Spring Science Symposium*, 16-17 May 2006 in Fort Collins, CO.

Philpott, A. W., A. S. Denning, S. Conner Gausepohl, I. Baker, M. E. Brown, and K. Schaefer, 2005. Temporal Interpolation of Satellite Vegetation Imagery and its Influence on Simulated Seasonal Carbon Uptake by Vegetation in the Middle Latitudes.□ *AGU Fall Meeting, 5-9 December 2005*, San Francisco, CA.

Schaefer, K., G. J. Collatz, A. S. Denning, D. Zupanski, L. Prihodko, P. Tans, and I. Baker, 2005: Estimating Biomass in a Combined SiB and CASA Model Using Data Assimilation. *AGU Fall Meeting, 5-9 December 2005*, San Francisco, CA.

Schuh, A.E., M. Ulliaz, S. Denning, and D. Zupanski, 2005: A case study in regional inverse carbon modeling. *The Seventh WMO International CO2 Conference*, September 26-30, 2005, Broomfield, CO.

Uliasz, M., A. S. Denning, A. Schuh, K. J. Davis, S. J. Richardson, and N. Miles, 2005: Estimation of regional sources and sinks of CO2 using mixing ratio data from the Ring of Towers in northern Wisconsin. *The Seventh WMO International CO2 Conference*, September 26-30, 2005, Broomfield, CO.

Uliasz, M., A. S. Denning, A. Schuh, S. J. Richardson, N. Miles, K. J. Davis, and D. Zupanski, 2005. Estimation of regional CO2 fluxes using concentration measurements from the ring of towers in northern Wisconsin□. *AGU Fall Meeting, 5-9 December 2005*, San Francisco, CA.

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., 2006: Ensemble Kalman filter. *Advanced Numerics Seminar*, March 8, 2006, Langen, Germany. (*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).

8. Publications:

Peters, W., J.B. Miller, J. Whitaker, A.S. Denning, A. Hirsch, M.C. Krol, D. Zupanski, L. Bruhwiler, and P.P. Tans, 2005: An ensemble data assimilation system to estimate CO_2 surface fluxes from atmospheric trace gas observations. *J. Geophys. Res.*, *110*, D24304, doi:10.1029/2005JD006157.

Zupanski D. and M. Zupanski, 2006: Model error estimation employing an ensemble data assimilation approach. *Mon. Wea. Rev.*, **134**, 1337-1354.

Zupanski D., A.S. Denning, and M. Uliasz, M., 2006: Ensemble data assimilation applications to atmospheric and carbon cycle science. *Extended abstracts of The 86th AMS Annual Meeting, 10th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface,* 29 January – 2 February 2006, Atlanta, GA, 4pp.

Zupanski, M., 2005: Maximum Likelihood Ensemble Filter: Theoretical Aspects. *Mon. Wea. Rev.*, **133**, 1710–1726.

<u>NASA</u> – Parameterizing Subgrid Snow-Vegetation-Atmosphere Interactions in Earth-System Models

Principal Investigators. Glen E. Liston/Christopher A. Hiemstra

NOAA Project Goal:

Key Words: Snow, Grassland, Shrubland, Energy Budget, Surface Fluxes

New Project – Nothing to report for this fiscal year.

<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

NOAA Programs: Environmental Modeling, Weather Water Science, Technology, and 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 is to develop an ensemble based data assimilation methodology, applicable to data assimilation problems involving moist physical processes. We employ Maximum Likelihood Ensemble Filter (MLEF, Zupanski 2005; Zupanski and Zupanski 2006) in application to the Goddard Earth Observing System Single Column Model (GEOS-5 SCM). The MLEF is a weak constraint data assimilation approach since it has a capability to estimate and correct model errors. An additional research objective is to upgrade the MLEF approach with the capability to extract maximum information from the available observations for a given ensemble size.

2. Research Accomplishments/Highlights:

During the past two years, our research was focused on testing and upgrading the MLEF approach in application the GEOS-5 Single Column Model (GEOS-5 SCM). One of the most significant upgrades of the basic MLEF algorithm is the capability to estimate information measures of observations, such as degrees of freedom (DOF) for signal and entropy reduction. This is accomplished via defining information matrix in ensemble subspace (Zupanski et al. 2006a,b). The main advantages of defining the information matrix in ensemble subspace are 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.

During the report period we employed the upgraded MLEF algorithm in data assimilation experiments with the GEOS-5 SCM 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 these two approaches. Comparisons of the KF and the 3D-VAR approaches can potentially indicate if there are benefits, on data assimilation and on the information measures, 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. This is illustrated in Figs. 1 and 2.

