Cooperative Institute for Mesoscale Meteorological Studies

Annual Report
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NOAA NA17RJ1227
Fiscal Year – 2007
**Cover figure** – A severe supercell in its mature stage at 5 hours of simulation in an idealized non-homogeneous environment. The surface blue colors indicate perturbation temperature compared to the far western surface values. Simulated lightning is shown by the red and light blue volume surfaces, with negative cloud-to-ground lightning flashes occurring in the storm core. As the storm moves eastward, it encounters increasingly cooler boundary layer air, which reduces CAPE and increases CIN. The capping inversion suppresses secondary convection, so that the storm remains isolated for almost 7 hours before dissipating. In a homogeneous environment, the storm would have grown into a squall line by about 3-4 hours. Research performed by Ted Mansell and colleagues; more on this project can be found under CIMMS research theme Basic Convective and Mesoscale Research on p. 17.
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COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES
THE UNIVERSITY OF OKLAHOMA

Annual Report of Research Progress under Cooperative Agreement NA17RJ1227
During Fiscal Year 2007

Peter J. Lamb, Director
Randy A. Peppler, Associate Director

INTRODUCTION

General Description of CIMMS and its Core Activities

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) was established in 1978 as a cooperative program between the National Oceanic and Atmospheric Administration (NOAA) and The University of Oklahoma (OU). CIMMS provides a mechanism to link the scientific and technical resources of OU and NOAA to create a center of research excellence in mesoscale meteorology, regional climate studies, and related subject areas. CIMMS-supported scientists and students conduct research in mesoscale dynamics, radar research, development, and analysis, atmospheric electricity, severe storms, cloud microphysics, and boundary layer studies, with increasing emphasis in recent years on the climatic effects of controls on mesoscale processes, the socioeconomic impact of such phenomena, and climate change monitoring and detection. Outreach activities are also performed in a number of ways described later in this report.

CIMMS promotes cooperation and collaboration on problems of mutual interest among OU research scientists and students and the NOAA Office of Oceanic and Atmospheric Research (OAR) National Severe Storms Laboratory (NSSL), National Weather Service (NWS) Radar Operations Center (ROC) for the WSR-88D (NEXRAD) Program, NWS NCEP (National Centers for Environmental Prediction) Storm Prediction Center (SPC), NWS Warning Decision Training Branch (WDTB), and a NWS Forecast Office, all located in Norman, Oklahoma. CIMMS also fosters collaboration with the NWS National Environmental Satellite, Data, and Information Service (NESDIS) National Climatic Data Center (NCDC) in Asheville, NC, and with the NWS Southern Region Headquarters (SRH) in Fort Worth, TX.

CIMMS research contributes to the NOAA mission through improvement of the observation, analysis, understanding, and prediction of weather elements and systems and climate anomalies ranging in size from cloud nuclei to multi-state areas. Advances in observational and analytical techniques lead to improved understanding of the evolution and structure of these phenomena. Understanding provides the foundation for more accurate prediction of hazardous weather and anomalous regional climate. Better prediction contributes to improved social and economic welfare. Because small-, meso-, and regional-scale phenomena are also important causes and manifestations of climate, CIMMS research is contributing to improved understanding of the global climate system and regional climate variability and change. CIMMS promotes research collaboration between scientists at OU and NOAA by providing a center where government and academic scientists may work together to learn about and apply their knowledge of mesoscale weather and regional-scale climate processes.

CIMMS is part of the National Weather Center, a unique confederation of federal, state, and OU organizations that work together in partnership to improve understanding of the Earth's atmosphere. Recognized for its collective expertise in severe weather, many of the research and development activities of the Center have served society by improving weather observing and forecasting, and thus have contributed to reductions in loss of life and property. Many entities of the National Weather Center played a key role in the decade-long, $2 billion dollar modernization and restructuring of the National
Weather Service. National Weather Center organizations employ approximately 650 men and women and provide more than $45 million annually to the Oklahoma economy.

In addition to CIMMS, National Weather Center organizations include:

- NOAA OAR National Severe Storms Laboratory
- NOAA NWS Warning Decision Training Branch
- NOAA NWS NCEP Storm Prediction Center
- NOAA NWS Radar Operations Center
- NOAA NWS Forecast Office, Norman
- Oklahoma Climatological Survey
- OU College of Geosciences
- OU School of Meteorology
- OU Department of Geography
- OU Center for Analysis and Prediction of Storms
- OU Center for Spatial Analysis
- OU Environmental Verification and Analysis Center
- OU Center for Natural Hazards and Disaster Research
- OU Sasaki Institute
- OU Supercomputing Center for Education and Research

CIMMS concentrates its research and outreach efforts and resources on the following principal themes: (1) basic convective and mesoscale research, (2) forecast improvements, (3) climatic effects of controls on mesoscale processes, (4) socioeconomic impacts of mesoscale weather systems and regional-scale climate variations, (5) Doppler weather radar research and development, and (6) climate change monitoring and detection.

This report describes NOAA-funded research and outreach progress made by CIMMS scientists at OU and those assigned to our collaborating NOAA units during OU fiscal year 2007 (1 July 2006 through 30 June 2007), and as such represents the sixth annual report written for the present cooperative agreement (NA17RJ1227). **NOAA-funded projects are explicitly identified in project titles.** This report also documents the NOAA-relevant research and outreach activities performed by core CIMMS scientists based at the university that may be funded by other agencies – these agencies are identified. Information on publications written, awards received, and employee and funding statistics is presented at the end.

**Management of CIMMS, including Mission and Vision Statements, and Organizational Structure**

CIMMS is defined organizationally by a Memorandum of Understanding between NOAA and OU, signed last in 1995. It is governed presently by a Council and an Assembly of Fellows. The most recent review of CIMMS was conducted by the NOAA Science Advisory Board in October 2003. One result of this review was the development of a strategic plan for 2006-09 (its executive summary is included in Appendix D). With the NOAA Science Advisory Board taking over the responsibility of reviewing CIMMS, the CIMMS Advisory Board no longer exists.

The CIMMS Council meets quarterly to provide advice and recommendations to the Director of CIMMS regarding appointments, procedures, and policies; to review and adopt bylaws; and to periodically review the accomplishments and progress of the technical and scientific programs and projects of the CIMMS. The Council's advice should not be viewed as binding on the Director relative to any recommendations that might be carried forward to the Advisory Board.

The Assembly of Fellows meets as needed and is composed of a cross-section of local and national scientists who have expertise relevant to the research themes of CIMMS and are actively involved in the
programs and projects of CIMMS. Appointment to the Assembly, by the CIMMS Council, is normally for a two year term, and reappointment is possible. Appointments may be made for a shorter period of time or on a part-time basis with the concurrence of the appointee and the CIMMS Council. The Assembly will review and suggest modifications of bylaws, participate in reviews of CIMMS activities, and elect two of their number to serve on the Council. The Assembly's advice should not be viewed as binding on the Director relative to any recommendations that might be carried forward to the Advisory Board. Fellows are appointed by the Council. The Fellows will be meeting several times in the next fiscal year to help plan for the CIMMS recompetition.

The Mission and Vision Statements of CIMMS are as follows:

**Mission** – To promote collaborative research between NOAA and OU scientists on problems of mutual interest to improve basic understanding of mesoscale meteorological phenomena, weather radar, and regional climate to help produce better forecasts and warnings that save lives and property

**Vision** – A center of research leadership and excellence in mesoscale meteorology, weather radar, regional climate, and forecast and warning improvement, fostering strong government/university collaborations

The organizational structure of CIMMS includes its Director (Peter Lamb), Associate Director and Assistant Director of NOAA Relations (Randy Peppler), Finance and Operations Director (Tracy Reinke), Administrative Assistant (Luwanda Byrd), and Staff Assistants (Judy Henry and Roxanne Hunt). Scientists, students, and post-docs were housed during the fiscal year on the campus of The University of Oklahoma at its new National Weather Center, which includes the offices of the NSSL, SPC, and WDTB. Some CIMMS staff remained off-campus at the offices of the ROC and SRH.

**Executive Summary of Important Activities and Results during FY2007**

**Basic Convective and Mesoscale Research**

The primary goals of this original CIMMS thematic area are to understand cloud and mesoscale dynamics, microphysics and the precipitation process and their relationships to large and small scale forcing, and to develop procedures for assimilation of meteorological data into simulation and prediction models of these processes. The work done here represents a fundamental building block for eventual applied techniques.

During the past year, research was conducted on:

- Severe weather warning applications and development
- Discrimination of mesoscale convective system environments using sounding observations
- Thunderstorm electrification modeling
- Formation and dynamics of mammatus and thunderstorm outflow anvils
- Doppler radar data quality control, analysis, and assimilation
- System for Atmospheric Modeling with Explicit Microphysics – SAMEX
- The role of precipitation on large eddy simulations of trade cumulus
- The role of a dynamically-balanced dataset in cloud microphysics parameterization development
- Mesoscale dynamics and mesoscale applications of information theory
- Numerical modeling study of the time-dependent behavior of convection
- Vertical vortices in the convective boundary layer
- Martian dust devils
- Evaluation of microphysical parameterizations
- Adaptive high-order methods for nonhydrostatic numerical weather prediction
- Firewhirls and firefighter safety
Forecast Improvements

The primary goal of this original thematic area is to accelerate the transfer of research knowledge and skills between the academic and NOAA operational mesoscale meteorological communities to both improve the design and utilization of mesoscale weather observing systems and improve mesoscale weather prediction and warning.

During the past year, research was conducted on:

- Predicting the longevity of mesoscale convective systems
- Dual-polarimetric WSR-88D development
- FSI and WDSS-II
- Investigate methods to provide improved forecasts of near surface conditions through the use of ensemble forecasts
- Measuring the evolution of tropical waves over West Africa into tropical storms over the eastern Atlantic
- Science and technology infusion
- Advanced Warning Operations Course (AWOC)
- AWIPS and WSR-88D improvements
- NOAA’s NWS Weather Event Simulator
- Distance Learning Operations Course (DLOC)
- WDTB Training and Research Toolkit and Real-Time System
- Department of Commerce and NOAA distance learning training development – The Nation’s Weather Enterprise
- Enhanced Fujita (EF) scale training
- Storm-based warnings
- An investigation of communicating weather information effectively using the Internet
- Advancing science to improve knowledge of mesoscale hazardous weather at SPC
- Severe Hazards Analysis and Verification Experiment (SHAVE)
- Hazardous Weather Testbed Experimental Warning Program
- A partnership to develop, conduct, and evaluate real-time high-resolution ensemble and deterministic forecasts for convective-scale hazardous weather
- Evaluation of synoptic-scale controls on tornado outbreaks
- Cloud radiative impacts of giant CCN
- Contribution to the WRF model development by CAPS
- Tri-State Tornado reanalysis
- Database of tornadic and nontornadic severe storm outbreak cases
- Characteristics of surface cold fronts
- Sample size and data quality issues with tornado occurrence data

Climatic Effects of/Controls on Mesoscale Processes

The primary goal of this thematic area is to extend and apply the understanding of mesoscale processes to the problem of climate maintenance and change. This theme also includes investigation of the influence of the large-scale climatic environment on the mesoscale systems that produce growing season rainfall in regions such as central North America and Sub-Saharan Africa.

During the past year, research was conducted on:

- Variability of the Intertropical Front and Rainfall over the West Africa Soudano-Sahel
- Evaluation and adaptation of a regional climate model for the Horn of Africa
- Collaboration and cooperation within the ACMAD Core Demonstration Project in Climate Prediction between ACMAD and CIMMS
- Explaining the spatial variability of the mid-summer drought over the Inter-American seas region
• Large-eddy observations and LES of liquid stratus over the ARM Southern Great Plains Climate Research Facility
• Parameterization of drop spectra in drizzling stratocumulus clouds
• Assessment of the severe weather environment in North America simulated by a global climate model

**Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations**

The primary goal of this thematic area is to estimate the socioeconomic impacts and values of mesoscale weather systems and regional-scale climate variations in central and eastern North America and across the world, to facilitate the mitigation (enhancement) of the adverse (beneficial) impacts. A continuing component of this work makes extensive use of climate scenarios and economic models, and is performed in collaboration with agricultural economists and social scientists. It is also complemented by a research thrust that is addressing a spectrum of weather- and climate-related disaster issues.

During the past year, research was conducted on:

• Climate information for agricultural management in the Southern Great Plains
• The value of tornado watches and warning false alarms
• Multiscale evolution and predictability of a warm season climate anomaly in the U.S. Southern Great Plains

**Doppler Weather Radar Research and Development**

The primary goal of this thematic area is to accelerate the transfer of knowledge between the meteorological and engineering communities (in academia, and government and private laboratories) to improve the design, usability, and supportability of the NEXRAD WSR-88D Doppler weather radar. Continual enhancements are needed to the system for improving the quality, format, accuracy, resolution, and update rate of the base data, and to keep pace with evolving hardware and software technologies. This work introduces, examines, and analyzes present and future technologies, including phased-array technology, with the goal of meeting the unfulfilled radar needs. This theme also includes a fertile research area for development and improvement of radar algorithms used for forecasting and warning.

During the past year, research was conducted on:

• National Quantitative Precipitation Estimation mosaic
• Polarimetric hydrometeor classification and rainfall estimation for better detecting and forecasting high-impact weather phenomena including flash floods
• Investigation of microphysical processes in clouds and precipitation using polarimetric radar measurements
• Identification of aircraft icing conditions with polarimetric radars
• Development of Kessler Farm Field Laboratory for the study of precipitation microphysics
• Sensitivity enhancement in the dual-polarization WSR-88D
• Open Radar Data Acquisition (ORDA) spectrum width estimation
• Mitigation of range and velocity ambiguities
• Improvement of spectral moment and polarimetric variable estimates using decorrelating transformations on oversampled range data
• Super Resolution Radar Data
• Signal processing upgrades for the National Weather Radar Testbed
• National Weather Radar Testbed – Phased Array Radar
• Rapid sampling of storms
• Spring 2007 National Weather Radar Testbed Demonstration
• Radar Control Interface
• Analysis of weather radar observations of severe convection to understand severe storm processes and improve warning decision support
• NEXRAD technology transfer
• Winter hydrometeor classification ground truth experiment
• Hail Size Discrimination Experiment (HaSDEX)
• Optimal use of phased array radar for multi-mission weather surveillance and aircraft tracking
• Development of mobile X-band dual-polarization weather radar
• Development of mobile C-band dual-polarization weather radar to evaluate polarimetric designs for the multi-mission phased array radar and for kinematic and microphysical studies of storms
• Study of the significance and mitigation of wind turbine clutter for the WSR-88D network
• Emergency mobile radar to supplement WSR-88D observations during hurricanes
• Improving tornado detection with WSR-88D data using spectral analysis
• Enhancement of radar retrievals by the use of higher moments of the drop size distribution

Climate Change Monitoring and Detection

The goal of this research theme is to study climate change monitoring and detection in general, and specifically the homogeneity or lack thereof of the historical station records in the U.S. and to use this information to help address the climate change questions.

During the past year, research was conducted on:

• Detection and attribution of climate change using climate indices for the United States
• The use of kernel methods in data selection and thinning for satellite data assimilation in NWP models
• Systems integration and prototype COOP operations management
• Program support for the assimilation, analysis, and dissemination of Pacific rain gauge data: PACRAIN

Public Affairs and Outreach

During the past year, public affairs and outreach activities included:

• NOAA Weather Partners educational outreach
• Outreach Activities performed by CIMMS Staff at WDTB
• ADVANCE-PAID: Promoting institutional change at the University of Oklahoma and within the Big XII Conference
• ADVANCE leadership award: FORWARD to professorship
• Radar data assimilation training for the Indian Meteorological Bureau
• ARM Program Outreach Activities

Awards

The following awards were bestowed in the past year:

• NSF ADVANCE leadership award – Catherine Mavriplis, CIMMS Scientist at NSSL
• AMS Editor Award for reviews of articles for the Journal of Applied Meteorology – Alexander Ryzhkov, CIMMS Scientist at NSSL
• For meritorious work as part of the NWS Southern Region Headquarters Team – Leon Minton, CIMMS Scientist at NWS Southern Region Headquarters
Distribution of NOAA Funding by CIMMS Task and Research Theme

NOAA Funding by Task FY07

- Task I: $323,550, 4%
- Task II: $1,547,344, 21%
- Task III: $16,644,006, 74%

NOAA Funding by Theme FY07

- Theme 1: $1,150,256, 2%
- Theme 2: $4,100,315, 56%
- Theme 3: $1,071,000, 17%
- Theme 4: $27,405, 1%
- Theme 5: $2,167,221, 30%
- Theme 6: $660,428, 11%
**CIMMS Council and Fellows Membership and Meeting Dates**

As described above, CIMMS is governed by the CIMMS Council and the Assembly of Fellows. During the Fiscal Year, CIMMS Council meetings were held 20 September 2006, 14 December 2006, and 24 April 2007.

CIMMS Council membership presently is:

- Dr. Peter J. Lamb (Chair), George Lynn Cross Research Professor of Meteorology, OU, and Director, CIMMS
- Dr. Kenneth C. Crawford, Regents’ Professor of Meteorology, OU, and Director, OCS (Provost designated)
- Dr. Jerry Crain, Professor and Director, School of Electrical and Computer Engineering (Provost designated)
- Dr. Baxter E. Vieux, Presidential Professor of Civil Engineering & Environmental Science, OU (Provost designated)
- Dr. David J. Stensrud, Research Meteorologist and Team Leader, Models and Assimilation Team, NSSL, and Affiliate Professor, School of Meteorology, OU (OAR designated)
- Mr. Kevin Kelleher, Deputy Director, NSSL (OAR designated)
- Dr. Russ Schneider, Chief, Science Support Branch, SPC (NWS designated)
- Mr. Richard Murnan, Radar Operations Center Applications Branch (NWS Designated)
- Dr. Michael L. Biggerstaff, Associate Professor of Meteorology, OU (Elected from CIMMS Assembly of Fellows)
- Mr. Doug Forsyth, Chief, Radar Research & Development Division, NSSL (Elected from CIMMS Assembly of Fellows)
- Dr. Frederick H. Carr, Director, OU School of Meteorology, and McCasland Chair Professor of Meteorology, and Associate Director, CAPS (ex-officio member)
- Dr. James F. Kimpel, Director, NSSL, and Emeritus and Affiliate Professor of Meteorology, OU (ex-officio member)
- Dr. Joseph T. Schaef er, Director, SPC, and Affiliate Professor of Meteorology (ex-officio member)
- Mr. Ed Mahoney, Director, WDBT (ex-officio member)
- Mr. Richard Vogt, Director, ROC (ex-officio member)
- Mr. Mike Foster, Meteorologist-in-Charge, Norman WFO (ex-officio member)
- Mr. Steven Cooper, Acting Director, NWS Southern Region Headquarters (ex officio member)
- Dr. Tom Karl, Director, NCDC (ex officio member)

CIMMS Fellows membership for 16 August 2005 through 15 August 2007 is:

- Dr. Jeffrey B. Basara, Director of Research, OCS and Affiliate Assistant Professor of Meteorology, OU
- Dr. William H. Beasley, Professor of Meteorology, OU
- Mr. James D. Belville, Emeritus Director, ROC
- Dr. Michael I. Biggerstaff, Associate Professor of Meteorology, OU
- Dr. Howard B. Bluestein, Presidential Professor of Meteorology, OU
- Dr. Harold E. Brooks, Research Meteorologist and Team Leader, Mesoscale Applications Group, NSSL
- Dr. Frederick H. Carr, McCasland Chair Professor of Meteorology and Director, School of Meteorology, OU, and Associate Director, CAPS
- Dr. Gerald E. Crain, Director, School of Electrical and Computer Engineering, OU
- Dr. Kenneth C. Crawford, Regents’ Professor of Meteorology, OU, and Director, OCS, OU
- Dr. Timothy D. Crum, Chief, Operations Branch, ROC
- Dr. Charles A. Doswell, III, retired, NSSL
- Dr. Michael W. Douglas, Research Meteorologist, Mesoscale Applications Group and Models and Assimilation Team, NSSL
- Dr. Richard J. Doviak, Senior Engineer, Doppler Radar and Remote Sensing Research Group, NSSL, and Affiliate Professor of Meteorology and of Electrical and Computer Engineering, OU
- Dr. Kelvin K. Droegemeier, Regents’ Professor of Meteorology, OU, Director, CAPS, Director, Sasaki Institute, and OU Assistant Vice President for Research
- Dr. Claude E. Duchon, Emeritus Professor of Meteorology, OU
- Dr. Imike Durre, Scientist, NCDC
- Dr. David R. Easterling, Scientist, NCDC
- Mr. Douglas E. Forsyth, Chief, Radar Research & Development Division, NSSL
- Dr. Carl E. Hane, Research Meteorologist, Convective Weather Research Group, NSSL, and Affiliate Professor of Meteorology, OU
- Dr. David P. Jorgensen, Chief, Warning Research & Development Division, NSSL
• Dr. David Karoly, Williams Chair Professor of Meteorology, OU
• Dr. Petra Kastner-Klein, Assistant Professor of Meteorology, OU
• Mr. Kevin E. Kelleher, Deputy Director, NSSL
• Dr. James F. Kimpel, Director, NSSL, and Emeritus Professor of Meteorology, OU
• Mr. Paul Kirkwood, Scientist, NOAA NWS Southern Region Headquarters
• Dr. S. Lakshminarahan, George Lynn Cross Research Professor of Computer Science, OU
• Dr. John Latham, Senior Research Associate, National Center for Atmospheric Research (NCAR)
• Mr. Leslie R. Lemon, Radar, Severe Storms, and Research Meteorologist, Basic Commerce and Industries, Inc., Moorestown, NJ
• Dr. Lance M. Leslie, Robert E. Lowry Chair and Professor of Meteorology, OU
• Mr. Jason Levit, Techniques Development Meteorologist, SPC
• Dr. John M. Lewis, Research Meteorologist, Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
• Dr. Donald R. MacGorman, Research Physicist, Convective Weather Research Group, NSSL, CIMMS Resident Fellow, and Affiliate Professor of Meteorology and of Physics and Astronomy, OU
• Mr. Ed Mahoney, Chief, WDTB
• Dr. Catherine Mavritsis, former Associate Professor of Mechanical and Aerospace Engineering, George Washington University, currently CIMMS Fellow at NSSL
• Dr. Renee McPherson, Associate Director, Oklahoma Climatological Survey, OU
• Dr. James W. Mjelde, Professor of Agricultural Economics, Texas A&M University
• Dr. Mark L. Morrissey, Professor of Meteorology, OU
• Dr. Robert D. Palmer, Professor of Meteorology, OU
• Dr. Ramkumar Parthasarathy, Assistant Professor of Aerospace and Mechanical Engineering, OU
• Dr. Thomas C. Peterson, Scientist, NCDC
• Mr. John R. Reed, Chief, Open System Team, ROC
• Dr. Michael B. Richman, Associate Professor of Meteorology, OU
• Dr. W. David Rust, Chief, Forecast Research and Development Division, and Team Leader, Field Observing Facilities and Services, NSSL, and Affiliate Professor of Meteorology and of Physics and Astronomy, OU
• Dr. Joseph T. Schaefer, Director, SPC, and Affiliate Professor of Meteorology, OU
• Dr. Russell Schneider, Chief, Science Support Branch, SPC
• Dr. Alan M. Shapiro, Associate Professor of Meteorology, OU
• Dr. John T. Snow, Dean, College of Geosciences, OU, and Professor of Meteorology, OU
• Dr. David J. Stensrud, Research Meteorologist and Team Leader - Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
• Dr. Jerry M. Straka, Associate Professor of Meteorology, OU
• Dr. Daniel S. Sutter, Associate Professor of Economics, OU
• Dr. Aondover A. Tarhule, Assistant Professor of Geography, OU
• Dr. Baxter E. Vieux, Presidential Professor of Civil Engineering & Environmental Science, OU
• Mr. Richard Vogt, Director, ROC
• Dr. G. Anderson White, III, Lecturer & Affiliate Professor of Meteorology
• Dr. Louis J. Wicker, Research Meteorologist, Convective Weather Research Group, NSSL, Affiliate Associate Professor of Meteorology, OU
• Dr. Qin Xu, Research Meteorologist, Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
• Dr. Tian-You Yu, Associate Professor, School of Electrical and Computer Engineering, OU
• Dr. May Yuan, Assistant Dean, OU College of Geosciences, Associate Professor of Geography, OU, and Director, Center for Spatial Analysis, OU
• Dr. Conrad Ziegler, Research Meteorologist, Models and Assimilation Team, NSSL
• Dr. Dusan S. Zrnic, Senior Engineer and Group Leader, Doppler Radar and Remote Sensing Research Group, NSSL, and Affiliate Professor of Meteorology and of Electrical and Computer Engineering, OU
General Description of Task I Activities

Task I Expenditures
FY07

- Administration: $34,906, 11%
- Research Salaries: $20,066, 6%
- Research Support: $103,042, 32%
- Indirect Costs: $198,776, 51%
Basic Convective and Mesoscale Research

NSSL Project 1 – Convective Weather Research: Severe Weather Warning Applications and Development
Coniglio (primary – CIMMS at NSSL), Wicker, Mansell

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Develop storm-scale data assimilation methods to be used for “warn on forecast” applications; examine performance of the ensemble Kalman filter for multiple convective modes and for assimilating multiple types of observations into numerical models; examine the sensitivity of the analyses to changes in the implementation of the EnKF algorithm for both practical considerations and to understand better how the assimilation procedure works on the storm scale with a complex convective situation.

Accomplishments
This study builds on past work by CIMMS research scientists by presenting a successful application of the ensemble Kalman filter data-assimilation technique using real Doppler radar observations of a mixed mode convective event, which has yet to be presented in the literature. It is shown that the quality of the storm-scale analysis produced by the technique can be at least maintained, if not improved, by using a relatively small localization radius and by implementing a threshold correlation to limit small, presumably noisy, covariances from influencing the analysis. The smaller localization radius has the added benefit of lowering the computation cost, substantially in some cases. It is also shown that the analysis system can accurately reproduce the reflectivity and velocity structures of the observed storms, but the low-level thermodynamic structures are very sensitive to the design of the system.

This project is ongoing.

Publications
Comparison of the reflectivity from KDDC observations on the 1.3° elevation scan (left column), the model reflectivity from the mean analysis of the control ensemble experiment (middle column), and the model reflectivity from a simple baseline experiment in which no assimilation of radar data takes place (right column) at 20 min [(a)-(c)], 40 min [(d)-(f)], 60 min [(g)-(l)], and 80 min [(j)-(l)]. Pertinent geographical features are identified in the upper-left panel.

**NSSL Project 1 – Convective Weather Research: Discrimination of Mesoscale Convective System Environments Using Sounding Observations**

Coniglio (primary – CIMMS at NSSL), Cohen, Corfidi, Taylor

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**

Identify environmental variables that may help to determine if a given quasi-linear mesoscale convective system (MCS) will produce widespread severe surface winds on 3-12 h time scales, with focus on the details of the kinematic environment and how the wind profiles may impact the strength and motion of the systems, which will hopefully provide forecasters with information that can be used to improve the short-term prediction of MCS.
Accomplishments
This study provided a description of the environments associated with severe wind-producing MCSs based on the analysis of numerous variables derived from observed sounding data. It is shown that the deep layer wind shear (0-6 to 0-10 km) is a better discriminator than the low-level shear (0-2 and 0-4 km), although the discriminatory ability of both the low-level-only and deep-layer shear is very good once the orientation of the convective line is known and the line-perpendicular shear component can be used. These results suggest that a shear variable that includes the physical benefits of low-level and upper-level shear together, such as the 0-10 km bulk shear, may be the best way to use the environmental shear to assess the potential for a quasi-linear MCS to produce severe winds.

Our results show quantitative evidence that the propagation component of system motion and the advective component are both large and additive for the long-lived severe MCSs. This shows that environmental relationships that can forecast MCS motion would be very useful in forecasting the intensity of MCSs. The present results support the notion that a configuration in which the deep-layer shear is large and in the same direction as the deep-layer mean wind (as is usually the case for a unidirectional shear profile) greatly favors a fast forward-propagating and severe MCS.

This project has been completed.

Publications

Box plots for the 0-2 km, 0-4 km, 0-6 km, and 0-10 km shear. Each set of three categories indicates the results for the weak MCSs (green), severe, non-derecho MCSs (yellow), and the derecho-producing MCSs. The boxes enclose the 25th and 75th percentiles. The dotted lines connect the medians for the distributions for each variable.
NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Thunderstorm Electrification Modeling
Mansell (primary – CIMMS at NSSL), Ziegler, Straka, MacGorman, Silveira, Cohen

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Gain insight into electrification and microphysical processes and lightning behavior of thunderstorms through numerical simulation.

