

ANNUAL REPORT 2003-2004

Cooperative Institute for



CIRA ANNUAL REPORT FY 03/04

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 Joint Institute concept for the period July 1, 2003 through June 30, 2004. 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 web site:

<http://www.cira.colostate.edu/>

CIRA MISSION

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

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

CIRA VISION

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

EDUCATION, TRAINING AND OUTREACH

AHPS CIRA is working 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 Toxics is a website that provides 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 is part of the ongoing work to support the deployment of a national air toxics monitoring system. <http://vista.cira.colostate.edu/atda/>

CoCo-RaHS is a multi-state informal science education program where volunteers help scientists measure, map and track patterns of rainfall, hail and snow across the sparsely populated, storm-prone Central Great Plains. This program is administered by the Department of Atmospheric Science at Colorado State University. Each year CIRA helps support educational activity connected with the CoCo-RaHS program. Recently CIRA has provided support for a teacher to develop a series of lesson plans at the middle school level to utilize weather concepts and CoCo RaHS precipitation data in math, science and geography lessons. <http://www.cocorahs.org> and click on "For Teachers."

ELC is a beginning development effort at CIRA to learn about the earth's environment and its connection with the atmosphere through an extensive series of web-based animations aimed at the elementary, middle, and high school/college grade levels.

FX-Net is a meteorological PC workstation system that provides access to the basic display capabilities of an AWIPS workstation via the Internet. This will allow students preparing for careers in operational meteorology to have the opportunity to work with the actual technology they will find in weather offices.

<http://www-id.fsl.noaa.gov/fxnet.html>

GLOBE is a worldwide hands-on primary and secondary school-based education and science program. Students have the opportunity to take scientifically valid measurements in the fields of atmosphere, hydrology, soils, and land cover/phenology; report their data through the Internet; analyze the data on a free interactive Web site; and collaborate with scientists and other Globe students around the world. As of July 1, 2004, 106 countries and over 15,000 schools have participated in GLOBE. CSU/CIRA is a major partner in this educational enterprise. <http://www.globe.gov>

IMPROVE is an effort implemented as an extensive long-term monitoring program to establish current visibility conditions, track changes in visibility and determine causal mechanisms for visibility impairment in the National Parks and Wilderness Areas. This Web site provides access to monitoring data resources and educational material on the science of visibility and regulations. <http://vista.cira.colostate.edu/improve/>

PINGREE PARK is a Colorado State University 1,200-acre campus within sight of Rocky Mountain National Park, the Comanche Peak Wilderness Area, and Roosevelt National Forest. During each year thousands of conference visitors, students, and vacationing tourists visit and stay at the Pingree Park location. As a continuing outreach activity, CIRA provides a Pingree Park Web site address for current weather information to assist these visitors in enjoying this beautiful mountain valley site. www.housing.colostate.edu/pingree/webcam_weather.htm

RMTCs are specialized satellite application training centers designated by the World Meteorological Organization (WMO). CIRA has interacted with RMTCs in Costa Rica and Barbados since 1996. <http://www.cira.colostate.edu/RAMM/trngtbl.htm>

ShyMet is a Satellite Hydrology and Meteorology Course under development. Taught through a combination of teletraining, CD-ROM, Web-based instruction and on-site training, the course will cover satellite instrumentation, orbits, calibration and navigation, identification of atmospheric and surface phenomena, radiation theory and the integration of meteorological techniques with satellite observing capabilities. The main objective is to prepare NOAA/NWS users for the latest polar orbiting and geostationary satellite data and products in the warning and forecast programs. http://www.cira.colostate.edu/RAMM/SHyMet/ShyMet_main.htm

VIEWS is an on-line exchange of visibility data, research, and ideas designed to support the Regional Haze Rule enacted by the U.S. Environmental Protection Agency (EPA) to reduce regional haze in National Parks and Wilderness Areas. In addition to this primary goal, VIEWS supports global efforts to better understand the effects of air pollution on visibility and to improve air quality in general. <http://vista.cira.colostate.edu/views/>

VISIT is a joint effort involving NOAA/NESDIS/NWS in accelerating the transfer of research results based on atmospheric remote sensing data into distance education techniques. <http://www.cira.colostate.edu/ramm/visit/visithome.asp>

CIRA RESEARCH HIGHLIGHTS

July 1, 2003 – June 30, 2004

Global and Regional Climate Dynamics

- Collaborations continued on the development of computer software for the parallelization of atmospheric and oceanic weather and climate models through enhancements of both the WRF model and the Scalable Modeling System (SMS). Feasibility of combining geographically distributed computing resources into a single virtual resource was explored by creating and demonstrating a WRF/ROMS coupled model running simultaneously at FSL and PMEL.
- Feasibility of forecasting runoff using a non-hydrostatic multi-scale regional climate model down to scales that resolve individual valleys and massifs was examined. Set of three 5-year experiments using a high-resolution coupled atmosphere-land surface modeling system to simulate runoff in a hydrologic model was conducted.
- Our climate modeling efforts (Northwest Mexican Monsoon and Great Plains Precipitation) found that soil moisture anomalies had a greater impact than SST anomalies on monsoon circulations and precipitation.
- Developed a stochastic process that can reproduce a climatology of the observed abrupt shifting dynamics in the Great Lakes basin.

Mesoscale and Local Area Forecasting and Evaluation

- Several new research collaborations on mesoscale studies occurred during the past year. One involved the development of a new convective ensemble-based parameterization for the RUC. Another effort involved the analysis of bore dynamics during the IHOP 2002 field experiment. A third effort involved the development of a time-lagged ensemble forecast system based on various RUC forecasts initialized at different times. Another effort was begun to develop a wavelet-based diagnostic tool to better detect gravity waves and clear air turbulence.
- GPS tomography technique was tested using actual GPS data and the resulting water vapor analysis was compared with satellite water vapor imagery and sounding data obtained during IHOP with good results.
- First year of proof-of-concept testing of local data assimilation and NWP within a NWS Forecast Office produced favorable results. Satellite, radar, and other local data were used for real-time initialization the WRF model on a Linux cluster.

- Collaborations with the Boulder WFO on evaluations of an experimental infrasound system developed by ETL have begun. Cases of tornado events will be examined to determine the potential value of the new system to provide enhancement to radar in the detection of tornadoes.
- A specially configured mesoscale ensemble forecast system comprised of MM5 and WRF model runs was developed to support the Road Weather Maintenance Decision Support System (MDSS) for the FHA. LAPS analysis was used to initialize both WRF and MM5 to produce 48 runs per day out to 15 hours during the entire 2003/2004 winter. These forecast grids serve as input to provide forecast winter road conditions and recommended treatment options for road maintenance personnel.
- Support of the US Fire Consortia for Advanced Modeling of Meteorology and Smoke continued with enhanced fire weather products including a “Critical Fire Weather Index.” Plots of surface latent heat flux forecasts and solar radiation observations were created to help diagnose and improve surface relative humidity forecasts.
- SCAN (System for Convection Analysis and Nowcasting) developed by the NWS/MDL was ported into Taiwan Central Weather Bureau’s AWIPS-like weather forecasting workstation to better integrate weather surveillance radar data for short-term severe weather analyses and forecasts. Follow-on effort to integrate MDL’s Flash Flood Monitoring Program into AWIPS for hydrologic forecast and emergency management support was initiated.
- Successfully completed the first dual Doppler micro-scale wind/density/turbulence study in the Oklahoma City area.

Applications of Satellite Observations

- Several research efforts in collaboration with the National Geophysical Data Center continued involving DMSP imagery, GIS, and other specialized remote sensing data manipulation and mapping techniques. These efforts included: 1) a project to demonstrate that coral reef bleaching can be detected with IKONOS satellite imagery using radiometric normalization of image pairs using change detection techniques; 2) compilation of data for comparison of the capabilities of different instruments (DMSP, MODIS, VIRS) for fire detection; and 3) data processing and analysis to estimate the amount of impervious surface area (ISA) within the conterminous United States, using DMSP satellite data, U.S. Census Bureau TIGER roads data, high-resolution aerial photography, and Landsat TM classification data from USGS EROS Data Center. This project is part of NASA’s Land Use Land Cover program, and the product is used as input to models for carbon cycling.

- Improved the dew point retrieval error statistics over the existing GOES sounder-only methodology and the NCEP first guess only method.
- Successfully implemented (at CIRA and NESDIS/OSDPD) a Total Precipitable Water product that combines AMSU and SSM/I sensor data from all the NOAA and DMSP satellites with these sensors.
- Created a GOES-IR-based wind field estimation method.
- A variational analysis system was applied to satellite wind data to produce a complete surface wind field. This method allows partial wind observations (such as wind speed obs with ambiguous direction) to be assimilated.
- Began simulation studies in support of NPOESS sensor risk reduction. Demonstrated a method for combining a numerical cloud model with an observational operator to produce synthetic NPOESS imagery.
- Validated AMSU temperature retrievals under cloudy and precipitating conditions in a hurricane system.
- Validated the GOES Aerosol and Smoke Product (GASP) output and applied it to large scale air pollution events over the US mid-Atlantic region.
- Developed a new ice cover mapping system that combines AVHRR and GOES. Current studies are looking at potential snow depth algorithm improvements.

Cloud Physics

- Retrieval of liquid water flux and drizzle properties from stratus clouds were developed and refined using millimeter cloud radar, along with Doppler lidar and wind profiler mounted on a ship.
- Series of eddy resolving simulations (ERS), and large eddy simulations (LES) of smoke-cloud interactions were performed to demonstrate the relative importance of various factors responsible for cloud suppression in the biomass burning regions of Amazonia.

Numerical Modeling

- A special configuration of the LAPS “hot-start” forecast system implemented operationally at Vandenberg AFB, CA last year was installed at Cape Canaveral this past year. This involves a triple-nested version of the MM5 model diabatically initialized with LAPS. Convective instabilities at the finer 1.1 km inner grid spacing were corrected that have resulted in improved QPF forecast fields.

- The WRF Standard Initialization (SI) was significantly improved, including support for the incorporation of the NCEP Nonhydrostatic Mesoscale Model (NMM) core. Capability to set up and initialize nested WRF domains was also implemented.
- Completed the development of our Regional Atmospheric Modeling and Data Assimilation System (RAMDAS).
- Developed a Southern Hemisphere tropical cyclone model now installed at the Joint Typhoon Warning Center.
- Completed the development of an ensemble method for determining the error covariance matrix for model and forecast errors.
- Applied ensemble data assimilation and model error method to NASA's GEOS column precipitation model.

Education, Training, and Outreach

- GLOBE Systems team comprised of 10 CIRA researchers successfully transferred their operation from the NOAA/FSL facility to the UCAR Foothills Lab campus with no impact to the Program's worldwide users now located in 106 countries. There are now more than 11 million observations in the GLOBE database collected by students in over 15,000 schools since the Program's inception in 1995.
- The PACE effort comprised of two separate investigative projects—TMU and FX-Connect—made significant progress this past year. The effort is driven by the need for innovative software tools and data products to minimize adverse weather disruptions in air traffic operations. For phase I of the TMU project, a prototype Tactical Convective Hazards Product was prototyped and enhanced. The FXC Volcanic Ash Coordination Tool project is a response to the needs of collaborating agencies in generating consistent Volcanic Ash Advisories. The initial release of the FXC VACT systems, including the delivery and installation of both hardware and software, along with major enhancements.
- During the 2003 fire season, FX-Net server systems were installed in four of the NWS Regional HQs offices (Western, Southern, Alaska, and Pacific). At one point during a very active wildfire season, 32 Incident Meteorologists in the field deployed by the Western Region were using FX-Net as their primary forecasting system.
- A new version of the wavelet data compression was applied to the FX-Net system to more efficiently compress satellite and model grid images, and to reduce the file encoding and decoding time. This new version of FX-Net was

fielded at the National Interagency Fire Center, at the Western and Southern NWS Regional HQs offices, and for university clients and NOAA researchers.

- Latest version of the Air Quality FX-Net was deployed to researchers involved in the AIRMAP Program over New England. Additional air quality observation data were also added to the FX-Net ingest and display capability during 2003.
- With the conversion of AWIPS from an HPUX to a Linux operating system, new technologies for implementation on Linux platforms were explored to address the ever-increasing amount of data. An Advanced Linux Prototype System was formulated focusing on employment of new network and database technologies.
- A specialized version of the Display-3D (D3D) interface for AWIPS was implemented for display of 3D lightning data at Cape Canaveral.
- Novel visualization of global weather phenomena and in-the-round visualization of other planets and moons in our solar system were developed for the Science on a Sphere display platform.
- Ported a new Wavelet-based compression algorithm to UNIX, Linux, and Win2000 operating systems. This system was targeted to uplink satellite data to NOAA's P-3 aircraft for hurricane surveillance and penetration.
- The Virtual Institute for Satellite Integration Training (VISIT) has issued over 12,000 training certificates.

Societal and Economic Impacts

- Several research efforts in collaboration with the National Geophysical Data Center continued involving DMSP imagery, GIS, and other specialized remote sensing data manipulation and mapping techniques. These efforts included: 1) a project to demonstrate that coral reef bleaching can be detected with IKONOS satellite imagery using radiometric normalization of image pairs using change detection techniques; 2) compilation of data for comparison of the capabilities of different instruments (DMSP, MODIS, VIRS) for fire detection; and 3) data processing and analysis to estimate the amount of impervious surface area (ISA) within the conterminous United States, using DMSP satellite data, U.S. Census Bureau TIGER roads data, high resolution aerial photography, and Landsat TM classification data from USGS EROS Data Center. This project is part of NASA's Land Use Land Cover program, and the product is used as input to models for carbon cycling. Ultimately, this information will be used with many other data in the global warming debate.
- 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.

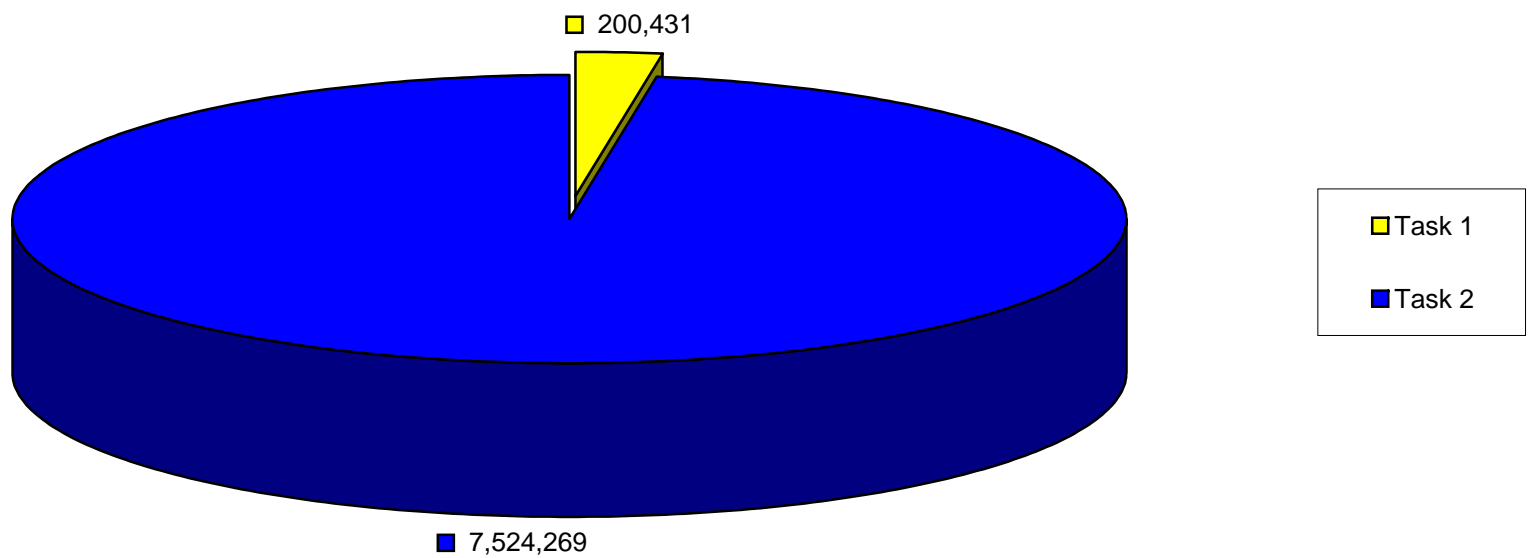
- Improved the AHPS information delivery by applying social science perspective to web page user interface.

Infrastructure

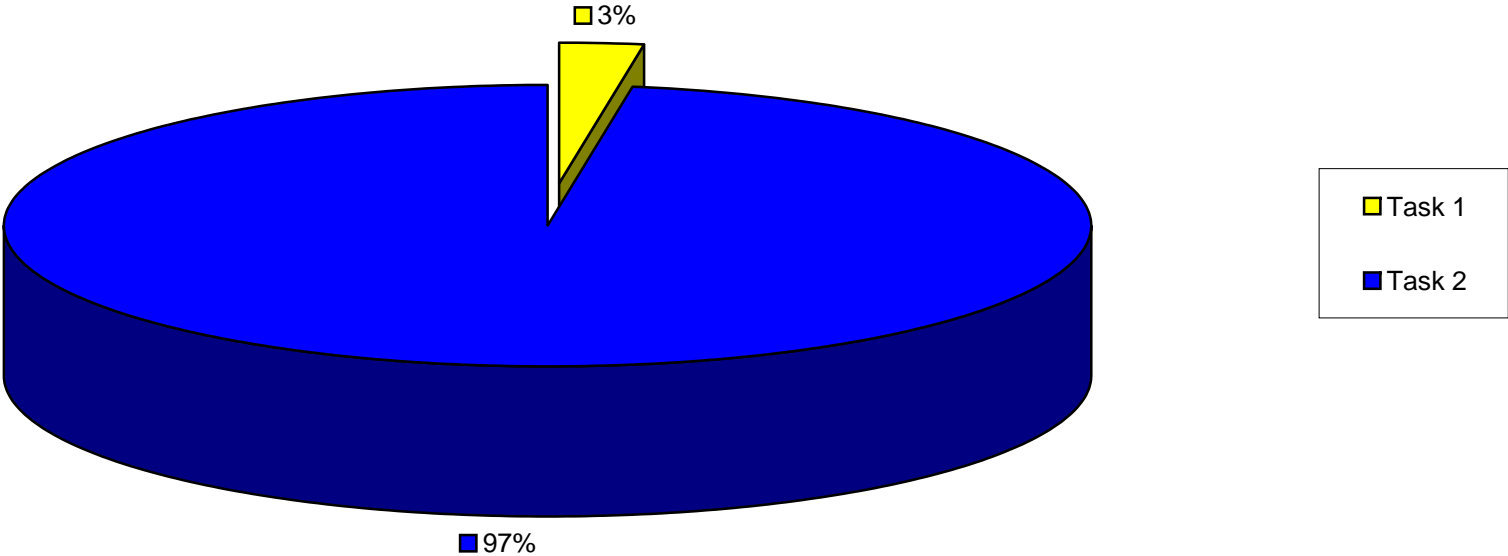
- Our Data Systems Group at FSL designed and developed new software to streamline the acquisition and processing of data. This new software was created using Object Oriented methods to reduce maintenance and to allow for the generic handling of data types thereby shortening the development time for decoders and translators by an order of magnitude.

FY 03/04 NOAA Final Report

NOAA Cost by Task (Dollars)

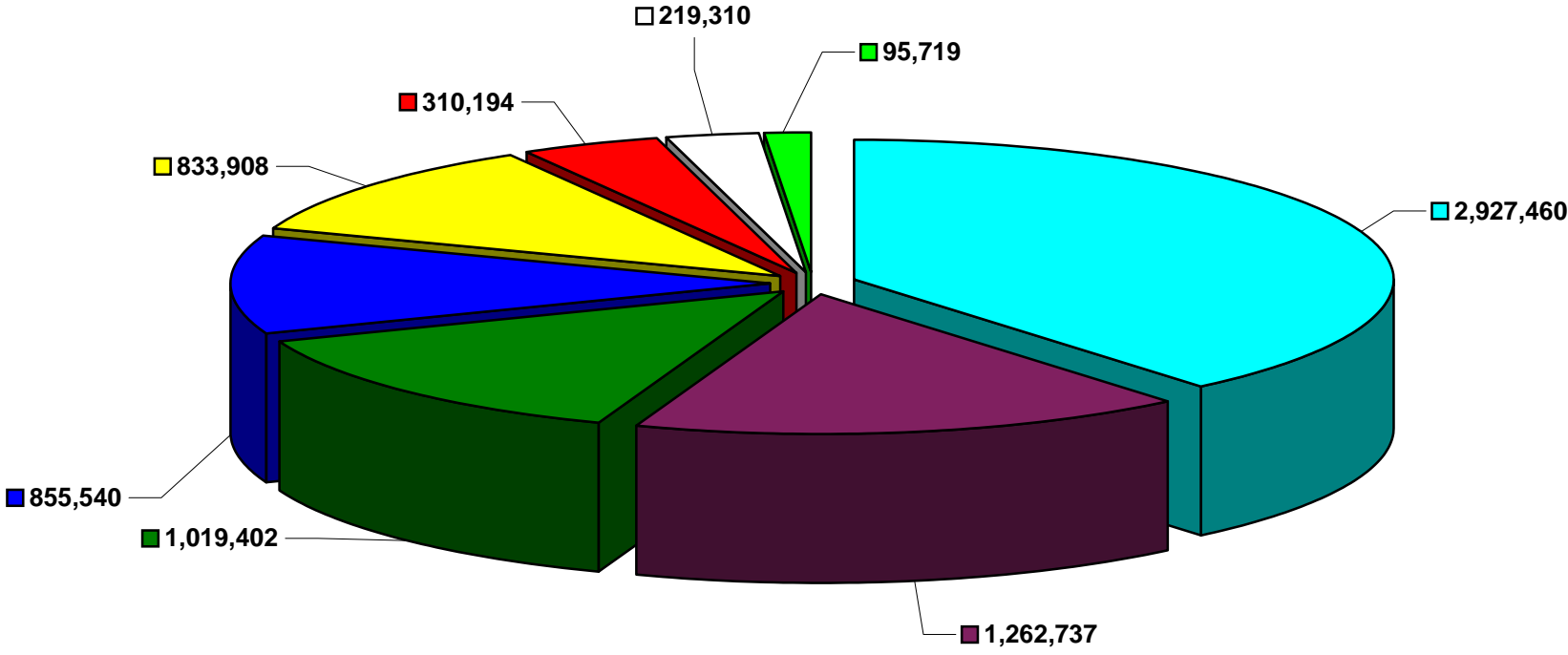


**FY 03/04 NOAA Final Report
NOAA Cost by Task (Percentage)**



FY 03/04 NOAA Final Report

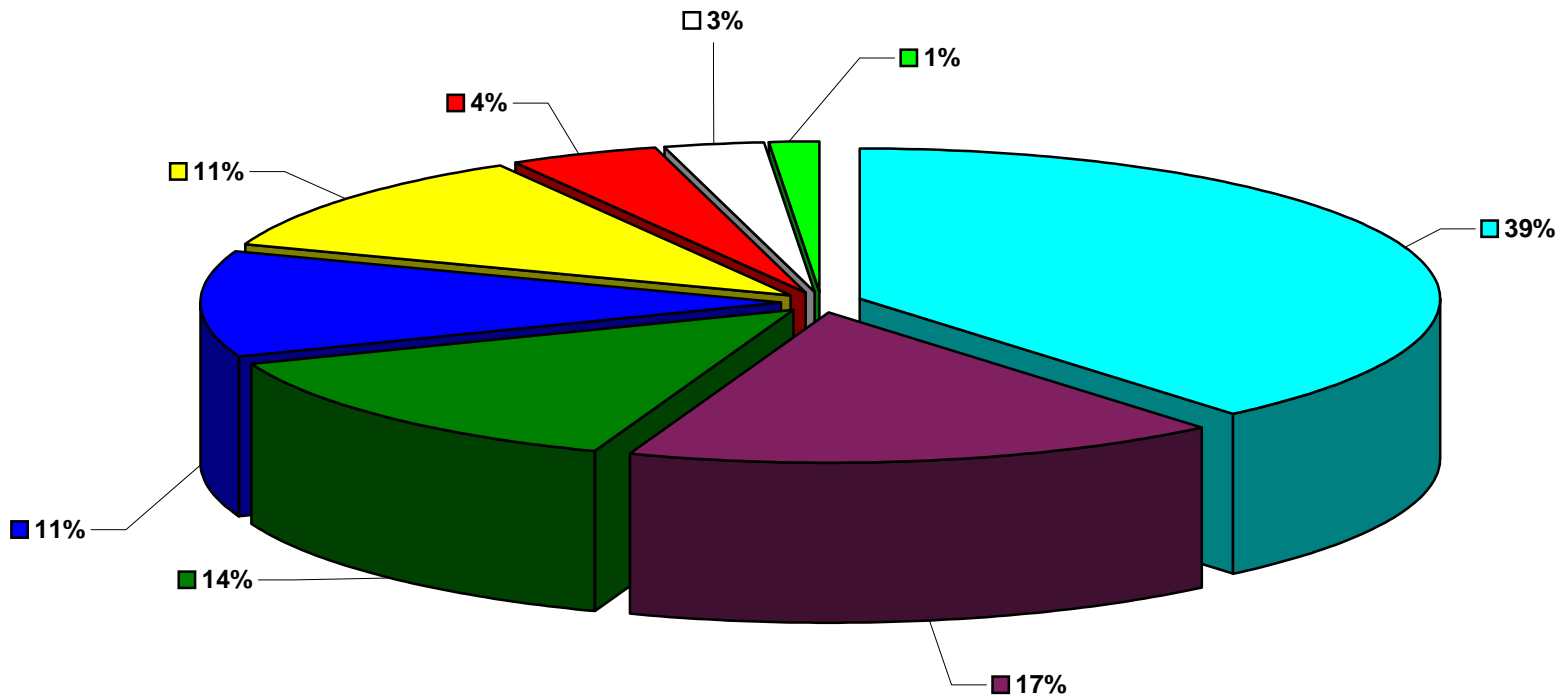
NOAA Expenditure by Task 2 Themes (Dollars)



- | | |
|---|-------------------------------------|
| Applications of Satellite Observations | Global and Regional Climate Studies |
| Local and Mesoscale Area Weather Forecasting and Evaluation | Air Quality and Visibility |
| Cloud Physics | Numerical Modeling |
| Education, Training, Outreach | Societal and Economic Impacts |

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NOAA Expenditure by Task 2 Themes (Percentage)



- | | |
|---|---------------------------------------|
| ■ Applications of Satellite Observations | ■ Global and Regional Climate Studies |
| ■ Local and Mesoscale Area Weather Forecasting and Evaluation | ■ Air Quality and Visibility |
| ■ Cloud Physics | ■ Numerical Modeling |
| ■ Education, Training, Outreach | ■ Societal and Economic Impacts |

ADVANCED ENVIRONMENTAL RESEARCH SUPPORT

Principal Investigator: James F.W. Purdom

NOAA Project Goal: Weather and Climate

Keywords: 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 of the Global Observing System.
- Investigations of the spectral, spatial and temporal requirements for geostationary satellites as part of a space based Global Observing System

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, Communications and Networking:

- WMO's Members through Chairing Commission on Basic Systems (CBS) Open Program Area Group (OPAG) on Integrated Observing Systems (IOS)
- 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
- Planning on the future use of satellite data as part of the THORPEX International Implementation Planning Team

6. Awards/Honors: None as yet.

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
- Chair, EURAINSAT International Review Board
- Co-Chair, Joint Center for Satellite Data Utilization Advisory Board
- 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
- GOES I/M Technical Advisory Committee
- THORPEX International Implementation Team

8. Publications:

Conference Presentations with Conference Papers

Sapporo, Japan. IUGG (Invited)

- Sushi address - Environmental Satellite Monitoring in the 21st Century – Challenges of Metamorphosis.
- CEOS panel presentation – Satellite Data Utilization in Atmospheric Science.

BACIMO, Monterey, California

- “Geostationary Hyperspectral Imaging From 0.4 To 1 Microns A Potent Tool For Analysis And Nowcasting”

EUMETSAT User’s Conference, Prague, CZ (Invited)

- Relative Motion: Diagnosis of Weather Systems and Storms Using Multispectral Geostationary Satellite Imagery
- The Virtual Laboratory for Satellite Training and Data Utilization

GOES-R User’s Conference (Invited)

- Satellite Instrument Synergy: Maximizing the Utilization of the Nation’s Civil Space-based Remote Sensing Observing Capabilities in the GOES-R era

Presentations at Workshops and Conferences with Extended Abstracts

MIT/Lincoln Lab, Bedford, Mass.

- Geostationary Hyperspectral Imaging and Sounding.

EUMETSAT, Darmstadt, Germany (Invited)

- Benefits of Hyperspectral Imaging from Geostationary Altitudes.

NESDIS MIT/LL Hyperspectral Workshop, Silver Spring, MD. (Invited)

- Hyperspectral observations for nowcasting severe weather in the GOES-R era.

International Winds Working Group, Helsinki, Finland

- “Geostationary Hyperspectral Imaging and Sounding: A revolutionary breakthrough in satellite derived cloud motion vectors”

WMO Training Workshop for RA III and RA IV, Barbados

- Using satellite data for mesoscale convective forecasting
- Multispectral and hyperspectral satellite data analysis

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

Keywords: Ultrasonic, snow depth, snowfall, measurement comparison study

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

Study ultrasonic snow depth sensors in the U.S. to evaluate their potential for providing much needed snow accumulation information. Various electronic sensors will be compared to traditional measurements of snowfall and snow depth at several climatically diverse locations. Other data will also be collected to aid in the interpretation of the results.

2. Research Accomplishments/Highlights:

Collected data for the 2003-2004 snow season from sites in Colorado (2), Ohio (2), and Arizona (1). Both manual and automatic measurements were taken for 6, 12 and 24-hr time periods.

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

Data are limited for this past snow season because funding for project did not arrive until December 2003, sensor equipment not available until mid-winter and late February making it impossible to install in high snow sites, and sensors were not fully investigated before deployment into the field.

4. Leveraging/Payoff:

Impacts from snow and hazardous winter weather climb into the hundreds of millions of dollars in the U.S. NWS sites are the primary means to verify and document these impacts on transportation, commerce and health. In addition, snowfall data are converted into climatological information which are used for design, construction, planning and management by the public. Currently there is no snowfall/depth data taken at NWS automated surface observing sites.

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

Doug Cripe, Kent State University; Garry Schaeffer, USDA-NRCS Snotel systems in Portland, OR; Yves Durocher of Environment Canada; and various National Weather Service Forecast Offices across the country.

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 Brazenec, second year of Masters of Science degree; (b) NOAA Snowfall Network Observations Workshop (SNOW) and NOAA Data User's Forum: Surface Weather & Climate Observations of Data; (c) None; (d) None; (e) None.

8. Publications: None as yet.

9. Additional Information:

Summary

Snow and hazardous winter weather are responsible for many deaths plus hundreds of millions of dollars in damages and loss of productivity each year. Snow measurements from the National Weather Service have long been used to verify and document these storms. The public and the media are accustomed to accurate and timely measurements of snow from all portions of the country. Unfortunately, the National Weather Service is currently facing a snow measurement crisis. The loss of manual snow observations at hundreds of airports and other first order weather stations in the past 10 years has left a critical void in the nation's climate records and has damaged the credibility of an agency responsible for both forecasting and reporting snowfall.

Up to this time, automation has not provided an adequate measurement technique for snowfall in existing NWS data collection platforms and systems. Other organizations and disciplines have been testing and using electronic methods for measuring snow. These technologies have now been perfected sufficiently that it is time for the NWS to investigate them for possible inclusion in surface measurements both at airport observing sites and at simple cooperative observer stations.

Ultrasonic depth sensors, originally designed for measuring fluid levels in storage tanks, have now been adapted to the challenging dynamic application of measuring snow. Tests using sensors from at least two different manufacturers deployed at sites where traditional manual observations will be taken right beside the electronic sensors. Through careful comparison of manual to automated observations will determine the viability of this approach to the NWS observing challenge. Comparisons will be made at five or more locations that represent a variety of climatic conditions. Based on the results of these comparisons, algorithms will be developed to estimate 6 and 24-hour snowfall from continuous measurements of changes in total snow depth.

Of various mechanical, optical, and sonic methods used to try to measure snow depth, the technology that has best succeeded uses ultrasonic transmissions from a known height above ground. Based on the time from transmission to the time a return signal is received, an average depth can be calculated. At least two manufacturers now sell systems for measuring the depth of snow electronically: Judd Communications and Campbell Scientific, both out of Utah, sell these instruments and have been testing them in deep snow environments in the western U.S. for many years.

The National Weather Service would benefit greatly by automated methods for measuring snow accumulation. If this could be accomplished at a modest cost, this would help solve the problem of snow measurement that has been frustrating NWS Data Acquisition Program managers ever since ASOS was first installed. NWS data needs are different than other organizations, however. Because of the very long tradition of measuring snow manually, the NWS has observational accuracy and data continuity issues that must be resolved before making data from automated sensors available to traditional data users as well as the general public. NWS snow measurements are most often taken at sites that only receive occasional snow and only maintain thin or intermittent snowpacks. Techniques used to measure deep snow may or may not work for measuring shallow and intermittent snow cover. Clearly the time has come for the NWS to explore automated approaches to snowfall measurement since many of the sites where snow data are needed are now unattended or infrequently attended locations.

Airport and major city snowfall measurements are the greatest immediate concern for the National Weather Service. But if there is a viable and cost-effective means for measuring snow, it would also be considered for use within the NWS Cooperative Observer Network. NWS management is currently planning for a major modernization of the traditional Cooperative Observer Network, and a low-cost snow depth sensor might be a very practical approach towards improving snow measurements all across the country.

Comparisons of the output of the ultrasonic sensors to manual measurements will begin as soon as there have been snow events at any of the sites. Doug Cripe at Kent State University will assist the project staff at Colorado State University in analyzing results.

While collecting our own data and making our own comparisons, we will also learn as much as we can from other organization's experiences. Interviews will be conducted with Garry Schaeffer with the USDA-NRCS SNOTEL system in Portland, OR and with Yves Durocher of Environment Canada, both of whom have been involved with similar evaluation activities.

Approach/Evaluation/Methodology:

A thorough study of ultrasonic snow depth sensors at various snow sites in the U.S. was begun in December 2003. The purpose was to evaluate the sensors' potential for providing much needed snow accumulation information. The outputs from various electronic sensors will be compared to traditional measurements of snowfall and snow depth at several climatically diverse locations. Other standard meteorological data was also collected to aid in the interpretation of results. Sensors from Campbell Scientific and from Judd Communications were used in this comparison.

Sites were selected on the following criteria: average seasonal snowfall sufficient to provide several measurement opportunities in almost all winter seasons, availability of a trained and enthusiastic on-site observer(s) for manually measuring precipitation, snowfall and snow depth at 6-hour increments, relatively easy access and availability of electricity, good exposure for taking both manual and automated snow measurements.

Manual data collection commenced as soon as sites were found, observers trained, and equipment purchased and installed. Measurements consisted of snowfall, snow depth, water content and standard meteorological observations of temperature, humidity, winds, visibility, weather and obstruction to vision, and cloud cover at 6-hour intervals during all precipitation events. At the same time, continuous measurements of snow depth and temperature (the ultrasonic measurement is a function of air temperature) was recorded by the ultrasonic sensors and data loggers system. No output display was provided for the automated sensors so that no opportunity will exist to bias the manual observations.

Currently, snow measurement sites are located in NE Ohio (data collected and analyzed by Doug Cripe, Kent University), northern Colorado (data collected by Carol Sullivan and Wendy Brazenec) and northern Arizona (data collected by National Weather Service Forecast Office Personnel). Data are also being collected in Grand Rapids, MI Milwaukee, WI and Indianapolis, IN but these sites are independently working on data collection and processing. Measurements continued through April 2003. A database was produced containing the data from all comparison sites and for all precipitation events during the comparison study. NWS or other scientists and investigators will be able to acquire the raw data on request.

A preliminary report was written with results and presented to NWS headquarters after the winter season of 2003-2004 ended.

Research Accomplishments and Results:

Below is a list of preliminary results during the 2003-2004 snow season. The data for this season are limited because of funding problems. The equipment was not ordered until mid-winter making it almost impossible to get the study up and running in traditionally high snow sites. Also, since the Campbell sensors did not arrive until late February there was little time to investigate the sensors before installing them in the field which

also led to problems. We are already underway for next season to alleviate some of these problems.

Results:

-- Unexplained noise in the zero reading needs to be investigated with more research to see if it can be reconciled.

-- Explained noise includes:

--High winds with blowing snow causes erroneous high or low peaks in the reading due to the sound pulse being "blown" from under the sensor. For windy sites a snow fence may need to be installed.

-Low density snow crystals (i.e. dendrites) cause the sensor pulse to be "scattered" causing erroneous readings.

-When side by side comparisons of the sensors are performed, there seems to be a minimum distance that must be kept between the sensors, otherwise the pulse beams can be crossed resulting in erroneous readings from both sensors.

--Critical criteria for positioning of the ultrasonic sensor snowboard:

Frost heaving must be taken into consideration when installing the snowboard because it can change the zero position as well as cause a non-parallel position.

Water pooling due to melt on the snowboard can be minimized by drilling holes in the snowboard for drainage.

--Manual measurements are high priority for sensor performance investigation and are requested to be done on a 6 and 24 hour basis if possible. The measurements include but are not limited to: snowfall, snow depth, snow water equivalent and gauge precipitation.

--Near uniform installation of all sensors is needed for good comparison of the data. Although we do realize that installation will vary slightly from site to site.

--The manual measurements need to be taken as close to the sensor as possible to reduce the error already associated with snow distribution.

--Site selection is also important in the performance of the sensors. The site should be open and free from wind obstructions such as buildings and trees which can cause snow drifting.

Conclusions and Recommendations:

Preparations for the 2004-2005 snow season are already underway. We are up to approximately 15 sites throughout the country. Next year all sites will be able to submit their data online, it will be compiled into a database and graphed real-time. The sites will be as uniform as possible in setup. Manual measurements are requested to be taken every 6 hours during snow events and include: snowfall, snow depth, water equivalent, gauge precipitation and any other pertinent observations like snow crystal type. Datalogger programs will be provided so that all data will be in the same format and easier to compare. Most sites will be participating in a side by side comparison of the Campbell vs. Judd sensors. The problems that we encountered with the Campbell sensor this past season are being worked out this summer in a controlled setting to ensure easy setup for the sites involved next season. Communications between all the sites are being expedited by an email list serve. The list is used for questions, comments, instructions and ideas from all sites involved.

APPLIED RESEARCH IN SUPPORT OF IMPLEMENTATION OF NATIONAL WEATHER SERVICE ADVANCE HYDROLOGIC PREDICTION SERVICES IN CENTRAL REGION

Principal Investigator: Shripad D. Deo

NOAA Project Goal: Climate, Weather and Water

Keywords: Social Science, Communication, Education

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

The infusion of science and technology to improve the quality and dissemination of water resources information needs to be complemented with improved understanding of the decision spaces of diverse user groups. The knowledge of institutional, economic, and cultural circumstances within which decisions are made by the consumers of information, includes, context in which information is used, cultivating social networks to provide information, and developing appropriate socio-technical graphs.

2. Research Accomplishments/Highlights:

- a) Improved delivery of hydrologic information through user-friendly web site
- b) Better appreciation of advantages of understanding users' decision spaces
- c) New recognition of social sciences perspective on science and technology

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

The objective of providing a social sciences perspective in improving quality and dissemination of water resources information was achieved during this reporting period.

4. Leveraging/Payoff:

The work done with water resources has provided a template for a social sciences perspective on weather and climate information. It has also spurred interest in reaching out to underserved communities and disseminating critical environmental information.

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

6. Awards/Honors:

Advanced Hydrologic Prediction Service was recognized with NOAA Administrator's Award in May 2004.

7. Outreach: Following presentations/symposia were conducted:

Deo, S. D. *AHPS: From Understanding to Explaining*, AAAS Annual meeting, Boston, MA 2002.

Deo, S. D. *Why AHPS needs to be social...* National Hydro Program Managers Conference, NWS, New Orleans, 2002.

Deo, S. D. *Translation and Transparency: Communicating Hydrologic Information*, AMS meeting, Long Beach, CA 2003.

Deo, S. D. *Meeting on their terms*, Midwest Sociological Society meeting, Chicago, IL 2003

Deo, S. D. *New Science and Information for Effective Forecasts*, International Water Conference, Moorhead, MN 2003.

8. Publications: None as yet

ATMOSPHERIC CO₂ INVERSION INTERCOMPARISON PROJECT

Principal Investigator: Scott Denning

NOAA Project Goal: Ecosystems

Keywords:

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

Quantify major sources of uncertainty in inverse calculations of atmospheric CO₂ exchange with the surface of the planet. To achieve this goal a large intercomparison experiment was constructed. This experiment included every research group working on atmospheric carbon inversions in the world. Through a series of controlled experiments and sensitivity work the major sources of uncertainty were identified and quantified. Furthermore, a best estimate of carbon sources and sinks was achieved.

2. Research Accomplishments/Highlights:

The TransCom 3 experiment has been one of the most successful intercomparisons ever attempted. The experiment has quantified the major sources of uncertainty in atmospheric inversions and has provided one of the most cited estimates of global carbon sources and sinks in carbon cycle science. Our initial findings regarding the annual mean carbon exchange was published in Nature and has now been cited 80 times in the peer-reviewed literature.

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

The objectives in the last year were to finalize and publish the interannual control inversion and sensitivity work. Both of these papers will be submitted in the next few weeks. As the final active year of this experiment, we planned to finalize the complete TransCom archive and website for public use. This has been accomplished.

4. Leveraging/Payoff:

The results of the TransCom 3 experiment are directly related to critical public policy concerns in two distinct ways. First, efforts to include carbon sequestration with climate policy require an understanding of the current global carbon cycle in space and time. Second, projections of future CO₂ concentrations must reflect an understanding of the current global carbon cycle and how it might evolve in the future. The TransCom 3 experiment attempted to better understand the global carbon cycle, the sources of estimation uncertainty, the current best estimate of sources and sinks, and how improvement in atmospheric inversions might best be achieved.

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

The TransCom 3 community is now attempting a partnership with the Global Carbon Project of the Earth Systems Science Partnership in an effort to synthesize inverse calculation of carbon exchange. We have extensive collaborative efforts ongoing with a number of researchers within the broader TransCom community. Many of these efforts are aimed at further analysis of the large amount of output generated by the experiment.

6. Awards/Honors: None as yet.

7. Outreach – Educational programs:

The TransCom 3 website now has a variety of educational information regarding the background and use of the inverse method in carbon cycle science.

8. Publications

Refereed

Gurney, K.R., R.M. Law, A.S. Denning, P.J. Rayner, D. Baker, P. Bousquet, L. Bruhwiler, Y.H. Chen, P. Ciais, S. Fan, I.Y. Fung, M. Gloor, M. Heimann, K. Higuchi, J. John, E. Kowalczyki, T. Maki, S. Maksyutov, P. Peylin, M. Prather, B.C. Pak, J. Sarmiento, S. Taguchi, T. Takahashi, C.W. Yuen, "Transcom 3 CO₂ Inversion Intercomparison: 1. Annual mean control results and sensitivity to transport and prior flux information," *Tellus*, 55B, 555-579, 2003.

Law, R., Y.H. Chen, K.R. Gurney, P. Rayner, A.S. Denning, and TransCom 3 modelers, "TransCom3 CO₂ inversion intercomparison: 2. Sensitivity of annual mean results to data choices," *Tellus*, 55B (2), 512-521, 2003.

Maksyutov, S., T. Machida, H. Mukai, P. Patra, T. Nakazawa, G. Inoue, and TransCom 3 modelers, "Effect of recent observations on Asian CO₂ flux estimates with transport model inversions," *Tellus*, 55B, 522-529, 2003.

Patra, P.K., S. Maksyutov, and TransCom 3 modelers, "Optimal network design for improved CO₂ source inversion," submitted to *Tellus*, 55B, 498-511, 2003.

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, "Seasonal and interannually varying fossil fuel emissions: impact on atmospheric CO₂ inversions," submitted to *J. Geophys. Res.* 2004.

Rayner PJ, Optimizing CO₂ observing networks in the presence of model error: results from TransCom 3, *Atmospheric Chemistry and Physics*, 4: 413-421, 2004

Baker, D. R.M . Law, K.R. Gurney, A.S. Denning, P.J. Rayner, and TransCom 3 modelers, "Interannually varying sources and sinks of CO₂: Results from the TransCom 3 intercomparison," 2004, *in preparation*.

Presentations

Gurney, K.R. et al., Interannual carbon sources and sinks: TransCom 3 sensitivity results, Tsukuba TransCom 3 meeting, Tsukuba, Japan, June 14-18, 2004.

Gurney, K.R., Where has all the carbon gone? Following clues through the atmosphere, biosphere and anthroposphere, Florida International University, March 2004.

Skidmore, J., A.S. Denning, K.R. Gurney, K.J. Davis, and P.J. Rayner, 2003. Using Virtual Tall Tower CO₂ Data in Inverse Models to Reduce Uncertainty in Global and Regional Estimates of Carbon Flux. EOS Trans. AGU, 84(47), Fall Meet. Suppl., Abstract A52B-0786.

Suits, N.S., A.S. Denning, I.T. Baker, P.E. Thornton, J.B. Miller, K. Schaefer, S.L. Conner-Gausepohl, and K.R. Gurney, 2003. Sensitivity of terrestrial ecosystem models of carbon isotope ratios to changes in vegetation properties and meteorology. EOS Trans. AGU, 84(47), Fall Meet. Suppl., Abstract A52A-0762, 2003.

Gurney, K.R., Chen, Y-H., Maki, T., Kawa, R., Andrews, A., and Zhu, Z., Sensitivity of inverted carbon sources and sinks from seasonal and interannual varying fossil fuel emissions. EOS Trans. AGU, 84(47), Fall Meet. Suppl., Abstract A51H-08, 2003

Dilling, L., Doney, S., Edmonds, J., Gurney, K.R., Harriss, R., Schimel, D., Stephens, B., and Stokes, G. A review of the role of carbon cycle science in supporting carbon management policy. EOS Trans. AGU, 84(47), Fall Meet. Suppl., Abstract B51F-01, 2003.

Newsletter

The TransCom 3 Experiment: Towards robust regional estimates of carbon sources and sinks using atmospheric transport models - the TransCom 3 Experiment, K.R. Gurney, A.S. Denning, R.M. Law, P.J. Rayner, IGBP newsletter, 57, pp. 3-7, March 2004.

Workshops

TransCom 3 Tsukuba meeting, Tsukuba Japan, June 14-18, 2004.

Dissertations

Towards robust regional estimates of carbon sources and sinks using atmospheric transport models, Kevin Robert Gurney, Colorado State University, Summer 2004

CARBON DIOXIDE MEASUREMENTS FROM AN AIRBORNE SPECTROMETER IN SUPPORT OF OPERATIONAL TEMPERATURE SOUNDINGS AND THE STUDY OF THE CARBON CYCLE

Principal Investigators: Graeme L. Stephens/Denis O'Brien

NOAA Project Goal: Climate

Keywords: CO₂, sources, satellites, climate

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

- To develop remote sensing and modeling techniques to monitor the global distribution of sources and sinks of CO₂. Specific steps:
 - a) design an airborne prototype for a satellite instrument;
 - b) develop procedures to retrieve CO₂ from airborne and satellite systems;
 - c) incorporate remotely sensed data in chemical transport models to identify sources and sinks.

2. Research Accomplishments/Highlights:

- (a) Preliminary retrievals of CO₂ using combined near infrared and thermal infrared radiances have been investigated and published.
- (b) A software simulator of the proposed airborne system has been developed and tested.
- (c) Candidate algorithms for operational inversion of airborne (and satellite) data have been identified and their physical bases explored. Testing with simulated data is in progress.

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

The start of the project was delayed significantly by the late arrival from overseas of one of the investigators. Otherwise, the project is on track.

4. Leveraging/Payoff:

This project is closely related to NASA's Orbiting Carbon Observatory mission (OCO), and the investigators are members of the OCO science team. There is strong public interest in climate change and the measures taken to monitor and mitigate its effects. To that end, this project is highly relevant.

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

This project is tightly linked to NASA's Orbiting Carbon Observatory mission.

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) M. L. Christi, PhD student.

8. Publications:

Christi M. J., and G. L. Stephens, Retrieving profiles of atmospheric CO₂ in clear sky and in the presence of thin cloud using spectroscopy from the near and thermal infrared: A preliminary case study, *J. Geophys. Res.*, 109, D04316, doi:10.1029/2003JD004058, 2004.

O'Brien, D. M., End-to-end simulation of an airborne spectrometer to measure CO₂ column density from radiances in the 1.6 micrometer absorption band of CO₂, Atmospheric Science Technical Report, Colorado State University, August 2004, in preparation.

Natraj, V., Z. Kuang, Z. Yang, G. C. Toon, P. O. Wennberg, D. M. O'Brien, D. Crisp and Y. L. Yung, Retrieval of oxygen A-band spectra from airborne measurements, American Geophysical Union, 2003 Fall Meeting, San Francisco, December, 2003.

Crisp, D., R. Atlas, F.-M. Breon, L. R. Brown, J. Burrows, P. Ciais, B. J. Connor, S. C. Doney, I. Y. Fung, D. J. Jacob, C. E. Miller, D. O'Brien, S. Pawson, J. T. Randerson, P. Rayner, R. J. Salawitch, S. P. Sander, B. Sen, G. L. Stephens, P. P. Tans, G. C. Toon, P. O. Wennberg, S. C. Wofsy, Y. L. Yung, Z. Kuang, B. Chudasama, G. Sprague, B. Weiss, R. Pollock, D. Kenyon, and S. Schroll, The Orbiting Carbon Observatory (OCO) mission, *Adv. Space Res.*, doi:10.1016/j.asr.2003.08.062, 2004.

Crisp, D., C. E. Miller, R. Atlas, F.-M. Breon, L. R. Brown, J. Burrows, P. Ciais, B. J. Connor, S. C. Doney, I. Y. Fung, D. J. Jacob, D. O'Brien, S. Pawson, J. T. Randerson, P. Rayner, R. J. Salawitch, S. P. Sander, B. Sen, G. Stephens, P. Tans, G. C. Toon, P. O. Wennberg, S. C. Wofsy, Y. L. Yung, Z. Kuang, M. Christi, N. Nichols, A. S. Denning, V. Natraj, D. Feldman, Z. Yang, D. Jones, The Orbiting Carbon Observatory (OCO). 1. XCO₂ science measurement requirements, *J. Geophys. Res.*, 2004, in preparation.

CIRA ACTIVITIES AND PARTICIPATION IN DMSP SATELLITE DATA PROCESSING AND ANALYSIS

Principal Investigator: Cliff Matsumoto

NOAA Project Goal: Ecosystems, Climate, Commerce & Transportation

Keywords: GIS and satellite image processing techniques; terrestrial carbon dynamics; estimation of impervious surface areas; coral bleaching; satellite monitoring of wildfire

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

CIRA proposed to join NESDIS/NGDC in collaborative research in several areas consisting of GIS and other satellite image processing techniques within their Solar-Terrestrial Physics Division. The primary research effort during this period will be investigation into the impacts of development sprawl on the terrestrial carbon dynamics of the US. Research will involve the preparation of high-resolution satellite imagery and aerial photography to develop sampling techniques to estimate land cover percentages. Significant effort is also required to integrate various GIS layers into imageries and aerial photographs. Other areas of research will involve the application of satellite data for studying the bleaching of coral reefs. This effort requires the use of change-detection image processing on the satellite data. A significant amount of effort will also be devoted to the satellite monitoring of global fires on a daily basis.

2. Research Accomplishments/Highlights: (see below)

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period: (see below)

4. Research Linkages/Partnerships/Collaborators, Communication and Networking: (see below)

5. Awards/Honors: None as yet.

6. Outreach:

7. Publications: (see below)

8. Additional Information:

The following specific research efforts fall directly under CIRA's long-standing research theme areas involving **Applications of Satellite Observations, Air Quality and Visibility**, as well as a more recent theme area of **Societal and Economic Impacts**.

- Extensive integration of DMSP imagery with various other data sets, including GIS data sets of nationwide streets, highways, and interstates, land cover classification compiled from Landsat 7 satellite, and transects of aerial photography from US metropolitan areas. This activity will involve significant effort in systematically sampling and grouping the integrated data into a grid of estimated percentage of impervious surfaces for the coterminous US. This in turn is used in ecosystem models for investigating carbon cycling within the US;

Data processing and analysis continued this past year to estimate the amount of impervious surface area (ISA) within the conterminous United States, using 2001 DMSP satellite data, 1998 U.S. Census Bureau TIGER roads data, high resolution aerial photography, and Landsat TM classification data from USGS EROS Data Center. The project is part of NASA's Land Use Land Cover program, and the product is used as input to models for carbon cycling. This effort supports NOAA Goal 2—Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond. The aerial photography was used to record amount of ISA in 1-km grid cells in transects across 13 U.S. cities, and these data were used to calibrate the DMSP and Landsat satellite data. A regression model was developed to estimate the percentage ISA for the conterminous USA. Figure 1 is the primary map for the EOS journal article for the ISA project.

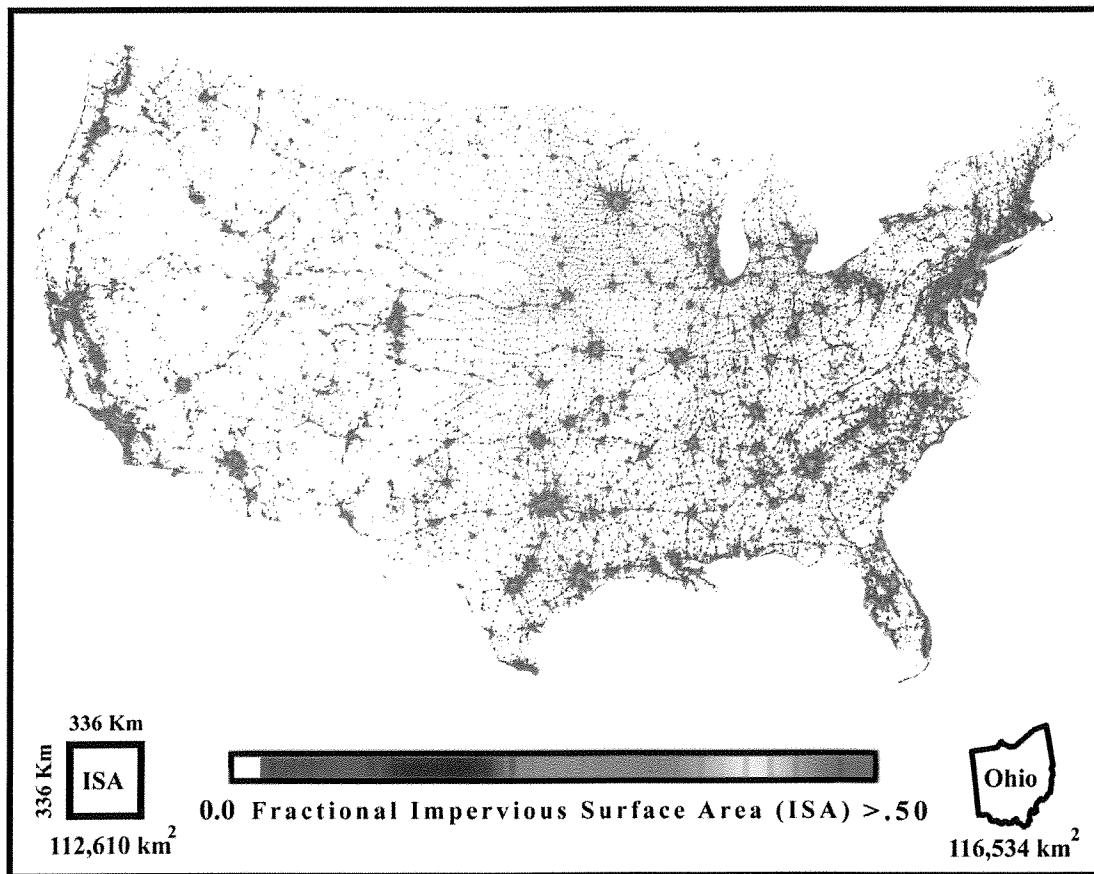


Fig. 1. Map depicting the fractional impervious surface area for the US in the EOS journal article.

Publications

Elvidge, C.D., Milesi, C., Dietz, J.B., Tuttle, B.T., Sutton, P.C., Nemani, R., Vogelmann, J.E., 2004, U.S. Constructed Area Approaches the Size of Ohio. **EOS**, Vol. 85, No. 24, June 15, 2004.

- Use of IKONOS satellite data and change-detection techniques to study the bleaching of coral reefs. Collaboration will investigate how precisely satellite imagery (from elevated sea surface temperatures) can document the location of bleaching, which may offer causal linkage to the prediction of El Niño and climate change. Comparative imagery from August 2001 and April 2002 for the Great Barrier Reef off the coast of Australia will initially be used to examine the reef bleaching. Data coregistration, image processing techniques of radiometric normalization, and change detection will be employed to record the bleaching phenomenon. Further research may include in-situ spectral measurements.

Data processing and analysis of IKONOS satellite data for detection of coral reef bleaching in an area off the coast of Australia in the Great Barrier Reef continued. This effort supports NOAA Goal 1—Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem Management Approaches. A pair of IKONOS satellite images, before and during a bleaching event in 2002, was analyzed to document the capability to detect the presence and extent of bleaching using the satellite data, in conjunction with ancillary field data acquired during the bleaching event. Imagery change detection techniques were refined for the analysis of the bleaching.

Publications

Elvidge, C.D., J.B. Dietz, R. Berkelmans, S. Andrefouet, W. Skirving, A.E. Strong, and B.T. Tuttle, 2004: Satellite observation of Keppel Islands (Great Barrier Reef) 2002 coral bleaching using IKONOS data. **Coral Reefs**, Vol. 23, 123-132.

Dietz, J.B., C. Elvidge, R. Berkelmans, S. Andrefouet, W. Skirving, A.E. Strong, and B.T. Tuttle, 2003: Satellite observation of Keppel Islands (Great Barrier Reef) coral bleaching using IKONOS satellite data. *30th International Symposium on Remote Sensing of Environment*, Honolulu, HI, November 2003.

Data processing of IKONOS satellite imagery from March 2004 and May 2001 for analysis of coral bleaching in 2004. The imagery is being incorporated with field data acquired in March 2004 for mapping of the bleaching at Heron Island, part of the Great Barrier Reef off the coast of Australia.

- Use of various satellite sensors (DMSP, MODIS, GOES), along with a predictive particle transport model to forecast movement of smoke from fires. Using observational data, the HYSPLIT model developed by NOAA/ARL, and the satellite-derived fire detection technique, prototype web-based maps of predicted movement of smoke will be generated interactively. Transport of smoke from large-scale fires in areas such as Southeast Asia significantly impact regional visibility, weather and climate;

Lack of funding support precluded any progress on this project.

- Use of GIS technologies and other image processing techniques in the analysis and manipulation of DMSP and other satellite data for various research efforts by both CIRA/CSU scientists and NESDIS collaborators.

GIS and image processing support was performed for a variety of projects with the DMSP program at NGDC, including compilation of data for comparison of the capabilities of different instruments (DMSP, MODIS, VIRS) for fire detection. These efforts support NOAA Goal 4—Support the Nation's Commerce with Information for Safe and Efficient Transportation.

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

Principal Investigator: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Keywords: 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 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 1-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 the Internet. Two basic types of product 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.

The focus of CIRA research for the upcoming year includes the following:

Tropical cyclone applied research and algorithm development with an emphasis on quantitative analysis of GOES data.

- Severe storm research, with an emphasis on the utilization of GOES sounder data.

- Analysis of GOES-12 data, with emphasis on the new Channel 6 and the increased resolution water vapor imagery.
- Investigations using MODIS and AIRS data, looking ahead towards future GOES channels.
- Satellite analysis of mid-latitude cyclones with an emphasis on storms striking the U.S. west coast.
- Continued development of satellite cloud climatologies.
- Continued training activities and development of web-based satellite product display, with interaction with the Virtual Institute for Satellite Integration Training (VISIT), the International Virtual Laboratory at CIRA, and the World Meteorological Agency Regional and Meteorological Training Centers (RMTCs) located in Barbados and Costa Rica.

2. Research Accomplishments/Highlights:

Some highlights of the research activity for GIMPAP include:

- GOES Sounder Verification Study: A verification study was performed for GOES Sounder point retrievals in AWIPS. It was found that on average, the sounder has errors comparable to the NCEP global model first-guess (6-h forecast) for dew point temperature. The Sounder is slightly better than the global model aloft (around 300 hPa), but slightly worse than the global model forecast in the lower atmosphere (near 850 hPa). However, a linear combination of the global model forecast and the sounder retrieved dew point produces a better estimate than either by itself. This result indicates that the Sounder is providing useful dew point temperature information that is independent of the first guess used in the retrieval.
- Severe Weather Publications: Two publications on aspects of CIRA's severe weather research. One of the papers details aspects of a tornadic left-moving thunderstorm. The other paper details some frequently overlooked visual severe thunderstorm characteristics observed on GOES imagery. See the references for full reference information.
- Fire Detection Publication: A publication entitled "Fire Detection using GOES-11 Rapid Scan Imagery" by J. Weaver, D. Bikos, D. Lindsey, C Schmidt and E. Prins appeared in the June 2004 issue of *Weather and Forecasting*. See the full publication at: http://www.cira.colostate.edu/RAMM/KFIntranet/Publications/Fire_Detection.pdf. The image below has been extracted from this publication.

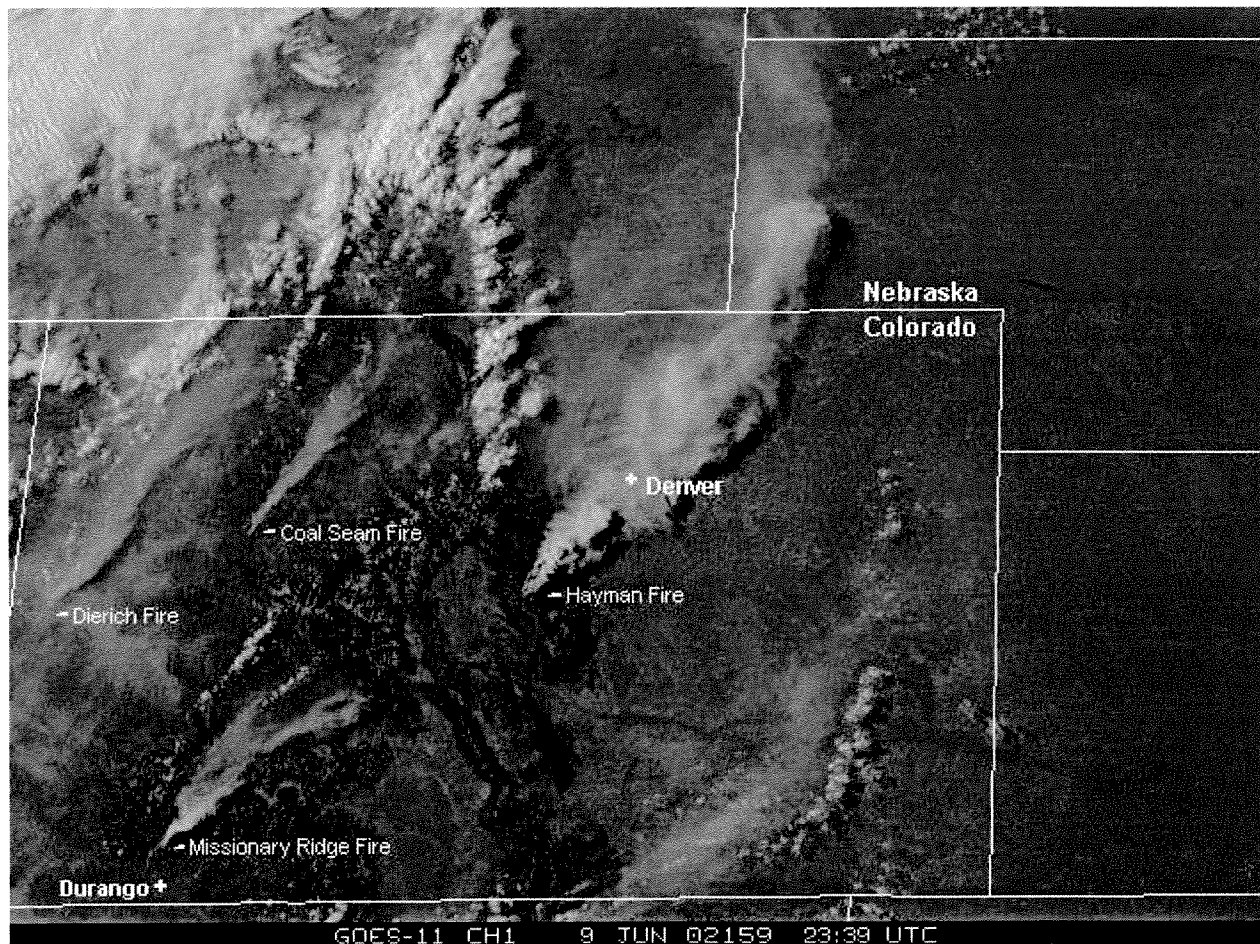


Figure 1: GOES-11 visible-wavelength image taken at 2339 UTC on 9 Jun 2002. Arrows point to the four major fires burning at the time. Note the thin smoke plume covering most of the western one-quarter of Colorado. This is smoke from fires burning in Arizona. The Long Canyon fire smoke plume is small and hidden beneath the Arizona smoke

- Much effort went into preparations for participation in the WMO sponsored Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV held in Barbados 2-12 December 2003. The lectures covered many aspects of image use and interpretation and included lecturers from the Caribbean Institute of Meteorology and Hydrology (CIMH), CIRA/RAMM, WMO, University of Costa Rica (UCR), EUMETSAT, ESA, COMET, and the Australian Bureau of Meteorology. CIRA/RAMM personnel provided lectures/laboratories on the following topics: interpretation of GOES and POES imagery and products, products from meteorological sounders, hyper-spectral imagery, identifying mesoscale weather features in satellite imagery, tropical weather systems, as well as volcanic ash detection and fire detection. There were fourteen participants from the Caribbean, Central America, and South America (Antigua and Barbuda, Barbados, Brazil, Costa Rica, Cuba, Grenada, Honduras, Jamaica, Martinique, Netherlands Antilles, Peru, St. Lucia, Trinidad and Tobago, and Venezuela). Computers were used for laboratory exercises that included

example loops of the various imagery or products as well as locating satellite resources on the Internet. One of the highlights of the seminar was an afternoon of “live” VISITview sessions. The first was a linkup with Dr. Vilma Castro at UCR for presentation on their experiences with RAMSDIS/RAMSDIS online and also the Hurricane Mitch Reconstruction project. The second VISITview session consisted of a live weather discussion with Boulder and Fort Collins, Colorado, Madison, Wisconsin; and Barbados.



Figure 2: Participants and presenters attending the training in Barbados December 2 – 12, 2003.

- **RAMMB experimental tropical cyclone product declared operational by the Tropical Prediction Center:** An experimental tropical cyclone product developed by RAMMB has been declared operational by the Tropical Prediction Center. The version of the Statistical Hurricane Intensity Prediction Scheme that includes predictors from GOES imagery will be operational for the 2004 season. After parallel runs during the 2002 and 2003 hurricane seasons, TPC found it to be useful for their operations, and will continue the GOES version in future seasons.
- **New Tropical Cyclone Formation Probability Algorithm Developed:** A new algorithm for estimating the probability of tropical cyclone formation in the Atlantic and east Pacific basins has been developed. The algorithm combines GOES channel-3 imagery, NCEP analyses, and climatological information as input to a linear discriminant analysis, and was developed from data from the 1995-2003 hurricane

seasons. The algorithm provides the probability in 5° by 5° areas over the entire Atlantic and east Pacific basins, and replaces the older experimental method that only considered a portion of the tropical Atlantic. This algorithm is being transitioned to NESDIS operations, and will be tested in real time during the 2004 season.

- **Satellite Observations Improve Operational Hurricane Intensity Forecasts:**
Operational hurricane intensity forecasts from National Centers for Environmental Prediction (NCEP) Tropical Prediction Center (TPC) have considerably less skill than track forecasts. During the 2002 and 2003 hurricane seasons, a version of the NCEP/TPC Statistical Hurricane Intensity Prediction Scheme (SHIPS) that includes satellite observations was developed and run in parallel with the operational version, which does not utilize satellite input. New input includes GOES channel 4 imagery to help identify the strength of deep convection near the storm center, and satellite altimetry observations (Atlantic only) that identify areas of the ocean that have very large heat contents, which favors intensification. The satellite data improved the 48-h SHIPS intensity forecasts by about 4% for Atlantic storms west of 50°W and by about 8% in the eastern North Pacific basin. Smaller improvements were obtained at all forecast periods out to 72 h. Based upon these positive impacts, the satellite version of the SHIPS model was made operational for the 2004 hurricane season, with implementation at NCEP on 21 May.

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

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

4. Leveraging/Payoff:

In response to the need to assure transition from GOES-7 to the new generation GOES products and beyond, CIRA has been involved in the NESDIS GOES-Improved Measurements and Product Assurance Plan, GIMPAP. The GIMPAP provides the means to assure the viability of GOES products, to improve initial products, to perform research to develop advanced products, and to ensure integration of the results into NESDIS and NWS operations.

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

GIMPAP projects involve considerable collaborations with other agencies. We are coordinating with the NOAA/NCEP tropical prediction center and the NESDIS Satellite Analysis Branch on testing of new experimental products and on operational transition. We also work closely with the National Weather Service and the World Meteorological Organization on satellite training.

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) Kimberly Mueller is working on her Masters of Science degree under GIMPAP funding. Several student hourly employees at CIRA (high school and undergraduate) are supported under this project.

(b) See section 8

(c) None

(d) J. Weaver gave a presentation on severe thunderstorms to middle school students participating in the Colorado State University summertime "Kids in College" program. D. Hillger, as Webmaster for the U.S. Metric Association (USMA), participated in a Board of Directors meeting for USMA held in Los Angeles CA on 22 May.

(e) J. Weaver met with staff from the Fort Collins Office of Emergency Management to provide both severe weather training, and information on plume-driven wildland fires.

8. Publications:

Refereed Journals

Chase, T.N., J.A. Knaff, R.A. Pielke, and E. Kalnay, 2003: Changes in Global Monsoon Circulations Since 1950. *Natural Hazards*, 29: 229-254.

Dostalek, J.F., J.F. Weaver, and L. Phillips, 2004: Aspects of a tornadic left-moving thunderstorm of 25 May 1999. *Wea. and Forecasting*, 19:3, 614-626.

Nolan, D.S., Grasso, L.D., 2003: Nonhydrostatic, Three-Dimensional Perturbations to Balanced, Hurricane-Like Vortices. Part II: Symmetric Response and Nonlinear Simulations. *J. Atmos. Sci.*, 60:22, 2717-2745.

Reasor P.D., M.T. Montgomery, and L.D. Grasso, 2004: A New Look at the Problem of Tropical Cyclones in Vertical Shear Flow: Vortex Resiliency. *J. Atmos. Sci.*, 61, 3-22.

Weaver, J.F., and D.T. Lindsey, 2004: Some frequently overlooked visual severe thunderstorm characteristics observed on GOES imagery – a topic for future research. *Mon. Wea. Rev.*, 132, 6, 1529-1533.

Weaver, J.F., D.T. Lindsey, D.E. Bikos, C.C. Schmidt, and E. Prins, 2004: Fire Detection using GOES-11 Rapid Scan Imagery. *Wea. and Forecasting*, 19:3, 496-510.