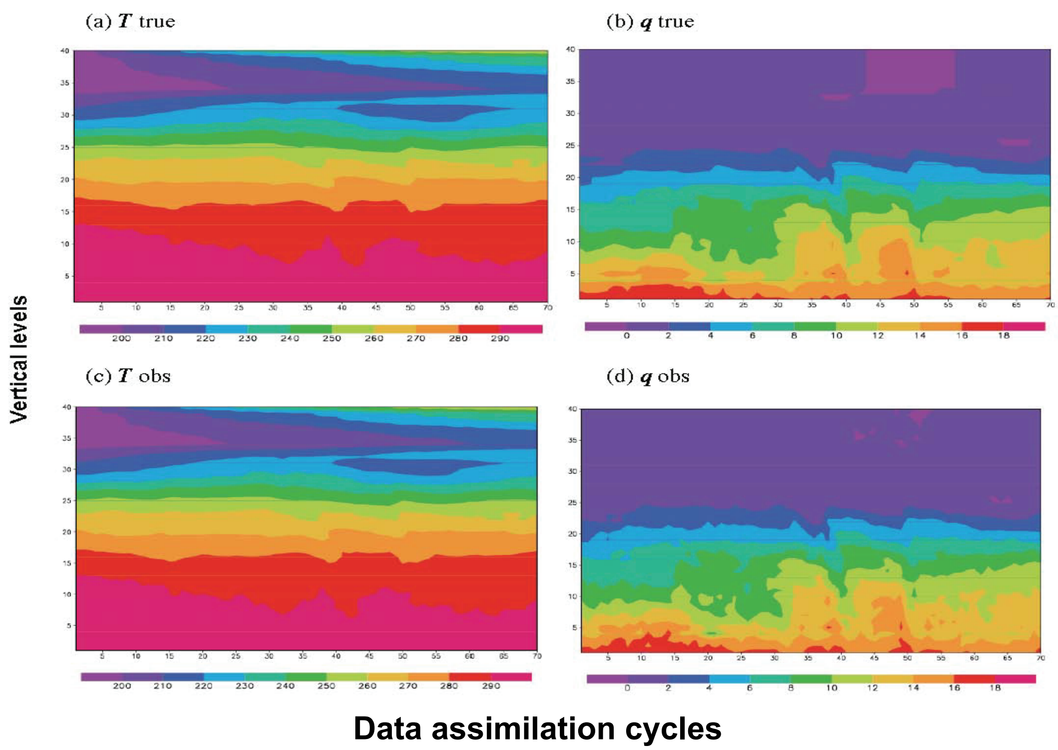


Fig. 1. (a) True temperature, (b) true specific humidity, (c) observed temperature, and (d) observed specific humidity, shown as functions of data assimilation cycles and model vertical levels. Observations in Figs. 1c and 1d are defined by imposing a random noise to the true model state. Units for temperature are K, and for specific humidity g kg^{-1}. Note rapid time-tilted changes in both temperature and humidity around data assimilation cycles 40 and 50. (Figure taken from Zupanski et al. 2006a).

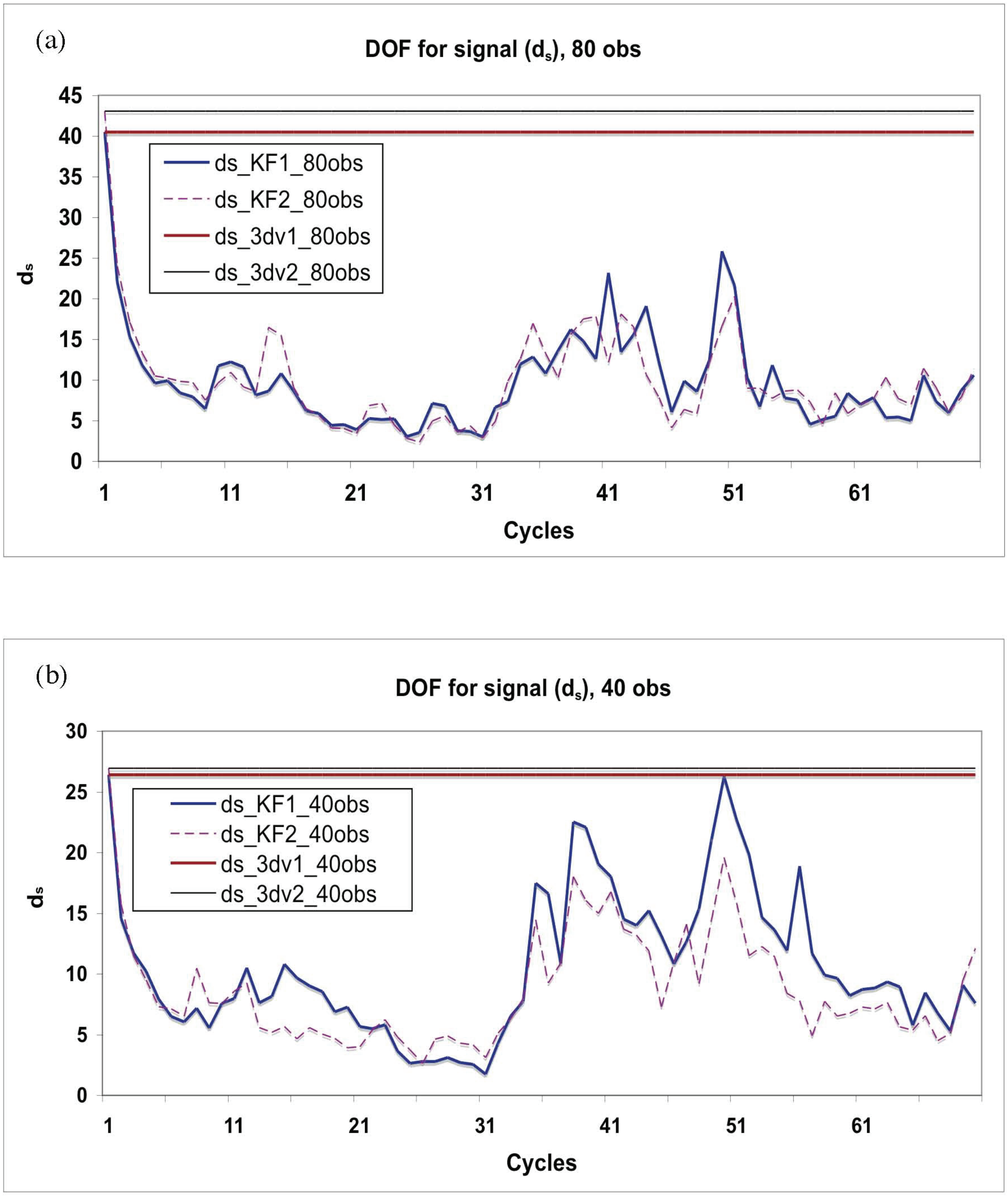


Fig. 2. Degrees of Freedom (DOF) for signal, denoted *ds*, shown as functions of data assimilation cycles, obtained in the experiments with (a) 80 observations and (b) 40 observations. Two different KF experiments, denoted KF1 and KF2, and corresponding 3D-VAR experiments, dented 3dv1 and 3dv2, are presented. Note that the KF experiments produce time varying information measures, which reflect the abrupt changes around cycles 40 and 50 in the true model state variables shown in Fig.1, while the 3D-VAR results are insensitive to the time variability of the true model state. (Figure taken from Zupanski et al. 2006b).

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 the value added of new observations (e.g., new satellite missions, such as GOES-R, GPM, and CloudSat).

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

This research is performed in collaboration with A. Y. Hou and S. Q. Zhang from the NASA/Global Modeling and Assimilation Office, and C. D. Kummerow from the CSU/Atmospheric Science Department. This research is in synergy with other CIRA research projects. These projects include: (i) NOAA/NESDIS research project titled "Research and Development for GOES-R Risk Reduction" (PI: T. Vonder Haar). 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 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:

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.

Presentations supported partly or fully by this project:

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. 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 Kalman filter. *Advanced Numerics Seminar*, March 8, 2006, Langen, Germany. (*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. 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.

8. Publications:

Zupanski D. and M. Zupanski, 2006: Model error estimation employing an ensemble data assimilation approach. *Mon. Wea. Rev.*, **134**, 1337-1354.