Accomplishments

**Idealized space-varying storm environment.** A successful simulation of the 22 May 1981 “Binger” supercell has been achieved with an idealized inhomogeneous environment (see figure). A complete kinematic and electrical lifecycle is simulated, from initiation to maturity to decay, as the storm moves from a low-CIN environment into increasingly cooler boundary layer air. Multiple observed soundings are used to parametrically generate time invariant fields of potential temperature, water vapor mixing ratio, and horizontal winds on a fixed mesoscale parent grid that contains the moving model grid. The effects of the scheme are two-fold: 1) the introduction of an environment with more inhibition suppresses secondary convection that previously caused upscale growth of the system, whereas the observed storm remained fairly isolated; 2) the storm first grows in a low-inhibition environment and is able to sustain itself in moderate inhibition, but as it enters the most hostile environment it weakens from a supercell into a small complex of multicell storms or completely dies out, depending on the severity of the introduced inhibition.

**Microphysics effects on electrification.** Prediction of number concentration as well as mass of cloud droplets and ice crystals has modified the model results concerning the relative importance of noninductive (graupel-ice) and inductive (graupel-droplet) charge separation. Previously, droplet concentrations were assumed to be constant throughout a storm or modulated by air density as a function of height. Predicted droplet concentrations, however, tend to be lower than these assumptions because of parcel expansion and collection by precipitation, resulting in reduced inductive charge separation by virtue of fewer particles to experience rebounding collisions. [Single-moment schemes have the unrealistic feature of reducing the average droplet size in response to collection by larger particles, but maintaining a constant concentration.] Noninductive charge separation, on the other hand can become enhanced at higher temperatures (0 to -20º C) because the production of crystals by ice multiplication can be properly tracked in terms of crystal size and concentration. Previous work suggested that the inductive charging mechanism was needed for generating strong lower charge regions (i.e., at higher temperatures), but that noninductive charge separation could also be responsible if the crystal concentrations were sufficiently high. Previously this could only be achieved by artificially forcing higher assumed concentrations. Results are now supporting the noninductive graupel-ice interaction as a possible primary mechanism for lower charge regions.

This project is ongoing.

Publications


A severe supercell in its mature stage at 5 hours of simulation in an idealized non-homogeneous environment. The surface blue colors indicate perturbation temperature compared to the far western surface values. Simulated lightning is shown by the red and light blue volume surfaces, with negative cloud-to-ground lightning flashes occurring in the storm core. As the storm moves eastward, it encounters increasingly cooler boundary layer air, which reduces CAPE and increases CIN. The capping inversion suppresses secondary convection, so that the storm remains isolated for almost 7 hours before dissipating. In a homogeneous environment, the storm would have grown into a squall line by about 3-4 hours.

**NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Formation and Dynamics of Mammatus and Thunderstorm Outflow Anvils**

Schultz and Kanak (co-primary – CIMMS at NSSL and CIMMS at OU), Straka, Trapp, Gordon, Zrnic, Bryan, Durant, Garrett, Klein, Lilly

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**

Review the state of the art knowledge of mammatus clouds; numerically investigate the dynamics and microphysics of mammatus clouds associated with cirrus outflow anvils and compare the results with observations and theory; isolate the conditions under which mammatus clouds form and are detectable, make case studies of mammatus events, and continue to collect soundings, photographs and other observations of mammatus events.

**Accomplishments**

Numerical simulations of mammatus-like clouds have been completed and a paper has been published in *Atmospheric Science Letters*. A portion of a cirrus outflow anvil was simulated including ice microphysical processes. A new paper that extends these results to explore more of the parameter space is in preparation for submission to the *Journal of Atmospheric Sciences*. The results show that mammatus-like clouds (see figure below) form when soundings obtained near observed mammatus are used to initialize
the simulations and do not form when other soundings are used. Furthermore, it is shown that sublimation is necessary but not sufficient for the formation of simulated mammatus.

A review paper of mammatus clouds is in press at the *Journal of the Atmospheric Sciences*. Observations, formation theories, and numerical simulation results, relevant to mammatus are presented and discussed. Observations of mammatus reported in the literature range from early aircraft penetration and visual observations from the 1940s, to recent polarimetric radar data. Formation theories remain speculative as mammatus clouds typically exist on short timescales and are thus difficult to measure. In addition, because they are benign entities, the observations that have been obtained have been mostly serendipitous, or tangential to other field program objectives. The plausibility of various theories is evaluated in light of the more recent observations, limited numerical simulations, and some new proximity soundings. Although mammatus are rarely studied, they remain an enigma and an intriguing problem of basic atmospheric fluid dynamics. It is hoped that this paper, which summarizes the current state of knowledge of the microphysics and dynamics of mammatus clouds and the environments in which they form, will motivate others to study mammatus.

This project is ongoing.

**Publications**


*XZ cross-sections of snow diameter contours at t = 26 min, y = 125 m for S1. Minimum value (gray) is 0.0 to maximum value (red) 0.58 mm with interval of 0.04 mm. Left panel: whole domain; right panel: expanded region within whole domain with velocity vectors in white.*
NOAA HPCC/NCEP/Other Agency – Doppler Radar Data Quality Control, Analyses, and Assimilation
Xu (primary – NSSL), P. Zhang, Nai, Wei, H. Lu, collaborators at NSSL, NCEP, NRL, Institute of Atmospheric Physics (IAP) in Beijing, and Lanzhou University

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Other Funding Agencies: Office of Naval Research, FAA, NSSL Director’s Discretionary Research Fund

Objectives
Advance knowledge and skill in storm-scale data assimilation; develop state-of-the-art technologies and software for real-time applications of remotely sensed high-resolution measurements, especially those from Doppler radars, to improve numerical nowcasts and forecasts of severe storms and hazardous weather conditions.

Accomplishments
Estimating radar wind observation error and NCEP WRF background wind error covariances from radar radial-velocity innovations. By using the non-isotropic form of error covariance function derived for radial-velocity fields on conical surfaces of low-elevation radar scans, a statistical method was developed based on least-square fitting to estimate Doppler radar radial-velocity observation error covariance and background vector wind error covariance from time series of radar radial-velocity innovation (observation minus independent background) fields. The method is applied to radar radial-velocity innovation data collected from six radars (KINX, KLZK, KSGF, KSRX, KTLX, and KVNX) from 11:00 to 23:50 UTC on 21 May 2005 under a clear but windy weather condition. The background wind fields were provided by NCEP WRF 3-hour forecasts (on a 321x161x61 E-grid with a sigma vertical coordinate and 8 km horizontal resolution) over the central U.S. The results show that radar radial-velocity observation errors are correlated between neighboring range gates and between neighboring beams. The radial-velocity observation error correlations can be quite consistently estimated along with the observation error variances and background wind biases and covariances by the method. The detailed results were presented at the 18th Conference on Numerical Weather Prediction (1B.3 by Xu et al. 2007, available online from AMS site http://ams.confex.com/ams/pdfpapers/123419.pdf).

Time-expanded sampling for ensemble-based filters. A time-expanded sampling approach was proposed for ensemble-based filters with covariance localization in data assimilation. This approach samples a series of perturbed state vectors from each prediction run within a subsynoptic-scale time window in the vicinity of the analysis time. As all the sampled state vectors are used to construct the ensemble and compute the localized covariance, the number of required prediction runs can be much smaller than the ensemble size, and this can reduce the computational cost significantly. The conventional approach, however, requires the number of prediction runs to be as large as the ensemble size, so the ensemble size can be severely limited by the computational cost for an intended operational application. By properly setting the sampling time interval, the proposed approach can improve the ensemble spread and ensemble representation of the forecast probability distribution and thus improve the filter performance even though the number of prediction runs is greatly reduced. The potential merits of the proposed time-expanded sampling are demonstrated by assimilation experiments. The detailed results were presented at the 18th Conference on Numerical Weather Prediction (6B.1A by Xu et al. 2007, see http://ams.confex.com/ams/pdfpapers/123409.pdf).

These projects are ongoing.

Publications

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**Other Agency – System for Atmospheric Modeling with Explicit Microphysics – SAMEX**

Y. Kogan (primary – CIMMS at OU), Mechem

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Agency:** Office of Naval Research

**Objectives**

Develop a large eddy simulation (LES) model with explicit microphysics capable of running on advanced, distributed-parallel computing architectures.

**Accomplishments**

We completed the transition of the CIMMS LES with explicit microphysics to a new dynamical core capable of running on distributed-parallel computing architectures. The model dynamical core consists of the System for Atmospheric Modeling (SAM), version 6.4, developed by Marat Khairoutdinov, a Colorado State University research scientist and formerly a CIMMS/OU PhD graduate. The similarity of the numerics in SAM and the CIMMS LES made this transition rather straightforward. The new model, called SAMEX, was tested extensively for marine stratocumulus (ASTEX case) and was employed in the latest GEWEX Cloud System Study (GCSS) model intercomparison of marine trade cumulus. Results for the ASTEX and RICO cases compare favorably with the original CIMMS LES and community versions of LES.

This project is completed.
Example of SAMEX microphysical output during simulation of a precipitating convective cloud system based on data from the RICO field project. The center plot depicts cloud drop spectra in a vertical cross-section through a cloud cell shown in the lower right corner. The plot in the upper left corner shows zoomed spectra at a spatial point indicated by the red arrow.

Other Agency – The Role of Precipitation on Large Eddy Simulations of Trade Cumulus
Mechem (primary – CIMMS at OU), Y. Kogan

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: Office of Naval Research

Objectives
Employ large eddy simulation with size-resolving microphysics (SAMEX) to evaluate the role of precipitation in trade cumulus dynamics.

Accomplishments
One of the foci of the RICO (Rain in Cumulus over the Ocean) project was to evaluate the role of precipitation in the dynamics and evolution of the trade cumulus boundary layer. The CIMMS cloud physics group was one of 15 international groups to participate in a model intercomparison to explore whether state of the art LES models are capable of producing the characteristic features of trade cumulus as sampled during the field project. The CIMMS group was one of only three to employ LES (SAMEX) with a size-resolving microphysical formulation.
Preliminary results from the 24-h intercomparison simulation emphasize overall cloud characteristics. Cloud fraction, for example, fluctuates between 0.1 and 0.2, consistent with the snapshot plan view of albedo. Cloud base is largely dictated by surface thermodynamics and remains relatively steady over the course of the simulation, while maximum cloud top is highly variable and closely tied to the life cycle of individual cumulus towers. The inversion height steadily increases, a result of penetrative entrainment from updrafts rising as far as several hundred meters above the inversion and into the free troposphere.

This project is ongoing.

*SAMEX results for the RICO trade cumulus intercomparison. Plan view of albedo at 12 h.*
Other Agency – The Role of a Dynamically-Balanced Dataset in Cloud Microphysics Parameterization Development
Y. Kogan (primary – CIMMS at OU), Corrao

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: Office of Naval Research

Objectives
Explore the effect of dataset selection on cloud microphysics parameterization.

Accomplishments
A number of cloud microphysical parameterizations have been developed during the last decade using various datasets of cloud drop spectra. These datasets can be obtained either from observations, or artificially produced by some drop size spectra generator (e.g., by solving the coagulation equation under different input conditions), or obtained as output of an LES model that can predict explicitly cloud drop spectra. Each of the methods has its deficiencies. For example, observations are limited to the path of an airplane flight, while coagulation equation solutions depend on the input conditions. The crucial problem is to create a cloud drop spectra dataset which mimics realistic cloud drop parameters in nature. These parameters are closely related to the distribution of thermodynamical conditions and are difficult, if not impossible, to obtain a priori.

The best tool to recreate these conditions is with an LES model possessing explicit microphysics that can provide the full range of drop spectra generated by realistically represented turbulence. Exploring effects of dataset selection on obtained from this dataset cloud microphysical parameterization is the topic of the thesis work by the OU MS student Danielle Corrao. We simulated several cases of stratocumulus clouds observed during the Atlantic Stratocumulus Transition Experiment (ASTEX) field experiment in clean and polluted air masses. The simulated cloud layers represented cases with light (LD), moderate (MD) and heavy (HD) intensities of drizzle in the cloud. The results of the study showed high sensitivity of the derived parameterization on the selection of the dataset. We emphasize that the development of accurate parameterizations should require the use of dynamically balanced cloud drop spectra datasets.

This project is ongoing.

Other Agency – Mesoscale Dynamics and Mesoscale Applications of Information Theory
Xu (primary – NSSL), Lei, Gao, collaborators at NSSL and Institute of Atmospheric Physics (IAP) in Beijing

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: NSF, Office of Naval Research, FAA, NSSL Director’s Discretionary Research Fund

Objectives
Explore various instability mechanisms that will provide possible explanations for initiation of some observed mesoscale rainbands and severe storm elements embedded in frontal rainbands, including but not limited to studies of modal and non-modal growths and structures in the presence of symmetric stability and instability.

Accomplishments
The relative entropy is compared with the previously used Shannon entropy difference as a measure of the amount of information extracted from observations by an optimal analysis in terms of the changes in the probability density function (pdf) produced by the analysis with respect to the background pdf. It is shown that the relative entropy measures both the signal and dispersion parts of the information content from observations, while the Shannon entropy difference measures only the dispersion part. When the pdfs are Gaussian or transformed to Gaussian, the signal part of the information content is given by a weighted inner-product of the analysis increment vector and the dispersion part is given by a non-
negative definite function of the analysis and background covariance matrices. When the observation space is transformed based on the singular value decomposition of the scaled observation operator, the information content becomes separable between components associated with different singular values. Densely distributed observations can be then compressed with minimum information loss by truncating the components associate with the smallest singular values. The differences between the relative entropy and Shannon entropy difference in measuring information content and information loss are analyzed in details. Illustrative examples are given for the velocity observations from the NSSL phased array radar with the background field from the Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System.

This project is ongoing.

Publications

Other Agency – Numerical Modeling Study of the Time-Dependent Behavior of Convection
Doswell (primary – CIMMS at OU), Weber, Loftus, Baranowski, DuFran

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: NSF

Objectives
Determine how environmental factors, notably the forcing that initiates deep convection and the environmental wind and thermodynamic profiles, control the time-dependent behavior of deep convective storms.

Accomplishments
This project is nearing completion - it involves the use of a 3-D cloud model ARPI3 (similar to the ARPS model), developed by Dr. Daniel Weber of CAPS. The aim has been to determine how environmental factors, notably the forcing that initiates deep convection and the environmental wind and thermodynamic profiles, control the time-dependent behavior of deep convective storms. Simulation study results can be viewed at: http://www.caps.ou.edu/~dweber/bubbles.html. Three Masters Theses were produced from this work. 192 model runs have been completed and diagnosis of the results has shown that the occurrence of sustained multicell convection is quite sensitive to the initial CAPE and less so on the shear. A measure of the behavior of the convection – the extent to which the multicell updrafts are more plume-like or bubble-like – has been developed. The frequency of new updraft regeneration also depends on the CAPE and shear, with a strong sensitivity to the CAPE. In fall 2007, we plan to submit a renewal proposal to continue this work, to include more simulations over a wider range of environmental conditions, to fill in more of the multidimensional parameter space.

This project is ongoing.

Publications
Other Agency – Vertical Vortices in the Convective Boundary Layer
Kanak (primary – CIMMS at OU), Snow, Lilly

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: NSF

Objectives
Identify the dynamical mechanisms of vertical vortex formation in the convective boundary layer and assess the role of these vertical vortices on boundary layer processes.

Accomplishments

Environments with no ambient winds. Continuing study of the dynamical formation mechanisms of atmospheric convective boundary layer vortices is being conducted. These vortices are typically manifest visibly as dust devils although there is mounting evidence that they exist with some frequency in the absence of visible flow tracers. For example, MacPherson and Betts (1997) point out instrument observations of invisible boundary layer vertical vortices over the boreal forest. Furthermore, Kanak et al. (2000; hereafter KLS2000) found that a circulation on 3 cm mobile Doppler that was associated with a dust devil persisted on the radar for several minutes after the dust devil had moved over a vegetated surface and was no longer visible to the eye. Most observational investigators have reported cases when observed mean winds are low or nearly calm (e.g., < 7-10 ms\(^{-1}\) (Morton 1966)), which seem to be their preferred environments. Morton even states that wind speeds greater than 7-10 ms\(^{-1}\) will break up the dust devil. However, there have been observations to the contrary where dust devils have been observed in association with larger scale convergence zones, boundaries or drylines, where mean winds have been as high as 15 m s\(^{-1}\) (e.g., Kanak, unpublished, VORTEX95 03 June 1995 south of Dimmitt, Texas; Pietrycha and Rasmussen 2004; Markowski and Hannon 2005). Prior simulation work by the principle investigator has represented only cases without larger scale boundaries which may be more similar to a typical day in the deserts of Arizona or California (e.g., Sinclair 1969). It is these latter cases, in which there is no obvious mean source of vorticity, which lead to a need to address why dust devils may be preferred in low wind environments. Furthermore, vertical vortex formation in convection without a mean shear has not often been documented in laboratory or numerical simulations. Thus, the main focus of the work thus far has been on the case of environments without mean winds and the formation mechanism for vortices in such environments is still being sought through the continuing study. In current work, a slightly shifted emphasis is to the vertical structure of vertical vortices which have dust devil-scale diameters near the surface, but then expand in diameter with height. In other words, the relationship between mososcale [O(10’s m)] and misoscale [O(100’s-1000’s m)] vortices (Fujita 1981), their formation mechanisms, and evolution, will be explored. Sinclair (1966) presents the results from observations taken from upper levels of dust devils that support the contention that misocyclones may be related to dust devils. He reports that the radius of disturbed wind fields associated with dust devils can be up to ten times the radius of the dust devil column. If dust devils and misocyclones are indeed associated with one another, dust devil-scale vortices may even been important to non-supercell genesis (Wakimoto and Wilson 1989). Thus, the dust devil vortex appears to be embedded within a larger-scale vortex which seems to be related to the larger-scale convective pattern. New simulations that are intended to revisit the larger-scale [O(km’s)] forcing mechanisms have just been performed. The broadening of the vortex circulations with height is also found in the numerical simulations (see figure below). The formation mechanisms at the larger scale may give insight into the dynamical formation mechanisms of the smaller, near surface vortices.

Environments with ambient wind shears. Wu et al. (1992) showed that in numerical simulations of Rayleigh-Benard convection, the turbulent perturbations had high helicity values when a mean wind that turns with height (helical hodograph) is imposed. To examine whether this is true for vertical vortices only (rather than the combination of vertical and horizontally helical perturbation flows) a new study has been designed. Two experiments have been completed using 6 m horizontal grid spacing. These preliminary results imply that the presence of environmental wind appears to inhibit the formation of vertical vortices as compared with the case of a quiescent environment. The first simulation includes the case of a linear mean wind shear, the second a circular hodograph (shear vector turning with height). The vortex...
detection algorithm will be used to quantify the effects of the various shear profiles on the number of vortices and their physical characteristics. In addition, other simulations are planned to expand the parameter space to include more shear profiles.

This project is ongoing.

**Publications**

*Horizontal velocity vectors from simulation using 40 m horizontal grid spacing. a) z = 10 m height; diameter of vortex approximately 100 m. b) z = 590 m height; diameter of vortex approximately 500 m.*

**Other Agency – Martian Dust Devils**
Kanak (primary – CIMMS at OU), Cantor, Edgett

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Agency:** NSF and CIMMS Task I

**Objectives**
Analyze Martian dust devil characteristics as determined by Mars Orbiter Camera (MOC) images and make comparisons with terrestrial dust devils; gain insight into dust devil formation and maintenance dynamics, and their role in boundary layer processes by comparison of their characteristics in two different atmospheres.

**Accomplishments**
Collaborative efforts with Dr. Ken Edgett and Dr. Bruce Cantor at Malin Space Science Systems (MSSS) have resulted in a paper on Martian dust devils in press at the *Journal of Geophysical Research*. In this paper, observations of dust devils and dust devil tracks from Mars Orbiter Camera images are described. Recent data from the Mars Rover Thermal Emission Spectrometer are used to determine a representative temperature profile that might be typical of Martian dust devil environments in order to make estimates of tangential wind speeds given the physical dimensions determined from the MOC images. Discussion of the ubiquitous dust devil tracks that mark the Martian surface are described.
An LES of the Martian boundary layer has been conducted to simulate Martian dust devils (see figure below). The vortex detection algorithm again will be used to quantify the simulated vortices and the results will be compared to the observations given in Fisher et al. (2005).

This project is ongoing.

**Publications**

Other Agency – Evaluation of Microphysical Parameterizations
Straka (primary – OU School of Meteorology), Gilmore, Kanak, Rasmussen

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: NSF and CIMMS Task I

Objectives
Explore the physical consistency of certain microphysical parameterizations with the physical processes they are designed to represent.

Accomplishments
The equations which represent two microphysical processes, for which total number concentration $N_t$ should be conserved, are integrated over sizes of hydrometeor diameters $D$ for one- and two-moment methods. The gamma distribution function is assumed and incorporates total mixing ratio $q$, $N_t$, and mean diameter $D_n$, (inverse of the distribution slope $l$). In all the methods, the slope intercept, $n_o$, is diagnosed or specified but not predicted. The moment methods explored include:

- Scheme-A: the one-moment method where $q$ is predicted, $n_o$ is specified, and $N_t$ and $D_n$ are diagnosed;
- Scheme B: the one-moment method where $q$ is predicted, $D_n$ is specified, and $N_t$ and $n_o$ are diagnosed;
- Scheme E: the two-moment method where $q$ and $D_n$ are predicted, and $N_t$ and $n_o$ are diagnosed;
- Scheme F: the two-moment method where $q$ and $N_t$ are predicted, and $n_o$ and $D_n$ are diagnosed.

To more easily discern the strengths and weaknesses of each moment-method, two processes are considered: vapor diffusional growth and continuous collection growth, and in both cases there is no introduction of new particles ($d N_t / d t = 0$). It is demonstrated for the processes examined that all of the schemes fail to conserve $N_t$ and have other unphysical attributes, except the two-moment method where $q$ and $N_t$ are predicted.

In a separate paper, it is demonstrated mathematically why $N_t$ is not conserved when it should be conserved for continuous collection growth. The results for vapor diffusional growth are qualitatively similar. The figure below shows a time series of the total number concentration for each of the schemes A-F listed above. It is clear that only Scheme F conserves $N_t$ for continuous collection growth. Scheme-B has the most erroneous solution with regard to the conservation of $N_t$.

This project is ongoing.

Publications
Fig. 1. Time series up to 600 s. a) $N_t$ in units of ($m^3$) vs. time (s). b) $q$ in units of (kg kg$^{-1}$) vs. time (s).
**Other Agency** – Adaptive High-Order Methods for Nonhydrostatic Numerical Weather Prediction  
Mavriplis (primary – CIMMS at NSSL), Wicker, Williams, Crowell, St.-Cyr, Thomas

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Agency:** NSF

**Objectives**
Explore the efficiency of high-order and adaptive formulations for nonhydrostatic equations.

**Accomplishments**
New students (one MS in meteorology and one PhD in Math) were trained in the basics of FORTRAN programming, numerical techniques (interpolation, quadrature, Legendre polynomials, finite element methods, finite difference methods, and time stepping methods) and participated in an NCAR WRF training workshop in preparation for research on this NSF-funded project. A presentation was made on early stages of this work at the SIAM Geosciences Meeting in March 2007.

This project is ongoing.

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CIMMS Special Project – Firewhirls and Firefighter Safety
Kanak (primary – CIMMS at OU), Savadel, Davis, Snow

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task I

Objectives
Isolate the meteorological conditions that support Firewhirls in order to provide this information to firefighters to increase their safety.

Accomplishments
A new collaborative effort with Jeff Savadel of the Nevada NWS and Dave Davis of the Bureau of Land Management has been started to better understand the meteorological conditions that support firewhirls. Firewhirls are extremely hazardous to firefighters; the more we can learn about forecasting them and the conditions which support them will help better protect wildfire firefighters. The principle investigator is currently running LES to explore the effects of varying surface heat flux and background ambient winds on vertical vortices in the convective boundary layer. The goal is to provide the NWS with matrix of meteorological conditions and the types of vortices that can be expected with them. We also are exploring the possibility of external funding to extend the scope of this project.

This project is ongoing.
Forecast Improvements

**NSSSL Project 1 – Convective Weather Research: Predicting the Longevity of Mesoscale Convective Systems**  
Coniglio (primary – CIMMS at NSSSL), Brooks, Corfidi, Weiss

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type:** CIMMS Task II

**Objectives**
Examine a large data set of observed proximity soundings to identify predictors of MCS dissipation and to improve our understanding of MCS environments; the ultimate goal of this work is to develop forecast tools that provide probabilistic guidance on the maintenance of MCSs with a focus on the 3-12 hour time scale, which could benefit Day 1 Severe Weather Outlooks, Mesoscale Discussions, and the issuance of Severe Weather Watches at SPC and short-term forecasts issued by local NWS forecast offices.

**Accomplishments**
Several environmental factors that can be used to predict the dissipation of MCSs were identified in this study. Shear vector magnitudes over very deep layers are the best discriminators among hundreds of kinematic and thermodynamic variables. The lapse rates over a significant portion of the convective cloud layer, the convective available potential energy, and the deep-layer mean wind speed are also very good discriminators and collectively provide a high level of discrimination between the mature and dissipation soundings as revealed by linear discriminant analysis. Probabilistic equations developed from these variables used with short-term numerical model output show utility in forecasting the transition of an MCS with a solid line of convection to a more disorganized system with unsteady changes in structure and propagation. This method to forecast the longevity of MCSs has been transferred to operations at the SPC and the NWS Forecast Office at LaCrosse, WI.

This work has been completed.

**Publications**

An example of a 9 h forecast of the MCS maintenance probability (MMP) calculated from Rapid Update Cycle (RUC) output valid at 1800 UTC on 20 June 2005. Values of MMP increase in 10% increments, from 10% in light blue to 90% in dark red. The thick green lines indicate the hourly position of the leading edge of a quasi-linear MCS that occurred in the morning and afternoon of 20 June 2005 (times, in UTC, are indicated in yellow) in the upper Midwest. The system propagated steadily forward and remained strong as it moved through the region of MMP values of 70 - 90% but became more disorganized and gained back building characteristics as it moved through the gradient to low MMP values.

**NSSL Project 3 – Severe Weather Warning Research and Application Development: Dual-Polarimetric WSR-88D Development**

*Scharfenberg* (primary – CIMMS at NSSL), *Manross*

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**
Provide technical coordination with NOAA and external agencies regarding the upcoming dual-polarimetric upgrade to the national WSR-88D network.

**Accomplishments**
CIMMS scientists coordinated a field evaluation of candidate dual-polarization WSR-88D products. Examples of base dual-polarization data and algorithm output from several significant weather events were distributed to users of WSR-88D data at numerous agencies internal and external to NOAA. Online
worksheets and questionnaires for the participants were created. Feedback from field participants was collected and analyzed, and a report was written containing a number of findings and recommendations for the developers of the final software for the dual-polarization of WSR-88D. This work will be followed by another formal evaluation of dual-polarization products at the first upgraded WSR-88D site in Wichita, Kansas. Preparation is underway for this field test.

Updated functional descriptions of the dual-polarization Quantitative Precipitation Estimation, Melting Layer Detection, and Hydrometeor Classification algorithms were written and delivered to the ROC. CIMMS scientists participated in numerous NOAA planning meetings regarding the upgrade, fielded phone calls and e-mail inquiries, and provided expertise on dual-polarization science to NOAA software developers.

This project is ongoing.

Example web module for field users of WSR-88D data to allow them to provide feedback on candidate dual-polarization WSR-88D products.
NSSL Project 4 – Investigation into the Use of Warning Decision Support Systems for Improving Hazardous Weather Detection, Warnings, and Forecasts: FSI and WDSS-II

Lakshmanan (primary – CIMMS at NSSL), Kerr, Brogden, Toomey

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Build an interactive Four-dimensional Storm-cell Investigator (FSI) to better visualize radar data in real-time; implement the FSI on the National Weather Service’s operational AWIPS system, verify and validate the new techniques; explore the processes and methods that forecasters use to analyze data and to develop research prototype systems that may contribute to ongoing CIMMS and NSSL research on the analysis of hazardous weather and the weather warning decision process; develop better algorithms to identify severe weather signatures or precursor signatures

Accomplishments
The FSI was developed and tested on the AWIPS platform. The FSI includes novel techniques for interactively visualizing radar data in 3D and updating the visualizations automatically with the arrival of new radar tilts. Compared to the traditional cross-section functionality on AWIPS, the FSI method delivers better interactivity, higher resolution and faster temporal responses.

