Cooperative Institute for Mesoscale Meteorological Studies

Annual Report
Prepared for the
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Fiscal Year – 2006
Cover figure – Examples of output from the new NSSL Historical Weather Data Archive, showing (from left to right and clockwise) surface data, a time series, an upper-air constant-pressure map, a selection window for choosing a region of the world, and a Skew T/log p chart. The archive is a web-based data portal that delivers surface and upper-air data to the online user. It can be found at http://data.nssl.noaa.gov/. Team members, including David Schultz, CIMMS Scientist at NSSL, and Kevin Kelleher, Deputy Director of NSSL, were awarded the NOAA Tech 2006 Best Presentation: Interactive Web Access to Historical Weather Data Archives.
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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 2006 (1 July 2005 through 30 June 2006), and as such represents the fifth of five annual reports to be written for the present cooperative agreement (NA17RJ1227). It also documents the NOAA-relevant research and outreach activities performed by core CIMMS scientists (based at the university) who are funded by other agencies – these agencies are identified – and also identifies projects that are jointly funded by NOAA and other agencies. Information on publications written, awards received, and employee and funding statistics is presented as well.

**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, as specified in the MOU, by an Advisory Board, Council, and Assembly of Fellows. A 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).

The Advisory Board, chosen with the advice and consent of the Fellows, OAR, NWS, and the university, provides advice on new and existing scientific program areas, and serves in a review and advisory capacity on budgetary and administrative matters. The Board may modify or expand its composition as appropriate to changing needs. Members of the Advisory Board should be well qualified to evaluate the program of the CIMMS, to judge performance, and to make appropriate suggestions for change. Members At Large may be from either U.S. or foreign institutions; their appointments are usually for three years, and are renewable. If requested, the CIMMS Council will submit a slate of nominations for new members or additions to the Advisory Board. The complete Board will meet regularly to review and comment upon CIMMS programs, administration, and budget. Other meetings of the complete Board may
be called by the Chair, by the Provost, by the Directors of OAR or NWS, or by a majority of the members. With the NOAA Science Advisory Board taking over the responsibility of reviewing CIMMS, the CIMMS Advisory Board no longer meets.

The Council meets regularly 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 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 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 Sarkeys Energy Center and also at the offices of the NSSL, SPC, ROC, WDTB, and SRH. Peppler and Reinke held dual offices on campus and at NSSL.

**Executive Summary of Important Activities and Results during FY2006**

**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
- Thunderstorm Electrification and Lightning Experiment (TELEX)
- Thunderstorm studies
- Thunderstorm early detection
- Thunderstorm electrification modeling
- Formation and dynamics of mammatus and thunderstorm outflow anvils
• Collaborative research study of the genesis, evolution, structure, and dynamic climatology of tornadoes and their environments
• Momentum transport processes in tropical warm pool mesoscale convective systems
• Mesoscale dynamics
• Doppler radar data quality control, analyses and assimilation
• Numerical modeling study of the time-dependent behavior of convection
• Vertical vortices in the convective boundary layer
• Dust devil dynamics on Mars
• Evaluation of microphysical parameterizations

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:

• 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
• National Basin Repository
• Polarimetric radar product evaluation
• Severe Hail Verification Experiment (SHAVE)
• WDSS-II development
• WDSS-II and FSI
• Tornado probability forecasting
• Forecast verification
• Value of modernized Mesonet observations for short-range numerical weather prediction
• Multipass distance-dependent weighted average objective analysis
• Comparison of triangulation and pentagon methods for estimating divergence
• Mesoscale research on the North American Monsoon
• Science and technology infusion
• Advancing science to improve knowledge of mesoscale hazardous weather at SPC
• Communicating weather information effectively using the Internet
• Tornado outbreak detection using modern numerical simulations
• Tri-State Tornado reanalysis
• Representing cloud processing of CCN in regional forecast models
• Three-dimensional aspects of droplet nucleation
• Development of a new bulk parameterization of giant CCN
• Verification of cloud microphysical parameterizations
• Contribution to the WRF model development by CAPS

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
- Collaboration and cooperation within the ACMAD Core Demonstration Project in Climate Prediction between ACMAD and CIMMS
- Pan American Climate Studies Sounding Network (PACS-SONET)
- Mesoscale research on the South American low-level jet (SALLJ)

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:

- The Warning Project
- Energy indices
- False alarms and tornado casualties
- 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:

- Study of the significance and mitigation of wind turbine clutter for the WSR-88D network
- Advanced weather studies with the National Weather Radar Testbed
- Quantitative Precipitation Estimation and Segregation using Multiple Sensors (QPE-SUMS)
- VCPExplorer
- CASA radar shear maxima algorithm development
- Polarimetric radar
- WSR-88D estimation of convective boundary layer depth
- Hail detection
- Polarimetric signal processing
- 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
- National Weather Radar Testbed – Phased Array Radar
- Crossbeam wind measurement
• Radar Control Interface
• Stimulus Wizard
• Analysis of weather radar observations of severe convection to understand severe storm processes and improve warning decision support
• NEXRAD technology transfer
• Emergency mobile radar
• Development of mobile X-band weather radar
• Polarimetric upgrade to a mobile C-band weather radar for kinematic and microphysical studies of storms
• Improving tornado detection with WSR-88D data using spectral analysis
• Enhancement of radar retrievals by the use of higher moments of drop spectrum

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
• Climate information for agricultural management in the Southern Great Plains
• Development and application of dynamic normals for investigation of climate variation and change
• Systems integration and prototype COOP operations management
• Prototype a modernization data ingest and quality assurance system for a National Surface Mesonet
• Multicriteria spatial decision support for the NOAA Environmental Real-Time Observation Network
• ARM Program Data Quality Office
• 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:

• NSSL Historical Weather Data Archives
• ARM Program Outreach
• Outreach Activities performed by CIMMS Staff at WDTB

Awards

The following awards were bestowed or nominations made:

• CIMMS Outstanding Paper Award for 2005 – David Schultz, CIMMS Scientist at NSSL, and Jeff Trapp, former CIMMS Scientist at NSSL
• NOAA OAR Outstanding Scientific Paper Award – Igor Ivic, Sebastian Torres, and Dusan Zrnic, CIMMS Scientists at NSSL
• Who’s Who in America – Katherine Kanak, CIMMS Scientist at OU
• Public Service Excellence Award from the Dallas-Fort Worth Federal Executive Board – May 2006 – Leon Minton, CIMMS Scientist at NWS Southern Region Headquarters
Distribution of NOAA Funding by CIMMS Task and Theme

NOAA Funding by Task FY06

- Task I, $341,614, 4%
- Task II, $5,548,031, 73%
- Task III, $1,800,910, 23%
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 August 11, 2005, December 21, 2005, March 23, 2006, and June 27, 2006. A CIMMS Fellows meeting was held on February 9, 2006, at which presentations were made by the Directors of ROC and WDTB on how their units interact with other CIMMS affiliates.

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 Murman, 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. Schaefer, Director, SPC, and Affiliate Professor of Meteorology (ex-officio member)
- Mr. Ed Mahoney, Director, WDTB (ex-officio member)
- Mr. Richard Vogt, Director, ROC (ex-officio member)
- Mr. Mike Foster, Meteorologist-in-Charge, Norman WFO (ex-officio member)
- Mr. William Proenza, Director, NWS Southern Region Headquarters (ex officio member)
CIMMS Fellows membership for August 16, 2005, through August 15, 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 Mavriplis, former Associate Professor of Mechanical and Aerospace Engineering, George Washington University, currently CIMMS Fellow at NSSL
- Dr. Renee McPherson, Acting 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
General Description of Task I Activities

Task I Expenditures
FY06

- $168,910, 50%
- $36,561, 11%
- $21,967, 6%
- $379, 0%
- $113,797, 33%

- Administration
- Research Salaries
- Student Support
- Other Research Support
- Indirect Costs

- 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
RESEARCH PERFORMANCE

Basic Convective and Mesoscale Research

Convective Weather Research – Severe Weather Warning Applications and Development
Dowell (primary – CIMMS at NSSL), Wicker, Burgess

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

Funding Agency: CIMMS Task II – NSSL Project 1

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.

Accomplishments
Techniques for ensemble Kalman filter (EnKF) assimilation of effective reflectivity factor (“reflectivity”) and Doppler velocity observations into numerical cloud models are being examined through the use of observing system simulation experiments (OSSEs). Part I of this study examines EnKF performance in a “perfect model” setting (that is, the same model that produces the reference simulation is used to assimilate observations), focusing particularly on how reflectivity observations should be assimilated and how results depend on convective mode. Future work (Part II) will consider how bias errors in the cloud model and the observations impact assimilation results.

Previous storm-scale EnKF studies (and the current one) have considered assimilation of radar observations of supercell thunderstorms. The current study has also validated the EnKF technique for a squall line. Experiments employing assimilation of synthetic Doppler velocity observations, effective reflectivity factor observations, and velocity together with reflectivity observations reveal the different roles that these observations can have in initializing storm-scale models. Doppler velocity observations provide relatively more information about the kinematic fields and cloud-water distributions inside thunderstorms. However, since Doppler velocity observations are only available in limited regions (only in precipitation or in “clear air” near the radar), spurious convective cells can develop in ensemble members during the assimilation. Assimilating only reflectivity observations produces accurate retrievals of hydrometeor fields in these experiments, but this success depends on the perfect-model assumption. In imperfect-model experiments, a mismatch between the precipitation microphysics parameterization in the reference simulation and the assimilation model makes assimilation of reflectivity observations problematic in precipitation regions. All experiments show great value in assimilating the low-reflectivity observations in precipitation-free regions because these observations suppress the spurious convective cells that can develop in some ensemble members. A simple method that requires less computation than the EnKF but that still suppresses spurious cells in low-reflectivity regions has been developed.

The observation operator (i.e., the function that maps the model variables to observation space) for reflectivity is nonlinear, which could lead to suboptimal EnKF performance. Current work is examining the impact of this nonlinearity, for assimilation of reflectivity observations either on the linear scale or the more customary logarithmic (dBZ) scale.

This project is ongoing.

Publications
Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – Thunderstorm Electrification and Lightning Experiment (TELEX)

MacGorman, Rust (primary – NSSL), Schuur

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

Funding Agency: CIMMS Task II – NSSL Project 6 and NSF

Objectives
Investigate unique electrical and lightning properties of large storm systems.

Accomplishments
TELEX (http://www.nssl.noaa.gov/projects/telex/index.html) is a five-year project, funded in part by the National Science Foundation. We are in year three, having completed the field phase in 2004 when several upgraded observing systems operated in central Oklahoma: the polarimetric modified WSR-88D 10-cm wavelength Doppler radar (KOUN), the Oklahoma three-dimensional lightning mapping array (OK-LMA), the two SMART Radars, mobile environmental soundings, and a mobile laboratory for storm intercept and mobile ballooning with up to four balloon soundings being made simultaneously. Thirty-six instrumented-balloon flights, each with a GPS radiosonde and an electric field meter, were made in 2004 into storms during thirteen ballooning missions. (In the initial, smaller field deployment in 2003, seven missions with 14 flights were done.) In both years, the flights were into a variety of storm types, including multicellular storms, supercells with and without tornadoes, and mesoscale convective systems.

The research being conducted in the wake of TELEX will enhance the knowledge of the electrical structure of large stratiform regions. Polarimetric radar data are being used in conjunction with electrical and lightning mapping information to develop conceptual models and numerical model enhancement to ascertain the effects of electrical structure and lightning on storm development.
This project is ongoing.

**Publications**


**Convective Weather Research – Thunderstorm Studies**

**MacGorman** (primary – CIMMS at NSSL), Rust, Schuur

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

**Funding Agency:** CIMMS Task II – NSSL Project 1 and NSF

**Objectives**

Increase understanding and applications of severe and hazardous convective weather; test and revise hypotheses concerning the inter-relationships among the wind field, microphysical characteristics, electrical structure, and lightning of isolated severe storms and of large storm systems.

**Accomplishments**

This new addition to our research seeks to analyze in situ observations of the vertical profiles of atmospheric thermodynamics, wind, and electric field vectors, and to analyze high time and space

**TELEX balloon launch and subsequent observation in 2004.**
mapping of total lightning and polarimetric radar. The blend of lightning and kinematics will improve research models of storm behavior and hazards. These data will be obtained in part using unique radars, balloon-borne sensors, and our three-dimensional lightning mapping array. This effort is underway with analyses of observations made in central Oklahoma in spring of 2003 and 2004. The first results, which show intriguing polarimetric radar signatures related to the electrification, are in the publication process.

This project is ongoing.

**Publications**


**Thunderstorm Early Detection**

*MacGorman* (primary – CIMMS at NSSL)

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

**Funding Agency:** CIMMS

**Objectives**

Compare the timeliness and reliability of thunderstorm detection with various lightning detection capabilities.

**Accomplishments**

Analysis was performed to compare the timeliness and reliability of thunderstorm detection with various lightning detection capabilities. Compared were the time at which the Oklahoma Lightning Mapping Array, which detects all types of lightning, detected the first flash in a storm and the time at which the National Lightning Detection Network (NLDN) detected the first flash of various types. Most flashes detected by the NLDN were cloud-to-ground flashes, but a limited cloud-flash detection option for the NLDN was enabled for this evaluation to examine how much thunderstorm detection would be improved by this option. Analyses continue.

This project is ongoing.
Publications

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – Thunderstorm Electrification Modeling
Mansell (primary – CIMMS at NSSL), Ziegler, Straka, MacGorman

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

Funding Agency: CIMMS Task II – NSSL Project 6 and NSF

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

Accomplishments
Microphysical and electrification parameterizations have been ported into a new version of the Collaborative Model for Multiscale Atmospheric Simulation (COMMAS). The COMMAS framework is more suited for student and classroom use (planned for fall 2006). Work on a full two-moment version of the 10-ice microphysics scheme was suspended in favor of reimplementing the simpler two-moment scheme of Ziegler (1985). The Ziegler scheme, which had never been used in a dynamic simulation model, has five hydrometeor categories: cloud droplets, rain, ice crystals (column ice), snow, and graupel. The Ziegler scheme has performed very well in preliminary tests of an intense supercell storm (without electrification) and a small airmass storm (with electrification and lightning).

This project is ongoing.

Publications
Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – Formation and Dynamics of Mammatus and Thunderstorm Outflow Anvils
Schultz and Kanak (Primary – CIMMS at NSSL and CIMMS at OU), Straka, Trapp, Gordon, Zrnic, Durant, Garrett, Kastner-Klein, Lilly

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

Funding Agency: CIMMS Task II – NSSL Project 6 and NSF

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 to 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 times scales 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
Collaborative Research Study of the Genesis, Evolution, Structure, and Dynamic Climatology of Tornadoes and Their Environments
Alexander (primary – OU School of Meteorology), Dowell, Biggerstaff, Carr, Shapiro, Wicker, Wurman

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

Funding Agency: NSF

Objectives
Construct a tornado climatology based upon high resolution radar observations of tornado structure, including quantifying the means, distributions and (co)variances of kinematic properties (velocities, vorticity, divergence, wavenumbers etc.) in tornadoes, and provide a calibration to the Fujita scale by comparing frequency distributions of radar-based and damage-based tornado intensity estimates.

Accomplishments
This work consists of two components. The first studies low level winds in tornadoes and the potentially catastrophic impacts tornadoes have in urban areas. Using an axisymmetric model of tornado structure tightly constrained by high resolution wind field measurements collected by Doppler On Wheels (DOW) mobile radars (from approximately 54 tornado days), the potential impacts of intense tornadoes crossing densely populated urban areas are evaluated. DOW radar measurements combined with in situ low level wind measurements permit the quantification of low level tornadic winds that would impact structures. Axisymmetric modeled wind fields from actual and hypothetical tornadoes are simulated to impact high density residential and commercial districts of several major cities. United States census block data, satellite imagery, and other sources are used to characterize and count the number of structures impacted by intense winds, up to 132 m s\(^{-1}\), and estimate the level and cost of resulting damage. Census data are used to estimate residential occupancy and human casualties. Results indicate that a large and intense tornado crossing through residential portions of Chicago could result in tragic consequences with winds in excess of 76 m s\(^{-1}\) impacting 99 km\(^2\), substantially destroying up to 239,000 single and dual-
family housing units, occupied by up to 699,000 people, resulting in 4,500 - 45,000 deaths, and causing substantial damage to over 400,000 homes occupied by over 1,100,000 people (see first figure below). Widespread damage caused by winds exceeding 102 m s\(^{-1}\) could occur over a broad area of the high rise office and apartment districts causing permanent structural damage to many such buildings. Smaller and less intense tornadoes would cause lesser, but still substantial levels of damage and mortality. Tornadoes crossing Houston, Dallas-Fort Worth, New York City, St. Louis, Washington, D.C., and Atlanta could cause varying levels of damage and mortality.

The second study performs a dual-Doppler and single-Doppler analysis of a tornadic storm undergoing mergers and repeated tornadogenesis. Dual-Doppler observations with unprecedented fine-scale spatial and temporal resolution are used to characterize the vector wind field in and near a tornado occurring near Kiefer, Oklahoma on 26 May 1997. Analyses of the dual-Doppler vector wind fields document in detail, for the first time, several structures associated with the tornado: a proximate updraft region, a rear flank downdraft wrapping around the tornado, a double gust front structure occluding near the tornado, and a region of enhanced vorticity separated from the tornado that may have been associated with cyclic tornadogenesis (see second figure below). The analyses are compared to conceptual and computer models of tornadic storms. A subsequent tornadogenesis was observed with radar every 18 seconds, providing a fine-scale temporal view of the genesis process. The genesis process was complex and the evolution of tornado intensity parameters was not monotonic in time. Low level rotation contracted and intensified, then broadened, then contracted and intensified a second time to form the tornado. The initial tornadogenesis was coincident with the merger of the main supercell and a much smaller convective storm. This tornado, which was always surrounded by substantial precipitation originating from both storms, began to dissipate just a few minutes after genesis, and the rotation both aloft and near the surface weakened substantially. A second storm merger, with a much larger and supercellular storm, was coincident with a reintensification of the mesocyclone aloft, new hook echo development, and the genesis of a short lived tornado. After the dissipation of this second tornado, the merger disrupted the structure of the supercell storm, the hook echo was absorbed, and the mesocyclone dissipated. The current analysis suggests a process in which storm mergers may, in sequence, aid tornadogenesis by enhancing surface convergence, or through another mechanism, but subsequently disrupt the tornado’s parent supercell in part by cooling the inflow air, with the result being short lived tornadoes.

These projects are ongoing.

**Publications**


Tracks of simulated tornadoes across Chicago. Track of the tornado center (black) and outlines of regions impacted by 120 (red), 102 (orange), 76 (yellow), 59 (green) and 43 m s$^{-1}$ (cyan) peak wind speeds shown. Population densities are much higher than those in Oklahoma City, over which the intense BC tornado actually crossed. Black cross-track line (BC panel) is break between low rise housing and high rise housing areas, green alternate tornado center tracks (BC panel) are those used in sensitivity study. Pink track is “worst case” track through length of high density residential regions.
The 0.5° elevation scan of convective storms A, B, A’, and C from KIX (located just off the upper right corner of the panels) showing base reflectivity (left panels) and Doppler velocity (right panels) at several times during the evolution of the tornadoes near Kiefer and Glenpool Oklahoma. The locations of DOW2 (red circle) and DOW3 (green circle) are shown.

Momentum Transport Processes in Tropical Warm Pool Mesoscale Convective Systems

Mechem (primary – CIMMS at OU), Chen, Houze

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

Funding Agency: NSF, ONR, NOAA, DOE

Objectives
Evaluate upscale feedback of the stratiform regions of mesoscale convective systems onto the large scale tropical circulation.