Zupanski, D., M. Zupanski, A. Y. Hou, S. Q. Zhang, and C. D. Kummerow, 2006a: Information theory and ensemble data assimilation. Part I: Theoretical aspects. *J. Atmos. Sci*. (Submitted, available at ftp://ftp.cira.colostate.edu/Zupanski/manuscripts/GEOS5_Part_I_JAS.pdf)

Zupanski, D., S. Q. Zhang, A. Y. Hou, and S. H. Cheung, 2006b: Information theory and ensemble data assimilation. Part II: Impact of different data assimilation approaches. (Submitted, available at ftp://ftp.cira.colostate.edu/Zupanski/manuscripts/GEOS5_Part_II_JAS.pdf)

Zupanski, M., 2005: Maximum Likelihood Ensemble Filter: Theoretical Aspects. *Mon. Wea. Rev*., **133**, 1710–1726.

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., M. Zupanski, A. Y. Hou, S. Q. Zhang, and C. D. Kummerow, 2006a: Information theory and ensemble data assimilation. Part I: Theoretical aspects. *J. Atmos. Sci*. (Submitted, available at ftp://ftp.cira.colostate.edu/Zupanski/manuscripts/GEOS5_Part_I_JAS.pdf)

Zupanski, D., S. Q. Zhang, A. Y. Hou, and S. H. Cheung, 2006b: Information theory and ensemble data assimilation. Part II: Impact of different data assimilation approaches. (Submitted, available at ftp://ftp.cira.colostate.edu/Zupanski/manuscripts/GEOS5_Part_II_JAS.pdf)

NATIONAL PARK SERVICE – Air Quality Research

Principal Investigator: Douglas G. Fox

NOAA Project Goal: Weather and Water, specifically the Air Quality component under the Goal

Key Words: Air Quality Research, Visibility Research; Visibility Monitoring; Aerosol Research, Aerosol Monitoring; Rural Air Quality; Air Quality Modeling.

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

The long-term objectives for 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 multi-year 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, Communication 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 material 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 websites: 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., 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. 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 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., 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., 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, Kreidenweis, S. M, Lunden, M., Carrillo, J., Carrico, C. M., Lee, T., Herckes, P., Engling, G., Day, D. E., Hand, J. L, Brown, N., Malm, W. C., and Collett Jr., J. L. 2005. Smoke-impacted regional haze in California during the summer of 2002. Submitted to Agricultural and Forest Meteorology.

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.

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.

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 Atmospheric 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., 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.

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.

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.

Yu, X. Y., Lee, T., Ayres, B., Kreidenweis, S. M., Collett Jr., J. L., and Malm, W. C. 2005. Particulate nitrate measurement using nylon filters. Journal of the Air & Waste Management Association, 55, 1100-1110.

NATIONAL PARK SERVICE - Development of a Mobile Aerosol Characterizational Laboratory and Analysis of Findings from the Yosemite Aerosol Visibility Special Study, the (IMPROVE) Site Ion Characterization Study, and the Missoula Burn Chamber Smoke Study

Principal Investigators: Sonia Kreidenweis/Jeff Collett

Key Words: Smoke, Biomass Combustion, Deposition, Air Quality, Air Pollution, Visibility, Aerosol, Precipitation

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

The long-term goals of this project are to improve understanding of visibility degradation in national parks, diagnose contributions to air quality problems in specific parks, and to generate new knowledge on fundamental aerosol-related properties relevant to air quality and visibility. The means of accomplishing these goals involve the undertaking and analysis of field measurements of aerosol properties at select national parks. Laboratory experiments involving the generation and measurement of aerosols such as those from biomass combustion processes, are also used for further understanding aerosol behavior.

This specific project addresses three main areas of emphasis: (1) improved characterization of wildland fire particulate matter emissions and their impacts on downwind air quality and visibility; (2) support of the IMPROVE monitoring network, and specifically evaluation of current aerosol measurement techniques; (3) design and development of the NPS mobile air quality laboratory. We also prepared for a pilot study for the Rocky Mountain National Park Nitrate Study under this award.

Specific project objectives were as follows:

--Conduct a pilot study at the USFS Missoula Fire Science Lab, to measure fresh smoke chemical and physical properties.

--Complete design and construction of the NPS Mobile Air Quality Lab.

--Complete publications still in progress for recent studies in Yosemite NP and in the various IMPROVE Nitrate Study sites (San Gorgonio, Grand Canyon, Bondville, Brigantine, and Great Smoky Mountains).

--Design Rocky Mountain National Park Nitrate Study.

2. Research Accomplishments/Highlights:

<u>Missoula 2003 Smoke Study</u>**:** The Missoula study of 2003 focused on laboratory measurements of smoke aerosol properties from a range of biomass combustion characteristics. During the past year, results from this project have been reduced and prepared for publication. Methodologies have been developed including use of High Performance Anion Exchange Chromatography with Pulsed Amperometric Detection

(HPAEC-PAD) as a simple and cost effective method for the analysis of the wood smoke marker, levoglucosan, in aqueous aerosol extracts. Several manuscripts are in progress from the study including one analyzing wood smoke markers (Engling et al., 2005b) and two examining primary smoke physical, optical and chemical properties (Carrico et al., in preparation; Day et al., in preparation).

--Completion of 2003 Missoula study filter analyses for anhydrosugars and continued development of High Performance Anion Exchange Chromatography with Pulsed Amperometric Detection (HPAEC-PAD) as a "cheap and easy" method for analysis of the wood smoke marker, levoglucosan, in aqueous aerosol extracts

--Gas-Chromatographic and ionic analysis of filter samples from 2003 Missoula study

--Submission of manuscript on organic carbon speciation from Missoula smoke chamber burn studies (Engling et al., 2005b)

--Continued work on manuscripts of aerosol physical and optical properties from Missoula study results “Primary Biomass Smoke Aerosol Properties from Laboratory Combustion of Forest Fuels,” (Carrico et al., in preparation) and “Optical and Chemical Properties of Fresh Smoke Aerosol from Several Forest Fire Fuels” (Day et al., in preparation)

Development of a Mobile Laboratory for National Park Studies. A mobile laboratory has been designed and construction was completed in late 2005. Related to this, a number of measurement systems have been constructed and tested for use as part of this laboratory including systems for dry particle sizing system, trace gas analysis (ammonia, nitrogen oxides, carbon monoxide, and ozone), a hygroscopic tandem differential mobility analyzer for measuring particle hygroscopic growth, and high time resolution inorganic and organic chemical composition.