Conference Proceedings

Black, M.L., J.P. Kossin, W.H. Schubert, C.S. Velden, J.P. Dunion, S.D. Aberson, P.G. Black, and R.M. Zehr, 2004: Mesovortices in Hurricane Isabel (2003): A comparison of satellite, radar, and photographic observations. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

DeMaria, M., 2004: 50 Years of Progress in Tropical Cyclone Modeling. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

DeMaria, M., C.W. Anderson, J.A. Knaff, and B.H. Connell, 2004: A New Product for Estimating the Probability of Tropical Cyclone Formation. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Gentemann, C., M. DeMaria and F.J. Wentz, 2004: Near real time global optimum interpolated microwave SSTs: applications to hurricane intensity forecasting. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Kaplan, J. and M. DeMaria, 2004: Estimating the probability of rapid intensification of tropical cyclones in the Atlantic and Eastern Pacific basins. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Kossin, J.P., W.H. Schubert, C.S. Velden, M.L. Black, P. Black, R.M. Zehr, S.D. Aberson, and J.P. Dunion, 2004: Mesovortices in Hurricane Isabel (2003). *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Velden, C., J. P. Kossin, T. L. Olander, D. Herndon, A. J. Wimmers, R. Wacker, R. T. Edson, J. D. Hawkins, K. F. Brueske, B.W. Kabat, and M. DeMaria, 2004: Toward an objective satellite-based algorithm to provide real-time estimates of TC intensity using integrated multispectral (IR and MW) observations. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Zehr, R.M., 2004: Atlantic Intense Hurricanes, 1995-2003 - Characteristics Based on Best Track, Aircraft, and IR Images. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Zehr, R.M., 2004: The Objective Dvorak Technique - Historical Perspective. Special Session on the Dvorak Technique: A 30-year test of time. *AMS 26th Conference on Hurricanes and Tropical Meteorology*, May 3-7, 2004, Miami, FL.

Technical Reports

Hillger, D.W., T.J. Schmit, and J.M. Daniels: 2003: Imager and Sounder Radiance and Product Validation for the GOES-12 Science Test, *NOAA Technical Report, NESDIS 115*, 66 p.

Presentations

Knaff, J.A., M. DeMaria, K. Mueller, 2004: Methods to Estimate and Predict Tropical Cyclone Wind Structure: Recent Developments and Future Goals, *58th Interdepartmental Hurricane Conference*, 1-4 March, Charleston, SC

M. DeMaria, D. Molenaar, D. Lindsey, D. Hillger, R. Zehr, B. Connell, J. Dostalek, and C. Combs, June 8, 2004: Overview of RAMMB/CIRA Activities to Fran Holt, CoRP Director, CIRA, Fort Collins, CO

Lindsey, D.T., 2004: Using satellite imagery to improve forecasts and nowcasts. *AMS 33rd Conference on Broadcast Meteorology*, 14-18 June, New Orleans, LA

Training

Castro, V., R. Alfaro, B.H. Connell, Jul 14-18, 2003: In-depth training on the RAMSDIS system. San Jose, Costa Rica

Connell, B.H. and R.M. Zehr, and V. Castro, Dec 2-12, 2003: WMO-sponsored Regional Training Course on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV. Barbados

Lindsey, D.T., May 17-28, 2004: The World Meteorological Organization (WMO) regional training seminar for national instructors from Regions III and IV, Buenos Aires, Argentina

Professional Meetings

DeMaria, M., October 21-24, 2003: ORA Retreat, Washington, DC

DeMaria, M., July 30-August 8, 2003: Tropical Prediction Center & Hurricane Research Division Meetings, Miami, FL

DeMaria, M., August 27-29, 2003: GIMPAP Review, Washington, DC

Newsletters

Connell, B.H., D.E. Bikos, D.T. Lindsey, J.F. Weaver, A. Mostek, 2004: National and International Training Activities at CIRA. *CIRA Magazine*. 7-9.

Workshops

Combs, C., April 30, 2004: *High Plains Mountain Weather Workshop*, Boulder, CO

Hillger, D.W., J.A. Knaff: CIRA Retreat, June 16-17, Pingree Park, CO

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

Principal Investigator: David Randall, et al

NOAA Project Goal:

Keywords:

This is a new project. No information available from Principal Investigator.

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

Principal Investigator: Roger Pielke, Sr.

NOAA Project Goal: Climate

Keywords:

1. Long-term Research Objectives and Specific Plans to Achieve Them:
2. Research Accomplishments/Highlights:
 - An observational study of the interannual variability of the North American Monsoon System (NAMS) was completed (Castro et al. 2001, J. Climate). Using the 50-yr NCEP-NCAR Reanalysis, this study found time-evolving teleconnection relationships associated with the El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) which influence NAMS evolution. A high (low) PDO phase and El Niño (La Niña) conditions favor a weaker (stronger) and southward (northward) displaced monsoon ridge in early summer. In the Great Plains, the spring wet season is lengthened (shortened) and early summer rainfall is above (below) average. In the southwest U.S., monsoon onset is late (early) and early summer rainfall is below (above) average.
 - An assessment of value added by dynamical downscaling for simulations where the interior initial values are forgotten was completed using the Regional Atmospheric Modeling System (RAMS) (Castro and Pielke 2004). The study quantified the effects of varying lateral boundaries and grid spacing versus surface forcing using specified initial and lateral boundary conditions in a regional climate model (RCM). At large scales, RCMs underestimate atmospheric variability absent interior nudging. As the grid spacing or domain size increases, the underestimation of atmospheric variability at large scales worsens. Dynamical downscaling never adds more value to the predictability of the large scale over and above that which exists in the larger global model (or reanalysis). The utility of the RCM is to resolve the smaller-scale features which have a greater dependence on the surface boundary.
 - The Kain-Fritsch (KF) cumulus parameterization scheme with a terrain-adjusted convective trigger was installed in RAMS (Castro et al. 2002). The incorporation of the modified KF scheme improved the spatial and temporal distribution of warm season precipitation as demonstrated for test simulations in North and South America. This new convection scheme is critical to a more accurate representation of the surface energy budget of the North American monsoon and its feedback to monsoon evolution over the course of a season.

- New Land Data Assimilation System (LDAS) products were incorporated and tested for use as an initial condition in RAMS. Specifically, the soil moisture from the 50-yr Variable Infiltration Capacity (VIC) model was employed. It was demonstrated that use of high-resolution VIC data versus more coarsely resolved soil moisture significantly affects the model surface energy budget, soil moisture, and precipitation over a long-term model integration.
- A series of summer simulations with RAMS was completed Spring 2003 for years of significant Pacific SST corresponding to positive and negative phases of ENSO and PDO. These simulations confirm the preliminary results for the summers of 1988 and 1993. The model demonstrated a reasonable representation of NAMS mesoscale features, such as low-level jets and the diurnal cycle. It also showed interannual differences between years of contrasting Pacific sea surface temperature (SST).
- We have executed RAMS RCM simulations which downscale data from the NASA Seasonal-to-Interannual Prediction Project (NSIPP) GCM (Schubert et al. 2002). The NSIPP GCM simulations are forced with different idealized distributions of sea surface temperature corresponding to climatology, positive and negative phases of ENSO, and positive and negative phases of PDO. The RAMS-NSIPP simulations are initialized with the same (VIC) climatological soil moisture at the start of the model simulation, so statistically significant differences in the simulations will reveal the idealized responses of the North American Monsoon solely due to remote SST forcing.

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

4. Leveraging/Payoff:

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

8. Publications:

Castro, C.L., and R.A. Pielke, Sr., 2004: Diagnosing the Effect of ENSO and PDO associated Summer Teleconnections in North America with a regional climate model. 84th AMS Annual Meeting, 15th Symposium on Global Change and Climate Variations. Seattle, WA, January 10-16, 2004.

Castro, C.L., and R.A. Pielke, Sr., 2004: Dynamical downscaling: An assessment of value added using a regional climate model. *J. Geophys. Res.* (submitted).

Castro, C.L., R.A. Pielke Sr., and G.E. Liston, 2000: The relationship and response of the North American monsoon to tropical and North Pacific sea surface temperatures. Postprint Volume, 2nd Southwest Weather Symposium, 21-22 September, Tucson, Arizona.

- Castro, C.L., T.B. McKee, and R.A. Pielke Sr., 2000: The climatology and interannual variability of the North American monsoon as revealed by the NCEP/NCAR Reanalysis. Preprints, 11th Symposium on Global Change Studies, 80th AMS Annual Meeting, Long Beach, CA, January 9-14, 2000, 168-171.
- Castro, C.L., R.A. Pielke, Sr., and G.E. Liston, 2001. Simulation of the North American Monsoon in Different Pacific SST Regimes Using RAMS. *26th Climate Diagnostics and Prediction Workshop*. Scripps Institute of Oceanography, La Jolla, California.
- Castro, C.L., T.B. McKee, and R.A. Pielke, Sr., 2001: The relationship of the North American monsoon to tropical and North Pacific sea surface temperatures as revealed by observational analyses. *J. Climate*, **14**, 4449-4473.
- Castro, C.L., W.Y.Y. Cheng, A.B. Beltrán, C.H. Marshall, Jr., R.A. Pielke, Sr., and W.R. Cotton, 2002. The Incorporation of the Kain-Fritsch Cumulus Parameterization Scheme in RAMS with a Terrain-Adjusted Trigger Function. *5th RAMS Users and Related Applications Workshop*. Santorini, Greece.
- Cotton, W.R., R.A. Pielke Sr., R.L. Walko, G.E. Liston, C. Tremback, H. Jiang, R.L. McAnelly, J.Y. Harrington, M.E. Nicholls, G.G. Carrio, and J.P. McFadden, 2003: RAMS 2001: Current status and future directions. *Meteor. Atmos. Phys.*, **82**, 5-29.
- Pielke, R.A. Sr., 2001: Earth system modeling -- An integrated assessment tool for environmental studies. In: Present and Future of Modeling Global Environmental Change: Toward Integrated Modeling, Terra Scientific Publishing Company, Tokyo, Japan, 311-337.
- Pielke Sr., R.A., T.N. Chase, T.G.F. Kittel, J. Knaff, and J. Eastman, 2001: Analysis of 200 mbar zonal wind for the period 1958-1997. *J. Geophys. Res.*, **106**, **D21**, 27287-27290.

COUPLING BETWEEN MONSOON CONVECTION AND SUBTROPICAL HIGHS IN THE PACS REGION ON SUBSEASONAL TO INTERANNUAL TIME SCALES

Principal Investigators: Richard H. Johnson and Wayne H. Schubert

NOAA Project Goal: Climate

Keywords: Monsoon convection, subtropical highs, PACS, intraseasonal

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

The objectives of this research are to document the nature, extent and mechanisms for the coupling between the monsoon heat sources of the Americas and adjacent subtropical anticyclones with their associated low-level jets using both modeling and observational approaches.

2. Research Accomplishments/Highlights:

(a) planning efforts for the North American Monsoon Experiment, (b) computation of latent heating profiles over the Amazon using data from the TRMM LBA experiment, (c) a study of moisture surges over the North American monsoon domain using QuikSCAT surface winds, (d) analysis of surface winds and divergence patterns in stratocumulus regions using QuikSCAT winds and reanalysis products, and (e) an analysis of the effects of fine scale potential vorticity structure on the stability of the East-Pacific ITCZ

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

The lack of a good upper air sounding network over the South American (and in particular the Amazon) region made it difficult to compute meaningful latent heating products over this region. This led us to focus our activities on investigating the structure and characteristics of subtropical highs and their attendant circulations using new datasets, such as QuikSCAT wind and TRMM rainfall products, over data-sparse oceanic regions.

4. Leveraging/Payoff:

Analysis of the relationship between Gulf of California wind/moisture surges and precipitation events has improved our understanding of these events in the flash-flood-prone regions of the southwestern U.S.

Comparison of QuikSCAT winds and derived fields to those computed from reanalysis products have revealed some deficiencies in the reanalysis models. Using this information should lead to improvements in operational models, and ultimately to better forecasts.

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

We collaborated with Minghua Zhang (SUNY at Stony Brook) to compute the LBA heat and moisture budgets using the constrained variational method, and with Simona Bordoni and Bjorn Stevens (UCLA) to analyze gulf surges using QuikSCAT winds. In addition, we

investigated the formation and maintenance of water vapor black holes with Takamitsu Ito (MIT) and Edwin Gerber (Princeton).

6. Awards/Honors:

Richard H. Johnson: NSF Creativity Award

7. Outreach:

PhD graduate student, Chris Rozoff, and Master graduate students, Todd Ellis and Peter Rodgers had partial support from this grant. Several of the project members (Wayne Schubert, Brian McNoldy, Chris Rozoff), have participated in outreach programs to the public, in particular, to students in K-12.

8. Publications:

Refereed

Bordoni, S., P. E. Ciesielski, R. H. Johnson, B. D. McNoldy and B. Stevens, 2004: The low-level circulation of the North American Monsoon as revealed by QuikSCAT. *Geophys. Res. Lett.*, 31, L10109, doi:10.1029/2004GL020009.

B. D. McNoldy, P. E. Ciesielski, W. H. Schubert, and R. H. Johnson, 2004: Surface winds, divergence, and vorticity in stratocumulus regions using QuikSCAT and reanalysis winds. *Geophys. Res. Lett.*, 31, L108105, doi:10.1029/2004GL019768.

Prieto, R., B. D. McNoldy, S. R. Fulton, and W. H. Schubert, 2003: A classification of binary tropical-cyclone-like vortex interactions. *Mon. Wea. Rev.*, 131, 2656--2606.

Ito, T., E. P. Gerber, and W. H. Schubert, 2004: Formation and maintenance of black holes of water vapor in an idealized model of the tropical atmosphere. *Quart. J. Roy. Meteorol. Soc.*, To be submitted.

Hausman, S. A., K. V. Ooyama, and W. H. Schubert, 2004: Potential vorticity structure of simulated hurricanes. Conditionally accepted for publication in *J. Atmos. Sci.*

Rozoff C. M., W. H. Schubert, B. D. McNoldy, and J. P. Kossin, 2004: Rapid filamentation zones in intense tropical cyclones. Conditionally accepted for publication in *J. Atmos. Sci.*

Randall D. A. and W. H. Schubert, 2004: Dreams of a stratocumulus sleeper. Chapter 4 of *The Lilly Festschrift Volume*. Cambridge University Press.

Conference/Workshop Proceedings

Ciesielski P. E., B. D. McNoldy, and R. H. Johnson, 2003: Analysis of summertime wind/moisture surges over the gulf of California using QuikSCAT data. Presented at the U.S. Clivar Pan-American Workshop, 17 Sept. 2003, Boulder, CO.

Johnson, R. H., P. E. Ciesielski, and B. D. McNoldy, 2003: A study of Gulf surges using QuikSCAT data. Paper presented at NAME Session of Mexico Geophysical Union, 5 Nov. 2003, Puerto Vallarta, MX.

McNoldy B. D., P. E. Ciesielski, and W. H. Schubert, 2003: QuikSCAT analysis of surface wind fields in stratocumulus regions. Presented at the U.S. Clivar Pan-American Workshop, 17 Sept. 2003, Boulder, CO.

CROSS-SENSOR PRODUCTS FOR IMPROVED WEATHER ANALYSIS AND FORECASTING

Principal Investigator: Stanley Q. Kidder

NOAA Project Goal: Weather & Water

Keywords: NOAA Satellites, DMSP, AMSU, SSM/I, Total Precipitable Water, Blended Products

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

This work is part of the NOAA/NESDIS/OSD Product Systems Development and Implementation (PSDI) Program. This year's goal was to produce a Total Precipitable Water (TPW) product which combines data from the Advanced Microwave Sounding Unit (AMSU) on the NOAA 15, 16, and 17 satellites with data from the Special Sensor Microwave/Imager (SSM/I) on the Defense Meteorological Satellite Program (DMSP) F13, F14, and F15 satellites.

The product was developed and now runs hourly (Fig. 1). It is made available in real time to forecasters at CIRA and at the NOAA/NESDIS/OSDPD Satellite Services Division (SSD) and to the general public on our Web site (see item 7). Approximately 200 GB of data per day are processed in the production of this product.

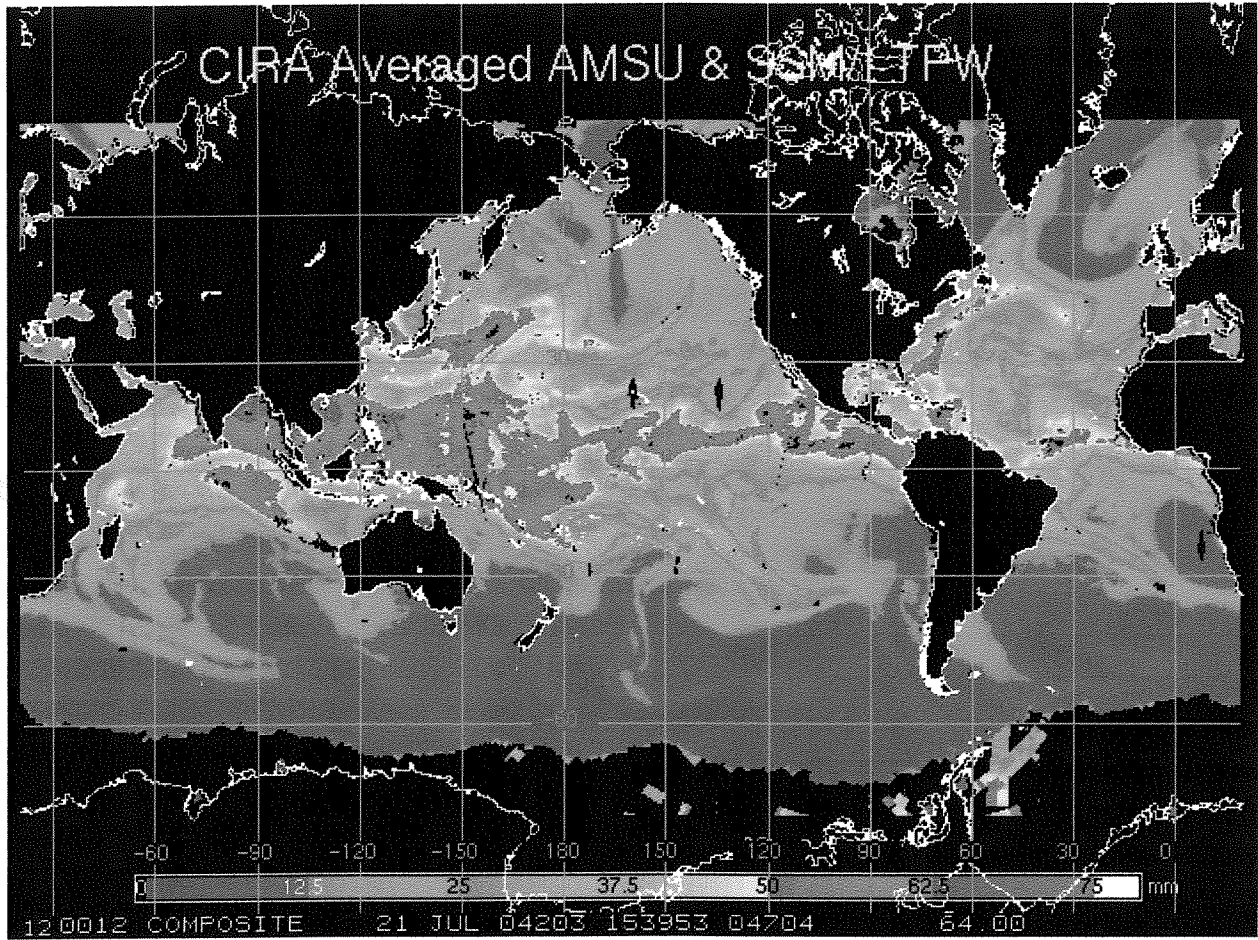


Figure 1. Average TPW for the 12-h period ending at 2030 UTC 21 July 2004. Approximately 30 orbits went into this composite

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

We actually got a lot more done than we imagined. Our PDF correction procedure which makes the observations from all satellites look as if they were made by the same instrument is quite general and will find use in many other projects. Also, the auxiliary data that we map with the TPW data (time of observation and satellite of observation) make the mapped data more useful. Further, we have installed our software at NESDIS and are testing it to see if it can become operational.

4. Leveraging/Payoff:

Two chief uses of the TPW data are in forecasting heavy rain, particularly in coastal regions, and monitoring tropical waves that could turn into tropical cyclones. The improved TPW composites give forecasters a clearer picture of where the water vapor is, which, we hope, will result in improved forecasts. These products are used daily by forecasters at SSD and CIRA.

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

The PSDI program is designed with partnerships in mind (see *Plan for Product Implementation: Microwave Image Products in AWIPS and McIDAS (9.1FY03-5)*, U. S. Dept. of Commerce, 2004 [available from Tom.Schott@noaa.gov]). Among our research partners at NESDIS are Ralph Ferraro (ORA), Sheldon Kusselson, John Paquette, and Joe Askew (OSDPD).

6. Awards/Honors: None as yet.

7. Outreach:

Our chief outreach activity is making our data available in real time on our AMSU Web site: [HTTP://AMSU.CIRA.COLOSTATE.EDU](http://amsu.cira.colostate.edu).

8. Publications:

Kidder, S. Q., and A. S. Jones, 2004: Blended satellite products for operational forecasting. 13th Conf. on Satellite Meteorology and Oceanography, 20–24 Sept. 2004, Norfolk, VA (in preparation).

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

Keywords: Tropical cyclone, hurricane, precipitation, rainfall, tropical cyclone intensity
Tropical cyclone formation

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

This project encompasses 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 and eastern North Pacific, and (3) improvements of the already operational NOAA/NESDIS Hydroestimator product using cloud resolving numerical modeling.

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

- 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 will be 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/IPB personnel the Algorithm will become part of SAB's set of operational products and will provide routine fixes of tropical cyclone to complement their DVORAK-based tropical cyclone intensity estimates.
- Using a combination of model analyses, GOES water vapor imagery, and historical tropical cyclone formation datasets, an algorithm to predict the probability of tropical cyclone formation will be developed. Development involves statistical screening of the data, and discriminant analysis to produce the probability of formation in the two dimensional plane. This product will be produced in a real-time manner both experimentally and then pre-operationally 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 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. Reserch Accomplishments/Highlights:

Using the same format as the previous section, the accomplishments and highlights associated with each product is discussed below.

- The AMSU-based tropical cyclone intensity estimation algorithm has been generalized to the global tropical cyclone database and is running in an experimental manner at CIRA using position information from the Automated Tropical Cyclone Forecast System maintained at the National Hurricane Center (NHC) and the Joint Typhoon Warning Center (JTWC) in which it is emailing results to the analysts working at NOAA/NESDIS/SAB. These results are also being disseminated in real-time to NHC and JTWC. Intensity estimates of Hurriane Isabel 2003 are shown in Fig. 1.

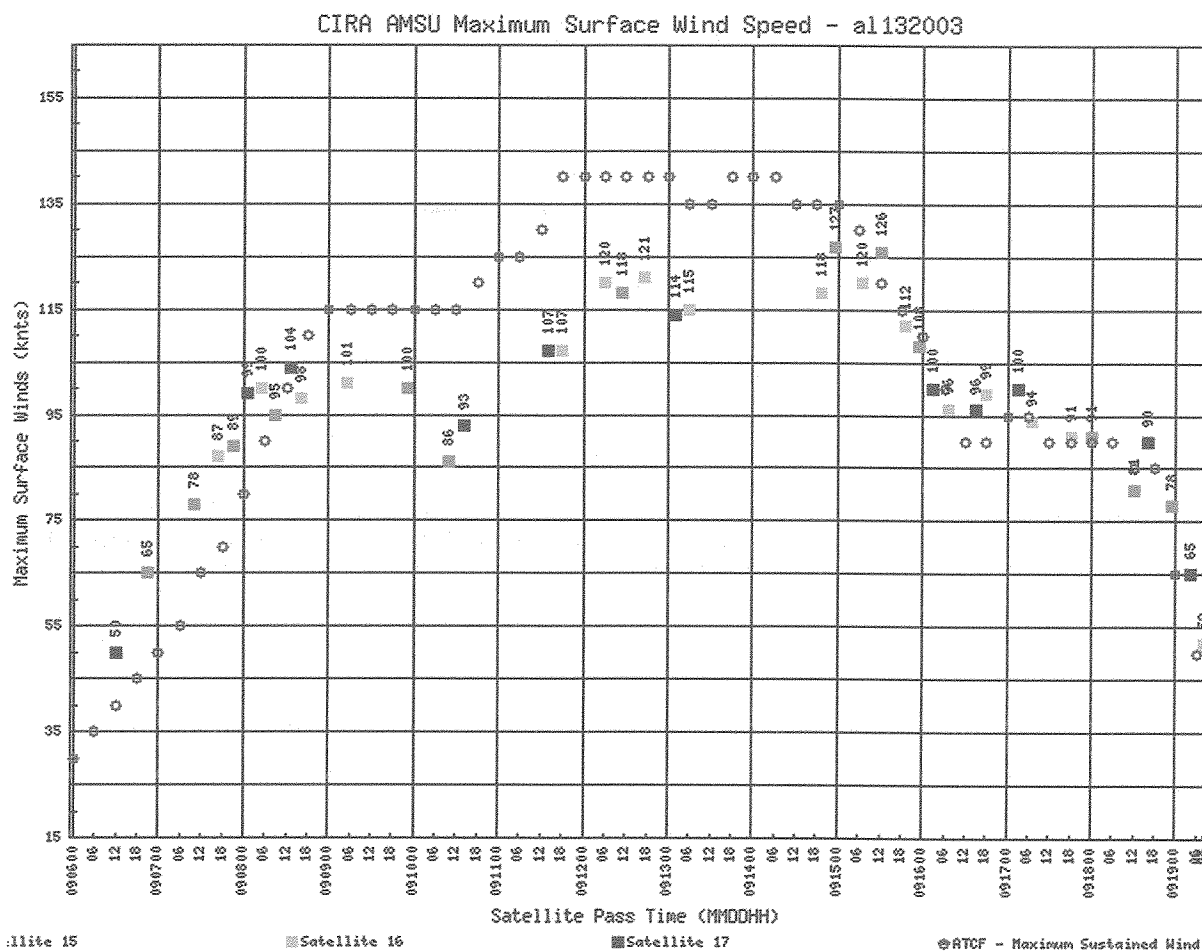


Figure 1. AMSU based estimates of maximum sustained 1-minute winds (in knots) associated with Hurricane Isabel along with operational estimates from NHC (pink).

- Expanding on previous research to predict regional probabilities associated with tropical cyclone formation, a spatially continuous method has been developed, which displays the probability associated with tropical cyclone formation in every 5 x 5 degree box in the eastern North Pacific and North Atlantic. Figure 2 has an example for Tropical Storm Blas in the eastern North Pacific Basin. The algorithm has been shown to improve on climatology by about an order of magnitude.

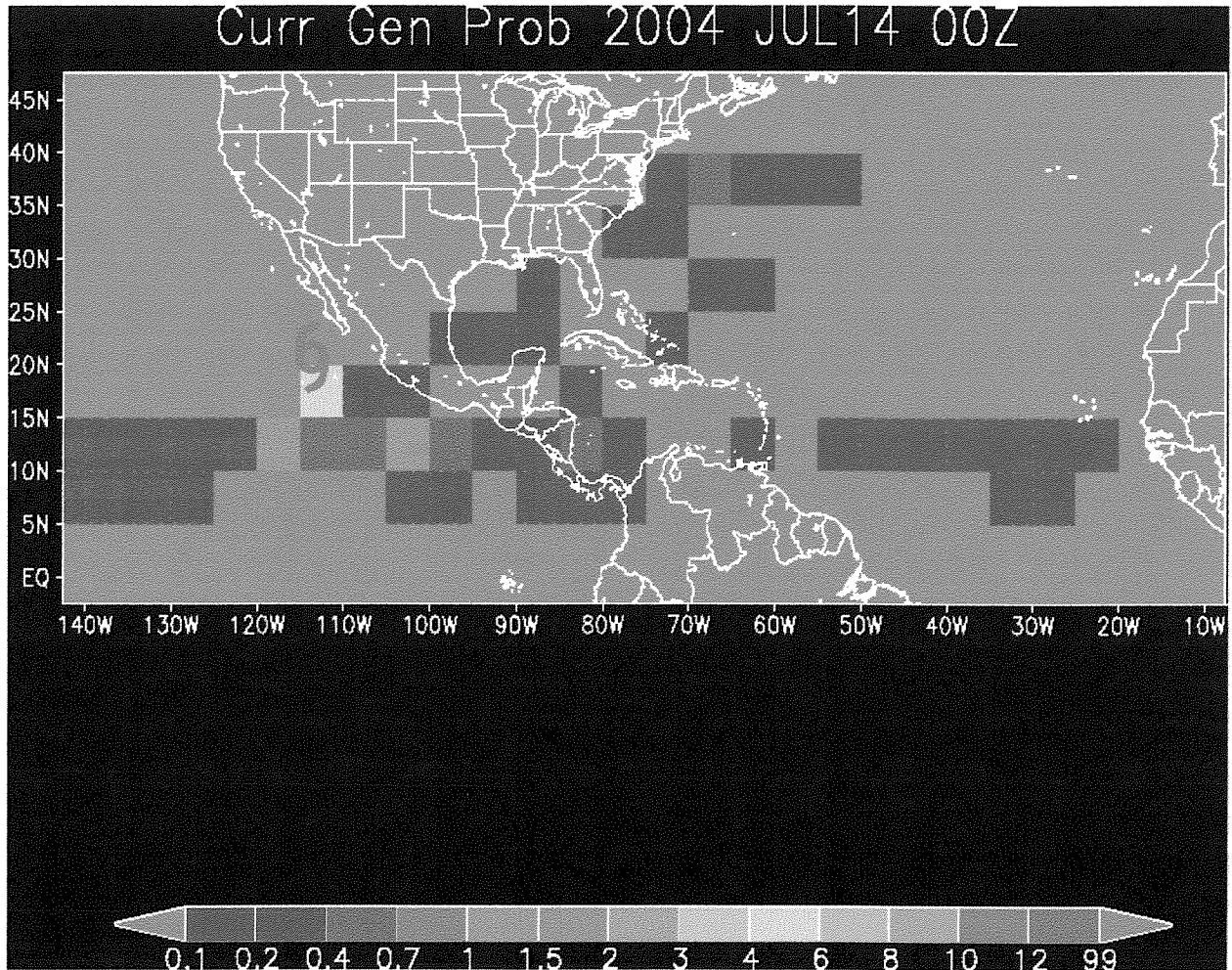


Figure 2. Example of the tropical cyclone formation product valid on 14 July 2004 at 12 UTC. Values are presented in terms of probabilities in percent.

This algorithm is being run in a real-time, experimental manner at CIRA and the output is being displayed on a secure web site. Access has been given to personnel at the NHC, the Naval Research Laboratory, and the JTWC.

- Several sensitivity simulations of the severe weather event over the Central Plains of the United States in which mid- to upper- tropospheric relative humidities have been varied from low to high. Output from each run is used to build statistics for the brightness temperature/rainrate relationship.

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

We have met our objectives for this reporting period.

4. Leveraging/Payoff:

There are several payoffs that affect both operational forecasting and the general public.

- There has long been a need for additional 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. This microwave-based algorithm fulfills a NOAA/NESDIS/OSDPD SPSRB requirement.
- 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 truly 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, Communication 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 James Gross (NOAA/NHC). Once operational, the tropical cyclone products will be available to global tropical cyclone centers and the DOD.

6. Awards/Honors:

Dr. John Knaff received the 2004 NOAA David Johnson Award in partial recognition of the tropical cyclone intensity work associated with this project and the research leading to the operational product.

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

- (a) None
- (b) J. Knaff , August 11, 2003: Research to Better Diagnose and Predict Tropical Cyclone Structure and Intensity Change, Naval Post Graduate School, Monterey, CA
- (c) None
- (d) None
- (e) None

8. Publications:

Refereed Journals

Demuth, J.L., M. DeMaria, J. A. Knaff, and T. H. Vonder Haar, 2004: Validation of an advanced microwave sounder unit (AMSU) tropical cyclone intensity and size estimation algorithm, *J. App. Met.*, 43, 282-296.

Conference Proceedings

DeMaria, M., C.W. Anderson, J.A. Knaff, and B.H. Connell, 2004: A New Product for Estimating the Probability of Tropical Cyclone Formation. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL

Presentations

J. Knaff , August 11, 2003: Research to Better Diagnose and Predict Tropical Cyclone Structure and Intensity Change, Naval Post Graduate School, Monterey, CA

Workshops

DeMaria, M., July 30-August 6, 2003: Tropical Prediction Center & Hurricane Research Division Meetings, Miami, FL

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

Principal Investigator: J.A. Knaff

NOAA Project Goal: Weather and Water

Keywords: 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 infrared or visible satellite imagery. However, it does not directly utilize other information available information such as microwave imagery. In this project, GOES infrared imagery and feature-tracked wind, the Advance Microwave Sounder Unit (AMSU) from the NOAA Polar-orbiting satellites, surface scattermeter winds (currently from QuikSCAT), and passive wind speed estimates from Defense Military Satellite Program (DMSP) microwave data will be combined. The wind information from these various sources will be combined in a specialized variational analysis that can include measures such as those from DMSP that only provide a wind speed estimate. The eventual goal of the project is to provide the multi-platform wind tropical cyclone wind analysis system to operational forecast centers.

2. Research Accomplishments/Highlights:

During the first year of the project, a method to estimate the wind field from GOES IR data was developed. The IR wind field estimate is the anchor for the variational analysis because that data is nearly always available in all tropical cyclone basins. The IR wind field estimate can then be refined when other data sources are available. For this part of the study, a dataset of 322 cases from 1995-2003 Atlantic and east Pacific tropical cyclones was constructed for development of the IR wind field algorithm. GOES infrared imagery was obtained for these cases, which also have aircraft reconnaissance data available for groundtruth. The IR wind algorithm uses a parameter wind model and requires an IR image, the storm position, the storm motion vector, and the storm intensity as input.

The variational analysis system was adapted to the problem of using satellite wind observations to estimate a complete surface wind field. The analysis system utilizes a "model fitting" approach, where the data on a regular grid that provide the best fit to the observations is determined. A smoothness constraint helps to determine the wind field in data void regions. In the solution for the final wind field, a "cost function" which measures the difference between the observations and the model counterpart of the observations (in this simplest version of the variational analysis used, the model counterpart of the observations is the analysis wind field interpolated to the observations points) is minimized.

In this framework, it is straightforward to include observations that only provide an estimate of the wind speed, but without a direction.

Two important contributions to tropical cyclone wind field outside of the eyewall region of the storm comes from the AMSU instrument and from QuikSCAT. Considerable effort was made to determine the error characteristics of these two wind instruments, and a method was developed to convert the AMSU winds (which are representative of winds above the boundary layer) to the surface. This work was performed by a CIRA visiting scientist from the Japanese Meteorological Agency (JMA).

Figure 1. shows an example of the multiplatform satellite analysis (red) and that obtained primarily from aircraft data (blue) for Hurricane Michelle from the 2001 hurricane season. The winds are along a north-south line through 84.1 °W. Results show that the two methods compare reasonably well. Only a very small portion of the global tropical cyclones are sampled with aircraft data. These preliminary results indicate that a reasonably accurate estimate of the tropical cyclone wind field can be determined using only satellite observations, which are available in all tropical cyclone basins around the world.

Cross Section of Wind Speed (kt) at 84.1W
Satellite Only (red), Recon+quick+cldrft (blue)
Valid 11-03 0000 UTC

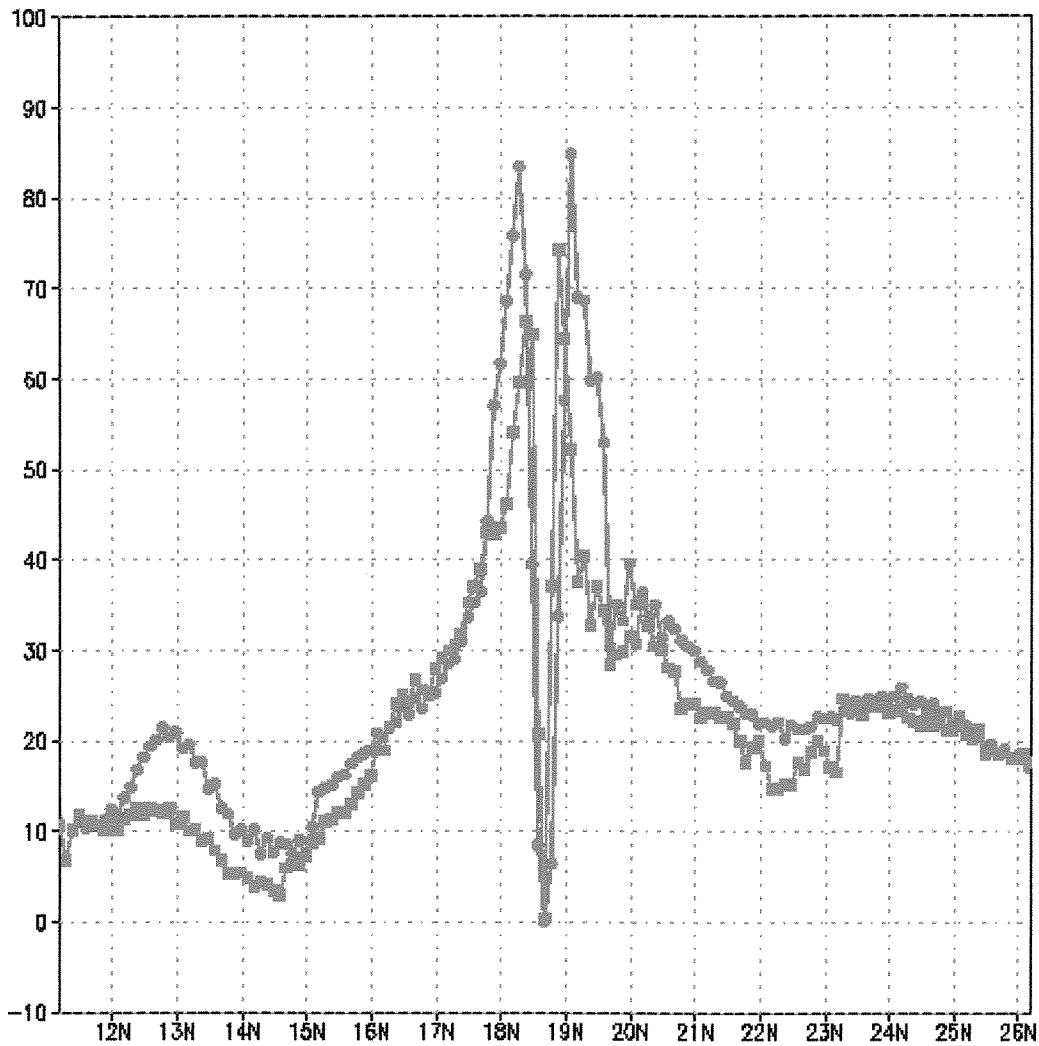


Figure 1. Comparison of satellite only (red) and aircraft analyses of the surface winds from Hurricane Michelle, 2001

The next step in this project is to apply the satellite tropical cyclone wind algorithm in near real time, and make the results available via a web site for evaluation by operational forecast centers. The longer term goal of the project is to transition this algorithm to operations.

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

The project is on schedule. The development of the components of the satellite tropical cyclone wind algorithm is essentially complete. In the second year of the project, analyses will be produced in real time for evaluation by operational forecast centers.

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.

5. Research Linkages/Partnerships/Collaborators, Communication 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 Japanese Meteorological Agency (JMA). It 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 at this time.

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

(b) See section 8, below

(c) None

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

8. Publications:

Refereed Journals

Demuth, J. L., M. DeMaria, J. A. Knaff, and T. H. Vonder Haar, 2004: Validation of an advanced microwave sounder unit (AMSU) tropical cyclone intensity and size estimation algorithm, *J. App. Met.*, 43, 282-296.

Conference Proceedings

Bessho, K., M. DeMaria, J.A. Knaff, and J. Demuth, 2004: Tropical Cyclone Wind Retrievals from the Advanced Microwave Sounding Unit (AMSU): Application to Surface Wind Analysis. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Velden, C., J. P. Kossin, T. L. Olander, D. Herndon, A. J. Wimmers, R. Wacker, R. T. Edson, J. D. Hawkins, K. F. Brueske, B.W. Kabat, and M. DeMaria, 2004: Toward an objective satellite-based algorithm to provide real-time estimates of TC intensity using integrated multispectral (IR and MW) observations. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Presentations

Knaff, J.A., M. DeMaria, K. Mueller, 2004: Methods to Estimate and Predict Tropical Cyclone Wind Structure: Recent Developments and Future Goals, *58th Interdepartmental Hurricane Conference*, 1-4 March, Charleston, SC

DEVELOPMENT OF EFFICIENT SATELLITE DATA COMPRESSION TECHNIQUES: TRANSMISSION OF GOES IMAGERY TO THE NOAA WP-3D AIRCRAFT

Principal Investigators: J.A. Knaff, N. Wang

NOAA Project Goal: Weather and Water

Keywords: Research Aircraft, reconnaissance, satellite, data compression, GOES

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

The ability to obtain real-time satellite data on the P-3 aircraft is limited by the bandwidth of the communications system. This low bandwidth also limits the transmission of important real-time information such as radar data from the aircraft back to the ground, for use by operational forecasters at the National Hurricane Center. An effort is underway at HRD to increase the communication capabilities to and from the P-3s using cell-phone and Internet technology. Although the bandwidth is still very limited (maximum rate of 2400 baud), it is a large improvement over what was previously available. With this improved communication capability and recent advancements in data compression technology, it is feasible to transmit a limited amount of GOES data to the P-3 aircraft. The funding will be used to support scientists at CIRA and FSL to continue research to improve satellite data compression (algorithms and symbolic encoding), and to test these capabilities during HRD's annual hurricane field project. The goals of this test will be to provide three real-time animated GOES image products (Visible, water vapor (6.7 μm), and IR (11 μm)) aboard the P-3. These would be updated during the mission and centered upon earth coordinates chosen by HRD scientists prior to the aircraft mission. This second year funding will also be used to research compression methods that will utilize the GOES-12 data feed which will begin 1 April 2003.

2. Research Accomplishments/Highlights:

As part of this continuing demonstration project, the previously successful wavelet based compression algorithms were updated, improved, and ported to several operating systems (HP-UX, Linux, Win2000). The necessary scripts and algorithms to encode and decode satellite data were installed on the tropical RAMSDIS system at the NOAA Hurricane Research Division, Miami, FL, and CIRA, and on both NOAA P-3 research aircraft. This allows scientists that plan the P-3 missions to assign the satellite sector to be disseminated to the aircraft.

These scripts and algorithms successfully created compressed files and served them via ftp to the world, including the P-3 aircraft. Such images were collected by NOAA personnel during flights into Hurricane Isabel (2003), demonstrating that the transmission of satellite data, and the display and animation of such data is possible even with the NOAA P-3's limited communications capabilities. Examples of products shown on the aircraft are displayed in Fig. 1

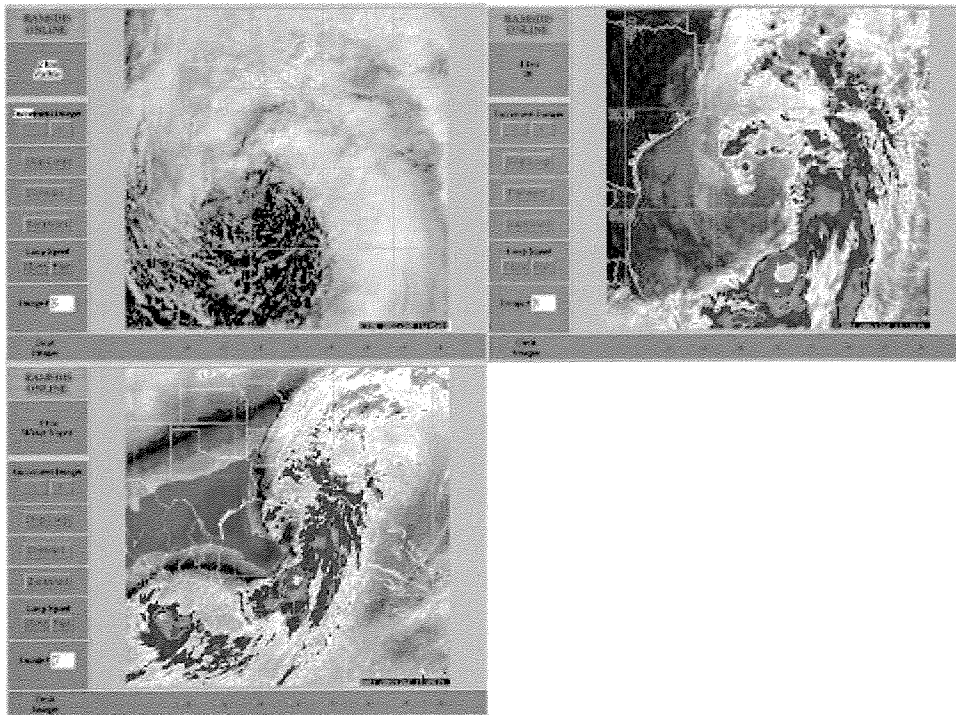


Figure 1. Examples of the satellite image products from Hurricane Isidore on 25 September 25, 2002 as they will appear on the JavaScript Application on the P-3 aircraft. The products are 2 km visible (left), 4km IR (middle) and 8 km water vapor (right). Note that there will be eight images in each product loop

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

The cable to connect the HP workstation was not installed on the NOAA P-3 aircraft so the ingest system on these platforms was not fully tested. This capability should be available for 2004. Otherwise, all aspects of this project were completed.

4. Leverage/Payoff:

This project demonstrates some advanced methods of data compression. Such technology will become more important to NOAA as datastreams associated with future satellite platforms increase.

In addition, this project has provided a means by which satellite data can be displayed and utilized during NOAA P-3 research and reconnaissance missions. Such use can make such missions more successful by giving onboard researchers the most recent views from space.

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

Collaborations included NOAA OAR/AOML/HRD, Miami, FL and NOAA OAR/AOC, Tampa, FL and could lead to similar projects with DOD, in particular the USAFR 53rd Weather

Reconnaissance Squadron stationed at Kessler, AFB – the primary source of operational hurricane reconnaissance.

6. Awards/Honors:

Dr. John Knaff received the 2004 NOAA David Johnson Award in partial recognition of this 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.

None

8. Publications:

Conference Papers

Knaff, J.A., N. Wang, R.M. Zehr, M. DeMaria, J.S. Griffin, and F.D. Marks, 2003: A demonstration of real-time transmission and display of GOES imagery aboard the NOAA P-3 aircraft during the 2002 hurricane season. *12th Conference on Satellite Meteorology and Oceanography*, 10-14 February, Long Beach, CA, Amer. Meteor. Soc., CD-ROM, JP1.5.

Presentations

M. DeMaria, D. Molenaar, D. Lindsey, D. Hillger, R. Zehr, B. Connell, J. Dostalek, and C. Combs, June 8, 2004: Overview of RAMMB/CIRA Activities to Fran Holt, CoRP Director. CIRA, Fort Collins, CO

ENHANCED COMMUNICATIONS AT CIRA FOR THE DEVELOPMENT OF REAL-TIME EVALUATION OF AMSU TROPICAL CYCLONE PRODUCTS

Principal Investigator: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Keywords: Satellite Processing, Communications

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

Long-term research plans required that CIRA move away from costly HP workstations. RAMM/CIRA's goal was a time-phased migration of HP applications to more powerful and economical Linux PC platforms over a period of three years. The funds were used to procure workstations, archive and mass store devices to support AMSU and other tropical cyclone product generation in a Linux environment, and to support joint research with other NOAA laboratories on a common Linux platform.

2. Research Accomplishments/Highlights:

The migration of all lab and user systems to Linux was completed this year.

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

The goals of this project were met.

4. Leveraging/Payoff:

These funds were used in conjunction with other NOAA hardware funds to provide state-of-the-art hardware and software technology for CIRA researchers. The workstations and mass storage devices purchased via this project are also utilized in joint projects by NOAA researchers outside of CIRA.

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

This project made some use of satellite processing software for the Linux environment developed at CIMSS.

6. Awards/Honors: None at this time

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.

None

8. Publications:

Presentations

M. DeMaria, D. Molenar, D. Lindsey, D. Hillger, R. Zehr, B. Connell, J. Dostalek, and C. Combs, June 8, 2004: Overview of RAMMB/CIRA Activities to Fran Holt, CoRP Director. CIRA, Fort Collins, CO

Training

V. Castro, R. Alfaro, B.H. Connell, Jul 14-18, 2003: In-depth training on the RAMSDIS system. San Jose, Costa Rica

Professional Meetings

Gosden, H., Oct. 15-16, 2003: McIDAS Users' Group Meeting, Madison, WI.

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 – Accomplishments in *Italics*

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. EAR -Research Collaborations with the Director's Office

Keywords: Mesoscale Modeling; 3-D and 4-D Variational Data Analysis; GPS Slant Path Water Vapor Analysis

CIRA proposed to collaborate closely with the Director's Office on the continued development of various research mesoscale models such as the Weather Research and Forecast (WRF) model. CIRA's efforts would be directed to the testing and implementation of boundary layer parameterization, along with improvements to the cloud microphysics processes and on additional initialization sensitivity studies.

Principal Researcher: Ming Ge

In support of NOAA Goal 3 to "Serve Society's Needs for Weather and Water Information," research efforts with the WRF model focused on data assimilation for the 2-km resolution version of the model and involved various sensitivity experiments with idealized cases such as supercells and baroclinic waves. The use of boundary and initial input data from sources such as MM5 were evaluated. Nesting experiments were also conducted with a new wrfsi GUI.

As part of the global UAV project, NCEP/NCAR reanalysis data were processed using bi-linear interpolation for use by the model.

In the area of data assimilation, CIRA proposed that important issues related to 3-D and 4-D variational data analysis be investigated. One initiative would involve the modification of the WRF 3DVAR system to incorporate velocity or vorticity fields as control variables.

CIRA proposed that the use of GPS slant path water vapor analyses in a 3DVAR system continue to be evaluated. This research would involve: 1) a proof-of-concept study for a national observing system consisting of TP/BLP profilers, ground-based GPS receivers and radiosondes with ground tracking systems; 2) OSSEs involving designs of simulated observation network; and 3) numerical models to validate system applicability and robustness. A GPS tomography technique previously developed would be compared with other internationally developed methods to benchmark existing capability.

CIRA proposed that research also be conducted on a new WRF global model using the most advanced numerical techniques, including the possible application of finite difference schemes on an icosahedron grid. This approach could result in a more efficient forecast model and permit the use of highly advanced physics packages.

Principal Scientist: Yuanfu Xie

On the new 3DVAR analysis, numerous discussions and revisions to the paper that was being prepared for submission—"Advantages of Using Vorticity and Divergence as Control Variables for Three-Dimensional Variational Systems"—ensued during the past year. This effort supports NOAA Goal 3 to "Serve Society's Needs for Weather and Water Information."

The major difference with the proposed new 3DVAR scheme is that the current 3DVAR treats the differences between model background and observations as unresolvable features and applies statistical analysis to them. Actually, based upon our analysis, these differences contain all scales of motions such that sophisticated techniques need to be applied to remove the resolvable components by the observation network before applying the statistical analysis. Plan is to implement a method to demonstrate this important difference in 3DVAR.

For the GPS project which also supports NOAA Goal 3, the GPS tomography software was redesigned and implemented for analyzing real GPS. The new features are:

- a. Recursive filter is introduced in order to compare with the multigrid technique used in the original development.*
- b. A mapping scheme is developed to handle real data over the Earth as an ellipsoidal instead of a perfect sphere.*
- c. User interface with the IHOP GPS data sets.*
- d. New physical constraints for restricting the solution of the tomography.*

With these new features, the June 13, 2002 storm case over the IHOP data domain was analyzed and found that the water vapor analysis matches the satellite water vapor image and sounding data from the IHOP central facility very well. This is the first time this analysis tool has been applied to real data following its development that had produced impressive results of GPS analysis based upon OSSE experiments. These real data analyses verified our conclusions made in the OSSE analysis. In addition, the new real data analysis did not use direct observations as used in our previous OSSE analysis. Instead, two new constraints were introduced: the water vapor is non-negative and it decays exponentially with height. These real data analyses were conducted collaboratively with FSL/DD, UCAR/GST, and Radiometric Corporation. Based upon these results, scientists from the Meteorology Research Institute in Japan are interested in analyzing some typhoon cases in Japan using GPS data and our GPS analysis tool.

Plans to develop a global numerical prediction model with distinguishing features such as parallelization, efficiency, and a uniform processing of the icosahedron grid over the whole globe were delayed. Intention is to build the model over a universal coordinate so that there is no pole problem and the grid operations would be uniform everywhere. Instead, effort was placed on a mesonet surface analysis in collaboration with FSL/FRD.

This proposed project in support of the NWS poses challenges in the use of very frequent data ingestion (target of 1-minute interval). The original schemes proposed were a variational analysis and a Kalman filter method. The variational method is to use harmonic base functions to fit the surface data and certain background field with control variables of amplitudes and frequencies. These two methods were implemented and tested on a few simple cases and found that require further modification. The variational scheme results in non-unique solutions and the Kalman filter requires a model describing the surface data. Decision was to leave the Kalman filter approach temporarily and to improve the variational scheme.

Truncated harmonic expansion series was used to fit the surface observations to avoid the multiple solutions. The method showed very good results for test cases with periodic flow.

However, problems arose near the spatial and time boundaries when non-periodic data (represents reality) were tested. This is because a harmonic analysis uses the average values of the true boundary values as its boundary values.

Proposed alternatives include Window Fourier base functions, spline base functions, and wavelet base functions. For non-periodic cases, the spline seems more attractive. However, regularly divided splines in x, y and t directions are very inefficient to resolve non-uniform meteorological fields, with the exception of triangular spline base functions, which would be difficult to implement. Therefore, decision was to proceed with the use of wavelet base functions developed by Dr. Wang, who will begin participating in this project.

Publications

Ware R., J. Braun, S.-Y. Ha, D. Hunt, Y.-H. Kuo, C. Rocken, M. Slezziak, T. Van Hove, J. Weber, Y. Xie, R. Anthes, and A. MacDonald, 2004: Real-time water vapor sensing with SuomiNet—today and tomorrow. *Bulletin of the American Meteorological Society* (submitted).

Xie, Y.-F., and A. E. MacDonald, 2004: Advantages of using vorticity and divergence as control variables for three-dimensional variational systems. (FSL internal review).

Koch, S.E., Y. Xie, N. Wang, J.A. McGinley, P.A. Miller, and S. Albers, 2005: A new approach for mesoscale surface analysis: The Space-Time Mesoscale Analysis System (STMAS). AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

Presentations

Braun J. and Y. Xie, 2003: Observed convergence of water vapor prior to and during the June 12-13, 2002 northern Oklahoma storm using the global positioning system. 31st International Conference on Radar Meteorology, Seattle, WA, August 2003.

Xie Y., 2003: Impact of cost function formulation and constraints on 3DVAR. National Weather Bureau, Taiwan, November 3, 2003.

Xie Y., 2003: Diagnosis of three-dimensional water vapor distribution using GPS slant water vapor observations. National Weather Bureau, Taiwan, November 5, 2003.

Xie Y., 2003: Impact of cost function formulation and constraints on 3DVAR. National Central University, Taiwan, November 6, 2003.

II. Research Collaborations with the Aviation Division

Keywords: High-performance Computing; Model Parallelization; Grid Computing; Aviation Weather Support; Collaborative Forecast Tools; Forecast Verification Tools

A. High Performance Computing-Advanced Computing

Principal Researchers: Jacques Middlecoff and Dan Schaffer

In the area of High Performance Computing-Advanced Computing, CIRA proposed four research efforts.

1) 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 FY03-04, CIRA researchers would enhance the SMS suite to allow for coupling of parallel models currently used by CIRA scientists as well as other NOAA and non-NOAA researchers across the country.

This effort, aimed at furthering NOAA Goals 2 (Understanding Climate Variability and Change to Enhance Society's Ability to Plan and Respond) and 3 (Serve Society's Needs for Weather and Water Information), was highly successful. CIRA researchers continued their collaborations on the development of computer software for the parallelization of atmospheric and oceanic weather and climate models. Responding to community needs, CIRA researchers enhanced the WRF model (rather than SMS) to allow for coupling of parallel models currently used by CIRA scientists as well as other NOAA and non-NOAA researchers across the country.

2) CIRA researchers would also continue to work closely with FSL and other research institutes to parallelize atmospheric and oceanic models for weather and climate applications. SMS will continue to be used by our researchers for the RUC, LAPS, and QNH models. SMS will also be upgraded to support the geodesic grid model currently being developed by the FSL advanced modeling group. It is expected this code would replace the QNH model. The SMS RUC model would also be optimized for the IBM Power 4.

This effort, aimed at furthering NOAA Goals 2 and 3, was successful although the geodesic grid model has not yet been completed and thus could not be supported by SMS. CIRA researchers continued to work closely with FSL and other research organizations to parallelize atmospheric and oceanic models for weather and climate applications. SMS continued to be used by our researchers for the RUC and QNH models. The SMS RUC model was optimized for the IBM Power4.

3) CIRA researchers would explore the feasibility of combining geographically distributed computing resources into a single virtual resource. This effort would begin with the coupling of simple component applications across multiple machines connected by the NSF-sponsored TeraGrid. If this effort is successful, we would extend the concept to the

coupling of the WRF with the Regional Ocean Modeling System across multiple TeraGrid machines.

This effort, also aimed at furthering NOAA Goals 2 and 3, was highly successful. Since the TeraGrid was not yet available, CIRA researchers created their own test grid between FSL and PMEL. CIRA researchers explored the feasibility of combining geographically distributed computing resources into a single virtual resource by creating and demonstrating a WRF/ROMS coupled model running simultaneously at FSL and PMEL.

4) CIRA scientists would: a) participate in preparing for the implementation of the WRF Test Plan by porting the WRF Post Processor, the WRF Verification software, and the WRF/NMM to Ijet; b) support the WRF Test Plan at FSL; and c) provide technical assistance where appropriate in the development of the procurement benchmark suite.

This effort, aimed at furthering NOAA Goal 2, was highly successful. CIRA scientists: a) participated in the implementation of the WRF Test Plan by porting the WRF Post Processor, the WRF Verification software, and the WRF/NMM to Ijet; b) supported the WRF Test Plan at FSL by debugging WRF/NMM and assisting in running WRF/NMM; and c) provided technical assistance in the development of the joint procurement benchmark suite.

B. Aviation Systems—Development and Deployment

CIRA proposed to continue their collaborations on an FX-Connect client system for a LINUX platform. Web development and applications would also continue for the FX-Connect TMU Project.

The AWIPS/FXC/TMU systems would be supported through the evaluation phase for the convective hazard product.

FX-Connect investigative research would focus on the following areas:

- Use of the FX-Connect systems to facilitate research collaboration between forecasters and researchers at separate locations
- Research, design and development of a java-based tool for creating CWA's
- Research into the collaborative spatial and temporal ARTCC boundary aspects of CWA's
- Investigation into the use of volcanic ash products for Alaskan WMO/CWSU with FXC enhancements for sharing these local WMO and CWSU products between these local offices

Principal Researchers: Jim Frimel, Young Chun, and Lisa Gifford

The FX-Collaborate software (FXC), developed at NOAA's Forecast Systems Lab Systems Development Division, is a major component of the FXC FAA and FXC Volcanic Ash Coordination Tool (VACT) projects. Both projects support NOAA Goals 3 (Serve Society's Needs for Weather and Water Information) and 4 (Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation). The major

system used to acquire, distribute, create and provide the required data sets for the Traffic Management Unit (TMU), FXC FAA, and the FXC VACT projects is the AWIPS Linux data ingest and display system. The FXC and AWIPS system software is being tailored, modified, extended, enhanced, and utilized in these projects for use at the participating agencies. 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 is comprised of AWIPS Linux data ingest systems and Web Servers specifically developed for the creation web-based products generated via output from the AWIPS system.

Prototyping and Aviation Collaboration Effort (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 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 Forecast Systems Lab 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 in the initial phase of a four-phase effort designed to address the weather information needs of the TMU relating to weather-related hazards such as convection, 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.

Relating to advanced product displays, visualization and the WWW, CIRA researchers have enhanced the prototype Tactical Convective Hazards Product (TCHP) on the TMU restricted web site (<http://tmu.fsl.noaa.gov>). The TMU web site home page has been redesigned and reorganized along with tactical and strategic placeholders for all products currently planned. Specific product descriptions used in the TCHP display are now accessible via links from the product checkboxes. The CCFP 2, 4, and 6 hour forecast and text products have been added to the static pages with the 2 Hour CCFP and 1 Hour Convective Sigmet products added to enhance the TCHP animation page. Additionally, the

capability for automatic updates of products has been added to the image player. A very useful added capability used in the evaluation of products and training is the ability to archive and playback TMU data sets. Enhancements have been made to the Impacted Jet routes product by additionally utilizing NCWD as input along with the NCWF and adding a 10 nautical mile impact buffer around the jet routes. Additional work has started on the NCWF Performance indicator to compare the current NCWD with the previous hour's NCWF. Also, a prototype runway crosswind impact concept page is available. This page displays the DFW runways in a color encoded go-caution-no go fashion of green, yellow, and red based on runway crosswind information. These added capabilities are some of the major enhancements made to the TMU project.

The goal of the TMU web site is to consolidate all tactical aviation weather hazards information into a suite of products for presentation to TMU decision-makers in an easily understood format. Such as 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.

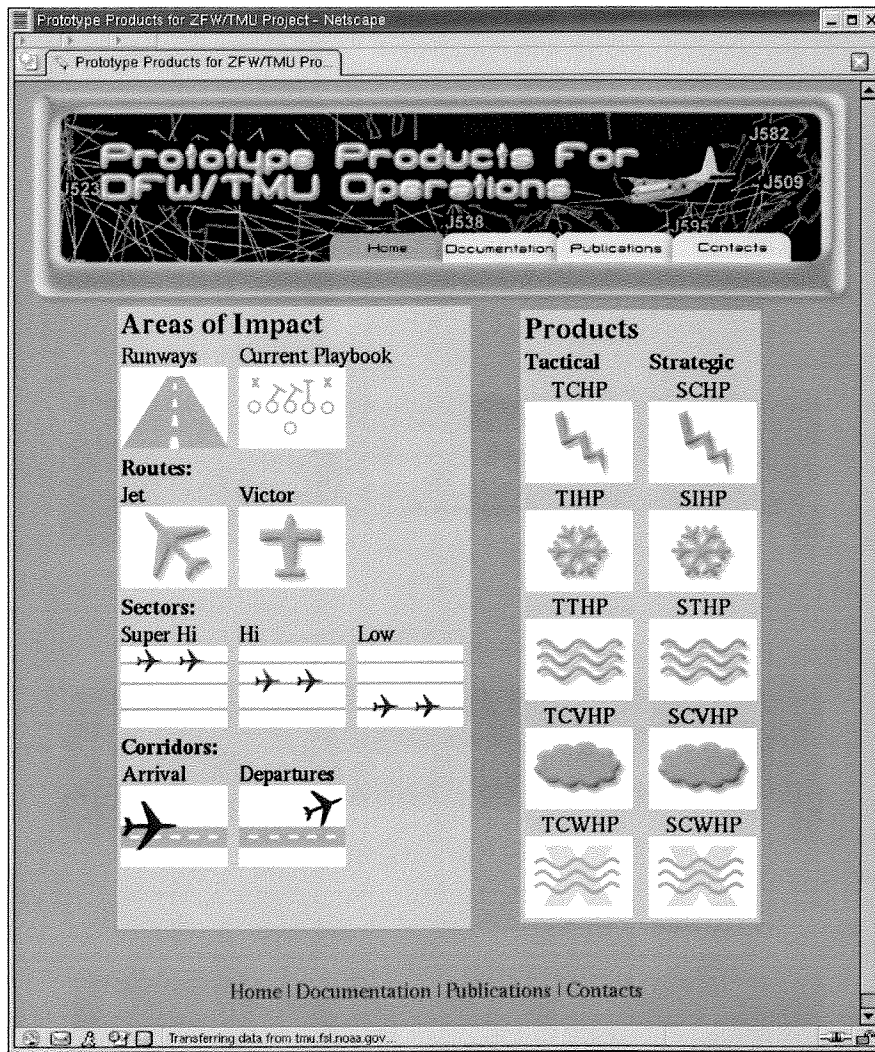


Fig. 1. A view of the newly redesigned TMU Web Site Home Page

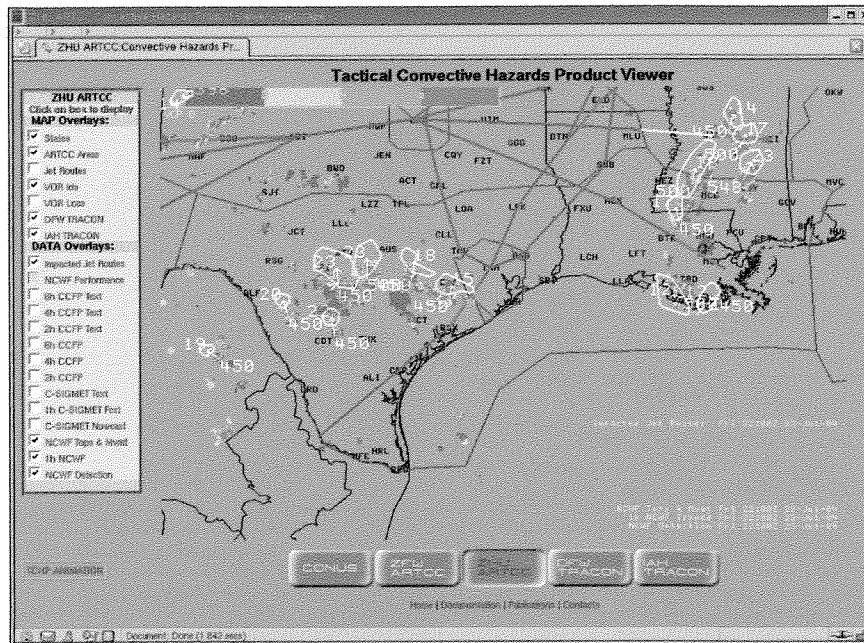


Fig. 2. A view of the redesigned TMU Web Site TCHP page ZHU ARTCC Scale showing Impacted Jet Routes utilizing both NCWD and NCWF products

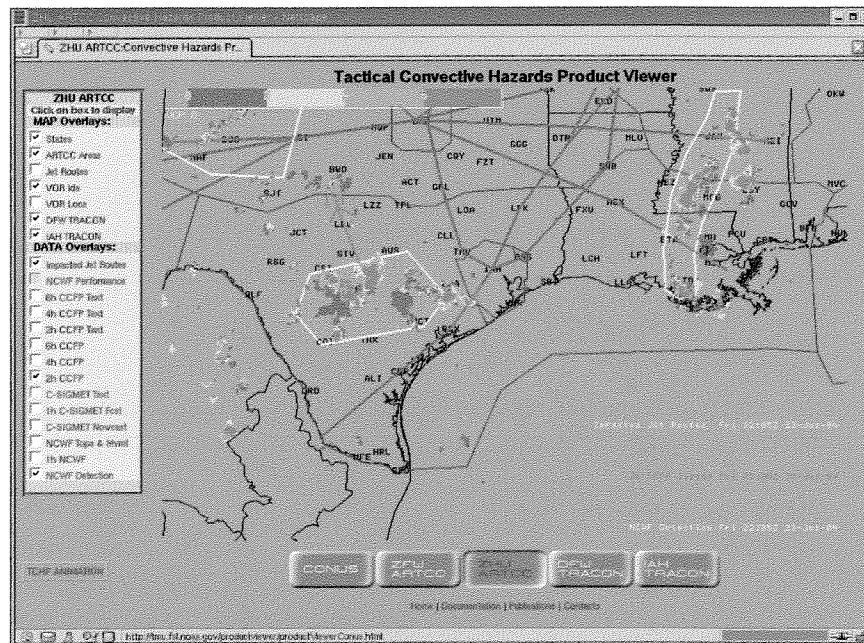


Fig. 3. A view of the redesigned TMU Web Site TCHP page ZHU ARTCC Scale showing Impacted Jet Routes, NCWD, and 2 Hour CCFP Forecast

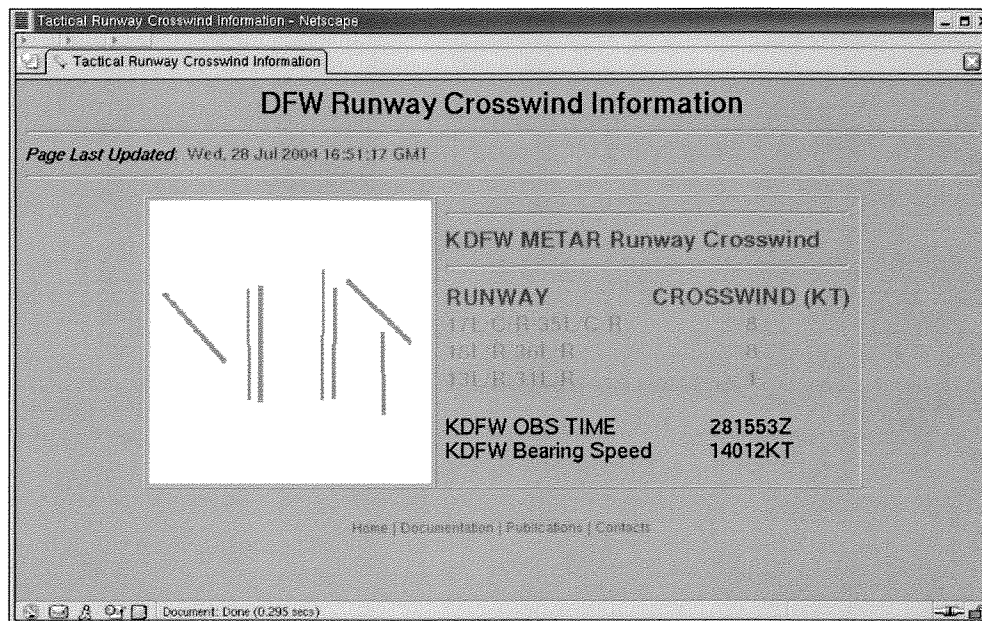


Fig. 4 provides a view the prototype DFW runway crosswind impact page

The FXC VACT Project is a custom client/server based application utilizing the Internet and is based on the FX-Collaborate system architecture. This 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 agencies currently participating in this effort are 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 FXC Volcanic Ash Coordination Tool is being used at each of these operational sites to simultaneously view identical displays and corroborate weather information in near real-time. The project will research collaborative approaches with the goal of helping to create a suite of fully consistent advisories and forecasts for volcanic ash.

The FXC VACT Project was rapidly spun up in 2003 by utilizing existing technologies, systems and infrastructure already in place within the ASDAD branch. Four new FXC Client systems were deployed running Windows XP as the operating system. A new Dell 2650 PowerEdge High Availability Server was configured to run the FXC and AWIPS data ingest server software. Previously the FXC server and AWIPS data ingest server ran on their own respective machine. Running the system in this configuration reduced hardware costs, maintenance costs, and rack space requirements, while improving system efficiency, reliability and software maintenance. Two systems were configured in this fashion as our primary and backup servers for the VACT Project.

CIRA researchers at NOAA's Forecast Systems Lab (FSL) are investigating and extending the current capabilities of the FX-Collaborate and AWIPS systems to apply towards the FXC VACT project requirements. Such changes will include adding volcanic ash data sets, dispersion models, and tools for generating volcanic ash products.

The initial release of the FXC VACT systems included the delivery and installation of both the hardware and software required by the project. The purpose of this release was to train and familiarize the participating agencies on the current capabilities of the FXC VACT software and systems. Successive software releases and enhancements included the creation of a new localization consisting of specific scales such as Kamchatka and the Aleutian Islands. Aviation maps backgrounds have been created and added to include Alaska navigation aids, Alaska Sigmet locations, airport runways and volcano locations. Capability to display and load specific model families and model data defined for the FXC VACT region has been added to the system. This includes the UKMET, AVN, MRF, ECMWF and the MesoETA model data. The satellite menus have been reorganized and renamed to include the HRPT, DMSP and FY3C. This Alaska HIPS Imagery satellite data has been added to the systems and is being ingested via an LDM feed from the National Weather Service Alaska Region Headquarters. Additionally, CCFP 2, 4, and 6 hour forecast and text products have been added. The ability to display an example of Puff model output, a volcanic ash particle-tracking model, from the University of Alaska, Fairbanks, has been added to the FXC VACT system. Design and development of an Interface for running Puff and other dispersion models from the FXC VACT still needs to be implemented. These added capabilities along with general software maintenance, hardening, bug fixes and enhancements, which include the underlying dynamic choice menu code and routines for generating model data keys, are some of the major enhancements made to the FXC VACT system.