Accomplishments
Momentum transport by the stratiform components of mesoscale convective systems (MCS) during the Tropical Ocean-Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA COARE) in December 1992 was investigated using a multiscale modeling approach. Mesoscale momentum transport by the stratiform regions of MCS was examined in two distinct large-scale flow regimes
associated with the intraseasonal oscillation over the western Pacific warm pool. Simulations were conducted representing the “westerly onset” period, which has relatively weak low-level westerlies with easterlies above, and the “strong westerly” regime, when westerlies extend from the upper troposphere to the surface.

In the westerly onset simulation, the extensive stratiform region of an MCS contained a broad region of descent that transported easterly momentum associated with the mid-level easterly jet downward. Thus, the stratiform regions acted as a negative feedback to decrease the large-scale mean westerly momentum developing at low levels. In the strong westerly regime, the mesoscale downward air motion in the stratiform regions of large MCS transported westerly momentum downward and thus acted as a positive feedback, strengthening the already strong westerly momentum at low levels. Momentum fluxes by the mesoscale stratiform region downdrafts have systematic and measurable impact on the large-scale momentum budget.

This project is completed.

**Publications**


Representative vertical cross sections of perturbation zonal velocity. Arrows represent downward transport of mid-level easterly momentum and westerly represent downward transport of mid-level easterly momentum and westerly momentum in the westerly onset and strong westerly simulations, respectively. Profiles show mean flux <w'u'> and flux divergence F_u averaged over the stratiform MCS regions.
Mesoscale Dynamics
Xu (primary – NSSL), Lei, Gao, NSSL scientists, Institute of Atmospheric Physics – Beijing

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

Funding Agency: NSF

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.

Accomplishments
Maximum non-modal growths of total perturbation energy are computed for symmetric perturbations constructed from the normal modes. The results show that the maximum non-modal growths are larger than the energy growth produced by any single normal mode for a give optimization time, and this is simply because the normal modes are non-orthogonal (measured by the inner product associated with the total perturbation energy norm). It is shown that the maximum non-modal growths are produced mainly by paired modes, and this can be explained by the fact that the streamfunction component modes are partially orthogonal between different pairs and parallel within each pair in the streamfunction subspace. When the optimization time is very short (compared with the inverse Coriolis parameter), the non-modal growth is produced mainly by the paired fastest propagating modes. When the optimization time is not short, the maximum non-modal growth is produced almost solely by the paired slowest propagating modes and the growth can be very large for a wide range of optimization time if the parameter point is near the boundary and outside the unstable region. If the parameter point is near the boundary but inside the unstable region, the paired slowest propagating modes can contribute significantly to the energy growth before the most unstable mode becomes the dominant component.

The maximum non-modal growths produced by paired modes are derived analytically. The analytical solutions compare well with the numerical results obtained in the truncated normal-mode space. The analytical solutions reveal the basic mechanisms for four types of maximum non-modal energy growths: the PP1 and PP2 non-modal growths produced by paired propagating modes, and the GD1 and GD2 non-modal growths produced by paired growing and decaying modes. The PP1 growth is characterized by the increase of the cross-band kinetic energy that overly offsets the decrease of the along-band kinetic and buoyancy energy. The situation is opposite for the PP2 growth. The GD1 (or GD2) growth is characterized by the reduction of the initial cross-band kinetic energy (or initial along-band kinetic and buoyancy energy) due to the inclusion of the decaying mode.

This project is ongoing.

Publications

Doppler Radar Data Quality Control, Analyses and Assimilation
Xu (primary – NSSL), P. Zhang, Nai, Wei, Lu, NSSL scientists, NRL, IAP, Lanzhou University

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

Funding Agency: CIMMS Task II, NSSL, ONR

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

**Radar wind retrieval system.** A two-dimensional form of cross-covariance function between the radar radial- and tangential-components (with respect to the direction of radar beam) of background wind errors is derived. Like the previously derived auto-covariance function for the radial-component, this cross-covariance function is homogeneous but non-isotropic in the horizontal. The auto- and cross-covariance functions are used with the statistical interpolation technique to perform a vector wind analysis from Doppler radial-velocity observations on a conical surface of low-elevation radar scans. The structures of the two covariance functions are compared and interpreted in terms of the influence of a single-point radial-velocity observation on the analyzed vector wind field. The utility and value of these covariance functions are demonstrated through analysis experiments that use either simulated radial-velocity data from idealized flows or real radar observations. The results of the statistical interpolation scheme utilizing the proposed covariance functions are shown to be superior to the results of traditional VAD technique. The proposed technique can actually be considered a generalization of the traditional VAD technique. This technique is being developed with the radar data quality control package into an automated radar wind retrieval system to produce high-resolution (2 km) vector wind fields for emergency response dispersion models at the Pacific Northwest National Laboratory. An example of the retrieved vector wind field is shown in the first figure below.

**High-resolution error covariance estimation using phased array radar observations.** By using the non-isotropic form of error covariance function derived for radial-velocity fields on conical surfaces of low-elevation radar scans, the conventional innovation method is reformulated 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 obtained from low-elevation radar scans for real cases. The results show that radar radial-velocity observation errors are correlated between neighboring range gates and between neighboring beams. The radial-velocity observation error correlation functions are estimated along with the observation error variance and background vector wind error covariance functions by the reformulated method. The estimated observation error correlation functions are plotted in the second figure below for two cases: (i) phased-array radar observations collected for a squall line on 2 June 2004, and (ii) NSSL KOUN radar observations collected for calm weather on 9 May 2004. As shown, the phased-array radar radial-velocity observation errors are correlated up to \( r = 3 \text{ km} \). The error standard deviation is 3.9 m s\(^{-1}\) (not shown). The KOUN radial-velocity observation errors are correlated only up to 2 km, and the error standard deviation is only 2.1 m s\(^{-1}\). The differences between the two types of observations can be explained in terms of instrumentation error and sampling error. First, the current phased-array radar (at the National Weather Radar Testbed in Norman) has less detection power and resolution than the KOUN. Limited by the size of the antenna, the phased-array radar beam is wider (about 1.7 degree depending on the viewing angle with respect to the antenna facing direction) than the KOUN beam (about 1 degree). This explains the above differences in terms of instrumentation error. Secondly, the phased-array radar observations were collected for a squall line, while the KOUN observations were collected for calm weather on 9 May 2004, so the above differences can be also partially due to different sampling errors. This new innovation method is being tested with a variety of radar radial-velocity innovation data. The method will be further improved, so it can take as much as possible the advantages of phased-array rapid and flexible scan capabilities to estimate the observation and background error covariances in real time for phased-array radar data assimilation

These projects are ongoing.

**Publications**


*KTLX observed reflectivity (left panel) and radial-wind (color field, right panel) overlaid with the retrieved wind vectors on 0.5° elevation at 20:09 UTC on July 12, 2003. The yellow and white dashed lines mark the boundaries of wind shear and convergence.*

*Observation error correlation data points: + for phased-array radar, and • for KOUN. Estimated observation error correlation functions $R_{ll}(r)$ (blue) and $R_{tt}(r)$ (red): solid for the phased-array radar, and dashed for KOUN.*
**Numerical Modeling Study of the Time-Dependent Behavior of Convection**
Doswell (primary – CIMMS at OU), Weber, Loftus, Baranowski

**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 work involves the use of a 3-dimensional cloud model ARPI3 (similar to the ARPS model), developed by Daniel Weber (CAPS). We have completed the second year of a NSF-funded three-year project. Early simulation study results can be viewed at http://www.caps.ou.edu/~dweber/bubbles.html. This work is in the process of being prepared for formal submission to *Monthly Weather Review*. Work by graduate student Benjamin Baranowski has been completed on the effects of resolution on the simulations.

This project is ongoing.

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

**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**
- **Quiescent environments.** Three-dimensional, two-meter resolution boundary layer LES have been conducted, the results of which exhibit vertical vortices with dust devil-scale motions. This is likely the first LES to resolve and simulate vertical vortices with dust devil characteristics. The vortices’ structure and intensity are compared to those of dust devil field observations by Sinclair and others. The latest results (2 m and 6 m resolution simulations) show that vertical vortices often form in a bookend vortex pattern with pairs of counter-rotating vortices. This structure implies that asymmetries in the convective cell pattern may be responsible for local horizontal jets that are associated with local horizontal wind shears. These may be a source of vertical vorticity for the dust devil-like vortices. It also appears that many vortices have quite asymmetric structure, with much stronger winds on one side of the vortex than the other. Similarly, the maximum updraft and minimum pressure centers are often offset from the center of the circulations. Preliminary analysis of terms of the vertical vorticity budget suggest that tilting terms are significant on one side of the vortex (where the wind speeds are greatest), and the stretching terms are relatively small in association with established vortices. A vortex detection algorithm is being applied to the data to quantify the existence and physical characteristics of the simulated vortices. The algorithm is based on the procedure described by McWilliams et al. (1999).

- **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 newly completed 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

Dust Devil Dynamics on Mars
Kanak (primary – CIMMS at OU), Cantor, Edgett

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

Funding Agency: CIMMS Task I and NSF

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. 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). A paper authored by Kanak is planned for these results, for submission to Journal of Geophysical Research – Planets.

This project is ongoing.

Publications
Top: sub-domain of XY cross-section at \( t = 4580 \) s and \( z = 21 \) m of vertical vorticity with every other wind vector overlain. Maximum vector length is 11 m s\(^{-1}\). Maximum value (red) is 0.198 s\(^{-1}\), minimum value (gray) is -0.32 s\(^{-1}\), and the contour interval is 0.037 s\(^{-1}\). Bottom: sub-domain XZ cross-section at \( t = 4580 \) s and \( Y = 1820 \) m of vertical vorticity. Cross-section is taken along the black line in (a). Maximum value (red) is 0.18 s\(^{-1}\), minimum value (gray) is -0.33 s\(^{-1}\) and the contour interval is 0.066 s\(^{-1}\). Zero values are denoted by yellow.
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: CIMMS Task I and NSF

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, $n_0$, is diagnosed or specified but not predicted. The moment methods explored include:

- Scheme-A: the one-moment method where $q$ is predicted, $n_0$ 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 $n_0$ are diagnosed;
- Scheme E: the two-moment method where $q$ and $D_n$ are predicted, and $N_t$ and $n_0$ are diagnosed;
- Scheme F: the two-moment method where $q$ and $N_t$ are predicted, and $n_0$ and $D_n$ are diagnosed.

In order 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 $n_0$ introduction of new particles ($dN_t/dt = 0$). 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
Forecast Improvements

Warning Decision-Making Research and Training – Advanced Warning Operations Course (AWOC)
Decker, Hoggard, Magsig, Mohammad Said, Schlatter, Sessing, Wood, X. Yu, Schultz, NWS/WDTB collaborators

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

Funding Agency: CIMMS Task II – WDTB

Objectives
Investigate winter weather warning decision making issues with NWS forecasters and transfer that knowledge to new NWS forecasters to improve performance.

Accomplishments
Warning decision-making analysis is a significant area of active collaborative research between CIMMS and the NWS Warning Decision Training Branch. As winter weather warning performance is critical to the country, two of the 14 NWS Government Performance Review Act (GPRA) goals involve winter weather warning performance. As a result of the effective, cost-efficient manner in which the Core and Severe Tracks of the Advanced Weather Operations Course (AWOC) were delivered to every forecaster in the NWS, a Winter Weather track was added to the AWOC for delivery prior to the 2006-2007 winter season.

The AWOC Winter Weather Track utilized Subject Matter Experts from across the country working in conjunction with CIMMS and NWS WDTB staff to develop over 20 hours of online training. The training content covers such topics as precipitation-type forecasting, climatology, forcing mechanisms, winter weather simulations, and user needs. CIMMS staff played a vital role in establishing the course content, determining the learning and performance objectives, establishing innovative ways to work collaboratively with other team members on their topics, and developing a winter weather simulation that could be used to evaluate how forecasters learned the course material.

The AWOC Winter Weather Track officially opened on June 5, 2006. The course is intended for every NWS forecaster who has responsibility for winter weather warning issuance. In the first two months since the course’s initial offering, almost 500 NWS personnel have started taking the course with approximately 59 people having completed all of the on-line portions of the training.

This project is ongoing.

Publications
WDTB AWOC official site: http://www.wdtb.noaa.gov/courses/winterawoc/index.html
AWOC Winter Weather Track statistics for all NWS personnel completing their first lesson since the initial delivery date of June 5, 2006.

Warning Decision-Making Research and Training – *AWIPS and WSR-88D Improvements*
Decker, Magsig, Schlatter, Wood, NWS/WDTB collaborators

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

**Funding Agency:** CIMMS Task II – WDTB

**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) 6.0 and 7.1 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 OB6 and OB7 well before it was 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 the OB6 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 ORPG Build 8 by assessing the contents of each build, investigating the build integration and testing process, and providing prototype materials for training to WDTB instructors during Beta Testing. CIMMS staff also served as backups to WDTB instructors during the teletraining of the Build 8 material. See publications for a link to the ORPG Build 8 training.

This project is ongoing.

Publications

Warning Decision-Making Research and Training – NOAA’s NWS Weather Event Simulator
Decker, Hoggard, Magsig, Mohammed Said, X. Yu, NWS/WDTB collaborators

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

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 fifth 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 take two simulations using the WES for each significant weather season per year. The WES has also been a key part of the Warning Decision Training Branch’s (WDTB) major new training initiative, the Advanced Warning Operations Course (AWOC). In AWOC, the WES was used by every student to apply AWOC learning in an operational context.

The WDTB is responsible for implementing the WES into NWS training, and CIMMS scientists support this initiative. Keeping WES up to date 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, and they create, test, distribute, and support WES for the NWS. CIMMS have also been proactive in releasing WES to non-NOAA collaborators and encouraging collaboration between NOAA and non-NOAA agencies.

In the past year, CIMMS scientists collaborated with the WDTB, the Forecast Systems Laboratory (FSL), the Meteorological Development Laboratory (MDL), and the Office of Science and Technology (OST) to develop and release several new versions of WES. WES5.0 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 5 of AWIPS, including new functionality such as the Terminal Doppler Weather Radar and the “Dig Digital Mesocyclone Detection” product. Additional improvements to the WES software included more realistic radar base data processing by utilizing fifteen second search intervals, and a new tool to allow for enhanced case review of static data sets. Improvements to the WES5.0 version of the WES Scripting Language (WESSL) included added image viewing capabilities and a new scrolling text tool.
WES6.0 was completely developed and deployed in the last CIMMS year. WES6.0 supported AWIPS Operational Build 6 including new functionality such as the Time of Arrival Tool and Enhanced FFMP performance. WES6.0 also supported the AWIPS OB6 change from an Informix text database to PostGres. This was a major change and required many changes to the Weather Event Simulator infrastructure. Also included in WES6.0 were many improvements to the WES Scripting Language (WESSL) version 6.0. WESSL now has the ability to pause simulations, show videos and launch Flash presentations.

Development of new WES functionality in support of the WDTB Winter Weather AWOC course also began in the past year. This update, called WES6.0ww, adds the AWIPS GFE (Graphical Forecast Editor) functionality to the WES. Forecasters use GFE to create gridded forecast datasets for the National Digital Forecast Database. They also use GFE to create longer fused watches and warnings, such as winter storm warnings. WES6.0ww contains a tool to generate gridded datasets, and it provides the infrastructure to run GFE in a simulation. WESSL was also updated in WES6.0 to provide an easier way to record and review input generated from query response boxes in a simulation. WES6.0ww is planned to be released in summer of 2006.

Development on WES7.1 began in the past year as well. CIMMS scientists integrated with AWIPS developers to begin working on incorporating OB7.1 into WES. OB7.1 and WES7.1 are planned to be released in fall 2006.

This project is ongoing.

**Publications**

![WES graphical interface](image)

*The WES graphical interface.*
Warning Decision-Making Research and Training – Distance Learning Operations Course (DLOC)
Decker, Hoggard, Magsig, Mohammad Said, Schlatter, Wood, X. Yu, NWS/WDTB collaborators

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

Funding Agency: CIMMS Task II – WDTB

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 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 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
Web Guides:
Introduction to the WSR-88D: http://www.wdtb.noaa.gov/courses/dloc/topic2/index.html
Warning Decision-Making Research and Training – *Training and Research Toolkit*
Hoggard, Mohammad Said, X. Yu, NWS/WDTB collaborators

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

**Funding Agency:** CIMMS Task II – WDTB

**Objectives**
Provide an advanced, effective and flexible platform and environment for interactive learning and research; design and develop techniques and tools which can be transferred to the NWS community for the operational forecasting or researches, and used 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 the tools. CIMMS staff successfully developed an advanced, efficient and flexible platform, LabControlPanel. With this platform, the handy and time consuming of setting up and managing the lab became very efficient, 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 in workshops, such as the NOAA’s NWS Advanced Warning Operations Course (AWOC) and the Distance Learning Operations Course (DLOC).
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 new 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 function directly benefits the simulation training.

This project is ongoing.

Publications
Sounding Toolkit 1.3: http://140.90.90.253/~applications/LAD/generalappinfoout.php3?appnum=1050
Warning Decision-Making Research and Training – *Real-Time System*
Decker, Hoggard, Magsig, Mohammad Said, Schlatter, X. Yu, NWS/WDTB collaborators

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

**Funding Agency:** CIMMS Task II – WDTB

**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.

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, such as radar data across the country. The new improvements also ensure the system running stably and efficiently.

This project is ongoing.

Quantitative Precipitation Estimation and Segregation Using Multiple Sensors – *National Basin Repository*
Arthur (primary – CIMMS at NSSL), Howard, Xia

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

**Funding Agency:** CIMMS Task II – NSSL Project 2

**Objectives**
Develop a repository to store, manage and serve the various spatial datasets that have been developed at NSSL

**Accomplishments**
To allow greater flexibility for expansion and improvement of the AWIPS Flash Flood Monitoring and Prediction (FFMP) system, a repository for the FFMP basin and stream GIS datasets has been assembled. This repository is powered by the ESRI ArcIMS software and Data Delivery Extension, and has a web interface through which users can view, query, and download FFMP basin and stream shapefiles for user-specified domains. To populate the repository, existing radar-centric FFMP basin and stream shapefiles for the CONUS were mosaiced into seamless, hydrologically-connected coverages for the nation. Additional Alaska basins and streams that were outside the existing radar-centric FFMP
domains have been delineated and will be mosaiced into a seamless, hydrologically-connected coverage to be included in the repository along with the other OCONUS sites (Hawaii, Guam, and Puerto Rico).

The FFMP basin dataset developers at NSSL continue to provide technical support to NWS Forecast Office staff and other data users to assist them in understanding and/or customizing their spatial datasets, ranging from e-mail and phone assistance to performing various customization tasks.

This project is ongoing.

**Publications**


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**Severe Weather Warning Research and Application Development – Polarimetric Radar Product Evaluation**

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

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

**Funding Agency:** CIMMS Task II – NSSL Project 3 and ROC

**Objectives**

Distribute examples of candidate products for the dual-polarization WSR-88D to numerous agencies within FAA, DoD/AFWA, and NOAA/NWS to solicit their comments and evaluation.
Accomplishments
Dual-polarization radar data cases selected were chosen to cover a wide variety of cases including severe thunderstorms, general rainfall, snow, mixed-phase precipitation, and significant contamination from non-precipitating echoes. These products and associated questionnaires were sent to numerous government agencies involved in operational meteorology for their comments and evaluation.

Many of these products have been developed by CIMMS/NSSL scientists. Feedback gathered will be used over the next year to refine these products before the national upgrade of the WSR-88D that will introduce dual-polarization capabilities to the nation's weather radar network.

This project is ongoing.