--Vendor construction of the truck and custom laboratory has been completed

--Preparation of a draft “memorandum of understanding” between UC-Davis and Colorado State University for use of mobile lab

--Continued testing of instruments for trace gas sampling instruments, dry particle sizing system including a water-based condensation particle counter (CPC), and the HTDMA

--Laboratory experiments with the HTDMA instrument on hygroscopic and nucleation Properties of mixtures of organic polymeric compounds and inorganic aerosols and extracted filter samples

Completion of analyses from past studies The final phase of the Yosemite Aerosol Characterization Study of 2002 was completed. This included the publication of a number of manuscripts from this study and preparation of a final project report. Among these were a manuscript comparing congruent measurement methods in the Yosemite study (Malm et al., 2005a), two manuscripts examining aerosol size distributions in relation to optical properties (McMeeking et al., 2005a,b), two manuscripts on aerosol hygroscopic properties (Carrico et al., 2005; Malm et al., 2005b), and a manuscript investigating particle morphology (Hand et al., 2005). Several more manuscripts are submitted or in preparation including organic carbon speciation (Engling et al.; 2005a, Herckes et al., 2005) and an overview of the Yosemite study (McMeeking et al., in 2006).

A combined laboratory and field study in support of the IMPROVE network focused on the characterization of nitrate and other ion measurements at IMPROVE network sites. As part of this effort, laboratory testing of nitric acid collection efficiencies of new and exposed IMPROVE denuders was conducted. A summary of nitrate study results to date was prepared for publication in the IMPROVE newsletter. A manuscript was finalized concerning nitrate extraction and measurements from nylon filters (Yu et al., 2005), a second manuscript was submitted concerning ammonium loss from nylon filters (Yu et al., 2006). Work continued on manuscripts concerning ionic speciation using conventional filter/denuder systems in comparison to online high time resolution methods and concerning the forms and size distributions of aerosol nitrate in several key national parks.

Rocky Mountain National Park Study. A study was designed to examine air quality issues in Colorado's Rocky Mountain National Park, commencing with a pilot study in summer 2005. Issues addressed include PM2.5 aerosol concentrations and trace gas species concentrations, meteorological transport, and in particular the deposition of sulfate and nitrate in the park and surrounding region. The group participated in planning meetings and study plan preparation and worked with NPS and the State of Colorado to garner state support for a RMNP pilot study in summer/fall 2005.

--In conjunction with NPS, CIRA, and other researchers, completed initial draft measurement and budget plan for the RMNP nitrogen and sulfur study (ROMANS)

--Obtained commitment for loan of instrumentation from Desert Research Institute and financial support commitments from State of Colorado for the 2005 pilot study

--Completed first phase of RMNP pilot study examining particulate and gas phase concentrations of nitrogen, sulfur and other major ions at one core site and 8 satellite sites in RMNP

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

All objectives were completed.

4. Leveraging/Payoff:

A number of graduate and undergraduate students were supported: PhD dissertation work for three students (T. Lee, G. Engling, and G. McMeeking); undergraduate student assistant participation (T. Hinerman, A. Evans).

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

N/A.

6. Awards/Honors: None.

7. Outreach: A number of publications and presentations were prepared and delivered (see listing).

Presentations

Carrico, C.M., S.M. Kreidenweis, J.L. Collett, Jr., G. Engling, D.E. Day, and W.C. Malm, " Smoke properties derived from the laboratory combustion of forest fuels," presented at the American Association for Aerosol Research conference, Atlanta, GA, October 4-8, 2004.

Day, D.E., W.C. Malm, C.M. Carrico, and G. Engling, G. 2004, "Hygroscopicity of smoke aerosols from several different forest fuels," presented at the Air & Waste Management Association Specialty Conference in Ashville, NC, October 25–29, 2004.

Day, D.E., W.C. Malm, C.M. Carrico, and G. Engling, "Optical, hygroscopic and chemical properties of smoke aerosols from several different forest fuels," presented at the American Association of Aerosol Research Conference in Atlanta, GA, October 4-8, 2004.

Engling, G., P. Herckes, J. Carrillo, S.M. Kreidenweis, and J.L. Collett, Jr., "Organic Aerosol Composition in Yosemite National Park During the 2002 Yosemite Aerosol Characterization Study", presented at the Air and Waste Management Association conference, Asheville, NC, October 25–29, 2004.

Engling, G., C.M. Carrico, P. Herckes, S.M. Kreidenweis, and J.L. Collett, Jr., D.E. Day, W.C. Malm, R. Babbitt, E. Lincoln, Y. Iinuma, H. Herrmann, "Determination of Levoglucosan in Biomass Combustion Aerosol by HPAEC-pAD," presented at the AAAR Specialty Conference, Atlanta, GA, February 2005.

Hand, J. L., W.C. Malm, A. Laskin, D. Day, T. Lee, J. Carrillo, and J.L. Collett, Jr., "Individual Particle Analysis of Biomass Burning Aerosols During the Yosemite Aerosol Characterization Study," presented at the 2004 Fall American Geophysical Union Meeting, San Francisco, CA, December 13-17, 2004.

Hand, J. L., W.C. Malm, A. Laskin, D.E. Day, J. Carrillo, T. Lee, C.M. Carrico, G. McMeeking, J.P. Cowin, M.J. Iedema, J.L. Collett, Jr., and S.M. Kreidenweis, "Single particle analysis during the Yosemite Aerosol Characterization Study" presented at the Air & Waste Management Association Specialty Conference in Ashville, NC, October 25–29, 2004.

Lee, T., X.-Y. Yu, B. Ayres, S.M. Kreidenweis, J.L. Collett, Jr., and W. Malm, "The Importance of Coarse Mode Aerosol Nitrate at Several IMPROVE Monitoring Sites," presented at the AAAR Specialty Conference, Atlanta, GA, February 2005.

Lee, T., X.-Y. Yu, B. Ayres, S. Kreidenweis, and J. L. Collett, Jr., “Characterization of Particulate Inorganic Ions at Selected IMPROVE Sites,” presented at the 2004 Fall American Geophysical Union Meeting, San Francisco, CA, December 13–17, 2004.

Lee, T., X.-Y. Yu , B. Ayres, J. Carrillo, C. Carrico, S.M. Kreidenweis, J.L. Collett, Jr., and W.C. Malm, “Characteristics of Aerosol Nitrate at Several IMPROVE Monitoring Sites”, presented at the Air and Waste Management Association conference, Asheville, NC, October 25–29, 2004.