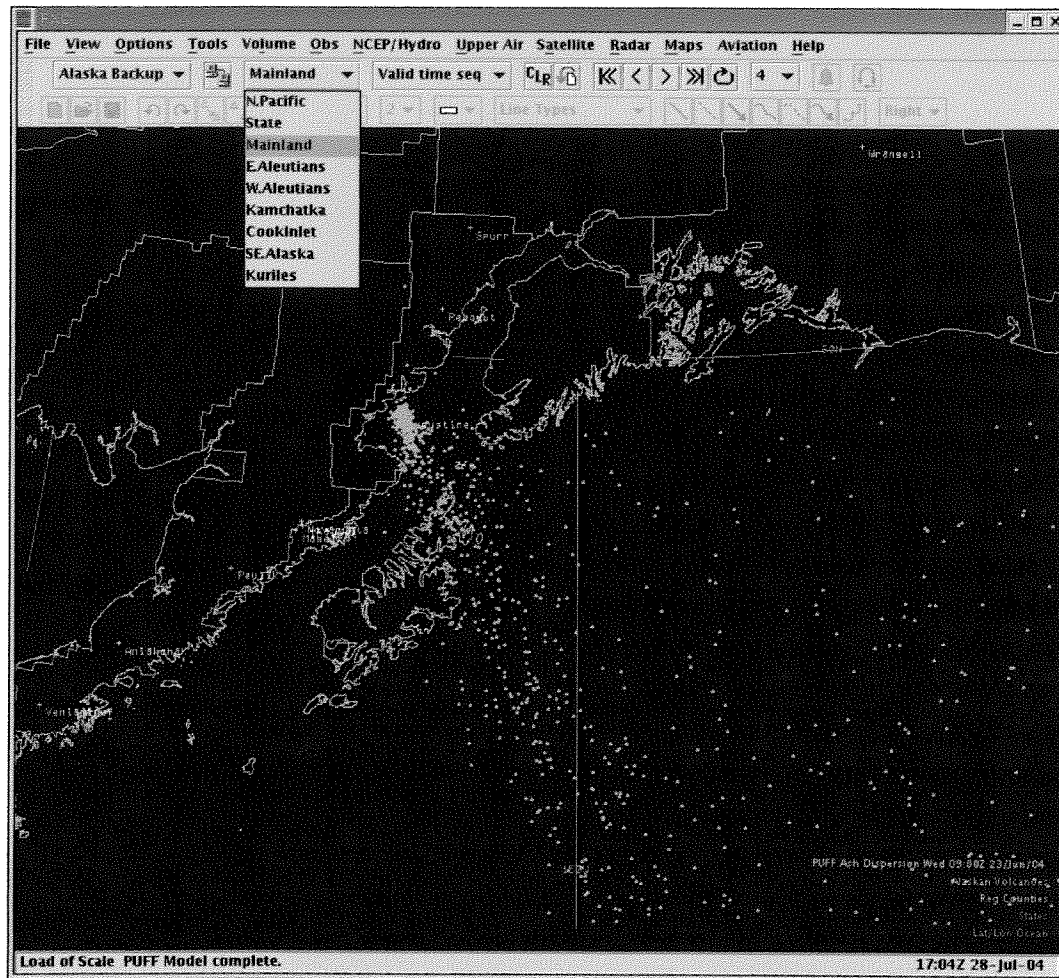


Fig. 5. A view of the FXC VACT tool with the Puff Ash Dispersion Model output, volcano locations and available scales

The Aviation Digital Data Service (ADDS) research project would focus on the following efforts for FY04:

- Designing and implementing a new ADDS Development and Test Web Server for investigating, researching and verifying the ADDS installation disks for meeting FAA QICP requirements
- Performing ADDS failure fire drills
- Redesigning the ADDS PIREP and TAF applets to an application utilizing Web Start Services
- Extending world satellite coverage using AWC's databases
- Investigating palm development showing NCWD, NCWF, TAF, PIREPS, and METARS
- Converting Netcdf Gempak for access by ADDS applications to the AWC operational databases
- Exploring the addition of national and regional mosaics from WARP data

Support for ADDS continued this past year with focus on the goal of transferring it from an experimental to an operational system in production at the Aviation Weather Center. This effort culminated in the granting of Operational Status by the Director of AWC in September. This project falls under NOAA Goal 4.

C. Forecast Verification Branch

CIRA proposed to collaborate on the Real Time Verification System (RTVS) for a Beowulf Linux Cluster. The RTVS System would be enhanced to process the increasing volume of data. New operational products such as CIP and FIP would be implemented. Compression of raw gridded data and output GIF display files would be implemented to reduce the size of the archived database saving disk space. Some of the code would be refactored for speed. Test harnesses were to be written to demonstrate functionality of the refactored code. A possible migration to a GIS location centric approach was also to be considered. Efforts to document the existing system architecture would continue.

Principal Researchers: Chris Steffen and Sean Madine

Background:

CIRA researchers collaborated with FSL's Aviation Division on the analysis and implementation of system enhancements that improved the verification capabilities of the RTVS. The system provides verification statistics for a variety of forecast products, both experimental and operational. Critical decisions regarding the quality of these products, primarily intended for use by the aviation community, are based upon the statistics computed by RTVS. Statistical plots and product displays are made available to the users via a Web interface. This research activity falls under NOAA Goals 3 (Serve Society's Needs for Weather and Water Information) and 4 (Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation).

Proposed Objectives and Accomplishments

Objective: Investigate alternative batch computing configurations for RTVS.

Various compute cluster configurations were studied in the context of the existing processing approach of RTVS. Many aspects of the problem were addressed including communication between nodes, access to network-accessed storage, and scheduling of interdependent processing jobs. Prototypes were developed to further understand the merit of the recommended enhancements.

Objective: Evaluate the operational Current Icing Potential (CIP) and Forecast Icing Potential (FIP) products.

A package was implemented to compute verification statistics in near real-time for the CIP and FIP products. Computations were structured to support the creation of a variety of analysis plots. This structure included a stratification of the results by a number of different attributes such as flight level and geographic region. Results were imported into the centralized RTVS statistical database to support on-demand queries. Documentation of computation package was written. Test harnesses were also created.

Objective: Investigate data compression of the large volume of information archived by RTVS.

Leveraging efforts from previous compression studies of NOAAPort data, the feasibility of compression of the RTVS archive was investigated. Challenges associated with the current approach were identified and recommendations were made.

Publications:

Steffen, C. E. and N. Wang, 2003. "Weather Data Compression", American Meteorological Society 2003 Conference Proceedings of Interactive Information and Processing Systems.

III. Research Collaboration with Information & Technology Services

Keywords: Data Acquisition, Processing and Archive

Principal Researcher: Christopher MacDermaid

In support of NOAA Goal 3 to "Serve Society's Needs for Weather and Water Information" and Goal 4 to "Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation," CIRA researchers in the Data Systems Group (DSG) collaborate with the NOAA Forecast Systems Lab (FSL) scientists, researchers and developers on research into how 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 modeling, 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. Figure 1 below illustrates schematically the Central Facility (CF) support provided by DSG.

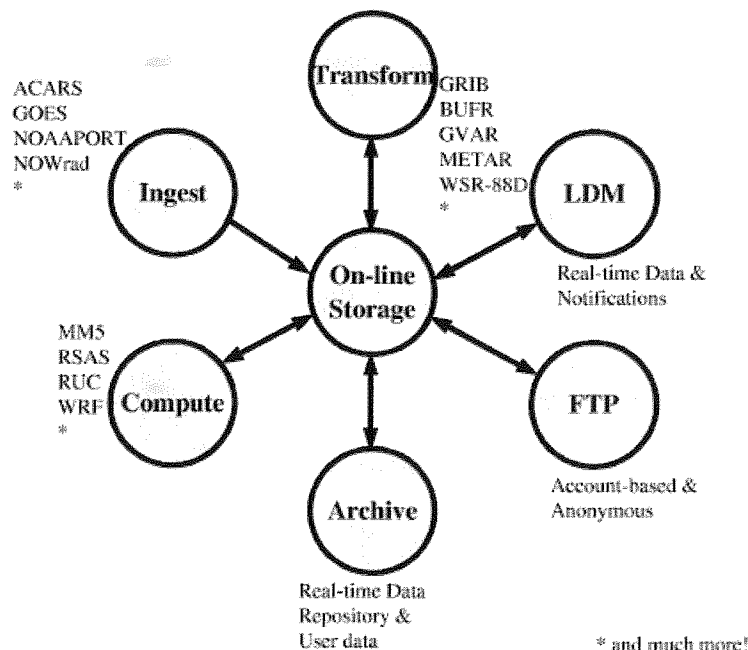


Fig. 1. Central Facility support provided by the Data Systems Group

Data are received from a variety of operational and experimental sources that include:

- * The National Weather Service (NWS)
- * NOAAPORT
- * The National Centers for Environmental Prediction (NCEP)
- * WSR-88D Doppler radar
- * Aeronautical Radio Inc. (ARINC)

- * *Weather Services International Corporation (WSI)*
- * *The Forecast Systems Lab (FSL) Demonstration Division*
- * *The Geostationary Operational Environmental Satellite (GOES)-10 and GOES-12*
- * *The National Center for Atmospheric Research (NCAR)*
- * *Meteorological Assimilation Data Ingest System (MADIS) data providers*
- * *U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC)*

Real-time data are also distributed to many external organizations using the Unidata Local Data Manager (LDM) protocol. Distributed data sets include:

- * *GOES imagery to the National Oceanic and Atmospheric Administration (NOAA) Environmental Technology Laboratory (ETL)*
- * *Wind profiler data to University Corporation for Atmospheric Research (UCAR) Unidata program*
- * *Quality controlled Aircraft Communications Addressing and Reporting System (ACARS) data to NCAR and a number of government agencies as well as universities*
- * *WSR-88D Level-II data to the Collaborative Radar Acquisition Field Test (CRAFT)*
- * *MADIS data to a number of government agencies as well as universities*

CIRA proposed continuing its efforts in the following research areas:

A. Acquisition of Meteorological Data

Acquisition of a large variety and volume of conventional (operational) and advanced (experimental) meteorological observations in real time would continue. The ingested data, which are used by CIRA 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. Data are also received from Canada, Mexico, and some observations from around the world. The richness of this meteorological database is illustrated by such diverse datasets as advanced automated aircraft, wind and temperature profiler, satellite imagery and soundings, Global Positioning System (GPS) moisture, Doppler radar measurements, and hourly surface observations.

Data ingest and processing was added for the acquisition of NCAR/Research Applications Program (RAP) Oceanic Weather Product Development Team (OW PDT) products, the Integrated Icing Diagnosis Algorithm (IIDA), the Integrated Icing Forecast Algorithm (IIFA) and Cloud Top Height products. Retrieval of the University of Wisconsin Space Science and Engineering Center (SSEC) Cloud Top Pressure and Total Water Vapor products, the Ice Mapping System (IMS) snow product from NCEP, and the Operational Mesoscale Model (MM5) data from the Air Force Weather Agency (AFWA) were added.

WSI ingest hardware and software were upgraded. A dedicated machine running Solaris X86 had been ingesting these data and an ethernet connection was being used to transport this to the processing node. This machine has been eliminated and the data are now being ingested directly by the processing node.

Several of the FTP ingest machines have been set up using high-availability software. This allows for an automated failover from one node to another when there is a system or hardware failure.

For MADIS, new methods were implemented for Local Data Acquisition and Dissemination (LDAD) that streamline the configuration management by replacing numerous specialized ftp scripts with a single common configurable script. Radiometer and Oklahoma Mesonet datasets were added.

B. Data Processing

These data are scientifically analyzed and processed into meteorological products in real time, and made available to CIRA and FSL researchers and systems developers for current and future research initiatives. The resultant meteorological products cover a broad range of complexity, from simple plots of surface observations to meteorological analyses and model prognoses generated by sophisticated mesoscale computer models.

Software was designed and developed to streamline the acquisition and processing of BUFR data and software was developed to create Advanced Weather Interactive Processing System (AWIPS) compatible netCDF files. This new software was created using Object Oriented (OO) methods to reduce maintenance and to allow for the generic handling of data types.

Research and development of an Open-source Project for a Network Data Access Protocol (OPeNDAP) server and Thematic Real-time Environmental Distributed Data Services (THREDDS) catalog for use with MADIS and RUC continued. OPeNDAP provides a discipline-neutral means of requesting and providing data across the World Wide Web. The goal is to allow end users, whoever they may be, to access immediately whatever data they require in a form they can use, using widely available applications.

Development of Concurrent Versions System (CVS) methods continued, focusing on efficiently maintaining real-time software configurations for over 30 CF servers.

Software and procedures to back up NCEP with the Rapid Update Cycle (RUC) model and the Rapid Update Cycle Surface Assimilation System (RSAS) were further enhanced for improved reliability.

Research into supporting the new NOAAPORT digital video broadcast system (DVBS) was begun.

For MADIS, new hardware was configured in a high-availability arrangement and processing was redesigned to improve throughput by recasting the data distribution scheme, thus eliminating a problem that previously resulted in data dropouts. The MADIS processing and distribution system is shown in Figure 2.

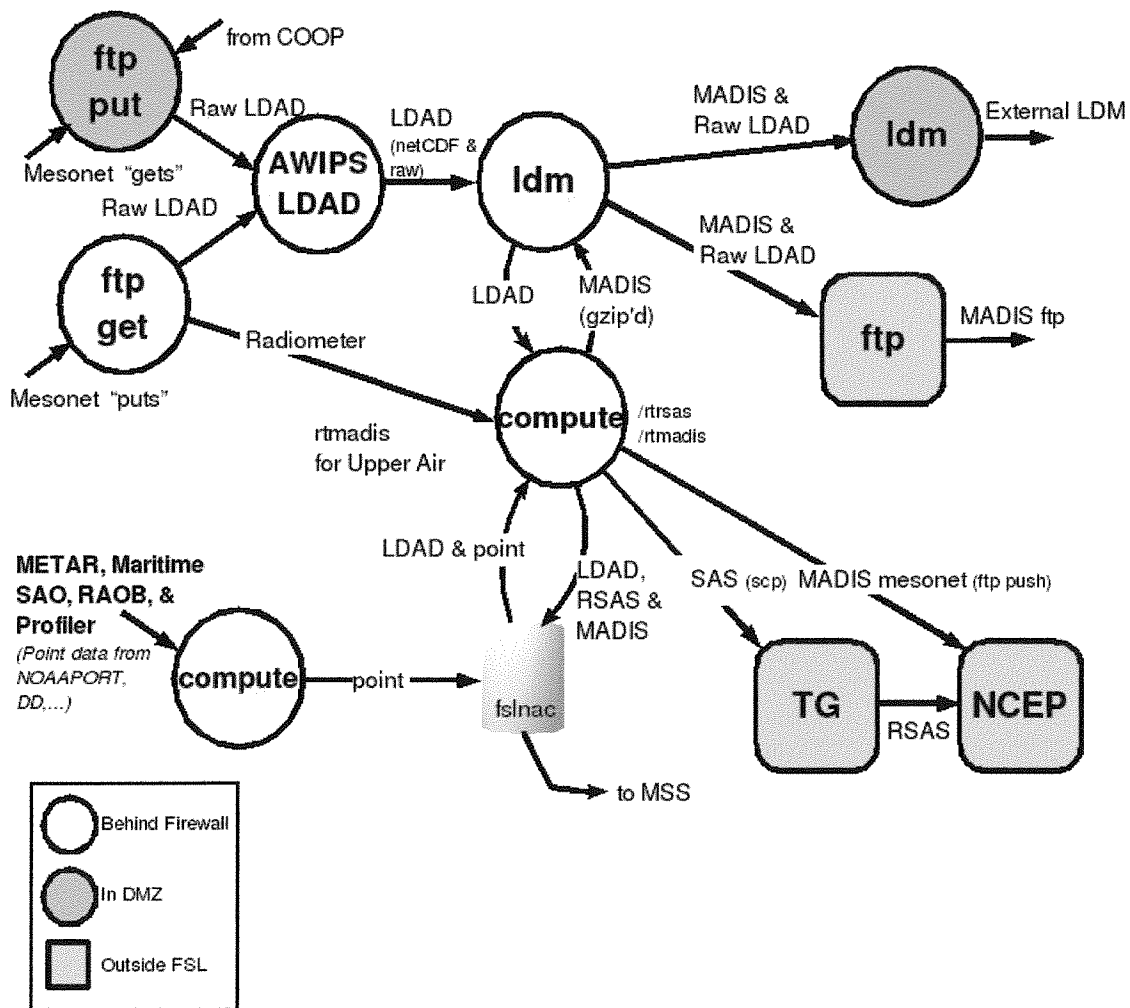


Fig 2. The MADIS processing and distribution system

Additionally, several of the CF data processing machines were converted into high-availability configurations to increase reliability and provide for an automated failover.

For the General Aviation Meteorological Information (GAMET) Project, CIRA researchers collaborated with NCEP's Computer Development Branch (CDB) scientists to create GAMET Text messages from Graphical Area Forecasts (GFA) to replace the existing text-based Area Forecast (FA). This project involved creating a National Center Advanced Weather Interactive Processing System (NAWIPS) Meteorological Analysis Package (NMAP) library to automatically create the GAMET text product.

A reference implementation METAR decoder was designed and developed. This software development effort was in collaboration with the FAA and Honeywell.

1. Object Data System (ODS) Improvements/Upgrades

It was proposed that the design and development for new and modified datasets would continue. Use of ODS applications and methods would expand as legacy translators and

product generation methods are replaced by the new techniques. Object Oriented (OO) software development for point data would continue.

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

Research on upgrading ODS is ongoing. Research toward creating metadata handling techniques was begun and continues.

2. Facility Information and Control System (FICS)

FICS Monitor changes would be implemented to account for the arrival of new datasets. Scripts would be developed to monitor operation of the High Performance Computing System (HPCS) Mass Store System (MSS).

FICS Monitor changes were implemented to handle a variety of new data sets. Porting of FICS to high-availability server pairs was begun. This will provide increased reliability and automated failover for the FICS servers.

3. Real-Time Advanced Weather Interactive Processing System (AWIPS) Data Processing

Design and development would continue on creating an automated research system for generating AWIPS review cases. As an integral part of CIRA collaboration with FSL, these design and development results would be available as additional products to the NOAAPORT dataset via upgrades and enhancements to AWIPS data servers.

Data provided by this system are used by several FSL projects including FX-Net, Real-Time Verification System (RTVS), Local Analysis and Prediction System (LAPS), National Interagency Fire Center (NIFC), and MADIS. This past year, the CF AWIPS data server was transitioned from an HP-UX system to Linux and the AWIPS software was upgraded to Operational Build 2. Configuration of a high-availability setup for increased reliability and automated failover was begun. Design and development will continue toward creating an automated "archive search" system to facilitate the retrieval of data sets for use by researchers studying challenging weather events.

C. Data Storage and User Access

FSL Data Repository (FDR)

The FSL Data Repository (FDR) and the Real-Time Data Saving (RTNDS) systems were merged. Using ODS software to create a configurable and scalable system, the new FDR method reduces both the number of files (using Unix tar-tape archive) and the volume of

data (using gzip compression) that is being stored using the MSS. CIRA proposes that improvements to CIRA's scientific access to this system would continue.

Research into decommissioning the legacy FileServ/VolServ-based MSS and UniTree MSS was begun. Design and development of the MSS wrapper scripts continued. These scripts provide simplified access for storing and retrieving data from the MSS.

Publications

Hamer, P., 2005: FSL Central Facility data systems concepts. 21st International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 9-13 January 2005, San Diego, CA.

MacDermaid, C., and R.C. Lipschutz, 2005: Recent advances in the FSL Central Facility data systems. 21st International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 9-13 January 2005, San Diego, CA.

MacDermaid, C., R.C. Lipschutz, P. Hildreth, R.A. Ryan, A.B. Stanley, M.F. Barth, and P.A. Miller, 2005: Architecture of MADIS data processing and distribution at FSL. 21st International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 9-13 January 2005, San Diego, CA.

IV. Research Collaborations with the Forecast Research Division

Keywords: Mesoscale modeling; model forecast applications for wind energy evaluation; time-lagged ensembles; wavelet-based diagnostic tools for gravity wave and turbulence research; convective parameterization ensembles; high-resolution regional climate modeling; bore dynamics; global observing platforms; hourly precipitation data QC; radiosonde datasets; low-level jet; local analysis and prediction system; local data and modeling; hot start forecasting technique; infrasound detection system; 3-D visualization; decision support system for winter road maintenance; fire weather support; IHOP case reviews; WRF development

A. Regional Analysis and Prediction

The primary focus of the Regional Analysis and Prediction Branch is the development of the Mesoscale Analysis and Prediction System (MAPS) and Rapid Update Cycle (RUC). MAPS and RUC are 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 and GOES soundings. CIRA proposed 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 MAPS, RUC and WRF fields. Additionally, CIRA researchers would work on applications of the RUC to forecast problems, including forecasts of wind energy generation potential. Investigations into the use of mesoscale model ensembles to improve the accuracy of short-range forecasts, in particular QPF and wind energy, would also continue.

Principal Researchers: Kevin Brundage and Tracy Smith

During the past year, support of the RUC development (which falls under NOAA Goals 3 and 4) continued, both at NCEP and at FSL. The analysis package was replaced with a 3D variational analysis package at NCEP following extensive testing and verification on the Jet and iJet systems.

The RUC backup system, which provides 20-km fields when the NCEP system becomes unavailable, was significantly improved. Parallel cycles were established on Jet and iJet to provide redundant processing, achieving 99+% availability during the past year.

A variety of other RUC development versions were also established. These cycles, including the 13-km, 20-km CONUS WRF, 10-km TAQ, and 10-km WRF-RUC, provide testing environments for new model development, verification for planned implementations, as well as convenient mechanism to compare various modeling schemes.

Web-based displays have become an important part of the RUC development. The ability to examine and compare results from various model configurations and evaluate the impact of proposed model changes is critical to effective model development. Software to generate graphic products from RUC model runs was replaced by a much more flexible package. The unified product generation system, which replaced 5-6 separately maintained systems, supports multiple resolution models and offloads computer resources

previously consumed by these processes. The biggest advantage of the new package is the reduced support and implementation time required to bring new realizations on-line.

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 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.

Publications

Smith, T.L., S.G. Benjamin, S.I. Gutman, and B.E. Schwartz, 2003: Impact of GPS-IPW data on RUC forecasts. *Seventh Symposium on the Water Cycle, Long Beach, CA, Amer. Meteor. Soc., CD-ROM, 3.2.*

Gutman, S.I., S. Sahm, J. Stewart, S. Benjamin, T. Smith, and B. Schwartz, 2003: A new composite observing system strategy for ground-based GPS meteorology. *12th Symposium on Meteorological Observations and Instrumentation, Long Beach, CA, Amer. Meteor. Soc., CD-ROM, 5.2.*

Koch, S.E., B. Jamison, T.L. Smith, E. Tollerud, C. Lu, N. Wang, M.A. Shapiro, C. Parrish, and O. Cooper, 2003: Field observations and RUC model simulations of turbulence and gravity waves. *10th Conf. on Mesoscale Processes, Portland, OR, Amer. Meteor. Soc., CD-ROM, P2.24.*

Gutman, S.I., K.L. Holub, S.R. Sahm, J.Q. Stewart, T.L. Smith, S.G. Benjamin, and B.E. Schwartz, 2004: Rapid retrieval and assimilation of ground based GPS-Met observations at the NOAA Forecast Systems Laboratory: Impact on weather forecasts. *J. Meteor. Society of Japan, 82, 1-10*

Benjamin, S.G., D. Devenyi, S.S. Weygandt, K.J. Brundage, J.M. Brown, G.A. Grell, D. Kim, B.E. Schwartz, T.G. Smirnova, T.L. Smith, and G.S. Manikin, 2004: An hourly assimilation/forecast cycle: The RUC. *Mon. Wea. Rev., 132, 495-518 (Feb. issue).*

Koch, S.E., B. Jamison, E. Tollerud, C. Girz, T. Smith, T.P. Lane, N. Wang, M.A. Shapiro, D.D. Parrish, and O. Cooper, 2004: Analysis of turbulence generation by gravity waves within an upper-tropospheric front. *AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.*

Benjamin, S.G., T.G. Smirnova, K. Brundage, S.S. Weygandt, T.L. Smith, B. Schwartz, D. Devenyi, J.M. Brown, and G.A. Grell, 2004: A 13-km RUC and beyond: Recent developments and future plans. *AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.*

Moninger, W.R., T.S. Daniels, R. Mamrosh, M.F. Barth, S.G. Benjamin, R.S. Collander, L. Ewy, B.D. Jamison, R.C. Lipschutz, P.A. Miller, B.E. Schwartz, T.L. Smith, and E.J. Szoke, 2004: TAMDAR, the Rapid Update Cycle, and the Great Lakes Flight Experiment. AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

Benjamin, S.G., S.S. Weygandt, J.M. Brown, T.L. Smith, T. Smirnova, W.R. Moninger, B. Schwartz, E.J. Szoke, and K. Brundage, 2004: Assimilation of METAR cloud and visibility observations in the RUC. AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

Additional collaborative research associated with MAPS activities used by CIRA researchers in their investigations would include:

-- Continued development of a RUC-based Short-Range Ensemble Forecast (RUC-SREF) system and expansion into a Lab-wide multi-model SREF system

Time-lagged ensemble forecast using Rapid-Update Cycle

Principal Researcher: Chungu Lu

NOAA Rapid Update Cycle (RUC) forecast system (Benjamin et al. 1993, 2004) has been consistently outputting regional weather forecasts in the short range for many years now. Because the RUC system ingests a lot of new observational data in an hourly cycle, its 1-3 h forecasts have provided a valuable reference and complement to the forecast community around the United States. Also, due to the same reason, one may wonder how forecasts from these hourly initializations vary, and, if there is some variability, how feasible and sensible an ensemble forecast is by using these forecasts as a set of ensemble members.

In the past year, a time-lagged ensemble forecast system based on various RUC forecasts initialized at different time was developed. Verifications of the ensemble forecasts compared to the deterministic forecasts in the short range of 1-3 h showed improved forecast skills, generally about 3 to 15 percent (Fig. 1). This improvement is attributed to the ensemble forecast correction of initial spin-up error in the RUC forecasts (Fig. 2).

Continued research and development on time-lagged ensemble using RUC forecasts are planned. In particular, an unequally weighted time-lag ensemble forecast system will be further developed and tested. The extension of time-lagged ensembles for the forecasts of aviation-related convective parameters is also planned.

Publications

Lu, C., 2003: NOAA Multi-Model Ensemble Forecast Project. Workshop on Ensemble Weather Forecasting in the Short to Medium Range, Val-Morin, Quebec.

Lu, C., 2004: RUC Short-Range Ensemble Forecast system. 20th Weather Analysis and Forecasting, AMS, Seattle WA.

Lu, C., B. Schwartz, and S. Benjamin, 2004: Short-range forecast using time-lagged ensembles. Mon. Wea. Rev. (in preparation)

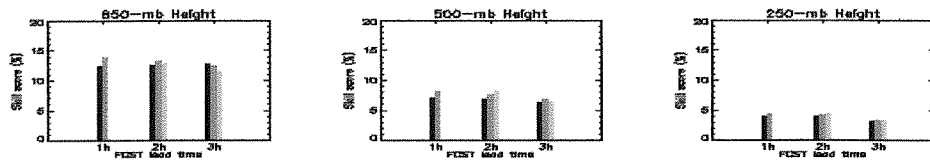


Fig. 1. Forecast skills of various time-lagged ensembles comparing to the deterministic forecasts at 1-3 h of forecast lead-time

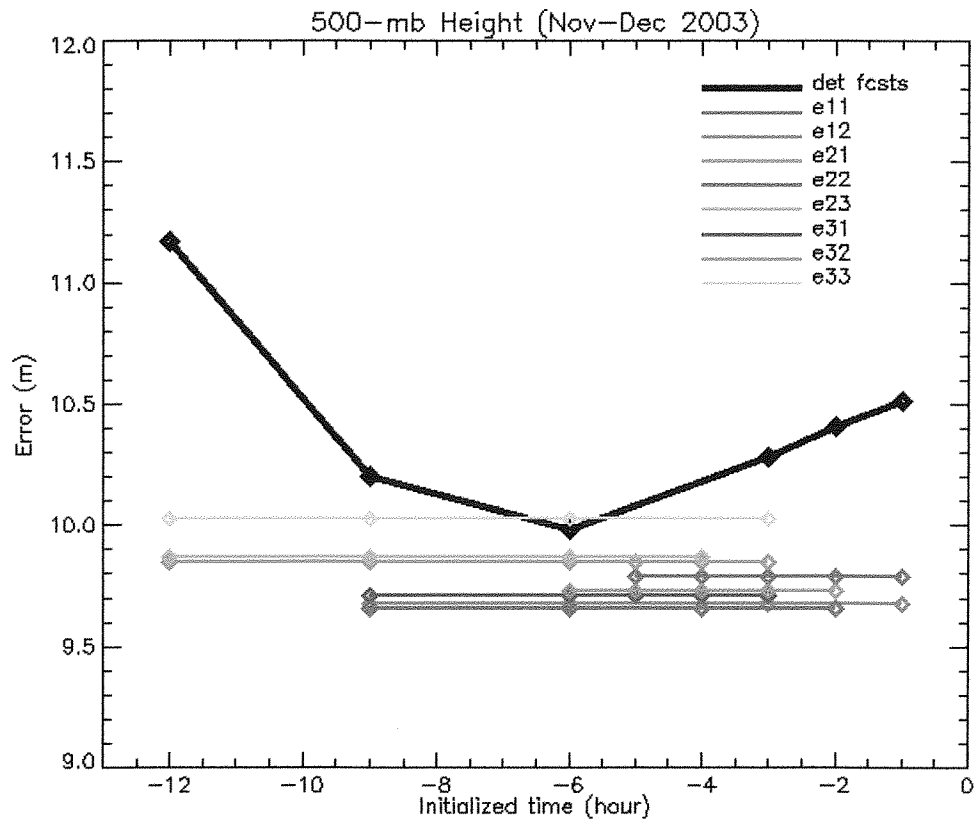


Fig. 2. Verification error of 500-mb height produced by various RUC deterministic forecasts (thick black curve), and by various time-lagged ensembles (colored curves)

- Application of wavelet transform technique to diagnose clear air turbulence

Development of Wavelet-based Diagnostic Tools for Aviation Weather Research

Principal Researchers: Chungu Lu and Ning Wang

The combined aircraft data obtained during SCATCAT (Severe Clear Air Turbulence Colliding with Aircraft Traffic) field program and Rapid-Update Cycle (RUC) model simulation of the SCATCAT case indicated the presence of both gravity waves and moderate-or-greater (MOG) turbulence events. While customary spectral techniques applied to these data do not lend themselves well to a proper understanding of the highly intermittent and non-stationary nature of interactions between waves and turbulence, wavelet technique can localize these temporally evolving phenomena via a frequency-time (or wavelength-space) display. Thus, an effort was begun to develop wavelet-based diagnostic tools to offer a better understanding of wave-wave and wave-turbulence interactions, which may improve the forecast accuracy for occurrences of clear-air turbulence in the atmosphere.

During the past year, various research and development work has been conducted. 1) Effort has been made to develop a 1D continuous wavelet package. Applying this package to aircraft observational data, a close relationship between gravity-wave intensification and turbulence burst (Fig. 1, panel a) was discovered. 2) Combining cross-spectral method and wavelet transformation, monochromatic and polychromatic gravity waves with localized characteristics in amplitude and phase (Fig. 1, panel b and c), and turbulence intensity (Fig. 1, panel d) were reconstructed. 3) Wavelet-based cross-spectral analysis package was also developed. This analysis is able to project bivariate data onto both frequency and time subspaces. This feature is ideal for studying polarization characteristics of gravity waves and turbulence. 4) 2D wavelet analysis can localize an atmospheric wave in space, and decompose wave energy in various wave spectra. Such a package has been developed and used for analyzing RUC and MM5 model simulations to identify wave propagation and wave-wave interactions (Fig. 2).

Continued research and development of wavelet-based diagnostic tools are planned in accordance with FAA's turbulence projects. In particular, the 2D wavelet diagnostic tools will be applied to analyze the high-resolution model simulations of gravity waves and turbulence and to determine the atmospheric conditions for the generation of turbulence by mesoscale gravity waves.

Publications

Lu, C., S. Koch, and N. Wang, 2004: Determination of temporal and spatial characteristics of gravity waves using cross-spectral analysis and wavelet transformation. J. Geophys. Res. (accepted)

Lu, C., S. Koch, N. Wang, and B. Jamison, 2004: Stokes parameter analysis of gravity waves and gravity-wave induced turbulence. J. Geophys. Res. (submitted)

Koch, S., B. Jamison, C. Lu, T. Smith, E. Tollerud, N. Wang, T. Lane, M Shapiro, D. Parrish, and O. Cooper, 2004: Turbulence and gravity waves within an upper-level front. *J. Atmos. Sci.* (submitted)

Lu, C., S. Koch, and N. Wang, 2004: Application of wavelet analysis techniques to the study of turbulence and gravity waves using aircraft data and mesoscale model fields. *AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms*, October 4 – 8, 2004, Hyannis, MA.

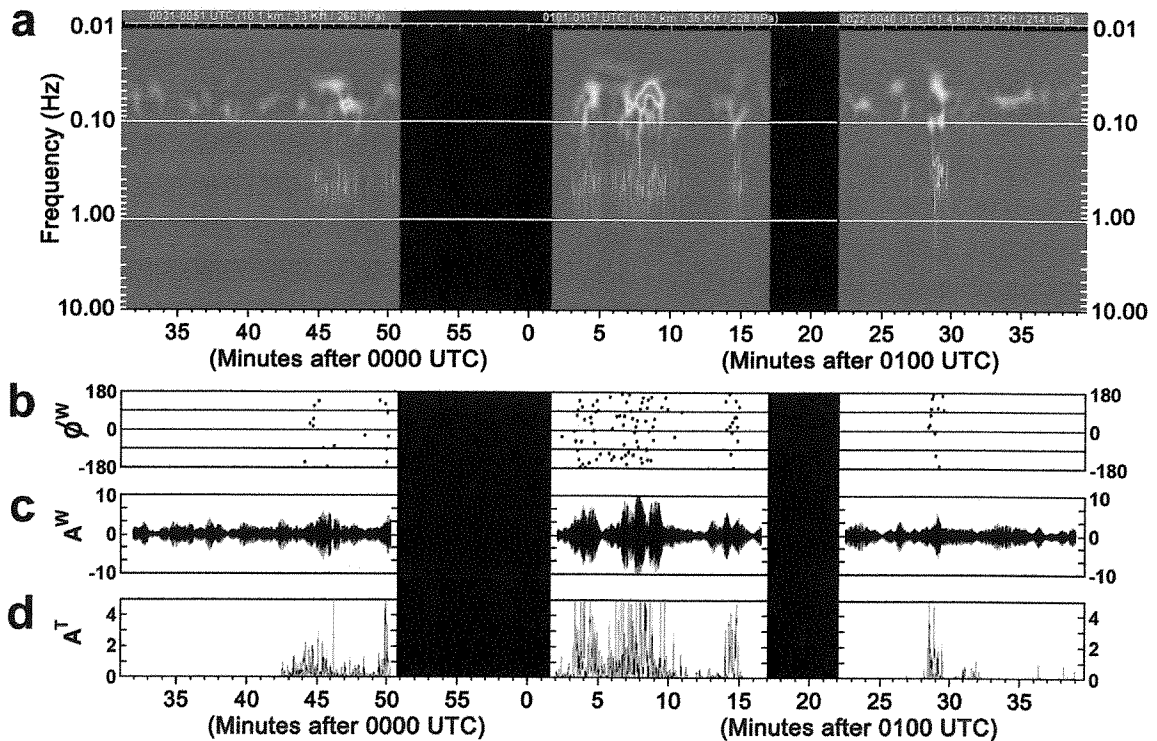


Fig. 1. (a) Time-frequency display of wavelet analysis of aircraft vertical acceleration data at 10.1, 10.7, and 11.4 km flight altitudes (cm s^{-2}). (b) Phase of gravity waves (degree) at which maximum turbulence intensity occurred for turbulence $> 0.5 \text{ cm}^2 \text{ s}^{-4}$, (c) gravity waves reconstructed from wavelet analysis in the 0.07 frequency band, and (d) turbulence intensity ($\text{cm}^2 \text{ s}^{-4}$) reconstructed from wavelet analysis in the 0.65 Hz frequency band. Background noise level of wavelet amplitudes is depicted by blue, with increasing intensity shown by yellow and red shading. Black segments indicate times when the aircraft was going through maneuvers (primarily changes in altitude) that invalidated the measurements.

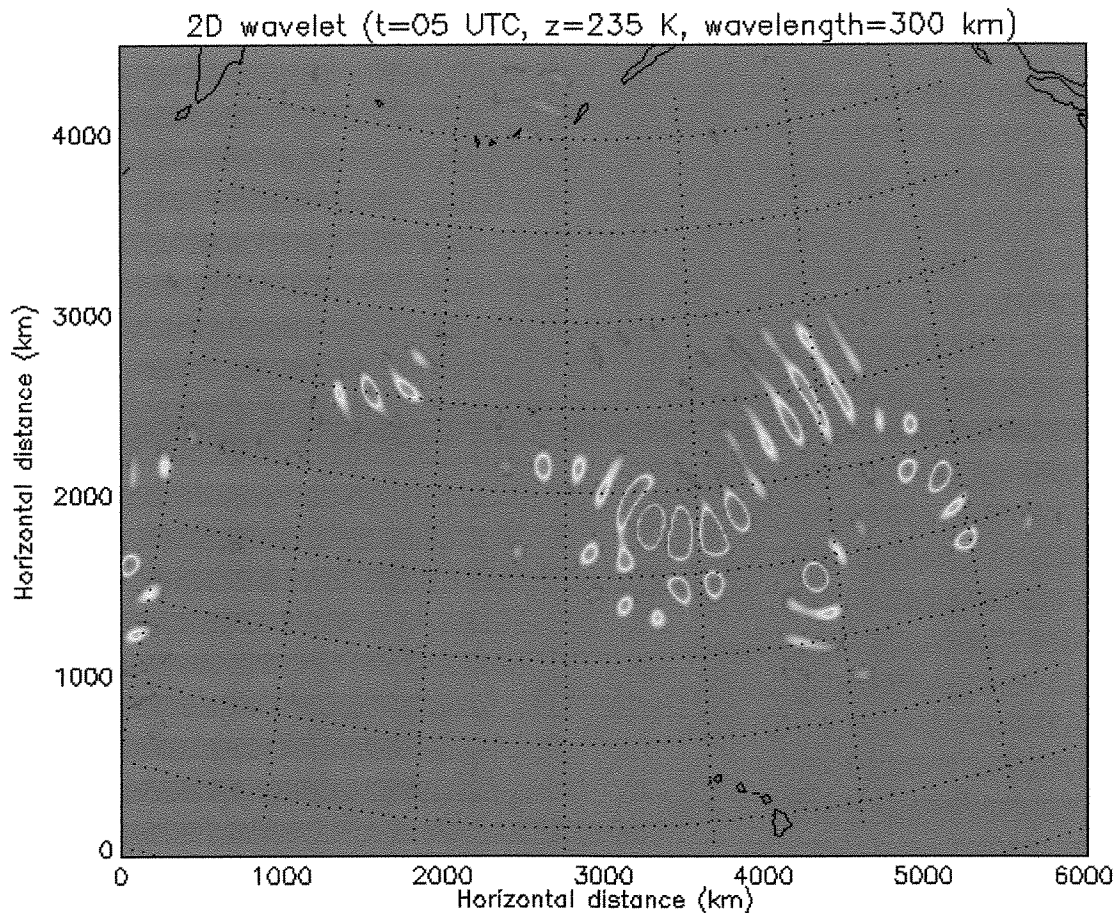


Fig. 2. 2D wavelet analysis of vertical velocity field from RUC model simulation of SCATCAT case.

- Development of convective parameterization ensembles for MM5/RUC/WRF

Principal Researcher: Mariusz Pagowski (NOAA Goal 3)

A new convective parameterization makes use of a large variety of assumptions previously introduced in earlier formulations. The assumptions are chosen so that they will generate a large spread in the solution. A method based on a minimization of forecast error with respect to observations has been devised. This method prescribes weights for ensemble members. During the summer of 2004, daily forecasts with the RUC model are being used to compute the weights. Depending on the success of the method, the new convective ensemble-based parameterization may replace the current default in RUC. Figure 1 displays the rank of the matrix of 5 ensembles currently being tested, which provides a measure of their independence. Future application of the scheme in WRF is possible.

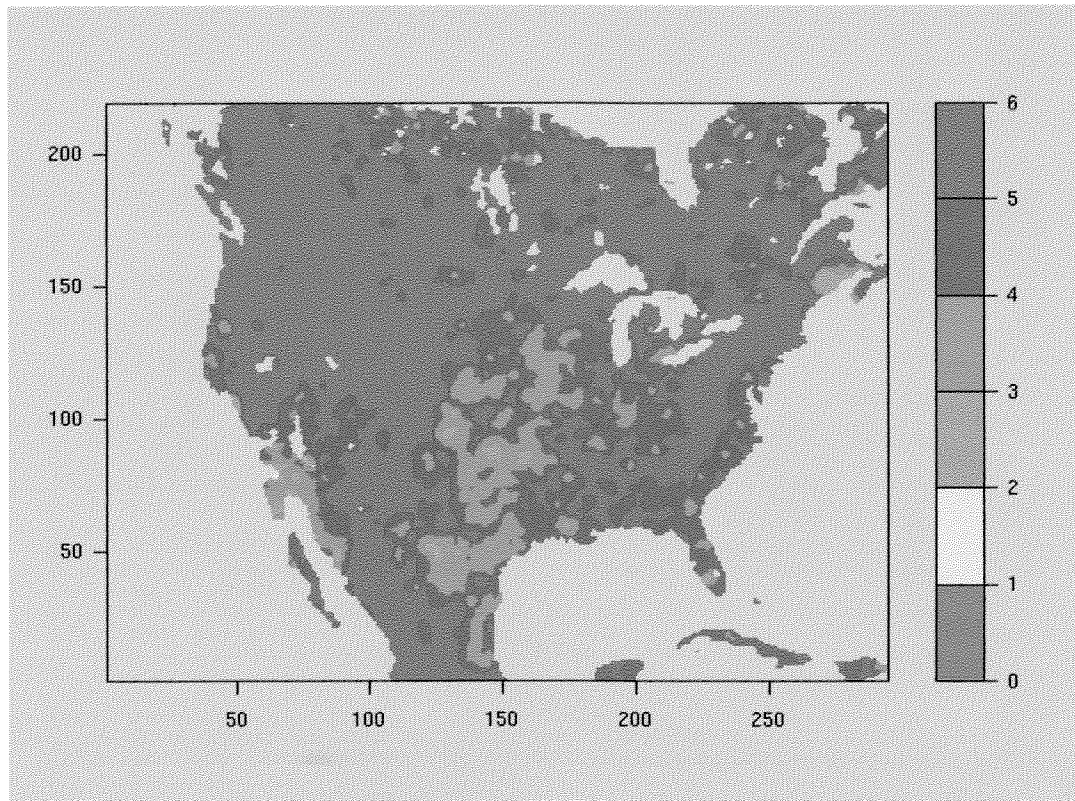


Fig. 1. The rank of the matrix of 5 ensembles currently being tested, which provides a measure of their independence

- Investigation into high-resolution regional climate modeling over Colorado

Principal Researcher: Mariusz Pagowski

Research with respect to climate simulation and prediction has attracted considerable efforts throughout the last 30 years, with global aspects clearly dominating. However, it is the regional and the local climate that are of central importance to societies and to the biosphere. For example, a hydrologist who is interested in the water budget of a reservoir may find little help from the output of global climate models. Even if the larger scale water budget would be predicted properly by the climate model, the high resolution patterns of precipitation and temperature would in this case be of great importance. Therefore research of "downscaling" methods has become important.

Because of a dramatic increase in computing power over the last few years, it is now possible to run very high resolution regional climate simulations over extended periods of time. This means that regional climate models may be used with very high resolution (about 1 km) over limited areas. This research focuses on the feasibility of forecasting runoff using a non-hydrostatic multi-scale regional climate model down to scales that resolve individual valleys and massifs. It supports NOAA Goal 2 (Understand Climate

Variability and Change to Enhance Society's Ability to Plan and Respond) and Goal 3 (Serve Society's Needs for Weather and Water Information).

To examine how well precipitation and temperature generated from a high resolution coupled atmosphere-land surface modeling system can simulate runoff in a hydrologic model, a set of three 5-year experiments using the atmospheric Fifth-Generation Pennsylvania State University-National Center for Atmospheric Research Mesoscale Model (MM5) were run. MM5 output was used as input to a distributed hydrologic model (U.S. Geological Survey's Precipitation Runoff Modeling System (PRMS)) and compared with runoff produced using standard climate observations in PRMS. The finer resolution MM5 simulations were centered over the Yampa River basin in Colorado, a mountainous basin where the runoff is strongly dependent on snow melt. The Yampa River basin is 1430 km² in area and ranges in elevation from 2000-3800 meters.

The strength of this study, compared to previous high-resolution mesoscale modeling efforts, is the: (1) long period of the simulations (5 years) and (2) automated calibration of PRMS to each of the input data sets (precipitation and temperature) being tested. This allows for the summary of the advantages and limitations of high resolution climate modeling with more confidence. This research provides significant advances in coupling atmospheric and hydrologic models, which, when combined with ongoing interactions with water managers as part of the NOAA Regional Integrated Sciences and Assessments (RISA) Program, will lead to improved management of water resources.

A climate version of MM5 was used to produce the daily precipitation and temperature data as PRMS input. A set of three MM5 simulations were run for five water years (October 1 1994 through September 30 1999). These simulations were conducted using the nesting capabilities of MM5. The first MM5 experiment (nest0) was run with 20 km resolution over the period of five water years. This simulation provided input for the higher resolution simulations. The second experiment (nest1), centered over the Yampa River basin, was run using a resolution of 5 km. The third experiment (nest2, centered over the Yampa River basin), was run using a resolution of 1.7 km.

All precipitation is predicted explicitly when using the 1.7 km resolution (nest2), and convective parameterizations, a likely source of error, are excluded from the model runs. Boundary conditions for the coarser domain (nest0) came from NCEP reanalysis output, while the higher resolution runs (nest1 and nest2) obtained their boundary conditions from the coarser resolution runs.

An output from model simulations in the high resolution domain and comparison with station data is shown in Figure 2. Currently, a journal publication on this study is being prepared.

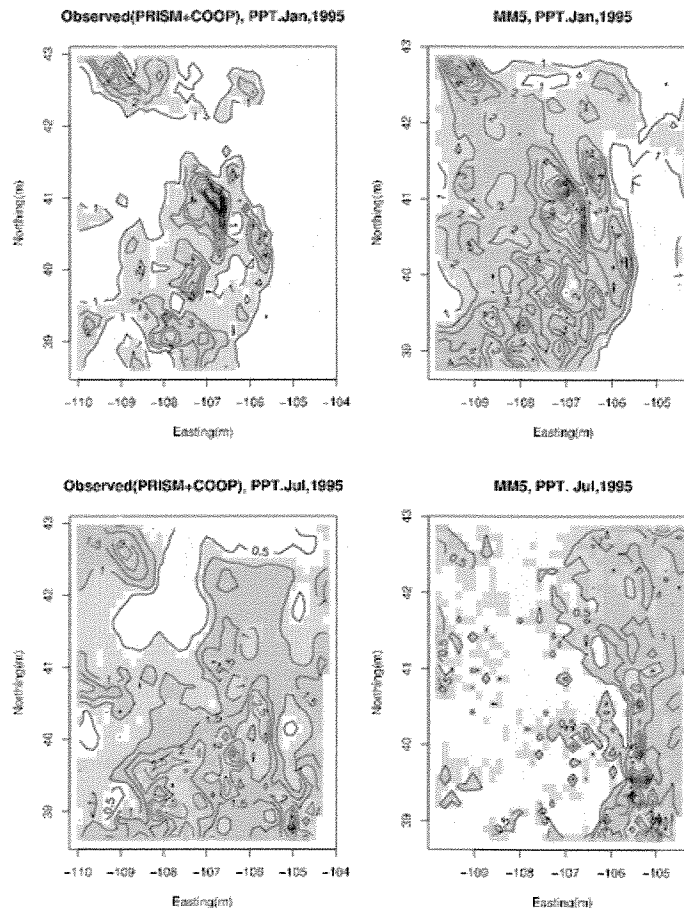


Fig. 2. A comparison of an output from model simulations in the high resolution domain with station data

- Analysis of bore dynamics during the IHOP field experiment, including their origin, propagation, and PBL modification associated with their passage

Principal Researcher: Mariusz Pagowski

The International H2O Project (IHOP) field experiment took place in the Southern Great Plains of the U.S. with the goal of obtaining an improved characterization of the time varying three dimensional water vapor field and to determine its importance in the understanding and prediction of convective processes. Understanding the role played by bores in initiating and maintaining nocturnal convection was one of the objectives of the project.

Ground-based remote sensing instruments at the Homestead site in the Oklahoma Panhandle included NCAR Integrated Sounding System and Multiple Antenna Profiler (ISS/MAPR), an Atmospheric Emitted Radiance Interferometer (AERI), FM-CW radar, Scanning Raman Lidar and aerosol backscatter lidar (HARLIE). These instruments were complemented by the polarimetric S-POL and Dodge City WSR-88D radars and 2 research aircrafts equipped with the water vapor differential absorption lidar and surface meso-

network recording temperature, dew-point and wind at 5-min intervals. The data gathered during IHOP constitutes probably the most comprehensive set of observations ever collected on structure and dynamics of bores.

On 4 June 2002, two bores were observed at Homestead. This study (in support of NOAA Goal 3) analyzed the “second” bore which developed in the early morning on this day as a result of an interaction of a cold front with a stable boundary layer. This bore was well documented by the IHOP measurements. Numerical simulations with MM5 reproduced the event quite accurately and are used to study turbulence and boundary layer growth in the wake of the bore.

An internal bore is a gravity wave which propagates on an interface between two fluids of different density. In the atmosphere, a bore typically develops when a gravity current enters a stably stratified boundary layer. Physics of bores depend on the depth of the stable layer, depth of the gravity current and stratification and wind in the atmosphere above the inversion. Depending on the Brunt-Vaisala frequency, wind shear and phase speed, vertically propagating gravity wave can be trapped leading to multiple reflections from the upper layers and wave-train appearance or, alternatively, can become a solitary wave traveling ahead of or behind the initial disturbance. Of particular interest was the entrainment process associated with the bore wave-train and the extent to which different PBL parameterization schemes can successfully reproduce the observed surface drying and warming (from mesonet and S-POL refractivity change computations) and the moistening and cooling aloft (from AERI and research aircraft data) associated with the bore passage.

Observations suggest that the bore originated when an outflow induced by the precipitation from a thunderstorm approached and strengthened the cold front which pushed into a stable boundary layer ahead of the front.

Simulations with MM5 were performed to model the bore event. Initial and lateral boundary conditions were provided by the 20-km resolution hourly analysis produced by Rapid Update Cycle (RUC) 3DVAR. Four one-way computational domains with resolutions of 18, 6, 2 and .666 km were used. Results of the 2-km simulation provided lateral and boundary conditions for the .666 km domain runs in sensitivity studies with respect to different turbulence parameterizations.

As seen in Fig. 3 (domain 4), where cross-front wind in the frame of reference moving with the front and isentropes are shown, the wind gust apparently steepened and strengthened the front which displayed a shallow elevated head not unlike a gravity current. Interaction of this shallow cold front with the stable boundary layer ahead induced a bore. Numerical experiments revealed small sensitivity of the simulated bore propagation to various vertical turbulent mixing schemes. This result suggests that the bore was undular (in agreement with observations) and role of turbulence in its evolution was limited.

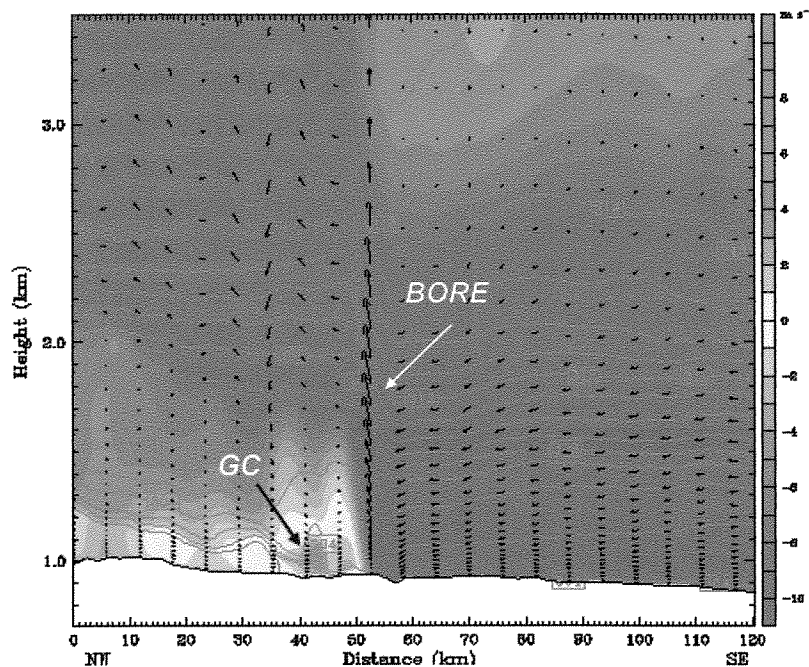


Fig. 3. Depiction of cross-front wind in the frame of reference moving with the front and isentropes.

A journal publication on this study is being prepared.

In addition to the three research topics outlined above, a study on PBL parameterizations in WRF was conducted and presented at the WRF Workshop in June 2004. Work on the PBL in RUC was also conducted with possible application in future RUC development. A paper on fog formation was published in the Journal of Applied Meteorology and a paper on application of a photochemical model Models-3 was published in the International Journal of Environmental Pollution.

B. Meteorological Applications

1. Global Air-Ocean IN-situ System (GAINS) Project

CIRA proposed the continuation of research activities to evaluate an advanced system for monitoring and observing environmental data in a global network. Major research efforts involving GAINS this year were:

- Modeling of launch and flight control of GAINS balloons, including the preparation of wind data sets from observations and model output
- Developing software code to simulate GAINS balloon trajectories
- Participating in field tests, analyzing test data and preparing reports of test results
- Preparing and processing data sets for trend analyses

Principal Coordinator: Randall Collander

The successful launch and recovery of an experimental balloon in March 2003 led to expectations of continued work and advancement of the Global Air-ocean IN-situ System (GAINS) project, and the proposed objectives centered around these activities. These objectives, written months ahead of the start of the federal fiscal year, were based upon budget expectations which were never realized. As a result, no tangible accomplishments can be shown for FY04. Funding is in place for an experimental GAINS flight to take place in September 2004, at which time many of the FY04 objectives are expected to be met. The project, described below, addresses two of NOAA's goals: Goal 2—Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond, and Goal 3—Serve Society's Needs for Weather and Water Information.

The GAINS project involves testing of a prototype weather balloon that differs from the "traditional" weather balloon in that it can ascend or descend on command. The "canni-balloon" as it is sometimes called, consists of a helium-filled balloon within an air-filled balloon within a non-expanding fabric shell. Using radio control and on-board pumps, the amount of air within the balloon can be controlled, and since the fabric shell holds the volume constant, the density of the air can be increased substantially. This makes it possible for the balloon to have super pressure which can overcome the buoyant effects of the helium, and allow the balloon to descend.

GAINS is a major change in system concept from earlier efforts in developing a Shear-Directed Balloon System (SDBS). The SDBS program represented development toward a recoverable, reusable global sounding system to be operated in the troposphere. GAINS, in contrast, is a long-duration stratospheric platform, instrumented for environmental sensing through a combination of dropsondes, XBTs, and chemistry, particulate, in-situ, and remote sensors. Designed as a 120-ft diameter superpressure vehicle carrying a payload of 780 pounds for year-long flights up to 75,000 ft, GAINS is targeted to meet NOAA's observing and monitoring mission in the next century.

GAINS uses rechargeable batteries to power nearly all balloon functions, and has external solar panels for recharging. Communications to and from the balloon are currently done by high frequency radio, which will eventually be replaced by employing Low Earth Orbiting (LEO) satellite communications. The balloon's position is provided by on-board Global Positioning System (GPS) instruments.

Accomplishments were made in support of the National Center for Atmospheric Research (NCAR) Driftsonde Project—a derivative of GAINS. This project involved organizations at NCAR and Global Solutions for Science and Learning (GSSL) in Tillamook, Oregon collaborating on the GAINS project. In FY04, trajectory prediction software and web-based data and image display processes were modified to meet the specifics of Driftsonde flight testing performed along the Oregon coast during Fall 2003. The project is described below.

NCAR DRIFTSONDE

The Inter-Continental Radiosonde Sounding System (ICARUSS), also called Driftsonde, is a proposed new atmospheric sounding system for use during the THORPEX experiment. The ICARUSS concept uses a thin polyethylene balloon (0.35 mil) with a volume of 268 cubic meters to lift a payload of 24 dropsondes or modified radiosondes to an altitude of about 100 to 75 mb ((53,000 - 60,000 feet) and maintain that altitude for 5-6 days. The altitude of the balloon can be adjusted over a limited range to take advantage of the most favorable upper-level westerly wind flow. The dropsondes would telemeter the measured profile data back to the balloon where it would be received, processed, and stored. A compressed data set (e.g. WMO message or 10 second data) would be sent through a Low Earth Orbiting satellite to a ground station and on to the THORPEX control center for further processing and/or input into the Global Telecommunications System (GTS).

The pause in GAINS activities allowed for advancements in additional areas aligned with NOAA's Goal 3 to "Serve Society's Needs for Weather and Water Information." These projects included web displays of coupled air quality models and quality control of precipitation data for use in numerical model verification, as described below.

WRF MODEL AIR CHEMISTRY WEB SITE

The mission of the WRF atmospheric chemistry working group (WG11) is to allow the option of simulating online chemistry and aerosols within the WRF model. The resulting WRF-chem model will have the capability to simulate the coupling between dynamics, radiation and chemistry. Uses include forecasting chemical-weather, testing air pollution abatement strategies, planning and forecasting for field campaigns, analyzing measurements from field campaigns and the assimilation of satellite and in-situ chemical measurements.

The WRF Working Group 11 website (http://www.wrf-model.org/WG11/wg11_new.html) and WRF-Chem model web site (<http://www-frd.fsl.noaa.gov/aq/wrf/>) were updated as advances in the model were implemented and products generated under the higher resolution models.

HOURLY PRECIPITATION DATA QUALITY CONTROL

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 and is currently being implemented on EMC systems.

Initial consultation with EMC and FSL researchers led to development of a set of criteria to be used in evaluating the validity of each station's observations. These criteria include evaluations for a single day as well as some that examine station performance over a 30 day period; the final output are listings of stations which passed the criteria and those which failed. The criteria 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). The software development and preliminary diagnostic evaluation is complete and the project concluded with a visit to EMC for assistance in implementation and consultation.

2. Science-Quality Data Sets

CIRA proposed that its efforts in creating and updating science-quality radiosonde upper air data sets be continued. The real-time access system, as well as an archive on CD-ROM, would be accessible to FSL scientists and the external research community as a source of quality-controlled observations.

Principal Coordinator: Brian Jamison

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. CIRA research efforts (in support of NOAA Goal 2 to Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond) included: updating the radiosonde data web page, responding to users' questions and requests, and creating periodic CD-ROM updates to the archive.

- Implemented software to remove log files more frequently to reduce server problems.*
- Made modifications to the archive software to include radiosonde type from Nimbus data.*
- Managed radiosonde station history lists, and provided corrections when necessary to the ITS branch master station list.*
- Developed software to examine log files and automatically add missing stations to the station history lists.*
- Made corrections to problems found in the archive and web page.*
- Made necessary software changes to move the radiosonde data web page to a new Linux server.*

3. Forecasting En-Route Turbulence

CIRA proposed that its efforts in conducting research to improve forecasts of clear air turbulence (CAT) by developing diagnostic algorithms and participating in field programs be continued. Activities to be performed in support of the turbulence project this year would include the development of new diagnostic algorithms, data processing and data analysis support of SCATCAT01 and SCATCAT03 case studies, and preparation of a mid-level turbulence climatology based on PIREPs and in-situ data to be correlated with shear and Richardson number obtained from RUC numerical output.

Principal Coordinator: Brian Jamison

FSL, under support from the FAA Aviation Weather Research Program, conducts research to improve forecasts of clear air turbulence (CAT) through field programs designed to measure in-situ turbulence and by developing diagnostic algorithms for turbulence prediction. Tasks related to this project (in support of NOAA Goal 4 to Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation) include: analysis of in-situ and model data, research and development of diagnostic algorithms, and climatological analysis of variables related to turbulence.

- Produced a large number of horizontal and vertical cross sections of several variables for analysis.*
- Modified software to examine specific variables, including geostrophic absolute vorticity and moist geostrophic potential vorticity, from which it was conclusively determined that the turbulence experienced during the SCATCAT field experiment was gravity wave induced.*
- Performed an isochron analysis of gravity waves to determine average phase velocity and wavelength.*
- Contributed to writing Fortran software to compute Unbalanced Flow (UBF) fields from the Rapid Update Cycle (RUC) model, and provided the software to NCAR for inclusion in the Integrated Turbulence Forecasting Algorithm (ITFA).*
- Collected 2 years of radiosonde data and interpolated the data to 500 meter levels in preparation for a climatological analysis of parameters associated with mid- and low-level turbulence.*

Publications

Koch, S. E., B. Jamison, C. Lu, T. L. Smith, E. Tollerud, T. P. Lane, N. Wang, M. A. Shapiro, D. D. Parrish, and O. Cooper, 2004: Analysis of turbulence generation by gravity waves within an upper-level front. Submitted to 11th Conf. on Aviation, Range, and Aerospace Meteorology, Hyannis, MA.

Moninger, W.R., T.S. Daniels, R. Mamrosh, M.F. Barth, S.G. Benjamin, R.S. Collander, L. Ewy, B.D. Jamison, R.C. Lipschutz, P.A. Miller, B.E. Schwartz, T.L. Smith, and E.J. Szoke, 2004: TAMDAR, the Rapid Update Cycle, and the Great Lakes Flight Experiment. AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

4. International H₂O Project (IHOP)

CIRA proposed to collaborate on the diagnostic study, data processing, analysis, and display of two low-level jet observation missions that occurred during the IHOP field experiment in an area over northwestern Oklahoma, southwestern Kansas, southeastern Colorado and the eastern Texas panhandle regions. Aircraft gathered high-resolution moisture and wind data using dropsondes and lidar systems during the field campaign in May and June 2002. CIRA researchers would also collaborate on the preparation of conference papers and/or journal articles resulting from this effort.

Principal Coordinator: Brian Jamison

IHOP is a project comprised of a number of diverse missions, one of which focussed on low-level jet observation and moisture transport. In this mission, four aircraft were employed, two of which flew opposite each other on paths defined by a rectangular "box" over northwestern Oklahoma, southwestern Kansas, southeastern Colorado and the eastern Texas panhandle regions. These aircraft dropped high-resolution dropsondes at pre-defined intervals for later analysis of moisture transport within the low-level jet. CIRA involvement (in support of NOAA Goal 3 to Serve Society's Needs for Weather and Water Information) included analysis and evaluation of variables associated with moisture flux from the available data.

--Collated dropsonde, aircraft Lidar, and radiosonde data and created plots for comparison of moisture flux values.

--Examined collocated dropsonde "pairs" for variances in moisture flux with time and height.

Publications

Tollerud, E.I., B. Jamison, F. Caracena, S. Koch, M. Hardesty, and G. Ehret, 2004: Multiscale analyses of moisture transport by the central plains low-level jet during IHOP. 20th Conf. on Weather Analysis and Forecasting/16th Conf. on Numerical Weather Prediction, Seattle, WA, Amer. Meteor. Soc.

Koch, S.E., B.D. Jamison, C. Lu, T.L. Smith, E.I. Tollerud, C.M.I.R. Girz, N. Wang, T.P. Lane, M.A. Shapiro, D.D. Parrish, and O.R. Cooper, 2004: Turbulence and gravity waves within an upper-level front. J. Atm. Sci. (submitted)

Bartels, D.L., F. Caracena, B.D. Jamison, S.E. Koch, and E.I. Tollerud, 2004: Observations of turbulence during BAMEX missions. AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

C. Local Analysis and Prediction

CIRA proposed the following scientific collaboration involving the Local Analysis and Prediction System. *Note: All research activities for the LAPS team fall under NOAA Goal 3 (Serve Society's Needs for Weather and Water Information) except for activity #8 (Federal Highways Road Weather Modeling), which also falls under NOAA Goal 4 (Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation).*

1. LAPS/WRF Improvements

LAPS would be updated and improved by utilizing 3-D variational and other methods including use of forward models for retrieval of temperature and moisture, application of

dynamic constraints, and inclusion of cloud information. One of the goals would be to maintain a LAPS presence in the development of any new generation of forecaster workstations.

Specific research efforts:

- Improvement of interfaces to a wider variety of observational datasets
- Radar processing improvements
- Surface analysis improvements
- Cloud/Precipitation analysis improvements
- Wind and temperature analysis improvements
- Overall software improvements
- Plotting of software and WWW interfaces
- Addition of grid point verification
- GOES 9 & 12 stretch tool for visible calibration
- Exploration of LAPS in Windows

Principal Researchers: Steve Albers and Brent Shaw

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 can be operated in with the ever-growing set of users. It is worth noting that LAPS and WRF improvements frequently have cross-cutting benefits towards many of the research projects described later in this report. Additional funding from external customers (e.g. FAA) has materialized for certain projects and 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

Solar radiation observations suitable for plotting are now read from the LDAD DataStream into the LAPS surface observation file. Soil temperature (useful for ground temperature analysis) was also added from the LDAD database. This first use of soil temperature in LAPS analyses comes from the Oklahoma Mesonet.

For the surface observation QC, data providers can now be blacklisted en masse for specific data fields. The blacklist has been expanded for pressure fields from a variety of individual stations and providers, particularly to help our reduced pressure analysis.

The observation ingest is being made increasingly generic towards the goal of processing LDAD observations from both NIMBUS and MADIS. This is planned to consist of continued handling of NIMBUS variables such as sea surface temperature observations as well as new utilization of MADIS mesonet QC flags.

Quality control checks were improved for the surface observation database (e.g. for sky cover, soil temperature, and sea surface temperature). This includes QC checks for LDAD mesonet data that were clarified along with significantly improved efficiency for a duplicate obs check.

Default runtime parameters were reset to allow more surface observations into LAPS. Ingest software is being further standardized to make it easier to add routines that handle new types of raw data. Formatting including the location precision of the surface observations was improved.

Changes have been made to improve the time windowing functionality in the METAR observation ingest, including the handling of multiple observations from a station within the time window. This was achieved with the help of further modularization of the observation ingest software. A bounds check was added within QC subroutine 'ck_array_real' to help prevent the intermediate surface observation file (LSO) from getting "Infinite" values with WFO/AWIPS METAR data.

Upper Air Observations

Ingest routines for radiometer data are running and being further refined. This includes soundings of temperature and humidity, and later may include information on integrated water vapor, integrated cloud liquid, and cloud base temperature. Retrieved cloud liquid profiles can also be considered in the data, though the more directly measured quantities may be easier to use for analysis and/or verification.

The lat/lon/time of every level has been added into the intermediate files for most soundings. This will permit direct specification of corrections such as balloon drift for the LAPS analyses. Time windows for rawinsondes and dropsondes were improved while profiler and RASS file handling was modified to better support a 15-min cycle. Cloud drift wind ingest was streamlined to prevent empty output files from being written thus helping with data tracking.

Surface Analysis

LAPS was augmented in support of the "Mesowave" FAA surface analysis project. This involved changes that allow LAPS the flexibility of choosing among several methods of performing the surface analysis, including the original "Bratsethian Barnes" LAPS, the recursive filter (from Dr. Yuanfu Xie), and the wavelet analysis (from Dr. Ning Wang). Related changes include increasing the default number of surface observations and enhancements to LAPS scripts. Scripts that sequence the analyses being run and that report the data getting into the analyses received particular attention. Portions of the multiple-pass Barnes (original LAPS) surface analysis were further modularized and placed in the library so that each of the three analysis programs could use common software for data ingest and analysis post-processing. Dewpoint QC was tightened while the analysis fit was loosened. Both of these changes should help provide a smoother looking dewpoint analysis with less non-meteorological noise. Rotation of background winds was removed since the backgrounds are now set to grid north.

The strategy for processing the reduced pressure observations and backgrounds was improved. This allows an additional QC step for reduced pressure observations, thus

helping the analysis. Logging of QC info and verification statistics has been improved. Verification statistics were corrected for reduced surface pressure. Our observation quality control blacklist continues to be updated.

A new subroutine 'read_sfc_snd' is in place so that the surface software now analyzes appropriate surface observations from meteorological towers (e.g. for the RSA project) and other soundings originating in the intermediate sounding (SND) file.

Bilinear interpolation instead of the nearest grid point value is now used in order to obtain a more accurate land fraction for use in the observation data structure. The output log now prints both nearest neighbor and bilinear land fractions. Further investigation will be conducted, as this will hopefully translate into a more accurate land fraction value used later on in the analysis. This should help the analyses in coastal environments.

Radar Processing

Progress has been made towards more efficiency and other functional improvements for radar remapping and mosaicing. For example, the vertical reflectivity interpolation in the radar remapper now has a range dependence allowing it to interpolate across larger gaps at more distant ranges. Some improvements were coded to use "hybrid scans" that define the lowest tilts used for wideband radar remapping as a function of range. This should help reduce ground clutter and improve QPE.

The radar remapper also has a preliminary inclusion of some of Dr. Deng's reflectivity QC routine that edits out radials containing spurious reflectivity data, in support of the CWB collaborative project. A velocity unfolding routine (from the CWB) is being tested that works on the polar radar data.

The wideband radar remapper was reorganized to make it more flexible, modular, and easier to understand. The allowed number of radials per tilt limit was increased. The radar remapper is also more flexible with respect to the number of radials in a tilt with further progress towards allowing variable gate spacing. Data compression for remapped volume radar data (using run-length encoding) was further tested and turned on operationally for LAPS. Software that compares compressed radar data results was improved to make it easier to assess the performance of new algorithms (e.g. velocity dealiasing). The radar remapper was optimized to better handle timing issues pertaining to archived data.

The radar mosaicing program was refined so that it can better work with several mosaics of narrowband data per analysis cycle (in support of AWIPS/WFO). This software has also been streamlined to make it easier to try alternate mosaicing strategies. As an example, the input of two-dimensional radar data from individual radars for mosaicing has been improved.

Wind / Temperature Analyses

A revamping of the wind analysis by storing observations in data structures was accomplished. This replaces the older gridded array method and allows for more complete use of the obs, especially if they are closely spaced with multiple obs in each grid volume.

This benefits numerous projects, for example the KMA wind analysis as well as WINDPADS—particularly if ACARS files are being used.

If sounding (SND) files are used with a sounding having dense vertical levels, the general procedure is to continue to pick one observation for each grid level that is interpolated from two sounding levels immediately bracketing the grid level. In this context, the remapping of wind profiles is being improved and streamlined, including a new option to use all levels from the raw sounding data in the wind analysis. This is now being tested for meteorological tower data (for the RSA project) and may be expanded to other types of soundings. A strategy for reduced weighting of vertically dense soundings is also being developed. The sub-sampling parameters for Doppler radar analysis can now be set dynamically via namelist. Input of boundary layer profilers has been reworked to permit the wind analysis to function with this data source. This especially supports our WIAP/RUC20 runs.

Changes were made with cloud-drift wind utilization in the wind analysis to help generalize LAPS for an arbitrary vertical coordinate. The accounting of observation type is now more flexible in the wind analysis, making it easier to add and statistically track new types of instruments (e.g. tower data). Logging information was improved, particularly for the metadata listing the observations making it into the wind analysis along with dependent data verification.

The temperature analysis was adjusted to loosen the fit to the observations, thus being more consistent with instrument error.