Progress was made on several fronts:

- A proof-of-concept FSI was developed by CIMMS engineers and scientists. The prototype will form part of the next AWIPS build to be used operationally at National Weather Service Forecast Offices in several test sites. Lessons learned from this prototype will be used to implement 4D storm cell interrogation into the NWS’ operational systems;
- Developed algorithms for use in the CASA radar system’s meteorological command-and-control module. Algorithms include storm identification and tracking, shear signature detection, and multi-radar data fusion;
- Developed a real-time virtual volume to enable visualization and automated information retrieval from adaptively scanned phased array radar scans;
- Provided research support for the real-time implementation and visualization of a radar refractivity algorithm;
- Provided research support for the Hazardous Weather Testbed including the creation, advection and visualization of and interaction with probabilistic warnings; and
- Continued to improve the quality control of WSR-88D radar reflectivity data for use in real-time nowcasting of severe weather and precipitation.

This project is ongoing.

Publications
NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Investigate Methods to Provide Improved Forecasts of Near Surface Conditions through the Use of Ensemble Forecasts

Stensrud (primary - NSSL), Yussouf

NOAA Strategic Goal 3 (Serve Society's Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Evaluate the performance of the Bias-Corrected Ensemble (BCE) forecasting system and the Binning Technique during the cool season; investigate methods for further improvement of the performance of these two post-processing techniques.

Accomplishments
A post-processing method initially developed to improve near surface forecasts from a summertime multimodel short-range ensemble forecasting system has been evaluated during the cool season of 2005-06. The method, known as the bias-corrected ensemble (BCE) approach, uses the past complete 12 days of model forecasts and surface observations to remove the mean bias of near surface variables from each ensemble member for each station location and forecast time. In addition, two other performance-based weighted average BCE schemes, the Exponential Smoothing Method BCE and Minimum Variance Estimate BCE were implemented and evaluated. Values of root-mean-squared error from the 2-m temperature and dewpoint temperature forecasts indicate that the BCE approach outperforms the routinely available Global Forecast System (GFS) Model Output Statistics (MOS) forecasts during the cool season by 9% and 8%, respectively. In contrast, the GFS MOS provides more accurate forecasts of 10-m wind speed than any of the BCE methods. The performance-weighted BCE schemes yield no significant improvement in forecast accuracy for 2-m temperature and 2-m dewpoint temperature when compared with the original BCE, although the weighted BCE schemes are found to improve the forecast accuracy of the 10-m wind speed. The probabilistic forecast guidance provided by the BCE system is found to be more reliable than the raw ensemble forecasts. These results parallel those obtained during the summers of 2002 to 2004 and indicate that the BCE method is a promising and inexpensive statistical post-processing scheme that could be used in all seasons.

The simple binning technique developed to produce reliable probabilistic quantitative precipitation forecasts (PQPFs) from a multimodel short-range ensemble forecasting system was evaluated during the cool season of 2005-06. The technique uses forecasts and observations of 3-h accumulated precipitation amounts from the past 12 days to adjust today’s 3-h quantitative precipitation forecasts from each ensemble member and for each 3-h forecast period. Results indicate that the PQPFs obtained from this simple binning technique are significantly more reliable than the raw (original) ensemble forecast probabilities. Brier skill scores and areas under the relative operating characteristic curve also reveal that this technique yields skillful probabilistic forecasts of rainfall amounts during the cool season. This holds true for accumulation periods of up to 48 h. The results obtained from this wintertime experiment parallel those obtained during the summer of 2004. In an attempt to reduce the effects of a small sample size on two-dimensional probability maps, the simple binning technique was modified by implementing 5- and 9-point smoothing schemes on the adjusted precipitation forecasts. Results indicate that the smoothed ensemble probabilities remain an improvement over the raw (original) ensemble forecast probabilities, although the smoothed probabilities are not as reliable as the unsmoothed adjusted probabilities. The skill of the PQPFs also is increased as the ensemble is expanded from 16 to 22 members during the period of study. These results highlight that simple post-processing techniques have the potential to provide greatly improved probabilistic guidance of rainfall events for all seasons of the year.

This project is ongoing.

Publications

Values of MAE, rmse and bias (K) plotted as a function of forecast hour for the BCE system and the GFS MOS calculated over 158 days from 25 October 2005 through 31 March 2006. The values are averaged over 1374 NWS stations.
NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Measuring the Evolution of Tropical Waves over West Africa into Tropical Storms over the Eastern Atlantic
Douglas (primary – NSSL), Murillo, Mejia

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Determine whether characteristics of tropical waves propagating over West Africa during August and September can be used to determine which of these waves will develop rapidly into hurricanes over the eastern Atlantic - the so-called "Cape Verde storms".

Accomplishments
A field data collection activity was carried out during August-September 2006; our team contributed to enhancing the sounding network over West Africa and also participated in the research aircraft program. The sounding data have been processed and were being used this summer, with the aid of a student. The aircraft observations have undergone preliminary analysis and some results presented at two meetings.

This project is ongoing.

Temperature and streamline analysis of NASA DC-8 observations showing the eye of tropical storm Debby off the coast of West Africa on 23 August 2006.
**NSSL Project 9 – Research on Integration and Use of Multi-Sensor Information in Weather Forecasting: Science and Technology Infusion**

Stumpf (primary – CIMMS at NWS/MDL), S. Smith

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**

Work with CIMMS/NSSL scientists to develop multiple-sensor severe weather warning applications and display systems and transfer that technology to NWS operational systems; maintain an Advanced Weather Information Processing System (AWIPS) Development Environment at CIMMS/NSSL; facilitate the development of the Hazardous Weather Testbed – Experimental Warning Program at the new National Weather Center in Norman.

**Accomplishments**

The third full year of the CIMMS/NWS/Meteorological Development Laboratory (MDL) scientist position was completed during this review period. The “AWIPS-Lite” system that was installed at NSSL last year was upgraded with the new workstation hardware, and is still being used for AWIPS application development and evaluation.

The project to adapt the NSSL Warning Decision Support System II (WDSSII) 3D/4D base radar display application (the WDSSII GUI, or ‘wg’) into an AWIPS application known as the Four-Dimensional Stormcell Investigator (FSI) was completed. The FSI is a version of the WDSSII display that simultaneously displays in four panels radar data at constant elevation angle, interactive vertical cross-sections and constant altitude cross-sections, along with a 3D display. The software has been delivered to the National Weather Service, and will be included in the AWIPS Operational Build 8.2 (OB8.2) slated for a winter 2008 release. The software is currently being operationally alpha-tested at three NWS forecast offices (Melbourne FL, Omaha NE, and Huntsville AL). Feedback from these alpha tests will be used to help better define the design of the FSI for future version releases. The next version of the FSI, for AWIPS OB8.3, is anticipated to include support for displaying super-resolution WSR-88D data and polarimetric radar data, as well as advanced data sampling capabilities. Beyond that, support for displaying Terminal Doppler Weather Radar (TDWR) data, and 3D isosurface capabilities is anticipated.

The CIMMS/MDL scientist continued to closely collaborate with the severe weather warning R&D activities at CIMMS and NSSL, in the areas of multiple-sensor severe weather warning applications which will eventually be transferred to NWS operations. We are still supporting the system to display various multiple-sensor WDSSII diagnostic grids for hail, storm rotation, and 3D lightning for the Norman, Fort Worth, and Tulsa WFOs.

The CIMMS/MDL scientist continued to work with collaborators in NSSL, the WDTB, and the Norman WFO to develop a WFO-scale component of the National Weather Center (NWC) Hazardous Weather Testbed (HWT), known as the Experimental Warning Program (EWP), designed to be a proving ground for new severe weather applications to assist short-fused (0-1 hour) warning decisions. The CIMMS/MDL scientist was instrumental in the development of ideas, and he participated during real-time exercises, of a national gridded probabilistic warning experiment which was started in the HWT/EWP during the spring of 2007. This experiment is expected to continue into 2008 and beyond.

The CIMMS/MDL scientist, along with the WDTB and the NSSL, co-organized the 2nd Workshop on Severe Weather Technology for NWS Warning Decision Making at the NWC in Norman. This workshop served to bring researchers, technology specialists, field forecasters, and management with the objectives of: 1) Identifying potential pathways to evolve severe weather warning decision making and technologies, and 2) providing recommendations for the evolution of the HWT/EWP.

This project is ongoing.
Publications

Example of a gridded probabilistic tornado warning.
WDTB Project 10 – Warning Decision-Making Research and Training: Advanced Warning Operations Course (AWOC)

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Improve understanding of warning related issues, helping the NWS achieve GPRA goals 1-7.

Accomplishments
CIMMS scientists were heavily integrated into the development, delivery, and support of WDTB’s Advanced Warning Operations Course (AWOC). AWOC is a blended learning course designed to provide training on advanced warning decision making techniques to every NWS forecaster with warning responsibility (meteorologists and hydrologists). AWOC was the first initiative to deliver warning decision-making training to all forecasters since the WSR-88D Operations Course of the 1990s, at a significantly reduced cost. WDTB was awarded the Department of Commerce Silver medal for the delivery of AWOC, and CIMMS scientists were critical to its success. After the initial AWOC release (which included tracks on Core Operations and Severe Weather), a third track (the AWOC Winter Weather track) was released in June 2006.

In collaboration with WDTB instructors, CIMMS scientists updated existing (from FY06) AWOC Core and Severe Track material with new information and better fit it with other existing curriculum for new hires to the NWS. One of the new projects involved the safety of large outdoor venues such as MLFB, MLB, NASCAR, etc. This involves presenting these groups with the threats from severe convective storms and urging the formulation of plans for the safety of the venues and the fans attending the programs of each. It also involves gaining the support and sponsorship of the International Association of Assembly Managers (IAAM) in holding a national meeting in FY08 for the purpose of generation templates for the venue plans. This work included adding a new lesson to the course, preparing new or better graphics and animations, applying the results of past research to training content, and developing interactivity for the modules. Minor updates to AWOC Winter Weather modules made after the initial release also were made.

CIMMS contributions also included logistics support for all three tracks of AWOC and its management, including responses to questions from the field, assistance for local facilitators, provision of certificates of completions to students, and development of a semi-automated method of producing statistical progress reports of students and WFOs using NOAA’s Learning Management System.

This project is ongoing.

Publications
WDTB AWOC official site: http://www.wdtb.noaa.gov/courses/awoc/
Winter Weather AWOC completion statistics for all NWS personnel since the delivery date in 2006 through 9 May 2007. The blue line tracts the numbers of those that have completed the entire Winter Track by the date listed on the bottom of the graph.

**WDTB Project 10 – Warning Decision-Making Research and Training: AWIPS and WSR-88D Improvements**  
Decker, Morris, Wood, Hoggard, NWS/WDTB collaborators

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type:** CIMMS Task II

**Objectives**
Improve understanding of warning-related issues.

**Accomplishments**
The warning decision makers within each NWS office rely heavily on computing systems that need to run both quickly and efficiently, display data in an easy to view and navigate format, and have zero down time. With these goals in mind, CIMMS staff have aided in the training, testing, and development of two of the primary systems used in NWS warning operations: The Advanced Weather Information Processing System (AWIPS) and the Radar Product Generator (RPG) for the WSR-88D.

CIMMS staff working as subject matter experts with colleagues at WDTB has aided NOAA’s NWS in many ways regarding the AWIPS program. In Operational Builds (OB) 7.1, 7.2 and 8.1 of AWIPS, CIMMS researchers were heavily involved in the design review, implementation, and training for the AWIPS software.
As part of the AWIPS software development process, beta versions may contain bugs or various performance issues which then could affect a forecaster's ability to make warning decisions. To help prevent these limitations from reaching the operational community, CIMMS researchers were invited to participate in thorough testing of the AWIPS software builds OB7.2, OB8.1, and OB8.2 well before they were released to the field. Their expertise in tracking down bugs or other performance-related problems was invaluable to the testing process. The testing also fed back into the development of all AWIPS training.

In addition to AWIPS related training, another vital system in each NWS office is the RPG. CIMMS staff assisted WDTB in the development of training for RDA/RPG Build 9 by assisting WDTB instructor staff in developing prototype material for training, developing training support materials, (i.e., animations and graphics), and helping instructors prepare the training for web delivery.

This project is ongoing.

Publications

**WDTB Project 10 – Warning Decision-Making Research and Training: NOAA’s NWS Weather Event Simulator**

Decker, Hoggard, Magsig, Mohamed Said, Morris, NWS/WDTB collaborators

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**
Develop simulation capabilities to enhance NWS warning decision making training and research; foster collaboration between NOAA and non-NOAA agencies using the Weather Event Simulator.

**Accomplishments**
Now in its sixth year since the initial release, NOAA’s NWS Weather Event Simulator (WES) continues to play an expanding role in NWS training. Every NWS forecaster with warning responsibility is required by NWS Directive 20-101 to complete two simulations using the WES prior to each significant weather season per year. The WES has also been a key part of the Warning Decision Training Branch’s (WDTB) major training initiatives. This includes the Advanced Warning Operations Course (AWOC), Winter Weather Advanced Warning Operations Course (WWAWOC) and the Distance Learning Operations Course (DLOC). In AWOC and WWAWOC, the WES was used by every student to apply lessons in an operational context. The WES was used in DLOC to expose inexperienced users to the Advanced Weather Interactive Processing System (AWIPS). Two new training courses developed in FY2007 also utilized the WES. Both the Distance Learning Aviation Course (DLAC2) and Storm-Based Warnings training provided forecasters with the opportunity to apply new concepts in operationally representative conditions.

The WDTB is responsible for implementing the WES into NWS training, and CIMMS scientists support this initiative. Keeping WES updated with the latest operational AWIPS tools and supporting the NWS WES program are two main areas in which CIMMS plays a prominent role. CIMMS scientists at the WDTB are the primary WES developers. They create, test, distribute, and support WES for the NWS. In addition, they have been proactive in releasing WES to non-NOWA to promote collaboration between NOAA and non-NOAA agencies.

In the past year, CIMMS scientists collaborated with the WDTB, the Global Systems Division (GSD), the Meteorological Development Laboratory (MDL), and the Office of Science and Technology (OST) to develop and release several new versions of WES.
WES7.1 was developed in the previous CIMMS year but was released to the field in the most recent year. In this release, CIMMS scientists upgraded WES to support Operational Build 7.1 of AWIPS, including functionality such as increased frame count, new all-tilts navigation and the WSR-88D Snow Accumulation Algorithm (SAA). Additional improvements to the WES software included a new test case containing a larger suite of products and improved installation of AWIPS freeware. WES7.1 was also the first regular WES release to contain the Graphical Forecasting Editor (GFE) software first introduced in WES6.0ww. Improvements to the WES7.1 version of the WES Scripting Language (WESSL) included updated CWA maps, improved response logging and easier script building.

WES7.2 was completely developed and deployed in the last CIMMS year. WES7.2 supported AWIPS Operational Build 7.2 with new functionality such as the General User Alert Display Panel (GUARDIAN), SPG products (for TDWR) and enhanced DMD time-height displays. Also new in WES7.2, WESSL commands can now be issued in 10 second increments.

Development on WES8.1 began in the past year as well. CIMMS scientists worked with AWIPS developers to incorporate OB8.1 into WES including the new Storm Based Warnings functionality. WES8.1 will also include AvnFPS functionality as well as improved point data processing. OB8.1 and WES8.1 were scheduled for release in late July 2007.

In the last calendar year, NOAA users received replacement WES machines based off the new AWIPS hardware refresh LX workstations. These new machines contained improved hardware and software necessary to support future WES and AWIPS builds. CIMMS scientists created a “WES machine replacement disk image” containing RHE4 and WES7.1 was released in late 2006/early 2007 to forecast offices in most regions.

This project is ongoing.

**Publications**


WDTB WES official site: http://www.wdtb.noaa.gov/tools/wes/index.htm

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*The WES graphical interface.*
WDTB Project 10 – Warning Decision-Making Research and Training: Distance Learning Operations Course (DLOC)  

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Investigate warning decision making issues with NWS forecasters; evoke a better understanding of the warning decision making process; and transfer that knowledge to warning decision makers to improve field performance.

Accomplishments
The WSR-88D Distance Learning Operations Course (DLOC) continues to be an area of active collaboration between CIMMS and the NWS Warning Decision Training Branch. DLOC teaches recently hired NWS meteorologists a wide range of topics regarding the WSR-88D and severe weather, including: radar theory, operations of the radar, AWIPS D2D functionality, radar data interpretation, storm interrogation techniques, and severe storm threat assessment and forecasting. In other words, DLOC is the integration of current meteorological and warning decision-making techniques with Doppler radar capabilities. This course is taught via a combination of teletraining, web-based instruction, on-station training, and residence training.

CIMMS staff has been closely involved with the development of DLOC. The collaborative work has included applied research on future radar improvements such as dual-polarization, as well as on current WSR-88D capabilities to assess hail and flash flooding threats. As part of this training, CIMMS personnel work closely with radar engineers and software developers to determine how recent updates to different components of the WSR-88D and AWIPS impact the system as a whole. This work has allowed CIMMS staff to assist their WDTB collaborators in developing and updating significant portions of DLOC during the past year. Another area where CIMMS staff has played a critical role with DLOC is during the residence component of the course. The collaborative work with WDTB during these classes includes development and presentation of lecture materials, development and delivery of exercises and simulations (in the WDTB Research and Training Laboratory), and providing expertise on warning-decision making issues to the class participants.

DLOC is significant because it is a critical piece in the development of new NWS forecasters for warning operations. All forecasters who may be responsible for issuing warnings for the NWS in the future are required to complete this training. Without the contributions of the CIMMS staff, DLOC would not have its current structure or effectiveness.

This project is ongoing.

Publications
WDTB DLOC official site: http://www.wdtb.noaa.gov/courses/dloc/
Simulation exercise in the WDTB Research and Training Laboratory during a recent DLOC workshop at the new National Weather Center.

**WDTB Project 10 – Warning Decision-Making Research and Training: Training and Research Toolkit**
Mohamad Said, Hoggard, X. Yu, NWS/WDTB collaborators

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type:** CIMMS Task II

**Objectives**
Provide an advanced, effective and flexible platform and environment for interactive learning and research; design and develop techniques and tools that can be transferred to the NWS community for operational forecasting or research, and for use in a simulated operational environment.

**Accomplishments**
The warning decision making process is multi-faceted, often being improved directly by analysis tools or data analysis techniques. CIMMS staff has developed some applications to apply these new tools and techniques into the operational forecasting, training, and research environment. The WDTB Research and Training (WRAT) Lab Toolkit is one of those applications. CIMMS staff successfully developed an advanced, efficient and flexible platform, LabControlPanel, as part of the application. With this platform, the time consuming tasks of setting up and managing the lab became very handy, efficient and flexible. The WRAT Toolkit also provides some new functions, including pause, resume, forward and group functions to support and enhance resident training strategies. This tool has been performing as an important role in setting up the lab’s configuration and enhancing the interactive learning for workshops,
such as the NOAA’s NWS Distance Learning Operations Course (DLOC) and for foreign meteorologist visits. This toolkit has made the setting up and configuring of the lab, after the move to the new building, easier.

The Sounding Toolkit, an application tool released by CIMMS researchers to AWIPS Local Application Database, is an updated sounding analysis program (the current version is 1.6). The new functionality in this application gives operational forecasters more flexibility to generate new convective parameters using D2D (AWIPS display software), allowing for the application of newly developed forecast techniques. The current version of the sounding toolkit includes the tropospheric airborne meteorological data reporting (TAMDAR) data, which allows forecasters and researchers to use more than one hundred airports' upper air data. The Weather Case Browser, developed by CIMMS researchers, has been a platform for researchers and instructors to view real-time events and archive cases. The latest version Weather Case Browser 2.0 includes a new tool, SmartArchiver. SmartArchiver supports users to archive AWIPS data with flexible and convenient options, such as various case date, location, and data types. This new functionality directly benefits simulation training.

This project is ongoing.

**Publications**

Sounding Toolkit 1.3: http://140.90.90.253/~applications/LAD/generalappinfoout.php3?appnum=1050

*The Weather Case Browser with SmartArchiver.*
WDTB Project 10 – Warning Decision-Making Research and Training: \textit{Real-Time System}
Mohamad Said, Decker, Hoggard, X. Yu, NWS/WDTB collaborators

NOAA Strategic Goal 3 \textit{(Serve Society’s Need for Weather and Water Information)}

Funding Type: CIMMS Task II

Objectives
Investigate warning decision making issues with real time events; evoke a better understanding of the warning decision making process; and transfer that knowledge to warning decision makers to improve performance.

Accomplishments
The warning decision making process is multi-faceted, often being improved directly by unique observing systems, data analysis techniques, human factors, or improvements in forecast verification. CIMMS scientists collaborated with the Warning Decision Training Branch (WDTB) on an ongoing project to provide various real time data, such as satellite data, radar data, model grid data, point data (including METAR, upper air, profiler, and lightning) and Bufr profiles. The WDTB real-time system provides an operationally realistic environment for researchers and instructors to experience various events over the country, and develop skills of warning decision making, and archive these events for future training. The system can be used for real-time viewing or briefing, case studying, or as an introduction to AWIPS for students of the University of Oklahoma School of Meteorology.

Because of the unique data requirements of the training community, the CIMMS staff has created unique solutions and builds up a unique real-time system which consists of multiple LDM servers and AWIPS servers on several machines with different priority levels. This configuration distributes data processing loads onto multiple computers and highlights various priority levels for different requests. These implementations and configurations enhance the AWIPS, so that users are able to view local data, as well as radar data, across the country. The new improvements also ensure the system running stably and efficiently.

This project is ongoing.

WDTB Project 10 – Warning Decision-Making Research and Training: \textit{Department of Commerce and NOAA Distance Learning Training Development – The Nation’s Weather Enterprise}
D. LaDue, Heinselman, Morris, Wood, NWS/WDTB collaborators

NOAA Strategic Goal 3 \textit{(Serve Society’s Need for Weather and Water Information)}

Funding Type: CIMMS Task II

Objectives
Repurpose materials from a live workshop to create a distance education module that allows both public and private sector meteorologists to better understand the roles of each sector in the Nation's weather enterprise.

Accomplishments
During the past year, CIMMS staff has used its expertise at developing distance learning materials to create several web modules for both Dept. of Commerce and NOAA management. These included a series of modules based on a short course at the Public-Private Sector Partnership Conference held in June 2006 at Howard University and on the DoC transition to employee performance plans.

By transferring these materials to web modules, information was provided to a wide audience on the nature of the Nation’s Weather Enterprise and the relationship between both the public and private
sectors to meet the Nation’s need for weather information, as well as educating Dept. of Commerce management about a significant change in employee performance evaluation. The Dept. of Commerce modules were produced at the request of the Office of Human Resources Management. The Public-Private Partnership course was produced through a request from the NOAA/NWS Office of Strategic Planning and Policy. Both sets of modules have been deployed using NOAA’s Learning Management System.

Focusing here on the Public-Private Partnership for weather, about 50 people representing both the public and private sectors attended the NOAA and NCIM Public-Private Partnership Workshop in June 2006. The workshop was created by John Toohey-Morales and Ed Johnson after the revision of the NOAA Partnership Policy. It was becoming clear to them that there were distinct differences between how the public and private weather sectors function. While there were many things the two sectors shared, there were also dramatic differences that made working together very difficult. This workshop was designed to educate both sectors about these differences to help them forge effective partnerships that grow the weather enterprise as a whole.

In order to reach a broad audience, the original workshop was modified by CIMMS staff at WDTB into a set of distance-learning modules. The first three modules explain the roles and capabilities of each sector, describe how the sectors overlap and complement each other, illustrate some examples of how the two sectors have partnered successfully, and explain the NOAA Partnership Policy so that people can access and use it to improve the enterprise. A lunch talk by a former NOAA Legislative Affairs Officer is included in video clip format. He reminds everyone about how Congress works, the role Congress plays and does not play in the enterprise, which House and Senate committees are most relevant, and how to work with Congress. The remaining modules become increasingly interactive, first through a dialogue about how planning, funding, terminology, and work culture differ between the sectors. Then, participants have the opportunity to apply what they have learned in two case studies that have no clear solution. The module was completed in November 2006 and released on CD-ROM at the AMS Annual Meeting in San Antonio, Texas, in January 2007.

This project has been completed.

**Publications**
The Nation's Weather Enterprise: The Public-Private Sector Partnership:
http://www.wdtb.noaa.gov/courses/PPP/index.html
http://www.ncim.org/pppcourse2006/

Dept. of Commerce Building Results-Oriented Performance Plans:
http://www.wdtb.noaa.gov/temp/commerce/lesson1/player.html
http://www.wdtb.noaa.gov/temp/commerce/lesson2/player.html
http://www.wdtb.noaa.gov/temp/commerce/lesson3/player.html

CD-ROM logo (top) and example module (bottom) from The Nation’s Weather Enterprise: Public-Private Sector Partnership distance learning course. Navigation through the module is facilitated by the menu at the left. This module discusses some of the different questions that are relevant to NWS forecasters in the event of a land-falling hurricane.
WDTB Project 10 – Warning Decision-Making Research and Training: Enhanced Fujita (EF) Scale Training
J. Murnan, Stumpf, Wood, NWS/WDTB collaborators

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Develop instructional material on the Enhanced Fujita-Scale training modules and the EFkit damage survey application.

Accomplishments
On 1 February 2007 the NWS began using a new damage rating scale, the Enhanced Fujita (EF) Scale, to assess the strength of tornadoes. Prior to the operational implementation of the scale, training on the new scale and how to implement it was developed by NOAA/NWS/WDTB staff along with collaborators from CIMMS and other agencies. This distance learning training allowed NWS staff to be prepared to implement the new rating scale during damage surveys.

In addition to developing training, CIMMS and WDTB staff collaborated to develop a PC-based application to assist NWS staff during and after damage surveys to help in the analysis of storm damage. This application, called EFkit, can be run on a standard PC, laptop, or even on a mobile Windows (e.g., PDA) operating system. The EFkit provides the operator an easy-to-navigate system of menus and images to help NWS staff compare the damage being observed to a series of visual examples of damage for a particular type of Damage Indicator (DI) and Degree of Damage (DOD). CIMMS staff has been developing simulated examples of DI and DOD categories for where no photographic examples are available. By creating illustrations for categories of DIs and DODs that lack an example, it increases the likelihood that NWS staff will accurately apply the correct rating to a damaged structure. These simulated illustrations are in the final stages of development and will be added to the next release of the EFkit.

This project is ongoing.

Publications
WDTB EF-Scale Training site: http://www.wdtb.noaa.gov/courses/EF-scale/
Simulated tornado damage image created for the EFkit for Damage Indicators and Degrees of Damage for where actual photos are not available.

WDTB Project 10 – Warning Decision-Making Research and Training: Storm-Based Warnings
Morris, Wood, NWS/WDTB collaborators

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Improve understanding of warning-related issues; help NWS implement service changes.

Accomplishments
On 1 October 2007, the NWS changes warning methodology for short-fused convective warnings from the legacy county-based system to a polygon, “storm-based” system. In the new system, more specificity and reduction of false alarm area are anticipated. However, verification methodologies also change because credit will no longer be given for a storm report outside a warning polygon but inside a warned county. Although forecasters have been drawing warning polygons for several years, the service change requires all forecasters to be refreshed on polygon design for a number of convective warning situations including:

- Tornado warning for an isolated, single supercell
- Tornado warning for supercells in close proximity
• Tornado warning for squall line storms (single tornado warning with multiple adjacent severe thunderstorm warnings)
• Tornado warnings for merging storms
• Tornado warnings for training supercells
• Severe thunderstorm warnings for bowing segments of squall lines
• Severe thunderstorm warnings for pulse storms
• Flash flood warning for isolated, single storm
• Flash warning for an area of storms
• Extreme wind warning for area of tropical-storm induced winds
• Tornado and/or severe thunderstorm warnings for storms that cross NWS County Warning Area borders (hand-off from one WFO to another)

In addition, all warning forecasters require updated information on requisite customer service issues, such as highlighting affected areas in warning products and recognizing that warned populations are still organized by county areas. Additional storm-based concepts include handling adjacent warnings, multiple threats for a single storm and anticipation of storm evolution and uncertainty.

To support this change, CIMMS and WDTB staff along with other NWS collaborators designed storm-based warning lessons, activities that include two training modules and a number of practice exercises involving the Weather Event Simulator.

This project has been completed.