Lunden, M., D. Black, N. Brown, G. McMeeking, S. Kreidenweis, C. Carrico, T. Lee, J. Carrillo, J.L. Collett, Jr., D. Day, J.L. Hand, and W.C. Malm, “The Influence of Forest Fires in the Western United States on Pollutant Concentrations in California During the Summer of 2002,” presented at the American Association for Aerosol Research conference, Atlanta, GA, October 4-8, 2004.

Malm, W.C., D.E. Day, C.M. Carrico, T. Lee, T., J. Collett, S. Kreidenweis, G. McMeeking, and J. Carrillo, “Chemical and optical properties of an organic-laden ambient aerosol in Yosemite National Park,” presented at the Air & Waste Management Association Specialty Conference, Asheville, NC, October 25–29, 2004.

McMeeking, G. R., S.M. Kreidenweis, C. Carrico, T. Lee, J. Carrillo, J.L. Collett, Jr., D.E. Day, J.L. Hand, and W.C. Malm, “Dry Aerosol Size Distributions and Derived Optical Properties During the Yosemite Aerosol Characterization Study,” presented at the Air and Waste Management Association conference, Asheville, NC, October 25–29, 2004.

8. Publications:

Carrico, C.M., S. M. Kreidenweis, W.C. Malm, D.E. Day, T. Lee, J. Carrillo, G.R. McMeeking, and J.L. Collett, Jr., Hygroscopic growth behavior of a carbon dominated aerosol in Yosemite National Park, *Atmos. Environ.,* 39, 8, 1393-1404, 2005.

Engling, G., P. Herckes, S.M. Kreidenweis, W.C. Malm, and J. L. Collett, Jr., Composition of the fine organic aerosol in Yosemite National Park during the 2002 Yosemite Aerosol Characterization Study, *Atmos. Environ*., 40, 2959–2972, 2006a.

Engling, G., C.M. Carrico, S.M. Kreidenweis, J.L. Collett, Jr., D.E. Day, W.C. Malm, W. M. Hao, E. Lincoln, Y. Iinuma, H. Herrmann, Determination of Levoglucosan in Biomass Combustion Aerosol by High Performance Anion Exchange Chromatography with Pulsed Amperometric Detection, *Atmos. Environ.*, in press, 2006b.

Hand, J.L., W.C. Malm, D. Day, T. Lee, C. Carrico, J. Carrillo, J. Collett, Jr. A. Laskin, C. Wang, J.P. Cowin, M.J. Iedema, Optical, physical and chemical properties of tar balls observed during the Yosemite Aerosol Characterization Study, *J. Geophys. Res.*, 110, D21210, doi:10.1029/2004JD005728, 2005.

Herckes, P., G. Engling, S.M. Kreidenweis, and J.L. Collett, Jr., Particle size distributions of organic aerosol constituents during the 2002 Yosemite Aerosol Characterization Study, *Environ. Sci. Technol.*, in press, 2006.

Lee, T., S.M. Kreidenweis, and J.L. Collett, Jr., Aerosol ion characteristics during the Big Bend Regional Aerosol and Visibility Observational study, *J. Air Waste Manage. Assoc.*, 54, 585-592, 2004.

Malm, W.C., D.E. Day, C. Carrico, S.M. Kreidenweis, J.L. Collett, Jr., G. McMeeking, T. Lee, and J. Carrillo, Intercomparison and closure calculations using measurements of aerosol species and optical properties during the Yosemite Aerosol Characterization Study, *J. Geophys. Res.*, 110, D14302, doi:10.1029/2004JD005494, 2005a.

Malm, W.C., D.E. Day, S.M. Kreidenweis, J.L. Collett, Jr., C. Carrico, G. McMeeking, and T. Lee, Hygroscopic properties of an organic-laden aerosol, *Atmos. Environ.*, 39, 4969-4982, 2005b.

McMeeking, G.R., S.M. Kreidenweis, C.M. Carrico, T. Lee, J.L. Collett, and W.C. Malm, Observations of smoke influenced aerosol during Yosemite Aerosol Characterization Study, Part I: Size distributions and chemical composition, *J. Geophys. Res.,* 110, D09206, doi:10.1029/2004JD005389, 2005a.

McMeeking, G.R., S.M. Kreidenweis, C.M. Carrico, T. Lee, J. Collett, D.E. Day, and W.C. Malm, Observations of smoke influenced aerosol during the Yosemite Aerosol Characterization Study Part II: Aerosol scattering and absorbing properties, *J. Geophys. Res.,* Vol. 110, No. D18, D18209, doi: 10.1029/2004JD005624, 2005.

McMeeking, G.R., S.M. Kreidenweis, M. Lunden, J. Carrillo, C.M. Carrico, T. Lee, P. Herckes, G. Engling, D.E. Day, J. Hand, N. Brown, W.C. Malm, and J.L. Collett, Jr., Smoke-impacted regional haze in California during the summer of 2002, *Agricultural and Forest Meteorology*, 137, 25–42, 2006.

Yu, X.-Y., T. Lee, B. Ayres, S.M. Kreidenweis, J L. Collett, Jr., and W. Malm, Particulate nitrate measurement using nylon filters, *J. Air Waste Manage. Assoc.*, 55, 1100-1110, 2005.

Yu, X.-Y., T. Lee, B. Ayres, S.M. Kreidenweis, W.C. Malm, and J.L. Collett, Jr., Loss of fine particle ammonium from denuded nylon filters, *Atmos. Environ.*, 40, 4797-4807, 2006.

NATIONAL PARK SERVICE – Investigation of the Fate and Origin of Sulfur and Nitrogen along the Colorado Front Range and in Rock Mountain National Park and Development of Improved Methods for Characterizing Wildland Fire Particulate Matter Emissions and Their Air Quality/Visibility Impacts

Principal Investigators: Jeff Collett/Sonia Kreidenweis

NOAA Project Goal: Air Quality

Key Words: Smoke, Biomass Combustion, Deposition, Air Quality, Air Pollution, Visibility, Aerosol, Precipitation

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

This project addresses two main areas of emphasis: (1) Investigation of the transport and fate of airborne nitrogen and sulfur species in Rocky Mountain National Park (RMNP) and upwind areas and (2) Improved characterization of wildland fire particulate matter emissions and their impacts on downwind air quality and visibility. We also are continuing development of the NPS mobile air quality laboratory, which will be deployed as part of each of these studies, and continuing analysis and publication of findings from previous NPS investigations, including the Yosemite aerosol characterization study and the IMPROVE site nitrate study.