Cloud / Precipitation Analyses

The utilization of cloud-top pressure data (processed into cloud-soundings) had some bugs fixed so all of the cloud-top pressures should now be in use for the cloud analysis. The use of surface cloud observations was enhanced by testing the pulling of SYNOP data from an expanded three hour time window to allow better accuracy and continuity in the hourly analyses. This may especially help our Taiwan runs. The radius of influence of point data (e.g. METARs) was reduced for better blending with and increased use of the model background. User control was added in the namelist for determining whether these METARs are used in the analysis.

The cloud fraction analysis was changed to match a cloud layer indicated by IR satellite imagery with the highest layer from nearby point (and low-resolution satellite) data sources. This replaces the correction that used the lowest METAR/CO2 slicing cloud base as a reference. This applies to cases where the 11 micron is the only useful image channel (i.e. no VIS or 3.9 micron). This hopefully provides better spatial and temporal consistency to cloud tops, including handling of partial cloudiness (day and night). The 'tb8_k' (brightness temperature) calculation as a forward model subroutine 'get_tb8_fwd' has also been reworked to improve modularity. Logfile and comment improvements related to satellite indicated cloud layers were made to help track the various multi-spectral and multi-sensor techniques being used in different situations.

A new subroutine 'correct_cldtop_t_rad' is being used in the visible cloud building step to solve for ambient cloud top temperature given visible satellite cloud cover, ground temp,

and observed brightness temp. Unlike its predecessor 'correct_cldtop_t', the new routine works in radiance space instead of temperature space. In a related development, a call to subroutine 'filter_2dx_array' (that can handle missing data) has been added for smoothing the visible to match the resolution of the IR when determining cloud tops.

The strategy for inserting 3.9 micron and visible satellite imagery for building clouds was improved. For example, the use of the 3.9 micron data is now screened only if the surface albedo is < 0.18 . This should help prevent false cloud detections caused in part by the thermal emission spectrum of bright (barren) ground. For nighttime stratus detection, isolated 3.9 micron points that have < 2 neighbors are now filtered out.

The radar/cloud consistency check now applies to both the clearing of echo and the adding of cloud, so clouds are no longer added for any cases where we have limited confidence in the radar echo (i.e. is "unresolved"). This provides improved quality control for the 3-D reflectivity field as well. For the reflectivity analysis, the echo-top threshold has been increased to 2000m AGL in most instances for keeping the radar when it disagrees with the other cloud data sources. This should help reduce the effects of ground clutter and AP with the wideband radar. Groundwork was laid towards making the column maximum reflectivity more consistent with the 3-D reflectivity analysis.

The precipitation accumulation analysis now carries better support for missing data values. This will be important if we want to do a multi-sensor precipitation analysis or ascribe better confidence values to the data. The precipitation accumulation analysis also has a new module that compares radar analyzed precipitation to rain gauge values.

General Software Improvements & Portability

LAPS software comments and documentation were updated and improved. Software was made more robust and understandable. Software was streamlined to improve organization and remove obsolete code. Software was reorganized and error checking was improved for better understandability and robustness. Various sections of software were streamlined to take advantage of new library subroutines.

Diagnostic logging information, comments, and other documentation were improved throughout LAPS. Output logs and diagnostics were enhanced to help give feedback for analysis and software build improvement. Logging information was also improved to help monitor analysis performance. Log files now have more complete time stamps.

Scripts for configuring, building, and running LAPS as well as tracking what data were used in the analyses were improved. Some of these scripts were reworked in relation to new computer security measures at FSL. Scripts for running LAPS on the HPTi supercomputer were augmented to work on the newer Linux side. Scripts for moving LAPS output from one platform to another now have a more complete set of products. Other scripts were improved to help in running LAPS with archive cases.

Improvements were made towards the use of an arbitrary vertical grid that is more flexible than the constant pressure grid. Parameters were refined to make it easier to specify the vertical pressure grid in LAPS. Initial changes were made towards the goal of adding time weighting to the wind, temperature, and surface analyses.

LAPS run-time processing scripts now better support the surface-only option, including the experimental wavelet and recursive filter analyses. Software was made more dynamic with regards to the number of filenames in directories. Efficiency was improved by removing redundant I/O that queries directory contents. Subroutines that do I/O of 2-D gridded fields were made more flexible.

WWW LAPS Interface

A number of improvements were made to our NCAR Graphics plotting software. This includes the use of a higher resolution coastline (with states and counties) database. Our plotting software was made more efficient for forecast fields. Plotting software was streamlined and made more robust. Time selection for plotting model backgrounds is now more flexible. Runtime and/or user input parameters allow a choice of units (English or Metric) for several fields, including the PBL and ground temperature plots. Difference plots are now functioning better for a wide variety of fields.

Labels, contouring, color tables, and color bars were improved for various fields. Color tables were improved with better defined breaks and easier to interpret hues. Images were added for several pre-generated fields while image color bars were improved with additional, more useful numerical labels. Most color tables are now specified in data files instead of in code to make changes easier. Runtime parameters now control the style of image colorable (continuous or discrete). Improved color tables for other image plots, such as vertical velocity, divergence, omega, RH, and precipitation. Images were added for visibility and 3-D temperature analyses. Images were improved for various surface forecast fields while user input for wind images was clarified. An option was added to adjust image intensity, first used for the balanced 500mb field. Pre-generated plots were added for 500mb balanced analyses.

Contour plots were refined for a number of fields and now have user adjustable line width. Contour intervals were made adjustable for satellite brightness temperature fields. Surface observation plotting software was streamlined (e.g. improved observation size control) and now includes low-level data from sounding (SND) files as well as improved cloud observation access routines. This allows better plotting of meteorological tower data in support of the RSA project. Observation plots were improved for wind (including Doppler velocities and in-situ data), temperature, as well as precipitation. Solar radiation observations were also added. Cloud type icons are now better sized for large domains.

Improvements were made to plotting of vertical velocity (omega), relative and specific humidity. Cloud liquid/ice plots were improved to support a weather modification presentation. Wind cross-section plots were improved in support of the IHOP project. Wind background model plots were improved in support of the CWB project. Web plots were improved for surface moisture convergence and wind divergence. Sounding plots were improved to aid in PBL diagnosis for the USFS project. Plotting for PBL mean wind, precipitation, and a variety of cloud microphysics fields was improved. This includes setting fixed colorable limits in some images to provide better animations. Improvements were made in adding incremental precipitation totals to allow plots to span arbitrary time intervals.

Web processing scripts were added to the export version of LAPS to make it easier for our collaborators to utilize our display software for making web products. These web processing scripts were made more reliable. Scripts that help generate analysis web page images were reworked to be more generic for external use and more versatile to handle new firewall environments. The export version of our "on-the-fly" web page has been updated to benefit outside LAPS users.

Mesoscale NWP Model Initialization and Evaluation

Improvements were made to the LAPSREP program to improve the LAPS diabatic initialization of the condensate fields. LAPSPREP adjusts the final, balanced LAPS state variables and condensate fields to be representative of an NWP model's typical representation of these fields based on horizontal scale and microphysical parameterization options. Improvements included improved tuning to the MM5 Schultz microphysics by investigating correlations between model forecast relative humidity and condensate mixing ratios. Using the IHOP_2002 data sets, we were able to significantly improve quantitative precipitation forecasts from our diabatically-initialized runs of MM5 and WRF.

2. GOES

CIRA proposed to perform case reruns using satellite datasets from the IHOP experiment to validate the accuracy of satellite data and to determine the added value provided by satellite observations.

Principal Researcher: Brent Shaw

Two case studies from the IHOP_2002 data have been run with the WRF model and are being investigated. Both cases occurred on 12 June 2002. Four WRF simulations were performed: two initialized at 17Z with LAPS and two initialized at 22Z with LAPS. For each of those two initialization hours, one of the LAPS runs included experimental NESDIS GOES-derived total precipitable water observations, and one did not. The goal is to determine what impact, if any, these observations have on the quality of the resulting NWP forecasts.

Additionally, work began on incorporating routines within our NWP model post-processor (LFMPOST) to use the OPTRAN90 libraries to generate synthetic satellite images from model output. Objective is to demonstrate that such products would be a useful forecaster tool and could also be used for advanced verification studies.

3. Range Standardization and Augmentation (RSA) Project

The RSA project is an ongoing effort to enhance weather support for space launch operations at Cape Canaveral AFS and Vandenberg AFB through the use of a LAPS and MM5-based data assimilation and forecast system. An initial implementation is being run in real time at both ranges, as well as on a developmental system within FSL. CIRA scientists proposed the following research be conducted as part of the RSA project:

a. Investigation of the optimum model configuration to meet operational weather forecasting needs at each range

- b. Tuning of the cloud analysis via improved exploitation of satellite, radar, and other data sources
- c. Developing improvements to the LAPS diabatic initialization with particular emphasis on convective weather
- d. Collaborating with NOAA/FSL scientists on the development of improved MM5 microphysics
- e. Providing technical expertise to the ranges regarding data assimilation and NWP
- f. Investigating methods for assimilating 3D lightning detection data
- g. Developing lightning potential and other specialized products to support range operations
- h. Testing the new WRF model as a follow-on upgrade to the system
- i. General research that enhances the utility of LAPS and/or MM5 to support the RSA project

Principal Researchers: Brent Shaw, Steve Albers, and Ed Szoke

In collaboration with other scientists at FSL, ingest of local range data for use in the LAPS analyses is on-going. This includes routines that read meteorological tower data (via LDAD), together with improvements in the analyses and displays that allow LAPS to effectively utilize this new data source. Meteorological tower ingest was streamlined to use more generic versions of LAPS ingest routines, while testing is continuing with the utilization of tower data in the analyses.

Progress continues in the ability to use other on-site observations in LAPS at the Eastern and Western ranges. New ingest software is being tested that brings RTAMPS balloon soundings and miniSODAR wind profiles into the LAPS analyses via the LDAD database. ACARS ingest from the SBN was expanded to work in the RSA environment. Improved specification of observation type in the analysis data summaries is now included to better track the performance of each new type of instrument from the ranges. Presentation to Lockheed-Martin in late June raised the issue of obtaining live data (instead of synthetic canned data) to help in LAPS Range-data ingest testing. Plan now is also to upgrade to a 30-min analysis cycle. The LAPS web plots now use the higher resolution coastline database mentioned earlier.

Our LAPS RSA system is running at the Eastern and Western Space Ranges. This involves a triple-nested version of the MM5 model diabatically initialized with LAPS. The finest grid utilizes a very high resolution grid spacing of 1.1 km. For the Eastern Range, centered at Cape Canaveral, a number of cases were collected and subjectively evaluated from last summer and fall. Results of this exercise indicated that while the model at all resolutions did a good job with boundaries such as the sea breeze front, at the smaller

scales the model tends to produce large “grid point” storms with a significant high bias in forecast precipitation. Subsequently, collaboration with Dr. Schultz of FSL resulted in the incorporation of a modified version of the Schultz microphysics scheme. Concurrently, problems in the LAPS analysis that were leading to convective instabilities within the model were identified and corrected. As a result, the forecast fields of QPF are now much improved.

Achievements and progress on this project compare favorably with the stated goals above. For example, cloud analysis was tuned via improved exploitation of satellite, radar, and other data sources. Developing improvements to the LAPS diabatic initialization was addressed with particular emphasis on convective weather. The microphysics scheme was adjusted based on evaluation of the runs, and this has helped reduce the over-prediction of convection and precipitation amounts. Some of the effort on lightning data was postponed in order to concentrate on remaining issues with the other range data.

4. Coastal Storms Initiative (CSI)

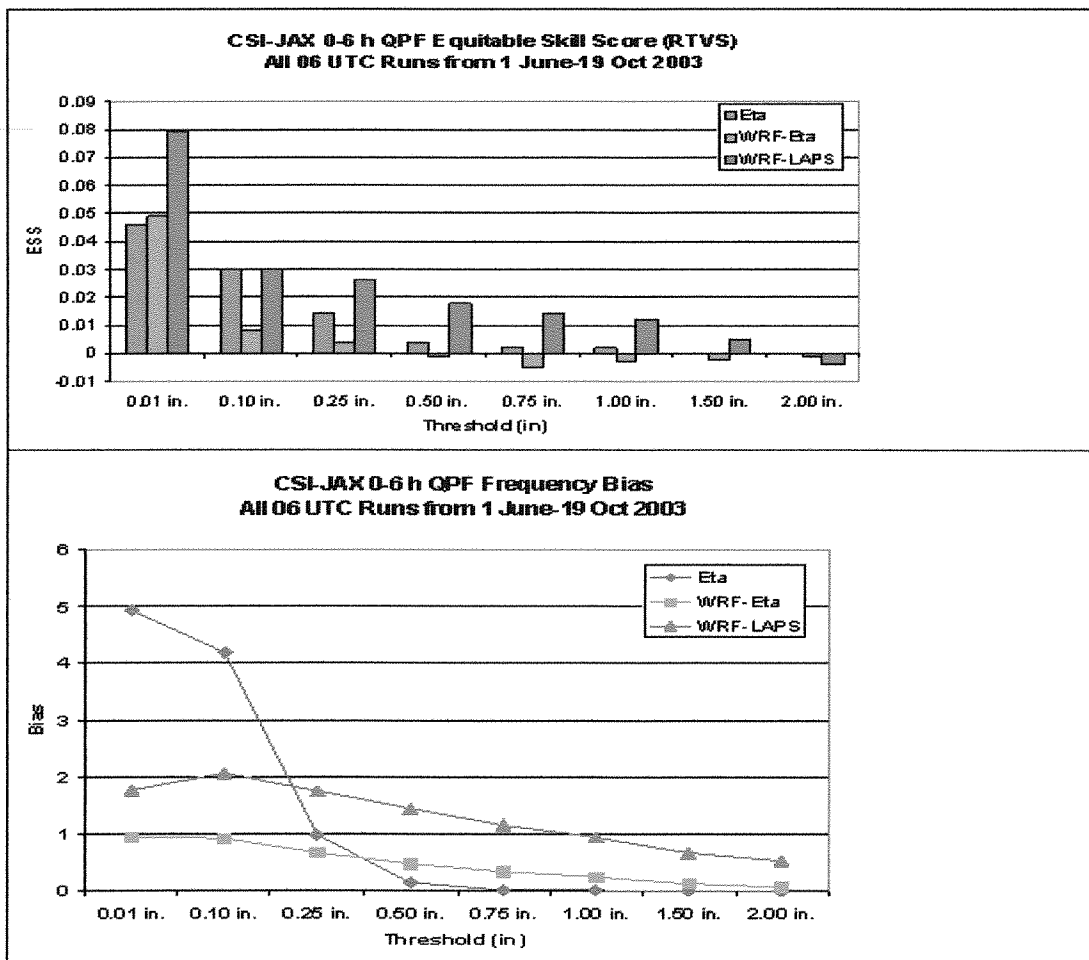
The LAPS group is continuing with an initiative to compare locally driven mesoscale model forecasts to the national model guidance provided by NCEP in order to evaluate how much added value a local model can provide. Included in this suite will be the WRF model running on a Linux PC cluster. CIRA proposed to conduct the following specific collaborative efforts:

- Assist in the system architecture design and integration
- Set up the LAPS analysis on-site on the Linux cluster
- Integrate local data sets into the LAPS analysis
- Set up a real-time version of the WRF model on the Linux cluster
- Provide a LAPS diabatic initialization capability for the WRF
- Perform subjective and objective evaluation of analysis and forecast quality

Principal Researcher: Brent Shaw

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 scientists 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. Beginning in June 2003, verification of these forecasts has been done in the FSL Real-Time Verification System (RTVS) and feedback has been obtained from the NWS forecasters. Both have shown favorable results, with the WRF runs being mentioned from time to time in the official Area Forecast Discussions. Figure 1 shows the verification of QPF and wind speed compared to the operational NCEP Eta as well as a run of WRF initialized only with the Eta

(no LAPS). These results show that a high-resolution model can add value to the forecast process compared to coarser national models, and that assimilating local data via an efficient system such as LAPS provides additional skill.



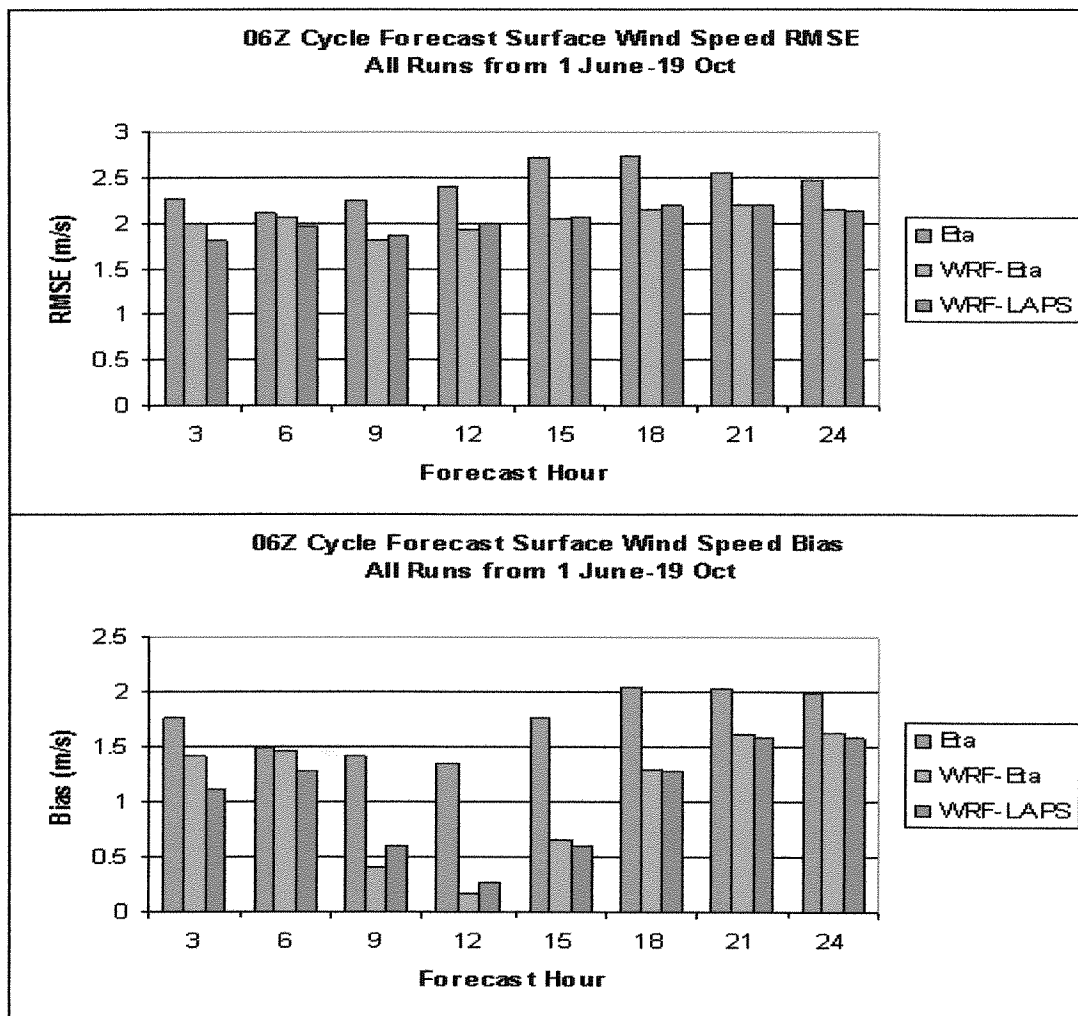


Fig 1. Verification of QPF (equitable skill score and bias) and wind speed (RMSE and bias) for the 5-km WRF model being run at the NWS Jacksonville, FL, forecast office. All statistics are event equalized and based on the 0600 UTC model cycle. "WRF-Eta" is initialized only with the 6-h forecast from the 00Z Eta (no LAPS data assimilation). The "WRF-LAPS" runs were initialized with LAPS, which blended observations (GOES, WSR-88D, surface observations) with the 00Z Eta 6-h forecast. The "Eta" stats are for the operational NCEP Eta model, also initialized at 06Z.

5. WINDPADS (Precision Airdrop)

CIRA proposed to work with Planning Systems Incorporated on the "WINDPADS" project. In support of this effort, an overhaul of the wind analysis was proposed so that the LAPS system can fully utilize dropsonde data with high vertical resolution. If the data has more than one observation in a given LAPS vertical level, then only one of the observations is currently being utilized. An expanded use of data structures for storing observations would help LAPS to improve on this strategy.

Principal Researcher: Steve Albers

In support of the WINDPADS effort, an overhaul of the wind analysis is well underway towards allowing fuller utilization of dropsonde data with high vertical resolution. If a sounding has multiple observations in a given LAPS vertical level, then only one or two of the observations is currently being utilized. A further phase-in of data structures for storing observations will help to improve the handling of increased observation density. The adjustment of wind observations for the model background time trend was improved by reading in the model background winds for the forward time step. Design and implementation of observation time weighting in the 3-D wind, temperature, and surface analyses have begun. This should increase the analysis accuracy when observations are spread out over various times.

6. CWB (Taiwan)

CIRA proposed to continue its long-term scientific collaboration with the Taiwan Central Weather Bureau (CWB) to update the LAPS analyses and hot-start forecast techniques at the CWB. CIRA, in collaboration with FSL, would host two visiting scientists working in the areas of the radar analyses and model initialization, particularly for tropical cyclone cases. CIRA proposed to study improvements with the Kalman filter, balance package, and model forecast verification.

Principal Researchers: Steve Albers, Brent Shaw, and Ed Szoke

Updates to the LAPS software on the various 9km & 3km Taiwan runs continued in collaboration with scientists at both FSL and the CWB. An example of the analyses is shown in Figure 2.

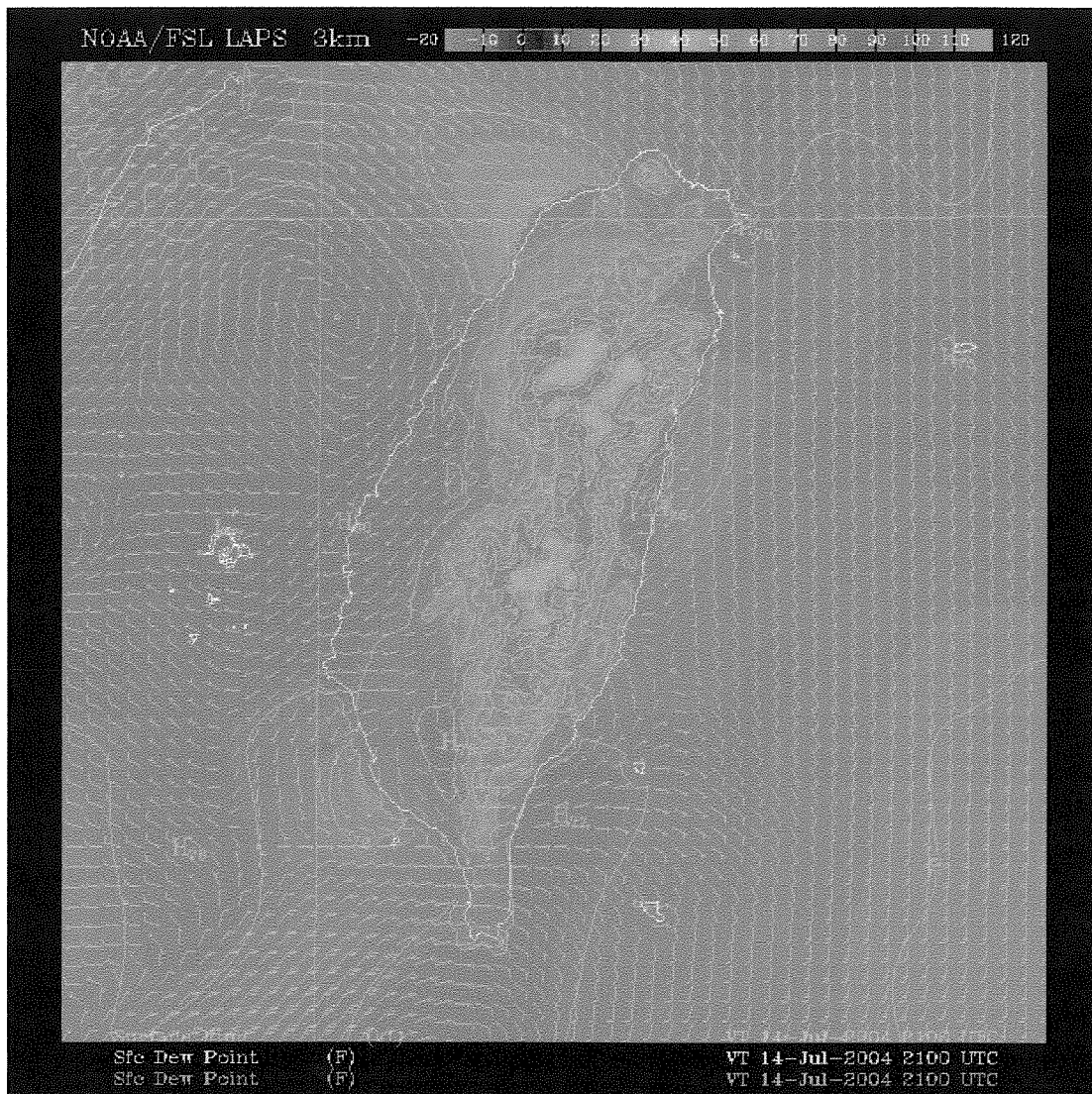


Fig. 2. Analyzed surface dewpoint (image and contours) is shown along with wind barbs over the 3km Taiwan domain running at the CWB. A good detail of structure is visible indicating dryer air in the high terrain along the spine of the island.

The latest version of the analyses includes ingest improvements for surface observations (e.g. METAR) for better results on the LINUX platform. Ingest routines for CWB RAOBs and dropsondes were updated to the latest sounding formatting used in LAPS. The GPS surface data ingest was expanded to accept the CWB filenames convention. Cloud drift wind ingest for CWB was adjusted to format the intermediate output in a manner compatible with the wind analysis. Cloud drift wind ingest was also improved to catch more observations with a wider time window.

The use of GOES-9 (IR and visible) for the Taiwan runs continues to be phased in for an interim period while GMS services are unavailable, pending the launch of a new GMS satellite. The new GMS may be an important addition, since some navigation offsets have

been noticed with the GOES-9 imagery that can have a negative impact on the cloud analysis and hot-start model initialization. CWB scientists are working to address this on their end.

Several aspects of improved radar processing are being collaborated with visiting scientist Dr. Shioh-Ming Deng. One area includes radar NetCDF improvements. With his help, the distribution of wideband data into separate tilt files was optimized to provide much more complete volume scans (free of ring shaped artifacts) for all the radars. Collaboration with Dr. Deng also included the successful interfacing with his dual- and multi-Doppler radar analysis routines for improved utilization of single/multiple Doppler data in the wind analysis. Other areas under consideration include quality control, vertical reflectivity profile (VPR) corrections, as well as use of rain gauge and satellite data in the quantitative precipitation analysis (QPE).

Dr. Deng's routine for de-aliasing Doppler radar data in polar format (using continuity and pattern recognition techniques) is being tested in the radar remapping software, using the LAPS shadow runs. He has also provided a continuous line reflectivity QC routine. We are considering strategies for modifying our remapping software so that it is able to call it. Preliminary discussions were held with Dr. Deng about the VPR routine to modify the reflectivity field at distant ranges based on known reflectivity profiles at short range. Dr. Deng also has VAD algorithm software that are currently being reviewed to see how it might be interfaced with LAPS.

The possibility of porting some of Dr. Deng's software for combined radar and rain gauge data into the LAPS precipitation accumulation analysis has been discussed. Work has begun on improving our precipitation analyses (QPE). This includes showing rain gauge plots in metric units and developing a verification routine within the precipitation accumulation analysis that displays rain gauge vs. radar derived pairs of precipitation accumulation. Precipitation field plots will (after further development) also support metric units if needed.

Presentations were made on Taiwan LAPS at the FSL LAPS Technical Review and to Dr. Adolphus Shen visiting from Taiwan. The Taiwan LAPS setup was also discussed with our second visitor of the year, Ms. Li-Hui Tai.

The CWB LAPS analyses running at FSL are now being used to initialize an MM5 shadow run. This should assist in interpreting and improving the model runs being done at the CWB. Effort has begun on transitioning the CWB from MM5 to the new WRF model as well, via collaboration with a CWB visiting scientist, Li-Hui Tai, who has been working with us to set up a real-time WRF shadow run.

Discussions were held with visiting Taiwan scientists about the best ways to use the cloud and radar analyses to initialize the MM5 forecast, particularly with the model vertical velocity field in tropical convection cases. We have included Dr. Adan Teng's improvements to the cloud associated vertical velocity as well as precipitate concentration fields into LAPS. This includes consideration of cloud type, assumed cloud top of combined cumulus/stratiform clouds, and effects of precipitating radar echoes.

Collaborating with Dr. Adan Teng of the CWB, routines that compute precipitation fall velocity were made more robust.

7. WFO Advanced

Principal Researchers: Ed Szoke, Steve Albers, and Brent Shaw

a. AWIPS/LAPS

CIRA proposed to continue its long-term collaboration with FSL to have LAPS software running in the National Weather Service WFO's for evaluation and use by operational forecasters. CIRA planned to port updated LAPS builds to an AWIPS platform and expand the range of AWIPS datasets that can be processed within LAPS. This effort enhances CIRA's research capability by providing advanced modeling and forecasting techniques for evaluation in an operational setting. The immediate and relevant feedback will help to shorten the time to transition improved products from research to operations.

A long term effort to have LAPS software running in the National Weather Service WFO's for evaluation and use by operational forecasters continues. The LAPS software is being periodically updated within successive AWIPS builds in order to use the latest LAPS analyses. Highlights of the latest build include improved coastline gradients of surface variables utilizing land fraction data and the new (Bunkers et. al.) method for computing storm motions feeding into helicity determination.

b. EFF

CIRA proposed that collaborative interaction with the local National Weather Service Weather Forecast Office (WFO) in Boulder, located within the David Skaggs Research Center, be continued. This involves FSL staff working some forecast shifts, as well as involvement in some cooperative projects. One project that was proposed would involve the Boulder WFO serving as one of three test sites for an experimental infrasound system developed by Al Bedard of the NOAA/Environmental Technology Lab in Boulder. This system is able to detect infrasound signals from phenomenon 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 of importance to CIRA research and critical National Weather Service goals. This would be the first formal test of the system.

Cooperative projects and interaction with the local National Weather Service (NWS) Weather Forecast Office (WFO) in Boulder, located within the David Skaggs Research Center, continue. An ongoing project has been the running of a local model, the MM5, initialized in a hot-start configuration with LAPS, out to 24 hours, four times a day. The model is run at FSL and the output sent to the Boulder WFO for display on their AWIPS, to obtain subjective feedback from the forecasters. This effort has led to several cooperative projects, and during the past year, were centered around an examination of model performance during the great March snowstorm of 2003. In particular, the model was rerun to see if it could better predict the evolution of surface temperatures during a critical early

period of the storm when the changeover from rain to snow was a difficult forecast problem. Results, somewhat mixed, were presented at the 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP) during the AMS 2004 Annual Meeting in Seattle. Results were also presented as part of the Warning Decision Training Branch (WDTB) Winter Weather Workshop, held at COMET in July 2003. Another aspect of this case involved the performance of NCEP and other models at the longer range, and, working with a forecaster at the Boulder WFO, made one presentation at the Meteorological Service of Canada's (MSC) Fourth Winter Weather Forecasting Course (November 30th to December 12th, 2003), hosted by COMET and at the 20th WAF/16th NWP Conference in Seattle.

Another project that began last year and continues through this year and into next year, with funding from the NWS, involves the Boulder WFO serving as one of three test sites for an experimental infrasound system developed by Dr. Al Bedard of the NOAA/Environmental Technology Lab in Boulder. 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. This will be the first formal test of the system. A workshop was held in Boulder in March, and some of the results were submitted by participating WFOs for the upcoming 22nd Conference on Severe Local Storms. Working with Boulder WFO forecasters, output from the infrasound system will be closely examined and compared to radar observations and storm spotter reports for several cases to help determine the potential value of this new system.

c. D3D

CIRA scientists and the D3D (Display 3-Dimensional) group at FSL are jointly exploring the potential of 3-dimensional displays for operational use, perhaps eventually as a part of AWIPS, within the National Weather Service as well as other operational environments. D3D uses the University of Wisconsin's Vis5D software, which has a long history of use by the meteorological research community, and contains options for 3D displays as well as highly interactive 2D displays such as point soundings and cross-sections. Currently, a number of NWS Weather Forecast Offices (WFOs) have the D3D software with some of them using it in a training environment. CIRA proposes to continue to provide limited support for field use of D3D for those WFOs currently possessing the software, and for other offices that may want to use D3D on an experimental basis. Some training materials, specifically examples of how D3D products might be used by forecasters, would be developed online, and possibly through cooperative efforts with COMET.

D3D (Display 3-Dimensional) is a highly interactive software package of 2-D and 3-D applications based on the University of Wisconsin's Vis5D software, and modified by FSL to work within the NWS AWIPS configuration. Although the FSL D3D group had no formal funding this past year, D3D is currently used by a number of NWS WFOs in a training environment. Limited support for field use of D3D for those WFOs currently possessing the software continued to be provided, along with distribution of the software (in the form of a CD) for other offices who may want to use D3D on an experimental basis. Close coordination continued with the Science Operations Officers (SOOs) at the Omaha WFO

and the Central Region, as well as the NWS Office of Science and Technology, to explore how best to proceed with allowing WFOs to use D3D in a real-time environment. A number of forecasters continue to be interested in D3D, and it was used during the weather briefings with the FY03 COMET Mesoscale Analysis and Prediction Course (COMAP), held at COMET in October-November. Presentations on D3D at this course, as well as at a workshop held at COMET and organized by the Cheyenne, Wyoming WFO, were made.

8. Federal Highways Road Weather Modeling

CIRA proposed the development and implementation of an ensemble of similarly configured mesoscale models for potential input to an automated decision support tool for use by public emergency management decision makers. This would require CIRA researchers to:

- Configure and maintain MM5, RAMS, and WRF models, initialized with ETA, AVN, and RUC model output
- Develop ensemble products
- Maintain real-time transmission of model outputs to NCAR for input to the decision support software
- Develop user interface for various modeling components

Principal Researchers: Brent Shaw and Brian Jamison

The Road Weather 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. This initial stage of the MDSS is focused on the state of Iowa. This was a collaboration between CIRA, FSL, NCAR, MIT/Lincoln Labs, and the Iowa State University Center for Transportation Research and Engineering (CTRE).

Building upon the success attained with a demonstration project during the winter of 2002-2003, CIRA scientists configured the mesoscale ensemble forecast system to support the MDSS, which was once again designed to support the Iowa Department of Transportation in a demonstration mode. FSL's role was to provide multiple, frequently updated, high-resolution model grids to NCAR for input into a "fuzzy logic" forecast system that is coupled with a Java-based graphical user interface to provide forecast winter road conditions and recommended treatment options.

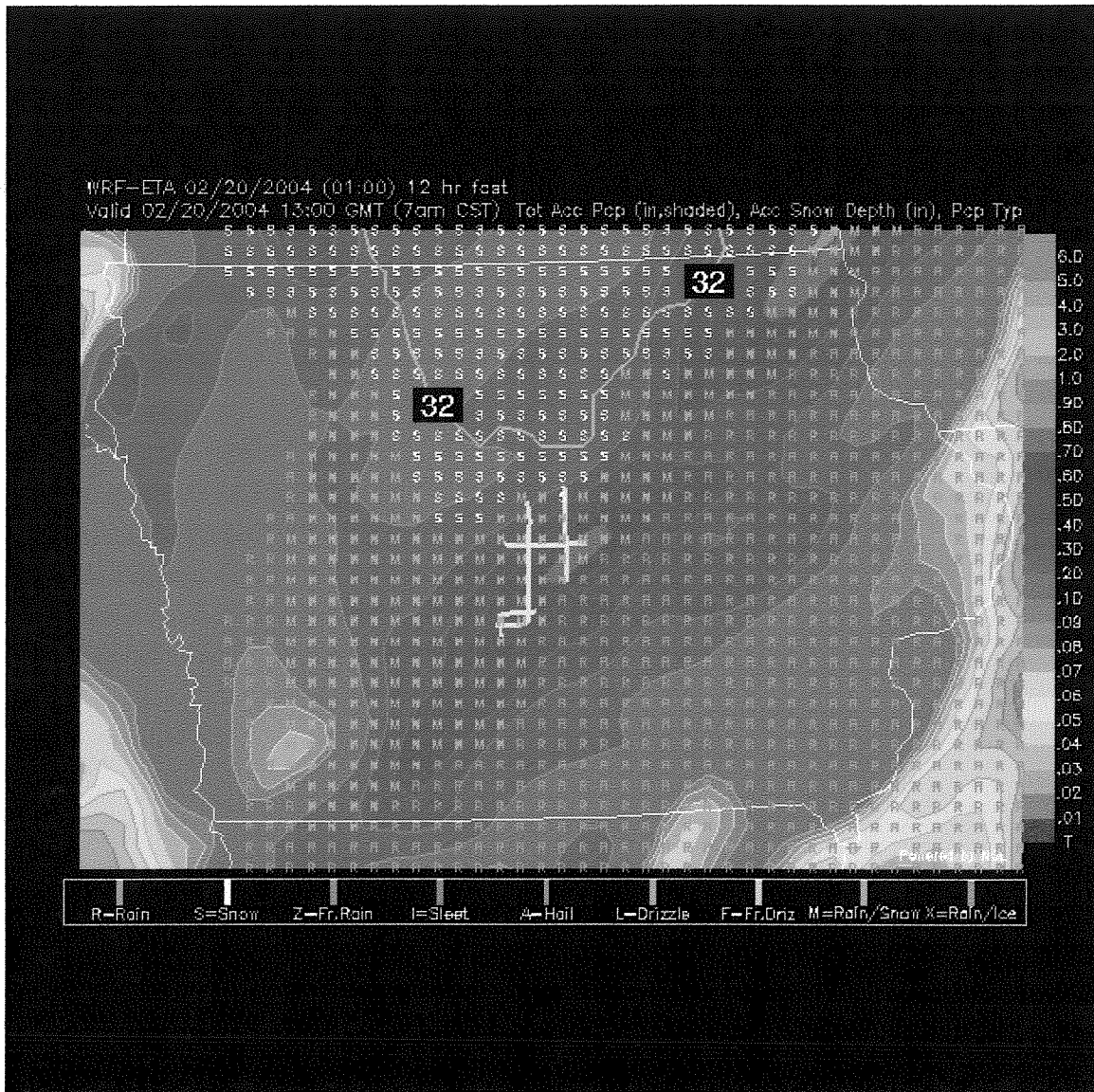
Lessons learned from the previous year were applied in setting up the 2003-2004 demonstration. First, the RAMS model was discontinued as a member because of poor performance the previous year, where it appeared to add no statistical value. The RAMS configuration is being investigated to see what improvements could be made to allow it to be better utilized. Second, a time-lagged ensemble approach is used, where ensemble diversity resulted from running a new forecast every hour from the latest LAPS analysis.

The LAPS analysis was used to initialize both WRF and MM5, so 48 runs per day out to 15 hours were performed during the entire winter on a small Linux cluster. Not only was a high degree of model output reliability demonstrated, but the quality of the forecasts were such that the NCAR fuzzy logic system was assigning them over 80% of the weight in the first few hours of their forecasts based on quantitative real-time verification. Additionally, one of the CIRA researchers traveled to Iowa as a field observer for a week in January to interact with the Iowa DOT maintenance garage staff and document road conditions during three events to aid in MDSS verification. Figure 3 is the snow plow used during the first event to collect data.



Fig. 3. CIRA researcher attended the MDSS field experiment in Ames, IA in January 2004. Tasks included interacting with road crews and monitoring the road conditions by riding on the plows

The FSL run ensembles of the MM5 and WRF models with boundary conditions from the Eta model provided web resources for graphical output. Currently, analyses and forecasts out to 15 hours are provided hourly from both ensemble models. Graphical products are created automatically in a timely manner; an example of these are shown in Figure 4.



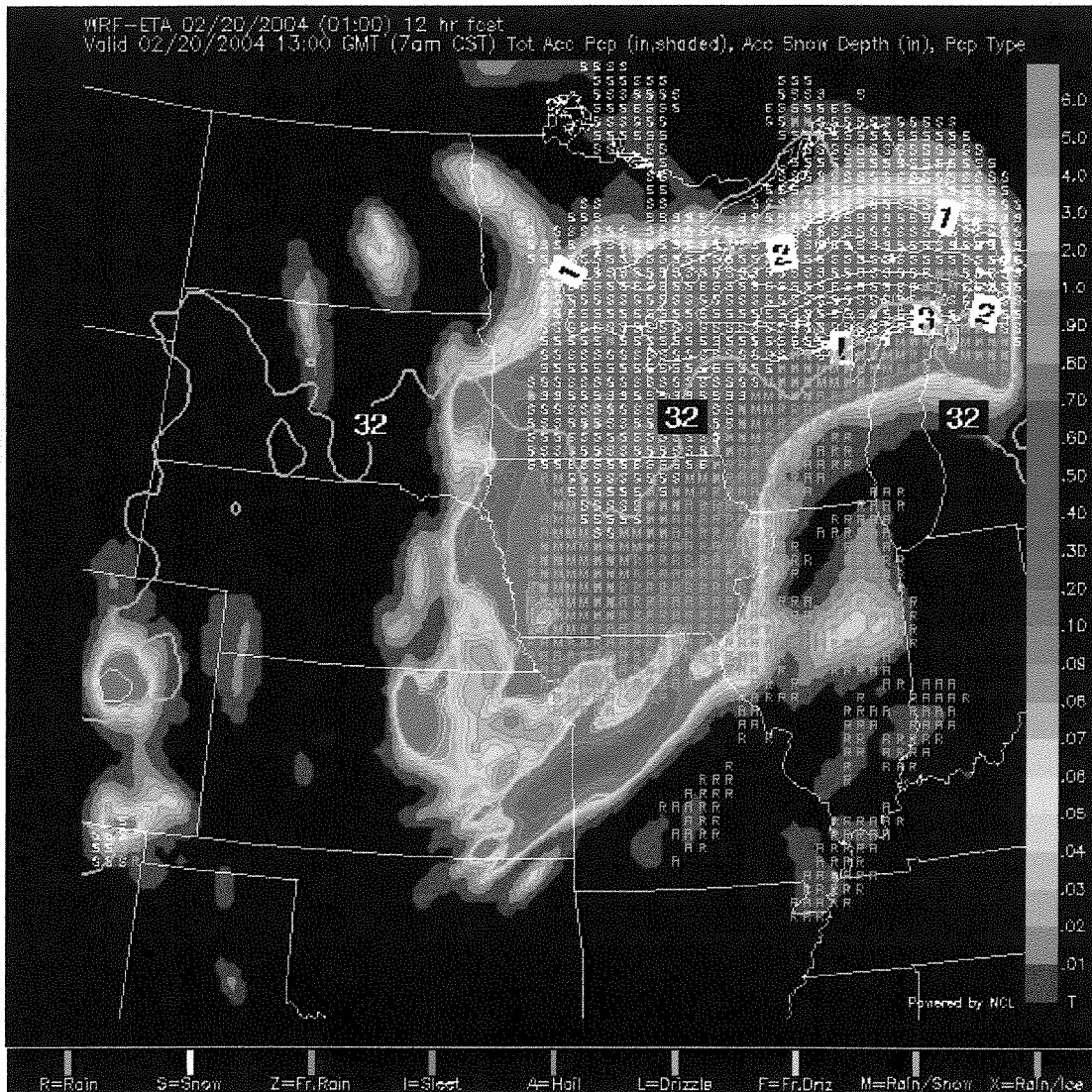


Fig 4. Broad and zoomed views of WRF-Eta ensemble model 12 hour precipitation forecast for February 20, 2004

Additionally, the following improvements were made to the graphical products:

- Made adjustments to NCL scripts to improve the quality and readability.
- Added some highway segments near Ames and Des Moines for reference.
- Created a version of the software to generate graphics from a past case.
- Created a version of the software to generate plots of Eta model data in the same fashion as the MDSS graphics.
- Wrote NCL and Perl scripts to generate plots of the LAPS Quantitative Precipitation Estimation (QPE) data to be compared with the ensemble forecasts.
- Created CD-ROM and DVD archives of all generated images.

9. United States Forest Service (USFS)

The LAPS group is prototyping the Rocky Mountain Regional Fire Modeling Center in association with the USFS and the Rocky Mountain Research Station (RMRS), located in Fort Collins. This involves a nested analysis and forecast system to be set up over two windows. The areas are centered in COMWY and AZ/NM. CIRA proposed to improve the Web interface to its existing fire products and extend the reach of the model forecasts. Various derived fire weather products will be evaluated. Research benefits will focus on exploring the utilization of lightning data for analyses and/or forecasts.

Principal Researchers: Steve Albers and Brent Shaw

CIRA researchers maintained five analysis windows for LAPS runs, with three of these also including forecasts, on the IJET supercomputer in support of the US Forest Service Fire Weather Consortium. Web page improvements for displays of fire weather products were made based on feedback from the end users. This includes general design and increasing the robustness of plots of analysis and forecast fields. The Mid- and High-level Haines indices are now supported and set to white if the layer used for computing extends below the ground. Collaboration with USFS resulted in the addition of a new "Critical Fire Weather Index" to the product set. Plots of surface latent heat flux forecasts and solar radiation observations were created to help diagnose the MM5 surface package for improving forecasts for surface relative humidity.

Other web display improvements were made in support of the USFS. For example, planetary boundary layer (PBL) depth is now being shown to the fire weather community along with PBL mean wind flow (Fig. 5). Runtime and/or user input parameters allow a choice of units (English or Metric) for several fields, including the PBL plots.

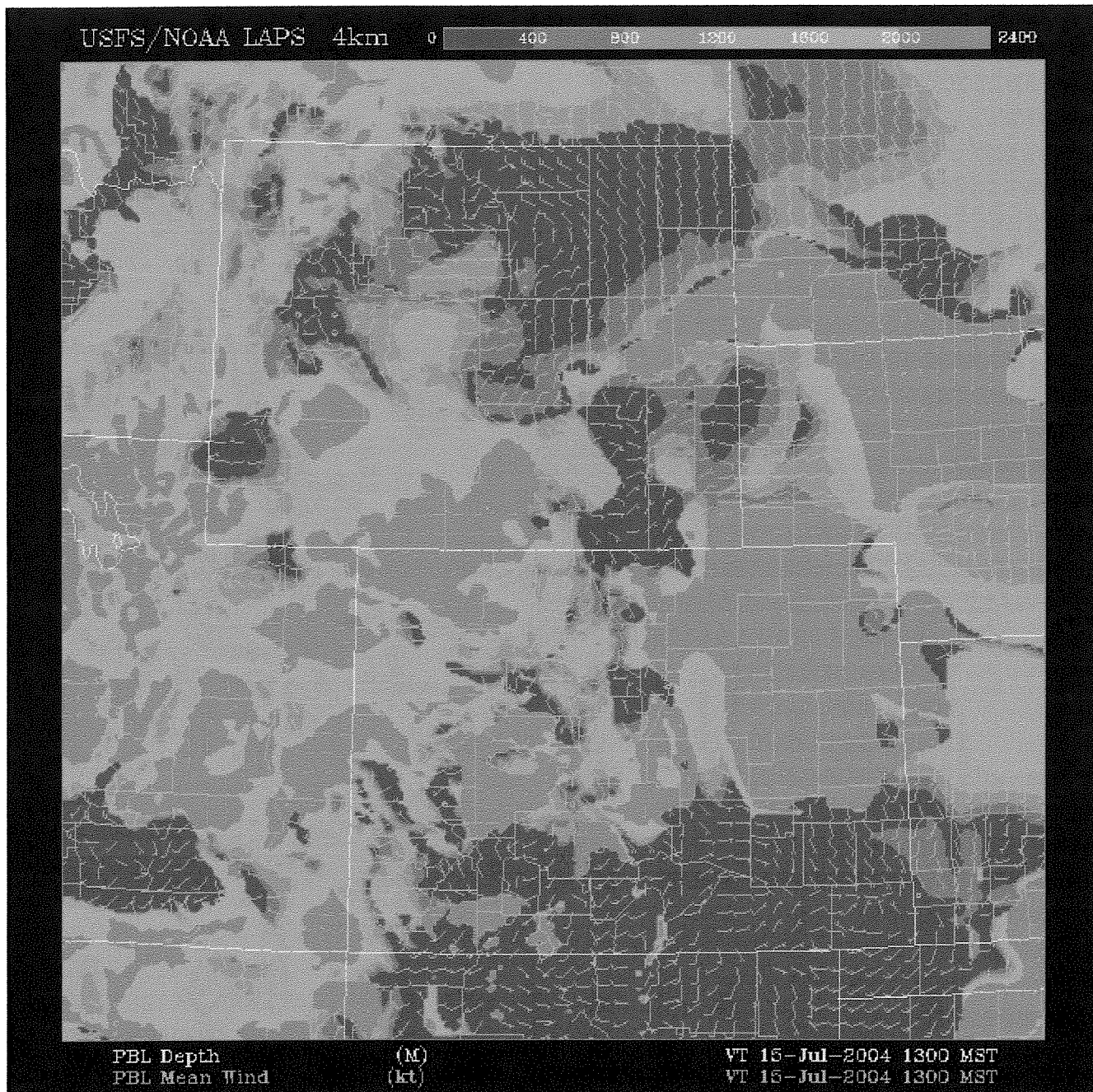


Fig. 5. Analyzed PBL depth in meters (image) along with PBL mean wind in knots (wind barbs). The purple areas have a shallow PBL while red denotes deeper PBL. Smoke from forest fires often extends vertically up to the PBL height and travels with the mean PBL wind

Color tables were improved with better defined breaks and easier-to-interpret hues. Options were added for having more discrete image color tables (selectable via namelist). Images were added for several pre-generated fields while image color bars were improved with additional, more useful numerical labels. Plotting software was made more efficient for

forecast fields to yield more timely output. See the above subsection entitled "WWW LAPS Interface" (Section 1) for further details on these and other improvements. Significant cutback in funding from the USFS prevented pursuit of the lightning research.

10. IHOP

a. One of the ways that FSL participated in IHOP (International H₂O Project, May-June 2002, centered in Oklahoma) was to run different versions of two mesoscale models in real time and use these models to aid in the nowcasting and forecasting effort to support IHOP operations. Formal real-time evaluation and documentation of the model forecasts was part of the IHOP effort, using online forms to record forecaster assessment of the quality and usefulness of the models. CIRA is currently undertaking a more formal evaluation of the model forecasts, in coordination with researchers at FSL, NCAR and at the Storm Prediction Center. As part of this effort, selected cases would be rerun and examined more closely.

b. CIRA has recently submitted to NSF/IHOP a proposal entitled "Surface Inhomogeneities and their impact on fluxes and Low Level Jet dynamics during IHOP: Diagnostic and Numerical Modeling Studies." Since this work is considered by CIRA scientists to be "high impact science" and related to our cooperative work with FSL, a project summary is reproduced below.

"Through a comprehensive variety of observations, the IHOP field campaign sought to address questions under four main scientific goals and hypotheses components: a) the qualitative precipitation forecast component, b) the convective initiation component, c) the atmospheric boundary layer processes component, and d) the instrumentation component. The main objectives of the present proposal are to investigate some of the issues addressed in the atmospheric boundary layer processes component. More specifically, by means of diagnostic and numerical modeling studies, the interactions between the LLJ and surface heterogeneities will be investigated. One of the aims of these studies will be to understand the influences of scale-dependent structures of the LLJ on the heat and moisture transport within the atmospheric boundary layer. To do so, we will incorporate IHOP observations into analyses, diagnoses, and simulations of pre-selected LLJ cases. The analyses and diagnostics activities, representing the basic framework of the proposal, will allow us to cast the heterogeneous IHOP observations into three-dimensional atmospheric fields, which can then be used to address issues (using diagnostic studies) of the atmospheric boundary layer processes component as well as providing the fields for model initialization and verification. The main objectives of the numerical simulations are: a) to investigate the adequacy of observational data to initialize models, b) to investigate the evolution and dynamics of the small-scale structures of the LLJ that impact the weather locally, c) to understand how the local surface conditions modulate the heat and moisture fluxes by the LLJ, and d) to investigate the adequacy of numerical weather prediction models for LLJ prediction. Furthermore, through sensitivity experiments, the use of high-resolution terrain, soil type, vegetation, soil moisture, urban area characteristics in the high-resolution simulations will help us assess the impact of human activities such as urban development, crop practices, and deforestation on the development and evolution of LLJs.

Scientifically, the proposed work addresses several areas of high interest and importance. First, it will be possible to derive a better understanding of small-scale structure in both the cross-flow and along-flow components (and their relation to surface inhomogeneities) of the daytime LLJ and their impact on the boundary layer circulations. Second, it will provide diagnostics relevant to the influence of the LLJ on mesoscale circulations (such as storm triggering) to be contrasted with the coarse description of the LLJ used until now to forecast MCSs. Finally, results from this work will provide guidelines for future work on the adequacy of fine-resolution simulations, planning of field experiments similar to IHOP, and other LLJ forecasting issues.”

From the perspective of the National Weather Service and other operational forecasting communities, two principal impacts of this research can be expected. First, it will provide confirmation and further elucidation of "common knowledge" forecasting techniques that exist for the LLJ. For instance, the forecasting rule of thumb that the intersections of the LLJ and frontal or other boundaries are locations prone to convective development may be quantitatively evaluated and assessed. Second, it is our presumption that the dense IHOP observations both on the ground and within the boundary layer will provide analyses of the LLJ and the moisture it transports that are unprecedented in detail and in temporal continuity. However, it must still be shown that these observations assimilated into numerical models do in fact improve forecasts. These model results in particular have obvious implications for predictability of the water cycle over the central U.S.

Principal Researchers: Ed Szoke, Brent Shaw, Steve Albers, and Adrian Marroquin

CIRA scientists played an important role in the development of a retrospective rerun capability of LAPS analyses in support of IHOP (International H2O Project, May-June 2002, centered in Oklahoma). The strategy for these runs entails LAPS analyses with various data configurations used to initialize the MM5 forecast model. This includes a number of elements, for example the reprocessing of Doppler wideband radar data. LAPS scripts were added and augmented to allow the processing of wideband radar data for archive cases. This involves converting the radar files from Archive-II format to NetCDF. LAPS analysis software was scaled upward to allow a greater number of files (particularly for radar data) covering long archival periods.

Development took place on the dropsonde sounding ingest using the AVAPS dropsonde format to help assess value added in our case study research runs. This includes supporting improvements in the wind and temperature analyses. RASS file checking was improved with respect to time window helped by these archive case reruns. A retrospective case-study low-level jet analysis rerun was then performed for June 9, 2002, including a run with the special dropsonde data that was collected during the experiment.

The evaluation of special model runs made by FSL for real-time use in IHOP in the second year of a USWRP and FSL funded project was continued. The goals are to assess the value of the models in forecasting convection, and in particular convective initiation, elevated convection, organized storms such as supercells, and upscale growth of convection into organized lines. The detailed subjective evaluation will help to determine both current advantages of methods such as the hot-start formulation, as well as limitations

that will need further development. Improvements already made have been applied to a set of reruns of the 12-km version of the MM5 and WRF models for the IHOP period, and these have been added to the overall evaluation. A number of presentations were made over the past year, including papers at the 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP) during the AMS 2004 Annual Meeting in Seattle, and a presentation in June at the 2nd International IHOP_2002 Science Workshop in Toulouse, France. A formal publication focusing on results for convective initiation forecasting will be submitted in August 2004 as part of a Monthly Weather Review IHOP special issue.

Evaluation for the modeling of upscale growth is being completed for a paper in the upcoming 22nd Conference on Severe Local Storms. An example of upscale growth as captured by the MM5 4- and 12-km IHOP runs for a very active day on 15 June 2002 is shown in Fig. 6. Both runs organize areas of convection into a bowing line, with the 4-km run showing more structure and faster motion, which turns out to be closer to what actually occurred (Fig. 7).

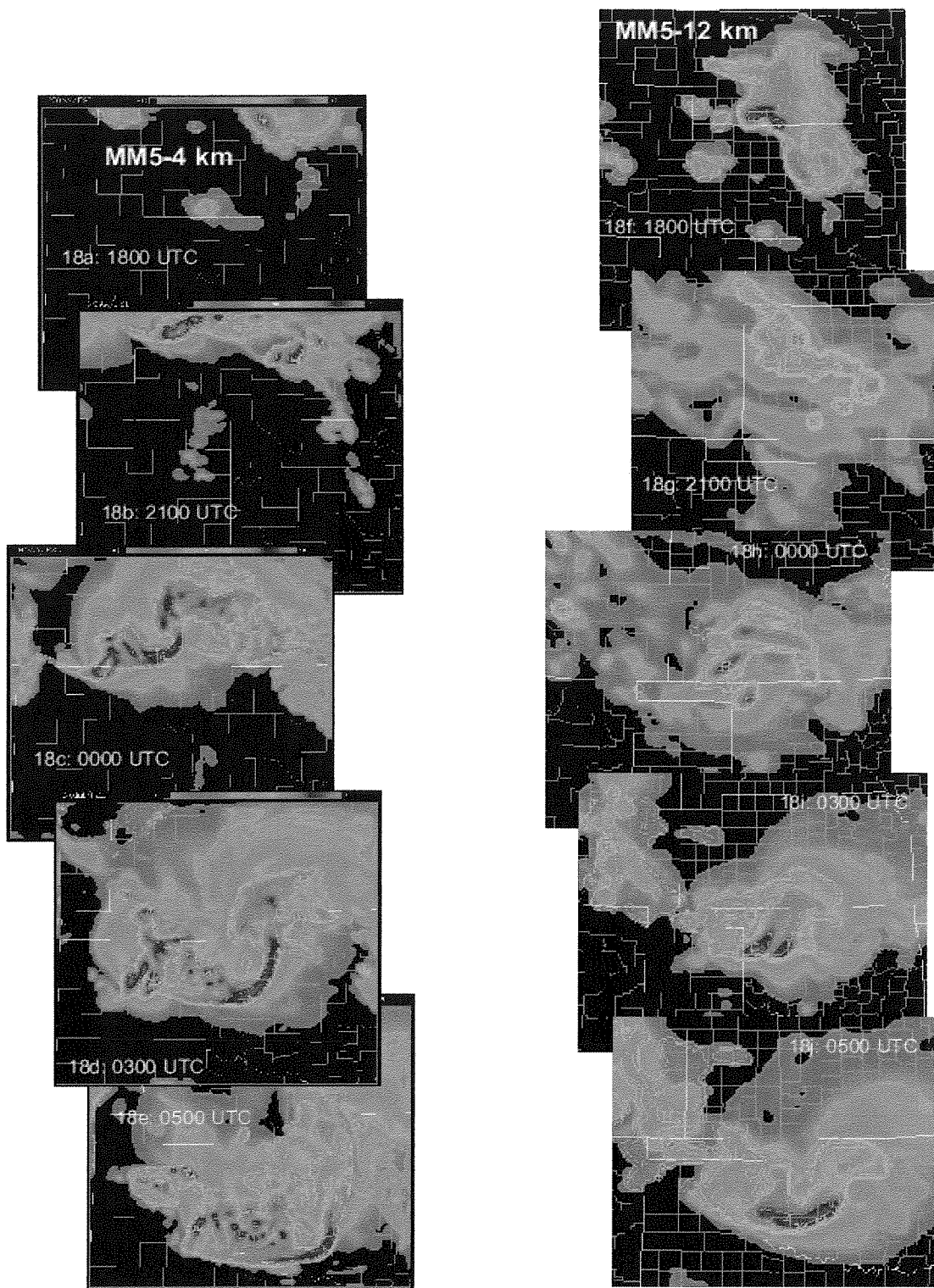


Fig. 6. Comparison of the real-time MM5 hot-start 4-km and 12-km special model runs made during IHOP by FSL. Shown are forecasts of composite (image) and surface (contours) reflectivity for the two runs, initialized at 1800 UTC on 15 June 2002. Both runs correctly organized the convection into a bowing line, with the 4-km run showing more structure and having a faster moving line, in agreement with the observed radar (figure 7)

Radar imagery for 15 June 02

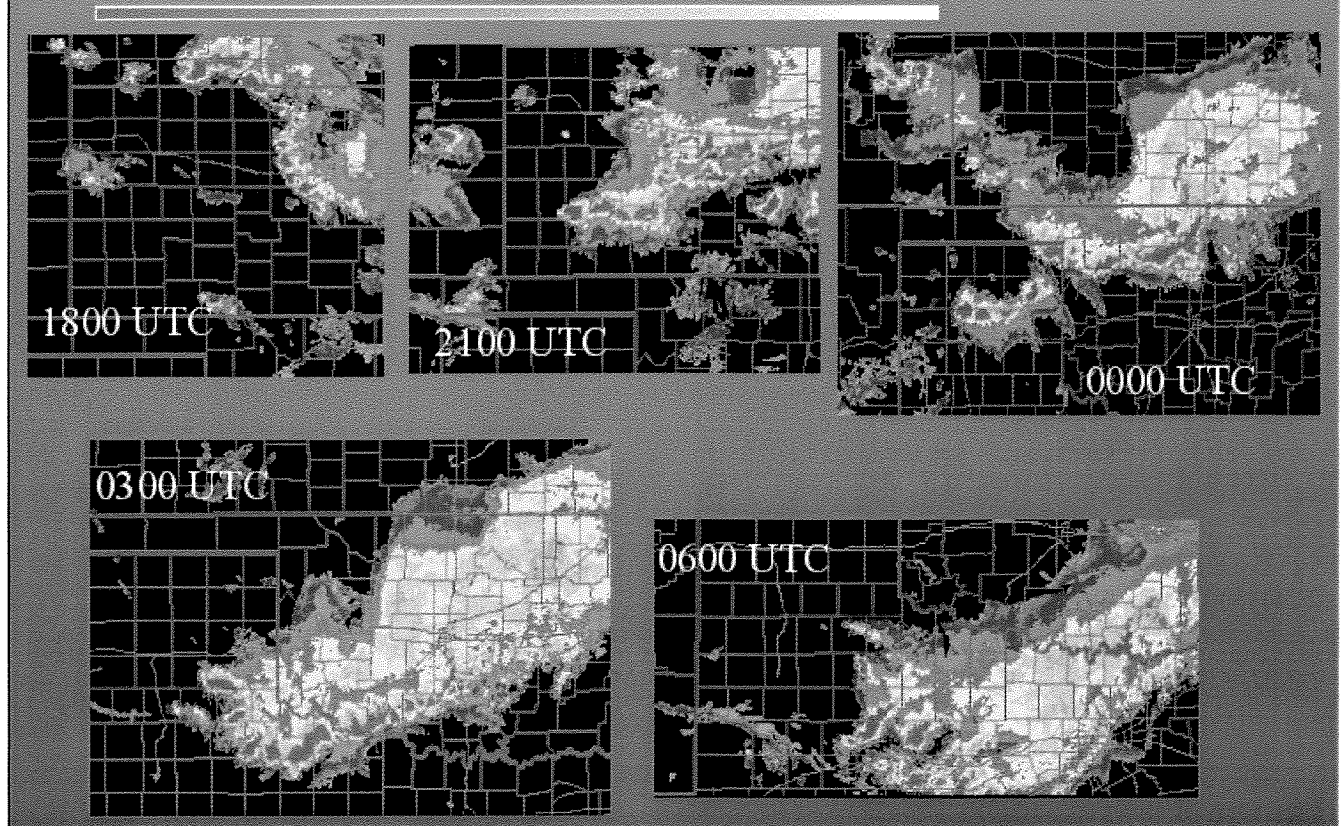


Fig. 7. Composite low-level radar imagery centered over the IHOP area (Kansas, Oklahoma, and northern Texas) for 15 to 16 June, 2002

Although the specific NSF proposal on the Low Level Jet was not funded, collaboration with our FSL partners on case reruns contributed to wide ranging IHOP and LLJ research.

Publications

Szoke, E.J., B.L. Shaw, and J. Brown, 2004: Performance of real-time and post-IHOP mesoscale models in determining storm type and evolution for the IHOP-2002 experimental period. AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

11. Weather Research and Forecast Model (WRF)

The LAPS group is represented on the Standard Initialization committee of the multi-agency WRF development team. The SI committee is responsible for developing a capability to load early prototypes of the WRF model with data from public-domain model grids.

As a scientific participant, CIRA proposed the following specific research efforts:

- Maintain and upgrade the current WRFSI's capabilities that handle NCEP datasets
- Support WRF model development, testing, and evaluation activities
- Improve the graphical user interface that assists model users in selecting the domain, grid size, paths to input data, etc.

Principal Researchers: Brent Shaw and Brian Jamison

Numerous improvements to the Weather Research and Forecasting (WRF) Standard Initialization (SI) were made during the past year. Notably, the capability to set up and initialize nested WRF domains was implemented, as was the capability to use the WRF Application Programmer Interface (API) to output data for direct input to the WRF modeling system. Additionally, support for the NCEP Non-hydrostatic Mesoscale Model (NMM) core was incorporated into the WRFSI. The LAPS branch of FSL has developed a graphical user interface (GUI) that allows a user to define a particular domain and resolution to run the WRF model using LAPS model initialization data. Improvements made to the GUI's graphics capability during this past year include the following:

--Corrected and improved NCL scripts to display static initialization fields. An example of these fields showing Dominant Land Use is shown in figure 8. The NCL scripts are dynamic, and conform to any defined domain by recognizing and setting the map projection used, scaling colormaps and contour intervals, and automatically adjusting the viewport to handle domains with different aspect ratios.

--Added NCL and Perl scripts to generate plots of maximum snow albedo and an interpolated albedo using the current time and monthly climatological snow albedo.

--Provided input regarding the NCL graphics products to the WRFSI Frequently Asked Questions web page.

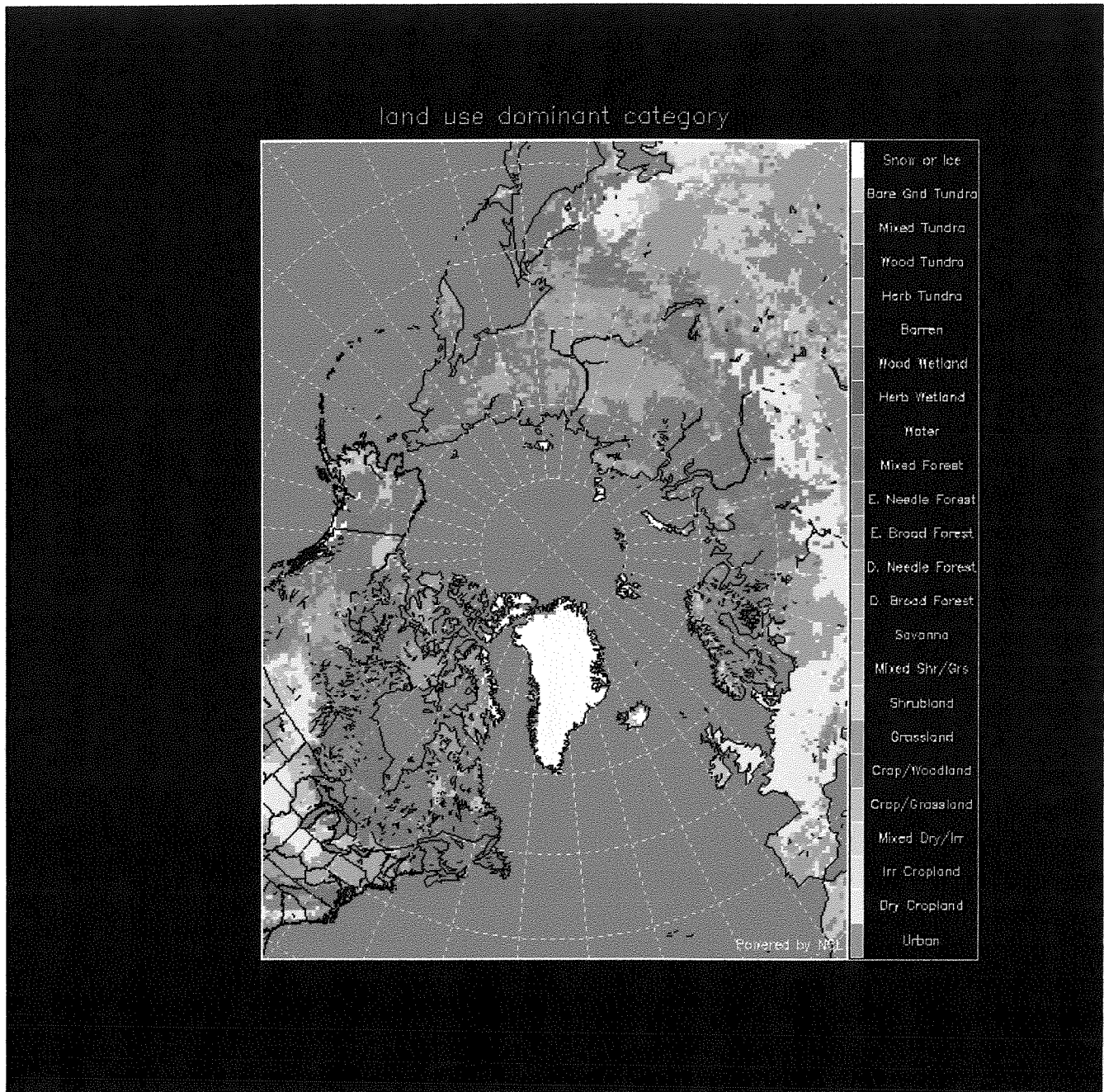


Fig. 8. Dominant Land Use categories as produced by the WRF SI GUI using NCL graphics

12. Joint Center for Satellite Data Assimilation (JCSDA)

CIRA proposed to continue discussions about the use of satellite data in LAPS and RUC. One outcome of this may be the application of these methodologies in a WRF and 3DVAR context.

Principal Researcher: Steve Albers

CIRA scientist participated in discussions about the use of satellite data in LAPS and RUC. One outcome of this may be to apply these methodologies in a WRF & 3DVAR context. To these ends, with our federal partners, a test case for LAPS cloud and other analyses over the RUC 20km domain was run and tested for possible use in the RUC/WRF models. Promising discussion followed a seminar at CIRA given by visiting scientist Hiromi Owada about satellite data assimilation at the JMA in Japan.

13. System Initialization (SI) for the Nonhydrostatic Mesoscale Model (NMM)

The LAPS group has been assigned the task of providing the SI for the NMM from the National Centers for Environmental Prediction (NCEP). The objective of this research is to provide the necessary software to initialize the NMM in much the same way that it is done for the weather research and forecast (WRF) model. Since the NMM is formulated on the Eta grid (Arakawa-B grid rotated 45 degrees), which is completely different from that of WRF or MM5, it requires special subroutines to provide interpolation of initial and boundary fields from a standard grid (e.g., uniform longitude-latitude or Lambert-conformal projection) to the staggered and rotated Eta grid. CIRA proposed to reconfigure the subroutines in order to run NMM in its research environment in the same way as the WRF for a series of tests to compare the performance of the two models.

This effort has been folded into the WRF research (see Section 11 above).

Publications

Koch, S.E., S.G. Benjamin, J.A. McGinley, J.M. Brown, P. Schultz, E.J. Szoke, T.G. Smirnova, B.L. Shaw, D. Birkenheuer, S. Albers, S.E. Peckham, and G.A. Grell, 2004: Real-time applications of the WRF model at the Forecast Systems Laboratory. 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), Seattle, WA, Amer. Meteor. Soc., Paper 12.1.

Koch, S.E., S.G. Benjamin, B.E. Schwartz, and E.J. Szoke, 2004: The value of wind profiler data in U.S. Weather Forecasting. 8th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Seattle, WA, Amer. Meteor. Soc., Paper 6.1.

Shaw, B.L., 2004: An objective inter-comparison of WRF, MM5, and NCEP Eta short-range quantitative precipitation forecasts for the International H2O Project (IHOP) domain. Preprints, 5th WRF/14th MM5 User's Workshop, Boulder, CO, NCAR, 75-78.

Shaw, B.L., S. Albers, D. Birkenheuer, J. Brown, J. McGinley, P. Schultz, J. Smart, and E. Szoke, 2004: Application of the Local Analysis and Prediction System (LAPS) diabatic initialization of mesoscale numerical weather prediction models for the IHOP-2002 field experiment. 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), Seattle, WA, Amer. Meteor. Soc., Paper P3.7.