Publications
Main Storm-Based Warnings Web Page:  http://www.wdtb.noaa.gov/modules/SBW/
Specific Modules produced by CIMMS staff:
Lesson 2-T4 (Merging Storms):  http://www.wdtb.noaa.gov/modules/SBW/lessons/2-t4-stormMerger/player.html
Lesson 2-T5 (Training Storms):  http://www.wdtb.noaa.gov/modules/SBW/lessons/2-t5-stormTraining/player.html

Three simultaneous tornadoes within line of severe thunderstorms

Currently

October 1, 2007

• More specific
• Increased clarity
• Supports new dissemination technology

County-Based Tornado Warnings
8 Counties under warning
Almost 1 million people warned

Storm-Based Tornado Warnings
70% less area covered
~600,000 fewer people warned

Service change presented by storm-based warnings.
SRH Project 11 – An Investigation of Communicating Weather Information Effectively using the Internet
Minton (primary – CIMMS at SRH), Kirkwood

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Investigate new applications to increase the capabilities of providing new digital services to the public; investigate enhancements to the back-end web applications, databases, and services that are the backbone of the Southern Region Headquarters web presence, now used within the overall Web Consolidation Project on three web farms; and study the usefulness and cost-effectiveness of new technologies.

Accomplishments
Work was done as part of the NWS Web Consolidation Project with back-end application servers at Central Region Headquarters and NWS Headquarters to mimic the success of the server operating so well at SRH. Work also was done to set up Watch Warning Advisory (WWA) map making and Mobile and Cell Phone pages on all three web farms. A new cities shape file was created that now is used throughout the NWS to improve city labeling on all WWA maps. Finally, polygon warning shape files were created each minute for new polygon warning WWA maps that will go into operation October 1; this work combines county warnings with new polygon warnings.

This project is ongoing.

SPC Project 12 – Advancing Science to Improve Knowledge of Mesoscale Hazardous Weather
Dean (CIMMS at SPC)

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Study research methodologies that can be used to verify predicted outcomes of meteorological phenomena; present research results to the meteorological community; assist SPC scientists and managers in science and technology transition efforts.

Accomplishments
Work was focused on the investigation of the frequency and distribution of convective storm environments that occur across the United States. The goal is to provide forecasters more specific information regarding forecast performance in different environments. Methods to determine the frequency of particular environments and how often they produce severe convection are also being investigated.

Initial storm environment estimates were provided by SPC’s hourly surface objective analysis grids, which uses the RUC as a background field and incorporates surface observations into the analysis to provide estimates of convective storm parameters such as CAPE, CIN, wind shear, helicity, etc. The environment for each official storm report from 2003-2006 was estimated using the analysis values from the nearest grid point at the most recent analysis time before the report. These analysis values were placed into a PostgreSQL database, allowing the data to be retrieved and displayed in many different combinations and formats.
In order to assess the soundness of the objective analysis, sounding data from 2003-2006 was entered into the database so that comparisons could be performed. This analysis is underway; preliminary results suggest that the objective analysis provides good estimates of the environment in most but not all cases. It is also planned in the near future to add North American Regional Reanalysis (NARR) data to the database. The NARR data would potentially provide estimates of storm environments back to 1979, assuming that it proves to accurately estimate convective parameters.

This project is ongoing.

Publications
Dean, A.R., and J.T. Schaefer, 2006: PDS watches: How dangerous are these "particularly dangerous situations?" 23rd Conf. on Severe Local Storms, St. Louis, MO, Amer. Meteor. Soc., CD-ROM.
Dean, A.R., R.S. Schneider, and J.T. Schaefer, 2006: Development of a comprehensive severe weather forecast verification system at the Storm Prediction Center. 23rd Conf. on Severe Local Storms, St. Louis, MO, Amer. Meteor. Soc., CD-ROM.

20030101-20061231 Reports (months: ALL)

Locations of reports from 2003-2006 that occurred in relatively low CAPE, high shear, low LCL environments, based on environmental estimates from SPC's surface objective analysis.

NSSL Special Project – Severe Hazards Analysis and Verification Experiment (SHAVE)
T. Smith (primary – CIMMS at NSSL), Manross, Scharfenberg, Witt, Ortega, Kolodziej, Legett, Riley, Irwin, Roberts

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Objectives
Improve the verification of severe weather events in the United States through use of very high resolution (1 km) multi-sensor/multi-radar data, phased array radar, and verification phone calls, integrated within a geographic information system.
Accomplishments
The Severe Hazards Analysis and Verification Experiment (SHAVE) is a unique project that blends high-resolution radar data with geographic information. The primary objective of this experiment is to collect high temporal and spatial resolution data that describe the distribution of hail sizes and wind damage produced by severe thunderstorms. These data will enable several goals, including to:

1. Provide high-resolution verification data for the National Weather Radar Testbed's multi-purpose phased array radar;
2. Use the high-resolution verification data in the development of techniques for probabilistic warnings of severe thunderstorms;
3. Evaluate the performance of multi-sensor, multi-radar severe weather algorithms;
4. Associate changes in hail size and wind damage distributions with storm evolution; and
5. Enhance climatological information about severe storm threats in the United States.

The high spatial and temporal resolution of the dataset collected during the project will facilitate the development of decision-making tools that improve forecasts and warnings of severe thunderstorms and tornadoes, and pave the way for improvements to the historical severe storms database. The 2007 data collection period was from mid-May to mid-August.

This project is ongoing.

Publications

The NSSL Hail Swath algorithm showing radar-estimated maximum hail size aloft over a 180 minute period for a storm that occurred in Lac qui Parie County, MN on 27 July 2006. The grey icons (no hail), green icons (hail up to 1” 2.54 cm) and yellow icons (hail >1” to 2” 2.54 cm to 5.08 cm) represent “ground truth” data points collected by SHAVE. The single “push pin” icon represents two data points collected in the county by the National Weather Service as part of warning verifications efforts. The yellow line is 10 km long in the scale of the map.
NSSL Special Project – Hazardous Weather Testbed Experimental Warning Program
T. Smith (primary – CIMMS at NSSL), Andra, Scharfenberg, Manross, Stumpf, Ortega, Heinselman, Adams, Priegnitz, Burgess, Witt, and many other NOAA staff

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Objectives
Improve the nation's hazardous weather warning services by bringing together forecasters, researchers, trainers, developers, and user groups to test and evaluate new techniques, applications, observing platforms, and technologies.

Accomplishments
The Experimental Warning Program (EWP) was established during 2007 to enable better collaboration between researchers and NWS operational forecasters. Two primary areas of research are in the application and evaluation of new remote sensing tools as well as 0-60 minute nowcasting applications and techniques. Although NSSL and CIMMS have a long history of collaboration with operational forecasters, new facilities at the National Weather Center have provided a much-needed space where these experiments may be conducted.

Several experiments were conducted in the EWP in the spring of 2007, involving CIMMS researchers collaborating with visiting NWS forecasters from across the U.S. as well as the Norman WFO and the WDTB. Specific experiments included the evaluation of experimental phased array radar and CASA radar data in real-time by operational forecasters. Additionally, forecasters were included in a test of grid-based probabilistic warning guidance tools.

This project is ongoing.

Publications

CIMMS researchers, NWS forecasters and WDTB trainers collaborate during an experiment in the Hazardous Weather Testbed / Experiment Warning Program facility.
NOAA/NWS/CSTAR – A Partnership to Develop, Conduct, and Evaluate Real-Time High-Resolution Ensemble and Deterministic Forecasts for Convective-Scale Hazardous Weather

Droegemeier (primary – School of Meteorology), Xue, Kong

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task III (Program Manager – Sam Contorno)

Objectives

Apply cloud-resolving models to the explicit prediction of deep convection using deterministic and ensemble approaches; understand the tradeoffs in deterministic versus ensemble methodologies and the value of radar data in initializing convection-resolving models; and understand how convection-resolving forecasts can be utilized in operations as a move toward warn-on-forecast concepts.

Accomplishments

This work is being conducted as part of the Spring 2007 Experiment of the NOAA Hazardous Weather Test Bed. The experiments extended from 15 April through 8 June 2007 with all forecasts run on dedicated NSF TeraGrid resources at the National Center for Supercomputing Applications and the Pittsburgh Supercomputing Center. The forecast suite included the following each day:

- A 33-hour, 10-member, 2/3rds continental US-scale (CONUS) ensemble at 4 km grid spacing (run at PSC using a mixture of initial condition and physics perturbations);
- A 33-hour, single 2 km grid spacing deterministic forecast in the same domain as the ensembles;
- One or more six- to nine-hour nested grid forecasts at 2 km spacing launched automatically over regions of expected severe weather, as determined by mesoscale discussions or tornado watches (run at NCSA); and
- One six- to nine-hour nested grid forecast, per day, at 2 km grid spacing launched manually when and where deemed most appropriate (run at NCSA).

All forecasts were completed as planned and were a central component of daily discussions, during which some 47 visitors from academia and Federal laboratories participated from outside of Oklahoma. Because the grant supporting this activity began only in May, 2007, we have relatively few results and are analyzing data from the experiment, which was completed in early June (less than a month ago). However, preliminary results are extremely exciting and Steve Weiss of the SPC described the experiment as “groundbreaking.”

This project is ongoing.

Publications


Forecast composite reflectivity ensemble mean (a) and spread (b), and ensemble-derived probability of composite reflectivity exceeding 35 dBZ (c) and the ‘spaghetti’ plot of 40 dBZ composite reflectivity contours(d), valid at 18 UTC, 24 May 2007, corresponding to a 21 hour forecast made with the WRF model as part of the 2007 Spring Experiment. From Xue et al. (2007).

Other Agency – Evaluation of Synoptic-Scale Controls on Tornado Outbreaks
Leslie (primary – CIMMS at OU), Mercer, C. Shafer, Richman, Doswell

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: NSF

Objectives
Determine signals in synoptic scale data that can distinguish between tornado and non-tornado outbreaks; create fields to be used to initialize the WRF model for the prediction of tornado outbreaks.

Accomplishments
An important tornado forecasting problem is to decide whether or not a particular synoptic-scale system is going to produce a significant outbreak of tornadoes. Although much work has been done on individual case studies over the decades since tornado forecasting began in the 1950s, this issue remains problematic for forecasters. In our second year of the project, a set of 50 tornado outbreaks and another set of 49 primarily nontornadic outbreaks of severe weather have been selected for analysis. All of these
cases have been run by research assistant Chad Shafer using the WRF model starting with coarse global NCEP Reanalysis data, 24 and 48 hours in advance. Runs beginning 72 hours in advance are in progress, to be completed by the fall. Diagnosis of the model simulations is in progress as well. The model runs include nests down to 2 km grid spacing, but will not resolve tornadoes, of course. Thus, we are seeking "proxy variables" to discriminate tornadic from primarily nontornadic simulations. This effort involving research assistant Andrew Mercer is underway and preliminary results look promising. Mr. Mercer is also developing composite analyses for use in the WRF model, based on principal component analysis of our selected outbreak cases. This effort will involve Eigen analysis of very large matrices and so is pushing the limits of the on-campus supercomputing system software.

This project is ongoing.

Publications


Subjective forecast quality evaluation for the 24-h WRF model forecasts run using the NCEP/NCAR global reanalysis data as input, for the 50 cases of major tornado outbreaks and 50 cases of primarily nontornadic severe weather. The majority of the forecasts are either "excellent" or "very good" for these cases.
Other Agency – Cloud Radiative Impacts of Giant CCN
Y. Kogan (primary – CIMMS at OU), Mechem

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency: Office of Naval Research

Objectives
Demonstrate the radiative impact of drizzle using the new CIMMS parameterization of giant cloud condensation nuclei (CCN).

Accomplishments
The addition of giant CCN (GCCN) to stratocumulus can have pronounced impacts, not only on precipitation development, but also on cloud radiative properties important for the large scale energy balance. The effect of adding giant CCN to background clean and polluted environments on radiative properties is evaluated in a large eddy simulation framework using the new CIMMS GCCN parameterization. Adding GCCN to a clean CCN background has little effect on cloud optical depth, largely because the clouds are already drizzling. Additional GCCN, however, tend to make them drizzle even more, and owing to the reduced optical depth and further depleted droplet concentration, GCCN leads to a modest reduction in albedo. Adding GCCN to the polluted background CCN results in a more noticeable reduction in optical depth, though a similar decrease in albedo.

Aerosol indirect effects, one of the largest uncertainties in global climate change scenarios, are frequently formulated in terms of a sensitivity (called “susceptibility”) of albedo to a change in droplet (or aerosol) number. Absolute susceptibility varies little with GCCN concentration but is smaller in the polluted background CCN environment. Equivalent changes in droplet number produce more albedo response in the clean case than in the polluted case, yet cloud properties in the polluted environment are considered sensitive to the addition of GCCN. For this reason, susceptibility relative to a baseline (control with no GCCN) more aptly illustrates the sensitivity of albedo to change in droplet number. As expected, the relative susceptibility of the polluted case is much greater than that of the clean case and increases with increasing GCCN.

This project is completed.

Publications
Radiative quantities as a function of GCCN concentration for polluted and clean background CCN conditions. (a) optical depth; (b) albedo; (c) susceptibility; (d) susceptibility relative to the control simulations without GCCN.

Other Agency – Contribution to WRF Model Development by CAPS
Xue (primary – CAPS), Gao, Brewster, Hu, Liu

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Agency/Type: FAA via NSSL and CIMMS Task III

Objectives
Complete further revisions and testing of the generalized cloud analysis package within GSI for stratiform clouds (using GOES cloud top and METAR cloud data) and begin an initial treatment for convective clouds at the parameterized scale assimilating radar reflectivity.

Accomplishments
Progress this year has included the design and development of an initial version of a new generalized cloud analysis package within the GSI, the updating of all cloud analysis packages to the latest GSI version, the testing and verifying of each component of the cloud analysis, and determination of the impacts of the different cloud analysis packages when used in the hourly assimilation cycles.
The new generalized cloud analysis combined the strengths of the ARPS and RUC cloud analysis with several improvements. It is able to build three-dimensional distributions of cloud and hydrometeors fields and adjust in-cloud temperature based on METAR data, NESDIS cloud products, and NSSL radar reflectivity mosaic.

The new cloud analysis was tested thoroughly using the 13 March 2006 central U.S. squall lines case under the RUC CONUS environment through both cold start and hourly assimilation cycles.

This project is ongoing.

**Publications**


Hu, M., S. Weygandt, M. Xue, and S. Benjamin, 2007: Development and testing of a new cloud analysis package using radar, satellite, and surface cloud observations within GSI for initializing rapid refresh. 18th Conf. on Numerical Weather Prediction and 22nd Conf. on Weather Analysis and Forecasting, Park City, UT, Amer. Meteor. Soc.

Analyzed (a) composite cloud cover (column maximum) at 0000 UTC 13 March 2006 with all available data, and west-east cross section of (b) the analyzed cloud cover; (c) background cloud water + cloud ice; and (d) analyzed cloud water + cloud ice along indicated line in (a).
Tri-State Tornado Reanalysis
Doswell (primary – CIMMS at OU), Maddox, Johns, Burgess, Gilmore, Piltz, Hart

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Objectives
Re-investigate the Tri-State tornado of 18 March 1925.

Accomplishments
An informal group of researchers – including Robert A. Maddox (retired NSSL Director), Robert H. Johns (retired SPC Science and Operations Officer), Donald W. Burgess (retired NSSL scientist, now with CIMMS), Charles A. Doswell III, Matthew S. Gilmore (University of Illinois), Steve Piltz (NWS Tulsa), and John A. Hart (SPC) – has continued this unfunded project, with multiple trips to investigate the track of the infamous Tri-State tornado of 18 March 1925. Work continues to find more meteorological data and track evidence. We are interacting informally with Drs. Tom Hamill, Gil Compo, and Jeff Whittaker (NOAA), who have employed Ensemble Kalman Filter (EnKF) methods to reconstruct the 4-dimensional atmospheric structure during this historical event. It is clear that the reconstructions are unable to resolve some of the details seen in the observations – notably, the surface moisture in the reconstructions is generally less than observed, as are the upper level winds.

This project is ongoing.

Publications

Database of Tornadic and Nontornadic Severe Storm Outbreak Cases
Doswell (primary – CIMMS at OU), Thompson, Hart, Crosbie, Edwards

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Objectives
Create a database of tornadic and nontornadic severe storm outbreak cases.

Accomplishments
In collaboration with Mr. Richard Thompson, Mr. John Hart, Mr. Casey Crosbie, and Mr. Roger Edwards of the Storm Prediction Center, the project to collect and rank tornadic and nontornadic severe storm outbreak cases and build a database for the study has been completed and a formal publication on the work has appeared in the literature. A second phase of this project will involve team members performing subjective analyses of all the cases.

This project is ongoing.

Publications

Characteristics of Surface Cold Fronts
Doswell (primary – CIMMS at OU), Haugland

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Objectives
Explain an unusual cold frontal passage in early winter 2006-07 using Oklahoma Mesonet data.
Accomplishments
This unfunded project, done in collaboration with Dr. Matt Haugland of NanoWeather, Inc., has sought to explain an unusual cold frontal passage early in the winter of 2006-2007 using Oklahoma Mesonet data. The frontal passage was initially marked by a temperature rise, followed by a gradual decline. The explanation for this behavior is shown to be related to characteristics in the pre-frontal boundary layer, and a contrasting case exhibiting classic cold frontal characteristics is presented for comparison. A publication regarding this work has been submitted for review and is in press as of this writing.

This project is ongoing.

Meteogram from the Norman Mesonet site, showing wind direction at 10 m (black) and temperature at 1.5 m (°F, red) for the period from 00 CST (06 UTC) on 7 December 2006, to 21 CST (03 UTC on 8 December). Note the abrupt initial temperature rise following the passage of the "cold front".

Sample Size and Data Quality Issues with Tornado Occurrence Data
Doswell (primary – CIMMS at OU)

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Objectives
Elucidate how adequate tornado occurrence data are for validating hypotheses about the relationship between climate change and tornado occurrence.

Accomplishments
This unfunded project has sought to elucidate the issue of how adequate tornado occurrence data are for validating hypotheses about the relationship between climate change and tornado occurrence. It is
shown that most efforts to mitigate the secular trends in tornado occurrence data result in reduction of sample size to below the point where meaningful conclusions can be drawn. A publication regarding this work has been submitted for review and is in press as of this writing.

This project is ongoing.

Publications

Other Doswell publications:


**Climatic Effects of/Controls on Mesoscale Processes**

**NOAA/NWS/International Activities Office** – Variability of the Intertropical Front and Rainfall over the West Africa Soudano-Sahel  
Lele, Lamb (primary – CIMMS at OU)

**NOAA Strategic Goal 2** *(Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)*

**Funding Type:** CIMMS Task III (Program Manager – Rob Masters)

**Objectives**
Document the intra-seasonal characteristics of intertropical front (ITF) displacements during its northward movement at the beginning of the rainy season and its southward retreat at the end of the rainy season; investigate the relationship between the variability of the ITF latitudinal position and summer monsoon rainfall amount in West Africa Soudano-Sahelian countries where society needs improved weather and seasonal climate prediction.

**Accomplishments**
The semi-arid region of West Africa is particularly sensitive to interannual fluctuation in the intertropical front position because it is only during one part of the year that the ITF extends far enough from its mean annual position for this region to receive normal annual rainfall. Space and time scales for analysis of the intraseasonal variability of sub-Sahelian rainfall and ITF displacement are determined. Analysis of daily dew point temperatures derived from observed stations daily minimum temperature and maximum relative humidity have been performed in a coherent area between 10°-25°N and 12°W-24°E for the period 1974-2003, and a 10-day (dekad) mean ITF position time series was constructed. Analysis of the relationship suggests that a one of causes of the rainfall pattern variability results from a displacement of the ITF.

The 1958-2003 National Center for Environmental Prediction – National Center for Atmospheric Research (NCEP-NCAR) winds, vertical velocity, surface pressure, and sea surface temperature reanalysis data have been analyzed for extreme years in the tropical Atlantic sector and the core Sahelian rainfall season. Results show that during dry years in Sub Saharan Africa, the ITF is displaced southward from its long-term mean position and the related zone of convergence also experiences a southward shift. During wetter years, the opposite is true.

This project is ongoing.
Long-term dekad average positions of West African Intertropical Front. Niger 2005 average ITF advance and retreat (left); West African Soudano-Sahel 1974-2003 average ITF advance and retreat (center); Niger 2006 average ITF advance and retreat (right).

**NOAA/NWS/International Activities Office** – Evaluation and Adaptation of a Regional Climate Model for the Horn of Africa

Segele, Lamb (primary – CIMMS at OU), Leslie

**NOAA Strategic Goal 2** *(Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)*

**Funding Type:** CIMMS Task III (Program Manager – Rob Masters)

**Objectives**
Evaluate the Abdus Salam International Center for Theoretical Physics (ICTP) version 3 RCM (RegCM3) to reproduce the observed rainfall amounts and distribution over the topographically varied region of the Horn of Africa.

**Accomplishments**
Regional climate models (RCMs) increasingly are being applied in various parts of the world to examine regional climate patterns and processes and to downscale seasonal climate predictions. This study evaluates the ability of the Abdus Salam International Center for Theoretical Physics (ICTP) version 3 RCM (RegCM3) to reproduce the observed rainfall amounts and distribution over the topographically...
varied region of the Horn of Africa. Simulations are performed for the widespread very dry 1984 and locally very wet 1996 years using all of the alternative convective schemes available in the ICTP RegCM3 -- the Modified Anthes-Kuo scheme, the Grell scheme with the Arakawa-Schubert closure, the Grell scheme with Fritsch-Chappell closure (default RegCM3 convective scheme), and the Emanuel scheme. Extensive comparisons of the simulations for 1984 and 1996 reveal that the Emanuel scheme best captures the rainfall patterns and interannual variations for the two extreme years over the Horn of Africa. This scheme therefore is selected for specific adaptation for the region, despite its excessive rainfall estimation there and its demonstrated deficiencies over other regions of Africa not of interest in this study.

To reduce rainfall overestimation by the selected Emanuel scheme, several sensitivity experiments are performed by varying the key parameters that control the rate of convective mass flux adjustment, the fraction of condensed water converted to precipitation, and the heating and moistening characteristics of the environment. Results show that the amount of condensed water that ultimately falls out as rain, which also governs the net heating and the vertical distribution of moistening, crucially affects simulated rainfall amounts. With an appropriate adjustment to this key parameter, the excessive rainfall amount produced by the Emanuel scheme is reduced substantially. This successful parameter modification results in root mean square error (bias) reductions, relative to observations, of 46-58% (58-83%) from those for the default Emanuel simulations over Ethiopia, East Africa, and Central Africa. Furthermore, evaluation of RegCM3 simulations for 1982-99 shows that the modified Emanuel convective scheme not only reproduces the 18-year average rainfall realistically, but also captures the interannual variability adequately over the Horn of Africa. The correlation between the modified Emanuel-simulated and Ethiopian station rainfall is quite strong (+0.66), whereas the counterpart correlation for the RegCM3’s default Grell scheme is -0.05. Despite this success, the modified Emanuel scheme still overestimates the observed Ethiopian station rainfall by 26% for 1982-99. This customized ICTP RegCM3 model now can be used with confidence for the Horn of Africa to study regional rainfall processes and variability and to dynamically downscale seasonal rainfall forecasts. To date, this customized model has been employed to examine the effects of SST variations in the Atlantic and Indian Oceans on Horn of Africa rainfall, and also to assess the likely impacts of changes in local vegetation coverage on that rainfall. The results of these investigations are being reported in separate papers.

This project is ongoing.

**Publications**

Interannual variations of Ethiopian June-September standardized rainfall rate anomalies for 1982-99. (a) Modeled with the standard default Grell convective scheme (GrFC; blue) and rain gauge (red). (b) Rain gauge (red), CRU (blue), CMAP (green), and modeled with modified Emanuel convective scheme (black).
NOAA/NWS/International Activities Office – Collaboration and Cooperation within the ACMAD Core Demonstration Project in Climate Prediction between ACMAD and CIMMS
Lamb (primary – CIMMS at OU), Lele, Segele, Mbainayel

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Funding Type: CIMMS Task III (Program Manager – Rob Masters)

Objectives
Continued research collaboration and cooperation between the African Centre of Meteorological Applications for Development (ACMAD) and CIMMS.

Accomplishments
Research collaboration and cooperation between the African Centre of Meteorological Applications for Development (ACMAD) and CIMMS continued strongly in the past year. CIMMS continued to fund and/or supervise three graduate students and one Post-Doctoral scientist from Africa whose research focuses on key weather- and climate-related problems of their countries. Those students come from Ethiopia (Segele, Ph.D. in Meteorology, completed), Niger (Lele, M.S. in Meteorology, completed; Ph.D. in meteorology, started), and Chad (Mbainayel, M.S. in Meteorology, recently commenced). A large paper derived from the Ethiopian student’s Ph.D. Dissertation was submitted to the International Journal of Climatology in 2007. In addition, CIMMS played a major role in the deployment the ARM Program’s (U.S. Department of Energy) Mobile Facility in Niamey (near ACMAD) for all of 2006, and in securing and facilitating funding for University of Niamey scientists to analyze ARM data collected in Niamey. The leader of the University of Niamey team (Professor Abdelkrim Ben Mohamed) also serves as Chair of the ACMAD Scientific Advisory Council. In support of the ARM Mobile Facility deployment in Niamey, CIMMS issued monthly and seasonal reports on the progress and quality of the West African monsoon at Niamey for 2005 and 2006. This work now is being incorporated into an overview paper on the Niamey deployment that soon will be submitted to the Journal of Geophysical Research. A key figure is shown below.

This project is ongoing.
ANNUAL CYCLE OF NIAMEY CLIMATE FOR 2005-2006


NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Explaining the Spatial Variability of the Mid-Summer Drought over the Inter-American Seas Region
Douglas (primary – NSSL), Murillo, Mejia, Orozco

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Map, at high spatial resolution, and explain the variability in rainfall and cloudiness associated with the mid-summer dry season that occurs over parts of the Caribbean Sea and Central America region.
Accomplishments
Satellite data from Internet web sites have been downloaded and processed into monthly means. North American regional reanalysis data are being prepared to stratify by mid-summer drought start and end dates.

This project is ongoing.

Publications

Average of 3 years of twice-daily MODIS visible imagery for the region of Costa Rica. Cloudiness information being extracted from the individual images is being used to map cloudiness variations related to the mid-summer drought over Central America.
Other Agency – Large-Eddy Observations and LES of Liquid Stratus over the ARM Southern Great Plains Climate Research Facility
Mechem (primary – CIMMS at OU), Y. Kogan, Schultz

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)*

**Funding Agency:** U.S. DOE

**Objectives**
Employ high resolution Doppler cloud radar and large eddy simulation to analyze the structure and dynamics of continental stratocumulus.

**Accomplishments**
Studies employing continuous years of low cloud observations over the Southern Great Plains ARM Climate Research Facility (ACRF) emphasized their climatological, microphysical, and radiative characteristics. The recently enhanced capabilities of the ACRF cloud radar suite, specifically, the higher sampling rate of the boundary layer, are ideal for exploring the dynamic aspects of these cloud systems. These upgraded sensors enable "large eddy observations" (LEOs; Kollias and Albrecht, JAS 2000) -- the coherent sampling of boundary layer turbulence structures responsible for most of the transport. High resolution cloud radar observations (95 GHz W-band ARM Cloud Radar -- WACR) and large eddy simulation (System for Atmospheric Modeling -- Explicit Microphysics (SAMEX)) were employed to analyze the cloud structure and turbulent quantities for a typical springtime postfrontal boundary layer stratocumulus case. Preliminary observational and modeling analyses suggest both similarities and differences relative to marine stratocumulus.

For clouds containing little or no precipitation, boundary layer turbulence structures sampled by the WACR are coherent in both time and in the vertical. Statistics from the WACR indicate a slightly subadiabatic cloud layer and an eddy structure dominated by updrafts and downdrafts of roughly similar properties. The slight negative skewness implies that convection driven top-down by cloud top longwave cooling weakly predominates. The overall magnitude of in-cloud and turbulence was relatively weak, compared to typical marine cases. LES captures the magnitude of in-cloud turbulence and skewness present in the WACR observations, which suggests it is representing the overall character of the flow reasonably. Relative to marine clouds, which are typically studied in a Lagrangian framework with relatively weak advective forcings, continental clouds associated with synoptic systems require highly constrained estimates of these advective terms.

This project is ongoing.

**Publications**
Characterization of stratocumulus associated with a midlatitude synoptic system passing over the Southern Great Plains ACRF. (a) GOES IR imagery from 0645 UTC 8 April 2006. Blue box indicates location of the ACRF; (b) Processed radar reflectivity and velocity data from the WACR; (c) Vertical velocity at three levels in the cloud corresponding to a nondimensional cloud-normalized height. The graphical distance between 0.50-0.75 corresponds to 1 m s\(^{-1}\); (d) Variance and skewness calculated from a large eddy simulation of this case. Statistics calculated from the WACR data are overlaid on the LES profiles.