During 2005/06 we have planned and executed a field campaign to examine properties of smoke produced during combustion of different biofuels in the USFS Missoula Fire Science Laboratory Combustion Chamber and conducted a pilot study and two field campaigns to examine spatial and temporal variability in airborne sulfur and nitrogen concentrations and deposition within Rocky Mountain National Park and at locations upwind.

Specific project objectives, and their current status, are as follows:
--Design and conduct a pilot study and two main field campaigns designed to look at pollutant transport into RMNP and pollutant concentrations and deposition within the park. Status – pilot study and spring campaign complete – summer campaign underway.

--Develop an unambiguous, routine, and cost effective methodology for IMPROVE and other monitoring networks to characterize carbonaceous and other compounds in $PM_{2.5}$ aerosol as originating with prescribed and wildfire burn activities. Status – marker measurement method optimization is continuing, with a manuscript on this method published as indicated below. First biofuel combustion tests completed; sample and data analysis in progress.

--Complete ongoing construction of the NPS Mobile Air Quality Lab. Field test the lab for subsequent deployment in the RMNP and smoke field studies. Status – mobile lab completed, tested, and deployed three times in field campaigns in 2006.

--Complete publications still in progress for recent studies in Yosemite NP and in the various IMPROVE Nitrate Study sites (San Gorgonio, Grand Canyon, Bondville, Brigantine, and Great Smoky Mountains). Status – manuscripts completed and published as indicated below.

Results of this project promise to improve the ability of regulators and policymakers to address high profile air quality issues including increased deposition of nitrogen species to sensitive, high elevation ecosystems in the Rocky Mountains and impacts of wild and prescribed fires on formation of regional haze. Partners in this research effort include the National Park Service, USDA Forest Service, USEPA, State of Colorado Department of Public Health and Environment, University of Nevada Desert Research Institute, University of California – Davis, Aerodyne, University of Colorado, National Science Foundation, NASA, Air Resource Specialists, and Academica Sinica (Taiwan).

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:

(a) CSU graduate students supported by this project include Gavin McMeeking, Taehyoung Lee, Courtney Gorin, Rich Cullin, and Katie Beem. Undergraduate students working on the project included Tim Hinerman, Alicia Evans, and Alice Bote.

8. Publications:

Collett, Jr., J. L., I can't see clearly now – atmospheric aerosol particles and their impact on visibility. Presented to the Department of Chemistry and Biochemistry, Arizona State University, Tempe, AZ, Nov. 2005.

Collett, J., Rocky Mountain National Park Air Quality Study: overview of 2005 pilot study findings. Presented at the Colorado Department of Public Health and Environment, Denver, Colorado, January 2006.

Collett, Jr., J. L., Nitrogen transport and deposition in Rocky Mountain National Park, Colorado Farm Bureau Summer Meeting, Breckenridge, Colorado, July 2006.

Carrico, C.M., M.D. Petters, S.M. Kreidenweis, G. Engling, J.L. Collett, Jr., W. Malm, Laboratory Investigations of Hygroscopic Properties and Cloud Droplet Activation of Biomass Burning Aerosols, 1PL15, American Association for Aerosol Research Conference, Austin, TX, October 2005.

Day, D.E., J. L. Hand, C.M. Carrico, G. Engling, and W.C. Malm, Humidification factors from laboratory studies of fresh smoke from biomass fuels, *J. Geophys. Res*., in review, 2006.

Engling, G., P. Herckes, S.M. Kreidenweis, W.C. Malm, and J. L. Collett, Jr., Composition of the fine organic aerosol in Yosemite National Park during the 2002 Yosemite Aerosol Characterization Study, *Atmos. Environ*., 40, 2959–2972, 2006a.

Engling, G., C.M. Carrico, S.M. Kreidenweis, J.L. Collett, Jr., D.E. Day, W.C. Malm, W. M. Hao, E. Lincoln, Y. Iinuma, H. Herrmann, Determination of Levoglucosan in Biomass Combustion Aerosol by High Performance Anion Exchange Chromatography with Pulsed Amperometric Detection, *Atmos. Environ.*, in press, 2006b.

Hand, J.L., W.C. Malm, D. Day, T. Lee, C. Carrico, J. Carrillo, J. Collett, Jr. A. Laskin, C. Wang, J.P. Cowin, M.J. Iedema, Optical, physical and chemical properties of tar balls observed during the Yosemite Aerosol Characterization Study, *J. Geophys. Res.*, 110, D21210, doi:10.1029/2004JD005728, 2005.

Herckes, P., G. Engling, S.M. Kreidenweis, and J.L. Collett, Jr., Particle size distributions of organic aerosol constituents during the 2002 Yosemite Aerosol Characterization Study, *Environ. Sci. Technol.*, in press, 2006.

Malm, W.C., D.E. Day, C. Carrico, S.M. Kreidenweis, J.L. Collett, Jr., G. McMeeking, T. Lee, and J. Carrillo, Intercomparison and closure calculations using measurements of aerosol species and optical properties during the Yosemite Aerosol Characterization Study, *J. Geophys. Res.*, 110, D14302, doi:10.1029/2004JD005494, 2005a.

Malm, W.C., D.E. Day, S.M. Kreidenweis, J.L. Collett, Jr., C. Carrico, G. McMeeking, and T. Lee, Hygroscopic properties of an organic-laden aerosol, *Atmos. Environ*., 39, 4969-4982, 2005b.

McMeeking, G., S. Kreidenweis, J. Carrillo, J. Collett, Jr., M. Lunden, D. Day, and W. Malm, Regional Scale Measurements of Smoke-Impacted Haze in California, Oregon, and Washington, 8PI14, American Association for Aerosol Research Conference, Austin, TX, October 2005.

McMeeking, G R, Kreidenweis, S M, Carrillo, J, Collett, J L, Lunden, M, Malm, W C, and Day, D, Regional-Scale Measurements of Smoke-Impacted Haze in California, Oregon and Washington. Presented at the Fall Meeting of the American Geophysical Union, San Francisco, CA, Dec. 2005.

McMeeking, G.R., S.M. Kreidenweis, C.M. Carrico, T. Lee, J. Collett, D.E. Day, and W.C. Malm, Observations of smoke influenced aerosol during the Yosemite Aerosol Characterization Study Part II: Aerosol scattering and absorbing properties, *J. Geophys. Res.,* Vol. 110, No. D18, D18209, doi: 10.1029/2004JD005624, 2005.