Severe Hail Verification Experiment (SHAVE)
Smith (primary – CIMMS at NSSL), Burgess, Echols, Kolodziej, Legett, Manross, Miller, Ortega, Riley, Scharfenberg, Sigler, Stumpf, Witt

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

Funding Agency: NOAA and NSSL Director’s Discretionary Fund

Objectives
Improve the verification of severe hail events in the United States through use of very high resolution (1 km) multi-sensor/multi-radar data and verification phone calls, integrated within a geographic information system.

Accomplishments
The Severe Hail Verification Experiment (SHAVE) was conducted during the spring and summer months of 2006. SHAVE utilizes high-resolution weather radar data blended with geographic information available in Google Earth and elsewhere to describe the distribution of hail sizes within the hail swaths of severe thunderstorms across the continental U.S. The high temporal and spatial resolution data collected during SHAVE will allow researchers to develop techniques for probabilistic warnings of severe hail.
thunderstorms, evaluate the performance of a multi-sensor hail detection algorithm, correlate changes in hail size distribution with storm evolution, and enhance climatological information about hail in the U.S. SHAVE combined real-time hail swath products from the Warning Decision Support System-Integrated Information (WDSS-II) with experimental data collected by verification telephone calls to select data points along a storm’s path immediately following storm passage. Data were collected by a team of University of Oklahoma meteorology students working closely with CIMMS scientists at the NSSL.

This project is ongoing.

**Publications**


The radar-derived hail swath product produced in the WDSS-II system along with measured hail sizes as reported by the public for two counties in Oregon. By comparison, traditional verification methods usually produce only one or two reports of severe weather per county.

Investigation into the Use of Warning Decision Support Systems for Improving Hazardous Weather Detection, Warnings, and Forecasts – *WDSS-II Development*

Lakshmanan and Smith (primary – CIMMS at NSSL), Cooper, Hondl, Manross, Ortega, Scharfenberg, Stumpf, Witt

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

**Funding Agency:** CIMMS Task II – NSSL Project 4 and NSF
**Objectives**

Develop decision-making guidance applications and displays for the analysis of severe weather hazards, and to provide a framework for the rapid development and testing of new scientific ideas so that they may be transitioned to operations.

**Accomplishments**

CIMMS has played the primary role in the prototype development and evaluation of severe weather warning applications used to analyze storm information using data from multiple Doppler radars and other remote sensing instruments (e.g., satellites, lightning detection networks, mesoscale models). Integrating data from multiple data sources reduces the uncertainty of the measurements, increases the accuracy of the diagnoses of severe weather, and allows forecasters to make more effective warning decisions.

During the previous year, CIMMS scientists continued to make improvements to these applications and develop new techniques for processing and displaying these voluminous data streams in the framework of the Warning Decision Support System Integrated Information (WDSS-II) system.

A variety of multi-sensor severe weather products are generated by NSSL and shared with Google Earth and other Geographic Information Systems (GIS) users via the Internet at http://wdssii.nssl.noaa.gov, as well as with National Weather Service forecast offices and the Storm Prediction Center via ingest into their operational systems. These products include spatially gridded fields of Vertically Integrated Liquid, Maximum Expected Hail Size, tracks of circulations derived from Doppler velocity data, composite reflectivity, and 30-to-60 minute forecast reflectivity fields, among others. These products, which have a spatial resolution of approximately 1 km by 1 km, are generated every one to five minutes within WDSS-II on the scale of the continental United States.

This project is ongoing.

**Publications**


Lakshmanan, V., I. Adrianto, T. Smith, and G. Stumpf, 2005a: A spatiotemporal approach to tornado prediction. *Int'I Joint Conf. on Neural Networks*, Montreal, Quebec, CD-ROM 1072.


Investigation into the Use of Warning Decision Support Systems for Improving Hazardous Weather Detection, Warnings, and Forecasts – WDSS-II and FSI

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

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

Funding Agency: CIMMS Task II – NSSL Project 4 and NOAA HPCC

Objectives
Build an interactive four-dimensional storm-scale 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.

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. We anticipate that the FSI will be installed and available to NWS forecasters for evaluation in the next AWIPS build.

This project is ongoing.

Publications
The four-dimensional storm scale investigator provides interactive visualization or radar data to enable forecasters to quickly and accurately make sense of the data.

Investigation into the Use of Warning Decision Support Systems for Improving Hazardous Weather Detection, Warnings, and Forecasts – Tornado Probability Forecasting
Lakshmanan (primary – CIMMS at NSSL), Ortega, Smith, Burgess

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

Funding Agency: CIMMS Task II – NSSL Project 4

Objectives
Develop a principled way to forecast the probability of a tornado at a given location within the next 30 minutes
Accomplishments
The underlying method was developed and a proof-of-concept was tested and shown to work. Current work is focused on adding new inputs, training, and verifying against a large dataset.

This project is ongoing.

Publications

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Forecast Verification*
Schultz (primary – CIMMS at NSSL), Weiss, Hoffman, Knox, Hales, Corfidi, Johns, Horgan, Doswell

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

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
Investigate the relationships between synoptic-scale processes and convective-scale phenomena to improve severe-weather forecasts, specifically examining the factors that control the strength of the dryline, the processes that control banding of precipitation, and the climatology of elevated convection producing severe weather.

Accomplishments
This research is a multifaceted exploration of the effect of synoptic-scale processes in influencing convective phenomena. One project was to investigate the factors that control the strength of the dryline, mesoscale feature attributed to the initiation of convection. Strong drylines were associated with a short-wave trough in the upper-level westerlies approaching west Texas, an accompanying surface cyclone over eastern New Mexico, and southerly flow over the south-central United States. This synoptic environment was favorable for enhancing the dryline confluence responsible for strengthening the dryline. In contrast, WEAK drylines were associated with an upper-level long-wave ridge over Texas and New Mexico, broad surface cyclogenesis over the southwestern United States, and a weak lee trough – the dryline confluence favorable for dryline intensification was much weaker. The results of this study demonstrate the important role that synoptic-scale processes (e.g., surface lee troughs, upper-level short-wave troughs) play in regulating the strength of the dryline. Once such a favorable synoptic pattern occurs, mesoscale and boundary-layer processes can lead to further intensification of the dryline.

A second project investigated the formation of several east/west-oriented bands of clouds and light precipitation on 20 July 2005 over eastern Montana and the Dakotas. The bands were spaced about 150 km apart, and the most intense band was 20 km wide and 300 km long, featuring areas of maximum radar reflectivity factor about 50 dBZ. The bands formed poleward of an area of lower-tropospheric frontogenesis, where air of modest convective available potential energy was being lifted. During initiation and maintenance of the bands, mesoscale regions of tropospheric-deep symmetric and inertial instability were present in the region of the bands, suggesting a possible mechanism for the banding. A high-resolution, numerical weather prediction model demonstrated that forecasting these types of events in such real-time models is possible. This case is compared to two other previous cases in the literature where banded convection was associated with a combination of conditional, symmetric, and inertial instability. A more rigorous comparison with theory was incapable of being performed because of the lack of theoretical studies on this complex situation with these three instabilities forced by frontogenesis.

A third project examined severe weather produced by convection from elevated storms. A five-year climatology of elevated severe convective storms was constructed for 1983-1987 east of the Rocky Mountains. Potential cases were selected by finding severe-storm reports on the cold side of surface fronts. Of the 1826 days during the five-year period, 1689 (91%) had surface fronts east of the Rockies.
Of the 1689 days with surface fronts, 129 (8%) were associated with elevated severe-storm cases. Of the 1066 severe-storm reports associated with the 129 elevated severe-storm cases, 624 (58%) were hail reports, 396 (37%) were wind reports, and 46 (4%) were tornado reports. A maximum of elevated severe-storm cases occurred in May with a secondary maximum in September. Elevated severe-storm cases vary geographically throughout the year with a maximum over the south-central United States in winter to a central and eastern United States maximum in spring and summer. A diurnal maximum of elevated severe-storm cases occurred at 2100 UTC, which coincided with the diurnal maximum of hail reports. The wind reports had a broad maximum during the daytime. Elevated severe-storm cases that produce only severe-wind reports occurred roughly five times a year. To examine the environments associated with cases that produced severe winds only, five cases were examined in more detail and were classified into three types. Type A cases were strongly forced, elevated squall lines. Type B cases were elevated isolated cellular cases, whereas Type C cases were elevated northwest-flow cases.

This project is ongoing.

**Publications**


**Other Schultz publications:**


STRONG (left column) vs. WEAK (right column) dryline composites: (a) and (b) 250-hPa geopotential height (solid lines every 120 m), wind speed (m s⁻¹, shaded according to scale), and wind direction (vectors); (c) and (d) 500-hPa geopotential height (solid lines every 60 m); (e) and (f) sea level pressure (solid lines every 2 hPa).
Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – Forecast Verification
Baldwin (primary – CIMMS at NSSL), Elmore, Kain, Schultz

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

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
Develop new and unique verification strategies for forecasts containing realistic detail; maintain and continue to build a database of forecasts and observations for ongoing verification studies.

Accomplishments
Data collection procedures have continued for precipitation forecasts from experimental versions of the WRF model running at CAPS, NCEP, NSSL and NCAR. These data are available for verification studies using analyses of both radar observations and the so-called “Stage IV” high-resolution multi-sensor precipitation fields from NCEP, which also have been archived. In particular, diagnostic fields of reflectivity from experimental WRF model runs during the 2005 NSSL/SPC Spring Program were archived along with the national mosaic of 2 km base reflectivity from the NEXRAD network. The archived forecast and observed reflectivity and precipitation fields were made available to the verification community to foster testing of new verification techniques.

Development of new verification techniques has also continued at NSSL. The sensitivity of commonly-used performance measures to displacement errors, bias, and event frequency has been analyzed using a hypothetical forecast situation. The spatial distribution of forecast biases has been analyzed by applying basic statistical tools. Appropriate corrections are made for temporal and spatial degrees of freedom, yielding the spatial distribution of 95% confidence intervals about the mean error at each grid point. These 2-D plots of mean error can be used by forecasters to improve the model guidance that they use in the preparation of their forecasts. The use of verification information to provide probabilistic forecast guidance from deterministic NWP model output was found to be both accurate and reliable. This is an example of a direct feedback between verification information and forecast improvement. In order to obtain more meaningful verification information, object-oriented verification techniques continue to be developed. The object-oriented verification approach compares characteristics of meteorological phenomena (objects) that can be identified in forecast and observed spatial fields. Automated procedures for identifying, analyzing, and classifying rainfall systems have been established. The automated classification procedure uses statistically-based attributes related to rainfall intensity and spatial organization to place rainfall systems into linear, cellular, or stratiform classes. Once systems have been identified and characterized, predicted and observed systems can be compared, and specific error characteristics (such as displacement error) can be computed for precipitating weather systems.

This project is ongoing.

Publications

Stensrud (primary - NSSL), Yussouf

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

Funding Agency: CIMMS Task II – NSSL Project 6 and NOAA/OAR Special Projects Initiative

Objectives
Investigate methods to quantify the potential impact of improved surface observations on short-range numerical weather prediction; apply the Bias-Corrected Ensemble (BCE) forecasting system on near surface variables and the Binning Technique on accumulated precipitation forecast from the multimodel short-range ensemble forecasting system archived during October 1, 2005 - March 31, 2006.

Accomplishments
Methods to incorporate surface temperature, mixing ratio, u and v wind component, soil temperature and soil moisture observations into the Advanced Research Weather Research and Forecast (WRF ARW) model initial conditions are explored. Starting April 1, 2006 three short-range (0 to 2 day) WRF runs are made on a daily basis at 1200 UTC with a 30 km parent domain covering the continental United States and a 10 km nest centered on Oklahoma. The first run of the WRF model uses initial and boundary conditions provided by the operational Eta Model from NCEP. The second run is identical, except that the soil temperature and soil moisture observations from the Oklahoma Mesonet are used to initialize these soil fields for the nested domain. The final WRF run is initialized from the surface temperature, mixing ratio, u and v wind components obtained from Oklahoma Mesonet and NWS observations. In order to compare the accuracy of these three runs, forecast from the nested domains are verified using

Scatter plot of location errors for precipitation systems identified from 2km WRF-ARW run during 2005 NSSL/SPC Spring Program.
the Mesonet surface observations. The mean error (bias; forecast-observed), mean absolute error (MAE), and the root-mean-square error (rmse) will be calculated for forecasts of 2-m temperature and dewpoint temperature, 10-m u and v wind component at all station locations and at each of the 49 forecast hours.

Previous research from the New England High Resolution Temperature Program (NEHRTP) indicates that the BCE post-processing technique using the past complete 12 days of forecasts to bias correct today’s forecast yields ensemble mean forecasts of 2-m temperature, 2-m dewpoint temperature, and 10-m wind speed that are competitive with or better than those available from the model output statistics (MOS) forecasts generated operationally in the United States. Also a binning technique using the past 12 days worth of 3-h accumulated precipitation forecasts and observations to produce probabilistic quantitative precipitation forecasts (PQPFs) is developed and results show that this technique provides significantly more skillful and reliable PQPFs of rainfall events than the raw forecast probabilities. Brier skill scores and the area under the relative operating characteristics curve also indicate that this technique yields skillful probabilistic forecasts. However, both these techniques are applied to summertime forecasts. To further explore the performance of these two techniques during winter time, the 22-member Short Range Ensemble Forecast (SREF) system from NCEP is archived for a six month period from October 1, 2005 to March 31, 2006 and these techniques are applied to the dataset.

This project is ongoing.

Publications

![Attribute diagram for 3-h precipitation amounts greater than 0.05 in (1.27 mm) valid at 0300 UTC 27 July 2004 from the adjusted (black line) and raw (gray line) ensembles calculated over the model domain. Inset histogram indicates the frequency of usage of each forecast probability category for the raw ensemble probabilities (gray bar) and adjusted ensemble probabilities (black bar). The solid diagonal line indicates perfect reliability, the dashed diagonal line is the no skill line, and the solid horizontal line is the no skill line.](image)
Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Multipass Distance-Dependent Weighted Average Objective Analysis*

Spencer (primary – CIMMS at NSSL), Askelson, Doswell

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

**Funding Agency:** CIMMS Task II – NSSL Project 6

**Objectives**
Investigate differences in the analyses of irregularly distributed observations for "equivalent" combinations of smoothing parameters within an objective analysis scheme.

**Accomplishments**
Various combinations of smoothing parameters within a two-pass Barnes objective analysis scheme have been applied to analytic observations obtained by regular and irregular sampling of a one-dimensional sinusoidal analytic wave in order to obtain gridded fields. Each of these various combinations of smoothing parameters would produce equivalent analyses if the observations were continuous and infinite (unbounded). We have demonstrated that, owing to the discreteness of the analytic observations, the actual analyses resulting from these various combinations of smoothing parameters are different. When spatial derivatives are computed, and as the stations become more irregularly distributed, these differences increase. Although this type of objective analysis scheme can be tuned to give a unique *theoretical* response at a given wavelength, during actual use for irregularly-distributed data the real response will not only differ from the theoretical value, but the different weightings during the multiple passes can give different results at that wavelength.

This project is completed.

**Publications**
Grid point values (dashed curves) for two "equivalent" combinations of smoothing parameters of the (a) analyzed observations, (b) first derivative, (c) second derivative, (d) amplitude response, and (e) phase shift (degrees). The amplitude responses and phase shifts are those associated with the gridded observations. In (a)-(c), the solid curves are the analytic (true) values. The small asterisks represent station locations. The horizontal lines in (d) and (e) represent the values if the analyses were perfect.

Douglas (primary – NSSL), Galvez, Mejia, Murillo, Orozco

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

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
The North American Monsoon Experiment (NAME) and related research aim to promote a better understanding and more realistic simulation of: warm season convective processes in complex terrain,
intraseasonal variability of the monsoon, and the response of the warm season precipitation patterns to the oceanic and continental surface boundary condition.

Accomplishments
As part of the North American Monsoon Experiment (NAME), a network of 22 pilot balloon stations (three in the U.S.) was set in place with help from many institutions and individuals in Mexico and in the states of Arizona and New Mexico. The network was operated for most of the summer with some stations making observations twice a day from June through September. The data collected have been quality checked for internal consistency. Temporal outliers have been identified and spatial outliers are now being identified by means of comparison with neighboring stations. When this process has been completed, the dataset will be released to the research community.

Research continued on the moisture flux variability over southwestern North America using observations obtained from the 2004 NAME. A PhD dissertation topic by graduate student John Mejia is focusing on determining the essential requirements for reproducing observed moisture surges during the NAME experiment. A careful analysis of the surface automated station data and aircraft data has been carried out for one particularly well-documented surge; simulations of this surge with WRF are being carried out.

This project is ongoing.

Publications

Research on Integration and Use of Multi-Sensor Information in Weather Forecasting –
Science and Technology Infusion
Stumpf (CIMMS at NWS/MDL)

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

Funding Agency: CIMMS Task II – NSSL Project 9

Objectives
Work with CIMMS/NSSL scientists in developing multiple-sensor severe weather warning applications and display systems and transferring that technology to NWS operational systems; maintain an Advanced Weather Information Processing System (AWIPS) Development Environment at CIMMS/NSSL; assist in setting up a severe weather warning testbed at the new National Weather Center in Norman.

Accomplishments
The second 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 is still being used for AWIPS application development and evaluation. A major development project undertaken was the adaptation of 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). The CIMMS/MDL scientist first developed the NWS
Operational Services Improvement Plan (OSIP) for the FSI project, and worked to secure its spot on the list of software upgrades for AWIPS Operational Build 8.2 (OB8.2) slated for a winter 2007 release. The CIMMS/MDL scientist worked with NSSL developers to develop design requirements for a customized “FSI” 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 alpha version of the FSI is mostly complete, and will be tested at several NWS Weather Forecast Offices during the autumn of 2006 and spring of 2007 before eventually being transferred to AWIPS OB8.2. Feedback from these operational tests will be used to help better define the design of the FSI for future version releases. The CIMMS/MDL scientist also worked with the new AWIPS contractor, Raytheon, to test and develop requirements for video graphics hardware to support 3D visualization. Future versions of the FSI are anticipated to include 3D volume rendering and iso-surfacing, as well as support viewing of Terminal Doppler Weather Radar (TDWR) and polarimetric radar data.

The CIMMS/MDL scientist, along with the Warning Decision Training Branch (WDTB), developed a new relationship with Klein Associates Division of Applied Research Associates (KAD/ARA), a leading decision science company which promotes the application of Cognitive Task Analysis (CTA) methods in the design of decision support systems. We will be working with KAD/ARA to integrate expert human factors analysis into the development of MDL decision support systems. Initial work was undertaken during the past year to use the FSI as the first application for new methods of CTA that KAD/ARA are developing.

The CIMMS/MDL scientist continues to work with collaborators in NSSL, the Storm Prediction Center (SPC), WDTB, and the Norman WFO to develop a WFO-scale component of the National Weather Center (NWC) Hazardous Weather Testbed (HWT), designed to be a proving ground for new severe weather applications to assist short-fused (0-1 hour) warning decisions. Recently, the NOAA units consolidated into the new NWC Building on the OU Research Campus. The HWT physical space is presently being populated with hardware to support experiments for the spring of 2007. These will include testing of the FSI, WDSSII multiple-sensor grids, and experimental severe weather warning concepts, such as probabilistic gridded warnings.

The CIMMS/MDL scientist participated in the National Center for Atmospheric Research’s (NCAR) Weather And Society - Integrated Studies (WAS*IS) workshop in July. There were students from different disciplines where weather and society intersect, representing meteorology, sociology, economy, anthropology, geography, education, hazards research, and emergency management. Items figuring prominently in the presentations and discussion included better methods for gauging perceptions of hazardous weather forecasts and warnings and new methods for hazardous weather warning dissemination and products, for a whole range of users of NWS information. We hope to foster new interdisciplinary research for the development and testing of new NWS decision support systems, severe weather applications, and improved short term hazardous weather information for decision makers inside and outside the WFOs via the HWT.