**Other Agency – Parameterization of Drop Spectra in Drizzling Stratocumulus Clouds**

Z. Kogan (primary – CIMMS at OU), Y. Kogan, Mechem

**NOAA Strategic Goal 2** *(Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)*

**Funding Agencies:** U.S. DOE, Office of Naval Research

**Objectives**
Parameterize drop spectra by analytical functions for use in remote sensing retrievals and cloud parameterization.
Accomplishments
The development of cloud microphysical retrievals and cloud microphysics parameterizations rely heavily on the knowledge of the shape of drop size distributions (DSDs). Many investigations assume that DSDs in the whole, or parts of the drop size range, may be approximated by known analytical functions. The most frequently employed approximations are gamma, lognormal, Khrgian-Mazin, and Marshall-Palmer type functions. At present, little is known about the accuracy of each of these approximations, especially their ability to successfully simulate the higher moments of the DSD. We present results from an evaluation of the applicability and accuracy of DSD approximations using a combination of lognormal and gamma-type functions for stratocumulus and shallow convective clouds.

The DSDs are generated using the new version of the CIMMS LES explicit microphysics model (SAMEX) in simulations of cases observed during the ASTEX and DYCOMS-II field projects. Special emphasis in the analysis is placed on the fidelity of representing the higher moments of the drop spectra, such as precipitation flux and radar reflectivity. Our results indicate that approximating drop spectra in drizzling stratocumulus by Gamma-type distributions proves to be much more accurate than approximation by the lognormal distribution. In drizzling stratocumulus the two mode approximations provide better accuracy than the one-mode approximations. In numerical models which use two-moment microphysical parameterization schemes, the six parameters defining the two-mode Gamma distribution can be expressed through the four predictive microphysical variables describing concentrations and mixing ratios of cloud and rain drops. The latter approach requires parameterization of the drizzle mode dispersion.

This project is ongoing.

Publications
Comparisons of rain rates (left panels) and radar reflectivity (right panels) approximated by two-mode Gamma-type distributions. Top row: Gamma-distribution is defined by three parameters. Middle row: Gamma-distribution is defined by two parameters with dispersion parameterized as a function of drizzle drop concentration. Bottom row: The dispersion is parameterized as a function of drizzle drop concentration and drizzle mixing ratio.
**Other Agency – Assessment of the Severe Weather Environment in North America Simulated by a Global Climate Model**

Karoly (primary – OU School of Meteorology), Marsh, Brooks

**NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)**

**Funding Agency:** NSF

**Objectives**
Estimate the frequency distribution of favorable conditions for severe weather from archived high-resolution data from simulations with the NCAR CCSM3 global climate model; evaluate the model-simulated distribution by comparison with that from global reanalyses, including the climatological seasonal and spatial variations, and the interannual variability.

**Accomplishments**
Severe thunderstorms and tornados are very important mesoscale weather events in the central United States because of their high frequency and intensity in this region, and the damage and loss of life that they cause every year. Recently, it has been shown that the frequency of favorable conditions for significant severe thunderstorms and tornados can be estimated for the United States and other regions using global atmospheric re-analyses with spatial resolution on the order of 200 km and temporal resolution of 6 h.

Global climate models are unable to simulate severe thunderstorms and tornados because their spatial resolution is too coarse to be able to simulate such mesoscale events. However, they should be able to simulate the environmental conditions under which such severe weather develops, including abundant lower tropospheric moisture, steep mid-tropospheric lapse rates, and strong tropospheric wind shear. High space and time resolution data from control simulations with the NCAR CCSM3 global climate model archived at NCAR have been used to estimate the frequency of favourable conditions for severe weather, as simulated by the model. The climatological distribution of the severe weather environment in the model simulations was compared with that from the reanalyses, including the seasonal and geographical variations and its interannual variability. This small exploratory project has been funded by an NSF SGER.

The CCSM3 does a respectable job simulating the current severe weather environment of the United States. Comparisons with reanalysis data find that the spatial distributions are qualitatively similar, even if the quantitative values are reduced by up to a factor of two. Examination of the CCSM3’s seasonal cycle and diurnal cycle of mean CAPE once again captures the same qualitative patterns of the reanalysis data. The product of CAPE and deep layer shear, an indicator of the probability of occurrence of severe weather, shows similar results as the examination of mean CAPE, namely, that the spatial distributions are qualitatively similar with the numerical values being less by a factor of a little less than two. The exception to both the mean CAPE and the product of CAPE and deep layer shear is found over areas with warm water (e.g., Gulf of Mexico and Gulf Stream Current) where the CCSM3 is considerably higher than that of the reanalysis. This result demonstrates the possibility for future studies aimed at determining possible changes in distribution of the environments associated with possible global climate change.

Patrick Marsh completed his MS thesis on this project in July 2007 and a paper arising from his research has been accepted for publication in *Atmospheric Science Letters*.

This project has been completed.

**Publications**
Annual spatial distribution of environments favorable for severe weather for both the CCSM3 (top) and reanalysis (bottom). A favorable environment for severe weather is defined to be an environment in which the product of CAPE and deep layer shear is greater than 10,000 m$^3$s$^{-3}$. 


Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

NOAA/CPO – Climate Information for Agricultural Management in the Southern Great Plains
Timmer, Lamb (primary – CIMMS at OU), Richman, Mjelde, Klinefelter, Le

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Funding Type: CIMMS Task III (Program Manager – Nancy Beller-Simms)

Objectives
Identify the potential to use substantial geographical separation of production areas as a risk management tool. Machinery and land contractual arrangements for production areas separated by substantial geographical distance will be the specific foci examined in pursuit of this general objective. Assessing the importance of climate variability within this risk management context also will be a major consideration.

Accomplishments
The maturation of crops from planting to harvest is dependent primarily on accumulated heat and a sufficient water supply, because plants grow in a stepwise manner which is strongly influenced by ambient temperature. Even the time between seed planting and emergence is very specific to the amount of accumulated heat given a constant planting depth, sufficient moisture, and non-freezing temperatures. Thus the use of calendar days to predict the timing of important agricultural windows is largely inaccurate and potentially costly, especially for large commercial farms, where such timing inaccuracies can have a negative impact on the bottom line. Since a deficient water supply can at least partially be compensated via irrigation practices, accumulated heat is the most important factor in predicting agricultural windows, as well as determining ideal planting and harvesting dates to maximize crop yields. In the present study, Pacific and Atlantic Ocean sea surface temperature patterns are used to form seasonal predictions of accumulated heat, precipitation, first freeze date, and drought stress, which can be used by farmers to estimate plant emergence, flowering, harvesting, and even crop yield.

Traditional growing degree days (GDDs) are used here as a measure of accumulated heat, similar to the heating degree days and cooling degree days of energy consumption studies, but tailored for specific crop analysis. GDDs are calculated by subtracting 10°C from the daily mean temperature, after setting daily minimum temperatures below 10°C equal to 10°C and daily maximum temperatures above 30°C equal to 30°C, and then totaling the daily values over a desired time period (Cox 2006). This assumes no appreciable plant growth for an ambient temperature below 10°C and above 30°C (Cox 2006). Generally, a higher number of GDDs results in faster plant emergence, and an earlier ideal harvesting date given a sufficient water supply (Cox 2006). For example, most corn hybrids require around 1300 GDDs from planting date to maturity, and an ideal hybrid must be selected prior to planting to optimize corn yield at harvest (Cox 2006). Growing season (date of mean last freeze in the spring to mean first freeze in the fall) and monthly mean GDD totals for the Eastern U. S. are presented in the figure below.

The accurate prediction of GDD anomalies during important agriculture windows can help farmers substantially in contractual arrangements involving the sharing of equipment and personnel between farms of different geographical location. Accurate predictions of GDDs can also be very helpful in the management of fertilizer and insecticide application, since the maturation of insects and fertilizer nitrification/mineralization are also dependent on cumulative heat (Griffin and Honeycutt 2000). In the present study, the linear and non-linear relationships between GDDs and other important climate variables and several Pacific and Atlantic Ocean sea surface temperature patterns are presented (Atlantic Ocean patterns yet to be determined), and objective physical reasoning for these relationships will soon be explored. The Pacific Ocean patterns include El Niño/Southern Oscillation (ENSO), the North Pacific Oscillation (NPO), and the Pacific Decadal Oscillation (PDO), and were determined from an S-mode
Principal Components Analysis (PCA) of seasonal sea surface temperatures of different time periods. The score time series from the PCA will be used to determine the linear and non-linear teleconnections with climate variables important to the agribusiness sector.

This project is ongoing.

Growing season and monthly mean GDD totals for the eastern U.S. calculated from a 1949-2000 mean.
NSSL Special Project – The Value of Tornado Watches and Warning False Alarms
Sutter (primary – Univ. of Texas-Pan American), Simmons, Erickson

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Funding Type: CIMMS Task III

Objectives
Test for evidence using a regression model that tornado watches or above normal levels of false alarms affect tornado casualties; examine differences in false alarm ratios and alternative ways to define false alarms.

Accomplishments
We extended our data set to include 2003, 2004 and 2005 tornadoes, and we have constructed some of the false alarm variables we wish to employ in our analysis. We have added some of the false alarm variables to our casualties’ data set, with regression analysis to follow.

We have also obtained tornado watch and severe thunderstorm watch records from the SPC. These have been used to construct variables to indicate if a tornado event occurred within either a tornado or severe thunderstorm watch box, and if so, determine the lead time on the tornado watch. These variables have been added to our data set, with regression analysis to follow.

During the fall 2007 semester we will complete the regression analysis using the newly-constructed false alarm and tornado watch variables.

This project is ongoing.

Publications

CIMMS/OU Sponsored Research Incentive – Multiscale Evolution and Predictability of a Warm Season Climate Anomaly in the U.S. Southern Great Plains
Portis (primary – CIMMS at the University of Illinois at Urbana-Champaign), Leslie, Lamb

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Objectives
Investigate the multiscale events and interactions that culminated in the Texas Hill Country flood during the summer of 2002; investigate why this flood marked a discontinuous jump in the regional climate.

Accomplishments
The Texas Hill Country flood during summer 2002 was remarkable in its duration, with 4-, 5-, 7-, and 10-day precipitation totals being more than twice the published values of the 100-year event. It is also noteworthy for ushering in a discontinuous jump in the regional climate from a prolonged drought to a 6-week cool and wet climate anomaly.

This year the second objective – investigation of why this flood marked a discontinuous jump in the regional climate – has been our focus. Our initial investigation revealed a southwest orientation of positive relative vorticity in July across Texas from the Baja Peninsula. This indicated that the large-scale
circulation for the North American Monsoon (NAM) might be contributing to the cool and wet regional anomaly. Previous research has linked the NAM to the Madden-Julian Oscillation (MJO) (Lorenz and Hartmann 2006). The 2002 MJO was very active and proxies for the MJO clearly indicate that Texas/Oklahoma were under the ascend phase (convectively active) during July of 2002. The figure below shows snapshots in July of the velocity potential field which is used as a proxy for the MJO. It is clear from this figure that the ascend phase of the MJO (indicated by negative values of the velocity potential field) was prevalent over the Texas/Oklahoma region during July. This upper air pattern, that was present through the end of July, would have provided a favorable environment for a cool and wet regional anomaly. Another paper (Zhou and Miller 2005) explored the interaction between the MJO and the Arctic Oscillation (AO). Consistent with this research, the active summer MJO for 2002 is coincident with a positive phase of the AO and a retraction of the East-Asian jet. This was in sharp contrast to the drought year of 1998 with an inactive MJO, a negative phase of the AO and an expansion of the East-Asian jet. This research suggests possible teleconnections might play a role in predisposing the Texas/Oklahoma region toward extremes in summer precipitation given other favorable synoptic conditions.

This project is ongoing.

Publications
Velocity potential anomalies (0.2101 sigma) every five days for the date shown. Anomalies are departures from 1968-1996. Blue, dashed contours indicate convective regions (ascend phase of the MJO) and red, solid contours indicate regions of suppressed convection (descend phase of the MJO).
Doppler Weather Radar Research and Development

NSSL Project 2 – National Quantitative Precipitation Estimation Mosaic (formerly called Quantitative Precipitation Estimation and Segregation Using Multiple Sensors)
J. Zhang (primary – CIMMS at NSSL), Langston, Xia, Fang, Arthur

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Develop a seamless high-resolution national 3-D grid of radar reflectivity for data assimilation, model verification, and aviation product development; develop automated multi-sensor QPE techniques at high spatial and temporal resolutions and accuracy for use in operational flash flood monitoring and prediction and water resource management.

Accomplishments
The 3-D high-resolution national radar reflectivity mosaic has been running at NSSL in real-time since June 2006. The software was transferred to NCEP for operational implementation during 2006. Meanwhile, the 3-D national radar mosaic at NSSL continues to serve as a prototype system and as a testbed for new research and development activities. Research and development this year included the integration of Canadian radar network (5-cm radar) with the WSR-88D network (10-cm radar) and creation of a gap filling technique based on the vertical profile of reflectivity (VPR). The figure below shows example horizontal cross-sections of reflectivity from 3-D mosaic grids with and without the Canadian radars. The Canadian radar network provides better coverage of this precipitation system at all altitudes. The additional coverage provided at the lower levels (panels b and d) is significant because of the Canadian radar’s lower elevation angle (0.3°) in comparison to the WSR-88D (0.5°). This could potentially improve quantitative precipitation estimation (QPE) in the Great Lakes region. At upper levels images (panels f and h) seamless mosaicing is shown between the WSR-88D and Canadian radars. The seamless 3-D reflectivity grid can be beneficial to aviation weather applications such as convective and winter weather monitoring and prediction as well as for icing condition analysis across the U.S./Canada border.

A new warm season radar-based QPE algorithm has been developed based on the 3-D radar mosaic produced through the Q2 initiative (Vasiloff et al. 2007). It was evaluated over 20 events during March 2007 using rain gauge data and NCEP Stage IV precipitation products. The performance of the new algorithm is comparable to the Stage IV for most events with the exception of in mountainous regions of California and the Pacific Northwest. The results are very encouraging since this radar-based QPE is a high-resolution (1-km versus 4-km for Stage IV) and rapidly-updating (every 5-min versus every hour for Stage IV) product. It has the potential for improving flash flood detection.

This project is ongoing.

Publications


Horizontal cross sections at 0.5 (row 1), 1.0 (row 2), 3.0 (row 3), and 5.0 (row 4) km above mean sea level from the 3-D mosaic grid with two WSR-88Ds (KDLH and KMVX) (left column) and from the 3-D mosaic grid with three additional Canadian radars (XWL, XDR, and XNI) (right column).
**NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Polarimetric Hydrometeor Classification and Rainfall Estimation for Better Detecting and Forecasting High-Impact Weather Phenomena Including Flash Floods**

Ryzhkov (primary – CIMMS at NSSL), Giangrande, Krause, Park, Schuur, Melnikov

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type:** CIMMS Task II

**Objectives**

Develop and validate polarimetric algorithms for quantitative precipitation estimation (QPE) and hydrometeor classification (HCA); explore the utility of polarimetric QPE and HCA for shorter wavelength (C- and X-band) radars.

**Accomplishments**

The latest versions of the polarimetric algorithms for hydrometeor classification and rainfall estimation (HCA v2 and QPE v2 respectively) have been transferred to NWS for operational implementation in the first deployment of polarimetric WSR-88D radars. The operational versions of the algorithms have been tested on the extensive KOUN dataset including rain events observed during 2002-2005.

The results of polarimetric echo classification have been integrated into the study to investigate the performance of radar rainfall estimation contingent on hydrometeor type. Separate statistics are obtained for widespread stratiform and warm season convective events to determine the significance of melting layer contamination. A new method for polarimetric rainfall estimation that capitalizes on the results of echo classification exhibits better performance than the conventional WSR-88D technique up to the distances of 180–200 km.

The S-band versions of HCA and QPE algorithms have been adapted for C band and tested on a number of storms observed in Ontario, Canada, with the King City C-band polarimetric radar and in Alabama using the data collected by the EEC Sidpol dual-polarization radar.

This project is ongoing.

**Publications**


Range dependencies of a bias and rms error of one-hour rainfall estimation performed by conventional and polarimetric algorithms. Polarimetric algorithm yields almost 2 times reduction in the rms error at relatively close distances from the radar.

**NSSL Project 5** – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: *Investigation of Microphysical Processes in Clouds and Precipitation Using Polarimetric Radar Measurements*

Ryzhkov (primary – CIMMS at NSSL), Kumjian, Schuur

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**

Investigate polarimetric signatures in tornadic and nontornadic supercell storms for better understanding microphysical aspects of tornadogenesis.

**Accomplishments**

Detailed analysis of polarimetric data from nine tornadic and six nontornadic supercell storms has been performed. It reveals a number of distinctive and repetitive polarimetric signatures attributed to different microphysical processes and features in the storms. These signatures are associated with tornadic debris, hail, vertical motions, updraft rotation, and size sorting due to vertical veering of the wind. Especially notable are polarimetric designations of tornadic debris and storm relative helicity (SREH). The latter one is linked to the “arc ZDR” signature, that is, arc-shaped area of differential reflectivity enhancement at the southern edge of the forward-flank downdraft. This signature may serve as a precursor of intense rotation in the storm and indicator of its potential severity.

This project is ongoing.

**Publications**

Examples of arc ZDR signatures in five supercell storms observed in Oklahoma. Contours of Z are overlaid.

**NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Identification of Aircraft Icing Conditions with Polarimetric Radars**

Schuur (primary – CIMMS at NSSL), Ryzhkov, Elmore

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type:** CIMMS Task II

**Objectives**
Investigate the utility of using polarimetric radar data to identify aircraft icing conditions.

**Accomplishments**
Data from the polarimetric KOUN WSR-88D radar are being analyzed to investigate polarimetric signatures associated with aircraft icing conditions. A database of 23 potential icing events has been created by classifying all polarimetric KOUN WSR-88D radar data collected over a 3 year period (from the spring of 2002 through the spring of 2005) according to precipitation type. From this, several events that exhibited extensive regions of stratiform precipitation were identified, encompassing both cold- and warm-season precipitation events. All pilot reports (PIREPS) within 150 km of the KOUN radar for these events were then obtained from a database maintained by the National Center for Atmospheric Research. From this search, approximately 120 PIREPS, with reported icing conditions ranging from trace to heavy, have been identified at times when coincident KOUN data are available.

Based on preliminary observations, polarimetric WSR-88D radar signatures at locations immediately above the freezing level in stratiform clouds, as well as in the radar bright band itself, might be useful for diagnosing the presence or absence of supercooled liquid water (SLW). For example, in systems where SLW is present and aircraft icing potential high, water mass in the 0 to -10ºC layer (a region where aircraft icing is most prevalent) is acquired by ice particles through accretion, resulting in particles that are on
average more heavily rimed, slightly more spherical in shape, and have a much lower aggregation rate than would be the case if SLW were not present. This typically results in a gradual increase in radar reflectivity $Z$ with decreasing height and, in general, a rather weak radar bright band signature. On the other hand, in stratiform regions where SLW is not present, no accretion takes place and aggregation is more intense, resulting in a much more steep increase in $Z$ with decreasing height and, by comparison with a stratiform cloud where SLW is present, a more intense radar bright band signature.

This project is ongoing.

Conceptual model describing hypotheses for microphysical differences, as shown by idealized profiles of polarimetric variables, between stratiform clouds with low icing potential (solid lines) and high icing potential (dashed lines). Radar reflectivity is depicted in red, differential reflectivity in blue, specific differential phase in green, and correlation coefficient in purple. Dotted lines in differential reflectivity and correlation coefficient low icing potential profiles show structure believed to be associated with enhanced depositional growth in the -10 and -20°C layer, resulting in stellars and dendrites that grow by aggregation as they fall.

**NSSL Project 5** – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Development of Kessler Farm Field Laboratory for the Study of Precipitation Microphysics

Chilson (primary – OU School of Meteorology), Schuur, G. Zhang, Ryzhkov, Teshiba

**NOAA Strategic Goal 3** (Serve Society’s Need for Weather and Water Information)

**Funding Type:** CIMMS Task II

**Objectives**
Develop an instrumented site that can be used for the detailed investigation of precipitation microphysics.
Accomplishments
Understanding the microphysics of precipitation and the atmosphere in which it forms and evolves is important for scientists to accurately estimate rainfall rates and improve parameterizations in models that predict the weather. Therefore, the University of Oklahoma, in collaboration with CIMMS scientists at the NSSL, is building up a suite of instrumentation to measure the properties of precipitation. This site, which is located approximately 30 km south of the polarimetric KOUN WSR-88D radar, is referred to as the Kessler Farm Field Laboratory (KFFL). Instrumentation already deployed to the site include a 404 MHz profiler (part of the NOAA profiler network), a 915 MHz profiler, a 2D-video disdrometer, and a network of tipping bucket rain gages. KFFL is also host to one of the stations in the Oklahoma Mesonet and a Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program boundary facility.

The overall goal of this research is to improve our understanding of the microphysics of precipitation formation in the Southern Great Plains. This is primarily being accomplished through the collection of vertical cross sections of polarimetric radar data over the KFFL site which, when combined with spectral data from the 404 and 915 MHz profilers, can be used to investigate the accuracy of polarimetric retrieval methods in a variety of precipitation regimes.

This project is ongoing.

Publications
Time-height cross-sections of radar reflectivity, differential reflectivity, and correlation coefficient over KFFL observed with the KOUN radar.

**NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts:** Sensitivity Enhancement in the Dual-Polarization WSR-88D

**Ivic** (primary – CIMMS at NSSL), Zrnic

**NOAA Strategic Goal 3** (Serve Society’s Need for Weather and Water Information)

**Funding Type:** CIMMS Task II

**Objectives**

Provide an alternative signal detection scheme that yields improved detection over the current approach and compensates for the effects of signal-to-noise ratio decrease.

**Accomplishments**

Currently the WSR-88D network uses only power estimates for signal censoring. The planned network upgrade to dual polarization will result in 3dB signal-to-noise ratio reduction because transmitter output will be split between H and V channels. As a result, this will diminish radar sensitivity if the current power
based censoring scheme is retained. The scheme that utilizes the weather signal coherency in sample-time and across H and V channels has been identified. Considerable improvement in signal detection compared to the currently utilized detection approach was demonstrated, both in simulations and on real data. Potential for even further enhancements to this novel approach was established.

This project is ongoing.

**Publications**


**NSSL Project 7 – Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings: Open Radar Data Acquisition (ORDA) Spectrum Width Estimation**

Torres (primary – CIMMS at NSSL), Curtis, Jain, Zrnic

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**

Recommend a spectrum width estimator for the ORDA that is equivalent to the legacy estimator.

**Accomplishments**

Recently, the NEXRAD network was upgraded with the Open Radar Data Acquisition (ORDA) subsystem, which includes new receivers, signal processors, and control subsystems. Before this upgrade, the legacy RDA estimated the spectrum width using the standard pulse-pair technique. The new signal processor implements a similar spectrum width estimator, but relies on a Discrete Fourier Transform (DFT)-based estimator to compute the first few lags of the time-series autocorrelation function. In general, the new and legacy autocorrelation estimators are not equivalent, resulting in inconsistent spectrum width estimates.

Theoretical, simulation, and data analyses showed that the ORDA spectrum width estimator on non-windowed data is positively biased, especially for narrow spectrum widths. Given that biased estimates would negatively impact the performance of algorithms that rely on the spectrum width (e.g., the radar echo classifier, or the new turbulence detection algorithm), we proposed changes to the new spectrum width estimator to make it unbiased, mathematically equivalent to the pulse-pair implementation, and naturally able to handle data window effects. These changes were approved for operational implementation by the NEXRAD Technical Advisory Committee and are currently underway.

This project has been completed.

**Publications**

NSSL Project 7 – Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings: Mitigation of Range and Velocity Ambiguities

Torres (primary – CIMMS at NSSL), Bachmann, Zrnic

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Resolve WSR-88D range and Doppler velocity ambiguities to the levels required for the efficient observation of severe weather, culminating in significantly improved WSR-88D data quality when implemented on the Open Radar Data Acquisition (ORDA) sub-system – the increased data quality will result in an improved ability for the WSR-88D to detect severe weather, flash floods, winter storms, and provide aviation forecasts.

Accomplishments
Over the past decade, two techniques have emerged as viable candidates to address the mitigation of range and velocity ambiguities in the WSR-88D, thus reducing the amount of purple haze obscuration currently encountered during the observation of severe phenomena. These are: 1) systematic phase coding (SZ-2) and 2) staggered pulse repetition time (SPRT). The two techniques are complementary since they offer advantages at specific elevation angles; hence, they can be simultaneously incorporated into the same volume coverage pattern (VCP).

One of this year’s major accomplishments was the NEXRAD Software Recommendation and Evaluation Committee’s (SREC) official approval of the SZ-2 algorithm for inclusion in the next build of ORDA. This was the result of successful technology transfer to the ROC. The second stage of NEXRAD upgrades dealing with range and velocity ambiguities involves the operational implementation of SPRT. During this
This year, we focused on designing operational VCPs using SPRT and on evaluating the performance of a novel ground clutter filter that operate on staggered samples.

This project is ongoing.

**Publications**


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**Volume Coverage Pattern (VCP) for NEXRAD range and velocity ambiguity mitigation. Systematic phase coding (SZ-2) is employed at the lower elevation angles and staggered pulse repetition time (SPRT) at the intermediate elevation angles.**

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**NSSL Project 7 – Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings:** *Improvement of Spectral Moment and Polarimetric Variable Estimates using Decorrelating Transformations on Oversampled Range Data*

**Torres** (primary – CIMMS at NSSL)

**NOAA Strategic Goal 3** (*Serve Society’s Need for Weather and Water Information*)

**Funding Type:** CIMMS Task II

**Objectives**

Exploit range oversampling followed by a decorrelation transformation for faster data temporal acquisition and denser spatial sampling as needed to satisfy some of the evolutionary requirements for the WSR-88D.
Accomplishments
Range oversampling followed by a decorrelation transformation is a novel method for increasing the number of independent samples from which to estimate the Doppler spectrum, its moments, as well as several polarimetric variables on pulsed weather radars. Since errors of estimates increase with increased antenna rotation speed, the decreased errors associated with decorrelation permit the antenna to rotate faster while maintaining the current errors of estimates. It follows that storms can be surveyed much faster than is possible with current processing methods. Alternatively, for a given volume scanning time, errors of estimates can be greatly reduced. These are important considerations in WSR-88D operations. This technique can be exploited in a combination of faster data temporal acquisition and denser spatial sampling as needed to satisfy some of the evolutionary requirements for the WSR-88D.

During the past year, we continued our focus on practical issues involving the implementation of oversampling and pseudo-whitening techniques within the WSR-88D operational environment. It was observed that if the amplitude and/or phase mismatch between transmission pulses is disregarded in the formulation of the decorrelation transformation, processing of range oversampled dual-polarization signals with the standard whitening transformation can produce biased polarimetric variable estimates. Our research demonstrated that, by properly accounting for the amplitude and/or phase differences in the two polarization channels, it is always possible to obtain unbiased polarimetric variable estimates. However, the accuracy of these estimators may degrade as the degree of mismatch between the horizontally and the vertically polarized transmitted pulses increases. Optimum estimators can be derived by solving a constrained minimization problem.

This project is ongoing.

Publications
Bias and standard deviation of cross-correlation coefficient estimates vs. amplitude and phase polarimetric channel mismatches. Different curves correspond to (a) traditional matched filtering (MFB), (b) oversampling and averaging (OAB), (c) original whitening transformation (WTB), (d) unbiased whitening transformation (UWTB), and (e) optimum, unbiased whitening transformation (OUWTB). OUWTB estimates are unbiased and exhibit minimum variance for the entire range of amplitude and phase channel mismatches.

**NSSL Project 7** – Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings: Super Resolution Radar Data

**Torres** (primary – CIMMS at NSSL), Curtis, Forren, Jain

**NOAA Strategic Goal 3** (Serve Society’s Need for Weather and Water Information)

**Funding Type:** CIMMS Task II

**Objectives**
Increase the detection range of mesocyclone and tornado vortex signatures; increase the visibility of the reflectivity signatures with super-resolution data; increase warning times for severe thunderstorms and tornadoes; and improve radar detection of severe weather, flash floods, and winter storms.

**Accomplishments**
Legacy-resolution base data on the NEXRAD network consists of reflectivity on a 1 km by 1 deg polar grid and Doppler velocity and spectrum width on a similar 250 m by 1 deg grid. It has been shown that some meteorological signatures can be detected at greater ranges using radar data with finer spatial resolution on a 250 m by 0.5 deg grid. Radar data produced this way is termed super-resolution data. Super-resolution radar data has the potential to increase the detection range of mesocyclone and tornado
vortex signatures as well as increase the visibility of reflectivity signatures associated with severe weather. These can contribute toward an increase in warning times for severe thunderstorms and tornadoes.