McMeeking, G.R., S.M. Kreidenweis, M. Lunden, J. Carrillo, C.M. Carrico, T. Lee, P. Herckes, G. Engling, D.E. Day, J. Hand, N. Brown, W.C. Malm, and J.L. Collett, Jr., Smoke-impacted regional haze in California during the summer of 2002, *Agricultural and Forest Meteorology*, 137, 25–42, 2006.

Yu, X.-Y., T. Lee, B. Ayres, S.M. Kreidenweis, J L. Collett, Jr., and W. Malm, Particulate nitrate measurement using nylon filters, *J. Air Waste Manage. Assoc.*, 55, 1100-1110, 2005.

Yu, X.-Y., T. Lee, B. Ayres, S.M. Kreidenweis, W.C. Malm, and J.L. Collett, Jr., Loss of fine particle ammonium from denuded nylon filters, *Atmos. Environ*., 40, 4797-4807, 2006.

NATIONAL PARK SERVICE - Statistical Analyses Related To Air Quality and Atmospheric Visibility

Principal Investigator: Hari Iyer

NOAA Project Goal: Air Quality

Key Words: Source Apportionment, Hybrid Model, Uncertainty Calculations, Computer Classification of Audio Signals Recorded in National Park Sites

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

Statistical modeling of air quality data, source apportionment, hybrid modeling using monitoring data along with numerical model predictions, characterization of uncertainties in visibility statistics, computer classification of different audio sources in national parks.

2. Research Accomplishments/Highlights:

--A hybrid model approach for source apportionment has been developed and simulation studies have been conducted to compare the hybrid model with other models (Chemical Mass Balance Model (CMB), Positive Matrix Factorization (PMF), and UNMIX based on eigenfunction techniques). The hybrid model approach appears to have the potential for providing results with smaller mean-squared errors.

--A method for quantifying uncertainties in air quality statistics has been developed based on FIDUCIAL INFERENCE. The method is akin to Bayesian methodology except for the fact that prior distributions need not be specified for model parameters. This approach also has great promise in the field of metrology.

--Recording of sounds from national parks has been analyzed using statistical learning methods and the feasibility of computer classification of sounds has been evaluated on preliminary audio samples from known sources. A method has been developed that uses the MEL Cepstral coefficients on audio segments from a continuous recording. Initial tests indicate that this method has satisfactory success rates of correct classification.

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

Complete except for a summary report of the sound classification results.

4. Leveraging/Payoff:

The fiducial inference method of quantifying uncertainties in measurements is also of interest to NIST for metrological applications.

5. Research/Linkages/Partnerships/Collaborators:

Some of the work on fiducial inference was carried out jointly with collaborators from NIST.

6. Awards/Honors: None

7. Outreach:

One statistics graduate student was supported (Ms. Stacey Hancock). She worked on audio classification as well as hybrid model simulations. She is a PhD student and is expected to complete her degree in one to two years.

8. Publications:

A key paper on Fiducial inference was published in the Journal of the American Statistical Association. The title and reference are given below.

Hannig, J., H. Iyer and P. Patterson, 2006: Fiducial generalized confidence intervals. J. of the American Statistical Association, 101 (473), March, pp, 254-69.

<u>NATIONAL SCIENCE FOUNDATION</u> – Collaborative Proposal to NSF: Ensemble Data Assimilation Based on Control Theory

Principal Investigator: Milija Zupanski

NOAA Project Goal: Weather and Water, Climate

Key Words: Non-Gaussian, Non-differentiable, Minimization, Ensemble Assimilation/Prediction, Maximum Likelihood Ensemble Filter, Shallow-water

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

The long-term objective of this research is to explore the possibility for using an ensemble assimilation/prediction system in general Weather and Climate applications. In particular, the 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. In particular, 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. 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

--Long-term impact of space-time dynamical correlations in weakly-chaotic systems is exploited in devising a new methodology for initiation of an ensemble system (M. Zupanski et al. 2006)

--MLEF system with lognormal observation errors is developed (Fletcher and Zupanski 2006b),

--Hybrid Normal-lognormal MLEF system allowing both the initial conditions and observation non-Gaussian errors is developed (Fletcher and Zupanski 2006a),

--MLEF system as a non-differentiable minimization algorithm is developed,

--Method for adaptive ensemble size reduction and inflation is developed and tested with shallow-water model (Uzunoglu et al. 2006).

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 *2005 AMS Annual Meeting* (San Diego, CA), *Workshop on Weather and Climate* (International Centre for Theoretical Physics, Trieste, Italy), *4th WMO Data Assimilation Workshop* (Prague, Czech Republic), *2005 EGS Annual Meeting*

(Vienna, Austria), the *2006 AMS Annual Meeting* (Atlanta, GA), and the *Workshop on Predictability, Observations, and Uncertainties in Geosciences* (Tallahassee, FL).

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

Fletcher, S.J., and M. Zupanski, 2006a: A hybrid multivariate Normal and lognormal distribution for data assimilation. *Atmos. Sci. Let*., 7, 43-46.

Fletcher, S.J., and M. Zupanski, 2006b: A data assimilation method for lognormally distributed observation errors. *Q. J. R. Meteorol. Soc*., in print.

Uzunoglu, B., S.J. Fletcher, I. M. Navon, and M. Zupanski, 2006: Adaptive ensemble size reduction and inflation. *Q. J. R. Meteorol. Soc.*, submitted.

Zupanski, D., and M. Zupanski, 2006: Model error estimation employing an ensemble data assimilation approach. *Mon. Wea. Rev*., 134, 1337-1354.

Zupanski, D., M. Zupanski, A. Y. Hou, S. Q. Zhang, and C. D. Kummerow, 2006: Information theory and ensemble data assimilation. Part I: Theoretical aspects. *J. Atmos. Sci*., submitted.

Zupanski, M., S.J. Fletcher, I.M. Navon, B. Uzunoglu, R.P. Heikes, D.A. Randall, T.D. Ringler, and D. Daescu, 2006: Initiation of ensemble data assimilation. *Tellus*, 58A, 159-170.

Zupanski, M., and I. M. Navon, 2006: Predictability, observations and uncertainties in geosciences. *Bull. Amer. Meteor. Soc*., submitted.

NATIONAL SCIENCE FOUNDATION – 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:

Key Words: Arctic, Winter, Snow, Precipitation, Sublimation

New Project – Nothing to report for this fiscal year.