The CIMMS/MDL scientist continued to closely collaborate with the severe weather warning research and development 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.

This project is ongoing.

Publications
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 Agency: CIMMS Task II – SPC

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
The verification database originally created during the fiscal year was further refined, allowing for more sophisticated verification data to be developed. For example, report coverage in SPC’s categorical outlooks was calculated over the most recent 5-year period, which facilitated a redefinition of the relationship between the categorical and probabilistic severe weather outlooks. This was necessary because of an explosion in the number of severe reports since the relationship was originally defined. The database also facilitated the development of baseline values for the watch hazard probabilities, which became operational during this period.

A new project to investigate the frequency and distribution of convective storm environments began this year. There is a large disconnect between the issuance of a forecast and the occurrence of an official storm report (or lack thereof); the goal is to fill in the gap in order to provide forecasters more specific information regarding forecast performance and to identify particular types of environments where forecast performance is enhances and where it suffers. Initial work has been done using archived data from a surface objective analysis routine run locally at SPC. Convective parameters (CAPE, shear, CIN, and others) have been assigned to each report from 2004-2005. Analysis of the results is currently underway. Methods to determine the frequency of particular environments and how often they produce severe convection are also being developed. It is anticipated that North American Regional Reanalysis data will eventually be incorporated into this project, greatly increasing the period of time for which environmental data is available.

This project is ongoing.

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.
Mean ML CAPE and 0-6 km shear vector for all 2005 tornado reports. A 10 km grid was used, with reports within 160km of each grid point considered (hence the overlapping circle effect). Generally speaking, tornadoes in 2005 were associated with higher CAPE values in the Plains, while being associated with lower CAPE and higher shear in the Ohio Valley and Southeast.

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 Agency: CIMMS Task II – SRH

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, and study the usefulness and cost-effectiveness of new technologies.

Accomplishments
A MySQL database was created for the Ridge Radar Program to allow for the creation of scripts and back-end application processes to produce the ridge-lite radar pages for both the Internet and PDA/Cell Phone devices. In addition, warning polygons in the KML/KMZ format were provided for use by customers using GIS client software such as Google Earth and WWA Map creation scripts were enhanced to paint Fire Weather Zones. A monitor script was created to flag certain web security violations.

This project is ongoing.
Tornado Outbreak Detection using Modern Numerical Simulations

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
Tornado outbreaks affect many geographical locations across the United States. No study has yet attempted to determine key synoptic differences in a tornado outbreak scenario versus a non-tornado outbreak scenario. The main goal of this project is to gain an understanding of the synoptic differences between tornado outbreak and non-tornado outbreak scenarios. Synoptic-scale data were used to initialize two numerical models, the MM5 and the WRF. The NCEP/NCAR 0000 UTC reanalysis database, from 1970–2003, provided initial fields and boundary conditions. A total of 50 tornado outbreak cases and 50 non-tornado outbreak cases were determined for comparison. A multivariate principal component analysis was performed on five different parameters: temperature, height, meridional and zonal wind components, and relative humidity, at all 17 of the reanalysis pressure levels. Errors introduced into the covariance estimates by poleward converging longitude lines were corrected by introducing an equally spaced grid on the spherical plane. Fields derived from the principal component analysis were used to initialize both numerical models. A large number of case studies selected from the tornado and non-tornado outbreak datasets were made with both WRF and MM5 using three forecast periods; 24 hours prior to the event, 48 hours prior to the event, and 72 hours prior to the outbreak events. An optimal set of covariates was determined from these studies, which were used as a means of distinguishing between tornado outbreak and non-tornado outbreak cases once the model simulations were complete. The viability of the covariates in forecast mode is being examined as a means of distinguishing between tornado and non-tornado outbreak cases with between 24 and 72 hours lead time.

This project is ongoing.

Publications

Model grid used for initial fields.
Tri-State Tornado Reanalysis
Doswell (primary – CIMMS at OU), Maddox, Johns, 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
Multiple trips have been made to investigate the track of the infamous Tri-State tornado of March 18, 1925. An aspect of the work is to reexamine the meteorological setting in which the storm developed. This important and apparently singular event in U.S. tornado history is poorly documented, with several apparent inconsistencies in the existing literature on the subject. Considerable evidence has been amassed regarding the issue of the continuity of the track; new evidence has come to light showing that the track is even longer than previously thought. At the time of this writing, no evident damage breaks of 10 miles in length or longer have been found. Preliminary meteorological analysis has indicated that the actual conditions giving rise to the storm differ from those reported previously in the literature and that other tornadic storms occurred on that fateful day. 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 are using Ensemble Kalman Filter (EnKF) methods to reconstruct the 4-dimensional atmospheric structure during this historical event.

This project is ongoing.

Publications

Representing Cloud Processing of CCN in Regional Forecast Models
Mechem (primary – CIMMS at OU), Y. Kogan, Robinson

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

Funding Agencies: ONR

Objectives
Formulate improvements in how regional models represent aerosol-cloud-precipitation interactions.

Accomplishments
The Naval Research Laboratory's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) is employed to explore the relative importance of source, sink, and transport processes in producing an accurate forecast of the aerosol-cloud-drizzle system. The behavior of cloud processing, defined to be the reduction of CCN via collision-coalescence, suggests relationships (scalings) based on cloud base drizzle rate (R) and cloud droplet concentration (Nc). Cloud processing is correlated with drizzle, a relationship that can be represented as a power law for drizzle rates less than 0.6 mm d⁻¹. A scaling for cloud processing based on the product of Nc and R is accurate over a wider range of drizzle rates. These scalings are analogous to the observation-based drizzle scalings derived in recent field projects and are valuable in developing and testing parameterizations for forecast models. Results from large eddy
simulation with size-resolved microphysical processes demonstrate reasonable agreement with COAMPS and the two parameter scaling.

A CCN budget demonstrates that entrainment plays an important role in strongly modulating the boundary layer concentration, both increasing and decreasing CCN, depending upon the entrainment velocity and the difference between boundary layer and free tropospheric CCN concentrations. The importance of entrainment suggests the importance of transport processes in the vertical play a fundamental role in the overall CCN balance. Because of the prevailing importance of cloud processing and entrainment over timescales of a typical mesoscale forecast, incorporating accurate vertical aerosol profiles into model update cycles is more important than highly constrained local CCN source rates.

This project is ongoing.

**Publications**

Two parameter scaling for the decrease in boundary layer-mean CCN arising from coalescence processing for COAMPS simulations with four different initial CCN concentrations (red -- 100 cm$^{-3}$; green -- 200 cm$^{-3}$; blue -- 400 cm$^{-3}$; magenta -- 800 cm$^{-3}$). Filled rectangles represent results from LES.
Three-Dimensional Aspects of Droplet Nucleation
Mechem (primary – CIMMS at OU), Y. Kogan

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

Funding Agencies: ONR

Objectives
Improve the representation of droplet nucleation in regional forecast models.

Accomplishments
Representing accurate droplet concentrations in numerical models is a critical component of correctly calculating radiative and microphysical processes. Recent parameterizations of droplet nucleation tend toward a detailed specification of aerosol parameters in a simple 1D dynamical framework of a non-entraining plume. Classical theory predicts that CCN activation occurs at or just above cloud base in buoyant updrafts. On the other hand, preliminary results from three-dimensional large eddy simulation (LES) employing size-resolved microphysics suggest that nucleation is more complicated than typical 1D models suggest.

Simulated stratocumulus cloud structure suggests that for some updrafts the maximum in droplet concentration is well above cloud base, indicating that additional droplet nucleation is occurring in a continuous fashion from cloud base up to the level of maximum concentration. Nucleation continues to occur despite supersaturation rapidly decreasing along the parcel path, above the maximum near cloud base. Nucleation increasing with height is nevertheless restricted to regions of supersaturation, and results strongly suggest the additional nucleation results from entrainment of non-activated CCN into the supersaturated updraft. Non-entraining parcel models do not capture this continuous aspect of nucleation. Since nucleation does not occur uniformly but only in supersaturated updraft regions, the number of nucleated droplets should be considered an upper bound on grid-mean droplet concentration.

This project is ongoing.

Publications
Scatterplot of cloud base droplet concentration as a function of updraft magnitude, stratified by supersaturation [percentage] according to color and symbol. Gray marks represent all regions of supersaturation, which most completely represent the nucleation zone. The black line illustrates an increase in droplet number along an updraft parcel path; this specific example shows an instance of droplet number increasing above the peak supersaturation value.

Development of a New Bulk Parameterization of Giant CCN

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

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

Funding Agencies: ONR

Objectives
Develop a parameterization of giant cloud condensational nuclei for use in regional forecast models.

Accomplishments
The classical model of warm-rain precipitation formation -- nucleation, condensation, and collection, is insufficient to explain the rapid growth of precipitation-sized droplets in observations. Giant cloud condensation nuclei (GCCN; 1 < r < 10 microns) have been suggested as a mechanism to develop drizzle nuclei in this size range, which may initiate the development of precipitation. We have developed from first principles a parameterization of giant CCN (GCCN) that can be straightforwardly incorporated into current bulk microphysical schemes. The parameterization is based on condensational growth of
deliquesced GCCN in the subcloud layer and includes a prognostic equation for GCCN concentration. GCCN conditions are specified using a total concentration and a power law exponent.

Preliminary tests of the GCCN parameterization employ the CIMMS large eddy simulation (LES) framework under clean and polluted background aerosol conditions for a case of typical marine stratocumulus. GCCN are specified as an initial value problem with various concentrations corresponding to a sea spray source under different wind speeds. Drizzle-free, polluted simulations show the greatest sensitivity to the addition of GCCN. Increasing amounts of GCCN result in depleted droplet concentration, reduction in liquid water content, enhanced drizzle production, and a tendency for the boundary layer circulation to decouple. Adding GCCN to the clean case, which is already precipitating, affects the simulation very little. In addition to the potential of improving mesoscale model forecasts, the parameterization is applicable for helping better represent aerosol indirect effects in large scale models.

This project is ongoing.

Publications

Verification of Cloud Microphysics Parameterizations
Mechem (primary – CIMMS at OU), Y. Kogan, Corrao

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

Funding Agencies: ONR

Objectives
Develop PDF-based techniques to apply to LES and high-resolution observational data for verifying cloud microphysical parameterizations.

Accomplishments
Lately new advanced techniques were developed for examining the structure of stratus clouds based on 3-mm wavelength Doppler radar using very fast processing systems (Kollias and Albrecht, 2000). The W-band Cloud Radar at the ARM SGP site Climate Research Facility is capable of providing 30-m vertical...
resolution with a 2-s time sampling rate. These high-resolution observational data sets are consistent with the ones produced in LES experiments. Kollias and Albrecht refer to this novel technique as “Large-Eddy Observations in Support of Large Eddy Simulations (LEO for LES)”. The question arises of how most efficiently utilize opportunities provided by new cloud radars for verification of LES models and microphysical parameterizations derived based on LES data. The traditional method of model verification is to compare the first and, in some cases, the second moments of predicted and observed cloud parameters. A more robust approach is to compare PDF of model and observational variables and study its dependence on environmental conditions.

Exploring various details of comparisons based on PDF approach is the topic of the thesis work by the OU Masters student Danielle Corrao. Specifically, we have studied PDF of cloud liquid water and drop concentration during two research flights, RF1 and RF2, conducted during the DYCOMS field project. The study revealed that PDF in non-precipitating clouds (flight RF1) differ significantly from PDF in precipitating clouds. The width of the PDF distribution is dependent on the intensity of turbulence in precipitating clouds, but rather insensitive to it in non-precipitating conditions. The latter reflects the fact that non-precipitating stratocumulus are more homogeneous. The PDF is also scale dependent, so the data shown in the accompanying figure is for length scale of about 6000m which is roughly the size of the domain of the LES simulation. The results of the study will lead to the development of more robust techniques of model and parameterization verification.

This project is ongoing.

![Graph showing the dependence of LWC standard deviation on the intensity of turbulence expressed by the vertical velocity standard deviation. Crosses and squares denote data from DYCOMS flights in non-precipitating stratocumulus (RF1) and precipitating (RF2) stratocumulus clouds. Note the smaller standard deviation of LWC (more homogeneity) in non-precipitating conditions, as well as the decrease in LWC standard deviation with the increase of turbulence in precipitating clouds (RF2).](image-url)
Contribution to the 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: CIMMS Task III – FAA

Objectives
Develop and test the radar data assimilation components for the WRF GSI 3DVAR systems and evaluate the impact of the data on short term storm and precipitation forecasts.

Accomplishments
Accomplishments include the further development and testing of radar data assimilation components to be used in the WRF 3DVAR system and the application of the 3DVAR system for the initialization of a convective storm (Hu and Xue 2006a; Hu et al. 2006a; Hu et al. 2006b), and the testing of radar data within the WRF-GSI system. Liu et al. (2005) examine the improvement of the radial velocity assimilation capabilities within GSI and it impact on WRF-NMM forecasts.

The group also worked on improved forward operators for radar data, the comparisons of methods for calculating radar ray paths, and studied the sensitivity of ray path calculations to refractive index gradient and the climatology of severe index gradient that cause ray ducting (Gao et al. 2006). In Hu (2005), very encouraging results are obtained in predicting the May 8, 2003, Oklahoma City tornadic supercell storm, using initial condition obtained through frequent assimilation cycles that include level II radar data using a 3DVAR-cloud analysis combination. The figure below shows that an F2-intensity tornado was obtained in the 100-m model prediction, with initial conditions interpolated from 1 km analysis.

The ARPS cloud analysis package has been adapted for use in the WRF-GSI framework and efforts continue to develop a generalized cloud analysis package combining the strengths of ARPS and RUC cloud analysis packages. The system now ingests both level-II reflectivity data and NSSL radar reflectivity mosaic data. A short paper demonstrating the impact of cloud analysis using reflectivity data on WRF-ARW forecast is summarized in Hu and Xue (2006b).

This project is ongoing.

Publications
Hu, M., 2005: 3DVAR and cloud analysis with WSR-88D level-II data for the prediction of tornadic thunderstorms, Ph. D. Dissertation, School of Meteorology, University of Oklahoma, 217 pp.
Predicted reflectivity and wind fields at the surface (left) and 2 km MSL (right) from at 7 minutes into the 100 m forecast. Wind vectors are plotted every 10 grid points. The presence of a tornado is indicated by the hook echo that contains reflectivity spirals into the circulation center.
**Climatic Effects of/Controls on Mesoscale Processes**

**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 Agency:** CIMMS Task III – NWS International Activities Office

**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 position of West African Intertropical Front (ITF, 1974-2003) for the northward excursion phase (top panel), and the southward surge (bottom panel). ITF appears north of 10º N for the first time in early April and retreat completely from it in mid-November. Note here the abrupt southward surge of the ITF (bottom panel) compare to it more gradual northward advance (top panel).

Collaboration and Cooperation within the ACMAD Core Demonstration Project in Climate Prediction between ACMAD and CIMMS
Lamb (primary – CIMMS at OU), LeLe, Segele, Mbainayel, Bana

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

Funding Agency:  CIMMS Task III – NWS International Activities Office

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 four graduate students 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,
nearing completion), Niger (Bana, M.A. in Geography, completed; LeLe, M.S. in Meteorology, nearing completion), and Chad (Mbainayel, M.S. in Meteorology, recently commenced). A large paper derived from the Ethiopian student’s M.S. Thesis was published in *Meteorology and Atmospheric Physics* in 2005. 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 has issued monthly and seasonal reports on the progress and quality of the West African monsoon at Niamey for 2005 and 2006; the relative dryness of the 2006 season is shown in the figure below.

Personnel interactions and exchanges between ACMAD and CIMMS also continued strongly in the past year. With money provided by ARM, CIMMS funded the participation of eight Niamey meteorologists in the large AMMA Scientific Conference in Dakar (Senegal) in late November 2005. Immediately following that Conference, the CIMMS Director (one week) and one of his Nigerian graduate students (Issa Lele Mohammadou, three weeks) visited ACMAD and other meteorological institutions in Niamey. In early 2006, the ACMAD Director-General (Dr. Abdoulaye Kignaman-Soro) visited CIMMS for several days, as did Professor Ben Mohamed and one of his colleagues. In early August, the CIMMS Director spent 10 days in Niamey participating in the AMMA Special Observing Period and visiting ACMAD and other meteorological institutions there.

This project is ongoing.

![Niamey monthly rainfall: April-September 2006 vs. 1941-2000 long-term mean.](image)

### Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Pan American Climate Studies Sounding Network (PACS-SONET)*

**Douglas** (primary – NSSL), Galvez, Mejia, Murillo, Nava, Orozco

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

**Funding Agency:** CIMMS Task II – NSSL Project 6
Objectives
Operate approximately 20 pilot balloon stations in countries ranging from Mexico to Peru, the essential goal being to describe the major circulation features of the lower-mid troposphere over its domain.

Accomplishments
The SONET project coordinates a network of special atmospheric soundings in Latin America. The network provides additional upper-air measurements over regions in Mexico and South America with insufficient radiosonde density. The project aims to improve climate monitoring by promoting sustainable observations, data dissemination, meteorological education and efficient regionally-coordinated network design. SONET is currently supporting observing sites in Colombia, Mexico, Peru and Venezuela.

In addition to continuing routine balloon soundings at more than 15 sites in Latin America, the PACS-SONET project carried out two short field programs to evaluate platforms and strategies for regional studies. The first involved using an Ecuadorian Navy oceanographic ship to make radiosonde observations around the eastern Pacific cold tongue between the Galapagos Islands and coastal Ecuador. One practical aspect of the measurements was to determine feasibility of using the ship, which makes several cruises per year along fixed tracks, as a platform for developing climate statistics over this relatively poorly sampled region.

A second SONET program involved describing the diurnal variation of the winds over the coastal plain and Andean slopes in southern Peru. Three sites made more than 30 soundings over a 72 hour period to describe the slope winds that modulate air pollution in Arequipa, Peru's second largest city. Daily SONET soundings have been made for more than 3 years at Arequipa, and these measurements not only help SENAMHI understand air pollution events, but also help us interpret the climatological bias inherent in measuring wind profiles only once per day at the site.

This project is ongoing.

Publications


Douglas, M W., J. Murillo, and J. F. Mejia, 2005: Conducting short duration field programs to evaluate sounding site representativeness and potential climate monitoring biases – examining the low level jet over the Venezuelan Llanos during the 2005 dry season. 13th Symp. on Meteorological Observations and Instrumentation, Savannah, GA, JP1.32.
Time-height sections for both the zonal (top panel) and meridional (bottom) monthly mean winds at Piura, Peru (~5.2° S). The figure summarizes 8 years of daily pilot balloon observations at Piura, one of 15 stations supported by the PACS Sounding Network (SONET). The easterly winds are strongest near 4 km during the cool season (JAS), with weaker zonal flow in the warm season (JFM). The meridional wind is much weaker above the boundary layer, with generally plausible, but weak, patterns. Notable is the asymmetry between the slow deepening and strengthening of the onshore (westerly) flow prior to February and the relatively rapid weakening afterwards. The shallowest and weakest zonal flow is seen in June, only 3-4 months after its maximum in February-March.
Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – Mesoscale Research on the South American Low-Level Jet (SALLJ)
Douglas (primary – NSSL), Galvez, Mejia, Murillo, Nava, Orozco

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

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
The Monsoon Experiment of South America (MESA) and related research aimed at promoting a better understanding of the role of the South American low-level jet (SALLJ) in the exchange of moisture and energy between the tropics and extratropics and related aspects of regional hydrology, climate and climate variability.