Shaw, B.L., Kay M., J. Mahoney, J. McGinley, J. Smart, P. Welsh, A. Wildman, J. Savadel, P. Bogenschutz, and P. Ruscher, 2004: *Applying the Weather Research and Forecast (WRF) Model to National Weather Service Forecast Office operations*. 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), Seattle, WA, Amer. Meteor. Soc., Paper P1.2.

Szoke, E.J., J.M. Brown, and B. Shaw, 2004: *Examination of the performance of several mesoscale models for convective forecasting during IHOP*. 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), Seattle, WA, Amer. Meteor. Soc., Paper J13.6.

Szoke, E.J., B. Shaw, P. Schultz, and D. Barjenbruch, 2004: *Performance of various operational and experimental numerical forecasts for the March 2003 Colorado snowstorm*. 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), Seattle, WA, Amer. Meteor. Soc., Paper 10.3A.

Wesley, D.A., G. Poulos, J. Snook, E. Szoke, M.P. Meyers, G. Byrd, R.A. Rozumalski, and H. McIntyre, 2004: *Mesoscale model simulations in quasi-forecast mode of the great western storm of 16-20 March 2003*. 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), Seattle, WA, Amer. Meteor. Soc., Paper 5.3A.

Zeller, K., J. McGinley, N. Nikolov, P. Schultz, B. Shaw, S. Albers, and J. Snook, 2003: *A Consortium for Comprehensive Mesoscale Weather Analysis and Forecasting to Monitor Fire Threat and Support Fire Management Operations*. 5th Symposium on Fire and Forest Meteorology Orlando, FL, Amer. Meteor. Soc. [Html](#),

Presentations:

July (Ed Szoke): *Warning Decision Training Branch (WDTB) Winter Weather Workshop, held at COMET in Boulder.*

October: *COMET COMAP course, Boulder (Albers, Szoke). Albers presented a lecture on "The fusion of radar and satellite data with other information in the LAPS analyses". This includes the use of satellite image data in the cloud analysis.*

December (Ed Szoke): *Meteorological Service of Canada's (MSC) Fourth Winter Weather Forecasting Course, COMET, Boulder.*

January (Ed Szoke): *Two talks at 20th Conference on Weather and Forecasting (WAF)/16th Conference on Numerical Weather Prediction (NWP), AMS 2004 Annual Meeting, Seattle.*

February (Ed Szoke): *USWRP Cool Season Workshop, NCAR, Boulder.*

June: *2nd International IHOP_2002 Science Workshop, Toulouse, France.*

Additional reports and LAPS information may be found on the [LAPS Presentations Page](#).

V. Research Collaborations with the Technology Outreach Division

Note: All CIRA research activities in the Technology Outreach Division fall under NOAA Goal 3 (Serve Society's Needs for Weather and Water Information).

Keywords: FX-Net Workstation; Fire Weather Forecasting Support; IHOP Forecasting Support; Temperature and Air Quality (AIRMAP) Forecasting Support; Wavelet Transform Data Compression Technique

A. FX-Net Project

FX-Net is a real-time meteorological workstation that creates and provides WFO-Advanced products over the Internet. There were a number of significant development milestones defined for the upcoming year:

1. NWS/Regions—Fire Weather Forecasting Support and Support of Remote Forecast Offices with AWIPS products

FX-Net systems have been installed at four NWS Regional Headquarters (Western, Southern, Pacific, and Alaska), as well as at CIRA, the Colorado State University Department of Atmospheric Science, Plymouth State College Meteorology Lab, and at the University of Northern Iowa Department of Earth Sciences. FX-Net will be used in the field to support IMETs with fire weather forecasting. FX-Net would also be used in remote data collection and forecast offices, which traditionally did not have any access to AWIPS products. CIRA proposed additional research be conducted by the FX-Net team to improve the transmission of FX-Net products via very low bandwidth (below 28 kbs), typically found in the Pacific and Alaska region. FX-Net development would also focus on providing additional products (like high-resolution visible satellite imagery and local high-resolution forecast models) and new functionalities.

Principal Researcher: Sher Schranz

During the 2003 fire season, FX-Net server systems were installed in four of the National Weather Services' Regional Headquarters offices. NWS Incident Meteorologists (IMETS) and remote area forecasters in the Western, Southern, Alaska, and Pacific regions became real-time FX-Net users. During a very active wild fire season, the Western Region deployed IMETS to fire sites across the United States. At one point, there were 32 IMETS in the field using FX-Net as their primary forecasting system. The NWS IMETS were deployed using FX-Net over a variety of communications systems ranging from two-way satellite phones to low-bandwidth dial-up lines. The requirement that the system support any type of communication link at any speed was validated during its rigorous use during the '03 fire season.

2. NIFC/GACC Fire Weather Support

FX-Net would continue to play the role of the primary meteorological workstation used by the meteorological staff at NIFC and in the GACC offices. During fiscal year 2003/04, the FX-Net team would also develop the following additional functionalities:

- Complete Text Product List
- Create the ability to change thickness of contours and line styles, one parameter at a time
- Create the ability to change individual product density
- Improve time matching and overlay performance
- Retain background map color during procedural recall
- Provide additional radar angles [1.5°, 2.4°, 3.5° + other radar products]

Principal Researcher: Sher Schranz

The National Interagency Fire Center (NIFC) requested (in 2001) that FX-Net be modified to permit its use as the primary real-time meteorological workstation by fire weather forecasters at NIFC and at the Geographic Area Coordination Centers (GACC). The plan called for the FX-Net workstation to be used during the 2002 fire season on an experimental basis, with the FX-Net server located at FSL in Boulder. After its experimental use during the 2002 wild fire season, FX-Net was used operationally during the 2003 season.

The FX-Net system was very reliable during the 2003 fire season. No data or system outages were experienced during this period. The FX-Net team worked very hard to continue to make improvements and add data and features to the FX-Net system during a year that saw significant changes in management and technical personnel. Still, system reliability was maintained and new tools and data were added to the system on schedule. Exciting new data sets such as GPS IPW and the Cooperative Agency Profilers were added through FSL's Meteorological Analysis and Data Ingest System (MADIS), along with new air quality data sets.

FX-Net proved to be a critical component for the fire management team struggling to save lives and control the fires in California last fall. (See Figure 1 for a photo of a fire coordination session.) In a conversation with Rich Douglas, the Chief of the Meteorological Services Division at the NWS Western Region Headquarters in Salt Lake City, Utah on Wednesday, October 29, he was quoted as saying "The FX-Net system is heavily used; to the IMETS, it's the most critical system they have." He went on to say that "The real-time wind and radar data display capability the FX-Net system gives the forecasters is incredibly critical to the fire management team's efforts to get fire fighters in the right position on the fire line and in moving people out of harm's way." He went on to say that, "FX-Net has had a huge impact on improving firefighter safety".

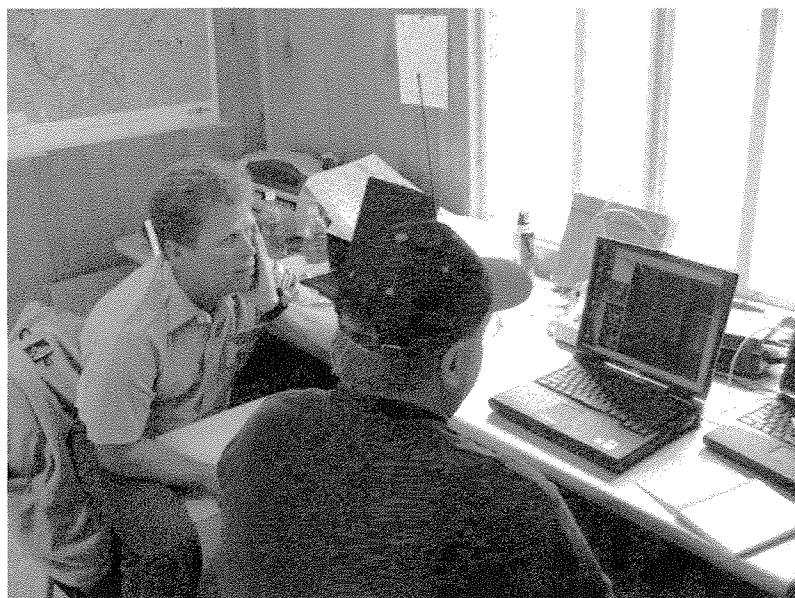


Fig. 1. NWS Incident Meteorologist briefing a Fire Fighter Coordinator using FX-Net during the 2003 California fires.

3. Support of BAMEX Field Experiment

During the past year, FX-Net has become an integral part of several large-scale meteorological field experiments (e.g., IHOP and TAQ). CIRA proposed to support the upcoming BAMEX experiment during the summer 2003 in a similar fashion. A special BAMEX FX-Net server would be configured and the FX-Net team would customize the workstation in order to serve high-resolution products for the regions of BAMEX interest.

Principal Researcher: Sean Madine

In support of the UCAR-sponsored BAMEX project, CIRA proposed to perform the following research tasks:

--Configure the standard FX-Net system to produce four BAMEX specific regional (partially overlapping) radar mosaic domains at 2-km resolution. SBN (level III) radar data will be projected on these sub domains based on desired specification (latitude/longitude corner points and projection type).

--Produce a latitude/longitude readout from cursor location.

--Provide assistance and consultation related to the operational FX-Net support and products during the 2-month field experiment.

The CIRA team completed the following support:

The AWIPS localization was configured to provide the appropriate scales and data sets as defined in task (1). Dr. Morris Weisman of NCAR provided the scientific input regarding the creation of the BAMEX specific scales.

One FX-Net workstation and one AWIPS data server were dedicated to operations for the duration of the BAMEX project. The data server was configured to receive the basic Satellite Broadcast Network (SBN) data feed as well as a number of internal FSL "special" data sets. Both servers were integrated into the operational monitoring system of the Central Facility at FSL. Troubleshooting documentation was provided to the operations staff to help ensure system availability to the BAMEX researchers.

All of the previously released features of the FX-Net system, including the newly developed latitude/longitude readout defined in task (2), were provided in the BAMEX client release.

A training session was conducted for the BAMEX researchers on 5/8/03. The 2.5-hour workshop, which was held at UCAR, began with the installation of the new client on designated laptops. The researchers were then guided through a 'hands on' tutorial that highlighted the main features of the system. The development team made some modifications to the source code and configuration in response to some minor bugs identified during the training session. The final version of the FX-Net client was then provided to Steve Williams for distribution to the BAMEX researchers.

According to internal system and operator logs, the FX-Net server had very close to 100% availability during the entire BAMEX exercise (5/15/03 – 7/15/03). Typical FX-Net usage consisted of approximately seven researchers per day utilizing the system.

B. Wavelet Transform Application Research

During 2002, much effort was exerted by CIRA researchers to improve the existing wavelet data compression code with the goal to achieve even higher compression ratios. The routine was also rewritten in order to improve its run time, which is an important aspect for its operational applications. A major new milestone was achieved with the introduction of the so-called "precision-control." Precision control allows the user to define what the acceptable maximum or average error for the compressed and reconstructed data set should be. Extensive studies were conducted using the original Eta 12 forecast model.

During the upcoming fiscal year, development efforts would focus on the following two aspects of the data compression scheme:

1) The approach to control the maximum round off error is computationally simple (or somewhat ad hoc). It is feasible with the current operational environment; however, to create an ideal algorithm that should be able to find the best bits allocation that minimizes the maximum error. An efficient algorithm that finds that allocation is very useful both in theory and in practice.

2) The adjacent vertical and time-dependent frames are highly correlated. Current results only reflect the compression performance of this scheme on the two-dimensional field (in the horizontal plane). We can apply three- or four-dimensional separable wavelet transform to the volume data. To meet the robust (error propagation control) requirement, CIRA researchers can possibly encode each partitioned group of coefficients individually into an independent bit stream to build a more error-resilient code.

The above technological advancements will feed directly into this workstation developments. Compression ratios of the above magnitude now allow for sending high-resolution forecast models (with typical model outputs sized at 1 GB and larger) via low-bandwidth to an FX-Net or WorldWide Weather Workstation (W⁴) client in very reasonable amounts of time. This would make satellite broadcasting mechanisms (with a bandwidth of 128 KBs or less) for meteorological data sets feasible.

Principal Researchers: Ning Wang and Sher Schranz

A new version of the wavelet data compression has been applied to the FX-Net Project to more efficiently compress the satellite and model images, and to reduce the file encoding and decoding time. A Java decoder has been developed for FX-Net client. It has been tuned and optimized to reduce the Java garbage collection operations, thereby speeding up the overall image downloading time. Extensive documentation of the proper startup and shutdown of an entire FX-Net system, logging capability, the client build process, and the new Client tools were developed. A new version of FX-Net was fielded at the National Interagency Fire Center, Southern and Western National Weather Service Regional Headquarters offices. This year, two new versions of the FX-Net Client software were delivered to the University of New Hampshire, Plymouth State College, the University of Northern Iowa, and to researchers throughout NOAA. Figure 2 shows one of the new data sets added, GPS IPW, overlaid on a GOES IR in Water Vapor image.

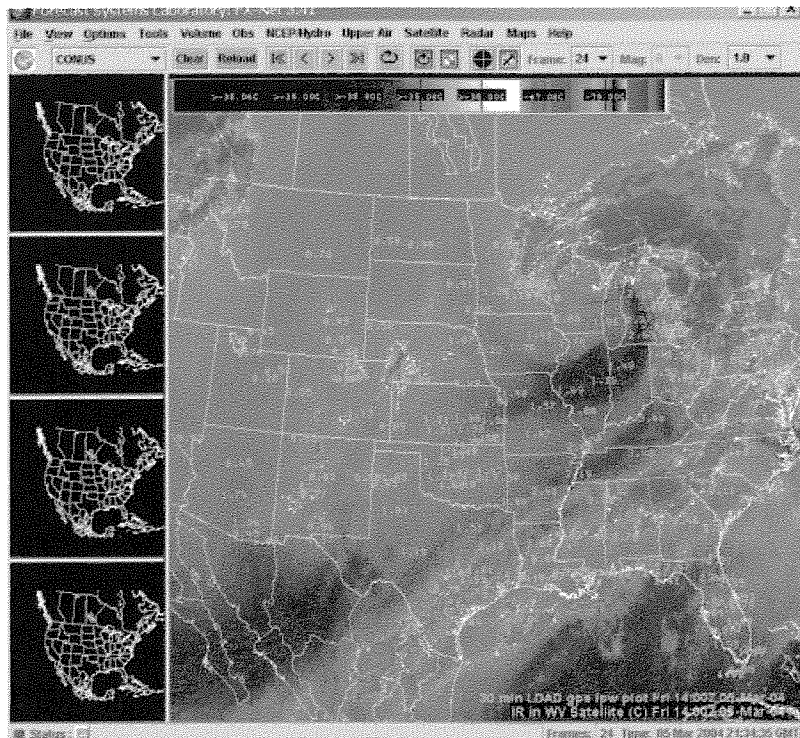


Fig 2. GOES IR in Water Vapor image overlaid with GPS-IPW data

New tools were also added to enhance forecasters' presentation capability. Figure 3 shows how the new selective line thickness tool can be used to enhance model contours. Other tools added include the ability to select the density of an individual observation or model contour graphic, or select all fields at all display times.

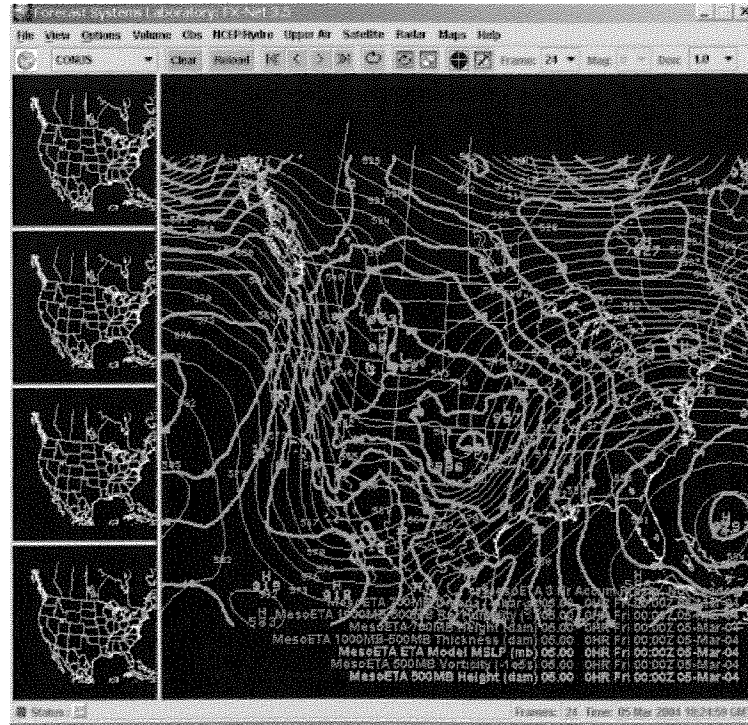


Fig 3. Selective line thickness for model graphics on FX-Net Display

Air Quality Programs

For the last few years, FX-Net had been supporting the AIRMAP (Atmospheric Investigations, Regional Monitoring, Analysis, and Prediction) Program. As a newly established Cooperative Institute between the University of New Hampshire (UNH) and NOAA, AIRMAP focuses on the long-term monitoring and forecasting of air quality parameters such as nitrogen oxides, sulfur dioxide, carbon monoxide, and low-level ozone. These pollutants can be hazardous to human health and other organisms when present in the lower atmosphere. Many of these chemicals are the result of burning fossil fuels, and are responsible for New Hampshire's high levels of acid rain. The primary mission of AIRMAP is to develop a detailed understanding of climate variability and the source of persistent air pollutants in New England. The availability of a real-time display workstation like FX-Net is very important to the program's success. The FX-Net team modified the existing real-time meteorological workstation by adding air quality-related datasets to the ingest and display system. Additional air quality observation data were added to the FX-Net system in 2003.

The FX-Net/AQ datasets include six parameters (O_3 , CO, NO, NO_y , SO_2 , and condensation particles) that are continuously measured at three UNH sites (Mount Washington, Castle in the Clouds, and Thompson Farm) located in the state of New Hampshire. The FX-Net/AQ user also has access to all of the Cooperative Agency Profilers (CAP). These wind

profilers have been installed around the U.S. by a number of state and local agencies as well as the U.S. Environmental Protection Agency (EPA). Data from the EPA's AIRNOW program are also ingested by FX-Net. These data include one-hour averages of ozone, Particulate Matter- Fine (PM 2.5), and Particulate Matter Coarse (PM 10). See Figure 4 for an FX-Net display of a WRF/Chem (G. Grell, S. Peckham) Ozone forecast image and AIRNOW and AIRMAP ozone observations.

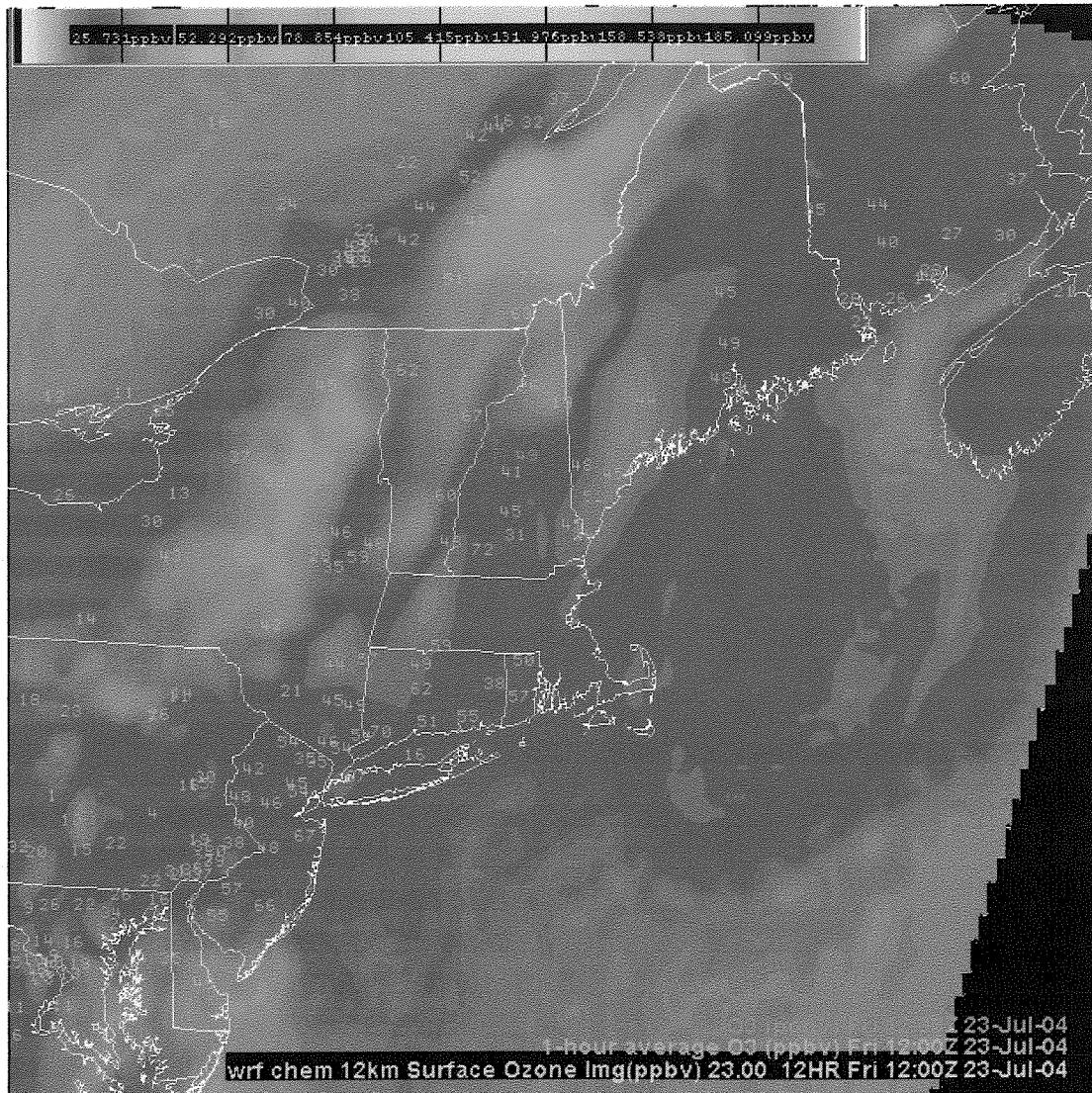


Fig 4. WRF/Chem Ozone forecast image and AIRNOW (EPA) and AIRMAP (UNH) monitoring data

Air Quality researchers from the University of New Hampshire, Plymouth State University, NOAA/ETL and NOAA/FSL, Florida State University, and field forecasters at Pease International Tradeport Airport for the NEAQS - ITCT 2004 will be using the latest version of the Air Quality FX-Net.

Air quality forecasters in the Mid Atlantic Regional Air quality Management Association area began an assessment of FX-Net as a complete real-time air quality forecasting workstation. A formal Pilot Project involving forecasters from Mid Atlantic Regional Air Management Association (MARAMA) agencies and other east coast state and local air quality forecasters will begin during Summer 2004. The results of this study will support the U.S. EPA's decision to fund a national wide demonstration of the use of FX-Net for air quality forecasters in 2005.

VI. Research Collaborations with the Modernization Division

Note: All CIRA research activities in collaboration with MD for the WFO-Advanced, ALPS and RSA projects fall under NOAA Goal 3—Serve Society's Needs for Weather and Water Information. The data processed by the AWIPS data ingest software aids in the creation of the weather forecasts that are distributed to the public. AWIPS also makes data available to the public via Web servers, and plans to continue to develop this capability as a result of the ALPS project.

Keywords: AWIPS Enhancements; Advanced Linux Prototype System; 3-D Lightning Visualization; Hydrologic Modeling; Profiler Data Acquisition

A. Data Ingest Group of the WFO-Advanced Project

CIRA researchers proposed to develop new software in support of the evolution of the WFO-Advanced system. Group members would develop and evolve a data management system for the ingest, storage and retrieval of data from a variety of sources. The software would store the data in several databases and make the data available to CIRA/CSU and FSL scientists as well as external users.

CIRA also proposed to explore new technologies to address the rapid increase in existing meteorological data, the introduction of new data sets, and the integration of these data into the development of the next generation of forecaster workstation—based on Linux instead of the current HPUX system.

Principal Researchers: MarySue Schultz and Joanne Edwards

The AWIPS project, sponsored by the National Weather Service (NWS), has the objective of modernizing the technology used in Weather Forecast Offices (WFOs) in the United States. As part of this effort, the Forecast Systems Laboratory (FSL) developed a data acquisition and display system (WFO-Advanced) which enables weather forecasters to receive and display the large amounts of data needed to produce accurate forecasts, watches and warnings. The WFO-Advanced software was installed at all of the WFOs, and has been running operationally for over 5 years. For the remainder of this report, the WFO-Advanced system will also be referred to as the AWIPS forecast system.

Over the course of the AWIPS project, CIRA researchers in the Modernization Division (MD) have made significant contributions to the data acquisition and data management components of the AWIPS forecast system. These components are responsible for decoding the incoming data from transmission format, and for providing information about the data to the display. Over the last several years, the amount of data that is available to the WFOs has increased rapidly. Model sounding, POES satellite, high density wind, Terminal Doppler Weather Radar (TDWR), 12-km ETA model output, and 12km DGEX model output data have all recently come on-line. One of the objectives stated for the CIRA researchers in MD was to evolve a data management system for the ingest, storage and retrieval of new datasets from a variety of sources. In support of this goal, the data acquisition and data management components were extended, to include the new data

sets mentioned above. New data ingest and storage modules were written, and new retrieval software was developed for displaying the data.

The increasing availability of new data presents interesting problems for a system such as AWIPS. There are limits to how much processing can be done effectively on each machine, and because of the age and cost of the existing hardware, simply adding more machines is not an option. In an effort to alleviate the processing problems, the NWS has decided to use PCs running the Linux operating system, instead of Hewlett Packard machines running HPUX. The PC/Linux option is faster and cheaper, and provides a desirable alternative to HPUX. One of the goals set for the Modernization Division last year was to design methods of integrating new data sets into the next generation AWIPS system, on Linux platforms. As a first step in this direction, the existing data acquisition and data management software was ported to Linux. Before moving the software, extensive testing was performed to prove that the software was stable on Linux, and that all of the data was being decoded correctly on the new platform. Statistics on memory usage, CPU usage, process size, and product storage time were collected and graphed, to determine if there were problems in the areas of performance, accuracy and service levels (service levels is a term that refers to the ability to provide data fast enough to satisfy the users' needs). In addition, the output from the data processing software on the Linux systems was compared to the output from the same software running on HPUX, to detect problems with accuracy. Some problems with byte order and reliability were revealed and fixed; service levels were generally good, and no modifications were needed in that area. After the software passed the testing phase, it was moved permanently to the Linux platforms. The testing techniques developed for this task can also be used in the future to validate new software.

Another objective established for MD was to explore new technologies that can be implemented on Linux platforms to address the ever increasing amounts of data. During the past year, CIRA researchers participated in the formulation of the Advanced Linux Prototype System (ALPS), which focuses on employing new network and database technologies in a redesign of the AWIPS database, and of the data notification software, which advises the AWIPS workstations when new data has arrived. Both of the new designs are expected to help performance by delaying data processing and notification until the data is needed by the forecasters, and by dividing the processing tasks among the numerous Linux machines in the AWIPS system.

The new database design will also involve storing some of the data on central servers that are accessible via the Internet. Software from the Open Source Project for a Network Data Access Protocol (OPeNDAP), developed by Unidata, will be integrated into the ALPS experimental system for testing and evaluation. OPeNDAP currently provides a way for researchers to access data anywhere on the Internet. The ALPS project will evaluate whether or not this technology can be applied to AWIPS. During the past year, CIRA researchers designed and began to implement a capability using OPeNDAP software to store and retrieve model output data on the central servers. The new database design also positions the project to be able to make this data available to researchers and outside agencies, which is one of MD's objectives as well.

The new ALPS designs will be tested and evaluated on an experimental AWIPS system. During the past year, the software to be used on the experimental system was designed, and software development began. Next year, the development phase will be completed, and extensive testing will be performed. The results of the experiment will be used to shape AWIPS development in the future.

B. Range Standardization and Augmentation Project (RSA) Software Support

The group will be responsible for exploring new techniques and methodologies for the use of meteorological data in supporting space launch decisions. There will be an emphasis on exploring and implementing new technologies for processing data on Linux platforms.

Principal Researcher: MarySue Schultz

The RSA project is a collaboration between the Air Force, Lockheed Martin and FSL. The purpose of the project is to provide Air Force launch sites with technology based on the AWIPS system, to aid in weather forecasting responsibilities at the sites. Collaboration involving CIRA researchers in MD has been to develop data processing capabilities for the forecast systems installed at Cape Canaveral in Florida, and at Vandenberg AFB in California.

During previous years, MD developed and installed data processing software on Linux systems at both sites to handle data collected from instruments such as radars, local lightning detection systems, and local towers. At the same time, new 3-dimensional display software (D-3D) was being developed by the Systems Development Division of FSL, to display lightning data at Cape Canaveral. The 3-dimensional display was a new concept for Cape Canaveral, and D-3D was developed carefully with much experimentation and testing.

The goal for MD for 2003/2004 was to continue to explore new techniques and methodologies for the use of meteorological data in supporting space launch decisions. There was an emphasis on exploring and implementing data processing technologies on Linux platforms. MD's accomplishments during the past year in support of these goals involved integrating the lightning data feed with D-3D. The display was connected to the real-time data feed for the first time, and both the ingest and display software were subjected to a series of tests prior to installation at the Cape. CIRA researchers conducted tests of reliability and performance, verifying that the software was stable over a period of several weeks, and that there were no noticeable problems. The 3D capability was installed at Cape Canaveral in April, 2004 just prior to their severe weather season. The capability was introduced at the operations center there as an experimental system, with the goal of integrating it into real-time operations within the next year.

Publications

Wakefield, J.S., P.A. McDonald, M.S. Schultz, J.E. Ramer, and X. Jing, 2004: Processing and display of atmospheric electricity data to support launch operations at the Eastern Range. AMS 11th Conference on Aviation, Range, and Aerospace Meteorology and the 22nd Conference on Severe Local Storms, October 4 – 8, 2004, Hyannis, MA.

C. Enhanced Forecast Methodologies

CIRA scientists currently collaborate with FSL on an Interactive Forecast Preparation System (IFPS). They are designing and building a graphical forecaster support system for maintaining a gridded database of forecast weather elements. A goal of the IFPS designers would be to minimize forecast preparation time and to maximize forecasters' ability to interact with the data, thus allowing more time to focus on the art and science of forecasting. Starting with the current forecast database and/or gridded fields initialized from existing weather analyses/forecasts or central guidance, and using a set of highly interactive and configurable applications, forecasters would visualize and modify surface sensible weather elements. Product generation utilities would then format the digital forecast data into a wide variety of graphical, gridded and text-based products with little additional effort from forecasters. CIRA proposed that this collaboration continue.

Due to severe funding cutbacks, this proposed collaboration was eliminated. Instead, a modest effort at obtaining forecaster feedback on their operational use of meteorological workstations was initiated. Implementation of training activities and User's Guide to help ensure optimum use of AWIPS in WFOs is also a part of this new initiative.

Publications

Roberts, W.F., and L. K. Cheatwood, 2005: Examples of GFE Suite and D2D Use in operations during 2004. 21st International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 9-13 January 2005, San Diego, CA

D. Advanced Development

The primary goal in this research partnership is to keep abreast of advanced technology and apply it to CIRA and FSL research results, particularly with regard to how it can be effectively used to develop the next generation of forecaster workstations. This has many aspects including configuration management, development applications and innovative systems studies, new programming languages, and techniques. Advanced Development staff research these areas and prototype promising technologies. The applied, joint research efforts result in new, innovative applications of these advanced technologies.

Several initiatives in collaboration with the Decision Assistance Branch at the NWS Meteorological Development Lab would include:

- Porting of SCAN (System for Convection Analysis and Nowcasting) into AWIPS to better integrate weather surveillance radar data for short-term severe weather analyses and forecasts
- Integrating MDL's FFMP (Flash Flood Monitoring Program) into AWIPS for hydrologic forecast and emergency management support
- Porting of NCAR's auto-nowcaster application (Cumulus Cloud Growth) algorithm into SCAN's nowcasting capability for 30- and/or 60-minute forecasts and displaying forecast products on D2D
- Investigating various GIS datasets to improve FFMP usability

Principal Researcher: Scott O'Donnell

All of the research activities described under this project supports NOAA Goal 3 (Serve Society's Needs for Weather and Water Information). During the past year, MDL's SCAN AWIPS application was ported for use on the CWB (Central Weather Bureau) WINS weather forecasting workstation. This task was facilitated by the collaboration with a CWB visiting scientist who reviewed existing SCAN and AWIPS software and assisted with the details of migrating the software to work with the CWB AWIPS-like WINS system.

This required the creation of a database of GIS datasets necessary to run SCAN and display SCAN's products. The GIS datasets included but were not limited to background vector maps (Country, Province, & County scales), a 'significant places' location map, a cities location map, etc. These data were acquired from publicly available data sets, many published on the Internet. Most data sets required coordinate transformations, attribute filtering, and extensive preprocessing to collect and format the data appropriately. Finally, programs were transformed to create the deliverable GIS data files.

The AWIPS localization scripts were designed to install SCAN data sets exclusively onto the US domain. The CWB SCAN localization scripts required a complete rewrite for a CWB installation. Several other scripts required less significant modification before a successful installation was achieved.

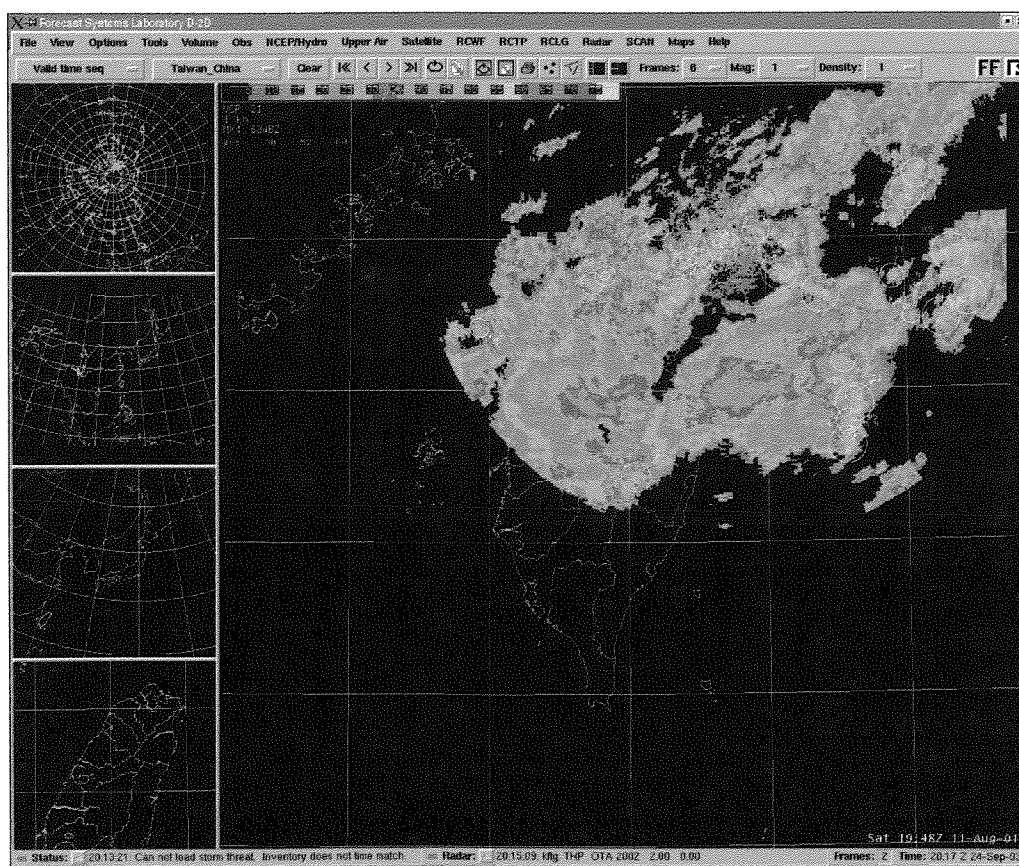


Fig. 1. An example display of SCAN on a realization for Taiwan's CWB

At the same time, in a parallel development effort, the KMA (Korean Meteorological Administration) is attempting to implement SCAN for their FAS (Forecaster Analysis System), an AWIPS-like weather forecasting workstation. Unlike CWB, all of the KMA radars are non-NEXRAD S-band and C-band radars, requiring a suite of applications to convert the raw, unprocessed weather surveillance radar data to be processed into the NEXRAD products (VIL, CZ, base Z) required by SCAN. This development requires a similar action as that conducted for CWB in the creation of a database of GIS datasets, and similar, but unique, localization scripts for the installation of SCAN and the GIS datasets.

MDL's FFMP software required a new capability to aggregate its small basin database into arbitrarily larger, hydrologically consistent, catchments. This was to be done using the Pfafstetter basin classification system and a hydrologically provided network. The Pfafstetter naming scheme implies catchment connectivity. This solution is being utilized in the AWIPS OB5 software release.

This project is in the early stages of porting of NCAR's auto-nowcaster application (the Cumulus Cloud Growth algorithm) into SCAN's nowcasting capability to enhance 30- and/or 60-minute forecasts. Resulting products will be displayed on AWIPS' D2D workstation. Algorithm development is being researched, data sets are being analyzed, and decision trees are being designed for this software implementation.

Various GIS tasks have been explored. The Basin Aggregation solution for FFMP grew out of this activity. Another outcome is the ability to dynamically define the upstream contributing area of a user selected point on the AWIPS display, and to plot the downstream flow path. This is a display the NWS weather forecasters have requested and should be included in FFMP in the AWIPS OB6 release.

There are several requests to explore distributed hydrological modeling and assess the level of effort necessary to develop a hydrologic model. While several interesting hydrologic models exist, the primary difficulty is in the identification of available datasets and other GIS resources for the necessary terrain model. While elevation data are generally available at a fairly coarse but adequate horizontal scale and vertical resolution, other necessary data sets are more difficult to obtain that completely cover the forecast area. Additional necessary datasets include land use, vegetative cover, soils classification, soil moisture measurements, river mappings and stream cross-section descriptions, etc. These parameters can be approximated, but the quality of data significantly affects the modeled results.

In a specific GIS exploration for KMA, a Basin Watershed database was created from existing elevation data sets. A sub-sampled equivalent database was then produced to determine if an improved watershed and stream network database could be produced using some newly available GIS techniques. A high resolution spatial terrain model is required to generate a detailed basin database to be used with FFMP. The results of the experiment were very good and the techniques will be used in other investigations where the scale of the data are fairly coarse and a finer grid resolution would produce better analysis and/or visualizations.

Additional planned activities include investigations into applying advanced technology to create a more efficient distributed processing architecture to support the NOAA Profiler Network and the national deployment of these profilers.

Principal Researcher: Robert Prentice

CIRA research includes development of software that supports atmospheric profiler data acquisition and quality assurance. This software is critical to supporting the wide distribution of profiler data to many government agencies. The NOAA profiler network (NPN) is one of the most effective means of gathering atmospheric wind data in support of weather forecasting and modeling activities. This fact is supported by an in-depth analysis performed for a COEA (Cost and Operations Effectiveness) report developed for Congress this year. A technical review of the project, recently presented to FSL by the Demonstration Division, emphasized both this point and the strong correlation between the profiler project's goals and NOAA's strategic plan and Goal 3 (Serve Society's Needs for Weather and Water Information). See <http://profilers.noaa.gov/jsp/presentations.jsp> for details. Fig. 2 below shows the locations of CAP and NPN profilers in the U.S.

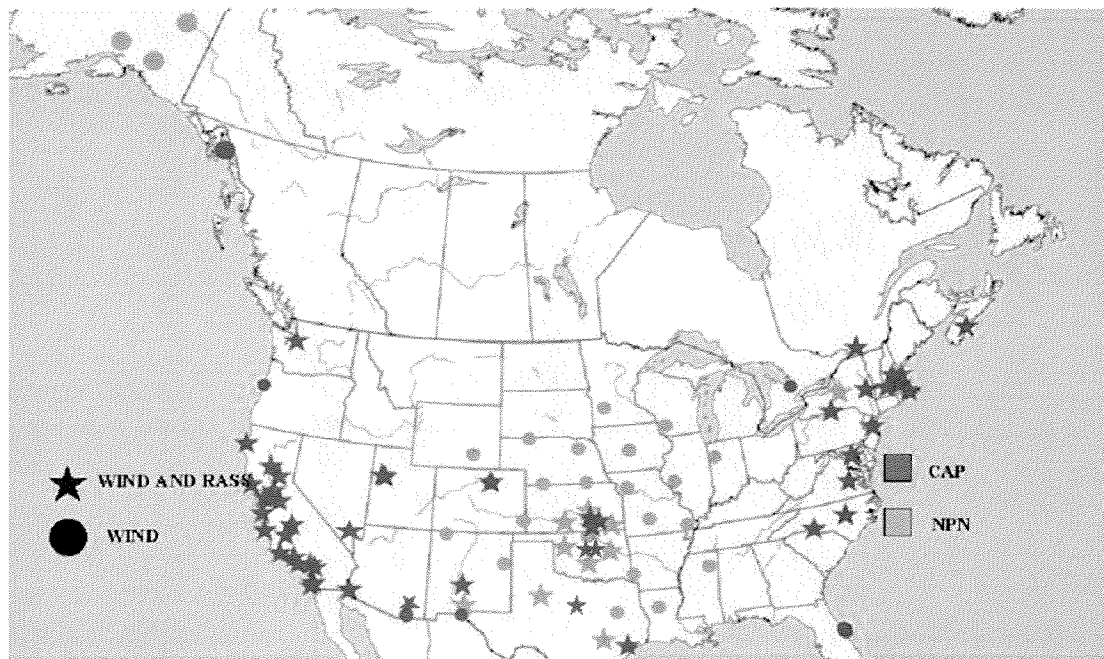


Fig 2. Locations of CAP and NPN profilers in the U.S.

CIRA research involves both the design of software to efficiently handle profiler data, and the application of engineering practices to the software environment supporting the profiler observation network. The recent focus of software development has been to replace an aging VAX hub system, which runs vintage FORTRAN software, with a more modern Java-based implementation running on a number of Linux and Windows servers. A second thrust has been the continuing support of an ever-expanding network of Cooperative Agency Profilers (CAP) systems.

All new software design efforts must necessarily take place in an environment where the support of an existing operational system and retaining the ability to incrementally upgrade

existing software are always a priority. One of the priorities for CIRA researchers have been to bring the incremental upgrade process under release control, so that personnel can more efficiently and reliably maintain the state of the system. This comes as increasing security requirements demand frequent upgrade of operating systems and software services.

CIRA's contribution has helped such upgrades to become routine and reliable operations. CAP software has been isolated from hub replacement software, and has been placed under revision control. It can be installed onto upgraded systems as needed, but will not be substantially altered until it can be re-engineered to be more compatible with the hub replacement software architecture. Hub replacement software is under automated build and release control, and is where active development is focused.

Standardizing software build, release, and installation processes has been challenging because of the unique needs of the profiler group. The software supporting the profiler observation network is a mix of Java, Perl, shell script, and system configuration files that are used on both Linux and Windows platforms. This mixed environment poses special requirements that are best automated so that operators and developers need not keep painstaking track of such details. One by-product of this work has been the generation of a software library that facilitates the development of Perl scripts that run identically on Windows XP and Linux platforms.

One of the biggest challenges of standardization has been one of bookkeeping. Prior builds had been incremental, manual installations. Systems contained many versions of files, only some of which were in current use. Changing development practices to the point where the state of all production systems are documented by a release process, and where production systems are protected by automated software release and installation processes, was a major undertaking. Production systems now contain only a single current set of software files, and the release/installation process can easily be rehearsed on development machines prior to use in production.

On another note, FSL has long had an obligation to convert 10+ years of historical profiler data into an updated format for use by the National Climatic Data Center (NCDC). CIRA researchers have taken the lead to perform this conversion, which has involved bringing together disparate software components, bridging design incompatibilities between them, and adding code that helps them to work together. Testing of this conversion code is nearing completion. This task, while important in its own right, has presented an opportunity to expose developers to the intricacies of existing profiler software. This has improved our ability to make the latest software architecture a more effective one.

A new product-based architecture is being introduced to greatly simplify profiler data management. Data collection, processing, and dissemination are broken down into processing steps that interact through the transmission of internal data products. Such products all conform to data access and communication standards that make them easily accessible to software processes. These processes can be easily adapted and rearranged to satisfy an abundance of unique requirements for various data streams. The result is an ability to better manage a system that must handle data from a wide variety of sites, process it in a variety of ways, and provide it in different forms to various data consumers.

VII. Research Collaborations with the Systems Development Division

CIRA proposed continued research collaboration to investigate, design, develop and test advanced meteorological workstation display software. The emphasis within SDD is on the exploratory development of new user interface and data rendering aspects of meteorological workstations.

Keywords: 2-D and 3-D Workstation Visualization; Science-on-a-Sphere Graphical User Interface

A. 2D Display (D2D) Development

The D2D display software and associated data storage software has become the central visualization component of the NWS AWIPS system. CIRA, collaborating with SDD, proposed to continue to augment this software base with novel data sources and visualization approaches. In some cases, these new capabilities would be driven by new requirements arising from the adaptation of AWIPS by organizations other than the NWS. For example, CIRA researchers expect to continue customizing AWIPS for the RSA project to meet weather forecast requirements at the Vandenberg AFB and Cape Canaveral space launch facilities. CIRA would also be continuing to implement new AWIPS algorithms and approaches for the NWS warning program. The results obtained from these visualization and customization approaches provide CIRA researchers alternative ways to view and interpret observational data and the meteorological environment.

Principal Researcher: Michael Biere

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-Connect workstations. CIRA researchers continued to extend and maintain the WFO-Advanced workstation capabilities, mainly in conjunction with AWIPS and RSA projects. This activity directly addresses NOAA Goal 3—Serve Society's Needs for Weather and Water Information.

The major new capability added to the AWIPS software base by CIRA researchers this year was the handling of Valid Time Event Codes (VTEC). These codes are now associated with every text product issued by an NWS forecaster, and provide a way of linking the possibly multiple text products, watches, warnings, and updates associated with a single weather event. Creation and management of VTECs required substantial changes both to AWIPS warning generation software and the text workstation component of AWIPS.

CIRA also continued to provide routine software maintenance support and bug-fixes to the AWIPS software, as well as software configuration management support for local developers working on AWIPS.

Some preliminary research into adding distributed data capabilities to AWIPS was started by CIRA researchers. They investigated the feasibility of using Unidata's OpenDAP distributed data model within AWIPS. While such an approach appears technically feasible, the performance aspects are not easy to predict and will require further research and prototyping to resolve.

B. 3D Display (D3D) Development

CIRA proposed continued development of D3D applications on Linux platforms. Previous experimentation with 3D visualization of radar and high-volume lightning data is expected to be integrated with modifications to the AWIPS system being used for the RSA project. Further research into the use of D3D in operational meteorological scenarios was also expected.

Principal Researcher: Phil McDonald

The Display-3D (D3D) workstation has the goal of providing an advanced meteorological workstation for operational forecasters with interactive three-dimensional visualization of atmospheric data. Although general development of D3D has been suspended, CIRA researchers completed a specialized version of the system for display of 3D lightning data. This activity directly addresses NOAA Goal 3--Serve Society's Needs for Weather and Water Information.

As part of the Range Standardization and Automation project, an operational user interface and data visualization display application for high-volume three-dimensional LDAR (Lightning Detection and Ranging) data was delivered and deployed as a replacement for the LDAR display at Cape Canaveral.

No further CIRA research in this area is currently anticipated.

C. Virtual Reality Research

CIRA proposed to apply meteorological workstation expertise to a relatively new science project initiated at FSL: Science On A Sphere (SOS). This project takes a three-dimensional visualization of global data sets and reconfigures it as a realistic animated globe. These research activities would focus on experimentation and development of new approaches for graphical user interfaces for SOS, as well as novel visualizations of global weather phenomena.

Principal Researcher: Mike Biere

The NOAA Science on a Sphere (SOS) project displays and animates global data sets in a spatially accurate and visually compelling way, on a 6-foot spherical screen. It addresses NOAA's cross-cutting priorities of environmental literacy, outreach, and education. CIRA provides key technical support to the project, particularly research into effective user interfaces for the system, and new visualizations.

Addressing CIRA's goal for the year of experimentation and development of new approaches to graphical user interfaces for SOS, specific accomplishments included development of a simple graphical user interface which, in addition to allowing user

selection of datasets to be viewed, provides for interactive control of the animation via a set of VCR-like controls. A serial-line control protocol was also developed, allowing control of SOS by other computers as an integrated and coordinated part of larger museum displays. CIRA also developed a wireless remote control for SOS, allowing a single presenter to run the system without needing a separate operator. Improvements to projector alignment procedures were also made by finding a technique to measure and compensate for slight distortions in the spherical screens used for projection.

A second CIRA goal for the year was developing novel visualizations of global weather phenomena. A real-time global IR satellite display was developed, including Internet data distribution to remotely located SOS systems. A CIRA researcher also developed several dramatic new in-the-round visualizations from NASA data of other bodies within our solar system, including Jupiter, Io (Fig. 1), Venus (Fig. 2), and Europa.

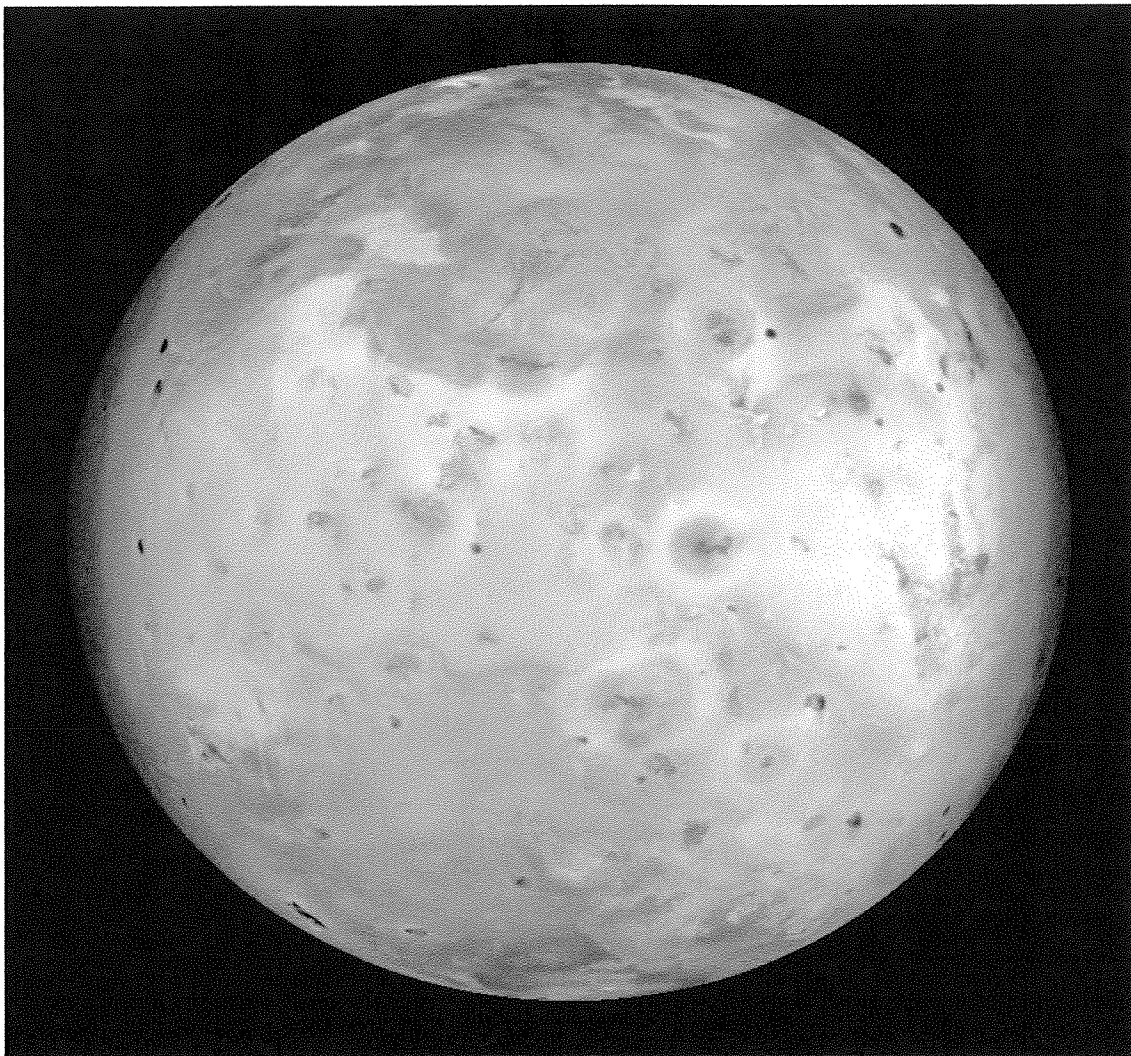


Fig. 1. A picture of Jupiter's Moon Io ready for display on SOS

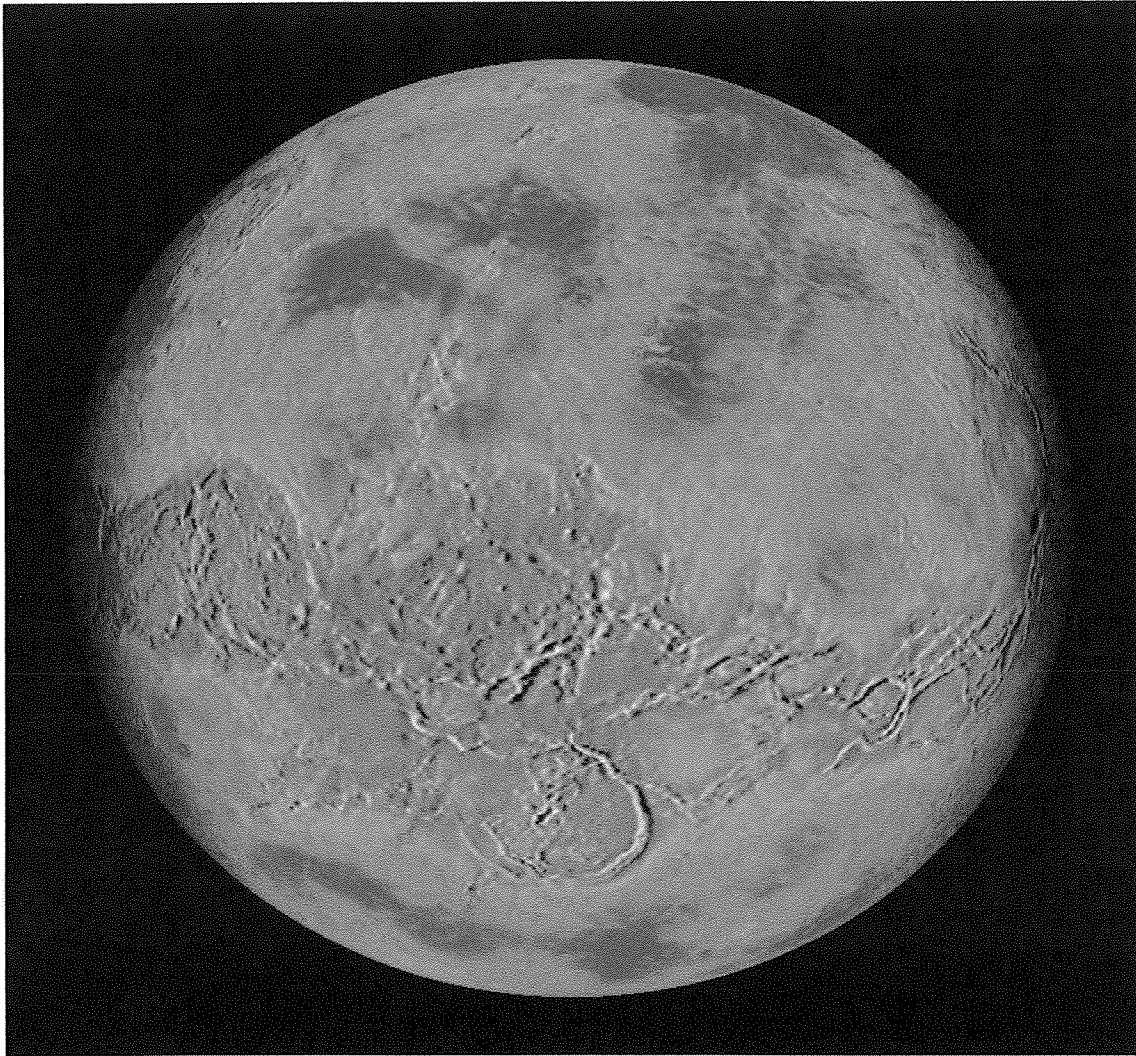


Fig. 2. Pseudo-color topography image of Venus, processed for viewing on SOS

EXAMINATION OF LINKAGES BETWEEN THE NORTHWEST MEXICAN MONSOON AND GREAT PLAINS PRECIPITATION

Principal Investigator: William R. Cotton; Stephen M. Saleeby, Co-PI

NOAA Project Goal: Climate

Keywords: Monsoon, regional scale simulations, PV anomalies, moisture surges

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

The primary objective of this project is to examine the dynamics of the North American Monsoon System (NAMS) in terms of monsoon onset and individual surge events and how this influences precipitation in the southwest U.S (NAMS upward branch), and the U.S. Great Plains and Midwest (NAMS subsiding branch). The Colorado State University - Regional Atmospheric Modeling System was used to investigate the southwest monsoon in the Great Plains drought year of 1988, the Mid-West flood year of 1993, and the strong El-Nino year of 1997. Sensitivity studies of the monsoon were performed to investigate the role of antecedent precipitation and soil moisture to the development of precipitation over the monsoon source region and the subsiding branch in the United States. Sensitivity studies of the monsoon were also performed to look at the role of sea surface temperatures (SSTs) to the monsoon.

2. Research Accomplishments/Highlights:

- The model was able to characterize the interseasonal variability for the years 1988, 1993, and 1997 very well
- It was found that soil moisture anomalies had a greater impact than SST anomalies on the monsoon circulations and precipitation
- The model simulated the development of PV anomalies periodically over northwest Mexico from monsoon-initiated convection. Given appropriate synoptic conditions these anomalies may propagate downstream around the periphery of the monsoon ridge, strengthen with convection to the lee of the Colorado Rocky Mountains. The PV anomalies initiate a jet streak, which forms transverse circulations and mesoscale ascent which helps drive the developing MCS, which, in turn, further intensifies the positive PV anomaly. Identification and tracking of such features may provide an aid to quantitative precipitation forecasting in the future.

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

We met the majority of the proposed objectives and had the added benefit of identifying PV anomalies associated with monsoon convection over Mexico.

4. Leveraging/Payoff:

The research demonstrated the potential for up to three day forecasts of monsoonal convection using mesoscale models. It showed that determination of antecedent precipitation and mesoscale patterns of soil moisture is very important to the predictability

of the system. In addition, key features associated with convection over Mexico during the monsoon such as PV anomalies provides a potential tool for precipitation prediction for periods of two to three days over the Rocky Mountains and central U.S.

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

Collaborated in the design of NAME.

6. Awards/Honors: None at this time.

7. Outreach: Graduate student Steve Saleeby is a PhD candidate at CSU who was a major contributor to this research. Research results were presented at the meetings listed below in the publications section.

8. Publications:

Refereed

Saleeby, S.M. and W.R. Cotton, 2004: Simulations of the North American Monsoon System. Part I: Model analysis of the 1993 monsoon season. *J. Climate*, 17, 1997-2018.

Saleeby, S.M. and W.R. Cotton, 2004: Simulations of the North American Monsoon System. Part II: Interseasonal variability and sensitivity to soil moisture and sea surface temperature. *J. Climate*, In revision.

Professional Meetings

Saleeby, S.M., and W.R. Cotton, 2001a: Examination of the Linkages between the Northwest Mexican Monsoon and Great Plains Precipitation." GAPP PI Meeting, Washington D.C., May 2001.

Saleeby, S.M., and W.R. Cotton, 2001b: Examinations of Linkages between the Northwest Mexican Monsoon and Great Plains Precipitation : Model Configuration and Performance For Initial Test Simulations. Presented at AGU Fall Meeting San Francisco, CA, American Geophysical Union, Dec 10-16, 2001.

Saleeby, S.M., and W.R. Cotton, 2002: Examinations of Linkages between the Northwest Mexican Monsoon and Great Plains Precipitation: Characteristics of Surge Events and Low to Mid-level Moisture Transport into the U.S. Southwest and Rocky Mountains. Presented at GAPP - Mississippi River Hydrology Conf New Orleans, LA, May 13-17, 2002.

Saleeby, S.M. and W. R. Cotton, 2003a: Impact of the Northwest Mexican monsoon on precipitation in the Central United States: A moisture and PV transport perspective. Proceedings, 83rd Annual Meeting of the American Meteorology Society, 9-13 February, Long Beach, CA.

Saleeby, S.M., and W.R. Cotton, 2003b: Potential Vorticity Transport From Mexican Monsoon Surges. GAPP PI Meeting, Seattle, WA, July 20, 2003.

GETTING READY FOR NOAA'S ADVANCED REMOTE SENSING PROGRAMS: A SATELLITE HYDRO-METEOROLOGY (SHyMet) TRAOMOMG AMD EDUCATION PROPOSAL

Principal Investigator: B.H. Connell

NOAA Project Goal: Weather and Water

Keywords: 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 will be done with close collaboration with experts from CIRA, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison, the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, the National Weather Service (NWS) Training Center (NWSTC) in Kansas City, Missouri, and the NWS Warning Decision Training Branch (WDTB) in Norman, Oklahoma. The challenge is to provide necessary background information to cover the many aspects of current image and product use and interpretation as well as evaluate data and products available from new satellite technologies and providing new training on the these tools to be used operationally.

The (SHyMet) Course will cover the necessary basics of remote sensing, satellite instrumentation, orbits, calibration, and navigation, and will heavily focus on identification of atmospheric and surface phenomena, and the integration of meteorological analysis with satellite observations and products into the weather forecasting and warning process. This course will be taught through a combination of teletraining, CD-ROM, web-based instruction, and on-site training. At the end of the distance portion, all participants will attend a 3.5-day SHyMet Workshop offered at the COMET Classroom in Boulder, Colorado. Plans to achieve them:

- Develop course outline
- Inventory existing training materials and assess relevency to course outline.
- Develop detailed outlines for proposed topics and identify learning and assessment activities.
- Develop weather event simulator cases to support training materials
- Organize course material for presentation
- Deliver course

2. Research Accomplishments/Highlights:

During the first year activities, CIRA and CIMSS prepared an outline of the Satellite Hydro-Meteorology (SHyMet) training course
(http://www.cira.colostate.edu/RAMM/SHyMet/ShyMet_main.htm)

An inventory of existing tutorial materials and potential resources for the course were also completed.

In addition, existing training materials were used or adapted for outreach efforts and collaborative training efforts.

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

For the specific plans mentioned above, the first year activities included the first two bullets and have been completed. The second year activities include bullets 3 and 4 and are in progress.

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, Communication and Networking:

Other government and international organizations have expressed a strong interest in the proposed training. The Naval Meteorology and Oceanography Professional Development Center (PDC) are planning to establish a course based on the SHyMet project. The Department of Defense (DOD) has also expressed interest in incorporating this satellite training course into their programs. Because of CIRA'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 at this time.

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

(a) None

(b) 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.

(c) None

(d) J. Weaver gave a presentation on severe thunderstorms to middle school students participating in the Colorado State University summertime "Kids in College" program.

(e) J. Weaver met with staff from the Fort Collins Office of Emergency Management to provide both severe weather training, and information on plume-driven wildland fires. He also distributed some computer-based training material, and a large number of NOAA brochures.

8. Publications:

Presentations

Lindsey, D.T., 2004: Using satellite imagery to improve forecasts and nowcasts. *AMS 33rd Conference on Broadcast Meteorology*, 14-18 June, New Orleans, LA

Training

Castro, V., R. Alfaro, B.H. Connell, July 14-18, 2003: In-depth training on the RAMSDIS system, San Jose, Costa Rica

J.F. Weaver, Oct 24, 2003: New focuses in satellite training. COMET Mesoscale Analysis and Prediction (COMAP), Boulder CO

Burton, S., H. Burton, B. H. Connell, J. Purdom, R. Zehr, and others, Dec 2-12, 2003: Satellite Training Course for RA III and RA IV, Barbados

Lindsey, D. T., and others, May 18-28, 2004: Regional training seminar for national instructors from RA III and RA IV, Buenos Aires, Argentina

Newsletters

Connell, B.H., D.E. Bikos, D.T, Lindsey, J.F. Weaver, A. Mostek, 2004: National and International Training Activities at CIRA. *CIRA Magazine*. 7-9.

Workshops

Combs, C., April 30, 2004: *High Plains Mountain Weather Workshop*, Boulder, CO

GLOBAL MICROWAVE SURFACE EMISSIVITY ERROR ANALYSIS

Principal Investigator: A. Jones

NOAA Project Goal: Improving Weather and Water Information

Keywords: Satellite Data Assimilation, Land Surface Characterization, Microwave Land Surface Emissivity

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 3D 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.

Approach:

The observational emissivity method is a 1DVAR algorithm where the emissivities are grouped into retrieved "bands". The emissivities are constrained by assumed covariance errors that will be incrementally updated as the analysis continues and matures. Coincident MEM model output is then intercompared with the direct 1DVAR emissivity retrievals to valid the MEM results. This results in the following project goals being meet:

- Improve atmospheric profiling capabilities (advanced data assimilation, 1DVAR)
- Conduct 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:

1. An initial case study was selected for retrieval testing purposes: (Aug. 3, 2003).
2. Convergence criteria were examined and found that the method is stable and converging as we would like but has room for technical improvements. In particular, dry/high-altitude regions appear to have a bias that is still being investigated.
3. MEM access was obtained from Drs. Fuzhong Weng and Banghua Yan (NESDIS/ORA). The MEM is now running locally using Air Force Weather Agency AGRMET model inputs (soil moisture, surface temperatures, etc.), along with the needed NOAA AMSU satellite data sets.

4. Initial innovation vector analysis has been performed on a relatively crude basis. Figure 1 contains preliminary analysis from the initial case study. These results demonstrate that the MEM is performing reasonably well for this single case ($\Delta\epsilon \sim \pm 3\%$), main differences are in the interior west, and in some regions of known irrigation (west Texas, California Imperial Valley). It is still premature to assign cause, investigations into this are continuing.
5. Supplemental satellite/model data sets are being merged onto the Global Microwave Surface Emissivity Validation Atlas (GMSEVA) grids. Currently we are working with NESDIS/OSDPD on their DMSP SSMIS data feeds, and have a prototype DMSP SSMIS data flow processing at CIRA in near realtime. The AGRMET feeds are now fully functional, and of course the DMSP SSM/I and NOAA AMSU data feeds are also active in near real-time. Total satellite/model throughput at this time is approximately 175 GB/day (including read and writes) using the CIRA Data Processing Error Analysis System (DPEAS). We are currently running two major sectors, a 24 km Global cylindrical equidistant lat/lon sector, and a smaller 24 km CONUS sector using the same projection.
6. A major new component was added to the data processing system which now allows us to perform generalized compositing and generation of nominal satellite output statistics (means and variances) without writing any new code. This will make the future coding work less redundant as we start the more advanced statistical work in Year 2 of this project. We expect to be able to perform most of this work in near real-time in the final constructed error analysis system.

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

In general the project is on track with most objectives. The data flow issues are more complex than anticipated, and the work to detangle the various 1DVAR inputs into a more modular approach has been quite a challenge. We expect to overcome the remaining data flow issues shortly with a rewrite of a selected subset of the input processing aspects. The initial case study testing of the 1DVAR method has been quite encouraging and has already pointed us into several research avenues with regards to the 1DVAR algorithm performance itself.

4. Leveraging/Payoff:

Microwave data over land is greatly under utilized. Knowledge of the microwave surface emissivity enables advanced data assimilation techniques to be used over land surface regions. The utilization of the microwave satellite data over land is much improved and results in improved weather forecasts.

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

Active research collaborations with Drs. Yan, Weng (NESDIS/ORA) using the NOAA Microwave Emissivity Model (MEM), Drs. Baker, and Ruston (NRL) via the JCSDA working groups and on-site visits to CIRA.

6. Awards/Honors: None as yet.

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

Seminars as listed below within the conference proceedings.

8. Publications:

Conference Proceedings

Forsythe, J., A. Jones, and T. Vonder Haar, 2004: Development of a global microwave land emissivity retrieval, SPIE Conference, August 2-6, Denver, CO.

Jones, A. S., J. M. Forsythe, S. Q. Kidder, T. H. Vonder Haar, 2003: Extension of a 1DVAR passive microwave algorithm for near-real time atmospheric profiles and emissivity over land, BACIMO 2003, September 9-11, Monterey, CA, paper 6.05.

“Global Microwave Surface Emissivity Error Analysis”, 2nd JCSDA Workshop on Satellite Data Assimilation, Camp Springs, MD, Apr. 15-16, 2004.

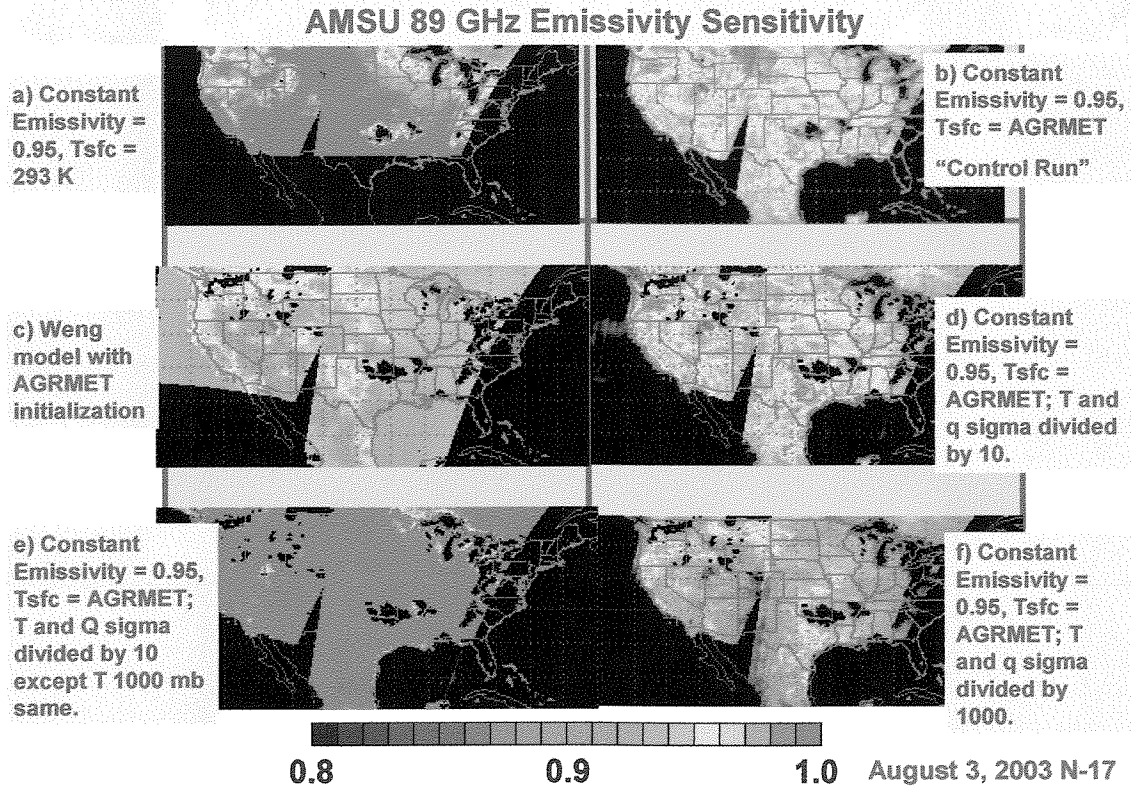


Figure 1: Intercomparison case study results for Aug. 3, 2003 using NOAA 17 AMSU data, A) Constant emissivity of 0.95 and a fixed land surface temperature for the retrieval, B) 1DVAR emissivity retrieval results using a simple constant emissivity assumption, but with AGRMET LST first guess information, C) The Weng/Yan MEM output using AGRMET LST and NOAA 17 AMSU data sets (comparable to (B) but substantial differences remain to be investigated), D) a sensitivity analysis of the 1DVAR results with the same assumptions as (B) but with T(p) and q(p) constraints tightened by a factor of 10 (this shows how dependent the results of (B) are with the atmospheric profile information – it is not overly dependent (since the patterns are very similar between B and D – thus we have a real emissivity data signal – this is encouraging), E) same as (D) except that the T(1000 mb) is fixed, F) Same as (D) except that the T(p) and q(p) are very tightly constrained (sigmas divided by 1000) (this helps us to examine the role of the atmosphere as a free variable within the model state vector and its associated importance. The sequence (B, D, F) demonstrates what role increasing knowledge of the atmospheric profile can play on the overall system. We will be accessing the GDAS atmospheric profiles shortly to objectively analyze this effect in much more detail

HARNESSING THE SPARE COMPUTING POWER OF DESKTOP PCs FOR IMPROVED SATELLITE DATA PROCESSING AND TECHNOLOGY TRANSITION

Principal Investigators: A. Jones/T. Vonder Haar

NOAA Project Goals: Integrated Global Environmental Observation and Data Management System; improving the availability of Weather and Water Information

Keywords: Satellite Data Analysis, Grid Computing, Collaborative Computing

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

This is a collaborative project with NESDIS/OSDPD (leads: Ms. Ingrid Guch) to harness the idle computing cycles of desktop PCs for satellite data processing. The work is funded by the NOAA High Performance Computing and Communications (HPCC) Program.