<u>VAISALA</u> -Collaborative FX-Net Technology Consultation with the Vaisala Group

Principal Investigators: Cliff Matsumoto and Sher Schranz

NOAA Project Goal/Program: 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

Background: Vaisala, an international company with headquarters in Vantaa, Finland develops, manufactures and markets products and services for environmental and industrial measurement, with a mission to provide the basis for better quality of life, environmental protection, safety, efficiency and cost savings. They wish to understand how the technologies surrounding the FX-Net and gridded FX-Net systems could be used by it and integrated into a commercial business plan. Due to the complexity of the candidate systems, Vaisala will approach the potential technology transfer in phases. Some preliminary planning meetings have taken place to provide Vaisala business units with basic information on these technology applications, with the intent of better defining the work required during subsequent phases. This initial collaboration covers Phase I of this approach.

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

Phase I – Vaisala Business Review: This phase will focus on Vaisala's thorough examination of the candidate FX-Net technology applications and the planning sessions required to determine how these applications can best be used within Vaisala's business units. In addition to the candidate FX-Net technologies, additional supporting technologies (e.g., AWIPS/ALPS workstation) may require review. FX-Net technology application experts will be available to support these discussions. It is anticipated that the primary support for these technology application discussions will be in the form of consulting services and will be supplied through telephone conferences, local meetings and a meeting in Helsinki.

2. Research Accomplishments/Highlights:

CIRA provided technical consulting services to support Vaisala's examination of CIRA and NOAA/ESRL/GSD candidate technology applications by performing the following tasks:

--Three Technical Interchange meetings in Boulder, Colorado that occurred February 1, April 24, and June 1, 2006.
--One Technical Seminar in Helsinki, Finland held during March 6-9, 2006.

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

All planned objectives were met.

CIRA AWARDS

- 2005 Research Initiative Awards:
  Each year CIRA is proud to recognize two employees (or groups) as Research Initiative Award winners. These are people who have significantly contributed to the success of CIRA's research effort.

  --Steve Albers was recognized for helping to create the Precision Airdrop System (PADS) in response to a request from the U.S. Army's Natick Soldier Systems Center and the U.S. Airforce Mobility Command.

  --Don Reinke was honored for his tremendous contributions to the CloudSat Data Processing Center, related projects and managerial accomplishments.

- Jebb Stewart was designated as FSL's Team Member of the Month for July 2005. He received this recognition for outstanding efforts in furthering the FX-Net technology and projects. The nomination came from Technology Outreach Division Chief, Bill Bendel.

- Professor Graeme Stephens, a longtime CIRA collaborator, was named a University Distinguished Professor in April 2005 by CSU President Larry Edward Penley.

- In 2005, CIRA research scientist Tomislava Vukicevic was selected as a Fulbright Scholar to teach at the University of Beograd in Serbia and Montenegro. The Fullbright program is sponsored by the U.S. Department of State.

- Jeff Smith and Glen Pankow were recognized for their innovative achievements in web technology and applications with the 2005 ESRL/GSD Web Awards: Jeff Smith - Aviation Branch, Advanced Computing Section, WRF Portal, Best New Site and Glen Pankow – Information and Technology Services, Data Systems Section, GRIB Data Viewer, Best Internal Use.

- Dr. Sonia Kreidenweis, a CIRA Fellow and Professor of Atmospheric Science, received the Outstanding Professor Award for 2005 in the Department of Atmospheric Science, CSU.

- Dr. Graeme Stephens, a CIRA Fellow and Professor of Atmospheric Science at CSU, was named a Fellow by the American Association for the Advancement of Science (AAAS) for his numerous contributions to research in atmospheric radiation and the use of remote sensing in climate studies.

- Dr. Mark DeMaria, NESDIS/RAMM Branch leader at CIRA and CSU Department of Atmospheric Science graduate, received the NOAA Silver Medal. This award is the second highest honorary award given by NOAA for exceptional performance. He and NOAA colleague Dr. Michelle Mainelli were honored for their collaborative effort to improve the operational intensity forecast tool known as the Statistical Hurricane Intensity Prediction Scheme (SHIPS).

- In recognition of Dr. Gerald Browning's long and extremely high-quality research contributions to CIRA, the title of Research Scientist Emeritus was granted to him. This marks the first time CIRA has awarded this prestigious designation to one of its employees.

- The Real Time Verification System – Next Generation Development Group includes Sean Madine, Missy Petty, Nick Matheson and Dale Betterton. This group received the March 2006 GSD Team Members of the Month Award. The nomination came from Aviation Branch Chief Mike Kraus.

- Dr. Dave Randall, Professor of Atmospheric Science and a CIRA collaborator, was awarded the Scholarship Impact Award for 2005. The Scholarship Impact Award is Colorado State University's highest award for accomplishment in research. Professor Randall is internationally recognized for his contributions to the understanding of global atmospheric circulation and the use of computers to model the Earth's climate.

CIRA EMPLOYEE MAXTRIX

Employees who received 50% support or more		Degree			
Category	Number	Bachelors	Masters	Doctorate	Non-Degreed
Research Scientists	61	24	17	19	1
Visiting Scientists	0	0	0	0	0
Postdoctoral Fellows	10	0	0	10	0
Research Support Staff & Administrative Personnel*	13	5	3	0	5
Total	84	29	20	6	61
Employees who received less than 50% support		**Degree**			
Category	Number	Bachelors	Masters	Doctorate	Non-Degreed
Research Scientists	23	5	9	9	0
Visiting Scientists	0	0	0	0	0
Postdoctoral Fellows	0	0	0	0	0
Research Support Staff & Administrative Personnel*	29	12	2	2	13
Total	52	17	11	13	0
Supported Students		**Degree**			
Category	Number	Bachelors	Masters	Doctorate	
Undergraduate	0	0	0	0	
Graduate	1	0	0	1	
Total	1	0	0	0	
Employees located at NOAA Laboratories		**GSD**	**PSD**	**CSD**	
Total	45	43	1	1	
Obtained NOAA Employment within the last year					
Total	2				

***CIRA does not differentiate between Research Support Staff and Administrative Personnel**

	CI Lead Author					NOAA Lead Author					Other Lead Author				
	FY 01-02	FY 02-03	FY 03-04	FY 04-05	FY 05-06	FY 01-02	FY 02-03	FY 03-04	FY 04-05	FY 05-06	FY 01-02	FY 02-03	FY 03-04	FY 04-05	FY 05-06
Peer-Reviewed	~~~	~~~	29	70	42	20	21	20	14	30	77	78	40	25	71
Non Peer-Reviewed	~~~	~~~	82	128	40	73	32	48	52	91	108	44	53	46	64