Accomplishments
The SONET project coordinates a network of special atmospheric soundings in Latin America. The network provides additional upper-air measurements over regions in Mexico and South America with insufficient radiosonde density. The project aims to improve climate monitoring by promoting sustainable observations, data dissemination, meteorological education and efficient regionally-coordinated network design. SONET is currently supporting observing sites in Colombia, Mexico, Peru and Venezuela.

Research into the effect of surface inhomogeneities on the rainfall over the South American altiplano continues as an extension of MS thesis work carried out by SOM graduate student Jose Galvez. WRF simulations are being carried out for differing flow regimes and moisture profiles, with the ultimate objective of reproducing important components of the altiplano climate as a summation of mesoscale circulations induced by Lake Titicaca and the larger dry lakes.

MODIS imagery is being used to obtain mean cloudiness over the South American Low-level Jet (SALLJ) domain at high (~250m) spatial resolution. This will help describe aridity patterns that can be used to remotely identify vegetation regimes.

This project is ongoing.

Publications
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 Iguacu - PR, Brazil, April 24-28.
Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

The Warning Project
Gruntfest, Schultz (primary – CIMMS at NSSL), Benight, Barnes, Hayden

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

Funding Agency: NSF

Objectives
Understand the factors affecting how people receive warnings (if at all) and improve how warnings are disseminated and examine what people say they would do in different flash-flood or tornado scenarios.

Accomplishments
To understand what people would do when faced with real-life flash floods and tornadoes, approximately 500 responses to a survey administered to Austin floodplain residents were analyzed. One aspect of interest is what factors control whether people make the right decision for themselves and for their family’s safety. Forty-five percent of people would stop their car under a highway overpass and climb up into the rafters of the overpass to seek protection from a nearby tornado. Thus, the message from the National Weather Service that highway overpasses are dangerous places during tornadoes needs to be more strongly conveyed. Future research will investigate who is likely to respond by climbing rafters in order to better target the message to these populations.

This project is ongoing.

Publications

Histogram of responses to the question "I would stop my car under a highway overpass and climb up in the rafters."
Energy Indices
Timmer, Lamb (primary – CIMMS at OU)

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

Funding Agency: CIMMS Task III – NOAA CPO

Objectives
Understand the relationship between temperature and residential natural gas consumption in the U.S.

Accomplishments
The increased U.S. natural gas price volatility since the mid-to-late 1980s deregulation generally is attributed to the deregulated market being more sensitive to temperature-related residential demand. This study therefore quantifies relations between winter (November-February) temperature and residential gas consumption for the U.S. east of the Rocky Mountains for 1989-2000, using a regional basis and monthly and seasonal time-scales. State-level monthly gas consumption data are aggregated for nine multi-state sub-regions within three U.S. Department of Energy Petroleum Administration for Defense Districts (PADDs). Two types of temperature indices (Days Below Percentile, DBP; Heating Degree Day, HHD) are developed using the Richman-Lamb fine resolution (~1° latitude-longitude) set of daily maximum and minimum temperatures for 1949-2000.

Maximum DBP and HDD correlations with gas consumption consistently are largest in the Great Lakes-Ohio Valley region on both monthly (+0.89 to +0.91) and seasonal (+0.93 to +0.97) time-scales, for which they are based on daily maximum temperature. Such correlations are markedly lower in New England on both time-scales (+0.62 to +0.80) where gas is less important than heating oil, and across the South on the monthly scale (+0.55 to +0.75) due to weakening by low January correlations. For the South, maximum correlations are for daily mean or minimum temperature-based DBP and HDD indices. The percentiles yielding the highest DBP index correlations with gas consumption are slightly higher for northern regions than across the South, because lower (higher) relative (absolute) temperature thresholds are reached in warmer regions before home heating occurs. However, these optimum percentiles for all regions are flanked broadly by surrounding percentiles for which the correlations are almost as high, which establishes the results’ robustness. The reference temperatures giving the highest HDD correlations with gas consumption are lower for the colder northern regions than further south where the temperature range is truncated. However, all HDD reference temperatures greater than +10°C (+15°C) yield similar such correlations for northern (southern) regions, further confirming the robustness of the findings. This robustness, coupled with the very high correlation magnitudes obtained, suggests potentially strong gas consumption predictability would follow from accurate seasonal temperature forecasts.

This project is ongoing.

Publications
Maximum monthly (left) and seasonal (right) correlations with residential natural gas consumption of (a) DBP indices and (b) HDD indices for each PADD for 3-month (upper correlation) and 4-month (lower correlation) winters during 1989-2000. DBP and HDD indices concerned are defined in Tables 1-3. Correlation thresholds for 5% (1%) statistical significance levels are +0.28 (+0.39) for monthly indices for 3-month winters, +0.24 (+0.33) for monthly indices for 4-month winters, and +0.50 (+0.66) for seasonal indices for 3- and 4-month winters, according to a 1-tailed t-test (Wilks 1995, pp. 127-129).

False Alarms and Tornado Casualties
Sutter (primary – OU Dept. of Economics), Simmons, Erickson

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

Funding Agency: CIMMS Task III – NSSL

Objectives
Understand whether and, if so, how false alarms on tornado warnings affect people’s response to warnings.

Accomplishments
Tornado warning records - both verified warnings and false alarms - have been assembled into a data set to provide warnings issued by county and year. This gives us a complete tornado warning history (1986-2004) for every county in the contiguous U.S. We have calculated the number of person hours spent under warnings in the U.S. each year, which provides a measure of the cost of tornado warnings. This archive is being used by Somer Erickson in her Masters thesis project. The records will allow calculation of different false alarm ratios by county, state, National Weather Service Forecast Office Warning area, or metropolitan area, which will provide for differences in the false alarm ratio and a way to test for a false alarm problem.
This project is ongoing.

**Publications**


**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)**

**Funding Agency:** CIMMS

**Objectives**

Investigate the multiscale events and interactions that culminated in the Texas Hill Country flood during the summer of 2002. This flood 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.

**Accomplishments**

The evolution of an extreme precipitation event depends on the multiscale interaction between large-scale conditions and synoptic-mesoscale processes. Large-scale conditions can provide a favorable environment for an extreme event, but a particular confluence of synoptic-to-mesoscale processes is also necessary. During this past fiscal year, we 1) continued our analysis of identifying the large-scale conditions in June 2002 that provided a favorable environment for heavy rainfall and contrasted those large-scale conditions with those of the summer of 1998 when a drought affected the region; 2) analyzed the recently released high resolution North American Regional Reanalysis data to document the interplay of dynamic and thermodynamic processes that maintained the intensity of the surface low and associated precipitation over the same local area; 3) prepared a journal article that will soon be submitted.

The following sequence of events occurred in the evolution and maintenance of the Texas flood within the favorable large-scale environment. A mid-tropospheric High-Low-High pattern centered over southeastern Texas developed around June 25th and can be traced to the break down of the eastern flank of the western drought-related ridge by a retrograding cut-off low. This cut-off low formed from the merger of the remnants of an MCS out of Kansas with a sheared upper level PV anomaly off of the east coast on June 21. This High-Low-High pattern optimized the transport of deep Gulf moisture into South-Central Texas and provided enough instability for explosive convective activity as the air was lifted over the Balcones escarpment. The localization of the rainfall over the 8-day period was made possible by a synchronization of dynamic and thermodynamic processes that maintained the intensity of the surface low. These processes include: 1) a baroclinic zone formed from the western ridge and the diabatically cooled air uplifted over the escarpment; 2) the upper PV anomaly on the dynamic tropopause, and 3) the mid-level PV anomaly that was generated from latent heat release and its position relative to the upper level PV anomaly. The figure below is a cross section from the Gulf, over the coastal plain and then through San Antonio and over the Balcones Escarpment in South-Central Texas for June 30 0000 UTC when the heavy, persistent precipitation began and June 30 1500 UTC when there was explosive development. All three of the above processes are shown in this figure.

This project is ongoing.
There are two panels for each time (June 30, 0000 UTC and June 30, 1500 UTC) with the topographical features represented in each of them. The first panel (a, c) contains the following fields: potential vorticity outlined by a long dash/dot blue line with values greater than one PVU shaded in yellow; theta as a solid green line; isotachs normal to the cross section indicated by the dashed red line and a circulation vector that is a combination of the ageostrophic and omega circulations. The second panel (b, d) contains the following fields: theta-e with a dashed blue line; relative vorticity in red with negative values indicated by a dashed line; upward omega values greater than 2 ub s\(^{-1}\) shaded in yellow; wind vectors tangential to the cross section (m s\(^{-1}\)).
Doppler Weather Radar Research and Development

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

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

Funding Agency: CIMMS Task III – ROC

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
Preliminary Level-I data were obtained from ROC engineers for the Dodge City, Kansas, radar and initial spectral analysis was performed. It was revealed that multiple turbines were present in each range resolution volume significantly complicating the interpretation. Therefore, an experimental campaign was organized for March 2006. Extensive planning took place including coordination with local NWS forecast office personnel, radar experimental configurations, and discussions with the wind farm manager. ROC personnel were instrumental in organizing this experiment. An extensive data set was obtained from the campaign and data analysis is currently underway. In addition to the WSR-88D radar, one of the C-band SMART radars was taken to Dodge City for the experiment. It is hoped that the finer spatial resolution of the SMART-R radar will facilitate our understanding of wind turbine clutter. Analysis of these data also continues. Two students are assisting on this project: one (Brad Isom) who is an electrical and computer engineering student working on signal processing techniques, and another (Tim Wiegman) who is a meteorology student focusing on the study of the significance of this clutter on the WSR-88D network.

This project is ongoing.
Doppler spectra from KDDC from March, 2006. Notice significant wind turbine clutter at elevation angle of 0.5 degrees.

Advanced Weather Studies with the National Weather Radar Testbed
Palmer (primary – OU School of Meteorology), Yu, Yeary, Zhang, Chilson

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

Funding Agency: CIMMS Task III – NSSL

Objectives
Develop an advanced radar simulator for phased array radars; study and implement several diverse techniques on either the radar simulator or the radar – examples include refractivity retrieval, beam multiplexing, and adaptive array processing for clutter mitigation and resolution enhancement, and waveform design (pulse compression).

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-function PAR (MPAR) project. The following paragraphs provide an
overview of the various components of the research being conducted for this project. In each case, a strong collaboration with NSSL scientists is emphasized.

**Refractivity retrieval (Palmer).** 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 Chris Curtis at NSSL, we have been able to provide the first results of refractivity retrieval using the PAR. Comparisons were made between the PAR results and those from KOUN (with the help of Sebastian Torres) and from the Oklahoma Mesonet. Preliminary analysis shows the capability of tracking storm-scale regions of either drying or moisture air. Significant effort has been placed on the robustness of the algorithm with an ultimate goal of real-time implementation and operational usage. Several conference presentations have been provided and are listed below. It is planned to submit a journal article in the next year.

**Beam multiplexing (T. Yu).** Beam multiplexing (BMX) leverages on the beam agility of the PAR to exploit the idea of collecting independent samples and maximizing the usage of radar resources. In other words, the radar will revisit the location of interest after signals become uncorrelated. As a result, the statistical error of the estimates can be minimized using a fewer samples. During the revisit time, the radar will be tasked to scan other locations to maximize the usage of the radar resources. As a result, the radar beam will be multiplexed over a designated region to provide measurements with low statistical error in a shorter period of time. An improvement factor is introduced to quantify the BMX performance, which is defined by the reduction in data acquisition time using BMX when the same data accuracy obtained by a conventional scanning strategy is maintained. In collaboration with engineers at the NSSL, BMX data collected at the NWRT were analyzed and compared with those obtained by step scan (SS), which is similar to the scanning strategy using by conventional mechanical-rotating weather radar. Statistical analysis has shown that BMX can provide fields of the three spectral moments that are consistent with those from SS. Moreover, the variance of the spectral moment estimates can be smaller than those from SS for the same data acquisition time. The results indicate that rapid scans can be achieved by BMX and the data quality required by conventional radar is still maintained. The improvement in data acquisition time with an average factor of 2 to 4 was obtained from the data. A new student (Ricardo Reinoso) was recently hired to assist on these, and related, aspects of the project.

**Target detection/tracking (Yeary).** Collaborative efforts have been devoted to point target detection with the Phased Array Radar (PAR) at the National Weather Radar Testbed (NWRT) in Norman, Oklahoma. These targets have been the aircraft at the Oklahoma City International Airport. Detections have been made based on processing the Level-I data from the radar. These observations have been subsequently input to a carefully designed tracking algorithm for off-line trajectory calculations. The importance of these studies is that they illustrate how predictive beam assignments by the adaptive tracking algorithms can be leveraged on a fully electronically steerable array: the next-generation MPAR. As commonly accepted, typical or friendly targets are non-maneuvering. By definition, they do not possess strong accelerations along their respective velocity vectors. However, uncooperative or unfriendly targets may experience erratic behavior on an undocumented flight plan. This behavior is modeled by significant accelerations or maneuvers. The dynamic properties of these maneuvers are highly non-linear. It is noted that several examples in the test data did illustrate slightly non-linear phenomena in regions close to the airport. As discussed in the most recent literature, particle filtering is the nickname given to an emerging Monte-Carlo non-linear state estimation method and was employed here. As typically done, the Kalman filter is utilized for the tracking of targets (either point target or distributed), and particle filters offer greater accuracy in their tracking. The non-linear tracking problem is described when the path of the moving or dynamic target is modeled by non-linear differential equations. The particles are sampling points of the probability distribution of the system. By doing this, the particle filter can circumvent the usual problems associated with Kalman filter.

**Crossbeam wind measurement (Zhang).** In collaboration with NSSL scientists and engineers, Spaced Antenna Interferometer (SAI) configurations have been suggested for the NWRT to measure crossbeam wind, shear, and turbulence. The theory for such weather measurements did not exist prior to our work. We developed a complete theory of weather radar interferometry for SAI measurements. Auto- and cross-correlation functions of received signals are derived based on wave scattering by randomly distributed particles. The antenna separation, mean wind, shear and anisotropic turbulence are all taken
into account in the formulation. 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 a radar resolution volume cannot be separated using monostatic Doppler techniques, angular shear and turbulence can be separated using the SAI. Currently, SAI hardware implementation is undergoing at NSRL. A PhD student (Qing Cao) has been hired to assist on this effort.

**Pulse compression (Chilson).** One portion of this work has been to investigate the impacts of pulse compression on MPAR using both phase and frequency modulation. Binary phase coding techniques are widely used for wind profiling radars, but before these are adapted for weather radars, other pulse compression algorithms should be considered. For example, frequency modulation offers several advantages over phase modulation such as improved integrated sidelobe level (ISL) suppression. The different algorithms will be tested using the weather radar simulator developed at OU. A graduate student, Tim Alberts, was hired in June 2006 to work on this project. He is pursuing an MS degree within the School of Meteorology. Tim Alberts has a background in Aeronautical Engineering and is well suited to meet the research challenges presented by the project. To date, Mr. Alberts has been primarily occupied with background reading; but, he will begin working with weather radar simulator in the Fall of 2006.

This project is ongoing.

**Publications**

First refractivity results from the Phased Array Radar. The upper-right panel shows the moisture field derived from ground clutter targets.

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Quantitative Precipitation Estimation and Segregation Using Multiple Sensors
J. Zhang (primary – CIMMS at NSSL), Langston, Xia, Fang, Gourley, Wang, Arthur, Ware

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

Funding Agency: CIMMS Task II – NSSL Project 2

Objectives
Study various aspects of forecast improvements in hydrometeorology.

Accomplishments
Evaluate improvements in accuracy of precipitation estimates using dual-polarization radar parameters. Through a collaboration built between the French weather service (MeteoFrance) and NSSL/CIMMS, several polarimetric data sets were examined using MeteoFrance’s Trappes radar. Although the radar operates at C-band, many of the developed algorithms are readily tunable for application at S-band. The first phase of this collaboration involved a detailed analysis of the raw, polarimetric variables. Several artifacts were discovered and correction methodologies were developed. Results from this study are in press. The second phase of this collaboration involved the development of a scheme to account for the effects of attenuation on the radar signal at C-band. The scheme utilizes a cross-correlation analysis to advect echoes and then examine their change over a 5-min period. The algorithm was shown to adequately correct for the power losses. A manuscript describing the results has been accepted for publication. The third component of this task involved the development of an algorithm to automatically remove non-precipitating echoes from rainfall accumulation maps. The algorithm relies on fuzzy logic and a method was presented to objectively derive membership functions that apply to any scanning radar operating at X-, C-, and S-band. As shown in Fig. 1, the algorithm successfully improved the data quality on the polarimetric variables. Results have been submitted for peer review.

Assess the usefulness of integrating data in a QPE scheme from radars operating at different wavelengths. The connection to the real-time Canadian radar base level data was established between the NCDC and the NSSL, and initial efforts for integrating the data into the National Mosaic QPE (NMQ) system are underway. The Canadian data will provide valuable hazardous weather information for the busy aviation corridor along the northeastern US-Canada border and the very much-needed hydrological information for the great lakes. The Canadian radar feed consists of 31 radars with average latency of 20 minutes from real time. Since there exist many differences between the Canadian radars (5-cm wavelength or C-band) and the US WSR-88D radars (10-cm or S-band), initial studies are focused on the inter-comparisons between the two radar networks. Examples of the Canadian radar data and nearby WSR-88D data were collected for selected events and will be examined. A real-time radar reflectivity comparison scheme is implemented for evaluating calibration difference among the Canadian radars and between the Canadian radars and WSR-88Ds. These research results will provide bases for developing scientifically sound strategies for the integration of radar data from different wavelengths.

Explore calibrating satellite data from multiple channels using radar-derived precipitation estimates. An ongoing study between the NWS Office of Hydrologic Development (OHD), National Environmental Satellite Data and Information Systems (NESDIS), and NSSL/CIMMS has chosen the Tar River Basin in North Carolina as a hydrometeorological testbed to evaluate a suite a next generation precipitation products. Several significant hydrologic events have been chosen for algorithm development and refinement. The satellite and radar-based algorithms will be compared to collocated rain gauges. At this stage of the project, we have identified two major rain events from 10 December 2004 to 15 January 2005 and flood-producing rain events from 02 June 2006 to 15 June 2006 for intensive study. The GOES-12 band 3, 4, and 6 data in McIDAS AREA file format from the CLASS archive have been ordered for the study. This work is part of the Coastal and Inland Flood Observation and Warning (CI-FLOW) project initiated by NSSL and NOAA Sea Grant in February 2000.

Utilize mesoscale model analyses and explore the use of forecast fields for improving diagnostic and ultimately, prognostic QPE. There are many uncertainties in radar and satellite derived precipitation
estimates. For instance, lacking of knowledge about the microphysical process and hydrometeor drop size distributions in a precipitation system is the cause for errors in Z-R relationships. The NWP model fields can be used to define the atmospheric environment and to identify microphysical processes (e.g., rain versus snow, warm rain, etc.). In the NMQ system, three-dimensional thermal fields from the hourly RUC analysis are used in convective/stratiform segmentation and surface precipitation type analysis. The 0C height field derived from RUC analyses is used as a background field for bright band top and bottom height analyses. RUC surface temperature is used in radar reflectivity quality control, in surface precipitation type analysis, and in a scheme that defines climate zones for satellite QPE.

Couple rainfall fields to a distributed rainfall/runoff model that will provide forecasts of impending floods based on model output of stream flow. A search for a community hydrologic model that employs distributed parameters and is physics-based led us to the TREX/CASC2D model developed at Colorado State University (CSU). A contract was developed between NSSL and CSU for training and support. The training session lasted a week and was largely successful. Now, the source code has been transported to NSSL and successfully compiled. Precipitation has been derived using the SMART radar data collected for the Hydrometeorological Testbed Experiment that took place during the winter of 2005-2006 near Sacramento, CA. All precipitation grids for an intense observation period have been formatted and reprojected so that they can be readily input to the model.