2. Research Accomplishments/Highlights:

- Publication of project results. Funded work was completed in previous year

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

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.

Because the hardware, operating system and maintenance of NOAA Office PC's are already paid for, the cost-savings are significant both in terms of short term (hardware purchases) and long term (staff hours for maintenance and upgrades) costs when compared to an equivalent Linux-cluster of machines.

The technology transition process is also now simplified. NOAA and CIRA have had a long-standing cooperative agreement for research in the atmosphere. However, until now, it has been significantly difficult to transfer research at CIRA (and other research institutions) to operations in NOAA. Now, both groups have access to Windows-based office machines that can process satellite data. A single executable from CIRA can be transferred to NOAA in a matter of hours rather than having to rewrite and recompile over a period of weeks or even months, leaving more time for NOAA to understand, optimize and document the code for operations.

4. Leveraging/Payoff:

A preliminary cost-benefit analysis compared a cluster of 100 Office PCs to a cluster of 40 dedicated dual-processor Linux machines and found the Office PCs provided a savings of over \$1,000,000 during a 5 year period (\$2,214 per Office PC per year)

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

Future efforts will include a follow-on collaborative effort with NESDIS/OSDPD (Lead: Limin Zhao) to expand the analysis to the technical transfer component of the cost-savings and expand the effort at OSDPD. We expect that work to begin shortly.

6. Awards/Honors:

(Guch et al., 2004) Best of Session Award– Collaborative Computing at NOAATECH 2004.

7. Outreach: None

8. Publications:

Technical Reports/Newsletter/Presentations

Jones, A. S., 2003: Grid Computing for Improved Technology Transition, *CIRA Newsletter*, 20, Fall 2003, 18.

Jones, A., I. Tcherednitchenko, 2004: Data Processing Error Analysis System (DPEAS) NOAA-Computer Incident Response Team (N-CIRT) Information Summary, 17 pp.

Guch, I. C., A. S. Jones, I. Tcherednitchenko, R. R. Ferraro, M. J. Kane, C. W. Karlburg, S. Q. Kidder, 2003: Harnessing the spare computing power of desktop PCs for improved satellite data processing and technology transition, NOAATECH 2004, Oct. 21-23. Award: Best of Session – Collaborative Computing.

IMPACT OF INTERACTIVE VEGETATION ON PREDICTIONS OF NORTH AMERICAN MONSOONS

Principal Investigators: Scott Denning/ Lixin Lu

NOAA Project Goal:

Keywords: Vegetation Phenology, Climate Prediction

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

Improve North American Monsoon prediction through realistic representation of vegetation phenology. We are refining the coupled RAMS-CENTURY modeling system to simulate two-way interactive atmosphere and biosphere, and improve regional climate prediction.

2. Research Accomplishments/Highlights:

- Latest version of Daily CENTURY has been implemented and tested against satellite NDVI observations.
- Sensitivity tests have been performed over Southwestern and Central U.S. with DayCENT to look at the regional vegetation response to variations in atmospheric forcings.
- Published a paper on Journal of Hydrometeorology, "Incorporating NDVI-derived-LAI into Climate Version of RAMS and Its Impact on Regional Climate". The paper is widely reported by media, such as CNN, etc., and NASA run a top story on it.

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

The 3rd year of project was postponed for one year because of principal investigator's illness.

4. Leveraging/Payoff:

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

Collaborator: Dr. Jim Shuttleworth, University of Arizona

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) Public awareness:

(a) N/A

(b) Seminar

The PI was invited to give seminar at Eros Data Center, and NCAR Environment and Societal Impacts Group.

(c) N/A

(d) N/A

(e) Yes, CNN, German Science News, NASA top story, Arizona Daily Star, have all reported our work and paper.

7. Publications

Lu, L., and J. Shuttleworth, 2002: Incorporating NDVI-derived LAI into the climate version of RAMS and its impact on regional climate. *Journal of Hydrometeorology*, 6, 347-362.

IMPROVEMENT IN DETERMINISTIC AND PROBABILISTIC TROPICAL CYCLONE SURFACE WIND PREDICTIONS

Principal Investigator: J.A. Knaff

NOAA Project Goal: Weather and Water

Keywords: Tropical Cyclones, Hurricanes, Ocean Heat Content, Hurricane Intensity Forecasting, GOES data

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

This purpose of this project is to develop new methods for improving deterministic and probabilistic surface wind predictions that will be evaluated in an operational setting.

The deterministic surface wind prediction improvements expand upon previous work with the Statistical Hurricane Intensity Prediction Scheme (SHIPS). A major limitation of SHIPS is that it relies almost entirely on relationships between the storm environment conditions and intensity changes. Research results have shown that internal processes such as eyewall contraction and replacement can also have large impacts on hurricane intensity changes. Since these processes can often be observed in aircraft reconnaissance observations and GOES imagery, a new component to the SHIPS model will be developed and evaluated where aircraft reconnaissance and GOES imagery will be utilized to better determine the inner core structure. Aircraft data are not currently used as SHIPS input, and the GOES 10.7 μm imagery is used in a rudimentary way that involves averages over large areas. The intensity forecast model with the inner core GOES and aircraft data will be a separate component that predicts deviations from the SHIPS prediction, and will be referred to as the GOES and Reconnaissance Intensity Prediction (GRIP) model. To account for nonlinear interactions between possible predictors, a neural network prediction method will be tested in addition to the multiple linear regression method that is currently used by SHIPS.

As part of the overall development of statistical tropical cyclone forecasting techniques, a new method for estimating the uncertainty associated with surface wind forecasts is proposed. The wind uncertainty estimate is obtained using a Monte Carlo Probability (MCP) model, where a large set of plausible tracks and intensities are determined by randomly sampling historical forecast errors distributions. Special procedures were developed to account for the effects of land, for the serial correlation between the track and intensity forecast errors, and for the relationships between intensity and wind structure. A prototype version of the MCP was developed for the Atlantic basin and provides fields of the probability of the surface wind exceeding specified wind thresholds over specified time intervals. In this proposal, the Atlantic MCP model will be generalized to include the East Pacific, Central Pacific, and West Pacific tropical cyclone basins. The code will also be generalized so that it can run as part of the Automated Tropical Cyclone Forecast (ATCF) system, and generate fields on the NWS National Digital Forecast Database grid system.

2. Research Accomplishments/Highlights:

The development of the GRIP model began by assembling the dependent dataset. The U.S. Air Force Reserve flight level data for all Atlantic and east Pacific tropical cyclone cases from 1995-2003 were obtained and put into a common format. This data is input to a variational analysis system, which combines observations in 12-hour intervals in a storm-relative coordinate system to produce tangential and radial flight level winds in a cylindrical coordinate system. Because this analysis must run in a fully automatic mode when implemented in real time, considerable effort was put into development of data quality control. The analysis provides radial and tangential winds at 16 azimuths at 5 km radial intervals out to 200 km from the storm center. The GOES infrared satellite images were also azimuthally averaged and interpolated to the same radial grid as the aircraft data. Empirical Orthogonal Functions (EOFs) of the radial profiles of azimuthally averaged tangential wind and GOES brightness temperatures. The amplitudes of the EOFs (principal components, PCs) were then determined for each forecast case and correlated with intensity change. It was found that the first few PCs from both the GOES and aircraft data provide intensity forecast information not contained in the operational SHIPS forecasts. Figure 1 shows the percent improvement of the GRIP-dependent forecast relative to the SHIPS predictions. As expected, the improvement (up to about 6%) tails off after about 48 h.

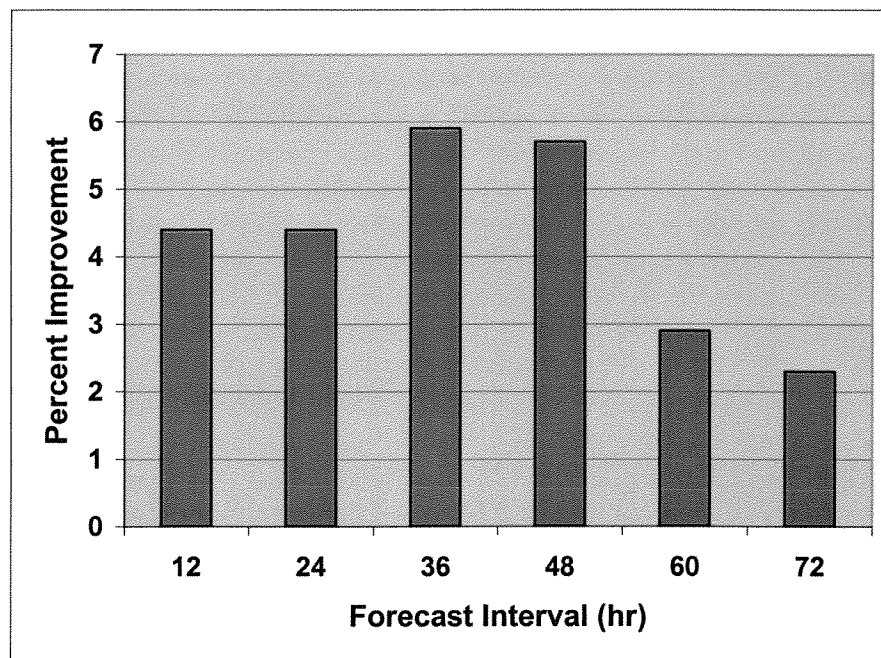


Figure 1. The improvement of the GRIP model relative to the SHIPS model for the dependent sample with aircraft data

The GRIP model is currently being adapted to run on the Tropical Prediction Center computing systems. The model will be run in real-time during the majority of the 2004 hurricane season, and evaluated in the post-season.

Work is proceeding to determine if neural network methods can provide improved prediction. This part of the project is in collaboration with Dr. Charles Anderson from the Colorado State University Computer Science Department, who is an expert on computer learning techniques. The size of the sample with the aircraft data available does not warrant the use of a more sophisticated prediction method because the chance of over-fitting is high. However, the complete SHIPS database now has more than 3000 cases in the Atlantic and 4000 cases in the east/central Pacific. A neural network prediction model is being developed from this input, and will be compared with the standard SHIPS model, which utilizes multiple regression. Preliminary results with dependent data show that the neural network model explains a larger fraction of the variance, and has smaller absolute errors. The cases obtained during the 2004 season will provide an independent test to determine if these improvements can be obtained in real time, or are due to over-fitting of the dependent sample by the neural network model.

Considerable progress was made on the new probability estimation technique. Monte Carlo models were completed for the Atlantic and eastern, central, and western North Pacific tropical cyclone basins, and transferred to an operational computer system at TPC. Real-time runs for 2004 will be made available via a password protected web site for evaluation by TPC in Miami, and the Central Pacific Hurricane Center and the Joint Typhoon Warning Center in Honolulu. Probability maps of 34, 50 and 64 kt winds from 12 to 120 hours will be provided on the web site, which will be updated every six hours. Figure 2 shows an example of the 0-120 hour cumulative probability of 64 kt winds for hurricane Fabian from the 2003 hurricane season.

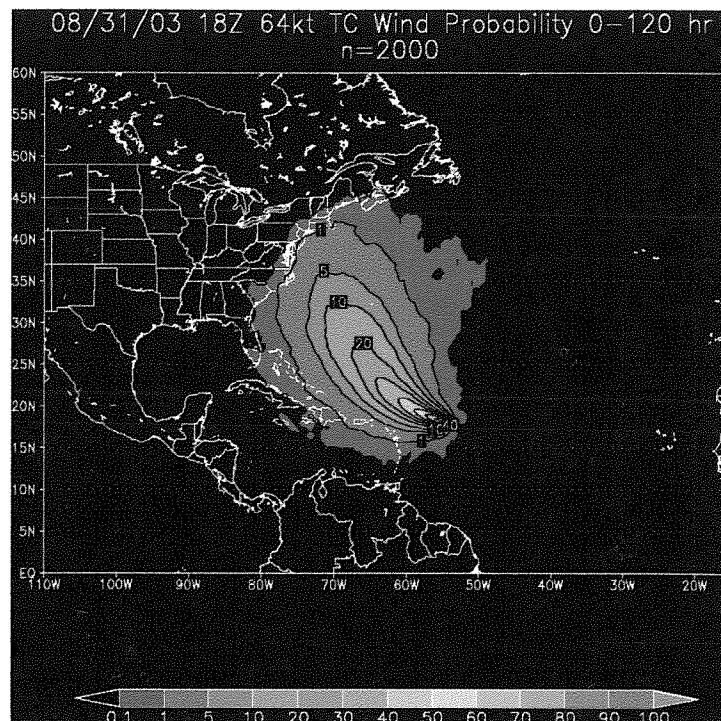


Figure 2. Example of the output of the Monte Carlo probability program for hurricane Fabian

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

All of the proposed objectives from the project have been accomplished. Both the GRIP and Monte Carlo probability models will be evaluated in real time during the 2004 season. Based upon the positive results, this project have been approved for a second year of funding.

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, Communication and Networking:

This research is a joint effort between several groups with NOAA and the university community, including the NOAA/NESDIS Office of Research and Applications, the NOAA/NCEP TPC, the NOAA/OAR Hurricane Research Division, Colorado State University and the University of Miami. The private sector research is also being included through Chelle Gentemann of Remote Sensing Systems to help determine the optimal sea surface temperature analysis to use in the intensity prediction.

6. Awards/Honors: None at this time

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) Kimberly Mueller is a graduate student (Masters) in the Department of Atmospheric Science at Colorado State University. As part of her thesis work, she helped to develop the quality control for the variational analysis system and assembled the aircraft database for the project.

(b) See Section 8 below

(c) None

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

(e) As part of this project, non-technical training will be developed and 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.

8. Publications

Refereed Journals

DeMaria, M., M. Mainelli, L.K. Shay, J.A. Knaff, and J. Kaplan, 2004: Further Improvements to the Statistical Hurricane Intensity Prediction Scheme (SHIPS), submitted to *Weather and Forecasting*.

Conference Proceedings

Berg, R., C. Sisko, and M. DeMaria, 2004: High resolution SST in the SHIPS model: improving operational guidance of tropical cyclone intensity forecasts. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Cecil, D., T.A. Jones, J.A. Knaff, and M. DeMaria, 2004: Statistical forecasting of Pacific and Indian Ocean tropical cyclone intensity using 19-, 37-, and 85- GHz brightness temperatures. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Gentemann, C., M. DeMaria and F.J. Wentz, 2004: Near real time global optimum interpolated microwave SSTs: applications to hurricane intensity forecasting. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Goni, G.J., M. DeMaria, J.A. Trinanes, and P.G. Black, 2004: Testing global estimates of the tropical cyclone heat potential fields to improve hurricane intensification prediction. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Gross, J.M., M. DeMaria, J.A. Knaff, and C.R. Sampson, 2004: A New Method for Determining Tropical Cyclone Wind Forecast Probabilities. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Kaplan, J. and M. DeMaria, 2004: Estimating the probability of rapid intensification of tropical cyclones in the Atlantic and Eastern Pacific basins. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Velden, C., J. P. Kossin, T. L. Olander, D. Herndon, A. J. Wimmers, R. Wacker, R. T. Edson, J. D. Hawkins, K. F. Brueske, B.W. Kabat, and M. DeMaria, 2004: Toward an objective satellite-based algorithm to provide real-time estimates of TC intensity using integrated multispectral (IR and MW) observations. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Presentations

DeMaria, M., Aug 6, 2003: Improvements in Deterministic and Probabilistic Tropical Intensity Forecasting. Hurricane Research Division (HRD), Miami, FL

DeMaria, M., Oct 14, 2003: Improvements in Deterministic and Probabilistic Hurricane Intensity Forecasts. CSU Department of Atmospheric Science Seminar Series, Fort Collins, CO

DeMaria, M., J.A. Knaff, J.F. Dostalek, K. Mueller, 2004: Improvements in Deterministic and Probabilistic Tropical Cyclone Surface Wind Predictions. *58th Interdepartmental Hurricane Conference*, 1-4 March, Charleston, SC

Training

DeMaria, M., Nov 12, 2003: Tropical cyclone storm surge, inland wind forecastings, and wind probabilities. COMET Mesoscale Analysis and Prediction Course (COMAP) Boulder, CO

Workshops

DeMaria, M., July 30-August 6, 2003: Tropical Prediction Center & Hurricane Research Division Meetings, Miami, FL

INTERACTIONS OF THE MONSOON AND ANTICYCLONES IN THE COUPLED ATMOSPHERE-OCEAN SYSTEM

Principal Investigators: David Randall/T. Ringler

NOAA Project Goal: Climate

Keywords:

1. Long-term Research Objectives and Specific Plans to Achieve Them: (see below)
2. Research Accomplishments/Highlights: (see below)
3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period: (see below)
4. Leveraging/Payoff:
5. Research Linkages/Partnerships/Collaborators, Communications and Networking:
6. Awards/Honors:
7. Outreach:
8. Publications:
9. Additional Information:

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.

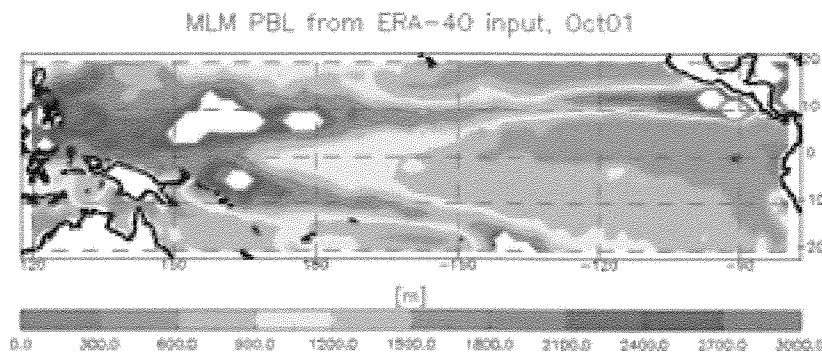


Figure 1: PBL depth diagnosed by the MLM from ERA-40 monthly mean re-analysis data for October 2001. White areas indicate above-scale values.

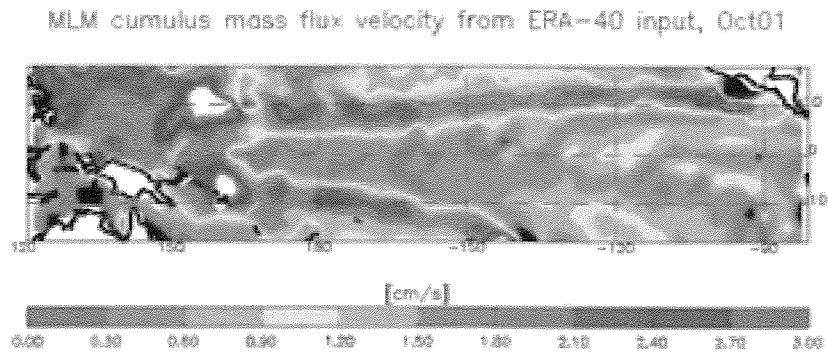


Figure 2: Cumulus mass flux velocity diagnosed by the MLM from ERA-40 monthly mean re-analysis data for October 2001. White areas indicate above-scale values, black below-scale values

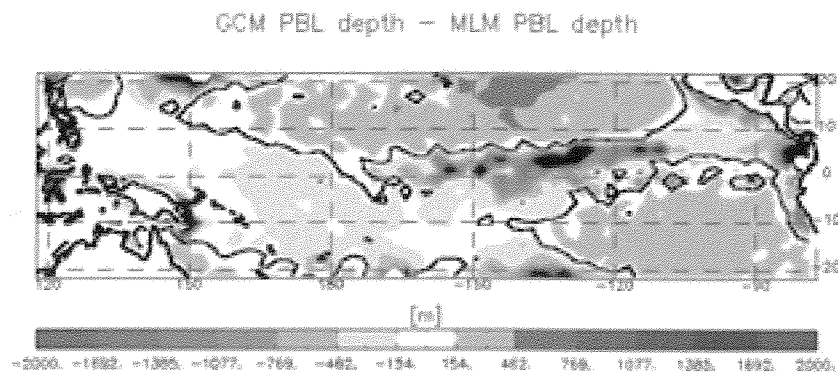


Figure 3: Difference plot between PBL depth from CSU GCM run and MLM run with GCM input data (i.e. model run with temporal covariances minus model run without temporal covariances). Run for climatological April conditions

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT SECTOR PROCESSING AND ANALYSIS

Principal Investigators: G.G. Campbell and T.H. Vonder Haar

NOAA Project Goal: Climate

Keywords: Climate, Clouds, Satellite Data, GOES, ISCCP

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

CIRA acts as the Sector Processing Center, SPC for GOES West for the International Satellite Cloud Climatology Project, ISCCP. This involves the collection of GOES full disk imagery 8 times per day and construction of an 8 km sampled data set from the 5 imager channels. The visible data is averaged to the IR resolution (4km X 4km). These data sets are sent to the ISCCP Archive Center (National Climatic Data Center) for long term storage. Next the data is further sampled to 32 km (figure 1) resolution and submitted to the ISCCP Global Processing Center (NASA Goddard Institute for Space Studies) for analysis into cloud amount and cloud properties. Although this process is automated with computers it requires quality control inspection of the data and inclusion of substitute imagery when the normal images are not transmitted. We began this data collection effort for ISCCP in 1983. Pending funding from the Office of Global Programs, we plan to continue this data collection and research to the end of 2007.

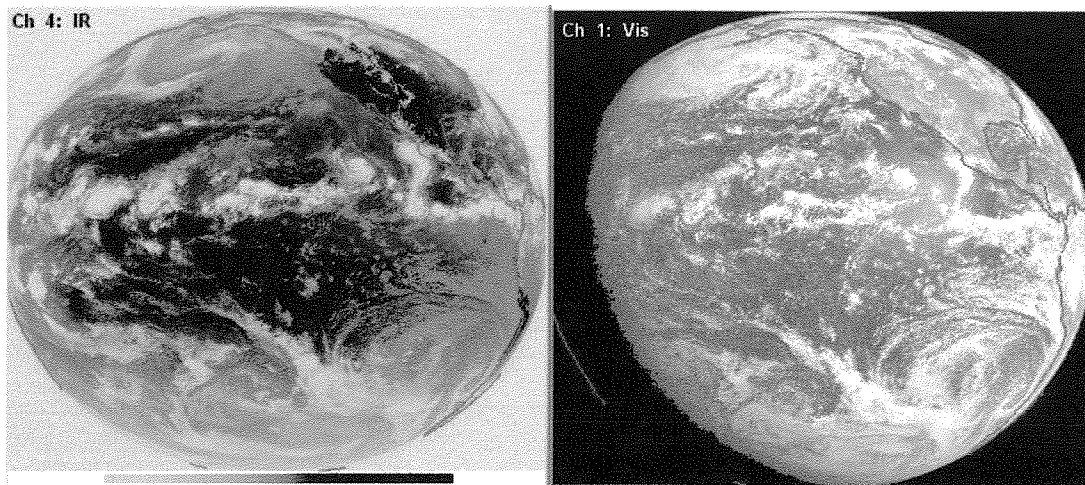


Figure 1: Sample images of digital data submitted to GPC.

2. Research Accomplishments/Highlights:

For the last year we have collected GOES East data for ISCCP because Environment Canada, a collaborator on the project, has not participated in their SPC activities.

In addition we have reviewed the ISCCP cloud products for validation purposes and for scientific analysis. Our most recent work has demonstrated that the trend (figure 2) in the ISCCP observed cloudiness is suspect (Campbell and Vonder Haar 2004) and that it may

stem from two causes: First clouds have an inherent view angle dependence: fewer clouds appear with normal views (straight down) versus oblique views. Second there may be calibration differences between the polar orbiter satellites which accumulate over time. The interesting scientific result is that the residual variation on the global cloudiness is associated with the El Nino's in the last 2 decades. Details of these results are embargoed by the publication process but will be made public later this year.

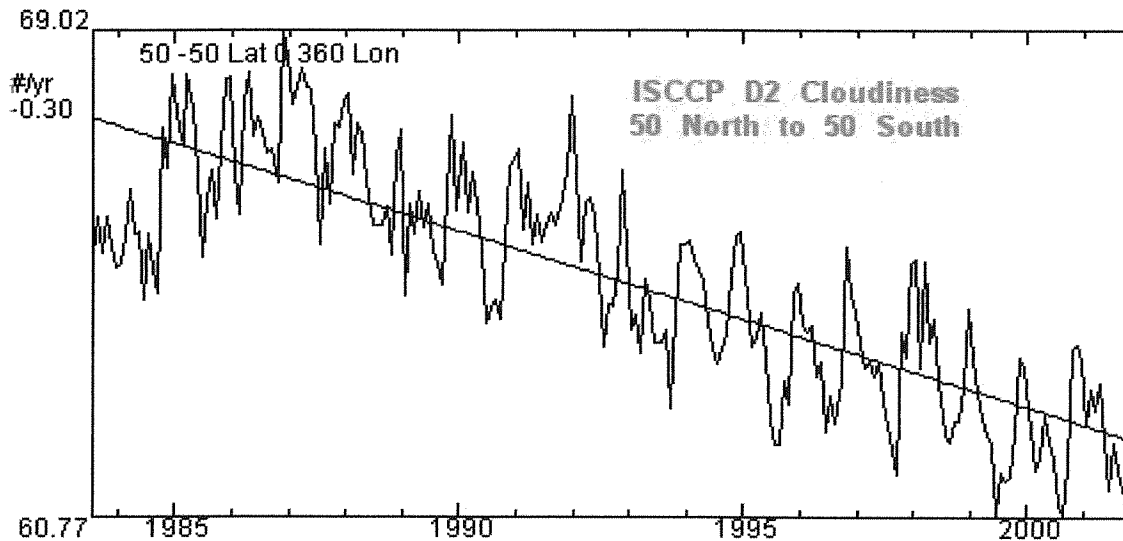


Figure 2: Trend in near global cloudiness: suspect.

4. Leveraging/Payoff:

Findings (details embargoed by publication process):

ISCCP trends suspect

 Caused by view angle dependence

 Caused by calibration problems

Global scale small variations < 1%

Real, not noise

Associated with El Nino

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

In the spring of 2004, the GEWEX Radiation Commission established four committees to review long term climatologies of Aerosols, Clouds, Precipitation, and Radiation budget. Campbell is co-chairman of the Cloud Review panel. Thus far we have solicited participation of 20 or 30 scientists in this review effort and we will organize a conference in the spring of 2005 to prepare a document describing the accuracy of cloud climatologies. This will be used in the next Inter-Governmental Panel on Climate Change assessment of the Earth's climate. Besides organizing this committee we will continue our validation of the ISCCP products leading to suggestions for algorithm improvements.

6. Awards/Honors: None as yet

7. Outreach:

CIRA Seminar (repeated at GISS 7/8/04): ISCCP Clouds: Angular dependence of cloudiness, Long term trends and correlations.

8. Publications:

G.G. Campbell and T.H. Vonder Haar, ISCCP Cloudiness: Constant in time.
Submit to Science July, 2004

NESDIS POST DOCTORAL PROGRAM

Principal Investigators: Various (See below)

NOAA Project Goal: Various (see below)

Christopher S. Kinkade – NESDIS Post Doc

Project Title: In Situ Ocean Color Observations for Improved Atmospheric Corrections

Principal Investigator: Christopher Kinkade

NOAA Project Goal: Climate

Keywords: Primary Productivity, Ocean Color

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

To investigate in situ ocean pigment composition and concentrations to provide an improved optical database for the atmospheric correction of remote retrieval of ocean color.

2. Research Accomplishments/Highlights:

Participated in 3 research cruises, Honolulu, HI, increasing bio-optical database; continued quality control of existing bio-optical data for satellite retrievals.

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

Current work is on target with objectives

4. Leveraging/Payoff:

Accurate ocean color observations provide information for marine ecosystem maintenance through monitoring significant ecological events and trends (e.g., harmful algal blooms) and can help rebuild and maintain sustainable fisheries by providing information on fishery resources, habitats, and provinces.

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

The PI collaborates closely with investigators from San Diego State University, University of Hawaii, and Moss Landing Marine Laboratories (San Jose State University).

6. Awards/Honors: Interim NOAA/NESDIS Ocean Color Science Team Leader 2003-04.

7. Outreach: N/A

8. Publications:

ASLO/TOS Ocean Sciences Meeting, Honolulu, HI 2004; NASA Ocean Color Team meetings April, June 2004; review article in Analytical and Bioanalytical Chemistry in preparation

Lei Ji – NESDIS Post Doc

Project Title: Risk Reduction for MODIS/VIIRS Vegetation Index and Vegetation Cover Products

Principal Investigator: Kevin Gallo (NOAA/NESDIS)

NOAA Project Goal: Climate

Keywords: Vegetation Index, AVHRR, MODIS, VIIRS

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

The operational and climatological use of the current AVHRR-based vegetation index (VI) suggests that the VIIRS VI will be heavily used. The risk reduction activities of this study will include evaluation of VI developed from MODIS and compared to current AVHRR products. The VI will be assessed for several vegetation land surface types. The study will result in a) assessment of the anticipated improvements in VI product from the VIIRS and b) general recommendations for future evaluations of MODIS and AVHRR VI datasets.

2. Research Accomplishments/Highlights:

- The 16-day composite normalized difference vegetation index (NDVI) data derived from AVHRR and MODIS were compared for the conterminous US from 2001-2003.
- The 2003 NDVI products acquired from the Terra and Aqua MODIS were compared for the conterminous US.
- A new statistical agreement coefficient was developed for evaluating data agreement.

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

Proposed research objectives were accomplished for reporting period.

4. Leveraging/Payoff: N/A

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

- NOAA/NESDIS
- USGS EROS Data Center

6. Awards/Honors: None as yet

7. Outreach:

- Seminar at CSU/CIRA by Lei Ji: Evaluation of the Agreement between NDVI data derived from AVHRR and MODIS.
- Paper abstracts “Comparison of MODIS and AVHRR 16-day Normalized Difference Vegetation Index Composite Data” and “A New Agreement Coefficient for Comparing Remotely Sensed Data Acquired from Different Sensors” were accepted for presentations at the American Society for Photogrammetry & Remote Sensing (ASPRS) 2005 Annual Conference.

8. Publications:

Refereed Journal Article

Gallo, K., L. Ji, B. Reed, J. Dwyer, J. Eidenshink, 2004, Comparison of MODIS and AVHRR 16-day normalized difference vegetation index composite data. Geophysical Research Letters, 31: L07502, doi:10.1029/2003GL019385.

Ana I. Prados – NESDIS Post Doc

Project Title: Operational Air Quality Monitoring from the GOES Imager

Principal Investigator: Shobha Kondragunta

NOAA/Project Goal: The GOES Aerosol and Smoke Product (GASP) and Air Quality Applications

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

- To perform a complete validation of the GASP product and in particular the diurnal variation of the retrieved aerosol optical depth
- To determine the applicability of GASP for air quality monitoring and forecasting
- To use GASP to enhance our understanding of particulate pollution over the eastern and mid-Atlantic US including transport patterns and diurnal variability

2. Research Accomplishments/Highlights:

- Completed initial validation studies of the GASP product
- Applied the GASP product to air pollution studies over the eastern and mid-Atlantic US.

3. Comparisons of objectives vs. actual accomplishments for reporting period:

- Stated goals are being met by the actual accomplishments

4. Leveraging/Payoff:

- This research supports NOAA's goal to provide information to the public on weather and water. This research meets congressional mandate (H.R.4 Energy Policy Act of 2002) guiding NOAA to issue air quality forecasts and warnings.

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

- This research includes collaborative work with the Environmental Protection Agency (EPA). Work will involve comparing GASP AODs to PM_{2.5} (fine particulate matter) concentrations generated with the EPA CMAQ model.
- NESDIS/ORA is providing GASP images through NESDIS/OSDPS, in support of a field campaign: the New England Air Quality Study (NEAQS).

6. Awards Honors: None as yet

7. Outreach: None

8. Publications:

February 23, 2004--presented a paper at the 2004 EPA National Air Quality Conference. The paper title was "Geostationary satellite observations of particulate pollution"

June 14, 2004--presented a paper entitled "GOES Observations of Particulate Pollution". This paper was presented at the Science Colloquium on Measuring and Modeling of Aerosols, sponsored by the NESDIS Cooperative Research Program

9. Additional Information:

Summary

My position as a CIRA visiting scientist at NOAA/NESDIS/Office of Research and Applications began on October 13, 2003. I have been working on maintaining ORA's near-real time GOES Aerosol and Smoke Product (GASP), assisting the Office of Satellite Data Processing and Distribution (OSDPD) with the transition of the aerosol retrieval algorithm to operations, conducting validation studies, and applying the GOES aerosol product to air pollution studies.

Approach/Evaluation/Methodology

- Validation: By comparing GASP AODs to observed AODs from the AERONET ground sampling network. This is a very large data set, which provides the opportunity to assess algorithm performance at different times of the day and in different geographical regions, where aerosol properties might differ.
- Assess the utility of GASP for air quality forecasting:
 - By comparison to PM_{2.5} (fine particulate matter) concentrations from the EPA sampling network.
 - By evaluating GASP during periods of high particulate pollution due to different sources, such as transport from upwind regions, local industrial sources, or smoke from biomass burning.
- Performing real-time retrievals of GOES aerosol optical depths: I maintain the near-real time GOES AOD product. I also make images and data available to users via the world wide web. A sample image showing forest fire smoke transported from Canada to the continental U.S on July 18, 2004 is attached.

Research Accomplishments and Results

- I have completed initial validation studies of the GASP product. The comparisons to ground based observations show reasonable agreement, with greatest discrepancies at the earlier and later part of the day.
- I applied the GASP product to air pollution studies over the eastern and mid-Atlantic US. The analysis indicates that GASP can be used for detecting summer-time large scale particulate pollution events over the US mid-Atlantic region at high temporal resolution. In addition, GASP can be used to monitor the long-range transport of air pollution.

Conclusions and Recommendations

- Conclusions: Initial validation and studies suggest that the GASP product has important potential applications for air quality monitoring.
- Recommendations: Continued validation of the diurnal cycle in the retrieved AOD and algorithm improvements are the necessary next steps, including a reassessment of the current cloud masking algorithm, and a careful evaluation of retrieved surface reflectivities.

Peter Romanov – NESDIS Post Doc

Project Title: Mapping and Monitoring Snow Cover From Satellites

Principal Investigator: Peter Romanov

NOAA Project Goal: Weather & Water

Keywords: Satellites, remote sensing, snow cover, snow depth

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

Development of an automated satellite-based system for global snow/ice cover and snow depth monitoring.

2. Research Accomplishments/Highlights:

Developed a new system for mapping ice cover using combined NOAA AVHRR and GOES Imager instruments. Developed an algorithm to estimate snow depth over open prairie environments. Studied potential for improving MODIS snow cover mapping algorithm.

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

All objectives have been met.

4. Leveraging/Payoff:

The results of automated snow cover mapping are used by NOAA to improve operational snow cover analysis. Maps of snow cover over North America and maps of snow depth over US Great Plains and Canadian prairies are used by several high schools and universities for educational purposes.

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

6. Awards/Honors:

7. Outreach:

8. Publications:

Refereed

Romanov, P. and D. Tarpley, 2004. Estimation of snow depth over open prairie environments using GOES imager observations. *Hydrological Processes*, 18(6): 1073-1087.

Simic, A. and R. Fernandes, et al, 2004. Validation of VEGETATION, MODIS and GOES plus SSM/I snow-cover products over Canada based on surface snow depth observations. *Hydrological Processes*, 18(6): 1089-1104.

Seminar

GOES-R User's Conference, University of Arizona.

William Skirving – NESDIS Post Doc

Project Title: Coral Reef Watch Project

Principal Investigator: Alan E. Strong

NOAA Project Goal: Ecosystems

Keywords: Coral Bleaching, Sea Surface Temperature

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

The objective is to improve the ability of satellites to monitor and hindcast coral bleaching. There are two main activities that are aimed at achieving this objective: The improvement of the current satellite algorithms for monitoring coral bleaching and the improvement of our understanding of the relationship between the satellite-derived SST and the 3D structure of the water temperature.

2. Research Accomplishments/Highlights:

Completion of the Palau hydrodynamic modeling project. This project is aimed at predicting the spatial patterns of SST during the next coral bleaching event. This information is being included within the design of the Palau National Marine Protected Areas Network.

3. Comparison of Objectives Vs. Actual Accomplishments:

All objectives have been met.

4. Leveraging/Payoff:

The Coral Reef Watch satellite HotSpot products are one of the most used sets of products produced by NESDIS. The bleaching risk map for Palau is being used by TNC to include bleaching resilience within the design of the Palau National MPS Network. If successful, this technique is likely to be applied to other regions.

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

This project has a wide range of linkages, partnerships and collaborators. From a scientific perspective links and collaborative projects are either underway or are being formed with the Australian Institute of Marine Science, Princeton University, the University of Queensland, Hawaii University, and most importantly, other NOAA Line Offices such as NOS, OAR, NMFS and the National Weather Service.

6. Awards/Honors: None as yet.

7. Outreach:

8. Publications:

Refereed Journal

Berkelmans, R., G. De'ath, S. Kinimonth and W. Skirving, Coral bleaching on the Great Barrier Reef: Correlation with sea surface temperature, a handle on 'patchiness' and comparison of the 1998 and 2002 events. *Coral Reefs*, 23: 74-83, 2004

Elvidge, C., J. Dietz, R. Berkelmans, S. Andréfouët, W. Skirving, A. Strong and B. Tuttle, Satellite observation of Keppel Islands (Great Barrier Reef) 2002 coral bleaching using IKONOS data. *Coral Reefs*, 23:123-132, 2004

Book Chapter

Skirving, W.J., A.E. Strong, G. Liu, F. Arzayus, C. Liu and J. Sapper, Extreme events and perturbations of coastal ecosystems: Sea Surface Temperature Change and Coral Bleaching. In: *Remote Sensing of Aquatic Coastal Ecosystem Processes*, L.L. Richardson and E.F. LeDrew, Co-Editors. Kluwer publishers (in review)

Conferences

Hoeke, R.K., R. Brainard, R. Moffitt, G. Liu, A. Strong, W. Skirving and J. Kenyon. Oceanographic Conditions Implicated in the 2002 Northwestern Hawaiian Islands Coral Bleaching Event, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review) Bleaching Event, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review)

Heron, M.L., W. Skirving and S. Heron. Coral Bleaching Limitations by Wave-induced Vertical Mixing at the Reef Front, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review).

Liu, G, A. Strong, W. Skirving and F. Arzayus. Overview of NOAA Coral Reef Watch Program's Near-Real-Time Global Satellite Coral Bleaching Monitoring Activity, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review)

Arzayus, F. and W. Skirving. The correlation between ENSO and Coral Bleaching events, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review).

Moffitt, R., R. Brainard, R. Hoeke, A. Strong, W. Skirving, J. Sibert and D. Foley. Oceanographic Atlas of the Pacific: An Accessible Interface to marine Environmental Data, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review)

Strong, A., W. Skirving and G. Liu. Corals and Climate – Natural Variability or Alarm? 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review)

Skirving, W., A. Strong, G. Liu, C. Liu and J. Oliver. NOAA's Coral Reef Watch Hotspot and DHW Products: Trends in the Extent of Mass Bleaching, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review)

Donner, S., M. Oppenheimer, W. Skirving and A. Strong. Projecting the Frequency of Coral Bleaching Events due to Possible Changes in Climate, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review)

Steinberg, C., W. Skirving and S. Heron. The Hydrodynamics of a Coral Bleaching Event, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review).

Howard, E. and W. Skirving. Mapping and Monitoring Coral Reefs from Space Platforms: Sensor Studies for Depth, Band Selection and Temporal Needs, 10th International Coral Reef Symposium, June 2004, Okinawa, Japan (proceedings in review).

9. Additional Information:

My work at the NOAA Coral Reef Watch project has two aspects to it: (1) improve the current satellite-based coral bleaching HotSpot and Degree Heating Week products, and (2) develop a technique for predicting bleaching risk based on future SST patterns.

- 1) The development of the HotSpot products is progressing well. I have been instrumental in the development of a number of new products that are currently in experimental mode awaiting an upgrade to operational product status. These are the SST trend analysis and the automated email bleaching alerts to managers.
- 2) The development of a technique for predicting bleaching risk based on future SST patterns has been the largest part of my work at NOAA. I was instrumental in the formation of a team that consisted of NOAA/NESDIS, NOAA/NOS, the Australian Institute of Marine Science, The Nature Conservancy (TNC), the Palau International Coral Reef Center, and various departments within the Federal and State Governments of Palau. This team came together to develop a hydrodynamic model of the Palau region which I then used to create a map of expected mixing during a severe coral bleaching event. This can then be easily converted into a map of relative SST that shows the cool regions and warm regions in and around Palau. A project during 2005 will work with TNC and the Palau Govt. to develop a methodology for imbedding this information into the design of a National Marine Protected Area Network for Palau, in the hopes that this will build some bleaching resilience into the MPA design and hence improve the ability of the Palau reefs to withstand a future coral bleaching event. If successful, this will represent the first time that an MPA has included bleaching resilience into its design, and as such this technique will most likely be used in many other regions around the world.

Tong Zhu – NESDIS Post Doc

Project Title: Microwave Remote Sensing of Atmospheric and Surface Parameters and Their Applications in Numerical Weather Prediction Models.

Principal Investigator: Fuzhong Weng, Tong Zhu

NOAA Project Goal: Weather & Water

Keywords: Hurricane Model Initialization, AMSU data, Data Assimilation

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

Develop hurricane model initialization and assimilation schemes to be implemented in the operational forecast models using microwave data from AMSU, SSM/IS and ATMS. The research will also include the validation of these microwave sensor-derived products and algorithms. Further assessment of the schemes and the usefulness in numerical weather prediction models will be studied.

2. Research Accomplishments/Highlights:

We have made validation of the AMSU retrieved temperatures under cloudy and precipitation conditions in hurricane system. We are performing numerical model simulations of Hurricane Isabel (2003) with and without AMSU retrieved temperature and wind fields to study the microwave data impacts on hurricane model prediction.

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

The project is going well during the last six months. Next, we are going to finish the impact study and submit a paper on this part in a few months. Our next task is to assimilate atmospheric temperature and moisture information from satellite microwave measurements into hurricane model initial condition using the three-dimensional variational (3DVAR) data analysis method.

4. Leveraging/Payoff:

Scientists from several U.S. and foreign agencies are interested in our 3D temperature and wind fields retrieval schemes. Our hurricane model initialization scheme is being tested on Navy hurricane model at NRL, Monterey.

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

We are collaborating with a research group in IPRC at University of Hawaii to implement the hurricane model initialization scheme into a operational forecast system.

6. Awards/Honors: None as yet.

7. Outreach:

This project offers Dr. Tong Zhu a postdoctoral fellowship at CIRA.

8. Publications:

Conference Proceedings

Zhu, T., and F. Weng, 2004: Hurricane Model Initialization with AMSU Measurements. Preprints, 26th Conference on Hurricanes and Tropical Meteorology, Miami, FL, Amer. Meteor. Soc., 464-465.

Conference Presentations

Hurricane Model Initialization with AMSU Measurements, at 26th Conference on Hurricanes and Tropical Meteorology, Miami, FL

POLARIMETRIC RADAR OBSERVATIONS OF PRECIPITATION: MEASUREMENTS, ANALYSIS AND MODELING

Principal Investigator: Dr. V. Chandrasekar, Colorado State University

NOAA Project Goal: Weather

Keywords: Polarimetric Radar, NEXRAD.

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

- Evaluate the feasibility and accuracy of the hybrid mode proposed for NEXRAD upgrade compared against the traditional eigen polarization mode;
- Provide methodology for interpretation and hydrometeor classification.

2. Research Accomplishments/Highlights:

- The characterization of the hybrid mode of polarimetric radar operation and study of its inherent errors in term of radar variables in alternating mode, which provides fundamental theoretical basis to evaluate the hybrid mode of operation in a variety of storm scenarios;
- Simulation of hybrid mode measurements using radar data obtained in alternating mode;
- Conducting radar operations in both alternating mode and hybrid mode;
- Comparison of theoretical model, simulation and radar observations.

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

Accomplishments match the objectives.

4. Leveraging/Payoff:

Leverage the CSU-CHILL radar facility with the capability of fast switching between eigen polarization mode and hybrid mode. This is not available elsewhere.

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

Partnership with the NOAA/NSSL Laboratory.

6. Awards/Honors:

Elected to fellow of IEEE - Geo Sciences and Remote Sensing.

7 Outreach:

Collaboration with summer undergrad research program.

8. Publications:

Ph.D. Dissertation

“Microphysics retrieval for radar meteorology using dual-polarization polarimetric covariance matrix”, in progress.

Report

“Hybrid mode: critical evaluation in a variety of precipitation, comparing against eigen polarization operation and experimental validation”, to Office of Science and Technology of NOAA, Silver Springs, Maryland.

RADAR REMOTE SENSING PROCESSES AND INVESTIGATION OF SMOKE AEROSOL CLOUD INTERACTIONS USING LARGE EDDY SIMULATIONS

Principal Investigator: Shelby Frish
Participating Scientist: Hongli Jiang

NOAA Project Goal: Weather and Water

Keywords: Liquid water flux retrievals using radar reflectivity; retrieval of stratus cloud drizzle properties; eddy resolving and large eddy simulations (LES) of smoke cloud interactions; coupled smoke aerosol-cloud-radiative feedbacks; suppression in biomass burning areas

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

Introduction

Measurements of cloud properties are important for many reasons, including their influence on climate. These measurements are difficult, and new techniques are needed in order to monitor clouds and determine their long-term effect. One new remote sensing tool that has been developed over the last few years is the cloud sensing Doppler radar. This radar has been used in numerous field programs for applications such as determining aircraft icing, and stratus and cirrus cloud parameter estimates. New applications that are promising are estimates of stratus cloud properties using combined microwave radiometer and cloud radar measurements. Other remote sensing developments include an X-band radar with sea surface measurement capabilities.

In addition, the role of smoke aerosol in modifying the microphysics and dynamics of cumulus cloud fields in biomass burning regions such as Brazil warrant further exploration. Numerous observations point to an absence of clouds in heavy smoke regimes and two primary reasons have been postulated. The first suggests that absorption by biomass burning aerosol embedded in cloud droplets is responsible for evaporation of the droplets. The second is based on a dynamical feedback due to the absorbing aerosol, and suggests that heavy smoke aerosol cools the earth's surface by blocking incoming solar radiation and in addition, warms the atmosphere. The combination of these effects results in a more stable boundary layer, which suppresses convection and cloud formation.

Proposed Research

CIRA proposed research collaboration with NOAA/ETL in various remote sensing experiments and analysis. Dr. Shelby Frisch would continue to work with research scientists at NOAA/ETL in cloud and air-sea interaction research with the focus primarily on cloud research. The primary focus of this research would be in the design and implementation of experiments utilizing remote sensing and in-situ instruments. The emphasis would be placed on those experiments and theories designed to understand the remote sensing measurements of clouds, the ocean

surface and their geophysical interpretations. Some of this work would involve projects with long-range implications for satellite remote sensing of clouds and the ocean surface such as calibration and validation of satellite products. This will be a long-term project, involving his collaboration with other agencies, universities and private industry. In addition, Dr. Frisch is involved with Arctic research using cloud radar and instrumented aircraft observations obtained during SHEBA and with shipboard measurements of stratus clouds in the Tropical Pacific. Some of his work would include the investigation of the use of cloud retrievals for these stratus clouds.

2. Research Accomplishments/Highlights:

Research activities for the past year are summarized below. These efforts fall under NOAA Goal 3—Serve Society's Needs for Weather and Water Information.

1) **Retrievals of liquid water flux from stratus cloud droplets using a millimeter cloud radar.** The divergence of the flux can be used to estimate the heating and cooling in the cloud due to condensation and evaporation of the cloud droplets. Using a lognormal droplet distribution as a cloud droplet representation, along with other facts about marine stratus clouds, one can show that the flux can be computed directly from the reflectivity. Figure 1 shows the results of this calculation for marine stratus clouds. This technique was published in the AMS radar conference proceedings.

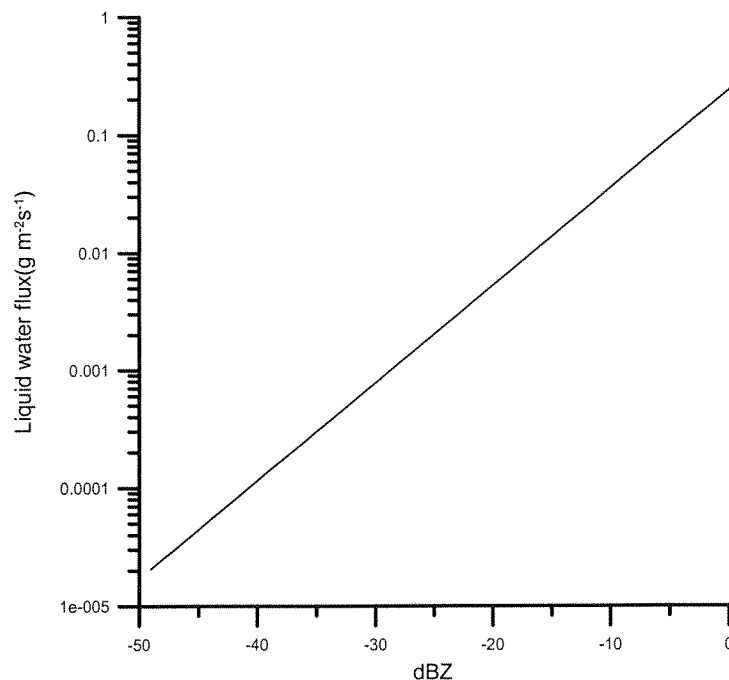


Fig. 1. Liquid water flux as a function of radar reflectivity.

2) **Retrievals of stratus cloud drizzle properties with a millimeter cloud radar, Doppler lidar, and a wind profiler mounted on a ship.** Ship motion is a problem for using radar drizzle retrieval techniques developed by Frisch, et al (1995). In order to use this technique, one needs to know the vertical air motion, plus the radar reflectivity, and the first and second moments of the Doppler spectra. In the case of the NOAA ship Ron Brown, the cloud radar antenna moves with the ship, and thus the first and second moments are contaminated by this motion. In addition, when the antenna is pointing off-zenith, the mean wind will generate an error in these vertical Doppler moments. The wind profiler has the motion removed with a phased antenna array, and is not subject to these motion errors. However, the reflectivity measurement from the profiler is poor; consequently, the millimeter cloud radar is used for reflectivity measurements because the cloud radar has a good reflectivity calibration. This work is in progress. A sample of a retrieved profile of effective radius and liquid water are shown in Figures 2 and 3.

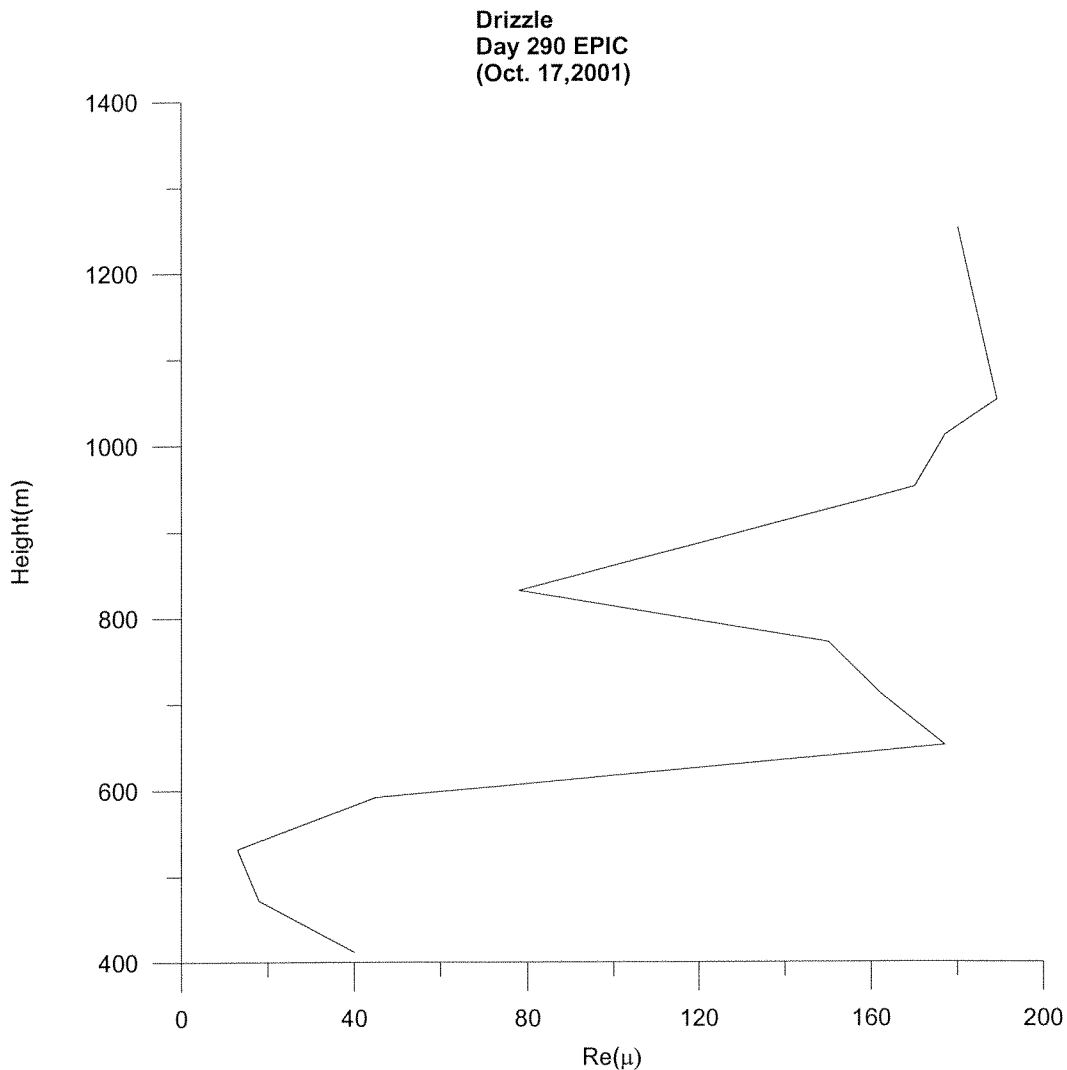


Fig. 2. Retrieved profile of effective radius.

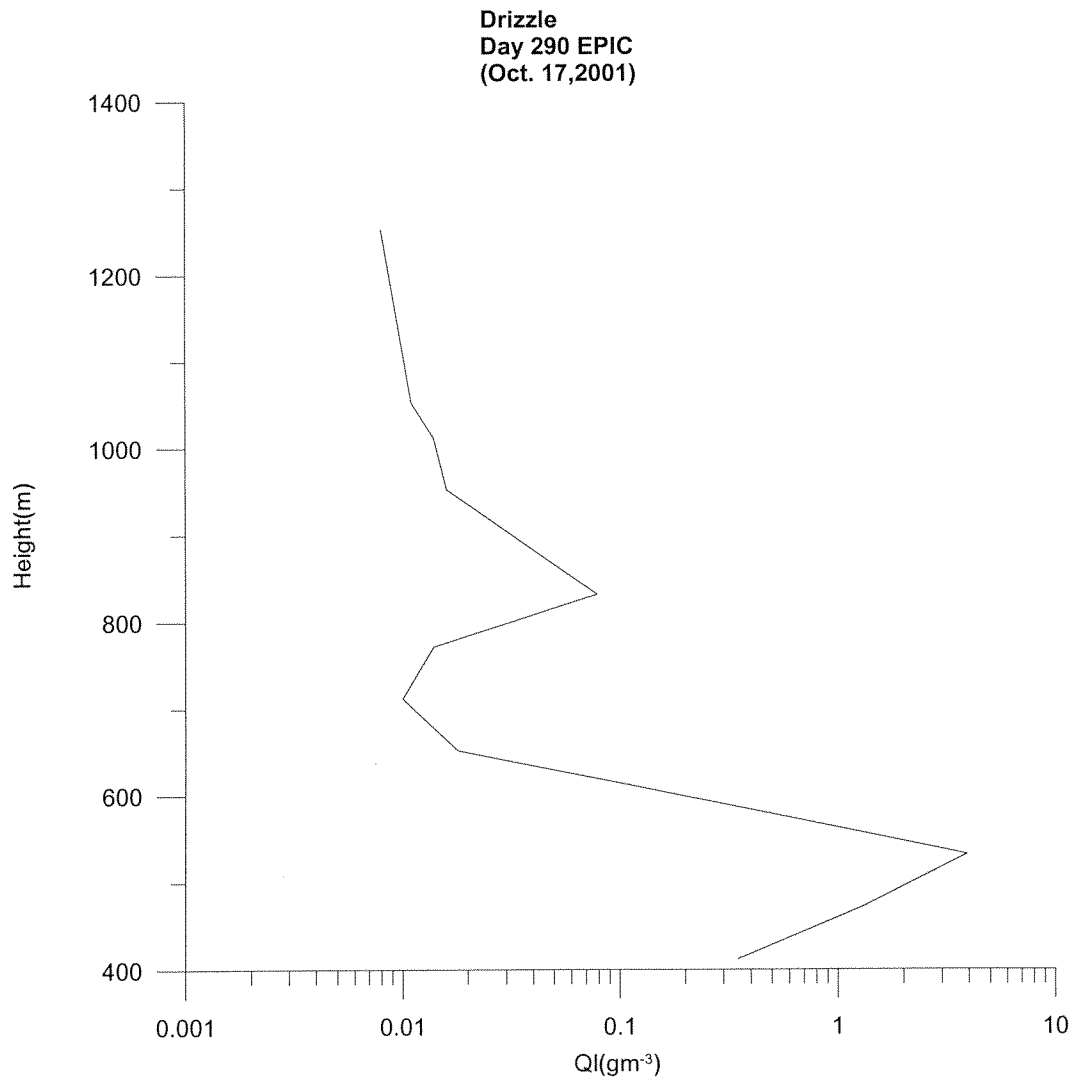


Fig 3. Retrieved profile of liquid water concentration.

Publications:

Frisch, S. and P. Zuidema, 2003: On the vertical profile of stratus liquid water flux using a millimeter cloud radar. *AMS 31st International Conference on Radar Meteorology*, Seattle, WA, 6-12 August 2003, P2A.4.

References

Frisch, A. S., C. W. Fairall, and J.B. Snider, 1995: Measurement of stratus cloud and drizzle parameters in ASTEX with a $K\alpha$ -band Doppler radar and a microwave radiometer. *J. Atmos. Sci.*, 52, 2788-2799.

Further, the interactions and the relative importance of the smoke aerosol-cloud processes would be explored using the Regional Atmospheric Modeling System

(RAMS) in large eddy simulation (LES) mode. This work will use a bin microphysical representation of both aerosol particles and cloud drops and incorporate aerosol tracking capabilities through the cloud droplets (Feingold et al. 1996). In this manner, heating rates inside individual droplets will be based on the prognosed amount of aerosol embedded inside drops. The model would be modified such that prognosed aerosol amounts generate heating rates based on their physical properties. These radiatively active aerosol particles will therefore allow feedbacks to model dynamics. Finally, surface cooling resulting from a reduction in incoming solar radiation would be simulated.

A series of numerical experiments designed to evaluate the relative importance of the various processes to suppression of cloudiness were to be performed. Finally, in conditions of moderate smoke where cloud formation is not suppressed, the role of shallow cumulus in vertical transport of smoke to the free troposphere would be examined.

During the past year, eddy resolving simulations (ERS), and large eddy simulations (LES) of smoke-cloud interactions were used to demonstrate the relative importance of various factors responsible for cloud suppression in the biomass burning regions of Amazonia. The model includes unprecedented treatment of coupled smoke aerosol-cloud-radiative feedbacks in 2-, and 3-dimensional (2D, 3D) model that resolves scales on the order of 200 m. In all of the simulations, the surface fluxes are imposed based on an analysis of AERONET data for relatively clean and polluted conditions.

Numerous 2D simulations were performed by varying the vertical distribution of initial smoke aerosol, by including or ignoring the coupling of smoke heating with the dynamical model, and by reducing the surface fluxes from its observed values. Although 2D ERS does not represent the eddy structure as well as 3D LES, it is able to capture many of the elements of the 3D simulations except for the differences between the timescales and structure of boundary-layer eddies (Stevens et al., 1996). Because it is computationally efficient, the 2D framework is used to explore a broader parameter space and for testing new numerical schemes before investing in 3D simulations. The initial results of 2D simulations were reported in the 14th International Conference on Clouds and Precipitation, held in Bologna, Italy.

A total of five, 3D simulations have also been performed as summarized in Table 1. All simulations have an aerosol optical depth $t_a \sim 0.6$, considered to be a polluted environment. The differences among the simulations are (i) the vertical distribution of initial smoke (S1 vs S3), (ii) the coupling of smoke heating with the dynamical model (S1 vs S2), and (iii) in the magnitude of the surface fluxes (S1 vs S5). Selective model statistics are collected every 30 seconds; a subset of the statistics, containing cloud fraction and cloud liquid water path in 3D simulations, is shown below in Figs. 5, 7 and 9. Also shown in Figs. 6 and 8 are the vertical profiles of radiative heating due to smoke aerosol averaged over the 4th hour of the simulations before clouds form.

Figure 4 shows the initial profiles of smoke aerosol, located in the lowest 1200m for S1, S2, and S5 and aloft (between 1200 m and 2400 m) for S3 and S4 runs. The first comparison is between simulations of S1 and S2 to investigate the effect of smoke heating. Figure 5 shows no clear differences in the x-y plane averaged values of liquid water path (LWP) and cloud fraction, despite the strong radiative heating at lower level due to aerosol heating (Fig. 6). There is a distinct reduction in LWP and cloud fraction when comparing simulations of S3 and S4 (Fig. 7). Aerosol heating rate profiles (Fig. 8) reflect the initial aerosol profiles (Fig. 4) with slight modification. Simulation S5 is a repeat of S1 with reduced surface fluxes. Figure 9 shows strong reduction in cloudiness due to reduced surface fluxes and that this factor alone appears to be sufficient to explain the observed reduction in cloudiness in biomass burning regions of Brazil.

In summary, the results of all the simulations have shown that the vertical distribution of smoke aerosol in the convective boundary layer is crucial to determining whether cloudiness is reduced; smoke aerosol emitted at the surface in a daytime convective boundary layer may reduce or increase cloudiness. On the other hand, the observed and modeled reduction in surface latent and sensible heat fluxes associated with biomass burning is sufficient by itself to substantially reduce cloudiness.

Publications

Feingold, G, H. Jiang, and J.Y. Harrington, 2004: Large eddy simulations of smoke-cloud interactions. Preprint for the 14th *International Conference on Clouds and Precipitation*. 12-16 July 2004, Bologna, Italy.

Feingold, G, H. Jiang, and J.Y. Harrington, 2004: On smoke suppression of clouds in Amazonia, to be submitted to *Geophys. Res. Lett.*

Table 1. Description of Simulations

Name	Aerosol heating	Fluxes	Smoke location
S1	No	Observed	Surface
S2	Yes	Observed	Surface
S3	No	Observed	Aloft
S4	Yes	Observed	Aloft
S5	No	Reduced	Surface

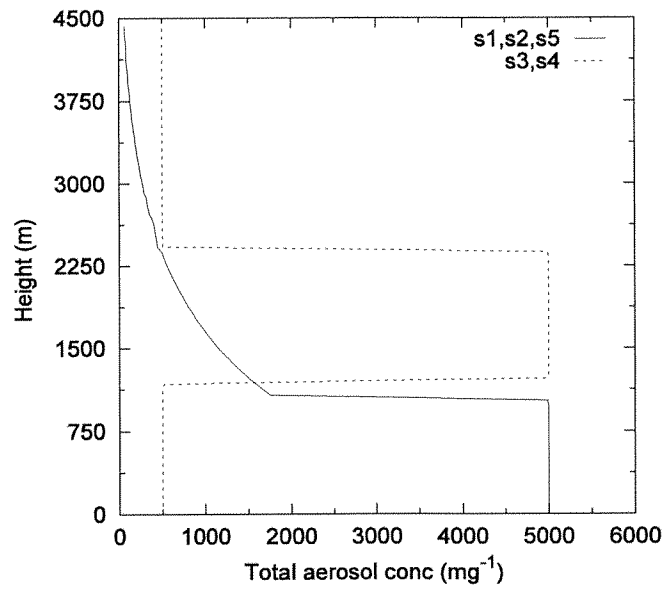


Fig 4. Initial aerosol profiles for simulations S1-S5 as described in Table 1.

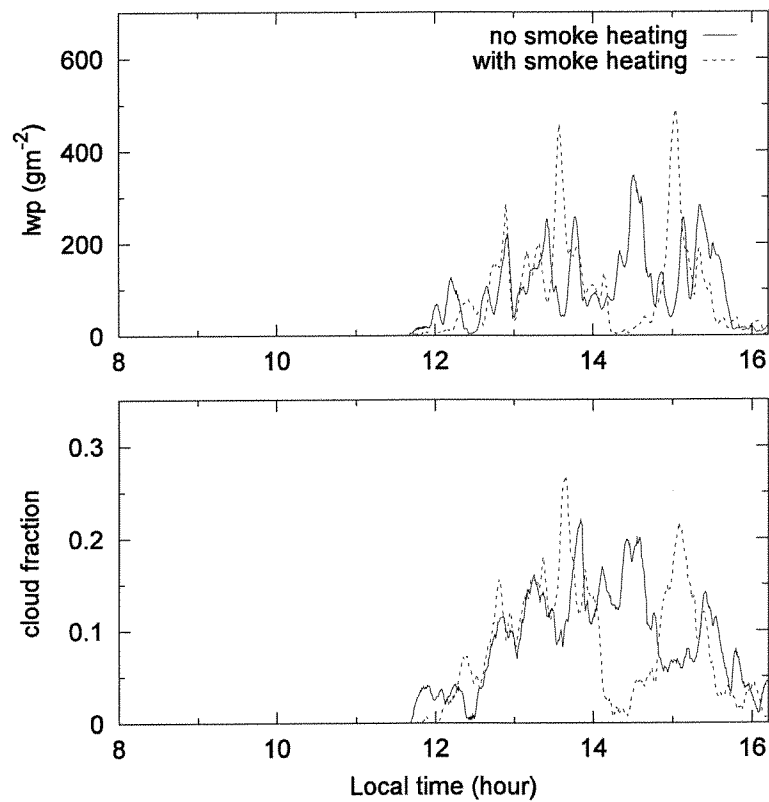


Fig 5. Time series of liquid water path LWP and cloud fraction for simulations of S1 and S2.

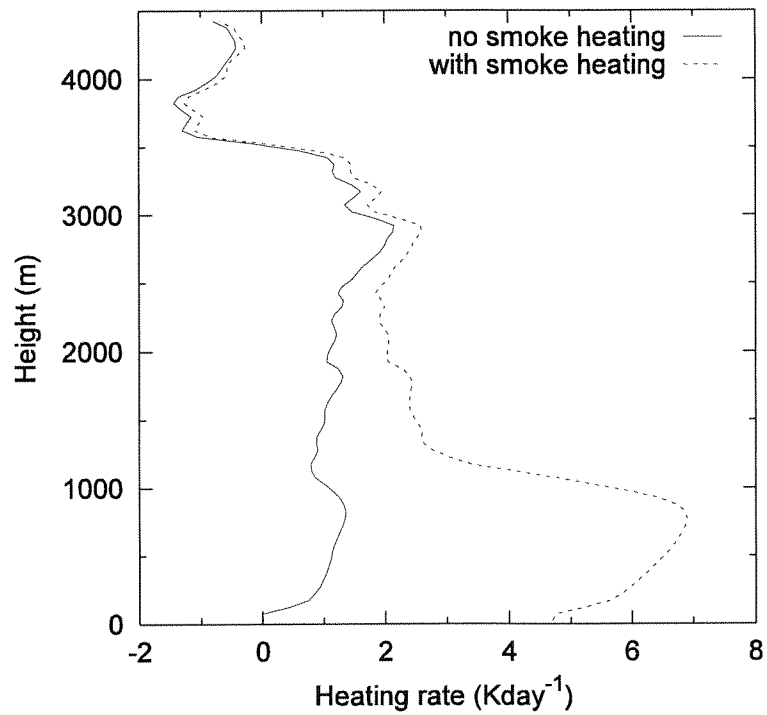


Fig. 6. Heating rate profiles for simulations S1 (no heating) and S2 (with heating) at 200 min.

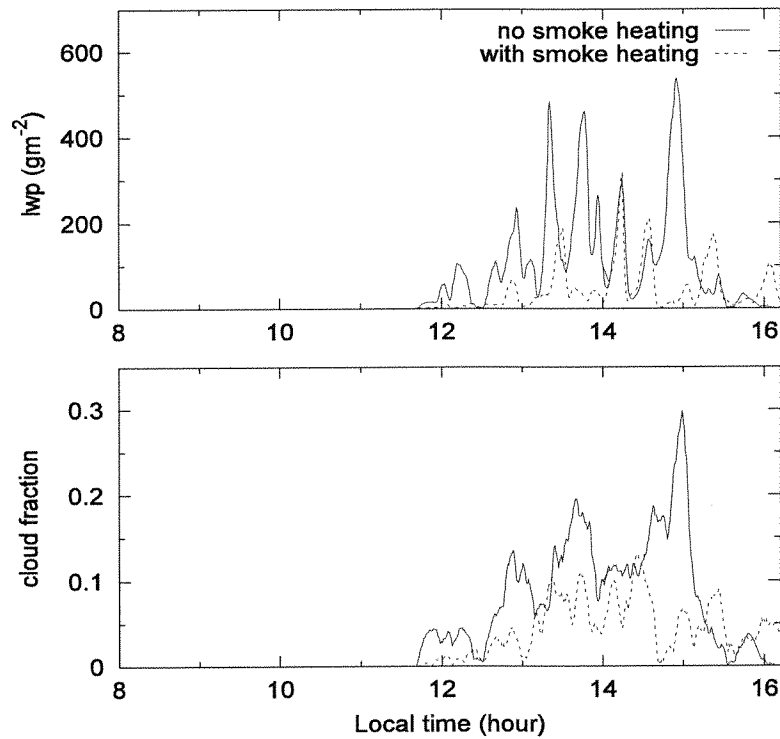


Fig. 7. Time series of liquid water path LWP and cloud fraction for simulations S3 (no heating) and S4 (with heating).