This year we completed the development of a super-resolution radial recombination algorithm. This algorithm is fundamental for this project because it allows legacy-like resolution data to be fed to ORPG algorithms when operating in the super-resolution mode. The recommended super-resolution radial recombination algorithm was transferred to the ROC for operational implementation. This implementation was carefully validated with our prototype to ensure the operational version of the algorithm performed as designed.

In close cooperation with the ROC Applications Branch, we began analyzing the effects of feeding recombined base data to the ORPG algorithms. We employed an off-line ORDA playback system to process numerous hours of time-series data. By statistically comparing base data moments obtained from processing the same data sets using the legacy and super-resolution modes of operation, we assessed the effectiveness of the radial recombination algorithm.

This project is ongoing.

**Publications**
Reflectivity field from time-series data collected on 23 September 2006 with the KOUN radar. Time-series data were processed using legacy resolution (top left panel) and super-resolution with radial recombination (top right panel). Fields were compared to assess the performance of the radial recombination algorithm. Difference fields (bottom left panel) and histograms (bottom right panel) were produced for all the base data moments.

**NSSL Project 8 – Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings: Signal Processing Upgrades for the National Weather Radar Testbed**

Torres (primary – CIMMS at NSSL), Curtis, Forren, Priegnitz

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**
Create a modern and improved multi-processor/multi-computer signal processing environment for the NWRT phased array radar.
Accomplishments
The National Weather Radar Testbed (NWRT) was established to demonstrate the potential to simultaneously perform aircraft tracking, wind profiling, and weather surveillance within a multi-mission phased-array radar (MPAR). Since its inception in September 2003, the NWRT system has undergone an extensive engineering evaluation and numerous hardware and software upgrades. However, in spite of significant engineering work, the real-time signal processing functionality currently implemented in the PAR is limited. Even with these limitations, several research experiments have successfully demonstrated many of the unique advantages of using phase-array technology in the context of weather observation. A modern and improved multi-processor/multi-computer signal processing environment will allow the implementation of new and advanced real-time signal processing techniques that will provide researchers and users with an optimum platform for demonstrating and evaluating the MPAR concept.

The first part of this project is underway and consists of implementing the Staggered PRT (SPRT) algorithm on the PAR. We successfully completed the initial stages which involved creating and testing scanning strategies using staggered PRT sampling, defining the SPRT algorithm and prototyping it for its real-time implementation. This project will continue and will be followed by the real-time implementation of other very interesting evolutionary signal processing techniques. These include schemes to effectively remove clutter contamination from meteorological signals, methods to mitigate range and velocity ambiguities, and techniques that allow for faster data collection.

This project is ongoing.

Publications

Adams, Burcham, Curtis, Forsyth (co-primary – NSSL), Heinselman, Hondl, Jain, Priegnitz, Staples, Suppes, J. Thompson, Zahrai, Žrnic (co-primary – NSSL)

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)
Funding Type: CIMMS Task II

Objectives
Prepare the National Weather Radar Testbed (NWRT) Phased Array Radar (PAR) for scientific and engineering evaluation; perform engineering analyses of PAR data to identify and assess data quality issues associated with the system; use these analyses to prioritize and resolve identified issues; and begin meteorological analyses of PAR data to evaluate the utility of using the PAR technology for meteorological purposes.

Accomplishments
Much progress has been made on research, development, and analysis of the Phased Array Radar system over the past year: beginning with the move of our main operations to the new National Weather Center (NWC) building, continuing with numerous hardware and software upgrades, and interlaced with the realization of several scientific projects collecting and utilizing data from the PAR.

The move to the NWC was an extensive logistical exercise with the necessary communications, control, processing, and display systems moving to new locations. Key systems components are now distributed throughout the University of Oklahoma and the radar can be operated from anywhere in the world. Operating locations within the NWC have varied due to the scientific projects utilizing this asset. When the Phased Array Smart radar (mobile C-band Doppler radar) Spring Experiment (PASSE) and Data
Assimilation Resolution Experiment (DARE) projects were in progress, the system was operated from the Hazardous Weather Testbed (HWT). This allowed close coordination with the Norman WFO and optimized the scan timing with the SMART radar vehicles in the field. When the PAR Downburst Detection Experiment (PARDDE) was started, operations were moved to the Development Lab for closer collaboration between the operators and research meteorologist. Many other significant collections were conducted in this lab as weather opportunities developed and presented themselves within our radar coverage.

The Moment Data Processor (MDP) is again being upgraded to a new design and hardware implementation to accelerate the system’s ability to interrogate and process meteorological structures, thus highlighting speed as one of the systems greatest advantages over conventional radars. The new Digital Signal Processor (DSP) will be operated in a distributed fashion with several nodes (processors) ingesting and manipulating the data as it is collected.

Testing of all operational software, hardware components, and design implementations has continued to provide for a user friendly and robust system. The evolution and testing of this design has continued without any significant operational interruptions.

This project is ongoing.

**Publications**


**NSSL Project 8 – Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings: Rapid Sampling of Storms**

Heinselman (primary – CIMMS at NSSL), Priegnitz, Manross, T. Smith, Adams

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**

Demonstrate the phased array radar’s ability to collect rapid-scan volumetric data that provide more detailed depictions of quickly-evolving severe storm structures (e.g., microburst precursors) than the WSR-88D and TDWR.

**Accomplishments**

A key advantage of the National Weather Radar Testbed Phased Array Radar (PAR) is the capability to adaptively scan storms at higher temporal resolution than is possible with the Weather Surveillance Radar-1988 Doppler (WSR-88D; 1 min or less vs. 4.1 min, respectively). High-temporal resolution volumetric radar data is a necessity for rapid identification and confirmation of weather phenomena that can develop within minutes. The purpose of this research is to demonstrate the PAR’s ability to collect rapid-scan volumetric data that provide more detailed depictions of quickly evolving storm structures than the WSR-88D and TDWR (for microbursts only).

Advantages of higher-temporal resolution PAR data are examined for three convective storms that occurred during the spring and summer of 2006, including a re-intensifying supercell, a microburst, and a hail storm. The analysis of the re-intensifying supercell (58 s updates) illustrates the opportunity to more quickly identify and confirm developing and/or intensifying areas of 1) low-altitude divergence and rotation and 2) rotation through the depth of the storm. The fuller sampling of the microburst’s storm life cycle (34 s updates) depicts precursors to the strong surface outflow that are essentially indiscernible in the WSR-
88D data. Furthermore, the 34 s scans provide a more precise sampling of peak outflow. The more frequent sampling of the hail storm (26 s updates) illustrates the opportunity to more confidently assess and track storm structures indicative of rapid intensification, the development of hail aloft, and the onset of the downdraft near the surface. These findings indicate the strong potential for rapid-update radar data to heighten forecaster confidence in the timing, location, and intensity of severe weather signatures and the possibility of increasing warning lead time, particularly on quickly developing hazards that are under-sampled by the WSR-88D.

This project is completed.

Publications
A time series of NWRT PAR and KTLX WSR-88D data showing the evolution of a strong microburst event on 10 July 2006. Each panel shows the vertical cross-section of reflectivity (dBZ; left) and linear least squares derivative radial divergence estimates (s\(^{-1}\); right) taken along the 12-km long line shown in the figure. Both the horizontal and vertical axes are given in km. The reflectivity (left) and radial divergence (right) color scales are shown at the top of the figure. The time stamps shown are for the beginning of each volume scan. Although the storm was sampled completely every 34 s, for brevity, every other cross section is displayed at ~1 min intervals.
Heinselman (primary – CIMMS at NSSL), Priegnitz, T. Smith, Biggerstaff, Andra, Palmer

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Assess the benefits and challenges of rapid update volumetric PAR moments (reflectivity, velocity, and spectrum width) to data interpretation and warning decision-making; emulate adaptable scanning; attain data sets for several research projects; and obtain high temporal and spatial resolution severe storm verification to support PAR application development and data analysis.

Accomplishments
Here we focus on only one of the five experiments comprising the Spring 2007 NWRT PAR Demonstration, entitled “Real-time Evaluation of the PAR”. During this experiment, users of radar data (e.g., NWS forecasters, NWS trainers, and researchers) were introduced to PAR data (reflectivity, velocity, and spectrum width fields) for the first time. The experiment was conducted 15 April through 15 June 2007 and was concerned primarily with data collection within 150 km of the PAR prior to and during severe weather episodes. Two overarching goals of this specific experiment are to test the adaptable scanning capability of the PAR and to collect feedback from NWS forecasters on benefits and challenges of integrating PAR data into operations. Participants responded to a survey designed to address these goals. Preliminary results about benefits and challenges of interpreting PAR data in real-time have been compiled.

Compared to the lower-temporal resolution WSR-88D data (4.1 min vs. 1 min or less), respondents noted the following benefits of higher-temporal resolution PAR data:

- “Rapid changes in core depth/intensity easy to monitor”
- “[Ability to track] rapid evolution of updraft/BWER”
- “30 sec data great for [tracking] contracting/tightening couplets”
- “Features in velocity have temporal continuity in rapid scans, not as dramatic in 4-5 min 88D scans!”

Respondents also voiced some challenges, including difficulty in keeping abreast of multiple storms with one-minute volumetric updates and deciding where to point the antenna. Looking toward the future, forecasters noted that communication of information to emergency managers, media, and the public should be consistent with the temporal resolution of the data.
Overview of the five experiments comprising the Spring 2007 National Weather Radar Testbed Phased Array Radar Demonstration.

**NSSL Project 8 – Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings: Radar Control Interface**

Priegnitz (CIMMS at NSSL)

**NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)**

**Funding Type:** CIMMS Task II

**Objectives**
Continue support for the Radar Control Interface (RCI) to the NWRT phased array radar; design a new scan control interface to support adaptive scanning.

**Accomplishments**
The Radar Control Interface (RCI) has been improved to provide enhanced status reporting. As an example, when scanning is active, feedback now is provided on the current stimulus that is queued for execution and on how much of the scan that has been processed. If the RCI software determines that a scan has "hung", notification is immediately provided to the user.

For the first time since its deployment, the NWRT PAR was a component of several research projects run from the National Weather Center’s new Hazardous Weather Test Bed (HWTB). The RCI played an important role in PAR operations to support these projects on a 24/7 basis. More than a dozen individuals were trained on RCI basics.
An important benefit of phased array technology versus conventional mechanically scanning radars is the ability to electronically steer a beam to a position without physically moving the antenna. This capability will allow new scanning strategies to be developed that "adaptively" scan selected regions of the atmosphere faster. The RCI is currently being enhanced to support adaptive scanning.

This project is ongoing.

**Publications**

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**Sample RCI client system display window.**

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**ROC Project 13** – Analysis of Weather Radar Observations of Severe Convection to Understand Severe Storm Processes and Improve Warning Decision Support

CIMMS students at ROC – Dunn, Bey, Jones, McCarroll, Ong, Setzer, Keel, Patchin, Tantillo; Reed, Haden, Lee, R. Murnan, Steadham, Zittel

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type:** CIMMS Task II

**Objectives**

Develop a data compression technique for the WSR-88D; improve Doppler radar reliability; ensure meteorologists and engineers at ROC have the tools they need for research and development; perform
ongoing assessments of WSR-88D data quality; evaluate algorithm performance; verify algorithm performance changes; assist with technology transfer tasks; obtain and analyze special radar data.

Accomplishments
Below is a summary of the activities of CIMMS students at the Radar Operations Center:

Initial research has been conducted on the data compression technique. A transmitter reliability modification has been developed, tested and deployed, and an encoder test set has been developed and updated. An image was developed for ROC computers and deployed on all applicable systems.

CIMMS student employees provide important assistance for the WSR-88D Data Quality Working Group and the ROC Applications Branch. Furthermore, an urgent branch project to evaluate recombination techniques from Super Resolution data required aggressive assistance from all of our CIMMS students.

Specifically, work was done to evaluate radar algorithm performance by reviewing products for defects, errors, and artifacts caused by poor data quality. The performance of a software change for the Mesocyclone Detection Algorithm (MDA) was analyzed and verified from numerous cases. The MDA will replace the legacy Mesocyclone (MESO) algorithm; however, because MDA feature identification criteria are far more lenient than the MESO, tests of adjustments to code were required in order to confirm no adverse operational impacts. In a branch activity to transfer dual polarization research software code into Algorithm Enunciation Language, code logic was organized and specified. Tasks involving recombination techniques included algorithm performance comparisons of the Vertically Integrated Liquid (VIL), the Digital VIL, and the Velocity Wind Profile (VWP) outputs.

One student (Sophia Tantillo) participated in the Oklahoma NASA Space Grant Geospatial Extension Program from 16-25 May. This geospatial extension activity enhanced our general awareness and understanding of geospatial information technology and revealed ways to transfer the technology to end-users.

Work was done on preparations to test lower elevation angles for several potential field sites. Weather for beam overshoot problems was monitored and, accordingly, Level II data were collected in order to establish baseline test information. Involvement with recombination included playback and analysis of the Storm Total Precipitation products as well as correlations of base moments. Histograms and other graphs were prepared using Excel to depict statistics.

Data playback, execution of special test software, and chart and graph preparation in Excel was done in support of a project to improve radial velocity values. The purpose of the project was to validate the reduction in range folding afforded by combining a special signal processing technique with the Multiple Pulse Repetition Frequency Dealiasing Algorithm (MPDA). Adaptable parameters of the MPDA were tested in an attempt to block out noisy data rings near the end of first trip and the start of second trip echo. Level II data sets were catalogued and algorithm performance was evaluated as part of general evaluation efforts in the Data Quality Working Group. Assessments related to deployment of the MDA were conducted. Recombination tasks included algorithm performance comparisons for the Echo Tops (ET), Enhanced Echo Tops (EET), VIL, DVL, MDA, and the Tornado Vortex Signature (TVS) algorithms.

Many of these projects are ongoing.
ROC Project 13 – Analysis of Weather Radar Observations of Severe Convective Storms to Understand Severe Storm Processes and Improve Warning Decision Support: NEXRAD Technology Transfer
Burgess (primary – CIMMS at NSSL), Manross, Scharfenberg, P. Zhang, Sigler, Roberts

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Develop, mature, and transition radar applications and algorithms into the WSR-88 baseline; improve WSR-88D data quality and usefulness.

Accomplishments
During the reporting period, progress was made on several tasks, including: 1) dual polarization – revised QPE and Particle Type Algorithms were transferred to the ROC, base data and algorithm products were evaluated, dual-polarization verifications work was performed, and preparation for the testing of the new WSR-88D prototype was started; 2) velocity dealiasing – two different dealiasing algorithms were tested on WSR-88D VCP 31 (low PRF) data to try to improve the quality of the data, and the advantages of each algorithm were documented and remaining deficiencies were listed; and 3) radar database – a large number of radar data sets (both baseline and experimental) were collected, including Level 1 time series data – these data sets were enhanced by the addition of supplemental data from other sensors and were added to the extensive archive maintained as a resource for application development and testing.

This project is ongoing.
NOAA/HPCC – Winter Hydrometeor Classification Ground Truth Experiment
Elmore (primary – CIMMS at NSSL), Scharfenberg, T. Smith, Leggett

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Create a reporting form hosted on the NSSL web site that encourages the public to log observations of winter storm hydrometeor type within about 150 km of the KOUN radar (Norman); test the ability of the KOUN polarimetric radar to discriminate between rain, drizzle, snow, ice pellets, freezing rain, and freezing drizzle – once data are gathered, score the current hydrometeor classification algorithm against observations gathered by the public.

Accomplishments
Observations of interest to this project consist of at a minimum time of occurrence, location, and hydrometeor type, but may also consist of temperature and wind speed and direction. General comments from observers can be entered as well. During the 2006-07 winter season three major winter storms occurred; approximately 2,600 separate observations were logged on the project’s web site during them. Of all the entries made, only about 3% were removed for quality control purposes. As expected, entries were clustered within the Oklahoma City metropolitan area, but many observations also were made at more remote locations. Observations close-in are useful for direct scoring of the hydrometeor classification algorithm, while observations from more distant locations are useful for developing diagnostic algorithms to determine the hydrometeor type most likely to be observed at the surface.

This project is ongoing.

Temporal distribution of observations for the first major winter storm event during the winter of 2006-07.
NSSL Special Project – Hail Size Discrimination Experiment (HaSDEEx)

Elmore (primary – CIMMS at NSSL), T. Smith, Scharfenberg, Leggett

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

Objectives
Use public observations of hail size to develop polarimetric radar-based algorithms.

Accomplishments
Polarimetric radar easily discriminates between rain and hail, but development of a hail-sizing algorithm for the KOUN radar requires more data than are currently available. Using the same ideas that were so successful in the Winter Hydrometeor Classification Ground Truth Experiment, the public has been invited to submit hail size information within a 150-km radius of the radar. In addition, hail size observations submitted directly to the Norman NWS Forecast Office are used.

Hail is far less widespread in time and space than is winter weather, so that fewer reports are expected. To date, about 80 reports have been directly collected via the web entry page (http://www.nssl.noaa.gov/projects/hail07/). Not all reports submitted to the NWS meet minimal quality requirements, but we expect that that 80-100 more reports from there will be useful to this project.

This project is ongoing.

The HaSDEEx web site.
NSSL Special Project – Optimal Use of Phased Array Radar for Multi-Mission Weather Surveillance and Aircraft Tracking

Palmer (primary – OU School of Meteorology), T. Yu, G. Zhang, Yeary, Chilson, Y. Zhang, Crain

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task III

Objectives
Develop a real-time data acquisition system for the storage and processing of I/Q data on the phased array radar; develop the theory and implement several important techniques related to multi-mission phased array radar, including: refractivity retrieval, cross-beam wind, advanced tracking, adaptive scanning, sidelobe canceling, pulse compression, and scattering experiments.

Accomplishments
This project represents a unique collaboration between scientists at the University of Oklahoma and the NSSL. The research is targeted to investigate several facets of system performance and optimization with the phased array radar (PAR) system. Ultimately, it is anticipated that this work will assist in the scientific justification of the multi-mission PAR (MPAR) project. The following paragraphs provide an overview of the various aspects of the research being conducted for this project. In each case, a strong collaboration with NSSL scientists is emphasized.

Refractivity retrieval (Palmer). An investigation of the potential of rapid refractivity retrieval has been conducted. The retrieval technique utilizes radar phase measurements of ground clutter to derive near-surface refractivity, which has been commonly used as a proxy for humidity given its close relation to vapor pressure. Surface humidity is an important meteorological parameter and has been known to play an important role in convective initiation. In the present work, the refractivity retrieval technique is exploited by using smaller numbers of samples for phase calculation, which is a fundamental process in refractivity retrieval. The impetus for this study is to explore the possibility of rapid refractivity retrieval by exploiting the rapid beam steering capability of phased array radar. Using the National Weather Radar Testbed (NWRT) in Norman, Oklahoma, a 64-pulse per radial raw dataset was collected for conventional refractivity processing. Then, subsets of the 64 samples were extracted to emulate shorter dwell periods and the corresponding more rapid experiments. The test cases that were considered are 2, 4, 8, 16 and 32 samples. Refractivity fields retrieved using smaller numbers of samples are compared against the reference field, which was obtained using the entire 64-samples dataset. It will be shown that statistically significant refractivity fields can be obtained from as short as a 2-sample dwell.

Boon Leng Cheong is supported part-time by this project and is in charge of the development of the radar simulator and the refractivity retrieval work. Working with NSSL scientists, we have just recently developed the real-time processing code on the PAR. By handling any scanning strategy, it is anticipated that we will have real-time refractivity measurements under any conditions. The new OU data acquisition node on the PAR is instrumental in this effort. We have recently submitted a journal article on PAR refractivity to the IEEE. Over the next year, we anticipate moving more to the meteorological applications working with CIMMS scientist at NSSL Pam Heinselman.

Target detection/tracking (Yeary). This work has evolved from target tracking to a more general area of adaptive scanning and storm tracking. Developing kinematic models, adaptive state estimation techniques, uncertainty measures and volumetric target libraries are crucial for the adaptive beam steering of phased array radar. In the characterization of real world dynamic systems, it is often required to estimate unknown quantities, such as future positions, based on given measurements. State space models are often used to approximate real world phenomena as systems, where the states (either observable or not) represent the internal variable that govern how systems evolve with time. In this framework, estimating the unknown quantities can be formulated in the problem of state estimation. The Kalman filter and the emerging particle filter are suitable for this task, and many open issues are present. Such as how can improved kinematic models be incorporated into statistical state estimation techniques to control the beam steering of modern-day multifunction radars? This will create precise beam location
instructions for the real-time controller and one-step-ahead prediction algorithms for new phased array systems. Severe weather observations to be tracked, such as convective storm cells, may also be classified as a maneuvering target in some cases, which presents additional tracking challenges. When tracking a target which can perform maneuvers, the estimations generated by a conventional single-model method are not always accurate enough. The problem of maneuvering target tracking is often referred to as a jump Markov process, in which the system is assumed to operate according to one model from a finite set of hypothetical models, known as regimes or modes. This assumption is made at each iteration of the filtering process, as radar measurements are received. Since the current posterior probability distribution of a storm’s trajectory can be computed, via a Kalman filter or other state estimation technique, future positions may be predicted with a high fidelity which may be used to adaptively steer radar resources or yield improved warnings. The long-term goal is to focus the resources of NWRT on a convective cell’s trajectory, without making unnecessary scans. Enhancements to storm tracking and short-time prediction will be gauged against (Cheng, et al, 1996) and (Johnson, et al, 1998), with an eye to the future of advanced nowcasting (Jankowski, et al, 2005) and (JAG report, 2006).

Crossbeam wind measurement (G. Zhang). The theory of measuring crossbeam wind, shear, and turbulence within the radar's resolution volume V6 is developed. Spaced antenna interferometry is formulated for such measurements using phased-array weather-radar. The formulation for a Spaced Antenna Interferometer (SAI) includes shear of the mean wind, allows turbulence to be anisotropic, and allows receiving beams to have elliptical cross sections. Auto- and cross-correlation functions are derived based on wave scattering by randomly distributed particles. Antenna separation, mean wind, shear, and turbulence all contribute to signal de-correlation. Crossbeam wind cannot be separated from shear and thus crossbeam wind measurements are biased by shear. It is shown that SAI measures an apparent crossbeam wind (i.e., the angular shear of the radial wind component). Whereas the apparent crossbeam wind and turbulence within V6 cannot be separated using monostatic Doppler techniques, angular shear and turbulence can be separated using the SAI. The antenna patterns for the sum and difference channels have been measured (by NSSL) and calculated, as shown in the attached figure. The sub-array discretizations have been taken into account. It shows good agreement between measurement and theory for the main beam and side lobes, including the large side lobes at 12-17 degrees due to the sub-array discretization. These antenna patterns allow the antenna beam balance factor and effective separation calibrated for SAI applications.

Pulse compression (Chilson). Whereas the MPAR offers many exciting opportunities, there are still several technological challenges to overcome. One of these challenges has been precipitated through the reduction in available transmit power associated with the need to use solid-state modules. In order to maintain the same levels of signal-to-noise ratios enjoyed by the NEXRAD systems without compromising in range resolution, it will be necessary to implement one of several pulse compression strategies. Pulse compression is a process that provides for enhanced range resolution in radar systems. This is achieved through transmitting a coded signal, which is then decoded to extract the desired high-resolution data. Coding of signals is implemented by altering the phase, frequency, or both during its transmission while decoding is achieved through filtering. An inherent problem of pulse compression systems is the self-cluttering effect whereby targets at nearby ranges corrupt the desired data. As weather systems are distributed in nature, the performance metric used to measure the amount of self-clutter is the Integrated Sidelobe Level (ISL). The ISL is a measure of the total amount of power corrupting the desired data so that minimizing this metric means a cleaner signal is obtained. Minimizing ISL is realized through the use of different code and filter combinations, each with their own pros and cons. The study being conducted has been focusing on the use of binary phase codes whereby the phase of the transmit signal is flipped at specified intervals throughout transmission. Decoding of the return signals is then processed through a matched filter that maximizes the signal-to-noise ratio but has relatively large ISL. Near term efforts will focus on incorporating other types of filters that will suppress the side lobes corrupting the desired data.

Adaptive array processing (R. Palmer). Phased array radars are attractive in weather surveillance primarily because of their capability to electronically steer. When combined with the recently developed beam multiplexing technique, these radars can obtain very rapid update scans that are useful in monitoring severe weather. A consequence is that the small number of contiguous samples of the time series obtained is problematic for temporal/spectral filters used for clutter mitigation. As a result, the
accurate extraction of weather signals can become the limiting performance barrier for phased array radars that employ beam multiplexing in clutter-dominated scattering fields. By exploiting the spatial correlation of the auxiliary channel signals, the effect of clutter contamination can be reduced in these conditions. In this paper, three spatial filtering techniques that used low-gain auxiliary receive channels are presented. The effect of clutter mitigation has been studied using numerical simulations of a tornadic environment for changes in signal-to-noise ratio, clutter-to-signal ratio, number of time series samples, varying fading regimes, and maximum weight constraints. Since such data are not currently available from horizontally-pointed phased array weather radar, experimental validation was applied to an existing data set from the Turbulent Eddy Profiler, which is vertically-pointed phased array radar. Although preliminary, the results show promise for clutter mitigation with extremely short non-uniform sampling.

**Adaptive scanning (T. Yu):** Phased array radar can simultaneously and dynamically position its beam to perform adaptive scanning and multiple tasks, for example. Unlike WSR-88D that only limited Volume Coverage Patterns (VCP) are available, a phased array system offers abundant possibilities for weather sensing. Therefore, new scanning strategies, which take full advantage of the phased array system, should be developed. At the same time due to the complex nature of the scanning strategy and limited radar resources, a dynamic resource manager is needed to maximize the radar performance. The goal of this project is to develop a framework of resource management, including two major components of priority assignment and scheduler. This framework will be demonstrated through simulations. We have been conducting literature survey on this topic, mainly for military applications. We will then modify their approaches for meteorological observations considering various types of weather such as single-cell storm, multi-cell storm, squall line, and supercell. Moreover, we have been experimenting different approaches for priority assignments based on severity of the region, which is currently defined by the reflectivity and radial velocity. Note our framework is developed using a modular approach that is flexible for incorporating additional requirements if necessary.

**Scattering experiments (Y. Zhang and G. Zhang):** To date, the following has been accomplished: (1) furnishing the lab room with broadband absorber materials; (2) scatterometer system: the NWA is now ready and system calibration with continuous wave mode and 12 calibration sphere is being conducted. Even before the new EM absorbers arrive, we are trying to control the in-door clutter scattering by searching the strong reflection spots and moving target locations; (3) components and parts: we have submitted all the purchase orders for the scatterometer experiments. We are working on the microphysics sample assembly parts and materials; (4) recruiting graduate student: is still in progress and we expect an EM-major graduate student come in spring 2008. Before that, using part-time student lab assistant is very possible; and (5) some natural hail-storm samples have been collected and stored in a freezer (with UPS battery supplied). For fall 2007, the following will occur: 1) EML will have its first external user from Intelligent Automation, Inc. for their SBIR project, which will perform time-domain test an X-band receiver assembly box during a 3-day period; 2) all absorbing materials will arrive and be installed; 3) and a better reflection-controlled room will be delivered at that time. Measurement will be extended to wider-bandwidth, longer range and pulsed waveforms.

These projects are ongoing.

**Publications**


Comparison of the theoretical and measured sum (top) and azimuth difference (bottom) receive patterns. Theoretical patterns assume a designed sidelobe level of -28 dB, N = 5 (N determines the number of close-in side lobes that have about a -28 dB level), and take the sub-array discretization into account.

**NSSL Special Project** – Development of Mobile X-Band Dual-Polarization Weather Radar

**Biggerstaff** (primary – OU School of Meteorology), **Zahrai** (primary – NSSL), **Carter, Curtis, Ivic, Wicker, Straka**

**NOAA Strategic Goal 3** (*Serve Society’s Need for Weather and Water Information*)

**Funding Type:** CIMMS Task III

**Objectives**

Develop a new mobile dual-polarimetric X-band Doppler radar to evaluate the utility of X-band polarimetric data for NWS applications in hydrology, flood warnings, and tornado detection and prediction and enable researchers to gain more insight into dual-polarization applications for short wavelengths.
Accomplishments
During the reporting period, the following tasks were accomplished: (1) acquisition of a mobile platform; (2) design and installation of bed and hydraulics on the mobile platform; (3) building and testing of the SCR-584 pedestal; (4) integration of the antenna controller with the pedestal; (5) fabrication and testing of the transmitter; and (6) acquisition and programming of the signal processor. The RF portion of the receiver was constructed and basic antenna control has been achieved. The hardware interface between the analog and digital portions of the system was designed and is in the process of being built. System testing is anticipated during fall/winter 2007/08.

This project is ongoing.