Mosaic reflectivity, velocity and their derivatives from multiple radars onto a common 3-D Cartesian reference frame. A new 3D adaptive mosaic system was researched and developed in the NMQ to increase the computational efficiency of the mosaicing process as well as improve the flexibility for high temporal and spatial resolution 3D rendering of radar reflectivity data. The adaptive radar mosaic facilitates an increase in the 3D mosaic grid resolution to support severe storm, flashflood and landslide monitoring and prediction. One of the key components of the adaptive radar mosaic is the transformation of an individual radar volumetric observation from a spherical to a Cartesian coordinate system. The individual radar data are mapped onto a 3-D single-radar Cartesian (SRC) grid of scalable resolutions (e.g., 250 m x 250 m with 230 km radius and 1 km x 1 km with 460 km radius). The SRC grid is centered at the radar site, and one or more sets (with different spatial resolutions) of SRC grid analysis can be generated for each volume scan of radar data. Using the individual radar Cartesian grids, the adaptive mosaic system assembles SRC grids into 3D seamless radar mosaic. The mosaic grid can be a storm motion-following grid that has very high spatial resolution (< 1km) and very rapid update cycle (≤ 5min).

The NMQ 3-D mosaic grid can be generated very quickly because that the most expensive computations related to the spherical-to-Cartesian coordinates transformation has been done in each individual SRC grids. Based on the national 3-D mosaic grid, a suite of next-generation QPE (Q2) algorithms have been developed and implemented in real-time NMQ system. The figure below shows a few examples of the real-time NMQ products.

These projects are ongoing.

Publications
Severe Weather Warning Research and Application Development – VCPExplorer
Manross (primary – CIMMS at NSSL), Smith

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

Funding Agency: CIMMS Task II – NSSL Project 3

Objectives
Upgrade the existing VCPExplorer to qualitatively illustrate data quality issues of radar estimated precipitation as related to terrain, range from radar, volume coverage pattern, precipitation type (Z-R, Z-S relationship), bright banding, and sub-cloud evaporation.

Accomplishments
The Volume Coverage Pattern Explorer (VCPExplorer) was delivered to the National Weather Service (NWS) Warning Decision Training Branch (WDTB) in the spring of 2004. Since then, the VCPExplorer has been used in the WDTB’s Advanced Warning Operations Course (AWOC) in the fall of 2004 to qualitatively explore areas of potential radar error. Perhaps the greatest illustration the VCPExplorer...
impressed on the AWOC attendees was the fluctuation of radar-based algorithm output, such as the Probability of Hail (POH), due to 1) range from the radar and 2) choice of VCP.

WDTB then asked that the VCPEXplorer be upgraded to illustrate radar precipitation estimation errors, as well as some refinement of the interface. Most of these changes have been incorporated and will be used in the WDTB Winter Weather AWOC.

This project is ongoing.

**Publications**


Severe Weather Warning Research and Application Development – CASA Radar Shear Maxima Algorithm Development
Manross (primary – CIMMS at NSSL), Lakshmanan, Smith, Hondl, Pimentes

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

Funding Agency: CIMMS Task II – NSSL Project 3

Objectives
Develop algorithms to detect and track the locations of maximum shear detected from simulated CASA radar data.

Accomplishments
Because CASA radar data have different range-resolution characteristics than NEXRAD data, new algorithms are required. The algorithm will form part of the meteorological command-and-control of the CASA radar network. CIMMS researchers developed a multi-Doppler wind field analysis algorithm, which is a linear least-squares derivative algorithm used to identify maxima in azimuthal shear, and adapted the existing NSSL Mesocyclone Detection Algorithm (MDA) and TVS Detection Algorithm (TDA) for use in the CASA/WDSS-II environment.

In summer 2006, Soralis Pimentes, a visiting NOAA scholarship student was supervised and aided by CIMMS researchers and NOAA employees. She used WDSS-II statistical tools to analyze the data resolution and clutter characteristics of radar reflectivity data from the initial testbed of two CASA radars by comparing the data to the Fredrick NEXRAD.

This project is completed.

Publications
Excerpts from a poster presented by Kurt Hondl (NSSL) at the NSF CASA site visit in April 2006. Images depict some of the shear maxima detection algorithms developed by CIMMS researchers. MDA/TDA output (top left), LLSD azimuthal shear (top right), multi-Doppler wind field (bottom).
Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – Polarimetric Radar
Ryzhkov (primary – CIMMS at NSSL), Schuur, Melnikov, Giangrande, Heinselman, P. Zhang, Bachman, Krause

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

Funding Agency: CIMMS Task II – NSSL Project 5 and NSF

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

Accomplishments
Preliminary versions of operational algorithms for polarimetric QPE and HCA have been developed and tested for implementation on polarimetric WSR-88D radars. A new methodology implies polarimetric classification of different hydrometeor types prior to quantification of their amounts and associated precipitation.

A new technique for attenuation correction and radar echo classification for C-band polarimetric data has been suggested and explored using theoretical simulations and observations in cooperation with Environment Canada. Analysis of polarimetric data collected at C-band demonstrates the unique capability of dual-polarization radar to delineate rain/snow boundaries and to distinguish between different types of winter precipitation.

This project is ongoing.

Publications
Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – WSR-88D Estimation of Convective Boundary Layer Depth

Heinselman (primary – CIMMS at NSSL), Stensrud, Spencer, Burke

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

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives
Explore the ability of present operational scanning radar systems to detect the convective boundary layer depth in comparison with 915 MHz profiler and sounding data.

Accomplishments
Knowledge of the depth of the convective boundary layer (CBL) is important to forecasting storm development and evolution, yet it is poorly predicted by numerical forecast models and can be in error by a factor of two. Numerous studies show that CBL depth is accurately estimated using the 915 MHz radar profiler signal-to-noise ratio (e.g., Angevine et al. 1994; Grimsdell and Angevine 1998). As the boundary layer evolves, the peak in signal-to-noise ratio corresponds with the inversion height. Information on CBL depth would be of great benefit to both operational forecasters, trying to gauge inversion strength and boundary layer growth into the inversion, as well as to numerical weather prediction.

The present observational system provides surface data at hourly intervals or less, yet we have little information to constrain or define the growth of the CBL in our numerical models. It is possible that improvements in the initial growth of the CBL into the residual layer early in the morning will lead to dramatic improvements in CBL depth forecasts later in the day. In this case, providing an observation of CBL depth to assimilate into numerical models, along with all the other observational data sets, will produce significant improvement in short-range forecasting. The CBL depth data would help to determine the correct flux profiles within the boundary layer, thereby leading to improved forecasts of boundary layer depth, convective inhibition, air quality, and perhaps even convective initiation and evolution. A preliminary analysis of four days of KTLX data, collected during the summer of 2004, indicates that the height of peaks in 4.5 degree (and 4.3 degree) elevation radar reflectivity data correspond closely (within 100 m) to peaks in 915 MHz radar profiler signal-to-noise ratio (see figure below). These findings suggest that WSR-88D reflectivity data have strong potential to accurately estimate the depth of the CBL.

This project is ongoing.
Evolution of the height (km AGL) of the CBL based on KTLX (red and green lines) and 915 MHz profiler data (blue line).

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – Hail Detection
Heinselman (primary – CIMMS at NSSL), Ryzhkov

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

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives
Describe, illustrate, and validate hail detection by a simplified version of the NSSL fuzzy logic polarimetric hydrometeor classification algorithm (HCA).

Accomplishments
This study describes, illustrates, and validates hail detection by a simplified version of the National Severe Storms Laboratory’s (NSSL) fuzzy logic polarimetric hydrometeor classification algorithm (HCA). The HCA uses four radar variables: reflectivity, differential reflectivity, cross-correlation coefficient, and reflectivity texture to classify echoes as rain mixed with hail, ground clutter / anomalous propagation, biological scatterers (insects, birds, and bats), big drops, light rain, moderate rain, and heavy rain. Diagnostic capabilities of HCA, such as detection of hail, are illustrated for a variety of storm
environments using polarimetric radar data collected mostly during the Joint Polarimetric Experiment (JPOLE; 28 April 2003 – 13 June 2003).

Hail classification with the HCA is validated using 47 rain and hail reports collected by storm-intercept teams during JPOLE. For comparison purposes, probability of hail output from the NEXRAD Hail Detection Algorithm (HDA) is validated using the same ground truth. The anticipated polarimetric upgrade of the WSR-88D network drives this direct comparison of performance. For the four examined cases, contingency table statistics show that the HCA outperforms the HDA. The superior performance of the HCA results primarily from the algorithm’s lack of false alarms compared to the HDA. Statistical significance testing via bootstrapping indicates that differences in POD and CSI between the algorithms are statistically significant at the 95% confidence level, whereas differences in FAR and HSS are statistically significant at the 90% confidence level.

This project is completed.

Publications:

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – Polarimetric Signal Processing
Melnikov (primary – CIMMS at NSSL), Carter, Ryzhkov, Zrnic, Ivic

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

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives
Work out calibration issues for future polarimetric WSR-88D radars.
Accomplishments
The simultaneous transmission scheme accepted for use in the polarimetric WSR-88D requires calibration of differential reflectivity. A calibration procedure has been worked out and tested on NSSL’s KOUN test radar. The procedure is based on utilization of solar radiation and well-calibrated test signals generated by the radar itself.

Polarimetric radars, including the updated WSR-88D, need to be calibrated on differential phase. A calibration procedure has been devised; it utilizes the radar returns from ground clutter. It was shown that the differential phase from the ground has a one-mode distribution with a maximum that corresponds to the radar system differential phase.

Polarimetric variables are vulnerable to noise impact. To eliminate noise biases, a technique has been devised called “one-lag estimators” because it utilizes the one-lag correlation functions. A technique for LDR measurements has been published and corresponding algorithms for ZDR measurements will be published in 2007.

This project is ongoing.

Publications

Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings – Mitigation of Range and Velocity Ambiguities
Torres

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

Funding Agency: CIMMS Task II – NSSL Project 7

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
In the WSR-88D, the range and Doppler velocity ambiguity problems are coupled such that trying to alleviate one of them worsens the other. Special techniques are necessary to resolve both ambiguities to the levels required for the efficient observation of severe weather. Over the last 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: systematic phase coding and staggered pulse repetition time (PRT). 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).

In conjunction with the National Center for Atmospheric Research, we have recently recommended and transferred to the Radar Operations Center of the National Weather Service an algorithm for the initial
deployment of range and velocity ambiguity mitigation techniques on the RDA subsystem. The algorithm, referred to as SZ-2, is based on systematic phase coding that uses the SZ(8/64) code and will replace the Doppler half of split cuts at the lowest elevation angles of the antenna beam. During this year, the SZ-2 algorithm was refined and tailored for integration into the operational environment. The SZ-2 algorithm will become operational on the NEXRAD network in 2007.

This project is ongoing.

Publications

Reflectivity (left panel), legacy Doppler velocity (central panel), and SZ-2 Doppler velocity (right panel) PPI displays corresponding to widespread precipitation in central Oklahoma. Data was obtained with the recently upgraded KCRI radar in Norman, OK. Purple color denotes an unrecoverable Doppler velocity due to overlaid echoes. The SZ-2 phase coding technique removes significant amounts of purple haze resulting in displays with larger areas of recovered Doppler velocities.

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), Curtis, Ivic

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

Funding Agency: CIMMS Task II – NSSL Project 7

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 research we continuing our focus on practical issues involving the implementation of oversampling and pseudo-whitening techniques within the WSR-88D operational environment.

Range oversampling techniques were tested on real dual-polarization data collected with the KOUN radar. The recently upgraded digital receiver allows collection of time series data at sampling rates higher than the legacy sampling rate. Results on real data were used to confirm theoretical and simulation findings. Compared to standard processing of signals using a matched filter, it was verified that a reduction in variance by a factor equivalent to the oversampling factor is achieved.

Preliminary results on real data have demonstrated that techniques employing range oversampling are feasible candidates to maintain data quality without sacrificing acquisition time in future enhancements of the national network of weather surveillance radars.

This project is ongoing.

Publications

Differential Reflectivity obtained using different range-oversampling techniques. As expected, all methods yield the same measurement mean value; however, statistical errors are lower with range-oversampling techniques that employ a pseudo-whitening transformation.
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**

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

**Funding Agency:** CIMMS Task II – NSSL Project 7

**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.

We continued investigation of different approaches to produce super-resolution radar data on the NEXRAD network. After a comprehensive trade-off evaluation, we recommended a technique that uses overlapping radials with data windowing to reduce the effective antenna beam width and thus improve the spatial resolution of radar data. In addition, to reduce bandwidth needs, we recommended a single-stream approach. That is, only super-resolution base data is transmitted from the Radar Data Acquisition (RDA) subsystem to the Radar Product Generation (RPG) subsystem where radial recombination is performed. Recombined radial data produced for the algorithms has legacy resolution and acceptable quality. Super-resolution radar data produced this way is scheduled to become available operationally in 2008. Through simulations of tornadic time-series data, we quantified the improvements in tornado detection that can be realized with super-resolution data. In addition, we developed the radial recombination algorithm and quantified its performance in producing legacy-resolution base data for the RPG algorithms. The recommended signal processing technique and radial recombination algorithms were implemented on the RDA and RPG subsystems of the KOUN radar which will serve as a test bed for various analysis and validation activities.

This project is ongoing.
Effective antenna patterns corresponding to legacy- and super-resolution processing for a Gaussian intrinsic antenna beam pattern with a two-way 6-dB beam width of 0.89 deg. A narrower effective pattern leads to data with improved spatial resolution.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – National Weather Radar Testbed
Adams, Burcham, Curtis, Forsyth (co-primary – NSSL), Hondl, Jain, Priegnitz, Staples, Suppes, J. Thompson, Zahrai, Zrnic (co-primary – NSSL)

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

Funding Agency: CIMMS Task II – NSSL Project 8

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; provide meteorological analyses of PAR data to evaluate the utility of using the PAR technology for weather detection purposes.

Accomplishments
The forward engineering and development of the Phased Array Radar system has continued at an accelerated pace over the past year. Testing of all operational software, hardware components, and design implementations have resulted in a very user friendly and robust system. The current system supports web based operations through a Radar Control Interface Server (RCIS) and operator inputs provided through separate Radar Client Interface (RCI) workstations. The testing on the design change was extensive and progressed without any significant operational interruptions to the system. A major milestone of this design and testing effort occurred during the American Meteorological Society (AMS) meeting in Atlanta Georgia. The Phased Array Radar was operated via an RCI running on a laptop in Atlanta, successfully collecting several data sets that were displayed at the convention.

The display of these products at the convention was the result of another major change to the system which allowed for ingest of radial data from the digital receiver and distribution of the radial data to linear buffers used by the display system. Once the Digital Signal Processing (DSP) capability was designed, implemented, and tested on the Moment Data Processor (MDP) (previously referred to as the Matrix), the radial data ingest and distribution software was ported to that system. The addition of the DSP to the MDP allowed for the development and implementation of a Beam Multiplexing collection concept. This
method of collection accelerates the systems ability to interrogate meteorological structures, thus highlighting speed as one of the PAR's biggest advantages over conventional radar systems.

The tracking portion of the PAR was also addressed with implementation and successful testing of the Federal Aviation Administrations (FAA) Track Processor. Several tests were conducted to show the collection and tracking of metallic spheres suspended from weather balloons with GPS attached. The display position correlated with the position indicated by the Track Processor.

The data collected via the NWRT has been redirected to a new RAID storage device that was configured to accept 3.5 terabytes of data. This data can be off loaded to 500 gigabyte self-contained hard drives for temporary storage or manual transfer to a long term storage device. There have been numerous other testing successes ranging from identification and correction of the GPS message through the Real Time Controller (RTC) to firmware upgrades for the Digital Receiver. There are too many problem identification, corrections, and validations to be listed here so only the key upgrades to the system are covered in this report.

This project is ongoing.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – Crossbeam Wind Measurement

Curtis (primary – CIMMS at NSSL), Doviak, P. Zhang, Carter, Wahkinney

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

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives
Measure the sum and difference patterns of the phased array antenna to facilitate crossbeam wind measurement.

Accomplishments
We used a signal generator attached to a horn to measure both the sum and difference receive patterns of the phased array antenna. We also used the signal generator to measure the receiver transfer curve
for the receiver portion of the phased array. More measurements are planned for the future, including transmit pattern measurements. Work is being done to install a high-speed switch to enable sum and difference measurements using the current single-channel receiver.

This project is ongoing.

Publications

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – Radar Control Interface (RCI)
Priegnitz (CIMMS at NSSL)

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

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives
Design a new radar control application that can be run remotely and by multiple users.

Accomplishments
The Radar Control Interface (RCI) application was developed as a full replacement for the Radar Scheduler application delivered with the original phased array system. Its main advantages are remote control, multiple user access and improved system status. The RCI is composed of two functional areas: a single server and one or more clients. The server functions as the focal point for all command and status activities. Commands are accepted from a single controlling user client and directed to the other system components. System status is available to all user clients regardless as to whether they are controlling or non-controlling. User client access is controlled through well defined security procedures implemented at the server. Users who are not included in the security access file on the server are denied access. Although the number of local severe weather events was limited this past season, the RCI has proven to be more robust and intuitive than its predecessor during operations.

This project is ongoing.

Publications
Sample Radar Control Interface (RCI) client display.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – *Stimulus Wizard*

Priegnitz (CIMMS at NSSL)

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

**Funding Agency:** CIMMS Task II – NSSL Project 8

**Objectives**

Design and develop a software application to help scientists develop scan control command (stimulus) files for the phased array radar testbed.

**Accomplishments**

A new software application, the Stimulus Wizard, has been developed to help scientists create scan control files, called stimulus files, which are used by the Real Time Controller (RTC) component of the phased array radar testbed. This Java-based application provides an intuitive graphical user interface to make the task of creating new stimulus files quick and simple. A number of these Stimulus Wizard-generated files were used during data collection operations in summer 2006. In several instances, the Stimulus Wizard was used during operations to modify an existing scan strategy (i.e., add additional elevation cuts). This process took only several minutes to complete, whereas in the past manual editing and conversion would have taken hours. Currently, work is underway to add a beam multiplexing option to the Stimulus Wizard so that each pulse in the scan control file is explicitly defined.
This project is ongoing.

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

CIMMS students at ROC – Setzer, Murnan, Muhammad, Patchin, Keel, Garfield, Dunn, Jones, McCarroll, Seelan, Garwood; George, Haden, Miller, Lee, Zittel, Reed

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

Funding Agency: CIMMS Task II - ROC

Objectives

Rewrite the ROC LAN training manual; help ensure the security of computers and networks; develop training material for relaying the importance of weather radar in protecting the public from severe weather; evaluate and test new radar software and algorithms prior to field implementation; perform daily assessments of WSR-88D data quality; verify validity of radar blockage maps; evaluate radar algorithm performance; develop and improve radar antenna pedestal simulators to allow more development efforts without the need for a complete radar system; develop technology upgrades to improve weather radar reliability and power efficiency.

Accomplishments

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

The ROC LAN training manual is an extremely important part of the ROC security posture. It provides every new employee with the necessary information to use the ROC network in a safe and secure manner. It also provides all of the information necessary to use the various applications available. Work was done to revise the manual to address the multitude of security changes that have occurred over the
last three years, work critical to the ROC being able to support its mission of Doppler radar research and support.

Extensive work was done with the Director’s office and the NOAA Public Affairs office on a variety of projects the past year. One of his key projects was to create new digital photography images and displays to tell the story of how weather radar is used by NWS personnel to inform and warn the public of severe weather. Work also was done with other Norman NOAA Weather Partners to update file photography and video imagery for NEXRAD, the Phased Array Radar test bed, Norman Weather Forecast Office, National Severe Storms Lab, and the Storm Prediction Center.