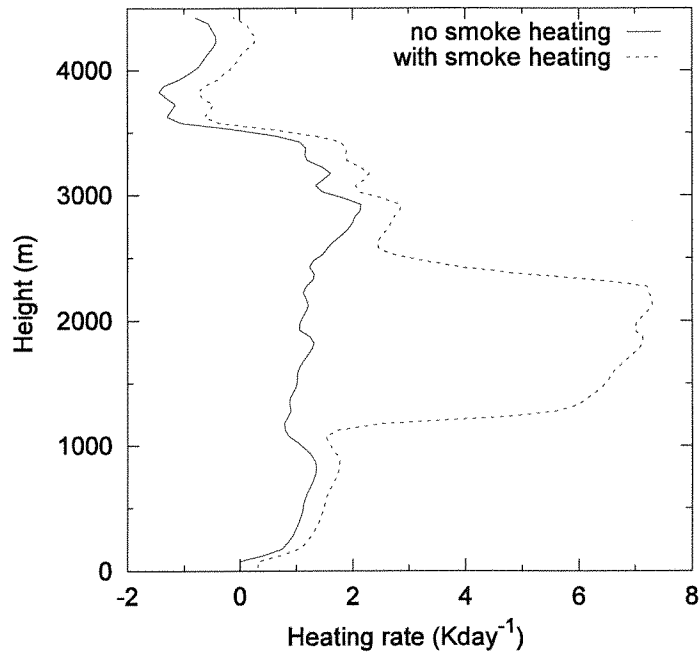


Fig. 8. Heating rate profiles for simulations S3 (no heating) and S4 (with heating) at 200 min.

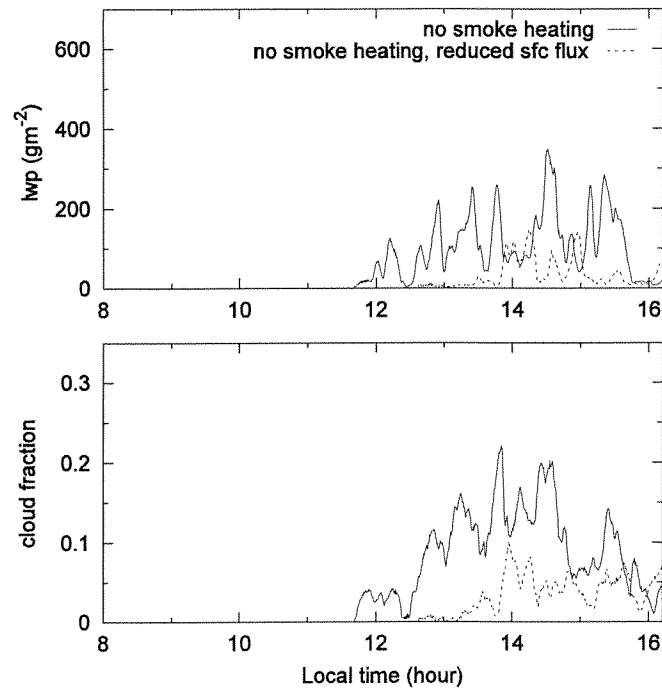


Fig. 9. Time series of LWP and cloud fraction for simulations S1 (no heating, observed fluxes) and S5 (no heating, reduced fluxes).

RESEARCH & DEVELOPMENT FOR GOES-R RISK REDUCTION

Principal Investigators: T.H. Vonder Haar

NOAA Project Goal: Weather and Water

Keywords: 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 achieve the above objectives are to focus on mesoscale weather events with fast time scales including hurricanes, severe thunderstorms, lake effect snow, and fog. In addition, long term objectives include simulating GOES-R data in the following two ways:

- Use existing operational and experimental satellite data.
- Use a numerical cloud model in conjunction with an observational operator—that contains OPTRAN code and radiative transfer models, to produce synthetic GOES-R images.

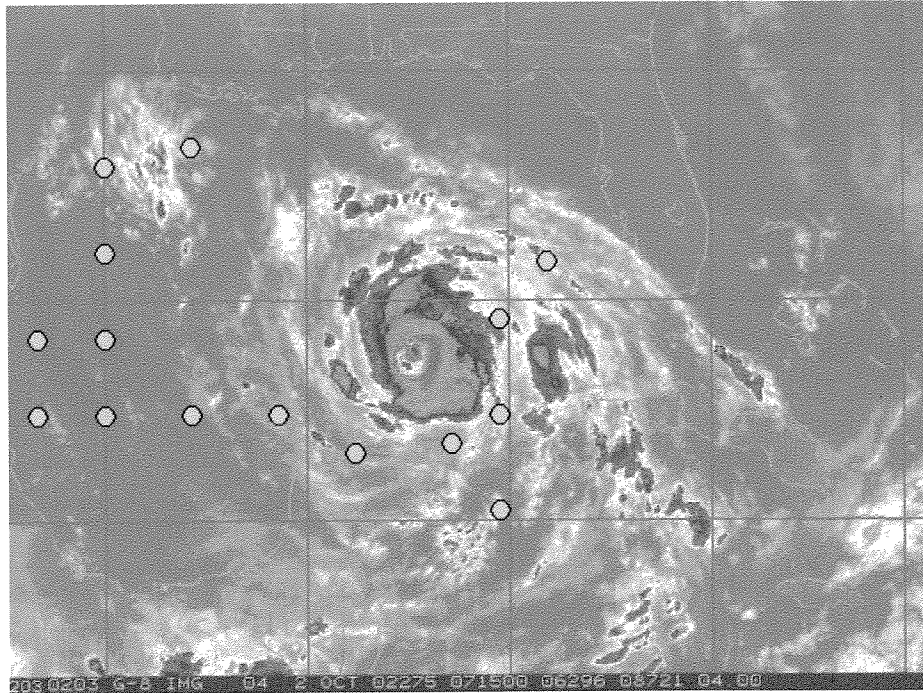
2. Research Accomplishments/Highlights:

- Data Collection: Collection of GOES, AIRS, AVHRR, and MODIS satellite data, and ancillary observations for the three case studies is continuing. Two additional cases have added, including hurricane Isabel from 2003 during its peak intensity and a California fog outbreak in January of 2004. Table 1 shows the data that has been collected so far. Two terabyte mass-storage devices built from “off-the-shelf” PC equipment has been set up to house these large datasets. A web site for displaying the various data types has also been established, and a more comprehensive database system is under development.

GOES-R/IPO Data Collection Tables												
Data Type	Severe Weather		Lake Effect Snow			Hurricane Lili					Hurricane Isabel	Fog
Date	2003		2003			2002					2003	2004
	May 8	May 9	Feb 12	Feb 13	Feb 14	Sep 30	Oct 1	Oct 2	Oct 3	Oct 4	Sep 12	Jan 11
GOES Imager	X	X	X	X	X	X	X	X	X	X	X	X
GOES Sounder	X	X	X	X	X		X	X	X		X	X
GOES Soundings	X	X										
AVHRR	X	X	X	X	X		X	X	X		X	
MODIS	X	X	X	X	X		X	X	X		X	X
AIRS Radiances	X	X	X	X	X		X	X	X			
AIRS Soundings	X	X					X	X	X			
ETA Analyses	X	X	X	X	X	X	X	X	X	X		
RAMS Simulation	X											
RADAR			X	X					X			
GPS Soundings	n/a	n/a	n/a	n/a	n/a	X	X	X				
ARM Soundings			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		
Rawinsondes	X	X	X	X	X	X	X	X	X	X		

Table 1: Summary of data types being collected for the GOES-R case studies. An x indicates that the data has already been obtained, and n/a indicates that data type is not available for the particular region of that case study

- Evaluation of Hyperspectral IR soundings: One of the first questions that will be explored is the information content of IR soundings from hyperspectral instruments. Temperature and moisture retrievals from the AIRS instrument for our case studies are being obtained from NESDIS/ORA and will be compared with in-situ data. For the tropical cyclone case, special GPS soundings from the NOAA Gulfstream jet in the data void regions of the Gulf of Mexico have been obtained for comparison. These soundings were available on three of the Lili case study days, and about 50 soundings are within +/- three hours of an AIRS overpass. Figure 1 shows the locations of the GPS sondes that are available for the AIRS pass on 02 October 2002 at about 0700 UTC. For the Lake Effect Snow case, the AIRS soundings will be compared with conventional radiosondes, and for the Severe Weather case, with conventional radiosondes and special soundings from the ARM site if available. The soundings will also be compared with the background field from corresponding NCEP analyses to determine if the AIRS soundings are providing new information.



GOES-8 10.7 μm – 2002-Oct-02 0715 UTC

Figure 1: Locations of GPS sondes from the NOAA Gulf Stream Jet (orange circles) plotted on a GOES-8 infrared image of Hurricane Lili on 2 Oct 2002. The plotted GPS sondes are within 3 hours of an AIRS overpass of this region. Note that many of the sondes (especially those to the west of the storm) are in relatively cloud free areas of the storm environment

- We have simulated the severe weather event of 8 May 2003 that occurred over the central plains of the United States and the 12 February 2003 lake effect snow event over the Great Lakes. Because spectral filter function coefficients were unavailable for GOES-R, synthetic images were created for the operational GOES. A favorable comparison existed between synthetic and real GOES images for these two cases. This comparison provides some confidence that inferences made from the synthetic data will be applicable to real GOES-R observations when they become available. As a result, synthetic DPI CAPE imagery was produced for the severe weather case with 50, 30, 10, 4, and 1 km footprint sizes for the HES component of the above objectives.

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

In general all of the objectives have been met with one exception. Preliminary results from the hurricane simulation suggested that the areal coverage of the simulated domain of interest was too small for practical application. As a result, we have decided to move the simulation to a new 64-bit machine so as to exceed the 4 GB RAM limit present on 32-bit architecture.

4. Leveraging/Payoff:

What NOAA will receive for resources invested is:

- Advanced product development, and
- Extended operational use of the GOES-R satellite.

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.
- 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.

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) An undergraduate student is partially supported by this project.

(b) See section 8

(c) None

(d) None

(e) None

8. Publications:

Refereed Journals

Grasso, L.D., and T.J. Greenwald, 2004: Analysis of 10.7 micron brightness temperatures of a simulated thunderstorm with two-moment microphysics. *Mon. Wea. Rev.*, 132:3, 815-825.

Greenwald, T.J., T. Vukicevic, L.D. Grasso, and T. H. Vonder Haar, 2004: Adjoint sensitivity analysis of an observational operator for visible and infrared cloudy-sky radiance assimilation. *Quart. Jour. Royal Met. Soc.*, 130:597, 685-705.

Conference Proceedings

DeMaria, M., D.W. Hillger, J.F.W. Purdom, R.M. Zehr, H. Gosden, D.L. Watson, J.A. Knaff, D.L. Lindsey, D.E. Bikos, 2004: Advance Mesoscale Product Development for GOES-R Using Operational and Experimental Satellite Observations. *3rd GOES Users Conference*. 10-13 May, Broomfield, CO.

Grasso, L.D. , M. Sengupta, D. Zupanski, M. Zupanski, J.F. Dostalek and M. DeMaria, 2004: Applications of Simulated GOES-R Observations for Advance Product Development for Mesoscale Weather Forecasting. *3rd GOES Users Conference*. 10-13 May, Broomfield, CO.

Newsletters

Hillger, D.W., M. DeMaria, and L.D. Grasso, 2004: GOES-R Risk Reduction Activities at CIRA. *CIRA Magazine*. 10-11.

Workshops

Grasso, L.D., August 19-20, 2003: *GOES-R Review*, Washington, DC

Hillger, D.W., August 19-20, 2003: *Workshop on Satellite Data Applications and Information Extraction*, Madison, WI

SEVERE WEATHER AND TROPICAL CYCLONE PRODUCT DEVELOPMENT FOR THE NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) PREPARATORY PROJECT

Principal Investigator: L.D. Grasso

NOAA Project Goal: Weather and Water

Keywords: NPOESS, VIIRS

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

The long term research objectives are to assess the utility of NPP/NPOESS instruments for severe weather and tropical cyclone applications and advanced—in time—product development. The specific plans to achieve the above objectives are to combine a numerical cloud model with an observational operator—that contains OPTRAN code along with radiative transfer models—to produce synthetic infrared images of simulated severe weather and tropical cyclone events. Synthetic VIIRS images can then be used to examine thunderstorm cloud top structure and build statistics comparing brightness temperatures to rain rates. Synthetic images will also be used to expand the scope of the project by including simulated tropical cyclones and the Advanced Technology Microwave Sounder (ATMS); that is, develop a real-time ATMS tropical cyclone intensity/size algorithm for NPP. This will be similar to the real-time AMSU algorithm that is being used by NHC and JTWC.

2. Research Accomplishments/Highlights:

Our research accomplishments include the following:

- Simulation of an idealized severe storm.
- Simulation of real-data severe weather case (8 May 2003 severe weather event over the central plains of the United States).
- Development of an observational operator for VIIRS channel near 10.8 μm .
- Comparison of synthetic imagery with GOES data for 8 May 2003 event.
- Effects of VIIRS resolution on brightness temperature/rain rate relationship.

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

We have essentially met our objectives of the first year: To demonstrate the procedure of combining a numerical cloud model with an observational operator to produce synthetic imagery from simulated output. Because OPTRAN code uses spectral weighting function coefficients specific to an instrument, we had to use the current GOES coefficients since VIIRS values are not yet available.

4. Leveraging/Payoff:

What NPOESS will receive for resources invested is

- Advanced product development, and
- Extended operational use of the satellite.

5. Research Linkages/Partnerships/Collaborators, Communications 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 NPP/NPOESS channels.
- 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.

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) None

(b) See section 8

(c) None

(d) None

(e) None

8. Publications:

Refereed Journals

Grasso, L.D., and T.J. Greenwald, 2004: Analysis of 10.7 micron brightness temperatures of a simulated thunderstorm with two-moment microphysics. *Mon. Wea. Rev.*, 132:3, 815-825.

Greenwald, T.J., T. Vukicevic, L.D. Grasso, and T. H. Vonder Haar, 2004: Adjoint sensitivity analysis of an observational operator for visible and infrared cloudy-sky radiance assimilation. *Quart. Jour. Royal Met. Soc.*, 130:597, 685-705.

Training

DeMaria, May 17 & 18, 2004: NPOESS Training Workshop at COMET, Boulder, CO

Presentations

Grasso, L.D., M. Zupanski, J. Dostalek, M. Sengupta, D. Zupanski, and M. DeMaria, 2004: Applications of simulated satellite observations for advanced product development of mesoscale weather events. CIRA directors meeting, Fort Collins, CO.

Workshops

Hillger, D., August 19-20, 2003: *Workshop on Satellite Data Applications and Information Extraction*, Madison, WI.

STOCHASTIC MODELING AND SIMULTION OF THE GRET LAKES NET BASIN SUPPLIES

Principal Investigator: Jose D. Salas, Department of Civil Engineering

NOAA Project Goal: Weather & Water

Keywords: Stochastic simulation, stochastic modeling, abrupt shifts, Great Lakes.

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

To better understand the dynamics of the net basin supplies and lake levels of the Great Lakes system. The plan is to improve the modeling efforts introducing concepts of non-stationarity.

2. Research Accomplishments/Highlights:

- A shifting mean stochastic process was developed that is capable of reproducing the abrupt shifting dynamics that has been observed in the historical records of the Great Lakes net basin supplies.
- The modeling framework has been developed for multisite (multivariate) systems in such a way that some of the sites can be modeled with shifting means while other sites with a stationary mean.

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

The project objectives have been met.

4. Leveraging/Payoff:

Empirical evidence and recent research have shown that certain hydro-climatic processes such as precipitation, sea surface temperature, and streamflows at some locations of the earth evolve with multiyear and multidecadal variations. The results of our research can be useful for making projections and developing possible scenarios of hydro-climatic variations that may occur in the future.

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

Collaboration with the Colorado Climate Center, particularly with Professor R. Pielke, and Professor U. Lall of the International Research Institute (IRI) of Columbia University.

6. Awards/Honors: None at this time.

7. Outreach: (a) Graduate/Undergraduate students; (b) Seminars, symposiums, classes, educational programs; (c) Fellowship programs; (d) K-12 outreach; (e) Public awareness:

(a) Oli Sveinsson, Ph.D. (finished in the Summer of 2002).

(b) Fall and Spring meetings at AGU, and ASCE/EWRI Conferences

8. Publications:

Refereed Journal Articles (in Press)

Sveinsson, O.G.B., Salas, J.D., and Boes, D.C., (2004). "Prediction of Extreme Events in Hydrologic Process that Exhibit Sudden Shifting Pattern". *ASCE Journal of Hydrologic Engineering*.

Refereed Journal Articles (submitted)

Sveinson, O.G.B., Salas, J.D., and Fortin, V., 2004. "Shifting Mean Plus Persistence Model for Simulating the Great Lakes Net Basing Supplies", *J. Hydrology*.

Chapter in Book

Salas, J.D. and Pielke, R.A., Sr., 2003, "Stochastic Characteristics and Modeling of Hydroclimatic Processes" by, *Handbook of Weather, Climate, and Water*, T.D. Potter and B.R. Colman, Editors, John Wiley Interscience, Chapter 32, 587-605.

Professional Meeting, Conferences, and Workshops

Perreault, L., Forting, V., and Salas, J.D., 2004, "Mixtures and Hidden Markov Models for Estimating Flood Quantiles and Risk", AGU/CGU Joint Assembly, May 17-21, 2004, Montreal, Québec, Canada.

Sveinsson, O. and Salas, J.D., 2004, "Predicting Floods and Low Flows Exhibiting Abrupt Shifting Flow Regimes", AGU/CGU Joint Assembly, May 17-21, 2004, Montreal, Québec, Canada.

Fagherazzi, L., José Salas, J.D., Sveinsson, O., Sparks, D., and Fay, D., 2004, "Stochastic Modeling and Simulation of the Great Lakes Ottawa River System", ASCE/EWRI Conference, Salt Lake City, June 2004.

Ph.D. Dissertation

Sveinsson, O.G.B. (2002). *Modeling of Stationary and Non-Stationary Hydrologic Processes*. Ph.D. Dissertation, Colorado State University, Fort Collins, 206 pp.

SUPPORT OF THE VIRTUAL INSTITUTE FOR SATELLITE INTEGRATION TRAINING (VISIT)

Principal Investigator: T. H. Vonder Haar

NOAA Project Goal: Weather and Water

Keywords: Professional Training, Satellite Interpretation, VISIT, NWS Training, GOES, Rapid Scan Operations

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

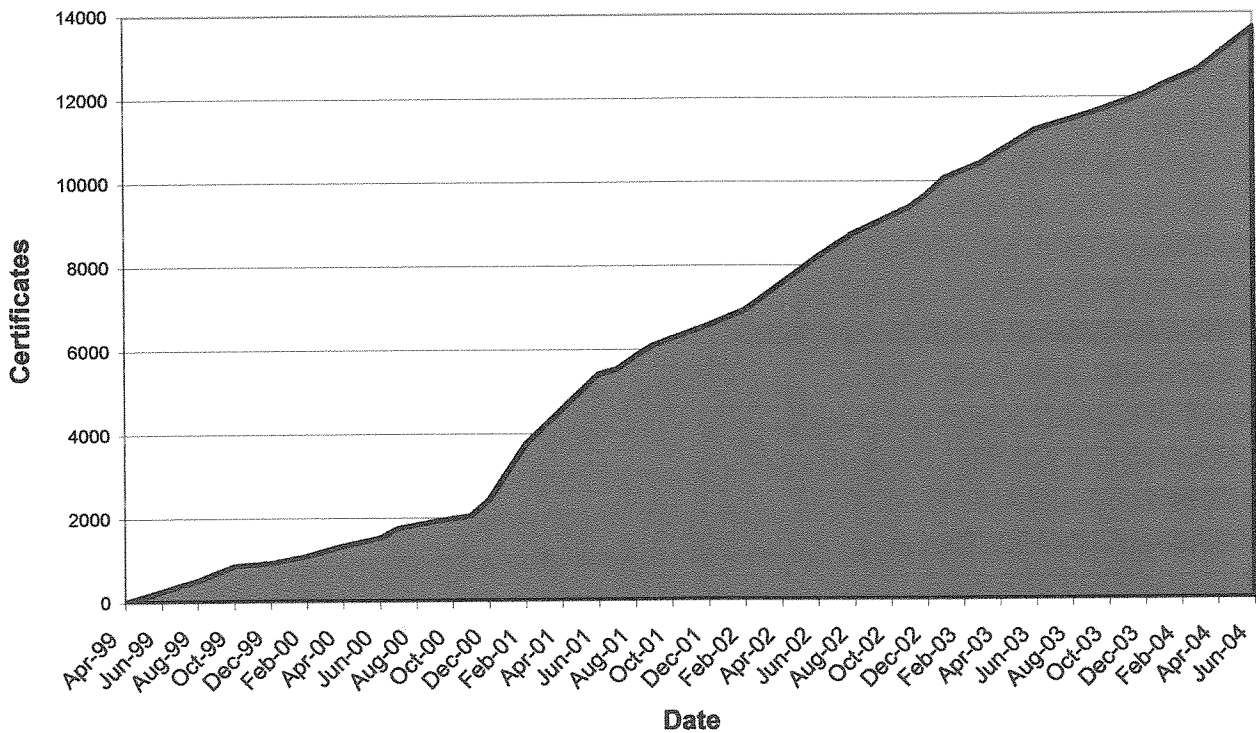
The primary objective of the VISIT program is to accelerate the transfer of research results based on atmospheric remote sensing data into National Weather Service (NWS) operations. This transfer is accomplished through teletraining modules developed at CIRA and delivered to NWS forecasters.

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 new teletraining sessions have been developed at CIRA, in addition to six sessions created by VISIT collaborators. As training needs develop for new research and products, VISIT personnel will address those needs by building new teletraining sessions.

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 twenty-to-thirty teletraining sessions over a wide variety of topics. To date, over 12,000 training certificates have been awarded (Fig. 1), and most student feedback suggests a direct applicability to current forecast problems. The VISIT website (<http://www.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 continues 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.

IST/VISIT Cumulative Training Certificates Issued



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

In the last year, the VISIT team at CIRA has developed three new teletraining sessions: 1) Use of GOES/RSO imagery with other remote sensor data for diagnosing severe weather across the CONUS, 2) The interactive cloud height algorithm and GOES sounder point retrievals in AWIPS (2 independent topics combined into 1 teletraining session), and 3) QuikSCAT Winds. Each of these sessions was recommended by operational forecasters from the NWS.

4. Leveraging/Payoff:

In the late 1990's, 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, Communications and Networking:

The project involves considerable collaboration within the National Weather Service through contributions to training material, input on "beta-tests" of training sessions, 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.

6. Awards/Honors: None as yet.

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

A high school student and a college undergraduate student are supported by this project.

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

See section 8.

(c) Fellowship programs;

None

(d) K-12 outreach:

J. Weaver gave a presentation on severe thunderstorms to middle school students participating in the Colorado State University summertime "Kids in College" program. Also, all of the VISIT training sessions are available via the Internet, and can be used in K-12 teaching programs.

(e) Public awareness.

VISIT training material is available to the public via the Internet.

8. Publications:

Refereed Journals

Mostek, A., J. Weaver, D. Bikos, D. Lindsey, B. Zajac, S. Bachmeier, T. Whittaker, B. Motta, B. Grant, J. LaDue, and J. Ferree, 2004: VISIT: Bringing Training to Weather Service Forecasters Using a New Distance -Learning Tool. *Bull. Amer. Meteor. Soc.*, 85:6, 823-829.

Hodanish, S., R.L. Holle, and D.T. Lindsey, 2004: A Small Updraft Producing a Fatal Lightning Flash. *Wea. and Forecasting*, 19:3, 627-632.

Dostalek, J.F., J.F. Weaver, and L. Phillips, 2004: Aspects of a tornadic left-moving thunderstorm of 25 May 1999. *Wea. and Forecasting*, 19:3, 614-626.

Weaver, J.F., and D.T. Lindsey, 2004: Some frequently overlooked visual severe thunderstorm characteristics observed on GOES imagery – a topic for future research. *Mon. Wea. Rev.*, 132:6, 1529-1533.

Weaver, J.F., D.T. Lindsey, D.E. Bikos, C.C. Schmidt, and E. Prins, 2004: Fire Detection using GOES-11 Rapid Scan Imagery. *Wea. and Forecasting*, 19:3, 496-510.

Conference Proceedings

Lindsey, D.T., D. Bikos, J. Weaver, and A. Mostek, 2004: The VISIT Program -- Transferring Research to Operations. *20th Conference on Weather Analysis and Forecasting*, 11-15 January, Seattle, WA, Amer. Meteor. Soc., paper 19.1.

Lindsey, D.T., D. Bikos, A. Mostek, S. Bachmeier, T. Whittaker, J.F. Weaver, B.N. Grant, and J. LaDue, 2004: VISIT -- Providing Teletraining for Operational Forecasters. *13th Symposium on Education*, 11-15 January, Seattle, WA, Amer. Meteor. Soc., paper 3.2.

Presentations

Lindsey, D.T., 2004: Using satellite imagery to improve forecasts and nowcasts. *AMS 33rd Conference on Broadcast Meteorology*, 14-18 June, New Orleans, LA

Training

Lindsey, D.T., D.E. Bikos, J.F. Weaver, and R.M. Zehr, Jul 1, 2003 – Jun 30, 2004: 162 VISIT teletraining sessions delivered to NWS offices, and others – CIRA, Fort Collins, CO

Weaver, J.F., Oct 24, 2003: New focuses in satellite training. COMET Mesoscale Analysis and Prediction (COMAP), Boulder CO

Lindsey, D.T., May 17-28, 2004: The World Meteorological Organization (WMO) regional training seminar for national instructors from Regions III and IV (provided three 50-minute lectures on satellite meteorology). Buenos Aires, Argentina

Newsletters

Connell, B.H., D.E. Bikos, D.T. Lindsey, J.F. Weaver, A. Mostek, 2004: National and International Training Activities at CIRA. *CIRA Magazine*. 7-9.

Workshops

Molenaar, D.A., March 3, 2004: AWIPS Meeting, Boulder, CO

TASK I: 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

July 8, 2003, P. Haertel (CIRES/NOAA). On the Dynamics of 2-Day Equatorial Disturbances

July 10, 2003, P. Artaxo (Univ. of San Paulo). Aerosols and Cloud Interactions in Amazonia: Results From the LBA/SMOCC Experiment

August 1, 2003, C. Golaz (NRL). Improvements and Simplifications to a PDF-Based Boundary layer Closure

September 4, 2003, J. Hurrell (NCAR). Tropical Forcing of North Atlantic Climate Change

September 11, 2003, G. Grell (NOAA/FSL). A Next Generation Air Quality Prediction Model Based on WRF

September 17, 2003, K.V. Ooyama (NOAA/AOML). Historical Aspects of Tropical Cyclone Research

September 18, 2003, G. Bryan (NCAR). Cloud Resolving Modeling and Interpretation of Midlatitude Squall Line Systems

September 23, 2003, M. Sengupta. The Importance of Accurate Liquid Water Path for Surface Radiation

September 25, 2003, B. Geerts (Univ. of WY). Classification and Characterization of Tropical Precipitation Based on High-Resolution Airborne Vertical-Incidence Radar

October 2, 2003, W.W. Tung (NCAR MMM). Interaction Between Tropical Convection and Large Scale Equatorial Waves

October 8, 2003, J.M. Chen (Univ. of Toronto). Deriving Large-Area Carbon Fluxes from Air CO₂ Concentration Measurements at a Boreal Site

October 9, 2003, B. Huebert (Univ. of Hawaii). ACE-Asia and AMMA: What Do and Don't We Know About the Impacts of Dust and Black Carbon

October 14, 2003, L. Grasso. GOES-R Risk Reduction Activities at CIRA

October 16, 2003, M. DeMaria. Improvements in Deterministic and Probabilistic Hurricane Intensity Forecasts

October 22, 2003, J. Lin (Harvard Univ.). Constraining Sources and Sinks of Carbon at the Regional Scale with Aircraft Observations

October 23, 2003, S. Rizvi (NCAR MMM). Recent Developments in Data Assimilation at NCAR

October 28, 2003, C. Lu (NOAA/FSL/CIRA). NOAA/FSL's RUC Short-Range Ensemble Forecast System

October 30, 2003, T. Vukicevic. 3D Clouds from Satellite Observations

October 31, 2003, T. Nguyen, T. Tien (Hanoi, Vietnam). A Numerical Study in Heavy Rainfall Causing Severe Flash Flood: Does Finer-grid-induced Airflow Affect Rainfall?

November 2, 2003, C. Jakob (BMRC). Cloud Regimes in the Tropical Western Pacific and Their Radiative Characteristics

November 6, 2003, A.Kellie (NCAR). Computing for the Atmospheric Science NCAR

November 11, 2003, B. Ruston. Characteristics of Summertime Microwave Land Emissivity.

November 13, 2003, S. Nesbitt (CSU/ATS.) Radar, Rainfall and Lighting Characteristics of Tropical Rainfall Systems According to TRMM

December 2, 2003, M. Barna. Simulating the Formation and Transport of Surface Aerosol for the BRAVO Study

December 4, 2003, J. Klemp (NCAR). Development and Evaluation of the WRF Model for Convection Resolving NWP

January 20, 2004, H. Gerber (Gerber Scientific). Holes and Entrainment in Stratocumulus

January 22, 2004, D. Ren (Univ. of Oklahoma, Sarkeys Energy Center). Hydrauliclift and Its Implication on Soil Moisture Simulation

January 22, 2004, C. Stroud (NCAR ASP). Predicting the Physico-Chemical Properties of Secondary Organic Aerosol Derived from the Photo-Oxidation of Toluene/NO_x Mixtures

January 27, 2004, D. Hillger. Metric Transition in the United States: Where We Are, and Where We Are Headed

January 29, 2004, D. Zupanski. Model Error Estimation in the Framework of Ensemble Data Assimilation

February 5, 2004, K. Davis (PSU). Multi-scale Observations of the Terrestrial Carbon Cycle: Progress, Puzzles and Motivation

February 12, 2004, S. Solomon (NOAA). Climate Change: A Review For Everyone

February 17, 2004, T. Kampe (Ball Aerospace). Earth Remote Sensing at Ball Aerospace

February 19, 2004, S. Koch (NOAA FSL). Structure and Dynamics of Atmospheric Solitons During IHOP

February 26, 2004, W. Robinson (Univ. of Illinois). Negative Viscosity Redux: Jets, Annular Variability, and Eddy Generation

March 1, 2004, A. Jacobson (Los Alamos National Lab.) Real-Time Monitoring of Severe Convection Using Radio-Frequency Sensors on Satellites

March 4, 2004, N. Gruber (UCLA). The Oceanic Sink for Anthropogenic CO₂

March 8, 2004, A. Tompkins (ECMWF). Organization of Tropical Deep Convection: The Ubiquitous Role of Coldpools

March 10, 2004, C.C. Wu (National Taiwan Univ.). Some Research Highlights on the Tropical Cyclone Dynamics and the Typhoon-Ocean-Biogeochemistry Interaction

March 11, 2004, R. Fovell (UCLA). Discrete Propagation of Midlatitude Squall Lines

March 25, 2004, H. Owada (Japan Meteorological Agency). Assimilation of Geostationary Satellite Data for Cloud Analysis at JMA

March 25, 2004, M. Baldwin (NRA, Bellevue, WA). How Are Weather and Climate Affected by Stratospheric Variability?

April 1, 2004, K. Moore (NCAR). Chemical Composition of Ultrafine Atmospheric Aerosol

April 2, 2004, C. Landsea (NOAA/AOML/HRD). The Atlantic Hurricane Database Re-analysis Project - Results for 1851 to 1910 and 1992's Hurricane Andrew

April 8, 2004, H. Dijkstra. Physics of Multidecadal Variability in the North Atlantic

April 14, 2004, N.T.K. Oanh (Asian Inst. Of Tech.). Preliminary Findings of the Asian Air Pollution Research Network: PM Levels, Composition and Source Apportionment in the Bangkok Metropolitan Region

April 15, 2004, B. Stevens (UCLA.). Scaling Laws for Shallow Moist Convection

April 20, 2004, K. Zeller, N. Nikolov (USDA Forest Service). Mesoscale Modeling and Forecasting Support at the Rocky Mountain Center

April 27, 2004, L. Bonaventura (Max Planck Inst. for Meteorology). The ICON Project: Modeling Strategies and Preliminary Results

May 5, 2004, W. Berg (CSU/ATS). The Status of Satellite-Based Climate Rainfall Observations

May 6, 2004, J. Seinfeld (California Institute of Technology). Secondary Organic Aerosol

May 14, 2004, J. Beven (NCEP). The TPC/NHC Hurricane Tracking and Forecast Process

May 17, 2004, W. Skirving (CIRA, NOAA/NESDIS). Coral Bleaching From Space: The Use of NOAA Environmental Satellite Data to Monitor Bleaching Conditions

May 21, 2004, L. Ji (CIRA/USGS, South Dakota). Comparison of MODIS and AVHRR 16-Day Normalized Difference Vegetation Index Composite Data

June 3, 2004, Y.P. Wang (CSIRO Atmospheric Research, Australia). Seasonal Variation of Maximal Photosynthetic Rates of Different Forest Canopies as Inferred from FLUXNET Dataset Using Nonlinear Inversion.

June 21, 2004, R. Wood (Hadley Centre for Climate Prediction and Research, UK). Modeling Past and Future Climate Changes in the Ocean.

June 22, 2004. G.G. Campbell (CIRA). ISCCP Clouds View Angle Dependence and the Long-term Trend.

*Some seminars were jointly sponsored with the CSU Department of Atmospheric Science.

Fellowship Program

Barbara Ervens – See *“The Role of Stratocumulus Clouds in Modifying Pollution Plumes Transported to North American Continent”*

Zhengzhao “Johnny” Luo – CIRA Post Doc

Project Title: Characterizing upper tropospheric temperature, moisture and cloud biases in NCAR Community Atmospheric Model 2 (CAM2) in comparison with HIRS and ISCCP satellite observations

Principal Investigator: Zhengzhao “Johnny” Luo

NOAA Project Goal: Climate

Keywords: GCM, CAM2, HIRS, ISCCP

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

The long term goal is to validate Global Climate Models (GCMs) using various satellite sensors (e.g. HIRS, MSU, ISCCP, TRMM, and CloudSat). The plan to achieve it is to insert forward models into GCMs and simulate satellite observations and then make a direct comparison with real satellite data.

2. Research Accomplishments/Highlights:

NCAR GCM CAM2 has been validated against HIRS and ISCCP via the method described above. Accomplishments/highlights include: 1) A paper in collaboration with Prof. Graeme Stephens is being prepared that is to be submitted to J. Geophys. Res. The paper is titled as “Characterizing upper tropospheric temperature, moisture and cloud biases in NCAR CAM2 in comparison with HRIS and ISCCP satellite observations”. 2) NCAR has invited me to a conference presenting my research results under their funding. NCAR Climate Modeling Section shows their interest in collaborating with us.

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

The short term objectives are mostly achieved. But since this is a long term project (i.e. validating GCMs), a lot more still remains to be done.

4. Leveraging/Payoff:

Global Climate Model (GCM) is almost the only tool to comprehensively understand future climate change, and model validation is a necessary approach to developing a physically sound GCM. Conventional model validation often involves a handful of field campaigns only. Our study explores on systematically using satellite sensors to validate GCMs.

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

Collaboration has been under way with Prof. Graeme Stephens at the Atmospheric Science Department of CSU. Phil Rasch from NCAR also expressed his interest in working with us on model validation and diagnostic studies.

6. Awards/Honors: None as yet.

7. Outreach:

Invited by NCAR to present my results at the Community Climate Modeling System (CCSM) workshop at Santa Fe, July 2004.

8. Publications:

Luo, Z. and G. L. Stephens (2004): Characterizing upper tropospheric temperature, moisture and cloud biases in NCAR CAM2 in comparison with HRIS and ISCCP satellite observations. To be submitted to J. Geophys. Res.

8. Task I General Publications:

Vonder Haar, T.H., 2004. *Annual Report on the Cooperative Institute for Reserch in the Atmosphere, 01 July 2003 – 30 June 2004*, Cooperative Institute for Research in the Atmosphere, Colorado State University, Ft. Collins, CO.

THE CIRES-NOAA WESTERN WATER ASSESSMENT—PROVIDING INCREASED FOCUS ON THE CRUCIAL AGRICULTURAL SECTOR

Principal Investigators: D.H. Smith/R.M. Waskom, CSU Department of Soil and Crop Sciences; John Wilkins-Wells, CSU Sociology Water Lab

NOAA Project Goal: Weather and Water

Keywords: Atmospheric Research, Agricultural Water, Irrigation, Climate Products

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

Goals:

- Determine opportunities within the agricultural sector for enhanced use of climate products
- Evaluate the acceptance of climate products that address agricultural needs by agricultural users

Plans:

- Identify canal companies and irrigation districts within the South Platte and Arkansas River basins that can be used as focus groups for evaluating climate products
- Determine existing processes used by these water supply entities in determining water supply quotas
- Establish formal linkages between agricultural water supply entities and the Western Water Assessment working group
- Develop models that characterize the use and acceptance of climate products by agricultural water suppliers

2. Research Accomplishments/Highlights

- Recruited graduate research assistant
- Developed preliminary research plan for five-year project

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

4. Leveraging/Payoff:

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

We have participated in two consultative sessions (with a third planned) with the Western Water Assessment group at the University of Colorado. These sessions have been useful in identifying mutual goals for participation by Colorado State University in the Western Water Assessment project. In addition, the Sociology Water Lab at CSU has been engaged as a key CSU participant in the project. The Sociology Water Lab has also played a significant role in our negotiations to extend the project over multiple years.

6. Awards/Honors: None as yet.

7. Outreach:

As a result of their participation, we have identified three irrigation companies within the South Platte River basin to conduct initial assessments during the first year of the project.

8. Publications:

9. Additional Information:

Report Summary

The Western Water Assessment (WWA) project, a joint effort between the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado and the NOAA-funded Climate Diagnostic Center (NOAA-CDC) in Boulder, Colorado, is one of several regional programs funded by the Office of Global Programs at NOAA with the charge of providing input to NOAA on the practical use of climate information. The primary mission of WWA is to improve water-related decision-making and management in the interior west by increasing the scope, quality, availability, and relevance of climate products and knowledge. Because agricultural water use (for irrigation) accounts for the greatest share of water use throughout the western US, the overall objective of the current project is to determine how the agricultural sector uses climate products and how climate products could be improved to address agricultural needs, especially with respect to management decisions and drought.

After the project was initially funded, we began to collaboratively explore with the WWA project their particular concerns with respect to climate information needs by the agricultural water users. After consulting with the WWA group, we identified the need for incorporating a social science perspective and received encouragement to pursue multiyear funding for the project so that a graduate student could be recruited. Based on these initial discussions with the WWA project, we asked the Sociology Water Lab at CSU to participate as a key collaborator. The Sociology water group has significant experience and expertise in working with agricultural water supply organizations to determine the structure, decision-making, and other aspects of how these organizations function. In working with this group, we have identified potential external collaborators (irrigation companies) to participate in the research and recruited a graduate student.

Approach/Evaluation/Methodology

Our primary approach during the initial phase of the project has been to pursue extensive dialog with the WWA group to insure that our approach meets their needs and that multiyear funding is likely. With the active participation and input of scientists from the Sociology Water Lab, we have identified potential external collaborative groups (agricultural irrigation companies) and the specific nature of informational needs of these groups. Irrigators in the western US generally depend upon local water organizations to predict and deliver water supplies to them. These organizations provide water to irrigators by generally announcing an initial quota of water at the beginning of the irrigation season and then adjusting these quotas monthly for the remainder of the season. Irrigators combine this quota or allotment information with their soil moisture conditions and pricing information to determine desirable crop choices and how much acreage to bring into production each year. Although it is known that many water supply entities combine information on their water storage, watershed snowpack, and anticipated streamflows to declare water quotas for irrigators served by these systems, it is not clear what specific elements of information are involved in establishing these quotas. It is also unclear how accurately the quotas reflect actual water availability, as measured by streamflows and reservoir storage levels, during the irrigation season. The information deficit described above meshes well with existing WWA projects with objectives of developing more accurate streamflow forecasts and determining the vulnerability of the agricultural sector to climate changes that decrease water supplies.

We have just completed the development of a five-year plan of work to determine the nature of current decision-making within agricultural water supply organizations and the potential information needs (in terms of climate products) of these suppliers. The plan of work will be presented to the WWA project leadership on 22 July for their comments and critique. If approved, our initial objective is to develop a thorough review of literature on the structure and function of local agricultural water supply companies in the western US, with particular emphasis on how these organizations establish supply quotas for their shareholders.

Research Accomplishments and Results

Our primary accomplishments to date include 1.) establishment of dialog with key project leaders within the WWA group at the University of Colorado, 2.) development of collaboration with the Sociology Water Lab at CSU, and 3.) identification of a graduate student with the background and interest necessary to pursue the research.

Conclusions and Recommendations

The collaborative arrangements established through this project between CSU and the WWA research group offer the potential of long-term productive relationships between agricultural researchers at CSU and the various NOAA funded agencies at CU such as CIRES-NOAA and NOAA-CDC.

THE ROLE OF STRATOCUMULUS CLOUDS IN MODIFYING POLLUTION PLUMES TRANSPORTED TO NORTH AMERICAN CONTINENT

Principal Investigator: Sonia M. Kreidenweis (Graham Feingold NOAA/ETL)

NOAA Project Goal: Climate

Keywords: Aerosols, indirect effect, tropospheric chemistry, clouds

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

The long-range transport of pollution plumes to North America is of interest from an air quality and a global climate perspective. Our focus is on understanding cloud-aerosol interactions. We have developed models that include aqueous-phase chemistry to predict modification and removal of pollutant species and effects on climate.

2. Research Accomplishments/Highlights:

Several models were revised and extended to include photochemistry, new aqueous-phase reaction mechanisms, and treatment of thermodynamic properties of complex aerosol mixtures. Model developments and applications were reported in 2 peer-reviewed papers. A third paper in progress reports implications for uncertainty estimates of aerosol indirect forcing of climate.

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

4. Leveraging/Payoff:

The results of this work will be applicable to reducing the current large uncertainty in estimates of indirect forcing of climate by aerosols.

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

6. Awards/Honors: None as yet.

7. Outreach:

8. Publications: (Year 3 of project only)

Refereed Journal Articles

B. Ervens, 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. J. Frost, and S. M. Kreidenweis, "A modeling study of aqueous Production of Dicarboxylic Acids 1: Chemical pathways and speciated organic mass production," J. Geophys. Res., in press, 2004a.

Ervens, B., G. Feingold, S. L. Clegg, and S. M. Kreidenweis, "A modeling study of aqueous Production of Dicarboxylic Acids 2: Implications on cloud microphysics," J. Geophys. Res., in press, 2004b.

Ervens, B., G. Feingold, and S. M. Kreidenweis, "Water soluble organic carbon and cloud drop number concentration," in preparation, 2004c.

Kanakidou, M., J. H. Seinfeld, S. Pandis, I. Barnes, F. J. Dentener, M. C. Facchini, R. van Dingenen, B. Ervens, A. Nenes, C. J. Nielsen, E. Swietlicki, J.P. Putaud, Y. Balkanski, C. E., Lund Myhre, K. Tsigaridis, E. Vignatti, E. Stephanou, J. Wilson, "Organic aerosol and climate modelling: A review," to be submitted to Atmos. Chem. Phys., 2004.

Conference Proceedings

Ervens, B., Feingold, G., Kreidenweis, S. M., and Clegg, S. L.: "Cloud processing of organic/inorganic aerosols: Organic mass production rates and implications for cloud physics," Organic Aerosol Workshop (EU Project PHOENICS), Belgirate, Italy, 2003.

Ervens, B., Feingold, G., Kreidenweis, S. M., Frost, G. J., and Clegg, S. L., 2003, "Modification of internally mixed organic/inorganic aerosols by cloud chemistry," AAAR Annual Conference, Anaheim, CA.

Ervens, B., Feingold, G., Kreidenweis, S. M., and Clegg, S. L., 2003, "Mass and composition modification of $(\text{NH}_4)_2\text{SO}_4$ aerosols by dicarboxylic acid formation in clouds: Implications on cloud physics," AGU Fall Meeting, San Francisco, CA.

Ervens, B., Feingold, G., Kreidenweis, S. M., and Clegg, S. L., 2004, "Organic aerosol mass production in clouds: Modification of the hygroscopic behavior of inorganic aerosols," EGU Meeting, Nice, France.

Kanakidou, M., J. H. Seinfeld, S. Pandis, I. Barnes, F. J. Dentener, M. C. Facchini, R. van Dingenen, B. Ervens, A. Nenes, C. J. Nielsen, E. Swietlicki, J.P. Putaud, Y. Balkanski, C. E., Lund Myhre, K. Tsigaridis, E. Vignatti, E. Stephanou, J. Wilson, "Organic aerosol and climate modelling: A review," to be submitted to Atmos. Chem. Phys., 2004.

9. Additional Information:

Excerpts from Annual Report to NOAA for Year 2

Introduction

The long-range transport of pollution plumes to North America is of interest from an air quality and a global climate perspective. Asian dust and pollution is transported to the

western U.S. each spring; Saharan dust is transported to the eastern and southeastern U.S. each summer; and smoke aerosols are transported to the southwestern, midwestern and southeastern U.S. each summer. We seek to gain a better understanding of the frequency and magnitude of such events, including examining the historical records for the past 12 years. Our other focus, which has been central to efforts in the third year of the grant, is on understanding how clouds can modify such pollution plumes. We have developed models that describe aerosol-gas-cloud interactions, including aqueous-phase chemistry, to predict modification and removal of pollutant species.

Project Goals

Our specific goals in Year 3 and through a no-cost extension period are:

- 1) perform theoretical modeling studies of aerosol processing pathways;
- 2) link aerosol composition, particularly organic content, to hygroscopicity and cloud nucleating behavior;
- 3) test the sensitivity of cloud drop number concentration (so-called first aerosol indirect effect) to the organic carbon species and mass fraction in the aerosol;
- 4) generalize results as far as possible to develop better-constrained estimates of uncertainty in indirect aerosol effects.

Methodology

We are continuing our 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. This allows us to test the effects of aerosol composition and size on activation of particles to cloud drops for any chosen environmental initial conditions.

Results and Accomplishments

Modeling studies of aerosol-gas-cloud interactions:

The parcel model designed for the simulation of aerosol/cloud chemistry and microphysical processes has been modified and further developed. It accounts for the chemical, physical, and thermodynamic properties of organic (or mixed organic/inorganic) aerosols relevant to cloud formation. As a first step, we addressed the importance of organic cloud chemistry on composition and mass modification of initial aerosols. We developed a multiphase mechanism that considers the formation of dicarboxylic acids in clouds and selected a few gas phase precursors which are representative for common anthropogenic or biogenic species. We showed that small dicarboxylic acids can be efficiently formed in clouds by

chemical multiphase processes and that these processes lead to significant addition of aerosol mass (Ervens et al., 2004a).

The second part of our simulations focused on the changes in hygroscopic behaviour of cloud-processed particles by addition of dicarboxylic acid mass. Under many conditions (i.e., for a variety of updraft velocities and aerosol size distributions), complex mixtures of ammonium sulfate and dicarboxylic acids as derived from cloud processing exhibit hygroscopic behaviour very similar to that of pure ammonium sulfate particles, at least when dilute. This means that the apparent complexity introduced by the mixed compositions studied here in fact leads to minimal changes in cloud properties. This is a rather surprising result, since the water content of these mixed particles below 100% relative humidity, important for calculations of visibility and radiative transfer (i.e. direct climate effects of aerosols), can be significantly different than that for pure ammonium sulfate.

Additional explorative model simulations have revealed that among small dicarboxylic acids only the least soluble one (adipic acid) might cause distinct differences in drop number concentrations. For dicarboxylic acids, their effect on other aerosol properties such as surface tension, do not lead to any significant effect on drop number concentration and effective cloud drop radius (Ervens et al., 2004b). Based on the results from the rigorous thermodynamic model, due to Clegg and co-workers, that we applied in our first studies, we have developed parameterizations for the treatment of water activities of mixed organic/inorganic aerosols in order to provide a computationally efficient approach for modeling the CCN activity of small dicarboxylic acids.

It must be noted that dicarboxylic acids represent only a small fraction of the water-soluble organic fraction in most atmospheric aerosols. In a more systematic approach, we have explored the importance of generalized organic aerosol properties (molecular weight, dissociation, solubility, and surface tension) on modification of cloud properties, using as the reference baseline aerosol the common inorganic compound ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$. Our simulations showed that under most atmospheric conditions, many organic aerosol compounds will exhibit hygroscopic behaviour similar to ammonium sulfate, since several composition effects, that are not truly independent of each other and should be considered in tandem, have counteracting effects on drop number concentration (Ervens et al., 2004c).

Postdoctoral researcher Dr. Barbara Ervens joined our groups in April 2002 and has focused on model development and applications. She has been reappointed for 2004-2005, contingent on granting of a no-cost extension on this project and a low-cost extension for this work to complete her third year of research.

VARIABILITY AND TRENDS IN GLOBAL PRECIPITATION

Principal Investigators: Christian Kummerow and Wesley Berg

NOAA Project Goal: Climate

Keywords:

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

Predictions of future climate scenarios by General Circulation Models (GCMs) forced with increased concentrations of greenhouse gases all show an enhanced global mean hydrologic cycle [IPCC report on Climate Change, 1996, p. 42]. The models also all show increased rainfall variability with a greater occurrence of floods and droughts. A comparison by Soden [2000] of 30 GCMs with satellite derived precipitation estimates from MSU [Spencer, 1993], however, reveals substantial disagreement between the magnitude of predicted variations in tropical mean precipitation and that indicated by the satellite observations.

Even more disconcerting is a dramatic disagreement in tropical mean rainfall between more recently developed long-term global rainfall datasets with regard to both interannual variability and long-term climate trends. A comparison of the time series of mean global tropical rainfall between the Climate Prediction Center's (CPC) Merged Analysis of Precipitation (or CMAP) [Xie and Arkin, 1997], and the Global Precipitation Climatology Project's (GPCP) combined precipitation dataset [Huffman et al., 1997] is shown in Figure 6. These two 22-year global rainfall datasets utilize similar and in some cases identical component estimates from state-of-the-art satellite retrievals along with rain gauge and other long-term satellite rainfall retrievals. Based on the striking differences, it is clear that the current long-term global rainfall datasets are inadequate for monitoring variability associated with the El Niño-Southern Oscillation (ENSO) or for detecting trends associated with increases in global mean temperatures.

Because both the CMAP and GPCP merge together many of the same component datasets, we propose to examine time-dependent regional biases in the individual retrievals and to determine how they affect the resulting tropical mean rainfall variability. The fact that these biases are both regionally and temporally dependent means that it is not possible to apply simple bias corrections based on a limited region or period of corresponding unbiased rain estimates. Instead, we propose to investigate the underlying physical basis for the various algorithm and sensor-dependent biases using a variety of datasets including recent observations from the Tropical Rainfall Measuring Mission's (TRMM) Precipitation Radar (PR). The ability of the PR to provide information on the vertical structure of rainfall systems will be used to identify and quantify biases in the component satellite retrievals used by the CMAP and GPCP products, and determine how these component biases lead to overall differences in both the interannual variability and climate trend.

2. Research Accomplishments/Highlights:

The effort during the second year was focused on using the coincident radar and IR data sets produced during the first year to analyze the relationship between IR inferred rainfall and that of the TRMM Precipitation radar (PR). A timely question arose in the scientific community that could be resolved with our data set. The Iris hypothesis put forth by Lindzen *et al.* (2001), hypothesized that as sea surface temperature increases, the precipitation efficiency increases, resulting in a decrease in the area of cold cloud. If correct, this Iris effect would have to be accounted for in IR rain estimates in order not to introduce artificial biases related to changes in the ratio of cold cloud to rainfall with warming SST as is the case during ENSO events.

Testing this hypothesis and its impact upon IR rain estimates was the subject of an MS thesis completed on May 10, 2004 by Ms. Anita Rapp at CSU. Pixel-level Visible and Infrared Scanner (VIRS) 10.8 μm brightness temperature data and Precipitation Radar (PR) rain rate data from TRMM were collocated and matched to determine individual convective cloud boundaries. Each cloudy pixel was then matched to the underlying SST. The effect of rainfall on the cold cloud area was examined using PR surface rainfall as a proxy for the precipitation efficiency. Normalizing the size of the cold cloud area by its underlying rainfall provided information on whether or not the precipitation efficiency was affecting the area of cold cloud at higher SSTs. Single-core and multi-core convective clouds were investigated separately.

Our results do not support the Iris hypothesis. No trend indicating changes in precipitation efficiency (defined as cloud area divided by surface rainfall) was found in the 18-month period covering from January 1998 to August 1999 in the tropical western Pacific. Results from both single-core and multi-core convective clouds show negligible correlations, indicating that in regions of higher SSTs, the rainfall from a cloud does not increase as area of cold cloud decreases. Results do, however, indicate the possibility that changes in precipitation efficiency at higher SSTs are affecting warm, shallow convection (not the hypothesized deep convection). These results are presented in the MS thesis of Ms. Anita Rapp, Dept. of Atmospheric Sciences, Colorado State University. They were presented at the AGU annual meeting in San Francisco and are being prepared for submission to the *Journal of Climate*.

While the Iris hypothesis does not seem to be responsible for changes between cold cloud area and precipitation, the large scatter inherent in the co-located data indicates that other large-scale dynamical forces are at play. Towards this end we are investigating the relationship between both the synoptic scale environmental conditions and forcing mechanisms and rainfall climate regimes. The idea being pursued is to relate changes in the vertical and horizontal structure of rain systems determined using a combination of visible, passive microwave, and radar data from TRMM to the synoptic environment. This eliminates the need for a time-dependent regional description of regimes, which currently limits the applicability of field programs to the validation of global satellite results. This work, which is ongoing, will be a major focus of our efforts in the final year of this project. (Ref: Lindzen, Richard S., Chou, Ming-Dah, Hou, Arthur Y. 2001: Does the Earth Have an Adaptive Infrared Iris?. *Bull. Amer. Meteorol. Soc.*: Vol. 82, No. 3, pp. 417–432).

3. Comparison of Objectives Vs. Actual Accomplishments for Reporting Period:
4. Leveraging/Payoff:
5. Research Linkages/Partnerships/Collaborators, Communications and Networking:
6. Awards/Honors: None as yet.
7. Outreach:
8. Publications:

WEATHER SATELLITE DATA AND ANALYSIS EQUIPMENT AND SUPPORT FOR RESEARCH ACTIVITIES

Principal Investigator/Group Manager: T. Vonder Haar/M. Hiatt

NOAA Project Goal: Infrastructure and Earthstation

Keywords: Infrastructure, Earthstation, Data Sets, Computer Resources, Networking, Cluster, Security, Archive

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: CIRA 2004 Research Initiative Award, The infrastructure was recognized for excellence in the November 2003 NOAA 5-Year Review Report.
7. Outreach:
8. Publications: N/A
9. Additional Information:

The CIRA Infrastructure provides all planning, development, deployment, maintenance, and support for CIRA's information technology including computer resources, networking, security, satellite earthstation, computational innovation and data archive.

The infrastructure was recognized for excellence during the January 2004 NOAA 5-year review. Reviewers specifically noted that one of the areas which provided significant contribution to CIRA research was "applications of information technology to atmospheric sciences".

Computer Resources

CIRA currently has 155 systems that represent CIRA's core computer base. These systems are custom designed, assembled, and maintained by the group. The following list gives an overview of the infrastructure resources managed by this group:

- Complete system management: Pentium-4 servers/workstations using the Microsoft Windows XP/2000/2003 operating system. Hardware/Software acquisition, installation, and support. System upgrades, software patches and service packs

- E-mail, primary website, accounts, accounting, FTP, DHCP, DNS, printing, dialup, security, antivirus, antispam, and property accounting
- Network LAN/WAN and CIRA subnet
- Infrastructure budget and expenditures. Infrastructure operates on less than \$300,000/year including salaries of group members.
- Technical consulting for: RAMM, NPS, Bacimo, AMSU, Geosciences, CHANCES, CloudSat, Students, Visiting Scientists
- Linux cluster: 24 nodes, totaling 40 processors. The master is a dual Xeon system with 6 GB memory and 1 TB of disk. It is a 32-bit system on a gigabit Ethernet backbone.

A notable change this year was the addition of RAID (Redundant Array of Inexpensive Disks) systems to several key servers. These RAID systems provide total uninterruptible hard drive redundancy further minimizing server downtime.

Earthstation

The satellite earthstation provides key metrological data for CIRA research. The earthstation collects, processes, distributes, and archives:

- GOES-8
- GOES-10
- GOES-11
- GOES-12
- NOAA-16/17
- Meteosat-5
- Meteosat-7
- GMS-5
- MSG-1 (Now GMS-8)

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 for future use.

Noted additions to the earthstation this year:

1. CIRA-developed DVD archive system
 - a. Innovative: Unique solution developed at CIRA leveraging mass market technology. Development time and cost were minimized.
 - b. Lower Cost: At today's prices, DVD media is 1/6 the price of tapes. Furthermore, DVD writers are 1/10 the cost and DVD readers are 1/20 the cost of tape drives.
 - c. Data verification: Verification on tape is not possible since there is physical contact between the tape and tape drive. Hence, during tape verification the tape may be damaged by the read process. DVD media does not touch the laser and therefore can be reliably verified.
 - d. Longer Life: DVD's are rated at least 30 years and less affected by environmental issues. Tapes are easily damaged by temperature, humidity, age, and magnetic fields.

- e. Random access: Data retrieval from DVD is significantly faster since the DVD's are random access. Tapes are sequential access.
 - f. Distribution: Large data requests can be handled faster since the DVD's can be quickly duplicated. The same process on tape media is time consuming and risks damage to the original media.
 - g. Retrieval: Web based HTML log files allow quick and easy searching from any Internet computer. Library style indexing and storage make it easy for student help to locate the correct DVD's.
2. MSG Earthstation
 - a. As planned, the MSG earthstation went online in May 2004 and is collecting and archiving the full MSG data stream.
 3. Data recovery: Meteosat-5 data and key NCAR data sets were converted to DVD using CIRA's new DVD system from aging tapes. About 4TB of data was saved.

CloudSat

The CloudSat Data Processing Center infrastructure design passed two key milestones with the implementation of System Version 0 in October 2003 and the generation of CloudSat standard data products using test data set #3 in April 2004. The system performed flawlessly and was given high praise by the CloudSat Project Manager, Thomas Livermore (NASA JPL), who called it "the most pleasant surprise" of the mission to date. The reason for the "surprise" is that CIRA took on the challenge of implementing the data processing center on a budget that was less than half of the nearest competitive bidder. CIRA developed a solution that will increase the data throughput by 50% of the initial goal, increase on-line storage from the required 3 months to 22 months (the entire mission) and will provide all of the data distribution and storage functions for the entire mission (both are additional capabilities that were not specified in the initial set of requirements). Of note is the fact that the automated DVD archive system will provide an additional copy (3 copies vs. the requirement for 2 copies) of all data with an equipment and supply cost savings of over \$50K from the initial estimate for DLT storage - plus it will also cut both workforce and storage space requirements. CloudSat is scheduled for launch in April 2005.

This CloudSat work will be exploited to benefit NOAA research in the near future. Relevant technologies developed include low-cost complex processing, multi-satellite sensor correlation and data management, and improved methods of technology transfer including scientist to operational code technology transfer.

DPEAS

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.

Because the hardware, operating system and maintenance of NOAA Office PC's are already paid for, the cost-savings are significant both in terms of short term (hardware purchases) and long term (staff hours for maintenance and upgrades) costs when

compared to an equivalent Linux-cluster of machines. A preliminary cost-benefit analysis compared a cluster of 100 Office PCs to a cluster of 40 dedicated dual-processor Linux machines and found the Office PCs provided a savings of over \$1,000,000 during a 5 year period (\$2,214 per Office PC per year)

Future Work

A new Linux cluster is planned as a joint project between CIRA, the RAMM team, and Atmospheric Science. The new system will start with 10 dual-processor nodes (upgradeable to over 200 nodes) and a quad-processor master node. The master will have 32 GB memory (it is a 64-bit system, so a single process can see almost the entire 32 GB as one contiguous piece of memory) which allows us to run certain weather models that were impossible under 32-bit. The master node will have a 10 gigabit connection to the gigabit cluster network. The master node will have 2 TB disk, upgradeable to over 10 TB.

The CIRA local area network (LAN) will be upgraded from 100Mb/s to 1000Mb/s to each system. 13 switches will be replaced to perform the upgrade. This upgrade uses the same CAT5e cable that has been used over the last 3 years. This cable was installed with the plan that 1000Mb/s service would be compatible.

The earthstation will receive several hardware upgrades this year to stay compatible with the DOMSAT data stream. Two new demodulators will be purchased to replace three obsolete demodulators. Two ingest systems will receive system upgrades.

CIRA will continue to explore and deploy 64-bit system architecture as the technology becomes more proven and cost effective. 64-bit routines are already planned and running today as 32-bit routines.

ADDITIONAL CIRA FUNDING

DEPARTMENT OF DEFENSE

DoD Center for Geosciences/Atmospheric Research CG/AR

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 theme areas

- Hydrometeorology
- Cloud Structure, Dynamics and Climatology
- Data Assimilation and Data Fusion
- Chemistry, Aerosols, and Visibility
- Remote Sensing of the Battlespace

all relate to NOAA's Climate, Weather and Water, and Commerce & Transportation Goal areas.

The leveraged payoff on these DoD-funded projects has had significant impacts on CIRA's NOAA research. Specifically the data assimilation work funded by CG/AR was well ahead of NOAA's interest in this area. The skills and infrastructure developed in this area have allowed CIRA to address the NOAA assimilation problems with minimum spin up and have allowed CIRA to contribute at a more significant level of effort than 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.

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 two years by theme area. NOAA-relevant comments have been added in *italics*.

1. Hydrometeorology
 - a. CG/AR researchers are working with Air Force AGRMET scientists to improve the USAF soil moisture model to allow it to take advantage of satellite data. *This work is also in support of NOAA NOHA soil moisture data assimilation.*
 - b. Soil moisture analysis using satellite data and modeling is now available to DoD users. A new method using microwave imaging from polar orbiting satellites is now running in test mode that provides soil moisture during cloud obscured periods.
 - c. Current work on soil moisture algorithms is focusing on using upcoming (to be launched) satellite sensors and will allow soil moisture detection at lower depths. The Army will be able to use this data to improve trafficability and possibly even mine detection methods.
 - d. We have completed the operational operator (OO) for the microwave 10 and 6 GHz channels for the WINDSAT and AMSU satellites. These OOs are required as a bridge between the forecast models and the satellite data. Full exploitation of the data for DoD use can now be realized.

- e. We are negotiating with the Naval Research Laboratory to place a CG/AR-sponsored postdoctoral candidate at NRL to improve the technology transition from CSU to the Navy.
- f. The new sediment transport version of CASC2-D has been delivered to Army ERDC. The model, used operationally by the Army for many years to determine flood levels in rivers, now has the ability to predict where erosion and mud deposits will occur as a result of river flows.
- g. *In a further development of CASC2-D, it has been improved to include the transport of toxic sediments. The model includes soil and sediment chemistry that will allow it to be used for HomeLand Defence and military superfund site management. CG/AR has now addressed the transport of toxic materials not only in the atmospheric winds but also in streams.*

2. Cloud Structure Dynamics and Climatology

- a. We completed a comparison study of various cloud detection methods with the Air Force's current operational system. The study showed how the USAF system can be significantly improved.
- b. By combining observations and modeling, diagnosed large-scale sinking motion in the upper atmosphere as a primary cause leading to dissipation of some mid-level, mixed-phase clouds. This information is useful in improving forecasts of these cloud processes.
- c. *Using satellite images collected recently, identified the tendency for some mid-level, mixed-phase clouds to dissipate shortly after sunrise. Knowledge of this tendency will help guide operational planning in data sparse areas.*
- d. *Using an instrument deployed on a research aircraft (which can image individual ice particles in clouds), determined that such particles rarely have pristine or regular shapes. This information is useful for modeling Electrical-Optical propagation through mid-level, mixed-phase clouds.*
- e. *Examined the accuracy of operational methods determining the height of the tops of mid-level, mixed-phase clouds and compared these findings with those of more advanced methods, which may be further improved by the knowledge of the cloud's microphysical composition.*
- f. Completed an additional year of the CHANCES global database (July 1999-July 2000).
- g. Implemented a terabyte Raid-5 mass storage system for CHANCES global cloud analysis applications.
- h. *Developed and implemented an improved technique for the production of an infrared radiance background (used in the global cloud analysis application). The result is the production of hourly infrared radiance backgrounds at a 5-km spatial resolution. A spin-off of this new product is the addition of a 24-hr temporal variance cloud analysis and a 5-km snow/ice product.*
- i. Designed and implemented the CHANCES Regional Products application. This complex software system generates cloud climatology products for a user specified subset of the global CHANCES database. An entire month of products can be built for a 5000 X 5000 km region within a few hours of run time.
- j. *Added temporal updating to the neural network cloud analysis to provide continuous 24-hr updating capability.*

k. *Developed a prototype cloud base algorithm for the neural network, using global surface observations to assign bases to classified structures.*

3. N-Dimensional Data Assimilation and Fusion

- a. *Conducted a model experiment that showed that new data assimilation techniques can overcome forecast model errors. This finding will help the entire weather community prioritize the research efforts between forecast model improvements and data assimilation improvements.*
- b. *Improved the initialization methods for the forecast models to produce a scheme where the spin-up times are reduced. Currently this is a major problem for DoD tactical use of forecast models since a model placed in a new forward location takes between 12 and 24 hours to stabilize before the forecasts are accurate.*
- c. *Directly ingested cloud images (long ignored in the standard numerical forecasting schemes) via satellite radiances for more accurate numerical modeling; and, conversely, allowed local area numerical modeling gridded field output to create accurate cloud fields.*
- d. *Extended the current 4DDA adjoint methods that are typically restricted to 3 dimensional analysis and only for clear sky cases to full 4 dimensional variational analysis with clouds present.*
- e. *Developed an adjoint version or “observational operator” for IR image ingest to meso-models.*
- f. *Completed the development of the first version of an adjoint system Regional Atmospheric Modeling and Data Assimilation System (RAMDAS). This development includes many parts:*
 - i. *Selection and linearization of radiation models including SHDOM, OPTRAN and other models specific to the spectral characteristics of the sensors whose data is to be assimilated.*
 - ii. *Creation of a tangent linear and adjoint for the cloud physics and optical properties subroutines in the predictive model.*
 - iii. *Completed the adjoint of the land surface module.*
- g. *Completed the development of an ensemble method for determining the error covariance matrix for the model and forecast error. This method will allow our data assimilation research to use better values than contemporary assimilation research. The result is an improved ability to ingest direct satellite radiances into the forecast models.*

4. Derivation of Battlespace Parameters

- a. *Successfully completed the first dual Doppler experiment conducted in the Oklahoma City area. This experiment is designed to observe low level nocturnal winds that are of critical importance to toxic material transport. Dual Doppler observations provide a full observation of the details of the turbulent wind structures that lead to toxic material mixing for the first time.*
- b. *Developed a neural network cloud detection scheme that for the first time used conventional surface data reports as part of the process. This is important to the DoD because all neural network schemes require “training” of datasets before they are used. Creating training sets is very difficult and requires satellite cloud*

- interpolation experts to create them. This new method uses readily available surface data so “training” becomes easy.
- c. Cirrus Cloud (CI) albedo research has been completed. Cirrus clouds pose a major problem to meteorologists. They tend to obscure underlying terrain and clouds. Thin cirrus can be detected in the IR (3.7 micron) but not in the visible. This new method detects CI at night thus eliminating the sunrise surprise. Besides the detection of CI, it also measures the actual optical depth of thin cirrus clouds. Intelligence/MASINT will be interested in this product since this cirrus contamination has always limited their data collection accuracy.
 - d. *Continued to analyze the CASES-99 field experiment data for Very Stable Boundary Layer information.*
 - e. *Transferring an advanced water vapor retrieval algorithm for the NOAA AMSU and DoD DMSP/SSM/T2 sensors. This algorithm will provide improved water vapor profiles critical to determining cloud, radiation, and precipitation forecasts. It simultaneously retrieves temperature and water vapor profiles in a cloudy atmosphere.*
 - f. Developed advanced boundary layer forecast parameterizations from the CASES-99 experimental data.
5. Technology Transition (these research items have all been delivered to one or more of the three services)
- a. Provided a thin cirrus algorithm to UPOS for subsequent transition to the USAF
 - b. Provided a microwave land surface model to the Navy (NRL Monterrey) that will improve the observational accuracy of near surface temperatures. This should improve the subsequent forecast accuracy of models that use this new technique.
 - c. Provided cave detection information to XOW and ARL.
 - d. *Provided USAF XOW with a white paper on the utility of a polarimetric instrument on the future NPOESS weather satellite.*
 - e. Delivered modeling system to ARL.
 - f. Delivered DPEAS software to ARL.
 - g. Completed the soil moisture algorithm with delivery to ARL and AFWA.
 - h. Completed a new filtering algorithm (Backus-Gilbert) that will improve the microwave data’s resolution without improving the instrument’s actual geometric resolution. This method has been delivered to ARL and will allow the DoD to get finer detail in their analysis close to coast lines and other surface features while resolving smaller features in the atmosphere.
 - i. Incorporated a sediment transport module to the current CASC2D hydrological stream flow model.
 - j. Hosted both the 2000 and the 2001 BACIMO Conferences. BACIMO is a significant military weather meeting each year for DoD (includes NATO and other allies), weather researchers, and the simulations and support communities.
 - k. CASC2D-SED version C was delivered to WES. This is an advanced hydrological stream flow model that now includes a sediment transport module. Additionally, the code was ported from FORTRAN to C for easier use by the Army Corps of Engineers.
 - l. Fifty-one technical papers were published in the last two years.
 - m. Worked with the University of Alaska on the soil moisture algorithm transfer to the MM5 model.

- n. Worked with the Naval Research Laboratory on improved retrieval methods for GOES imagery.
- o. Hosted technical discussions with numerous ARL and NRL personnel, briefed AFWA staff at Omaha and hosted BGen Johnson, USAF/XOW.
- p. *Conducted a short course on Dynamic Data Assimilation at CSU, February 27-March 2, 2001. This course was attended by DoD members, graduate students and colleagues from other agencies.*
- q. *Upgraded our modeling cluster performance by a factor of 3. New computer systems have allowed more model runs and test sets to be run in the development of our Data Assimilation research.*

Educational Impacts

Current and past Center research has supported 96 graduate students including several Army and USAF officers going through graduate programs while on active duty. The Center's research has produced numerous graduates in engineering and meteorology with sensitivities and skills related to DoD-related issues. A good number have found career opportunities related to DoD environmental support.

INSURANCE FRIENDS

Development of Tropical Cyclone Wind Speed Probabilities

Principal Investigator: J.A. Knaff

NOAA Project Goal: Weather and Water

Keywords: Tropical Cyclones, Hurricanes, Probabilistic Forecasts, Monte Carlo

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

Using the error characteristics from a long-term sample of the official NHC track, intensity and size forecasts, a "Monte Carlo" method will be used to estimate the spatial distribution of the probability of winds exceeding specified thresholds (34-, 50-, and 64-kt) within various time windows. Special techniques for handling tropical cyclones affected by land, and the best methodology for sampling variations in storm size within this framework will be developed.

2. Research Accomplishments/Highlights:

A "Monte Carlo" (MC) method was developed to estimate the spatial distribution of the probability of winds exceeding specified thresholds within various time windows. A large sample of plausible tracks (termed "realizations") relative to a given forecast track are generated by randomly selecting from the error distributions determined from a historical database of NHC track forecasts. A similar method is used to provide the intensity and wind radii for each of the MC realizations. Probabilities are then determined by counting how many times each spatial point comes within the radius of a given wind speed threshold for a given number of MC realizations.

The MC wind probability model utilizes the error characteristics of the NHC track and intensity forecast along with the climatological variations of tropical cyclone size. These errors are randomly sampled using a portable random number generator providing an ensemble of tropical cyclone tracks, intensities and sizes. Special methods have been developed to sample these errors in a physically consistent manner, and account for landfall effects on intensity. The resulting realizations (or perturbations about the official forecasts) are combined to form wind speed probabilities about the official NHC forecast.

Track and intensity error sampling adjusts for the strong serial correlation inherent in these errors. This was accomplished by sampling the 12 h errors randomly. Then, the 24 h error is predicted from the 12 h error, and a perturbation is added from the sample distribution of the 24 h errors with the serial correlation included. This process is repeated for all subsequent forecast periods. Unexpected landfall of the individual realizations was also accounted for by using an exponential inland decay model for the time period the realization was over land.