NSSL Special Project – Development of Mobile C-Band Dual-Polarization Weather Radar to Evaluate Polarimetric Designs for the Multi-Mission Phased Array Radar and for Kinematic and Microphysical Studies of Storms
Biggerstaff (primary – OU School of Meteorology), Straka, Wicker, Zrnic, Zahrai

NOAA Strategic Goal 3 (Serve Society's Need for Weather and Water Information)
Funding Type: CIMMS Task III

Objectives
Develop a dual-polarimetric upgrade to existing SMART radar.

Accomplishments
Dual-polarimetric data will improve QPE, especially in land-falling hurricane environments. A project has begun to upgrade existing the NSSL/OU/Texas A&M/Texas Tech SMART radar with a dual-polarimetric capability. Design specifications have been reviewed and updated and bids have been submitted for acquiring project hardware.

A literature review has been conducted of all papers written on C-band radar usage to study bulk precipitation identification and interpretation of the signatures. In addition, the one phase (ice or liquid) T-matrix model and the mixed phase (mix of ice and liquid) T-matrix models provided by Dr. Bringi are being modified to be used with a radar emulator with cloud model information to see if cloud models can produce observed radar signatures besides just reflectivity. Also, a fuzzy logic program for bulk hydrometeor identification is being constructed for use to deduce bulk hydrometeor types from polarimetric radar data.

This project is ongoing.

ROC Special Project – Study of the Significance and Mitigation of Wind Turbine Clutter for the WSR-88D Network
Palmer (primary – OU School of Meteorology), Snow, Isom

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)
Funding Type: CIMMS Task III

Objectives
Study the extent, significance, and mitigation of wind turbine clutter on the WSR-88D radar network; develop advanced signal processing techniques to reduce the effects of such clutter.
Accomplishments
Graduate student Brad Isom has made significant progress over the last year. Data collected during March 2006 from the Dodge City, Kansas, radar (KDDC) were analyzed and a second set of wind turbine clutter (WTC) data was collected in late November and early December 2006 from the Great Falls, Montana, radar. Since then, a technique has been developed that successfully masks the effects of WTC, thereby reducing the level of contamination in radar-generated products. The algorithm makes use of a robust nowcasting technique and optimal interpolation. Discussions are ongoing with the ROC regarding the move to an operational testing phase. Mr. Isom is currently writing his thesis for the MS in ECE degree and will defend his thesis in September 2007, but will continue for a PhD degree showing that this project has helped to excite a student for continued graduate education.

This project is ongoing.

Publications

The left panel displays a sector plot of radar reflectivity from KDDC with the precipitation echo contaminated by wind turbine clutter. The nowcasting/interpolation scheme corrected reflectivity are provided in the right panel.
**ROC Special Project** – Emergency Mobile Radar to Supplement WSR-88D Observations during Hurricanes

Biggerstaff (primary – OU School of Meteorology), Hondl

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type**: CIMMS Task II

**Objectives**
Test WDSS-II software and point-to-point data communications link in preparation for using SMART radar as a back-up to the WSR-88D network during hurricane season.

**Accomplishments**
This project intends to prepare SMART radars for emergency use by the National Weather Service as backups to the WSR-88D system during landfalling hurricanes. A wireless communications system for point-to-point transfer of data from the radar into a NWS forecast office was installed and successfully tested.

This project is ongoing.

**NOAA/NWS/CSTAR – Improving Tornado Detection with WSR-88D Data using Spectral Analysis**

T. Yu (primary – OU School of Electrical and Computer Engineering), Shapiro, Yeary

**NOAA Strategic Goal 3** *(Serve Society’s Need for Weather and Water Information)*

**Funding Type** – CIMMS Task III (Program Manager – Sam Contorno)

**Objectives**
Develop a novel algorithm to provide accurate tornado detection and extend the detection range.

**Accomplishments**
Current tornado detection algorithms (TDA) that employ WSR-88D data search for strong and localized azimuth shear in the velocity field. However, the shear signature deteriorates with increasing range due to the smoothing effect of radar weighting functions. Previous work by others, and our recent analysis, has shown that a tornado vortex has a distinct spectral signature that deviates from the typical Gaussian shape obtained from non-tornadic regions.

We have developed and refined the Neuro-Fuzzy Tornado Detection Algorithm (NFTDA) that integrates both shear and spectral signatures. A comprehensive statistical analysis of NFTDA is performed using numerical simulations. The probability of detection (POD) as a function of the normalized range is presented on the left panel of the figure for the two tornado sizes of rt=100 and rt=200 m, where rt is radius of the tornado. The normalized range is defined as \( r_0 = \frac{\theta_b}{r_t} \), where \( r_0 \) is the range from the tornado to the center of the radar resolution volume and \( \theta_b \) represents the radar beam width in radians. Each data point represents the mean of POD from 50 realizations, and each one has a different noise sequence added to the time series data. For the purposes of comparison, a tornado detection solely based on the thresholding of azimuthal velocity difference is also implemented and is termed “thresholding tornado detection” (TTD). The POD from the TTD using a threshold of 20 m/s, one of the thresholds used in the NSSL’s TDA, is provided in the figure. For the larger tornado of rt=200 m both NFTDA and TTD have PODs of approximately 100% when the normalized distance is smaller than 8.7. At larger ranges, NFTDA still has high PODs even though the shear signature is diminishing with increasing range. For the case of rt=100 m NFTDA has a POD of approximately 80% at a range of 14 (80 km) while the TTD has a
POD of 10%. It is evident that NFTDA provides higher PODs than TTD especially at far ranges for the two tornado sizes. The improvement is caused by the fact that even when a tornado is far from the radar, wide and flat spectra are still obtained from the vortex, but the shear signature is degraded significantly. Although the performance of the TTD method can be improved by lowering the threshold, the false detections will be increased.

It has been demonstrated that NFTDA can improve the detection from conventional TDA to extend the detection range and to detect small-size tornadoes. However, the spectral products are not readily available from operational WSR-88Ds. On the other hand, polarimetry products are expected to be available in the near future. Therefore, it is of interest to evaluate the performance of NFTDA with only operationally available products (i.e., mean Doppler velocity and spectrum width) and further to investigate the impact of polarimetric products on the tornado detection. Note that NFTDA is extremely flexible to vary the combinations of input parameters with minimum training from the existing data. The evaluation result is shown on the right panel using KOUN data from the 10 May 2003 case, for which polarimetric products are also available from NSSL. The ground damage path is denoted by cyan-shaded area. Note that the tornadoes were traveling away from the radar and tornado of F0-scale was reported during 0405–0419 UTC. The detection results from conventional TDA are denoted by green downward triangles. Conventional TDA can provide detection results that are consistent with the damage path up to 0353 UTC. Three NFTDA with three different sets of inputs were developed, i.e., (1) spectrum width ($\sigma_v$) and azimuthal velocity difference ($\delta v$), (2) spectrum width, azimuthal velocity difference, and polarimetric products (cross correlation coefficient and differential reflectivity), and (3) spectrum width, azimuthal velocity difference, and tornado spectral signatures (TSS) developed earlier. The results show that all NFTDA produce similar detections during 0329-0353 UTC that agree well with the damage path and conventional TDA. For latter time (i.e., tornado was weaker and located far from the radar), the NFTDA with level II-derived data (blue squares) produce two accurate detections at 0405 UTC and 0411 UTC, but several false detections occur. The addition of polarimetric products (red circles) can help to eliminate most false detections and extend the detection to 0417 UTC. Note that the false detection at 0359 UTC is still presented, which can be eliminated using NFTDA with spectral signatures.

This project is ongoing.

**Publications**


(Left panel) Statistical analysis of the performance of NFTDA as a function of normalized range for \( r_t = 50 \) and \( 200 \) m, where \( r_t \) is the radius of the tornado. The NFTDA results are denoted by thick solid lines. The results from the detection based on a threshold of velocity difference of \( 20 \) m/s (termed TTD) are also provided for comparison and are denoted by the thin dashed lines. It is evident that NFTDA can provide more accurate tornado detection than the conventional shear-based detection. (Right panel) Tornado detection results from conventional TDA (green triangles), NFTDA with Level-II data as input (blue squares), NFTDA with Level-II and polarimetric data (red circles), and NFTDA with Level-II and spectral data (yellow asterisks). It is shown that NFTDA with even only Level-II data can improve the conventional TDA. The polarimetric products can further improve the detection.

**Other Agency** – Enhancement of Radar Retrievals by Use of Higher Moments of the Drop Size Distribution

Y. Kogan (primary – CIMMS at OU), Z. Kogan, Mechem

NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

**Funding Agency:** U.S. DOE

**Objectives**

Improve retrievals of cloud and drizzle parameters using information from Doppler radar.

**Accomplishments**

Errors of cloud property retrieval formulations based on radar reflectivity, mean Doppler velocity, and Doppler spectrum width are evaluated under the controlled framework of the Observing System Simulation Experiments (OSSEs). Cloud radar parameters are obtained from drop size distributions generated by the high-resolution CIMMS LES model with explicit microphysics. We show that in drizzling stratocumulus the accuracy of cloud liquid water (Ql) retrieval can be substantially increased when information on Doppler velocity or Doppler spectrum width is included in addition to radar reflectivity. In the moderate drizzle case (drizzle rate \( R \) of about \( 1 \) mm d\(^{-1}\)) the mean and standard deviation of errors is of the order of \( 10\% \) for Ql values larger than \( 0.2 \) g m\(^{-3}\); in stratocumulus with heavy drizzle \( (R > 2 \) mm d\(^{-1}\)) these values are approximately 20-30\%. Similarly, employing Doppler radar parameters significantly improves the accuracy of drizzle flux retrieval. The use of Doppler spectrum width instead of Doppler velocity yields about the same accuracy, thus demonstrating that both Doppler parameters have approximately the same potential for improving microphysical retrievals. We note that our error estimates represent the theoretical lower bound on retrieval errors, because the actual errors will inevitably increase, first and foremost, due to uncertainties in estimation contributions from air turbulence.

This project is completed.

**Publications**

The errors of drizzle flux retrieval for the heavy drizzle case. The black and white lines are the one (1P) and two-parameter (2P) retrieval mean errors; the shading areas represent the mean plus/minus one standard deviation. Light/dark gray shading corresponds to the 1P and 2P retrievals, respectively.
Climate Change Monitoring and Detection

NOAA/CPO – Detection and Attribution of Climate Change Using Climate Indices for the United States
Karoly (primary – OU School of Meteorology), Burkholder, Easterling (NCDC), Gleason (NCDC), Lawrimore (NCDC)

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Funding Type: CIMMS Task III (Program Manager – Chris Miller, Climate Change Data and Detection)

Objectives
Evaluate US climate extremes indices from observational data and climate model simulations; document the observed changes in climate extremes in the U.S. over the 20th century; and attribute the observed changes to specific climate forcings, where possible.

Accomplishments
Recent studies have used climate indices to detect changes in the climate on continental and regional scales. This study utilizes a modified version of the Climate Extremes Index (CEI) (Karl et al. 1996), which is used by the National Climatic Data Center to operationally monitor the tails of the distributions of various climate parameters within the contiguous United States. Some issues with the operational calculation of the CEI at NCDC were identified. Modifications to the operational algorithm have been implemented at NCDC (Gleason et al. 2007) and the new version of the CEI is available on the NCDC web site. The components of this index use frequency-based statistics at each location and estimate the fraction of the contiguous United States experiencing extreme values during a given period. The components of the CEI are related to the variations in extremes of mean maximum temperatures, mean minimum temperatures, drought, heavy daily rainfall and the number of rain days. Extreme is used to represent either much above normal (above the ninetieth percentile) or much below normal (below the tenth percentile).

An assessment of the modified version of the CEI (mCEI) has been undertaken over the twentieth century using observations from the United States Historical Climatology Network (USHCN). The assessment encompasses annual, seasonal, and regional trends of the modified CEI as well as an evaluation of using daily temperature extremes over the period from 1910-2005. The observed variations have been compared with variations of the index using data from global climate model simulations for the twentieth century that include increasing concentrations of greenhouse gases and the effects of aerosols. Pre-industrial control runs of the global climate models are also used to estimate the natural variability of the index with no greenhouse gas forcing to determine if observed trends are outside the range of natural climate variability. Model data from twentieth century experiment simulations with the NCAR PCM and CCSM3.0, GFDL CM2.0 and CM2.1, and CCCMA CGCM3.1 models, as well as the available pre-industrial control runs for these models have been used.

Observed trends over the last thirty to fifty years in the temperature components of the mCEI for the whole United States, the western, central, and eastern U.S. are found to be statistically significant. Observed increases in the temperature components in the spring and winter are also found to be statistically significant. Daily warm temperature extremes are also shown to have large increases in areal coverage over the last thirty years, and the increase is unprecedented in the observed record. Model simulations for the twentieth century agree relatively well with these increases, and the increase is consistent with the expected response to anthropogenic increases in the concentrations of greenhouse gases. Therefore, the increased areal coverage of warm temperature extremes in the latter half of the twentieth century can be attributed to the anthropogenic increases in greenhouse gases.
Many of the other components of the mCEI do not show significant trends, with the exception of increases of the heavy precipitation component being marginally significant for the entire United States and the eastern portion of the United States. However, overall increases in many of the components, combined with the statistically significant increases in temperature extremes, yields significant increases in the modified CEI as a whole. Interpretation of the increases of the combined mCEI must be done with care by looking at the individual components before reaching a conclusion of the overall change in the observed climate.

Bryan Burkholder completed his MS thesis on this project in May 2007 and a paper arising from his research is being prepared for submission to the journal Science.

This project has been completed.

Publications

Low-pass filtered values of the modified Climate Extremes Index (mCEI) from observations for the US from NCDC (bold, solid), from climate model simulations for the twentieth century (light dash and dot patterns), and the 95% confidence interval for decadal variations of the mCEI (bold, dashed) based on long unforced model control runs. There is a significant increasing trend in the observed mCEI over the 20th century that is outside the range of natural variability and consistent with the model simulations that include changes in anthropogenic climate forcing factors.
NOAA/JCSDA – The Use of Kernel Methods in Data Selection and Thinning for Satellite Data Assimilation in NWP Models
Leslie (primary – OU School of Meteorology), Richman

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Funding Type: CIMMS Task III (Program Manager – Dr. Fuzhong Weng)

Objectives
Funded by the Joint Center for Satellite Data Assimilation, the main objective of the first part of task is to thin the WindSat data; for the second part, the main goal is ingestion and assimilation of scatterometer data from the QuikSCAT instrument.

Accomplishments

Data thinning. To accomplish this task, we apply Support vector machines (SVMs) and then keep only support vectors. To show the quality of those support vectors as predictors, we reconstruct the wind field and then compare it to the observed values. SVMs are a family of learning algorithms used in supervised learning tasks such as statistical classification and regression analysis. To use a SVM method, we need to solve a quadratic programming problems with linear constraints. Therefore, the number of data points used during the training period is critical for the speed of the algorithm. In this work, given the massive number of satellite data, we use Voronoi tessellation to make the analysis efficient.

The primary data provided by WindSat are Sea Surface Wind Speed (SSWS) and Sea Surface Wind Direction (SSWD). In addition to ocean surface wind vector, the WindSat system will provide a host of secondary ocean-scene environmental data products. These products include column integrated Cloud Liquid Water (CLW), column integrated Precipitable Water (PW), and Sea Surface Temperature (SST).

Various experiments were performed. Initially, we used data from 1 January 2005 over the domain spanning the region defined by (127W, 145E) and (23N, 42N). After we removed all data points that have some missing information, we were left with 13,540 points. Previous work on imputation of missing data (Richman et al. 2007) suggests that support vector imputation can be applied to these data to improve the results further for reducing the error in the mean and the variance.

The key results to date for data thinning are that:

- In our experiments we used Support Vector Regression is used successfully to thin the WindSat data.
- Unlike normal quadratic programming, which would not be able to handle the massive data sets generated from WindSat, by applying linear constraints and Voronoi tesselation, the SVM approach sales up efficiently. In the largest experiment attempted, 24 hours of satellite data with over 1.6 million data points, the programs made excellent predictions on a desktop computer in minutes.
- The results obtained show that fewer than 15% of the data are needed to reconstruct the wind field with high accuracy (the correlation coefficient is greater than +0.99).
- The MAE of both the U- and V-components is < 0.6 m/s. This is in the range of uncertainty of the wind observations.
- The geographical distribution of the winds match well to the observed winds at various time scales.

This project is ongoing.
Assimilation of satellite data. Work is continuing on the ingestion and assimilation of scatterometer data from the QuikSCAT instrument. The initial results had a large positive impact on the forecast skill of the OU-HIRES NWP model when the scatterometer data are thinned and included (Fig. 10). The 48 hour forecast error in the OU-HIRES model with the scatterometer data was 146 km compared with 267 km without the scatterometer data. (Leslie and Buckley, 2006).

Recently, work has focused more on the impact of QuikSCAT data over the data sparse East Indian Ocean. The assimilation has been applied to tropical cyclones, mid-latitude cyclones and strong frontal systems. The QuikSCAT data were necessary to obtain realistic results. In the absence of these data, early detection and issuance of marine weather warnings would not have been possible. When the QuikSCAT data were included, the complete life cycles of the all systems (particularly intensification to severe status) was identifiable and verified with observations available in real-time and when post-analysis data became available (Leslie and Buckley, 2007). In the more recent work, the focus was on the impact of QuikSCAT data for the preparation of accurate operational weather forecasts and the timely issuance of severe marine weather and ocean warnings and advisories for major oceanic weather systems, affecting both coastal areas and the open ocean, and which are major forecasting problems facing the all marine meteorology weather programs and forecast centers. In Leslie and Buckley (2007), all results were for the Australian Bureau of Meteorology’s Regional Forecast Centre (RFC) and its co-located Tropical Cyclone Warning Centre (TCWC) in Perth, Western Australia. The region of responsibility for the Perth RFC is vast, covering a large portion of the southeast Indian and Southern Oceans, both of which are extremely data sparse, especially for near-surface marine wind data. Given that these coastline and open ocean areas are subject to some of the world’s most intense tropical cyclones, rapidly intensifying mid-latitude cyclones, and powerful cold fronts (that frequent the southwest corner of Australia), there is now a heavy reliance upon the QuikSCAT data for both routine and severe weather warning forecasts.

The main findings were the need for QuikSCAT data in the Perth RFC for accurate and early detection of maritime severe weather systems, both tropical and extra-tropical. First the role of the QuikSCAT data
was described, and then three cases were presented in which the QuikSCAT data were pivotal in providing forecast guidance. The cases are a severe tropical cyclone in its development phase off the northwest coast of Australia, a strong southeast Indian Ocean cold front, and an explosively developing mid-latitude Southern Ocean cyclone. In each case, the Perth RFC would have been unable to provide the early and high quality forecast and warning guidance without the timely availability of the near surface wind data made possible by QuikSCAT.

This project is ongoing.

Operational track of Severe Tropical Cyclone Clare (January 2006) with HIRES 12 hourly forecasts shown as stars out to 1200 UTC 10 January (times correspond to adjacent analysis positions).

Publications

**NOAA/NWS/OST – Systems Integration and Prototype COOP Operations Management**
**Essenberg** (primary – CIMMS at NERON), R. McPherson, Lamb

**NOAA Strategic Goal 2** (*Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond*)

**Funding Type:** CIMMS Task III

**Objectives**
Research the integration of climate observing stations and communications systems for the NWS COOP Modernization with a prototype operations and monitoring component; investigate solutions to problems or limitations in previous climate observing networks so as to provide advice to the NWS regarding the state-of-the-art in observing systems technologies.

**Accomplishments**
*Documentation and training.* NERON technical plan documents have been completed, including (1) the Plan Functional Requirements document, which adjusted requirements based on a comparison of
requirements and measurement practices recommended or in use by the US Climate Reference Network, NWS climate and aviation directives, the WMO, and state-run mesonets; (2) the addition of a procedure for installing 10-meter wind direction and speed sensors to the Site Installation Plan; (3) a major revision of the Site Installation Plan with Short and Associates to reflect the new site configuration agreed upon by NWS and NESDIS for the modernization of the Historical Climate Network (HCN); and (4) a revision of the Site Maintenance Plan. To improve maintenance technician training, we developed an updated NERON technician training course, including a reference manual for field use. To aid in budget planning and future acquisition should NERON continue, we specified and developed a detailed list of parts necessary to install a modernized HCN station, including cost and vendor information.

**New deployments.** The project staff participated in several new deployments and system improvements. We worked with the Oklahoma Climatological Survey (OCS), the Georgia Bureau of Investigation, and the National Law Enforcement Telecommunications System to coordinate the setup and equipment installation for network and radio telemetry links between the NERON Operations and Monitoring System and three stations of the Georgia Automated Environmental Monitoring Network as a test bed for communication in the Georgia Mesonet. For the New England network, we wrote and released new versions of the data logger software, which update the data report formats for uniformity across logger manufacturers, allow algorithm processing after ingest, and add redundant data transmission at sites with GOES transmitters. In addition, we developed and revised detailed procedures for uploading the new programs. Working with OCS, we developed requirements to improve the metadata database and the associated web-based interface for technicians to track NERON equipment locations and enter trouble ticket problems and fixes, rather than submitting separate electronic documents to an FTP site.

This pilot project is completed.

**Publications**


Meteogram showing one-minute resolution data collected from the Cape Cod National Seashore NERON station during the passage of tropical storm Beryl on July 20, 2006. The top panel shows 1-minute average air temperature, the middle panel shows one-minute average wind direction, wind speed, and one-minute maximum wind speed, and the bottom panel shows the precipitation bucket depths measured independently by the three vibrating wire sensors in the Geonor precipitation gauge. The new data logger code loaded in the loggers in 2006 made the collection of one-minute data during interesting weather events possible at NERON sites with two-way cellular communication.
NOAA/OCO – Program Support for the Assimilation, Analysis and Dissemination of Pacific Rain Gauge Data: PACRAIN
Morrissey (primary – OU School of Meteorology), Postawko, Greene

NOAA Strategic Goal 2 (Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)

Funding Type: CIMMS Task III (Program Manager – Mike Johnson and Joel Levy)

Objectives
Support NOAA’s Office of Climate Observation (OCO) effort to “build and sustain the global climate observing system that is needed to satisfy the long-term observational requirements of the operational forecast centers, international research programs, and major scientific assessments”; continue in our role as the Surface Reference Data Center (SRDC), a core program which supports the Global Precipitation Climatology Project (GPCP) and the Global Energy and Water Cycle Experiment (GEWEX), by expanding our mission to collect, analyze, verify and disseminate global rainfall data sets and products deemed useful for Operational Forecast Centers, International Research Programs and individual researchers in their scientific endeavors. Housed in the Environmental Verification and Analysis Center (EVAC) at the University of Oklahoma, the EVAC/SRDC has built upon work from past NOAA-supported projects to become a unique location for scientists to obtain scarce rain gauge data and to conduct research into verification activities. These data are continually analyzed to produce error-assessed rainfall products.

Accomplishments
Rainfall data is particularly important in the tropics. Not only is it a tracer of latent heat, it is vitally important to the understanding of ocean properties as well, such as latent and sensible heat flux, salinity changes and attendant local ocean circulation changes. In addition, raingauge observations from low-lying atolls are required to conduct verification exercises of nearby buoy-mounted rain gauges, many of which are funded by the OCO Program.

Scientists need only to access the EVAC/SRDC web site, http://www.evac.ou.edu/pacrain, to obtain the most comprehensive Pacific rainfall data set anywhere, and http://www.evac.ou.edu/srdc to obtain critical regional raingauge data sets. Many of these regional data sets are impossible to obtain elsewhere. The EVAC/SRDC serves the research community by actively working with individual countries in environmentally important locations to help provide them with infrastructure, education and other short and long-term support. The return on this investment by NOAA has been significant in terms of enabling EVAC/SRDC to provide the scientific community with critical, one-of-a-kind raingauge data sets and to have established ongoing mutually beneficial relationships which should lead to future collaborations. Past successes with this strategy have proven very worthwhile on a cost-benefit basis.

Due to the importance of tropical Pacific rainfall data to climate research and operational and climate forecasting we are intensifying our efforts by working collaboratively with the Pacific Island Global Climate Observing System (PI-GCOS) program to effectively and efficiently match the areas of commonality among both OCO’s and PI-GCOS’s objectives. One of these common areas is the strengthening of the existing Pacific observation climate networks for both atmosphere and ocean.

Of particular importance is rain rate of which few data records exist in the tropics. This year our project implemented an automate instrumentation program to distribute high quality MetONE tipping bucket rain gauges to various Pacific meteorological services. These gauges each contain a data logger which is read once every three months and contains tip data which is translated into rain rate. The use of data loggers is necessarily useful for the understaffed Pacific meteorological services which do not have the capability of implementing a climate network in their countries which require frequent maintenance and data recording. The data loggers allow a single meteorological staff member to maintain the network and record the data. To date we have sent 50 gauges to 7 Pacific countries and are now receiving tip data from several of these countries. Our goal this year is to have all 50 gauges installed and maintained on an operational basis with regular receipt of data for the PACRAIN data base.
We are using the above strategy to expand our efforts to increase the raingauge climate observing data base representing specific, environmentally critical locations. It is not our intention to collect all raingauge data world-wide, but to assimilate raingauge data 1) in environmentally critical locations (e.g. tropical Pacific), 2) where dense raingauge networks exist and 3) where agreements can be made to help construct raingauge networks in these critical locations. We organized a workshop on automated weather systems for tropics which was held in Noumea, New Caledonia, during June 2006. The members of the workshop recommended that this project go forward with our automated rain gauge instrumentation program and try to expand the automated instrumentation beyond the tipping bucket project.

It is our belief that by working directly with local Pacific Island meteorological services, we bring tangible benefits to the global climate research community through data base enhancement. In turn, the local meteorological services benefit directly through enhanced forecast products developed by the scientific community using these critical data sets.

This project is ongoing.
PUBLIC AFFAIRS AND OUTREACH

NOAA Weather Partners Educational Outreach
D. Thompson (primary – CIMMS at NSSL) and Tarp

NOAA Cross-Cutting Priority *(Promote Environmental Literacy)*

**Objectives**
Provide outreach to the public on the activities of the NOAA Weather Partners in Norman.

**Accomplishments**
NOAA’s Weather Partners offer scheduled tours of the National Weather Center (NWC) throughout the work week for groups interested in learning more about the five NOAA organizations in Norman. These tours are offered to anyone from 3rd grade and up. Between 1 July 2006 and 30 June 2007 more than 3,000 people visited the building during 168 scheduled tours. Tours have been given to public school groups, homeschooled children, private schools, church groups, engineering groups, senior citizen groups, and many others. In the summer of 2007, many science, math, and aeronautic camps also visited the building.

A tour of the NWC includes a presentation about the NSSL along with a weather safety lesson. Visitors then see the 7th floor observatory where the NSSL and ROC radars located on the north edge of Norman are pointed out. The training activities of the WDTB are also discussed. On the second floor, the forecast floors of the SPC and Norman WFO are toured so that visitors can see forecasters at work and learn about the watch/warning process.

Besides the scheduled tours, other large events showcased the various research and forecasting of the NOAA Weather Partners to the public. Among such events, an estimated 3,000 people attended the National Weather Festival on 4 November 2006, 600 visitors came for the Norman Public Library-sponsored Big Read on 9 February 2007, and numerous others toured the building during its official dedication in September 2006.

Additional highlights included tours provided to 200 students attending the Jr. ROTC Honors Camp at the University of Oklahoma, 175 students attending the Lead America program for young pilots, individuals in a French Rotary exchange group, math and science teachers from across Oklahoma, and many families with children interested in becoming meteorologists.

This activity is ongoing.
Daphne Thompson provides a tour presentation to Jr. ROTC Honors Camp participants.

Outreach Activities of CIMMS Staff at WDTB
Lemon, Morris, Wood

NOAA Cross-Cutting Priority *(Promote Environmental Literacy)*

**Objectives**
Inform college students, emergency personnel, and the general public about warning-related research and training.

**Accomplishments**
Outreach activities conducted during the fiscal year include:

- Assisted with planning and conducting National Severe Weather Workshop;
- Hosted delegation from China Meteorological Administration (CMA) during June 2007;
- Conducted 10-day Decision-Making in Weather Impacted Disasters workshop for nine visitors from Indonesia, Nigeria, Sri Lanka, Romania, Philippines, Ethiopia, Russia, and Nepal in partnership with Oklahoma Climatological Survey and United States Telecommunications Training Institute (http://www.ustti.org);
- Attended Norman Chamber of Commerce, Weather Committee and sub-committee meetings;
- Participated as a member of the National Weather Committee Photo Contest committee;
- Participated in the Oklahoma Weather Centennial Day activities at the Oklahoma State Capitol;
- Met with visitors from the Korean Meteorological Association during their November 2006 visit.