Work was done that has contributed to the success of the Radar Support Team's WSR-88D software testing mission, including particularly the testing of the Build 8.0 Radar Product Generator software. This included testing the new Snow Accumulation Algorithm to ensure it operated correctly and output accurately on the NWS AWIPS and DOD Open Principal User Processor display systems. Work also was done to assist in updating and revising test procedures to ensure comprehensive testing of the new software to ensure it worked correctly in an operational setting. This contributed to the successful deployment of this system upgrade with minimal impact to forecast office operations around the U.S.

Work was done to evaluate radar algorithm performance by reviewing output products for defects, errors, and artifacts caused by poor data quality. Averaging 60 products per case, 35 cases, and 18 different algorithms, more than 37,000 products were evaluated. The Data Quality Working Group was supported by ordering, playing back, and evaluating special cases for radar engineers, helping problems get identified in a timely manner. Additionally, data was cataloged for future use by researchers.

Valuable contributions were made in support of the Multiple PRF Dealiassing Algorithm (MPDA). The MPDA is used to mitigate range aliasing prevalent in large scale weather systems such as Tropical Cyclones. The MPDA must remove noisy velocities that occur at the end of the first trip for each of the three PRF-unique velocity scans. This data cleanup is handled via adaptable parameters. The original values were designed for use with the Legacy (previous generation) Radar Data Acquisition (RDA) system. Twenty different sites were analyzed to determine the precise position of potential noisy rings with the newly deployed Open RDAs. The new values for the adaptable parameters will be fielded with Build 9 software to be released in the spring of 2007.

Work was also done to assist radar meteorologists in the Applications Branch in reviewing radar blockage files which were generated for all radar sites using updated geopositioning system (GPS) readings. These file comparisons required finding cases from radars with widespread precipitation events, involving a tedious search through data archives for just the right scenario to be of use to the investigating scientist.

Another project has developed an improved pedestal simulator that better simulates actual time responses of normal weather radars. This simulator will allow future researchers and developers to perform work without needing actual radar time since much can be done without the need for an actual radar antenna. This work will be of great benefit to the upcoming dual polarization development effort.

A major radar transmitter reliability improvement was researched, developed, and deployment started. This development effort will mean that weather radars are more likely to be operating during severe weather events when they are most needed. A major technology upgrade that will allow more new science to be inserted into weather radars also was developed. In addition, a LED-based warning light was researched and approved for deployment. The application of this new technology to weather radar will lower energy consumption during routine radar operation.

Many of these projects are ongoing.
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), Farmer, Lakshmanan, Legett, Manross, Scharfenberg, Sigler, P. Zhang

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

Funding Agency: CIMMS Task II – ROC

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. For Dual-Polarization (DP) technology, 1) functional descriptions of the initial set of 4 algorithms were prepared, 2) DP training and consultation was given to ROC and NEXRAD tri-agency personnel, 3) DP product evaluation was begun, 4) assistance was given to DP IV&V efforts. Analysis was begun on different versions of Super-Resolution data (0.5 deg and 250 m gate spacing). Work was begun on a new Mode Selection Function for correct VCP selection. Specialized data quality software was investigated for data going to algorithms. No appreciable improvement to legacy data quality software was found. Two different dealiasing algorithms (WSR-88D legacy and 2-D multipass) were tested on Terminal Doppler Weather Radar data. Advantages of each algorithm were documented. Many special data sets (Level 1 data on NSSL and
ROC test radars, and others) were collected, archived, enhanced by supplemental data, and made available for use by this project and other researchers in Norman and elsewhere.

This project is ongoing.

**Publications**

**Emergency Mobile Radar**
Biggerstaff (primary – OU School of Meteorology), Hondl, Crum, Carrie

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

**Funding Agency:** CIMMS Task II - ROC

**Objectives**
Install the Weather Decision Support System Integrated Information (WDSS-II) in Shared Mobile Atmospheric Research and Teaching (SMART) radar to serve as an emergency backup for the WSR-88D network during land-falling hurricanes; test transmission of real-time data from the radar to a remote computer in a Forecast Office via direct Ethernet link and wireless radio.

**Accomplishments**
This project intends to prepare SMART radars for emergency use by the National Weather Service as backups to the WSR-88D system during land-falling hurricanes. WDSS-II software was installed and tested twice. The SMART radar data were successfully ingested and displayed without loss for the duration of each four hour test. Transmission to a remote computer was tested via Ethernet cable link and via wireless radios. All data were successfully received at the remote computer site.

The testing phase of this project is completed.

**Publications**

*Display of SMART radar data in WDSS-II for raw files collected during a tornadic supercell observed on 16 May 2003 in the Texas panhandle.*
Development of Mobile X-Band Weather Radar
Biggerstaff (primary – OU School of Meteorology), Wicker, Straka, Zahrai, Zrnic

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

Funding Agency: CIMMS Task III – NSSL

Objectives
Develop and test a mobile dual-polarimetric X-band Doppler radar for weather research including quantitative precipitation estimation, lightning research, hurricanes, tornadoes, microphysics, and numerical forecasting; an immediate objective is to evaluate the utility of X-band dual-polarimetric data for operational use in preparation for the polarimetric addition to the multi-function phased array radar.

Accomplishments
During the reporting period, the transmitter has been modified to split the transmitted pulse down two orthogonal sets of waveguide and the receiver chain has been developed based on a RVP8 signal processor capable of processing both channels of the dual-polarimetric datastream. Additionally, a SCR-584 pedestal has been purchased and modified to upgrade its electronics package and integrated with the RCP08 antenna controller. A reflector has been received and mounting brackets have been designed to attach the reflector to the pedestal. An international 4400 series truck has been purchased and will serve as the mobile platform for the NSSL-OU X-band Polarimetric (NO-XP) radar. Integration and final testing will be conducted during spring-summer 2007.

The testing phase of this project is completed.

Polarimetric Upgrade to a Mobile C-Band Weather Radar for Kinematic and Microphysical Studies of Storms
Straka (primary – OU School of Meteorology), Biggerstaff, Wicker

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

Funding Agency: CIMMS Task III – NSSL

Objectives
Develop mobile, polarimetric C-band radar.

Accomplishments
During the reporting period a transmitter was purchased for the radar.

This project is ongoing.

Improving Tornado Detection with WSR-88D Data using Spectral Analysis
T-Y 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 Agency – CIMMS Task III – CSTAR

Objectives
Develop an algorithm to provide accurate tornado detection using the WSR-88D and extend detection range.
Accomplishments
We continue testing and refining the Neuro-Fuzzy Tornado Detection Algorithm (NFTDA) with emphasis of developing new parameters to characterize tornado signatures. The two new parameters are the phase of radially integrated bispectrum (PRIB) derived from the higher order spectra (HOS) and the eigenvalue ratio from Level I time series data. Both parameters were successfully integrated into NFTDA. The input of current NFTDA includes azimuthal shear, spectrum width, eigenvalue ratio and two spectral signatures (flatness of spectrum and the spectrum shape). The NFTDA on KOUN data (red filled circles) from both May 8 and May 9, 2003 tornadoes are shown in the figure below. KOUN is located at the origin (not shown). Tornado damage paths from May 8 and May 9 tornadoes, provided by the NWS Weather Forecast Office in Norman, are denoted by green-shaded and blue-shaded regions. Moreover, blue triangles indicate the detection of NSSL TDA on KOUN data. The black triangles are the TDA results from KTLX radar. KTLX is located at approximately 15 km east and 12 km north of KOUN and was closer to the both tornadoes than KOUN. The time index of each volume scan from KOUN and KTLX is marked in red and black, respectively. It is evident that NFTDA can provide more accurate detection compared to the conventional shear-based TDA (TDA-KOUN, blue triangles). In other words, NFTDA will reject regions with only strong shear signature. For example, two false detections at 0401 UTC 10 May 2003 and three false detections at 2238 UTC 8 May 2003. Furthermore, from the May 9 case it is evident that NFTDA can extend the detection range of the NSSL TDA to at least 55 km. Note that the KOUN Level I data were available for only part of May 8 tornado.

Another accomplishment is the development of a “Resolution Enhancement Technique using Range Oversampling” known as RETRO. Oversampled signals are radar returns from shifted and overlapped resolution volumes in range. It has been recently shown that these signals can be whitened and averaged to optimally reduce the statistical error of weather spectral moment estimations for the case of uniform reflectivity and velocity. Using the same oversampled data, when the resolution is of interest, RETRO can reveal the variation of reflectivity and velocity in range at fine-scale. The idea is to utilize the redundant information contained in oversampled signals, which come from common regions, to improve the resolution defined by the range weighting function. As a result, oversampled data are optimally combined to produce high-resolution signals for spectral moment estimations. It is demonstrated that the range variation of a tornadic vortex with a diameter of 120 m can be reconstructed by RETRO at a scale of 25 m when a 250 m pulse and an oversampling factor of 10 are used. The results were recently published in the Journal of Atmospheric and Oceanic Technology.

This project is ongoing.

Publications
Comparison of tornado detection results from both KOUN and KTLX radars. The x-axis is the east-west distance from the KOUN and the y-axis denotes the north-south distance. Tornado damage paths of May 8 and May 9 tornadoes in Central Oklahoma are denoted by green and blue shaded regions, respectively. Detection results using NFTDA on KOUN data are indicated by red triangles. Conventional shear-based TDA results from KOUN and KTLX are denoted by blue and black triangles, respectively. It is evident that NFTDA produce more accurate and robust results compared to conventional TDA on KOUN (TDA-KOUN). Note that KTLX is closer to the tornado than the KOUN for both cases. Therefore tornado can still be detected.

Enhancement of Radar Retrievals by Use of Higher Moments of the Drop Size Spectrum

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

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

Funding Agency: U.S. DOE

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

Accomplishments
Errors of cloud property retrievals based on radar reflectivity, radial velocity, and spectrum width are evaluated under the controlled framework of the Observing System Simulation Experiments (OSSEs). Cloud radar parameters are obtained from drop size distributions obtained from a synthetic observational dataset generated by the high-resolution CIMMS LES model with size-resolved microphysics.

Including Doppler velocity or spectrum width in retrievals of liquid water content (LWC) or precipitation flux significantly reduces retrieval errors relative to methods employing reflectivity alone. In moderate drizzle (~1 mm d−1) the correlation (R²) between retrieved LWC and observed increases from 0.756 to 0.969 when Doppler velocity is incorporated into the retrieval. Correlation for retrieved precipitation rate improves similarly and increases from 0.794 to 0.962. Both velocity and spectrum width yield approximately the same potential for improving microphysical parameters, and the error estimates in this study constitute the lower bound on errors of microphysical retrievals. If the contributions to the radar
moments from air turbulence can be constrained and minimized, then the additional radar parameters may contribute to substantial improvement of microphysical retrievals under a wide range of precipitation conditions.

This project is ongoing.

**Publications**


The comparison of liquid water retrievals based on LES data and ASTEX observations by Fox and Illingworth (1999). The green line shows the ratio of Qi retrievals based on LES and ASTEX data.
Climate Change Monitoring and Detection

Detection and Attribution of Climate Change Using Climate Indices for the United States
Karoly (primary – OU School of Meteorology), Ruppert, 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 Agency: CIMMS Task III – NOAA CPO

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
Karl et al. (1996) developed the United States Climate Extremes Index (CEI) to quantify observed changes in climate within the contiguous U.S. The CEI is based on a combination of climate extreme indicators that integrates changes in climate over several different temperature and precipitation measures and is likely to provide early detection of important changes in climate in the U.S. The CEI is updated annually and used for operational climate monitoring at NCDC. An assessment of variations of the CEI over the twentieth century has been undertaken, including comparison of the observed indices with those calculated from global climate model simulations. 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., 2006) and the new version of the CEI is available on the NCDC web site.

The definition of most components (steps 1, 2, 3 and 5) of the CEI involves the sum of the percentage of the U.S. area with much below normal (below the 10th percentile) values of a temperature or precipitation variable and the percentage of the US with much above normal (above the 90th percentile) values. A change in the mean would lead to an increase in the values much above normal and a decrease in those much below normal, which would cancel in the sum. It is easy to show that the warming trend from 1910 to 1940 and from 1970 to 2005 in the US leads to more cold extremes at the beginning of the period and more warm extremes at the end, giving a rough U-shape to the century-scale variations in the temperature extremes index. Modified versions of CEI Steps 1, 2, 3, and 5 were developed as the difference of the percentage of the US area with much above normal values minus the percentage of the US with much below normal values. These modified CEI Steps more clearly show changes in the extremes associated with changes in the mean and are easier to interpret.

The modified CEI Steps have been calculated from climate model simulations for the 20th century from three different global climate models, the NCAR PCM 1.1 model, the NCAR CCSM 3.0 model, and the Japanese MIROC medium resolution model. Data from these models was obtained from the IPCC AR4 model data archive at PCMDI. The CEI variations from the model simulations agree well with observed variations. The observed increasing trends over the last 30 years and over the last 50 years in modified CEI steps 1, 2, and 4 have been compared with climate model simulations of the 20th century to assess whether these trends are consistent with the climate response to anthropogenic forcing. Significant increasing trends are found in the components of the modified CEI associated with extreme maximum (Step 1) and minimum (Step 2) temperatures. These variations are outside the range of internal climate variations simulated by climate models and are consistent with the models’ responses to increasing greenhouse gases and sulfate aerosols. Hence, it is likely that anthropogenic climate change is contributing to changes in annual mean temperature extremes in the United States. There also have been recent significant increases in the component of the CEI associated with more intense precipitation (Step 4). The increased precipitation intensity in the continental U.S. is consistent with the modeled response to anthropogenic forcing for the PCM model but not for the CCSM model.
This project is ongoing.

**Publications**

Operational CEI Step 1: the percentage of the U.S. area with annual mean maximum temperatures much above normal (red bars in upper plot) and percentage of the U.S. area with monthly mean maximum temperatures much below normal (blue bars in upper plot), together with their sum, combined percent in the lower plot. Each bar is the annual value, with the 5-year running average also shown. Note the increase in fraction of warm extremes and decrease in cold extremes over the period, which leads to the "U" shape in the combined Step 1 index. Reproduced from the CEI web site at NCDC.
Climate Information for Managing Risk through Agricultural Land and Machinery Contractual Agreements

Lamb (primary – CIMMS at OU), Richman, Timmer, Mjelde, Klinefelter, Le

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

Funding Agency: CIMMS Task III – NOAA CPO

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 extension of the unique Richman-Lamb set of daily precipitation totals and daily maximum and minimum temperatures for North America east of the Rocky Mountains was completed through 2000. This high density data set commences in 1949 and contains complete data for 776 evenly distributed (grid-like) stations with separations of about 110 km (65 miles). The recent extension of the data set was for 1992-2000. The entire data set is being used in the preliminary analyses of climate variability now being performed for key agricultural production “windows” for six locations across North America.

Literature reviews have commenced in the several areas of relevance to the project. One thrust is identifying the most important articles in very large literature that deals with risk, diversification, and contractual issues. Also being reviewed is relevant work in the areas of agronomy, agronomic and economic model building and linkage, and climate-agriculture relations. More narrowly, information is being assembled on the costs of tillage and harvesting across the study region. We have begun using the above Richman-Lamb data set to quantify the climate variability that has occurred during those production windows during the last half-century. In addition, we are using NOAA data for Washington State (not in the Richman-Lamb data set) to perform similar preliminary analyses.

To initiate the key involvement of members of the Association of Agricultural Production Executives (AAPEX) in the project, PI Peter Lamb participated in the AAPEX Annual Meeting in Cabo San Lucas, BCS, Mexico, during February 3-5, 2005. The results of the preliminary climate-agriculture analyses will be shared with the AAPEX members, and used to elicit feedback from them. Those interactions will help guide our future interactions with these and other AAPEX members.

This project is ongoing.
Small dots give locations of the stations in the Richman-Lamb daily precipitation and temperature data sets. Large colored-in circles locate the AAPEX farming operations for which preliminary climate-agriculture analyses have been initiated.

Development and Application of Dynamic Normals for Investigation of Climate Variation and Change
Richman (primary – OU School of Meteorology), Lamb, Hamm

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

Funding Agency: CIMMS Task III – NOAA/NESDIS/NCDC

Objectives
Use dynamic normals to investigate climate variation and change.

Accomplishments
Dynamic normals differ from the standard climate normals in two ways: (1) using an “optimal” averaging period, instead of the standard 30 year averaging period and (2) utilizing the vast quantity of model-generated future climate data to further refine the normal. By employing these dynamic climate normals as long-range forecasts that can be verified, the optimal length averaging period (for a given location, season, and meteorological variable) can be determined which adds an important tool for climate outlooks and detecting climate change.
A literature review of past and current methodologies employed for optimal and dynamic normals began with the frequency method used by Lamb (1981) "On the 'best' temperature and precipitation normals: The Illinois situation." The frequency method provides absolute values for determining the optimal length averaging period; however, confidence intervals must be applied to these results to determine their statistical significance. An efficient and accurate method to create such intervals is through the bootstrap. Other methods will also be used, including the investigation of correlations between forecast anomalies and observed anomalies (with respect to the standard 30 year climate normal) and the method of finding the minimum mean square error. Based on previous work, it is expected that different length averaging periods will be optimal in different parts of the country, in different seasons, and among different meteorological variables; however, regional consistency is likely and the identification of such regions is important for forecasts and the ability to detect climate change.

This project is ongoing.
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, and we trained two technicians and a manager in NERON site maintenance procedures. To aid in budget planning and future acquisition, 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. In Fall of 2005, we installed wind sensors and antennas for cellular and GOES communication at the Norman test sites, and in Spring of 2006, we worked with the manufacturers to install an OTT Pluvio I and a Vaisala VRG101 precipitation gauge at the Norman test sites for evaluation and comparison with the existing Geonor T-200B gauges.

This project is ongoing.

**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.
Prototype a Modernization Data Ingest and Quality Assurance System for a National Surface Mesonetwork

R. McPherson (primary – Oklahoma Climatological Survey), Fiebrich, Wolfinbarger, Bain, Morgan, Guiliano, Tapp, Fain, Henslee, Hurlbut

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

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives
Prototype operations, monitoring, and quality assurance capabilities for NOAA's Environmental Real-time Observing Network (NERON); document source code and SOPs (standard operating procedures) needed to operate and maintain the operations and monitoring.

Accomplishments
Accomplishments this year include:

- Performed automated quality assurance (QA) in real-time for all modernized NERON stations that had accurate latitude, longitude, and elevation;
- Issued 939 new trouble tickets and entered 866 trouble ticket fixes in near real-time;
- Monitored temperature, precipitation, wind speed, wind direction, and battery voltage data for possible problems;
- Maintained automated e-mail reports for daily QA and other diagnostic information;
- Created manual QA tool that plots temperature difference between two NERON sites for any given time period;
- Sent out weekly reports on trouble ticket and maintenance activities to WFOs, technicians, and NERON personnel;
- Responded to all requests/concerns regarding suspicious NERON data and data questions (mainly from WFOs and site hosts);
- Educated CO, AL, and KY surveyors on how to submit information to FTP site and proper way to fill out site survey forms;
- Implemented the second-generation Geonor algorithm;
- Implemented the CRN air temperature algorithm for sites with triple thermistors;
- Wrote decoders to ingest data streams from the new logger programs;
- Wrote ingest software to collect data from two-way Vaisala sites with new logger programs;
- Maintained hardware, operating system and system software, for routine and emergency operations

This project is ongoing.