Special methods were also developed for sampling tropical cyclone size variations, which utilized the development of a climatological wind radii forecast model. Using this model, a

method was created for providing the wind radii distributions. Wind radii were generated directly from the same parametric wind model used to create the climatological wind model. This is done by adjusting the size parameter of the parametric wind model for each case in the 1988-2002 sample to best fit the observed radii for that case. Then, the distribution of the errors of this parameter can be randomly sampled to provide the wind radii for each realization. Because the radii are still calculated from the parametric model, but with a randomly sampled size parameter, they will always be physically consistent. The technique is easily generalized to provide a method to take into account the initial size of the storm, as determined from the radii in the operational forecast/advisory.

The MC method was developed for the Atlantic basin, and a version was implemented at NHC in August of 2003 for their evaluation. An example is shown in Fig. 1.

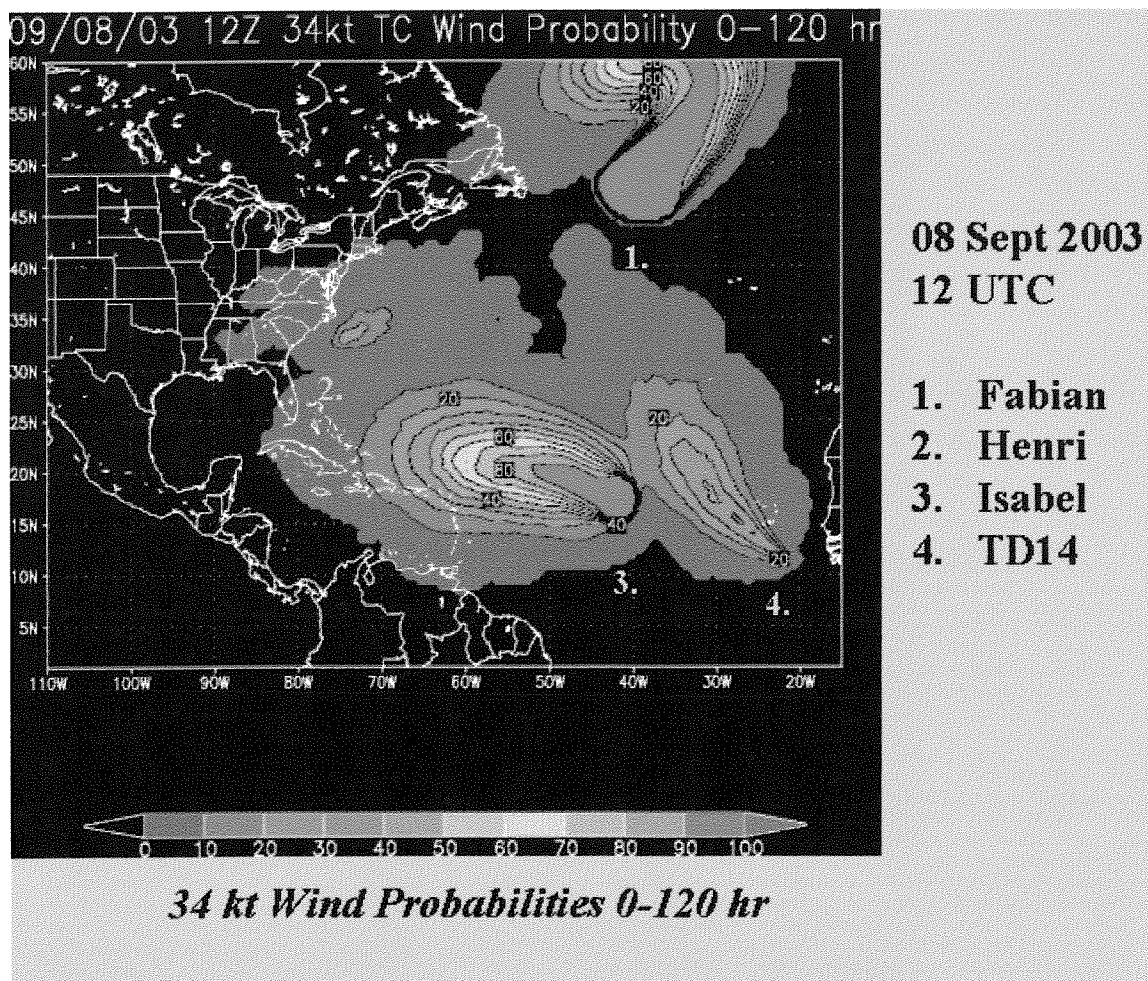


Figure 1. Example of the MC wind probability output being produced at the National Hurricane Center. Shown is the probability of experiencing 34kt or greater wind speeds over a 120-h period based on NHC's forecast of 4 active tropical cyclones on 8 September 2003 at 12 UTC. The values of the probabilities (%) are indicated by the color bar at the bottom of the figure. To the right is a guide to the individual tropical cyclones, which are labeled within the figure 1 through 4.

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

All stated objectives were met during the 1-year reporting period.

4. Leveraging/Payoff:

The final product provides a probabilistic assessment of hurricane-related wind risk and nicely complements the deterministic forecast issued by the National Hurricane Center. Such a product has a variety of decision making uses affecting the general public (i.e. use by emergency managers in public warning and evacuation activities), the National Weather Service (assessment of potential national deterministic forecast grids), industry (i.e., insurance, reinsurance), and commerce (i.e., ship routing). It also offers a unique way of assessing the improvement over the years in track, intensity, and wind radii forecasting since each can be evaluated separately.

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

This work was done in collaboration with several personnel at the National Hurricane Center and has led to additional funding opportunities under the United States Weather Research Program's Joint Hurricane Testbed.

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) None

(b) M. DeMaria, Oct 14, 2003: Improvements in Deterministic and Probabilistic Hurricane Intensity Forecasts. CSU Department of Atmospheric Science Seminar Series, Fort Collins, CO

M. DeMaria, Aug 6, 2003: Improvements in Deterministic and Probabilistic Tropical Intensity Forecasting. Hurricane Research Division (HRD), Miami, FL

J. Knaff, August 11, 2003: Research to Better Diagnose and Predict Tropical Cyclone Structure and Intensity Change, Naval Post Graduate School, Monterey, CA

(c) None

(d) None

(e) None

8. Publications:

Conference Proceedings

Gross, J.M., M. DeMaria, J.A. Knaff, and C.R. Sampson, 2004: A New Method for Determining Tropical Cyclone Wind Forecast Probabilities. *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

Presentations

J. Knaff , August 11, 2003: Research to Better Diagnose and Predict Tropical Cyclone Structure and Intensity Change, Naval Post Graduate School, Monterey, CA

M. DeMaria, Aug 6, 2003: Improvements in Deterministic and Probabilistic Tropical Intensity Forecasting. Hurricane Research Division (HRD), Miami, FL

M. DeMaria, Oct 14, 2003: Improvements in Deterministic and Probabilistic Hurricane Intensity Forecasts. CSU Department of Atmospheric Science Seminar Series, Fort Collins, CO

DeMaria, M., J.A. Knaff, J.F. Dostalek, K. Mueller, 2004: Improvements in Deterministic and Probabilistic Tropical Cyclone Surface Wind Predictions. *58th Interdepartmental Hurricane Conference*, 1-4 March, Charleston, SC

LOCKHEED MARTIN CORPORATION

Project Title: Forecasting and Modeling Studies and Services

Principal Investigator: Kenneth Eis

NOAA Project Goal: None – this is an Air Force funded project

Keywords: MSG, AFWA, MeteoSat-8

This project is a subcontract to Lockheed Martin Co to provide Meteosat Second Generations to AFWA to improve their use of this new satellite with its additional channels. Specific products have been agreed to and are as follows:

- Layered cloud mask
- Nocturnal Fog and Stratus
- Contrail Detection
- Multi-channel surface temperature
- Snow vs Cloud detection
- Thin CI detection
- Precipitation

The work should be completed in February 2005 and takes advantage of previous NOAA-sponsored research and MODIS algorithm ideas. It is a good example of NOAA-leveraged research and collaborations that have payoff to the US outside of NOAA.

NASA - CLOUDSAT

Report Provided by: Ken Eis/Don Reinke

CIRA will provide the data processing element (DPC) for this NASA-sponsored satellite program. NOAA relevance includes the basic science products that fit into the NOAA Climate Goal as well as the computer software development that has a potential impact on all science-to-operations software programming activities.

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 and precipitation. The primary CloudSat instrument is a 94-GHz, nadir-pointing, Cloud Profiling Radar (CPR). The current launch date for CloudSat is April 15, 2005. (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. CloudSat will be a part of a constellation of satellites that currently include NASA's EOS Aqua and Aura satellites as well as a NASA-CNES lidar satellite (CALIPSO), and a CNES satellite carrying a polarimeter (PARASOL). A unique feature that CloudSat brings to the constellation is the ability to fly a precise orbit enabling the fields 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 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 will provide 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 (completed in June, 2002, and located adjacent to CIRA and the Atmospheric Science Department). CloudSat data will be 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 (see figure 1). 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 will develop the Science algorithms and software for each of these products (Table 1). Four universities and the NASA Jet Propulsion Lab (JPL) are participants on the CloudSat algorithm development team.

Standard Data Product	Description	Algorithm Dev.
1B-CPR	Level 1b CPR	JPL
2B-GEOPROF	CPR Geometrical Profile	U. Utah
2B-CLDCLASS	Cloud Classification	U. Maryland
2B-TAU	Cloud Optical Depth	CSU/Atmos
2B-LWC	Cloud Liquid Water Content	CSU/Atmos
2B-IWC	Cloud Ice Water Content	U. Utah
2B-FLXHR	Atmospheric Radiative Fluxes and Heating Rates	CSU/Atmos
2B-GEOPROF-LIDAR	CPR Geometrical Profile (CPR + Lidar)	U. Utah
2B-CLDCLASS-LIDAR	Cloud Classification (CPR + Lidar)	U. Alaska

Table 1. CloudSat Standard Data Products and responsible Algorithm Development Group

During the Operational (on-orbit) Phase, the DPC will be 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://cloudsat.cira.colostate.edu>

Progress During the Past Year:

During the past year, CIRA's has made significant progress in the development and implementation of all of the CloudSat Data Processing Center sub-systems. The first operational version of the CloudSat Data Processing System (Version 0) was delivered in October of 2003. The second operational system (Version 1) is scheduled for delivery in July of 2004. A formal NASA review of DPC Version 1 is scheduled for August 30th, 2004, with the final version due in December of 2004.

In compliance with the milestones that have been laid out for DPC System Version 1, we have developed, and implemented, a system that is capable of supporting the CloudSat data processing requirements as specified at CDR. In addition, we have completed the majority of the objectives of the additional processing capabilities that have been added during successive informal reviews or Standard Data Products Working Group (SDPWG) recommendations which were not part of the original contract requirements. These additions to the DPC were due to the two launch delays, changes to the CloudSat orbit configuration, and a short-fall in the data distribution and storage that was identified since the CDR. The resultant modifications to the requirements list include the decision to have CIRA take on the responsibility for data distribution and storage for the entire mission (DASC function), the modification of the DPC design to include a web-based monitoring and control system, and the development of a web-based interface management /

configuration control system. Also added to the original design was a robust ancillary data processing system for the production of the auxiliary data ("-AUX") products.

The DPC system is functionally ready to support the current set of CloudSat requirements. The ability to process CloudSat and ancillary data and produce the standard data products described at CDR has been demonstrated through the processing of test data set #2. And, except for difficulties with one of the standard data product applications (TAU-OFF-N), the progress to date has been steady and on or ahead of schedule.

In addition, CIRA has completed the testing of Test Data Set #3 through the first three standard data products. Test Data Set #3 is the "meteorologically significant" test data that were constructed from airborne radar and MODIS satellite data. In contrast, test data set #2 was intended to provide a test of the DPC system's ability to process, end-to-end, the CloudSat and Ancillary data streams. At present, test data set #3 has been run, successfully, through the first two standard products, but has not been run through the third (TAU-OFF-N) and successive (LWC, IWC, FLXHR) products. The delay is due to an unfortunate event (computer theft) that caused the TAU-OFF-N developer to fall back to a previous version of his code that was considerably removed from the version he was planning to deliver prior to June 1st. This delay does not, in principle, affect the delivery of the DPC system version 1, because the demonstration of the ability to produce level 1 and 2 products was based on test data set #2. If we were required to become operational without the new TAU-OFF-N we could do that by falling back to the code versions that successfully ran on test data set #2. We are confident, however, that the TAU-OFF-N code can be delivered sooner than the time it would take to fall back to the previous versions of code. A decision will be made on this issue at the CloudSat Standard Data Products Working Group (SDPWG) meeting to be held on July 30th.

Additionally, the implementation plan put forward at CDR called for the Version 1 to represent the point where approximately 85% of the implementation tasks would be complete. This subjective number was based on the workforce plan for completing the delivery of the operational system four months prior to launch. The system implementation schedule is now on track to finish all remaining objectives with approximately 80% of the work completed at the delivery of Version 1. The change in percent completion is due to a planned re-allocation of the work schedule of a CloudSat programmer to allow him to work on a previously scheduled task, outside of CloudSat, for a 3-month period (due to the 4-month launch delay). With staffing now back to the previous level, the implementation of Version 2 is still on track to be complete by the scheduled date of December 20th 2004.

Finally, the two combined CPR-Lidar products are not included in the Version 1 delivery. These products have been delayed from the original implementation dates to accommodate the acquisition of CALIPSO test data and are currently scheduled for implementation prior to the delivery of system Version 2. Because CALIPSO data may not be available for four to five months after launch – the implementation of these two products are now scheduled to take place prior to the Version 2 delivery – with the caveat that they will be done in a "non-interference" basis with the implementation and testing of all of the other standard data products and requirements objectives.

The following tables list the summary of deliverables / milestones and the specific objectives of the Version 1 delivery, along with the status of each (with the TAU-OFF-N exception described above).

CloudSat Data Processing Center Version 1 - Summary of Deliverables / Milestones:

Deliverable / Milestone	Status
All sub-system tasks required for standard data product generation are complete	Complete
All documentation updated to match version implementation	Complete
All external interface documents signed (including a goal of ancillary data agreements)	All of the documents have been received and reviewed. They will be signed at the next SDPWG meeting scheduled for July 30 th . All ancillary data agreements have been received and either physically or electronically signed.
All Science Data Processing software under configuration control	Complete (with the exception of TAU-OFF-N)

CloudSat Data Processing Center Version 1 Objectives (as defined at Version 0 review):

Objectives	Status
The DPC system will process test data set #3 to generate all of the standard data products, produce diagnostic output, provide a functional product display and data quality assessment and data distribution capability. (Note: products 8 and 9, which require input of CALIPSO data may not be implemented at the software version 2 level.)	<p>Complete except for TAU-OFF-N delay (see description above).</p> <p>Test data set #3 has been processed through the 2B-GEOPROF and 2B-CLDCLASS products and these products have been run through the QA, product display and data distribution sub-systems.</p> <p>Combined CPR-Lidar product applications are still under development and testing and (with the agreement of the SDPWG) will be implemented "prior to launch" – with a target date of December 2004.</p>

<p>All sub-system tasks that are required for ingest through standard data product generation should be complete to the cumulative 90% level, with remaining tasks centered on QA, Data Distribution, Documentation, CloudSat system level testing, and operator training</p>	<p>Sub-system tasks required to process data from ingest through standard data products is complete to the 95% level.</p> <p>Product display, QA, and Data Distribution are functional with limited manual intervention required and will be fully automated with the delivery of Version 2.</p> <p>Operator and Data User manuals will be generated prior to Version 2 delivery.</p>
<p>All changes have been documented in an updated version 1 ICD and system description document</p>	<p>Complete except for TAU-OFF-N</p>
<p>CIRA will provide an updated version 1 system overview and operations plan and a draft <i>DPC system operator's manual</i>, <i>cloudsat data user's manual</i>, and <i>data distribution system manual</i></p>	<p>These documents are available via the CloudSat DPC website and are in various levels of completion. As specified in the DPC work plan, the majority of this documentation is scheduled to be completed after the Version 1 delivery.</p>
<p>All science data processing software must be placed under configuration control</p>	<p>Completed (via an upgrade to AIMS)</p>

NASA – THE GLOBE PROGRAM (Global Learning and Observations to Better the Environment)

Principal Investigators: Cliff Matsumoto and Renate Brummer

Keywords: International education and science program; student observations and reporting of science protocols

Introduction

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 around their schools and post their observations and measurements through the Internet on the GLOBE Website. 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 11 million student measurements of atmospheric, soil, land cover, hydrological, and phenological data, all of which are universally accessible on the Web for research. Since it was initiated, the GLOBE Program has grown from 500 U.S. schools in 1995 to more than 14,000 GLOBE schools located in 106 partner countries (as of August 2004).

In Spring 2003, NASA announced that a partnership between the University Corporation for Atmospheric Research (UCAR) and Colorado State University (CSU) was selected as the winning proposal for the operation of the GLOBE Program. CIRA, along with the Atmospheric Science Department and CSMATE (Center for Science, Mathematics, and Technology Education) at CSU, comprise the CSU team.



Fig. 1. The new GLOBE Team at a Program retreat in November 2003

Under the new GLOBE management, the responsibilities for the CIRA GLOBE Team changed significantly. The Team used to be responsible for the development and maintenance of the main GLOBE Website, real-time GLOBE data acquisition tools, the central GLOBE database, and the mirrored GLOBE Web and database systems. In addition to CSU/CIRA, other groups providing systems support to GLOBE before the transition included staffs at NASA Goddard Space Flight Center (GSFC) for visualization functions, at the National Geophysical Data Center (NGDC) for data access, and at NASA Ames Research Center (ARC) for additional systems tasks and the GLOBE Help Desk function. Since October 2003, the responsibilities for all these GLOBE systems tasks are handled by the CSU/CIRA Team.

GLOBE Highlights in 2003/2004

In July 2003, GLOBE hosted its second GLOBE Learning Expedition (GLE) Conference in Šibenik, Croatia, and students, teachers and scientists from around the world participated in the conference. The GLE ran from June 29th through July 4th as students presented their research projects that showcased their use of Earth Science data. Students also had a day of field work at Krka National Park and on the island of Obonjan. The GLE provided students a great opportunity to take measurements in a new environment and learn from each other.



Fig. 2. Waterfall at Krka National Park (left) and GLOBE students conducting hydrology measurements (right) at the National Park

The new GLOBE management team organized a “GLOBE Community Meeting” in January 2004. GLOBE partners from the US as well as overseas attended the meeting. The meeting objective was to discuss GLOBE Program plans for Education, Science, and Partner support. Based on their feedback during the 3-day event, a final version of a “GLOBE Roadmap” was produced.

During spring 2004, GLOBE initiated its first field campaign called GLOBE One. GLOBE One is a focused field campaign that bring partners students and scientists together to investigate the impacts of tilling soil for farming. The campaign is taking place in Black Hawk County, Iowa and is looking at a variety of aspects of the environment—from how much rain and snow fall in northeastern Iowa throughout the year, to the properties of local streams and soil, to how plants and animals change as the seasons change. The project will end in fall of 2005.

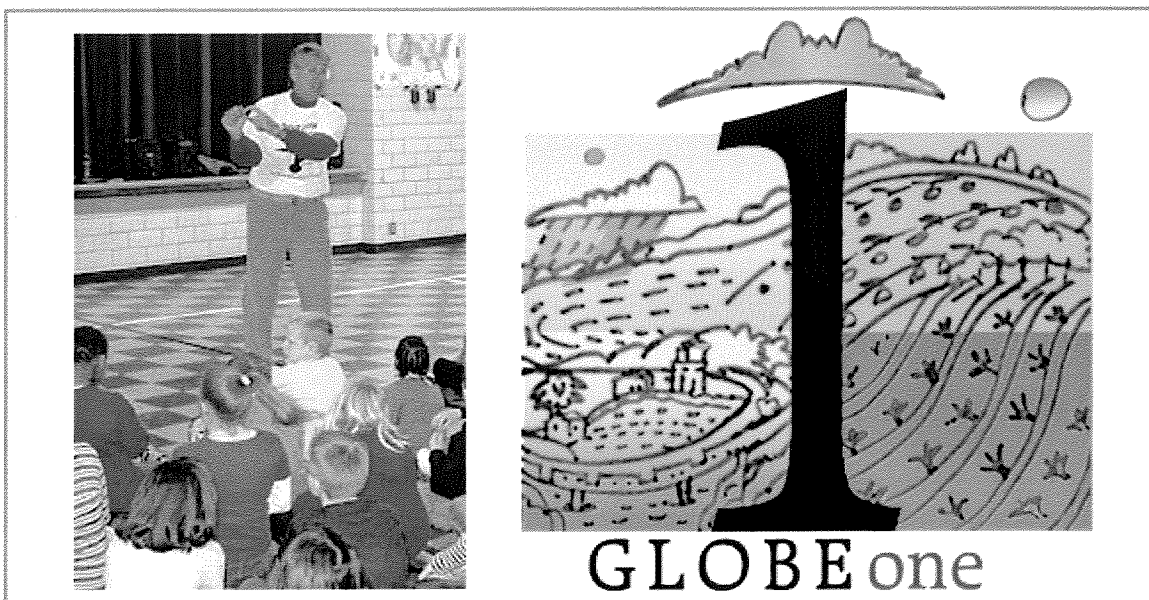


Fig.3. GLOBE One field campaign logo (right) and hummingbird scientist Bill Hilton, Jr. teaching GLOBE One students in Iowa (left)

The GLOBE Education Team successfully developed its first distance-learning GLOBE trainer workshop. This GLOBE Trainer Certification Program (TCP) consists of three parts: an on-line orientation course, a face-to-face TTT workshop, and an on-line practicum course. The first TCP course began in early summer.

The GLOBE Systems Team and the GLOBE Education Team began a close collaboration with the UCAR Digital Library for Earth System Education (DLESE) staff. DLESE (www.dlese.org) is a geoscience community resource that supports teaching and learning about the Earth system. The DLESE Collections Accessioning Taskforce of the Collections Committee met in June 2004 to review collections for accessioning into DLESE and the GLOBE atmospheric chapter can now be accessioned as a DLESE reviewed collection. GLOBE plans to add one (or two) additional chapters to their collection during the fall and to continue adding all of the chapters by the end of 2005.

Systems Accomplishments

Following the announcement that the UCAR/CSU team was selected to manage the GLOBE Program, the CSU/CIRA team began to prepare for its move to a new location at UCAR's Foothills Laboratory 4. The challenge was to move all GLOBE computer systems including the operational servers from NOAA/FSL to UCAR with a minimum of interruption to the thousands of GLOBE users worldwide. In order to get the servers to run, a globe.gov domain had to be created inside the ucar.edu domain in full compliance with all UCAR security regulations. In addition, the team had to assume all of the systems responsibilities formerly handled by staffs at NASA/GSFC, NASA/Ames and NGDC. The most challenging of these new responsibilities was taking over the NASA/GSFC GLOBE visualization code, comprised of thousands of lines of "home-grown" code unfamiliar to the CIRA team. Not only did the team have to install and compile this code on CIRA computers, but also had to quickly gain a thorough understanding of it, to accommodate 10 new GLOBE protocols created by the previous management team awaiting release in 2003. Together with these new protocols came the release of a new electronic GLOBE Teacher's Guide, new data entry pages, new email data entry code, and an endless list of necessary modifications of the GLOBE database to accommodate the new parameters.

Soon after the transition was completed, it became clear that the new GLOBE Help Desk in Fort Collins was understaffed and not quite prepared to take on its new responsibility. The CIRA GLOBE Systems Team immediately offered support to this important GLOBE function. On the technical side, the team worked with NCAR's SCD division to add the GLOBE Help Desk to SCD's existing Remedy server and database. Remedy is a help desk call-tracking application that enables help desk staff to log information related to a call (person's name, problem description) into a database. This database can then be searched (with Remedy) to answer questions such as how many calls of a particular problem type came into the help desk in the past month. By keeping a thorough description of the problem and the resolution, staff can quickly find answers to future callers' questions. The software had

previously been handled by NASA/Ames and there was inadequate handoff of this function to the CIRA Team. But the team managed to install Remedy clients at the new GLOBE Help Desk and trained the new staff accordingly. In addition, Team members continue to voluntarily operate the Help Desk whenever the Fort Collins staff requires assistance.

The Systems Team also took over the responsibility of training new GLOBE staff members, including the new GLOBE Directors, in the use of the GLOBE Website administrative pages and existing Web tools. A huge effort was invested in the development of a new GLOBE Partner Administration section. The result of this design was more user-friendly pages, better tools to support the partners with their teacher training efforts, and a detailed partner administration manual. In addition to the partner page redesign, effort was expended on the development of many additional administration pages to support the new GLOBE management.

Links to NASA's Earth Science Enterprise as well as other Earth science programs and education missions were established to foster collaborative endeavors involving our integrated science and education teams. Examples include the integration of websites and databases with those of DLESE, the establishment of links to Web sites like REASoN, Earth Observatory (Ozone), NASA for Educators, and NASA ESE Education Update. The link between GLOBE and REASoN includes collaboration with scientist Lin Chambers at NASA/Langley to merge CERES satellite cloud data into the GLOBE reference data system so that it can be visualized on a map.

Majority of the Team was involved in an extended evaluation process to select the optimum GIS server software to support the Program. At the end of the 2-month comparison and evaluation, IONIC's RedSpider Web/Studio suite was selected.

Clearly, the Systems Team's central task is the support of the Education and Science teams. Science support was dominated by the difficult task to accommodate GLOBE One and its website needs. The Education team successfully launched their first distance learning program for GLOBE trainers.

The development of many new Web pages, new data entry pages, the needs for presentations to introduce the new GLOBE Team, and the preparation for the big GLOBE Annual Conference put a high work load onto the back of the graphics design team. It resulted in excellent new computer artwork like Web page banners, special images and photos for presentations, very high-resolution products for posters, and GLOBE flyers and brochures in six different languages.

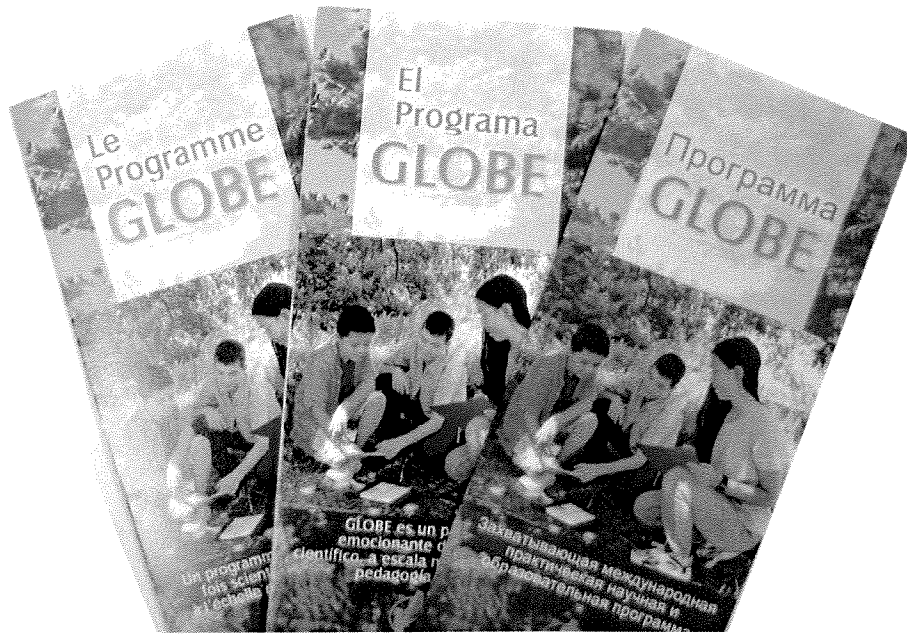


Fig. 4. GLOBE brochures in different languages

In addition to the above list of accomplishments, “standard” tasks, including daily maintenance of servers, frequent updates of the homepage, development and design of new pages, and investigating new technology and equipment to enhance the Program, contribute to a consistently demanding environment.

Publications:

Brown, D.H., R. Brummer, C.R. Matsumoto, and M. Turpin, 2004: The GLOBE Program Data System Architecture. International Conference on Computers in Education (ICCE2004), Melbourne, Australia, November 30-December 3, 2004.

NASA – WEAK CONSTRAINT APPROACH TO ENSEMBLE DATA ASSIMILATION: APPLICATION TO MICROWAVE PRECIPITATION OBSERVATIONS

Principal Investigator: Dusanka Zupanski

NOAA Project Goal: Weather and Water

Keywords: Ensemble, Data Assimilation, Model Error Estimation, Precipitation Observations

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

Develop ensemble data assimilation and model error estimation methodology applicable to assimilation of precipitation observations. Evaluate the methodology in application to NASA's GEOS column precipitation model

2. Research Accomplishments/Highlights:

- Basic ensemble data assimilation algorithm has been developed
- Initial data assimilation experiments are currently being performed

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

4. Leveraging/Payoff:

This research advances data assimilation methodologies. It is expected that the research results will improve the use of satellite observations and contribute to improvements of the weather and climate forecasts.

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

This is collaborative research involving cost sharing from NASA/Global Modeling and Assimilation Office (PI: Dr. Arthur Y. Hou).

6. Awards/Honors: None as yet

7. Outreach:

Derek Poselt, a Ph.D. student at CSU/Atmospheric Science Department, supervised by Prof. Graeme Stephens, is collaborating on the issues of ensemble data assimilation under this research project.

8. Publications:

Presentations

Zupanski, D., 2004: Model error estimation employing data assimilation methodologies. Presented at NOAA/NCEP Seminar Series, 20 February 2004, Camp Springs, MD.

Professional Meetings

Hou, A.Y., 2004: Ensemble data assimilation for clouds and precipitation. Presented at CloudSat Science Team Meeting, 24-25 May 2004.

Conference or Workshops

Zupanski, D., A.Y. Hou, S. Zhang, M. Zupanski, and C.D. Kummerow, 2004: Ensemble data assimilation: Experiment using NASA's GEOS column precipitation model. Abstract submitted to the AMS Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans and Land Surface (IOAS-AOLS) to be held 9-13 January 2005, San Diego, CA.

9. Additional Information:

Summary

The goal of this research is to develop an ensemble based data assimilation methodology, applicable to atmospheric models including precipitation processes. An essential part of this research is to appropriately estimate and correct model errors. Model error estimation has been recognized as one of the major problems of modern data assimilation techniques. Ensemble data assimilation algorithm will be developed and tested in application to NASA's GEOS column precipitation model. The impact of model error estimation and assimilation of precipitation related observations are in the focus of this research.

Major collaborators include Drs. Arthur Y. Hou and Sara Zhang from NASA/Global Modeling and Assimilation Office, and Prof. Christian D. Kummerow from CSU/Atmospheric Science Department.

It is anticipated that the research results will contribute to further advancements in data assimilation and model error estimation techniques, ensemble forecasting, and will also lead to improved use precipitation observations. The most direct benefits are expected for other collaborative research projects at CSU, NASA, NOAA and DoD employing the same ensemble data assimilation approach.

Approach/Evaluation/Methodology

This project employs an ensemble data assimilation approach, based on Kalman filter theory, coupled in a new way with the state augmentation approach. The methodology was first proposed in Zupanski and Zupanski (2004). Evaluation of the results is performed in terms of innovation statistics, RMS errors with respect to the "truth" as well as real observations.

References:

Zupanski D. and M. Zupanski, 2004: Model error estimation employing ensemble data assimilation approach. Submitted to Mon. Wea. Rev. (also available at ftp://ftp.cira.colostate.edu/Zupanski/manuscripts/MLEF_model_err.revised.pdf).

Research Accomplishments and Results

Basic ensemble data assimilation algorithm has been developed. Initial data assimilation experiments are currently being performed, employing simulated observations. One project meeting was held in Washington D. C. in February 2004 to discuss major issues regarding the algorithm development and the experimental set-up. Additional discussions were carried out during Dr. Arthur Hou's visit to CSU in April 2004, and via e-mails and telephone conversations.

Preliminary results were presented as a part of the seminar given by D. Zupanski in February 2004 at NOAA/NCEP, a part of A. Hou's talk in May 2004 at the CloudSat Science Team meeting, and an abstract has been submitted to the AMS conference to be held in January 2005, in San Diego CA (references given below).

References:

Zupanski D., 2004: "Model Error Estimation Employing Data Assimilation Methodologies", Presented at NOAA/NCEP Seminar Series, 10 February 2004, Camp Springs, MD.

Hou, A. Y., 2004: "Ensemble Data Assimilation for Clouds and Precipitation", Presented at CloudSat Science Team meeting, 24-25 May 2004.

Zupanski D., A. Y. Hou, S. Zhang, M. Zupanski, and C. D. Kummerow, 2004: "Ensemble Data Assimilation: Experiments Using NASA's GEOS Column Precipitation Model", Abstract submitted to the AMS Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), to be held 9-13 January 2005 in San Diego, CA.

Conclusions and Recommendations

The ensemble data assimilation and model error estimation approach examined under this project should be applicable to other research projects, employing various atmospheric models. The algorithm developed under this study is easily applicable to other atmospheric and geophysical models. Future research employing this algorithm, in application to complex atmospheric models and real observations might further improve the proposed methodology and the algorithm and lead to new knowledge about model errors.

NATIONAL PARK SERVICE (AIR QUALITY DIVISION) FORT COLLINS

Principal Scientists: W. Malm / B. Schichtel / D. Fox

Introduction & Background

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 been responsible for formulating and implementing the Clean Air Act mandate to land managers to protect the visual resources of such special federal areas as National Parks and Wilderness, so called class 1 areas. The Clean Air Act, in 1977, set as "...a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Federal class 1 areas which impairment results from manmade air pollution."

Since the Act passed, the EPA has issued regulations to accomplish this goal, first, in 1980 addressing pollution that was "reasonably attributable" to a specific source, and most recently, in April 1999 addressing "regional haze." The regional haze regulations require States to plan to achieve "natural" visibility conditions within the next 60 years.

The NPS/CIRA research group under Malm's leadership has been instrumental in advancing the science and developing the methodologies that have enabled these regulations. Included in past accomplishments is development of the appropriate metrics to use for characterizing visibility, determination of the most appropriate instruments to measure visibility for this application and designing and implementing the national monitoring network for visibility. It is the national monitoring network, the IMPROVE network, that represents the group's most important contribution. IMPROVE is supported by the EPA, federal land managers and States, and implemented through contracts with the University of California, Davis and Air Resources Specialists, Inc. as well as others. This network has developed from its initial form as primarily a research tool to its current existence supporting the EPA and the States in developing and tracking accomplishments under the regional haze regulations. In addition to the IMPROVE network based aerosol research, the group conducts special studies associated with specific National Parks often, attempting to improve the understanding of relative contributions of individual pollution sources to visibility. Recently the group has developed the capability of simulating regional air quality using the REMSAD model.

Current Results from the IMPROVE Network

IMPROVE is a network of 163 sites located to represent the class 1 areas, National Parks and Wilderness identified in the Clean Air Act. It has been expanded over the past year from about 70 sites which are used for the analysis reported in the latest IMPROVE report (Malm, 2000a). The basic measurements at each site are particles that are smaller than 2.5 micrometer in diameter. These particles are collected on Teflon, nylon and quartz filter substrates so that they can be subjected to a variety of chemical analyses that yield data allowing an approximation of the chemical nature of these particles to be determined. This chemical speciation has been essential in establishing the relationship between pollution sources and their final impact on visibility even after hundreds to thousands of kilometers of transport and both photochemical and aqueous phase transformations.

The EPA regional haze regulatory program requires a determination of what levels of visibility impairment are 'natural.' This is difficult to determine because there are a number of natural activities that contribute particles to the atmosphere (forest fires, volcanoes, dust.) However, it is helpful to look at the chemical species that contribute to visibility degradation in order to identify linkage between these concentrations and sources of pollution.

Special Studies Results

Periodically, the group participates in special intensive monitoring studies, such as the current Big Bend Regional Aerosol and Visibility Observational Study (BRAVO) study. Recent work to characterize the Grand Canyon visibility is also included here. These studies are designed to more fully characterize atmospheric aerosols and their optical properties, as well as to identify the major contributing sources to a particular class I area's haze. In addition, special research activities are pursued which currently, include characterizing species dependent aerosol hygroscopicity; identifying the contribution of smoke to organic and sulfur aerosols; and characterization of coarse particle optical properties. This past year has seen a significant effort to characterize the sources of visibility impairment at Big Bend. This has involved conducting regional air quality simulation modeling using REMSAD, the CAPITA MonteCarlo model and CMAQ, as well as analyzing trajectories. These studies have led to quantified source-receptor relationships.

Web Site Development

The NPS research group at CIRA initiated development and presentation of research results including the monitoring data and information from the IMPROVE network in two newly developed, state of the science web sites. For more information about the IMPROVE Web site see: <http://vista.cira.colostate.edu/improve/>.

For the Western Regional Air Partnership, the group developed a Web site capable of delivering all of the IMPROVE data as well as a presenting a catalogue of air quality and meteorological data in the western United States. This site was so successful that it was implemented nationally for all of the Regional Planning Organizations (RPOs). This site the Visibility Information Exchange Web Service (VIEWS) can be found at the following: <http://vista.cira.colostate.edu/views/>.

Future Directions for the Research

There are a number of sources of the organic carbon aerosol measured by IMPROVE. Transportation sources, other sources of volatile organic compounds, VOC's, indeed all combustion of carbon containing fuels are included. Important to the National Parks and wilderness, however, are vegetation fires. Forest, grassland and agriculture burning, either as wildfire or within a management program, represents a source of carbon particulate that must be better understood.

Effects of Forest Fires on Visibility

We recently (Fox, et. al. 1999) suggested a list of research needs associated with smoke and visibility, largely repeated below:

--The attribution of smoke to PM_{2.5} and visibility degradation at points that are 100 km or more distant from a fire. While newly developed measurements of "markers" which allow attribution of elemental and organic carbon to wood smoke exist, they need to be tested in realistic field experiments.

--Instrumentation that has the capability to measure the mass of smoke emitted from various kinds of fire should be developed and tested in realistic field experiments.

--Assessing visibility impacts of smoke emission requires knowledge of the optical characteristics of smoke. The ability to accurately measure atmospheric absorption is essential for estimating the visibility effects of smoke. Smoke particle scattering albedos, extinction properties, particle size distributions, and microstructure (internal mixing characteristics) are all important for the accurate modeling of smoke optical properties. Instrumentation to estimate atmospheric absorption to an accuracy of 10% is needed.

--It is necessary to improve the capacity to simulate fire emissions and their effects on ambient aerosol concentrations. New measurement technologies combined with their use in field experiments will collect new data that can improve understanding of generation, transformation and removal processes for fine particulate. However, to determine historical levels of smoke and to evaluate the effectiveness of air quality management programs, these new data will need to be incorporated into the next generation of air quality models.

Publications:

Assistance for Visibility Data Analysis and Image Display Techniques

Ames, R. B., J. L. Hand, B. A. Schichtel, W. C. Malm, and D. G. Fox. 2004. Preliminary apportionments of carbonaceous aerosols to wild fire smoke using long-term records from the IMPROVE network. Presented to the Electric Utilities Environmental Conference, Tucson.

Ashbaugh, L. L. 2003. Quality assurance of aerosol data in the IMPROVE program. Presentation 10PD14, 22nd Annual American Association of Aerosol Research Conference at the Anaheim Hilton, Anaheim, California.

Ashbaugh, L. L., R. A. Eldred, and A. B. Rubin. 2003. Composition of wildfire smoke at western U.S. IMPROVE sites in summer 2002. Presentation 8PD11, 22nd Annual American Association of Aerosol Research Conference at the Anaheim Hilton, Anaheim, California.

Ashbaugh, L. L., C. McDade, and S. Lee. 2003. Comparison of speciated PM₁₀ and PM_{2.5} samples at selected IMPROVE sampling sites. Presentation 2PC10, 22nd Annual American Association of Aerosol Research Conference at the Anaheim Hilton, Anaheim, California.

Barna, M. G., K. A. Gebhart, B. A. Schichtel, and W. C. Malm. 2003. Investigating pollutant sources that contribute sulfate aerosol to Big Bend National Park with the REMSAD air quality model. Presented to the Big Bend National Park management and staff, Big Bend National Park, TX.

Barna, M. G., E. Knipping, and M. Chin. 2003. Incorporating sulfur predictions from the GOCART global aerosol model as boundary conditions to the REMSAD regional air quality model. Presented at the Western Regional Air Partnership (WRAP) Modeling Forum Meeting, Riverside, CA.

Barna, M. G., W. C. Malm, M. L. Pitchford, and B. A. Schichtel. 2003. Introduction to visibility. Presented at the Western Regional Air Partnership (WRAP) Tribal Policy and Technical Workshop, Albuquerque, NM.

Barna, M. G., B. A. Schichtel, K. A. Gebhart, and W. C. Malm. 2004. Evaluation of REMSAD-BRAVO simulation using tracer data and synthesized modeling. Presented at the Particulate Matter Model Performance Workshop, Research Triangle Park, NC.

----- . 2004. Regional simulation of sulfate aerosol for the BRAVO study. Presented at the Electric Utilities Environmental Conference, Air Quality, Global Climate Change and Renewable Energy, Tucson, AZ.

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NATIONAL PARK SERVICE -Analysis of Findings from the Yosemite Aerosol and Visibility Special Study and Characterization of Nitrate and Other Ion Measurements at IMPROVE Sites

Principal Investigators: Jeffrey Collett, Jr. and Sonia Kreidenweis, Department of Atmospheric Science, Colorado State University

Introduction

Beginning in 2002 and continuing through 2004, Colorado State University scientists conducted a series of special studies, characterizing the properties of aerosol particles in a series of field campaigns and laboratory studies. Studies completed are shown in Table 1.

Table 1. CSU field studies conducted in the period 2002-04 with NPS support

Study Location	Study Period	Study Focus
Yosemite NP	July-Sept, 2002	Determining impacts of smoke on regional visibility and characterizing the chemical, physical, and optical properties of smoke aerosol
Bondville, IL	February 2003	Ion study (characterization of aerosol ion composition, ion size distributions, gas-particle partitioning of ammonia and nitric acid, and evaluation of IMPROVE ion measurement protocols)
San Geronio Wilderness CA	April 2003	Ion study
Grand Canyon, NP	May 2003	Ion study
San Geronio Wilderness CA	July 2003	Ion study
Brigantine National Seashore, NJ	November 2003	Ion Study
Missoula, MT	November 2003	Wood smoke source characterization
San Geronio Wilderness Area, CA	July 2004	Ion study
Great Smoky Mtns. NP	July-August 2004	Ion Study + Aerosol acidity testing and evaluation of neutralization by NH ₃

In addition to these field campaigns, we have been busy analyzing collected field samples, designing and constructing a new Hygroscopic Tandem Differential Mobility Analyzer (HTDMA) system, designing and purchasing equipment and parts for a mobile aerosol characterization laboratory in conjunction with UC Davis, and conducting a series of laboratory tests to evaluate the efficiency of IMPROVE denuders for nitric acid collection and to develop new, sensitive techniques better suited to routine analysis of wood smoke marker compounds at moderate cost.

Accomplishments in each of these areas are detailed in the following.

Yosemite Aerosol Characterization Study

The first phase of planned analyses of data collected as part of the Yosemite aerosol special study in 2002 has been completed, and additional analyses are ongoing. Two manuscripts have been submitted for publication. One paper that has already appeared (Bench and Herckes, 2004) deals with carbon isotope measurements in Yosemite aerosol samples and indicates that the carbonaceous fraction of aerosol present during the study was strongly dominated by modern carbon sources (e.g., biogenic emissions, wood smoke). The second manuscript (Carrico et al., 2004), submitted for publication, illustrates the relatively low hygroscopicity of wood smoke influenced aerosol measured in Yosemite.

A Master's thesis based on the Yosemite project (McMeeking, 2004), presenting results of aerosol size distribution measurements and implications for visibility, has been completed and defended. Manuscripts based on this thesis, in preparation or close to submission, address (1) the size distribution and scattering efficiencies of Yosemite aerosol particles in smoky and non-smoky periods (McMeeking et al., 2004, Parts I and II) Additional manuscripts currently in preparation discuss (2) characterization of the frequency, duration and effects of smoke plume impacts during the study (Carrillo et al., 2004), (3) the time series of wood smoke and secondary organic aerosol contributions to Yosemite OC concentrations as determined by organic source marker approaches, (4) size distributions of aerosol particles from organic carbon sources, and (5) aerosol ion concentrations and ion size distributions, including the importance of coarse mode nitrate, observed during the study. We are also contributing to overview paper(s) that seek closure between the various complementary data sets (for example, measured aerosol scattering coefficients compared with those computed from size distribution and aerosol composition information).

Findings from the Yosemite study analyses will provide NPS scientists with a much better understanding of the physical, chemical, and optical properties of aged smoke particles and of aerosol sources in Yosemite during summer. They are also helping to pinpoint critical areas for more accurate measurements in future campaigns. For example, data comparisons show the importance of multipoint nephelometer calibrations, suggest that matching of the wavelengths of various measurements is highly desirable, and indicate the need for independent methods for determining aerosol absorption and total extinction coefficients.

IMPROVE Nitrate Study

A series of seven field campaigns will have been completed by August 2004 to investigate characteristics of nitrate and other ions in aerosol particles at selected, characteristic IMPROVE sites. These measurements were designed to address the following issues:

- Does extraction of IMPROVE nylon filters with deionized water provide efficient recovery of collected nitrate particles?
- Does collection of fine particles on nylon filters produce a negative bias in ammonium concentrations, due to loss of volatilized ammonia, at IMPROVE sites?
- What are the size distributions of nitrate, and other species, in aerosol particles present at characteristic IMPROVE sites?
- What are the gas-particle distributions of nitric acid/nitrate and ammonia/ammonium at selected IMPROVE sites?
- What sort of temporal variability is seen in fine particle ion concentrations at IMPROVE sites?

Measurements conducted for these studies included:

- Daily paired 24 hr denuder/filter/denuder setups to examine nylon filter extraction via water vs. basic (IC extract) solution, ammonium loss from nylon filters, and gas/particle partitioning of ammonia/ammonium and nitric acid/nitrate. Major anions (NO_3^- , Cl^- , SO_4^{2-}) and cations (Na^+ , K^+ , NH_4^+ , Ca^{2+} , Mg^{2+}) are being examined as are gaseous ammonia and nitric acid.
- 12 hr denuder/filter/denuder setups to examine day/night differences in gas-particle partitioning and ammonium loss.
- 48 hr MOUDI samples for anions and cations
- Semi-continuous measurements of $\text{PM}_{2.5}$ aerosol anion and cation concentrations using the Particle-Into-Liquid Sampler PILS. (PILS measurements were not originally planned for these campaigns but were added due to their utility as demonstrated in the Yosemite work).

Additional measurements are also planned during a July-Aug 2004 field campaign at Great Smoky Mtns. (GRSM) NP, in conjunction with UC Davis, to examine aerosol acidity and its neutralization during post-sampling handling of IMPROVE ion filters.

Results from the first several field campaigns have been analyzed. The data analysis is focused on addressing the questions outlined above, and a series of manuscripts is planned for submission addressing issues such as: (1) the form and size distribution of nitrate at IMPROVE sites, (2) the efficiency of aqueous extraction of nylon filters, (3) losses of ammonium from particles collected on nylon filters, and (4) the temporal variability of fine particle ion concentrations observed at IMPROVE sites.

Mobile lab construction and testing

Purchasing of equipment slated for inclusion in the new mobile aerosol characterization laboratory was begun and completed in 2003/04. Several items already purchased are being assembled (e.g., the HTDMA system) or are slated for field testing (e.g., the PILS

system at GRSM). We have developed detailed specifications for the vehicle, including weight, power and interior layout, that will be used by UC Davis to assemble a bid package and ultimately choose a vendor to build the mobile laboratory housing.

IMPROVE denuder efficiency tests

CSU collaborated with scientists at UC Davis to characterize the efficiency of IMPROVE denuders for collection of nitric acid. High collection efficiency is important to prevent contamination of particle nitrate measured on downstream nylon filters (gaseous nitric acid is efficiently collected by nylon media). CSU assisted UC Davis in a series of field tests of denuder collection efficiency and conducted a series of lab collection efficiency studies.

The lab studies involved sending a stream of gaseous nitric acid, at a controlled relative humidity (RH), through a denuder. The concentrations of nitric acid entering and leaving the denuder were measured using a coil diffusion scrubber and ion chromatography. By comparing the upstream and downstream concentrations, the denuder collection efficiency was obtained. The nitric acid generation and collection systems were designed and constructed in 2003/04. Tests of a series of denuders (uncoated, freshly coated with and without glycerol, and exposed) at a variety of RH levels began in May 2004 and will be completed by project end.

Results from both the lab and field denuder efficiency tests will be compared to examine whether the denuders have high collection efficiency when first coated and maintain high collection efficiency during lengthy field deployment. The findings from these tests will be critical for IMPROVE scientists and IMPROVE data users to understand concentrations of nitrate measured in the IMPROVE network.

Smoke marker measurement techniques

Current approaches to identification of wood smoke contributions to particulate organic carbon rely on the use of organic molecular markers. The most commonly used marker is levoglucosan, a product of the incomplete combustion of cellulose. Levoglucosan is typically measured by GC/MS, following a lengthy multi-step solvent extraction and chemical derivatization process. This analytical approach is relatively expensive and requires large amounts of collected aerosol mass to be effective. We have investigated a number of alternative approaches to levoglucosan measurement. The most promising of these at present involves aqueous extraction and analysis by High Performance Anion Exchange Chromatography (HPAEC) with pulsed amperometric detection. This method shows excellent sensitivity for measurement of levoglucosan and a series of other, related sugar and anhydro-sugar compounds, including mannosan and galactosan. Both on- and offline application of this new analytical approach hold great promise for IMPROVE or other networks to better characterize, at reasonable cost, spatial and temporal variability in wood smoke contributions to particulate organic carbon.

Missoula smoke aerosol source characterization tests

CSU joined colleagues from USFS and DRI in November 2003 at the USFS' large burn chamber in Missoula, MT for a series of wood smoke aerosol source characterization tests.

Instrumentation deployed by CSU included aerosol sizing instruments and filter samplers suited for later chemical analysis of the organic and inorganic components of the smoke aerosol. An extensive series of tests was completed utilizing different fuels and burn conditions.

Initial evaluation of data has been completed. A focus of the CSU team has been integrating the aerosol size distribution and scattering coefficient data. In the Missoula study, we had additional measurements, provided by USFS colleagues, representing aerosol backscatter fraction and scattering coefficients at three wavelengths. We have used these additional constraints to model, via Mie theory, the aerosol optical properties from the size distribution and assumed refractive indices. The approach has enabled us to deduce best-fit parameters for the smoke properties that will be compared with chemical data when these become available. We anticipate that a manuscript reporting the data and modeling results will be prepared early in 2005. Results such as these will provide scientists with a much-improved understanding of the chemical and physical properties of smoke particles produced from a variety of fuel types under a variety of burn conditions (flaming, smoldering, and backing).

Reporting

Regular progress reports (at least bi-monthly) were submitted to Dave Maxwell of the NPS as requested.

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Collett, Jr., J. L., Engling, G., Herckes, P., Garcia, C. Henry, C. and Malm, W., "New techniques for the measurement of wood smoke marker compounds," presented at the AWMA Symposium on Air Quality Measurement Methods, Cary, NC, April 2004.

Collett, Jr., J.L., T. Lee, X-Y, Yu, B. Ayres, J. Carrillo, C. Carrico, and S. M. Kreidenweis, "Continuous measurement of PM_{2.5} ion concentrations at IMPROVE sites", presented at the AWMA Conference, Indianapolis, June 2004.

Collett Jr., J.L., T. Lee, X-Y, Yu, B. Ayres, and S. M. Kreidenweis, "Characterizing Biases in Speciation Network Measurements of Fine Particle Ion Concentrations", presented at the AWMA Conference, Indianapolis, June 2004.

Presentations

Carrico, C., Kreidenweis, S., Collett, J. and Malm, W., "Measurements of Particle Diameter Growth Factors of a Biomass Burning Influenced Aerosol", presented at the 22 Annual American Association for Aerosol Research Conference, Anaheim, California, October 20-24, 2003.

Collett, J., Lee, T., Yu, X-Y., Kreidenweis, S. M. and Malm, W. J., "On the speciation and measurement of aerosol nitrate in regional aerosols", presented at the 22 Annual American Association for Aerosol Research Conference, Anaheim, California, October 20-24, 2003. Herckes, P., Engling, G., Carrillo, J., Lee, T., Carrico, C., Collett, J., Kreidenweis, S., Day,

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Lee, T., Yu, X., Collett, J. L., and Kreidenweis, S., "Aerosol chemical characterization by a Particle-Into-Liquid Sampler and an annular denuder/filter pack system in three field experiments in 2003," presented at the AGU meeting in San Francisco, December, 2003.

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Lee, T., X-Y. Yu, B. Ayres, J. Carrillo, C. Carrico, P. Herckes, G. Engling, S. M. Kreidenweis and J. L. Collett, Jr., "Continuous measurement of aerosol ionic composition during Yosemite National Park Special Study (2002), Special Nitrate Study (2003-2004), and Fresno Fog Study (2003-2004)," to be presented at the Korean Society for Atmospheric Environment Spring meeting, Korea, May 13–15, 2004

Collett, Jr., J.L., T. Lee, X-Y, Yu, B. Ayres, J. Carrillo, C. Carrico, and S. M. Kreidenweis, "Continuous measurement of PM_{2.5} ion concentrations at IMPROVE sites", to be presented at the AWMA Conference, Indianapolis, June 2004.

Collett Jr., J.L.,T. Lee, X-Y, Yu, B. Ayres, and S. M. Kreidenweis, "Characterizing Biases in Speciation Network Measurements of Fine Particle Ion Concentrations", to be presented at the AWMA Conference, Indianapolis, June 2004.

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**NATIONAL SCIENCE FOUNDATION--COLLABORATIVE PROPOSAL TO NSF:
ENSEMBLE DATA ASSIMILATION BASED ON CONTROL THEORY**

Principal Investigator: Milija Zupanski

NOAA Project Goal: Weather and Water

Keywords: Ensemble, Data Assimilation, Control Theory

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

Evaluate the potential of the Maximum Likelihood Ensemble Filter in applications to climate and weather. Develop a non-Gaussian framework for ensemble data assimilation based on direct optimization of non-Gaussian probability density functions.

2. Research Accomplishments/Highlights:

- The CSU shallow-water model changed for use with ensemble data assimilation algorithm
- Validation and visualization developed
- Experiments with full ensemble data assimilation algorithm started

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

4. Leveraging/Payoff:

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

A collaboration with Florida State University (Prof. Michael Navon, Dept. of Mathematics, and his research group) is an intrinsic component of this collaborative project.

6. Awards/Honors: None as yet.

7. Outreach:

There are two graduate students at FSU who will be working on this project. Prof. Michael Navon is their advisor and I am on their committees.

8. Publications:

Zupanski, M., 2004. Issues in further development of ensemble data assimilation. 2004 SIAM Annual Meeting, Portland, OR, July 12-16, *Final Program and Abstracts*, p. 154.

9. Additional Information:

Summary

The project titled "*Collaboration in Mathematical Geosciences: Ensemble Data Assimilation Based on Control Theory*" is funded by National Science Foundation, from September 2003 until August 2006. The proposed research encompasses an evaluation of the Maximum Likelihood Ensemble Filter (MLEF) with the CSU global shallow-water model, as well as further development of a non-Gaussian framework. All current data assimilation, and ensemble data assimilation techniques are based on the Gaussian probability density function (PDF) assumption, although it is known that nonlinearity, and physics related observations introduce non-Gaussian PDFs. By employing the control theory in maximization of the posterior PDF, the MLEF algorithm will be further developed to include non-Gaussian framework, and tested on a controlled set of problems. Since the work is done on the powerful NCAR IBM SP computer, even hundreds and thousands of ensembles are feasible. This will allow a detailed examination of the number of degrees of freedom required by ensemble data assimilation, and help understand if, and how, the non-Gaussian mathematical framework can be used to alleviate current limitations of ensemble techniques.

Through the use of ensemble data assimilation algorithm developed at CIRA, this research has an instant benefit for all other ensemble data assimilation efforts at CIRA and CSU, as well as outside the university. Major collaborators at CSU are Prof. Dave Randall, ATS (Co-PI), and Steven Fletcher, CIRA (postdoctoral scientist), with Milija Zupanski as a PI on the CSU side. Collaborators at the Florida State University are Prof. Michael Navon, Dept. of Mathematics (PI), Bahri Uzunoglu (postdoctoral scientist), and two graduate students from Prof. Navon's group. There also outside collaborators, Prof. Owe Axelsson of the University of Nijmegen, The Netherlands, and Prof. Geir Evensen, of the University of Bergen, Norway.

First project group meeting was held at FSU on June 7-9, 2004, and detailed plans for collaboration specified.

Approach/Evaluation/Methodology

This project is employing an ensemble approach to data assimilation and forecasting. It relies on the use of control theory, and will require detailed evaluation of current, gradient based optimization algorithms, in applications with ensembles, and highly nonlinear non-Gaussian PDFs. Examination of potential non-Gaussian PDFs will be an important part of this project as well.

The means for collaboration are through regular project group meeting, and by maintaining a common computer code, that could be easily shared between the parties. Major activities so far were related to basic algorithm development with the shallow-water model, testing on the NCAR IBM SP computer, and training of postdoctoral scientist to work with the code. All members of the team were involved in these activities. Planned

activities include testing in the Gaussian framework first, with increasing nonlinearity (and difficulty), and then introducing a non-Gaussian PDFs.

Research Accomplishments and Results

The research is right on track. As anticipated, first year of the project was mainly directed toward setting-up the ensemble system and model on the NCAR computer, and training of the postdoctoral researchers. At this point, everything is ready for detailed testing of the Gaussian framework, which was planned for the next year of the project (starting in September 2004). An invited paper was presented at the 2004 SIAM Annual Meeting, where the issues and the need for non-Gaussian framework were discussed.

Conclusions and Recommendations

This project was beneficial for other ensemble data assimilation related projects at CIRA, since the algorithm improvements were transferred to other projects, simply by using a transferable code. The use of different prediction models and observation operators, involved in other projects, is transparent to the ensemble data assimilation code, and thus results from one project have a direct benefit on other projects. The background of personnel of this project group is mostly in applied mathematics, which is ideally suited for the coming period, where the knowledge of control theory and other mathematical tools will be essential.

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OFFICE OF NAVAL RESEARCH—DEVELOPMENT AND IMPLEMENTATION OF A STATISTICAL TROPICAL CYCLONE INTENSITY PREDICTION SCHEMES IN THE SOUTHERN HEMISPHERE AND NORTH INDIAN OCEAN

Principal Investigator: J.A. Knaff

NOAA Project Goal: Weather and Water

Keywords: Tropical cyclone, prediction, intensity, maximum wind speed

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

This project builds from the previously and successful development of tropical cyclone intensity guidance developed for the Northwest Pacific tropical cyclone basin. It is proposed that two statistical tropical cyclone intensity prediction models will be developed to make forecasts of tropical cyclone intensity out to 120-hours in the Southern Hemisphere and N. Indian Ocean. The first is a purely statistical model based on climatological information (data, location, current intensity etc.) and persistence of initial conditions, which is used primarily for verification purposes. The second is a statistical-dynamical model which utilizes environmental conditions predicted by a global atmospheric model in combinations with climatology and persistence factors. The atmospheric fields used for this models development will be acquired from the Navy Operational Global Atmospheric Prediction System (NOGAPS) analyses available at the Naval Research Laboratory (NRL). A comprehensive statistical analysis will be performed to determine the best set of predictors for intensity change in both the Southern Hemisphere and North Indian Ocean.

These models will be transitioned for use in operational tropical cyclone forecasting at the Joint Typhoon Warning Center, Honolulu, HI.

2. Research Accomplishments/Highlights:

A purely statistical tropical cyclone intensity model has been developed for the Southern Hemisphere regions using the historical tropical cyclone tracks for the 1980-2002 Southern Hemisphere tropical cyclone seasons. This model has been added to the operational suite of products at the Joint Typhoon Warning Center.

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

Accomplishments are ahead of scheduled delivery for this project.

4. Leveraging/Payoff:

These tools will lead to better tropical cyclone intensity forecasting in these regions and will likely aid in more efficient Naval operations.

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

Work is sponsored by the Office of Naval Research and requires close collaboration with personnel at both the Naval Research Laboratory in Monterey, CA (C. Sampson) and the Joint Typhoon Warning Center in Honolulu, HI (E. Fukada, S. Gruber).

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) None

(b) None at this time

(c) None at this time

(d) None

(e) None

8. Publications:

Journal Articles

Knaff, J.A., C.R. Sampson, and M. DeMaria, 2004: An operational statistical typhoon intensity prediction scheme for the Western North Pacific, Submitted to *Wea. Forecasting*.

Conference Proceedings

Knaff, J.A., C.R. Sampson, and M. DeMaria, 2004: An introduction to the statistical typhoon intensity prediction scheme (STIPS). *AMS 26th Conference on Hurricanes and Tropical Meteorology*. 3-7 May, Miami, FL.

CIRA RESEARCH ACTIVITIES MATRIX

		Weather and Water							Climate					Commerce and Transportation							
		Local Forecasts and Warnings	Tropical Storm Program	Space Weather	Hydrology- Rivers, Lakes, Floods	Air Quality	Environmental Modeling	Weather Science and Technology Infusion Program	Climate Observations and Analysis	Climate Forcing	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transportation Systems	Aviation Weather	Marine Weather	Geodesy	NOAA Emergency Response	Commercial and Remote Sensing	Licensing	Commerce and Transportation Science and Techn Program
Advanced Environmental Satellite Research Support	5-31147	x	x		x	x	x	x	x	x											
An Evaluation of Ultrasonic Snow Depth Sensors for Estimating 6 and 12 hr Snowfall Totals	5-31174				x																
Analysis of Findings from the Yosemite Aerosol and Visibility Special Study and Characterization of Nitrate and Other Ion Measurements at IMPROVE	5-34156							x													
Application of Remotely Sensed Imagery to Assessing the Probabilities and Carbon Consequences of Fire	5-31956							x	x	x		x	x								
Applied Research in Support of Implementation of National Weather Service Advance Hydrologic Prediction Services in Central Region	5-31155				x					x							x				
Assistance for Visibility Data Analysis & Image Display Techniques	5-31703							x		x											
Atmospheric CO2 Inversion Intercomparison Project	5-31163							x													
Carbon Dioxide Measurements from an Airborne Spectrometer in Support of Operational Temperature Soundings and the Study of the Carbon Cycle	5-31146							x	x	x											
Center for Geosciences/Atmospheric Research	5-37400-7488	x	x		x	x	x	x													
CIRA Activities and Participation in DMSP Satellite Data Processing and Analysis	5-31139							x													
CIRA Activities and Participation in the GOES I-M Product Assurance Plan	5-31153	x	x					x													
Climate Process Team on Low-Latitude Cloud Feedbacks on Climate Sensitivity	5-31154																				
CloudSat Data Processing Center	5-35737																				
Collaborative Proposal to NSF: ENSEMBLE DATA ASSIMILATION BASED ON CONTROL THEORY	5-33023	x						x	x												
Continued Investigation of the NA Monsoon Sensitivity to Boundary and Regional Forcing with a Focus on Land-Atmosphere Interaction	5-31133							x													
Coupling Between Monsoon Convection and Subtropical Highs in the PACS Region on Subseasonal to Interannual Time Scales	5-31148		x					x		x											
Cross-Sensor Products for Improved Weather Analysis and Forecasting	5-31167	x			x	x	x	x													
Design, Development and Maintenance of the GLOBE Program Website and Database	5-31934																				
Development and Evaluation of GOES and POES Products for Tropical Cyclone and Precipitation Analysis	5-31165		x																		
Development and Implementation of a Statistical Tropical Cyclone Intensity Prediction Schemes in the Southern Hemisphere and North Indian Ocean	5-37268	x	x																		
Development of a multi-platform satellite tropical cyclone wind analysis system	5-31176	x	x																		
Development of Efficient Satellite Data Compression Techniques: Transmission of GOES Imagery to the NOAA WP-3D Aircraft	5-31156	x																			
Development of Tropical Cyclone Wind Speed Probabilities	5-37132		x																		
Enhanced Communications at CIRA for the Development of Real-Time Evaluation of AMSU Tropical Cyclone Products	5-31149		x																		
Environmental Applications Research (EAR)	5-31144	x			x	x	x	x	x												
Examination of the Linkages Between the Northwest Mexican Monsoon and Great Plains Precipitation	5-31138	x			x																
Fast Fluxes and Slow Pools: Integrating Eddy Covariance, Remote Sensing and Ecosystem Processes Data Within a Data Assimilation Framework	5-32705							x	x												
Fire Effects on Regional Air Quality including Visibility	5-31875							x	x	x											
Forecasting and Modeling Studies and Services	5-32634																				

		Weather and Water							Climate					Commerce and Transportation							
		Local Forecasts and Warnings	Tropical Storm Program	Space Weather	Hydrology-Rivers, Lakes, Floods	Air Quality	Environmental Modeling	Weather Water Science and Technology Infusion Program	Climate Observations and Analysis	Climate Forcing	Climate Predictions and Projections	Climate and Ecosystems	Regional Decision Support	Marine Transportation Systems	Aviation Weather	Marine Weather	Geodesy	NOAA Emergency Response	Commercial and Remote Sensing	Licensing	Commerce and Transportation Science and Techn Program
Getting Ready for NOAA's Advanced Remote Sensing Programs A Satellite Hydro-Meteorology (SHyMet) Training and Education Proposal	5-31168	X			X		X													X	
Global Microwave Surface Emissivity Error Analysis	5-31170	X	X		X	X	X				X							X			
GLOBE: Inspiring the Next Generation of Explorers	5-32730						X														
Harnessing the Spare Computing Power of Desktop PCs for Improved Satellite Data Processing and Technology Transition	5-31162	X					X														
Impact of Interactive Vegetation on Predictions of North American Monsoons	5-31136						X	X	X	X	X							X			
Improvement in Deterministic and Probabilistic Tropical Cyclone Surface Wind Predictions	5-31171		X					X													
Interactions of the Monsoon and Anticyclones in the Coupled Atmosphere-Ocean System	5-31131		X					X													
International Satellite Cloud Climatology Project Sector Processing and Analysis	5-31151								X	X	X	X	X								
NESDIS Postdoctoral Program	5-31143	X	X		X	X	X	X	X	X	X	X	X								
Polarimetric Radar Observations of Precipitation: Measurements, Analysis and Modeling	5-31173	X				X		X													
Radar Remote Sensing Processes and Investigation of Smoke Aerosol Cloud Interactions Using Large Eddy Simulations	5-31137						X														
Research & Development for GOES-R Risk Reduction	5-31172	X			X	X	X	X						X	X	X		X	X		
Research for Validation of NESDIS Microwave Land Emissivity Model	5-31164	X			X	X	X	X	X			X						X	X		
Severe Weather and Tropical Cyclone Product Development for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project	5-31169	X	X		X	X	X	X	X			X						X	X		
Statistical Analyses Related to Air Quality and Atmospheric Visibility	5-32810					X		X													
Stochastic Modeling and Simulation of the Great Lakes Net Basin Supplies	5-31157	X					X	X						X							
Support of the Virtual Institute for Satellite Integration Training (VISIT)	5-31159	X	X											X	X	X		X			
Task I: Funds for the Cooperative Institute for Research in the Atmosphere	5-31130							X													
The CIRES-NOAA Western Water Assessment--Providing increased focus on the crucial agricultural sector	5-31100	X					X	X				X									
The Role of Atmospheric Water Content in Climate and Climate Change	5-31920								X	X	X	X	X								
The Role of Stratocumulus Clouds In Modifying Pollution Plumes Transported To North American Continent	5-31150					X				X		X	X								
Variability and Trends in Global Precipitation	5-31160				X				X	X	X	X	X								
Visibility Information Exchange Web Systems	5-37137							X													
Weak Constraint Approach To Ensemble Data Assimilation: Application To Microwave Precipitation Observations	5-31942				X		X	X													
Weather Satellite Data and Analysis Equipment and Support for Research Activities	5-31152	X						X													

CIRA AWARDS

APPLIED RESEARCH IN SUPPORT OF IMPLEMENTATION OF NATIONAL WEATHER SERVICE ADVANCE HYDROLOGIC PREDICTION SERVICES IN CENTRAL REGION

Principal Investigator: Shripad D. Deo

Advanced Hydrologic Prediction Service was recognized with NOAA Administrator's Award in May 2004.

COUPLING BETWEEN MONSOON CONVECTION AND SUBTROPICAL HIGHS IN THE PACS REGION ON SUBSEASONAL TO INTERANNUAL TIME SCALES

Principal Investigators: Richard H. Johnson and Wayne H. Schubert

Richard H. Johnson: NSF Creativity Award

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

Principal Investigators: J.A. Knaff, L.D. Grasso

Dr. John Knaff received the 2004 NOAA David Johnson Award in partial recognition of the tropical cyclone intensity work associated with this project and the research leading to the operational product.

DEVELOPMENT OF EFFICIENT SATELLITE DATA COMPRESSION TECHNIQUES: TRANSMISSION OF GOES IMAGERY TO THE NOAA WP-3D AIRCRAFT

Principal Investigators: J.A. Knaff, N. Wang

Dr. John Knaff received the 2004 NOAA David Johnson Award in partial recognition of this project.

HARNESSING THE SPARE COMPUTING POWER OF DESKTOP PCs FOR IMPROVED SATELLITE DATA PROCESSING AND TECHNOLOGY TRANSITION

Principal Investigators: A. Jones/T. Vonder Haar

Guch et al., 2004) Best of Session Award– Collaborative Computing at NOAATECH 2004.

Postdocs- Kinkade: Interim NOAA/NESDIS Ocean Color Science Team Leader 2003-04.

**POLARIMETRIC RADAR OBSERVATIONS OF PRECIPITATION:
MEASUREMENTS, ANALYSIS AND MODELING**

Principal Investigator: Dr. V. Chandrasekar, Colorado State University

Elected to fellow of IEEE - Geo Sciences and Remote Sensing.

**WEATHER SATELLITE DATA AND ANALYSIS EQUIPMENT AND SUPPORT FOR
RESEARCH ACTIVITIES**

Principal Investigator/Group Manager: Michael Hiatt

CIRA 2004 Research Initiative Award, The infrastructure was recognized for excellence in the November 2003 NOAA 5-Year Review Report.

GLOBE

Principal Investigator: Cliff Matsumoto

CIRA 2004 Research Initiative Award to GLOBE Team: Travis Andersen, Matt Hansen, Mike Leon, Karen Milberger, Maureen Murray, Dave Salisbury, Mike Turpin, and Ali Zimmerman

The CIRA GLOBE Systems Team consistently demonstrated exceptional initiative throughout its involvement with the GLOBE Program. Beginning with the Program's initial development in 1994, the Team assumed ever-increasing responsibilities as the Program increased from 450 US schools at its inception to more than 14,000 participating schools in 105 countries in early 2004. The Team designed, developed, and implemented the GLOBE interactive website comprised of more than 1500 pages, the central database containing more than a million observations, and all of the key data distribution functions. Their dedication and innovative efforts culminated this past year with the transition of all of the hardware and associated software from NOAA to the UCAR campus under the new Cooperative Agreement with NASA--performed with no impact on the Program's worldwide clients and users.

	JI Lead Author			NOAA Lead Author			Other Lead Author		
	FY01	FY02	FY03	FY01	FY02	FY03	FY01	FY02	FY03
Peer-Reviewed	~~~	~~~	29	20	21	20	77	78	40
Non Peer-Reviewed	~~~	~~~	82	73	32	48	108	44	53

CIRA Employees FY03/04

Category	Total	Exp.		B.S.		M.S.		Ph.D.	
		NOAA	Other	NOAA	Other	NOAA	Other	NOAA	Other
Research Scientist	89		2	23	13	20	8	14	9
Visiting Scientist	1							1	
Postdoctoral Fellow	8							8	
Research Support Staff	5	1	1		2	1			
Administrative	10		2	1	3	1	2	1	0
Undergraduate Students	28	15	13						
Sub Total	141								
Students (supported by CIRA)	16			11	5				
TOTAL	157								
Located at FSL, ETL, UCAR, or NGDC	54								
Obtained NOAA employment within the last year								1	

CIERA

Cooperative Institute for Research in the Atmosphere

Colorado
State
University

Knowledge to Go Places