These activities are ongoing.
Other Agency – ADVANCE-PAID: Promoting Institutional Change at the University of Oklahoma and within the Big XII Conference
Mavriplis (primary – CIMMS at NSSL), Riley, Murphy, Murphy, Snyder, Kosmopoulou, Damphousse

Funding Agency: NSF

Objectives
Initiate awareness and institutional change for gender and other diversity at the faculty level at OU in the sciences and engineering, in the Big XII Conference, and outreach to the community.

Accomplishments
As part of this project, we have been organizing events on the OU campus to inform faculty and build momentum for institutional change for faculty diversity. In December, we hosted the OU Academic Dual Career Couples for a discussion on the advantages and disadvantages of being a dual-career couple at OU. Other events, such as a distinguished Speaker Lecture Series and Brown Bag Lunches took place throughout the Winter-Spring semester.

Outreach to the community included organizing through the Oklahoma EPSCOR Office a “Women in Science” Meeting for 600 high school students from across Oklahoma in February 2007 at the Oklahoma City Omniplex.

We also trained ourselves for a workshop for Search Committee Chairs and a Chairs Workshop that we will implement at OU. We also met with OU administrators to inform them of the project and to determine what the project could do to help the individual colleges.

A climate survey has been developed and will be administered in the fall. Preparations for the Big XII Workshop on Faculty Recruitment, Retention and Leadership at OU 10-11 January 2008 are underway.

This project is ongoing.

High School girls listen to women scientists speak about their careers at the Oklahoma City Omniplex.
Other Agency – ADVANCE Leadership Award: FORWARD to Professorship
Mavriplis (primary – CIMMS at NSSL)

Funding Agency: NSF

Objectives
Continue to develop and deliver the FORWARD to Professorship workshop for women assistant professors in science and engineering.

Accomplishments
Developed a new writing component for the FORWARD to Professorship workshop and developed a 4-year retrospective survey based the participants from 2003-2006. Also, developed a NIH funding initiative for additional life sciences participants, and a component on stress management and career achievement motivation.

This project is ongoing.

55 participants met in Washington, D.C., for FORWARD to Professorship in May 2007.

Other Agency – Radar Data Assimilation Training for the Indian Meteorological Bureau
Lakshmanan (primary – CIMMS at NSSL), Arthur, Gao, Xue

Funding Agency: USAID

Objectives
Provide training to Indian scientists as the Indian Meteorological Department begins its use of Doppler weather radar.
Accomplishments
CIMMS and CAPS scientists trained three scientists on the control and scanning of radar data, the use of radar data in severe weather forecasting, rainfall estimation, and flood prediction, and in the assimilation of radar data into numerical weather prediction models. Lakshmanan visited two Indian radar sites and assisted radar operators in defining a routine volume coverage pattern suitable for these various uses.

This activity is ongoing.

Other Agency - ARM Program Outreach Activities
M. Shafer (primary – Oklahoma Climatological Survey), Melvin

NOAA Cross-Cutting Priority (Promote Environmental Literacy)

Funding Agency: U.S. DOE

Objectives
Provide outreach support for the Atmospheric Radiation Measurement (ARM) Program to K-12 teachers and students throughout Oklahoma, Kansas, and the U.S.

Accomplishments
ARM Program/SGP educational outreach activities are conducted through the Oklahoma Climatological Survey’s (OCS) Outreach Group. During the fiscal year, the activities were marked most notably by the July 2006 EarthStorm workshop for K-12 teachers, the 2006 National Weather Center WeatherFest, the 15th Anniversary Mesonet/ARM Science Fair, the 2007 ScienceFest, and summer camp presentations for Girls Scouts and Chickasaw Nation students. ARM/SGP Outreach staff presented at the Kansas Association of Teachers of Science Annual Meeting in Junction City, KS, and at regional and local teacher in-services and workshops throughout Oklahoma.

The Southern Great Plains has an educational outreach web site located at http://arm.ocs.ou.edu/. The home page displays observational data from yesterday at your choice of SGP ARM sites. In the data section, visitors can view SGP ARM data using the WxScope Plugin. The data can be displayed as maps of observations across the network, color gradients, or as a time series graph from your selected SGP ARM station. The site provides lessons, glossary, variable descriptions, and information about each of the 3 ARM regions, along with PowerPoint and pdf documents of presentations, posters, and symposium papers.

The 2006 EarthStorm Workshop took place July 17-20 in Enid, Oklahoma at Coolidge Elementary School. Thirty teachers from Kansas and Oklahoma attended. Below is a daily summary of activities followed by teacher comments about the workshop. On the first day the new teachers were introduced to basic meteorology concepts like state variables, observing systems, air masses, fronts, global weather patterns and forecasting. On the second day veteran teachers joined the group to tackle climate, severe weather, and radar topics. Teachers were divided into small groups and given a climate question. They used tools available at http://climate.ocs.ou.edu/ to answer their questions. The third day saw a tour of North Central Oklahoma through Garfield, Kay, and Grant counties. Our first stop was at the ARM Central Facility near Lamont. Dan Rusk provided an overview of ARM programs and the unique instruments used by scientists. We spent about 30 minutes walking around looking at the instruments. Questions were answered by Dan and John Harris. Next, we were off to Ponca City for lunch. Before leaving Ponca City, we stopped at the Pioneer Woman Museum. Our last stop was the Medford Mesonet site, but we made a slight detour to Wakita to visit the home of the Twister Movie museum. It is a small converted garage which contains memorabilia of the movie including Dorothy I. After Wakita, we stopped in Medford. The teachers were able to see an Oklahoma Mesonet station up close. Throughout the bus ride, the teachers watched The Weather in the Classroom DVD series produced by The Weather Channel. Teachers were provided copies of these DVDs in their workshop packets. On the fourth day everyone finally made it through the content lectures. The teachers spent the day using the computers and learning to use the
WeatherScope software. Many of them had not seen the software before. Others were pleased by the expanded graphing features. The software greatly impressed them. The speaker could barely be heard above the side conversations occurring around the room. Each time someone found a new feature there was a gasp then a cry of "Show me!". You could literally feel the steam engine of ideas pick up speed. They were all very excited about how they could use the software with their students. Many of them were pleased that it was user-friendly enough that most students would be able to figure out how to use it on their own. The teachers finished the day anticipating the start of the new school year.

OCS moved into its new home in the National Weather Center building on August 28th. The majority of OCS staff is located on the second floor connected by an interior (non-public) hallway. The Distance Learning Lab is located on the third floor just above the OCS office. The Lab is a new feature to OCS. In the past we had to borrow computer labs from other units. This will allow us to hold workshops when they are convenient for our users instead of when computers are available. September 29th was the grand opening of the National Weather Center. Speakers during the ceremony included: John Snow, Dean, of the College of Atmospheric and Geographic Sciences; Jacqueline Dubois Miller, Meteorology Masters student; David A. Sampson, Deputy Secretary, U.S. Department Commerce; Brad Henry, Governor, of Oklahoma; and David L. Boren, President, University of Oklahoma. A luncheon was provided for guests at the Student Union. The lunch speakers were Jim Cantore from The Weather Channel and Gary England from Oklahoma local television station KWTV (Transcript of speeches - http://www.nwc.ou.edu/pdf/NWCspeeches.pdf). In the afternoon, guests returned to the NWC for a reception and tours of the facilities.

The Oklahoma Climate and Loss Mitigation Conference 2006 was held on October 18th at the NWC. Eighty-three attendees from the insurance industry were treated to a panel of expert speakers from weather to agriculture to emergency management. Participants enjoyed the unique blending of related topics. Many said they would attend future conferences if offered.

Andrea Melvin was asked to speak about OCS Outreach activities at the Oklahoma Environmental Education Coordinating Committee annual retreat. The OKEECC is organized by the Oklahoma Conservation Commission. The committee members are state and federal agencies that provide environmental education resources to Oklahomans. The committee was formed in 1992 by House Bill 2227. At the end of the day Andrea was asked to represent OCS on the committee. Andrea agreed to join the committee. Meetings are held quarterly with one longer meeting a year referred to as the annual retreat.

Andrea Melvin and Andrew Reader presented and exhibited at the Oklahoma Science Teachers Association (OSTA) Conference in Oklahoma City on October 19th. The conference was set up with multiple sessions occurring at the same time. Andrea's talks focused on the outreach programs of the Oklahoma Climatological Survey. Teachers learned about the science fair, speaker's service, and summer workshops. They were provided with information on how to schedule tours of the NWC. Andrew introduced teachers to CoCoRaHS (http://www.cocorahs.org). Teachers can involve their students in daily reporting of rainfall amounts from their school. These data are ingested into the local NWS forecast offices for use in predicting drought and flooding conditions. Andrew was able to provide rain gauges for 5 teachers to take home with them. A donation of $25 helps to offset the cost of the rain gauges. Most observers gladly donate to the program. The program has only been available in Oklahoma since June 2006. Already we have 86 volunteers in 28 of 77 counties signed up to observer rainfall data. At the booth, teachers could sign up for CoCoRaHS and pick up posters, a set of Weather Channel dvds and other information about the Oklahoma Climatological Survey or the upcoming National Weather Festival.

OCS exhibited at the Oklahoma Emergency Management Association Fall Conference held at the Reed Center in Midwest City. The conference brings together the local, county, state, and military emergency managers to discuss issues facing their jurisdictions. The term emergency manager encompasses fire, police, EMTs, and other with responsibilities for public safety. Many Oklahoma agencies helped during last year's Hurricane Katrina. The conference focused on lessons learned during Katrina, response to the winter Oklahoma Wildfires, better ways of communicating between agencies, funding sources, and the restructuring of FEMA. Derek Arndt gave a presentation on OK-First (the OCS emergency management
outreach program) and CASA radar initiative. OCS outreach staff manned a booth in the exhibit hall displaying the latest updates to the web site and new features in the WeatherScope software.

Andrea Melvin and Cerry Leffler hosted a booth called "Air- A powerful force" at the Super Science Night. The booth contained hands-on activities for children to learn about air/wind. Students learned about Bernoulli's Principle of Air Pressure and how an area of low pressure causes objects to move. The museum had booths from 20 different agencies and an attendance of close to 300. The staff at Sam Noble hopes to offer more free science nights in the future.

Even on a cold, windy day the National Weather Festival drew a crowd of about 3,000. The attendance nearly quadrupled any previous open house by the individual agencies. Hourly balloon launches were emceed by meteorologists from the local ABC, CBS, NBC, and Fox affiliates with help from children in the audience. The SMART-R radar and other research vehicles were on display for visitors to view the instruments used when tracking severe storms. Exhibitor booths were located in the National Weather Center Atria with informational handouts, festival t-shirts, and interactive displays. Visitors toured the National Weather Service and Storm Prediction offices. The windowed hallway allowed visitors to see the forecasters at work without disturbing them. The David L. Boren Auditorium was packed most of the day with visitors watching severe weather videos. Outside, Oklahoma Mesonet staff was available at the National Weather Center tower to answer questions and explain how the network benefits Oklahomans. Next to the Mesonet tower was a section of the parking lot dedicated to the Storm Chaser Car Show. Weather enthusiast and storm spotters proudly displayed their weather instruments and ham radio equipment. Twenty-five cars and trucks were on display and eligible for special awards like: "Most Working Sensors", "Most Cutting Edge", "Meatwagon", and Most Hail Damage". If you looked real close, you probably spotted the many NWC agency staff wearing “Ask Me! I'm a Meteorologist!” buttons. These volunteers were available to answer those, "I've always wondered about...” questions. The youngest visitors enjoyed the day eating funnel cakes and Indian tacos from the food vendors in addition to the many activities provided in the Children's Tent. They learned to map wind direction with Oklahoma Mesonet data, classify clouds with the NWS Cloud Spotter Wheels, played Weather Jingo, make groundhog puppets, and took home severe weather safety posters for their walls. The activity booklet provided to visitors was sponsored by Republic Bank & Trust of Norman. Several school buses full of students spent their Saturday enjoying the event. We hope the National Weather Festival will become just as popular to the state as the annual Medieval Fair or Jazz In June. Once the event is established locally, we hope to draw attendance from surrounding states.

The Oklahoma Climatological Survey hosted the December meeting of OKCCEE at the National Weather Center. Committee members spent time going over sub-committee reports and wrap-up from the H2Oklahoma Water Festival that was held in September. Retiring committee members were presented with poinsettia plants. New members to the committee include Andrea Melvin from OCS and Laura McKay from the Oklahoma Mesonet.

Andrea Melvin and Derek Arndt were invited to give a presentation at the EE Expo 2007 on February 8th at the Sam Noble Museum of Natural History sponsored by the Oklahoma Association of Environmental Educators. The conference theme was "From Dust to Dreams". Derek and Andrea's presentation was called "Winds of Change: Ten Events that Impacted History in Oklahoma and Beyond". Derek began with a discussion of significant weather events that changed the way Oklahomans live with extreme weather in Oklahoma. Andrea finished by showing how to use WeatherScope to create custom weather maps and graphs. Additionally, OCS had a booth in the exhibit area. About 40 of the 300 attendees attended the breakout session. The others visited OCS staff at the booth.

Andrea Melvin traveled to Ardmore on February 10th to speak to a group of about 30 retired teachers from Delta Kappa Gamma. She shared pictures of the National Weather Center and spoke about the unique opportunities available now that all the weather agencies are in one building. Andrea shared web address to find weather information and data. The teachers were especially intrigued with the WeatherScope software for creating custom weather maps.

Students from Emerson Junior High (Enid), Gage Junior High, Jefferson Middle School (OKC), Monroe
Elementary (Enid), and Southeast High School (OKC) competed at the 15th Annual OK Mesonet/ARM Science Fair hosted by the Oklahoma Climatological Survey. The science fair had been postponed to February 24 because schools were closed for one week in January. Students and teachers needed additional time to complete their projects. The fair took place inside the National Weather Center. After their projects were judged, students, parents, and teachers toured the new facilities. The judging team spanned all education levels from undergraduates to professional meteorologists. The judges included undergraduates Darren Clabo, Sara Johnson, Melissa Koeka, Nicole Light and Nick Nauslar; graduate students Kodi Nemunaitis, and Justin Monroe; meteorologists Derek Arndt, Dr. Jeffrey Basara, James Hocker, and Andrew Reader from the Oklahoma Climatological Survey; Michael Klatt from the Environmental Verification and Analysis Center; Christopher Godfrey from the School of Meteorology; Dale Morris from NOAA/NWS Warning Decision Training Branch; and Daphne Thompson from NOAA Weather Partners. The judges are key to helping the students critique their projects for regional and state competitions. The time they spend asking questions and making suggestions for additional research encourages the students to improve their speaking skills, board layout and design, unit usage, and catching those pesky spelling errors. A list of overall winners can be found at http://earthstorm.ocs.ou.edu/for_teachers/2007_ov.php, and a list of results is at http://earthstorm.ocs.ou.edu/for_teachers/2007_cat.php. In honor of Oklahoma's Centennial celebration, the OK Mesonet/ARM Science Fair was listed as an official centennial event. Five special awards in addition to the annual awards were presented to students at this year's fair; they can be found at http://earthstorm.ocs.ou.edu/for_teachers/2007_okcent.php.

Andrea Melvin, Nicki Hickmon, Jessica Rathke, Celia Jones, and Dr. Susan Postawko provided information about the National Weather Center agencies, OU School of Meteorology undergraduate programs, the Atmospheric Radiation Measurement Program, and the Oklahoma Mesonet at Women In Science Conference on February 27th at the Omniplex Science Museum sponsored by the Oklahoma Experimental Program to Stimulate Competitive Research (OK-EPSCOR). Conference attendance was about 300 students and teachers. Panel discussions were divided by discipline: natural and environmental sciences, physical sciences and health sciences. Most of the panel speakers were female scientists from each discipline spoke about their careers, educational backgrounds, and how to better prepare in middle and high school for science majors. Nicki was the meteorologist on the physical sciences panel. After lunch, students participated in career planning sessions.

Four schools participated in a special Weather Program at the National Weather Center offered by the Oklahoma Climatological Survey. Andrea Melvin coordinated a full day field trip for each school. Bethel Middle School visited on March 7th with 25 students plus 2 adults. Tomlinson Middle School in Lawton, OK visited on March 28th. The large group (63 students plus 10 adults) resulted in 4 groups and repeated sessions. The only high school group was from Moore High School on April 30th. The smallest student group was from Mulhall-Orlando Middle School with 19 students and 6 adults on May 2nd. The Moore meteorology class consisted of 34 students and 2 adults. The Weather Programs included a basic meteorology lecture, a computer lab to learn to use the WeatherScope software, a tour of the Oklahoma Mesonet calibration lab and tower (located at the back of the NWC parking lot), a tour of the NWC facilities, and a short video on storms.

OCS partnered with The Oklahoman, the state-wide newspaper, on the second series of in-paper articles called Weather Wise which ran in the Oklahoman on April 2-5, 2007. Teachers receive 25 copies of the Oklahoman containing the Weather Wise series. There were over 94,700 individual newspapers containing the Weather Wise lessons delivered to 900 schools. The poster celebrated Oklahoma’s Centennial year with a timeline of weather events from 1907 to 2007. The lesson topics were spring planting, water conservation, severe winds, and wildfires. PDF copies of the articles are available at http://earthstorm.ocs.ou.edu/materials/lessons_OK_arti.php. The Newspapers in Education Staff submitted the 2006 series to the Southern Newspaper Publishers Association. The 2007 Honorable Mention for Best Newspaper in Education Literacy Idea for circulations over 150,000 was awarded to The Oklahoman, Oklahoma City for Weather Wise.

Andrea Melvin served on the National Weather Center Research Experiences for Undergraduates Selection Committee. The selection determined which 10 students should be offered positions in 2007.
summer's program. The committee received nearly 100 applications for the 10 available positions. The applicants came from large schools like Penn State and Purdue to smaller schools like Millersville and Northland College. In April, the committee focused on finding mentors to lead the individual projects conducted by the students. The students were in Norman from May 28th through August 3rd.

Andrea Melvin visited Lexington Middle School to speak with the Science Club about meteorology, automated weather networks, and building weather maps with WeatherScope. About 15 students attended two after school programs held on April 11th and 25th. Using a box of old Mesonet instruments, the students were able to touch and see inside a tipping bucket rain gauge and compare different types of anemometers and pyranometers.

Dr. Suzanne Van Cooten of the National Severe Storms Lab and Andrea Melvin spent the day in Mrs. Kelly Reynolds' class. Topics included fronts, weather safety, careers in meteorology, making maps with WeatherScope, and what classes they should take in high school to prepare for science careers. Dr. Van Cooten and Andrea visited with about 180 students by the end of the day.

ScienceFest 2007 was held on April 19th. We lost about 600 students who were unable to attend due to the scheduling changes of standardized test resulting from the winter storms. However, schools continued to register up to the deadline. On April 12th, training sessions were held for volunteers. On April 13th, committee members and the Zoo’s student volunteers assembled the teacher resource bags. April 18th was the committee work day. Tents, tables, and chairs were disbursed around the zoo to the proper locations for activity stations and exhibitors.

Students learned about air, water, and soil conservation and protection. The activity stations did a wonderful job of engaging the students. Activities ranged from Water Limbo and Survivor to quizzes like Environmental Jeopardy. Students mined for bird seeds and used the sun to cook chocolate cake and cherry upside-down cake. Exhibitors from the Wichita and Washita Wildlife Refuges helped students understand how animals adapt to their environment from the foods they eat to their coverings like feathers and fur. Alternative fuel vehicles run on ethanol and electricity were on display along with a Segway personal transporter. Student took the Earth Day pledge to take care of their environment. They signed pledge pennants that were given to the funding agencies as thank you for making ScienceFest possible.

For Oklahoma's Centennial, the Oklahoma City Zoo opened a new exhibit area celebrating the animals, insects, and plants native to Oklahoma. Students saw animals they don't typically associate with Oklahoma like alligators and bats. The exhibit is arranged by ecoregions. It is amazing to see the predatory animals right next to their prey surrounded by natural vegetation.

ScienceFest included 2 Fin and Feather shows for the first 3000 students who registered. The Fin and Feather shows teach recycling through trained behaviors of sea lions and various birds. This year the shows were introduced by Rick Mitchell, TV meteorologist for KOCO-TV in Oklahoma City. Rick spent time talking with the students about the McReady (www.mcready.org) weather safety program. After each show, students were able to speak with Rick and get autographs. Rick's participation helped to gain needed publicity for the event. Local radio stations also spoke about the event on-air. Three local newspapers did feature articles on the event.

Andrea Melvin and 6th grade teacher Lori Painter from Monroe Elementary in Enid, OK spent a weekend in Kansas at the Kansas Association of Teachers of Science (KATS) annual teacher meeting. They presented two workshops entitled Weather Made By You and Groundhog Weather. Each workshop was presented twice with a total attendance of 15 teachers. Several teachers stopped by and mentioned that they will be coming to EarthStorm and opted to attend other sessions. Attendance for the conference was much lower than in past years. Unfortunately, schools no longer defray the cost for teachers to attend this annual conference.

Al Sutherland and Andrea Melvin presented at the Progressive Ag Safety Day held at the Oklahoma County Fairgrounds. Middle schools students from the Oklahoma Metro area learned about safety issues.
Al and Andrea focused on weather safety ranging from tornadoes to flooding and lightning. Students learned to access radar and surface wind data from the Internet. Students learned the importance of having a NOAA weather radio in their homes and schools but especially carrying a portable one when outside on the farm or at sporting events. Other speakers presented fire, small equipment, ATV, bicycle, firearm, and tractor safety.

As part of the University of Oklahoma's Speaker Service, Andrea Melvin was invited to speak at the Rambling Oaks Retirement Home. Residents learned about creating a disaster supply kit and a preparing a list of important contact information. They learned about tornado, lightning, and flooding safety procedures. Fifteen residents attended this meeting. Rambling Oaks is located across the street from Westmoore High School. Westmoore was damaged during the May 3rd, 1999 tornado. Several residents shared their experiences from 1999.

Lexington Elementary hosted a summer program to bridge the gap between the time school ends and summer camps begin. Guest speakers are invited to read a children's book related to their occupation, provide a craft activity related to the story, and provide a themed snack. Andrea Melvin read "Cloudy With a Chance of Meatballs" by Judi Barrett. Sun Thermometer kits were purchased from a hobby supply company. For snack the children made "sunny faces" made from half a bagel, yellow cream cheese, raisins, and yogurt dots.

Andrea Melvin, Cindy Morgan and Laura McKay worked with 4th grade Girl Scouts to earn their tornado badges. The theme for this year's camp was "Little House on the Prairie" in honor of Oklahoma's centennial year. The girls made cloud wheels to use when identifying and recording daily cloud types. They practiced estimating hail size using wooden balls of various diameters. They learned important weather safety procedures for tornadoes, lightning, and flooding. They looked at items contained in a Red Cross 1-person/3-day disaster supply backpack. The group discussed additional items they would include in their own kits. The girls learned the importance of creating a family emergency contact list. In fine Girl Scouts tradition, the day ended with a song called "Get Prepared!" written by students at Parks Elementary School in Oklahoma City. The song helps kids get prepared during National Preparedness Month annual held in September.

In partnership with the College of Atmospheric and Geographic Sciences and the NOAA Weather Partners Outreach staff, the Oklahoma Climatological Survey hosted Tech Success. Tech-Success is a three year service project geared toward fostering Science, Technology, Engineering and Math (STEM) skills and interests among 110 middle school students with disabilities. Building upon a successful after-school program, High School High Tech, established by a private–nonprofit company, Tech-Now, Inc., the University of Oklahoma plans to create innovative STEM activities for targeted students. The students participated in a similar program to what was provided to the school groups earlier in the year. Dr. Kevin Kloesel had students predict whether or not several "atmospheres" (coffee cups) would produce rainfall. It wasn't enough to get just one student wet (only way to verify rainfall occurred is to measure it or have a witness). The National Weather Service did a special Noon balloon launch so that the students could witness it. After the weather balloon was released, the skies opened and all of us got soaked.

For the second year in a row, NWC agency staff has participated in the Chickasaw summer space camps, C-NASA. The Chickasaws hold two camps each summer: one for middle school and one for high school students. Instead of staff traveling to Ada, the students loaded the travel coach and headed to Norman. They were dazzled by Dr. Kevin Kloesel's (College of Atmospheric and Geographic Sciences) disappearing water. Dr. Suzanne Van Cooten, Chickasaw tribe member and NSSL Research Hydrologist, showed the atmospheric process of distributing heat with a tub full of warm, red-colored water and blue-colored ice cubes. Students could see the cold, blue dye sink to the bottom of the tub and the warm, red dye float to the surface. Eventually, the water turned purple when it reached an equilibrium temperature. Daphne Thompson, NOAA Weather Partners, helped the students make tomatoes in a bottle with a little dish soap and glitter. Andrea Melvin tested the students' estimation abilities with the Hail Box activity. The students watched a short video on the 2006 El Reno, OK tornado which damaged an airplane hanger at a small airport. Andrew Reader from the Oklahoma Climatological Survey showed the students the radar data from El Reno. They built weather maps looking for severe weather ingredients before finally
animating the radar data.

The second FOSS workshop held in Norman was a huge success. While we only had 6 participants along with three instructors from the Lawrence Hall of Science (FOSS kit developers), they were amazed by the National Weather Center Facilities and the openness of the scientists. Workshop participants were from MA, NY, PA, and WV. The workshop consisted of half the time spent on FOSS materials and content and half the time with guest speakers from the NWC or tours of NWC facilities. Dr. Kevin Kloesel, Assistant Dean of the College of Atmospheric and Geographic Sciences gave a presentation on basic meteorology and forecasting. The first day ended quite dramatically when lightning struck the building or very near the building. When the building was evacuated, we decided to end the day early. On Tuesday, Andrea Melvin spoke about the surface observing networks which cover Oklahoma. The afternoon was spent touring the NWC facilities. Wednesday began with a look at meteorology research conducted at the Oklahoma Climatological Survey presented by research meteorologist, Brad Illston. The day ended with a visit to one of the Norman weather businesses, Weather Decision Technologies. J.T. Johnson, Chief Technology Officer, explained how his company benefits by close proximity to university students and research units along with the many branches of the federal government. Friday was another full day of activities. Andrea Melvin introduced the teachers to several weather web pages including the EarthStorm page. Rick Smith from the Norman NWS Forecast Office showed pictures used to train Storm Spotters. The last guest speaker was Derek Arndt of OCS. He spoke about Climate Change and the debate over global warming. The teachers left tired but very excited to share with their students what they did on their summer vacation.

These activities are ongoing.
Appendix A

CIMMS AWARDS AND HONORS

Catherine Mavriplis was presented the NSF ADVANCE Leadership Award

Alexander Ryzhkov was presented the AMS Editor Award for his reviews for the *Journal of Applied Meteorology*

Leon Minton (right) was honored by Interim Director Steven Cooper for his meritorious work as part of the NWS Southern Region Headquarters team.
### Appendix B

#### PUBLICATION SUMMARY

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Theses: M.S. – 8 in meteorology, 1 in math; PhD – 2 in meteorology, 1 in electrical engineering.

(Publication numbers are approximate; those listed throughout this document as “Submitted”, “In Review”, or “To be Submitted” are not included in the above summary; however, those listed in the document as “Accepted” or “In Press” are included in the above summary. CIMMS Fellows are included as CIMMS Lead Authors unless having a Federal affiliation.)
### NOAA Funded Research

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#### Located at NOAA Unit

- SPC – 2
- SRH – 1
- ROC – 10
- WDTB – 10
- NSSL – 60

#### Obtained NOAA employment within past year

- 2
Appendix D

COMPILATION OF CIMMS-RELATED PUBLICATION 2006-2007

A. Peer-Reviewed Journal Articles, Books, and Book Chapters Published, In Press, or Accepted


146


**B. Peer-Reviewed Journal Articles, Books, and Book Chapters Submitted**


C. Other Publications


Dean, A. R., R. S. Schneider, and J. T. Schaefer, 2006: Development of a comprehensive severe weather forecast verification system at the Storm Prediction Center. 23rd Conf. on Severe Local Storms, St. Louis, MO, Amer. Meteor. Soc., CD-ROM.

Dean, A. R., and J. T. Schaefer, 2006: PDS watches: How dangerous are these “particularly dangerous situations?” 23rd Conf. on Severe Local Storms, St. Louis, MO, Amer. Meteor. Soc., CD-ROM.


Douglas, M. W. J. F. Mejia, and T. J. Killeen, 2006: Developing cloudiness climatologies from satellite imagery to map cloud forests and other vegetation features over the tropical Americas, 8th International Conference on Southern Hemisphere Meteorology and Oceanography - 8 ICSHMO, Foz do Iguaçu - PR, Brazil, April 24-28.


Appendix E

EXECUTIVE SUMMARY OF CIMMS STRATEGIC PLAN

See next page