Publications
Multicriteria Spatial Decision Support for the NOAA Environmental Real-Time Observation Network
Yuan, W. McPherson (primary – OU Center for Spatial Analysis), Bennet, Swan, Bardon, Benson

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

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives
Compile GIS data for focus states for NERON siting and conduct site mapping, evaluation, and modeling alternative sites for these states according to guidance from the national NERON management team; design the conceptual framework, identify data and functional requirements, and prototype a NERON GIS Web Collaboratory to enable on-line interactive analysis and collaboration among NERON teams.

Accomplishments
Data for all states requested at the time of this report have been collected (including Texas, Kansas, Kentucky, Arizona, New Mexico, and Colorado). Most data have been processed into the GIS. Additional states may still be collected and processed for NERON as needs are identified. Custom GIS products have been provided on an as-needed basis to NERON and regional teams in all the states where NERON has been working. A GIS web portal is being tested in Kentucky.
Based on previous work the GIS multi-criteria selection methods and model have been revised and enhanced to meet the needs for individual new states during the project period. Output from our GIS model shows locations suitable for siting climate monitoring stations. Products based on model output and other GIS data layers have been provided to the NERON team as requested to aid in the selection of sites.

This project is ongoing.

Publications

Prototype GIS web portal showing suitability analysis in Kentucky.
ARM Program Data Quality Office  
Peppler (primary – CIMMS at OU), Kehoe, Sonntag, Moore, T. Thompson, Schwarz, Hiers

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

Funding Agency: U.S. DOE Pacific Northwest National Laboratory

Objectives
Inspect, assess, and report on U.S. DOE ARM data from the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska sites on a near real-time basis, develop the tools necessary to conduct the activity, and provide support to site operators, site scientists, and instrument mentors to solve instrument measurement problems.

Accomplishments
The Atmospheric Radiation Measurement (ARM) Program Data Quality Office was formed in July 2000 to coordinate the data quality activities of the ARM Program, in response to a program review in 1999 identifying such a need. The ARM Program fields instrumentation and collects data from Climate Research Facilities located in the U.S. Southern Great Plains, North Slope of Alaska, and Tropical Western Pacific. These data are used by ARM scientists to learn more about the climate system and to apply this knowledge to improve the treatment of clouds and atmospheric radiation in climate models. Thus, to support the research properly, the data the ARM Program collects must be of high quality.

The Data Quality Office is responsible for making sure that ARM data are usable, so that data users are able to readily determine whether the data have been reviewed, how they were reviewed, and whether there are known problems. To facilitate this process, the Data Quality Office has developed a web-based tool called the Data Quality Health and Status (DQ HandS) system (http://dq.arm.gov/). DQ HandS reads ARM data files, displays flag information in the form of color tables, provides pop-up information indicating the nature of the flags violated, produces diagnostic plots of key parameters and allows for the interactive plotting of any file variables, and hosts various assessment and problem reporting mechanisms.

A key improvement developed this year was the creation of a statistical analysis report system. For each b-level or c-level datastream (the type available to ARM scientists and general data users), the system will generate long time-series plots, create and plot frequency distributions and various other statistics, and save the results in a MySQL database. For data quality purposes, its goals are to define QC limits for data streams without any valid_min or valid_max attributes and to improve existing QC limits for b-level and c-level products based on the historical record; determine which measurements might benefit from imposing monthly- and/ or site/facility-specific varying limits; and use long time-series plots to identify slow-developing trends. For the ARM program in general, the goal is to provide a new tool for visualizing long time-series measurements.

This project is ongoing.

Publications


Analysis of AERI limits for shortwave responsivity at the Niamey mobile facility deployment. As a new instrument in a dry, hot environment, no limits were pre-defined in the datastream’s netCDF files. The analysis tool automatically analyzed all AERI engineering data, assessed behavior, and helped identify reasonable data ranges. The frequency distribution shows a monthly data range distinct from overall range (January colored green), suggesting that monthly varying limits may be appropriate for these data.

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 Agency: CIMMS Task III – NOAA Office of Climate Observations (OCO)

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 raingauges, 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.

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. An experimental effort focused on the latter objective with the governments of individual Pacific Island countries has resulted in a large network of hundreds of new manual-read rain gauges located on various atolls and islands managed by the local Meteorological Service (refer to SPaRCE project; http://sparce.evac.ou.edu/). In addition, similar pilot projects using high tech tipping bucket rain gauges have produced a relatively dense rain gauge network on the island of Niue in the south Pacific and a critical all-weather observation platform on Pitcairn island in the south east Pacific. The success of these relatively low-cost efforts has motivated us to expand both and low instrumentation technology projects in collaboration with PI-GCOS to other Pacific Island locales.

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.

A pilot program has been conducted to assess the feasibility and practicality of distributing 55 high quality tipping bucket rain gauges donated by EVAC to various Pacific Island Meteorological Services. The initial results of this pilot strongly suggest that it should be expanded and managed in a collaborative manner with the current PI-GCOS coordinator at SPREP and the PI-GCOS Technical Support Project (TSP) headquartered at the New Zealand Meteorological Service. Initial results of comparisons with manual-read gauges indicate a close correspondence in daily rainfall accumulations. Such tipping bucket gauges are installed with data loggers and have the potential to allow a relatively small Pacific Island Meteorology Service to set up a large climate observing system providing high resolution data to the global research community. In addition to the work above, we are working with the Australian Bureau of Meteorology to implement and verify a seasonal rainfall forecast tool being developed by them using an artificial
intelligence/statistical method. Only through the use of the PACRAIN data base could the tool be used successfully in both forecasting and verification of the results.

This project is ongoing.

The Siviri Village Vanuatu RANET community radio station (left), and Mark Morrissey and the Vanuatu Meteorological Service Director (Jotham Napat) meeting with Siviri Village elders (right), discussing ways in which to manage and sustain the radio station and to work with the Meteorological Service in collecting meteorological data.
PUBLIC AFFAIRS AND OUTREACH

National Severe Storms Laboratory Historical Weather Data Archives
Schultz (primary – CIMMS at NSSL), Zhu, Kennedy, Kelleher, Soreide

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

Funding Agency: NOAA ESDIM

Objectives
The NOAA/National Severe Storms Laboratory Historical Weather Data Archive (NSSL HWDA) is a new web-based data portal that delivers surface and upper-air data to the online user through horizontal maps, vertical profiles on Skew T/log p charts, time series, and ASCII data listings.

Accomplishments
The current configuration of the HWDA delivers surface and upper-air data to the user through horizontal maps, vertical profiles on Skew T/log p charts, time series, and ASCII data listings. Users arriving at the HWDA to view or download data are first asked to select a region of the world from a drop-down menu of choices. Users can later subset the map for smaller domains, focusing just on a state or region by drawing a box around the area of interest. Because the amount of plotted data is filtered for legibility for larger domains, plotting smaller domains is useful for seeing data from a greater number of stations, especially at the surface. Users then select surface or upper-air data and their choice of plot type or data listing. For surface data, users can create a surface map with plotted station models, time series, or data listing. For upper-air data, users can create upper-level maps (in height, pressure, or isentropic coordinates), time series, vertical profiles on Skew T/log p charts, or data listings. Future work will include portal access to real-time data and other datasets. The portal can be found at http://data.nssl.noaa.gov/.

Publications

Examples of output from NSSL HWDA (from left to right and clockwise): listing of surface data, time series, upper-air constant-pressure map, selection window for choosing region of world, and Skew T/log p chart.
ARM Program Outreach Activities
Shafer (primary – Oklahoma Climatological Survey), Kloesel, Melvin

Funding Agency: U.S. DOE

Objectives
Provide outreach support for the 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 2005 EarthStorm workshop for K-12 teachers, the 2005 National Weather Center WeatherFest, the 14th Anniversary Mesonet/ARM Science Fair, the 2006 ScienceFest, and summer camp presentations for Girls Scouts and Chickasaw Nation students. ARM/SGP Outreach staff presented papers or posters at the American Meteorological Society Annual Meeting in Atlanta, GA; 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 updated educational outreach website 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, information about each of the 3 ARM regions, along with PowerPoint and PDF documents of presentations, posters, and symposium papers.

The 2005 EarthStorm Workshop took place July 18-21 in Norman, Oklahoma, at the Stephenson Research Center located on the University of Oklahoma’s Research Campus. Twenty-five teachers from Oklahoma and Kansas attended. The new teachers began with a day dedicated to basic meteorology topics. The advanced topic was radar. Presentations were given on how Doppler radar operate and how to interpret radar data. The teachers visited the National Weather Service to see a weather balloon launch. They were treated to a tour inside of the Phased Array radar. The teachers were introduced to the new features on OCS websites and WxScope software. They finished the workshop by spending time writing mini lessons to use in their classrooms.

The “Magic School Bus Kicks up a Storm” traveling children’s museum exhibit continues to tour the country (http://www.cmhouston.org/ExportedSite/Exhibits/Magic School Bus.htm). Attendance for both tours totaled over 1.7 million. The exhibit was seen at The Children’s Museum in Seattle WA, The Minnesota Children’s Museum in St. Paul, MN, the Orlando Science Center in Orlando, FL, and the Children's Museum of Indianapolis in Indianapolis, IN. Both exhibits took time out this year to be completely refurbished. Additional stops are scheduled through 2008. The exhibit is a joint effort between the OCS and numerous other entities. ARM data are used heavily in the training of teachers and students so that they may get the most out of their field trip experience.

OCS staff participated in the National Weather Festival, a free public event featuring tours of the Norman NOAA Weather Partner agencies, displays by local weather organizations, children's activities, and hourly weather balloon launches. OCS distributed severe weather safety posters as well as activity sheets on how to build a home-made anemometer. Staff discussed with children attendees and their families how wind is being used to create electricity by wind farms. Estimated attendance was 800.

Students from Cheyenne High School, Cordell Elementary, Emerson Junior High (Enid), Enid High School, Gage Junior High, Jefferson Middle School (OKC), Monroe Elementary (Enid), and Sayre Elementary competed at the 14th Annual Mesonet/ARM Science Fair hosted by the Oklahoma Climatological Survey. The fair took place inside the Sam Noble Oklahoma Museum of Natural History. After their projects were judged, students, parents, and teachers were free to enjoy the museum. The
judging team spanned all education levels from undergraduates to professional meteorologists with a few non-meteorologists to balance the questions. The judges are an important part of helping the students critique their projects for regional and state competitions. The time they spend asking questions and making suggestions for additional research encourage the students to improve their speaking skills, board layout and design, unit usage, and catching those pesky spelling errors. For example, the project "Up on the Rooftop" by Krystal Cato, Tanya Dodds and Rocio Manriquez received a Superior award at the Mesonet/ARM Science Fair. They did not receive a Best in Show award. The judges suggested better graphics to display their data and results. The students qualified for the state science fair before competing in the Mesonet/ARM fair. The students were able to make modifications before the state competition based on the suggestions from the judges. Their project placed 3rd in Team Projects at the state fair. This is the first year a project from Jefferson Middle School has placed at the state competition. The Cordell students were featured in their local paper, The Cordell Beacon, on March 22, 2006.

OCS staff have partnered with Dr. Suzanne Van Cooten, a Chickasaw Nation member who works for the NSSL, to offer meteorology programs to the children of the Chickasaw Nation. After meeting with the Chickasaw Education Committee, the meteorologists decided to participate in three Chickasaw events, the Johnson-O'Malley Conference, the Chickasaw Career Day, and the C-NASA Summer Camp.

OCS and NSSL staff spoke with a group of 25 teachers from various Oklahoma tribes at the Johnson-O'Malley Conference in Tulsa. The title of the talk was "Wondering about Weather". The speakers provided web sites where teachers and students could access outlooks, forecasts, and current weather conditions. Participants learned the sequence of products issued and the role of the Storm Prediction Center versus local National Weather Service Forecast Offices. Teachers were provided the dates of the EarthStorm workshop and encouraged to register.

A group of volunteers from several OU and NOAA weather agencies set up a booth at the Chickasaw Nation Career Day held in Ada, OK at the Pontotoc Technology Center. Students were provided information about careers in meteorology, web sites where they can find data, severe weather safety posters, cloud chart posters, and business cards of staff willing to help students find out more about meteorology.

After a year of planning, ScienceFest 2006 arrived on April 20th. The committee worked very hard to address negative issues from the previous year including the procedures for arrival and departure of busses. Arm bands for admission were mailed to teachers before the event eliminating the long line at the gate. Bus greeters provided updated maps of the activity stations and reminded teachers to make sure everyone was wearing their arm bands. In addition to working on the Steering Committee, OCS staff helped as bus greeters and crossing guards. Arm bands for a special aquatics show, "Fin and Feather," featuring sea lions, cockatoos, and cranes were distributed to the first 3,000 people entering the gates. During the show, students learned about the behaviors of sea lions and various birds. The animals displayed their skills. They helped encourage the students to recycle. The cockatoo sorted aluminum and plastic into the appropriate recycling bin. The sea lion retrieved plastic bottles from the water and returned them to the recycling bin. The VIP's from the sponsoring agencies (OG&E, the State Superintendent, Secretary of the Environment, etc.) also attended the 11:45 show. The VIPs saw first hand how their dollars were used to create a fun science day for 4th and 5th graders. The Zoo staff and animals interacted with their largest crowd of the year. ScienceFest is the only time when the stadium is full to capacity. Not everyone was able to see the Fin and Feather show, but they all participated in the various activity stations scattered along the walking trails between the animal enclosures. There were 23 activity stations for students to visit. The staff of state agencies like the Wildlife Commission and Department of Environmental Quality along with environmental non-profits like OKC (Oklahoma City) Beautiful and Martin Park Nature Center presented hands-on activities about the environment. Students learned about protecting and wisely using our wind, water, air, and mineral resources. They learned about alternative fuel vehicles and methods of recycling. Popular TV shows like Jeopardy and Survivor provided an opportunity for students to compete while testing their knowledge on air pollution and the importance of biodiversity. Students, teachers, chaperones, and bus drivers were treated to a hot dog, chips, and soda lunch. Volunteers were invaluable in making this run smoothly. Aluminum cans were collected and recycled, generating $168 from 210 pounds of aluminum. The money was donated to Lewa Wildlife
Conservancy in Kenya. Agencies without a hands-on activity were grouped together in a tent for exhibitors. They explained how their agencies work to protect or monitor the environment. The OCS Research Group displayed their portable mesonet station (PARMS, see spring 2005 issue of Oklahoma Climate). The stations can be transported on the back of a pickup truck with very little disassembly. Once unloaded and settled onto a flat area, the instruments can begin collecting weather data. Students blew across the anemometer to see who was the "windiest". The event received media coverage from local TV stations (NBC Ch 4 and CBS Ch 9), radio (KTKO and KOKC), and a few hometown papers. In the fall, teachers will receive a binder of all the activities presented during ScienceFest.

OCS presented two sessions at the Kansas Association of Teachers of Science annual conference in Junction City, KS on April 21-23. The sessions focused on the EarthStorm workshop and the use of the WxScope application to create custom weather maps. Both sessions were repeated on Sunday morning. About 50 teachers saw at least one of the sessions. Most saw both presentations.

OCS partnered with The Oklahoman, the state-wide newspaper, on a series of in-paper articles called "Weather Wise" that ran April 25-28. Each article had a different weather safety focus: tornadoes, heat, lightning, and floods. The Oklahoman made 25 copies of the newspaper available to any school who signed up for the series. The severe weather poster that was created for last year's National Science Teachers Association Conference was re-worked to be included as an insert to the first issue received by the schools. The Oklahoman circulated over 24,850 papers to schools. On average, The Oklahoman distributes the classroom sets to about 900 schools. The Weather Wise series attracted 250 additional schools. PDF copies of the articles are available at http://earthstorm.ocs.ou.edu/materials/lessons_OK_arti.php. The Oklahoman has already requested that this series become an annual April event.

OCS spent half a day helping local Girl Scout troops earn their Weather Badges. Nearly 100 girls participated in the camp. The camp was held outside at a local park. Station topics included pressure and temperature, weather maps, fronts, tornadoes, lightning, heat, and seeing the instruments of a weather station. The volunteers, all female, ranged from professional meteorologists to undergraduate and graduate students. During the camp, the troops rotated every 20 minutes through all 7 stations. A portable weather station was borrowed from the OCS Research group. The female volunteers had as much fun as the scouts. Many volunteers expressed interest in helping plan activities for next summer.

OCS and NSSL teamed up to present a half day weather session during each of the two C-NASA Camps (Chickasaw Nation Aviation and Space Camp). Campers learned to decode station model plots, contour temperature, create tornadoes in a bottle, and build wind resistant houses. Students were given maps of April 24, 2006 to see how the weather changed throughout the day eventually producing a small tornado near El Reno, OK. The students watched video of the El Reno tornado as it tore through an abandoned airplane hanger at the El Reno airport. Students were given materials like meat trays, straws, popsicle sticks, tape, cardboard, and construction paper to build a wind resistant structure. A multi-speed leaf blower was used to test the strength of each structure.

OCS supplied a mentor for the Wyandotte High School Envirothon Team. They won the Oklahoma competition and were preparing to compete at the Internationals which will be held at the University of Manitoba in Winnipeg, Manitoba July 23-29, 2006. (National - http://www.envirothon.org/; Oklahoma - http://www.envirothonok.com/) The Oral Presentation will consist of a 10 minute presentation on this year's current issue: Water Stewardship in a Changing Climate. All teams will be given resource materials and a limited amount of time to prepare their presentations. OCS Climatologist, Gary McManus, met with the Wyandotte team to discuss how climate issues like drought, floods, and global circulations impact a community's need to develop and implement a water stewardship plan.

These projects are ongoing.
Publications


Students build wind resistant structures at the C-NASA Camp in Ada, OK.

Outreach Activities of CIMMS Staff at WDTB
Schlatter, Wood

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

Accomplishments
Outreach activities conducted during the fiscal year include:

- Assisted in planning the National Severe Weather Workshop;
- Participated in the National Weather Festival in Norman, OK, on November 4, 2005;
- Mentored a Research Experiences for Undergraduates student (Michelle Harrold) during summer 2005;
- Attended Norman Chamber of Commerce, Weather Committee, and Subcommittee meetings;
- Participated in planning the Spring of Celebration events at the new National Weather Center on the University of Oklahoma campus
Appendix A

CIMMS AWARDS AND HONORS

CIMMS Outstanding Paper Award for 2005

*David Schultz, CIMMS Scientist at NSSL, and Jeff Trapp, former CIMMS Scientist at NSSL*


NSSL Outstanding Scientific Paper Award for 2005

*David Stensrud, CIMMS Fellow at NSSL, and Nusrat Yussouf, CIMMS Scientist at NSSL*


NOAA Tech 2006 Best Presentation: Interactive Web Access to Historical Weather Data Archives

*Willa Zhu, David Schultz – CIMMS Scientist at NSSL, Kevin Kelleher – NSSL, Nancy Soreide*

Who’s Who in America – Elected a Member in 2006

*Katherine Kanak, CIMMS Scientist at OU*
Public Service Excellence Award from the Dallas-Fort Worth Federal Executive Board – May 2006

Leon Minton, CIMMS Scientist at NWS Southern Region Headquarters

Public Service Excellence Award presented to Leon Minton in recognition of outstanding achievement and commitment and dedication to public service.
Appendix B

PUBLICATION SUMMARY

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2005-06 Summary

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(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)
### NOAA Funded Research

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Appendix D

COMPILATION OF CIMMS-RELATED PUBLICATION 2005-2006

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


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.


Hu, M., 2005: 3DVAR and cloud analysis with WSR-88D level-II data for the prediction of tornadic thunderstorms, Ph.D. Dissertation, School of Meteorology, University of Oklahoma, 217 pp.


Appendix E

EXECUTIVE SUMMARY OF CIMMS STRATEGIC PLAN

See next page