Cooperative Institute for Mesoscale Meteorological Studies

Annual Report
Prepared for the National Oceanic and Atmospheric Administration Office of Oceanic and Atmospheric Research

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Cover figure – Mesoscale Convective System maintenance probability (MMP; %) based on WRF model ensembles a) without and b) with data assimilation, valid at 1200 UTC 12 June 2009, and Significant Tornado Parameter (STP) based on WRF model ensembles c) without and d) with data assimilation, valid at 0200 UTC 25 June 2009. Research was performed by David Stensrud (NSSL) and Dustan Wheatley (CIMMS Post-Doc). More on this project can be found under CIMMS research theme “Forecast Improvements” on p. 31.
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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 the Norman, Oklahoma, NWS Forecast Office. CIMMS also fosters collaboration with the NWS National Environmental Satellite, Data, and Information Service (NESDIS) National Climatic Data Center (NCDC) in Asheville, NC.

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
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 (NSSL)
- NOAA NWS Warning Decision Training Branch (WDTB)
- NOAA NWS NCEP Storm Prediction Center (SPC)
- NOAA NWS Radar Operations Center (ROC)
- NOAA NWS Forecast Office, Norman
- Oklahoma Climatological Survey (OCS)
- OU College of Atmospheric and Geographic Sciences
- OU School of Meteorology
- OU Department of Geography
- OU Center for Analysis and Prediction of Storms (CAPS)
- OU Atmospheric Radar Research Center (ARRC)
- OU Center for Spatial Analysis (CSA)
- OU Center for Natural Hazards and Disaster Research (NHDR)
- OU Supercomputing Center for Education and Research (OSCER)

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
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 2009 (1 July 2008 through 30 June 2009), and as such represents the seventh annual report written for the present cooperative agreement (NA17RJ1227), an extension agreement (NA08OAR4320904), and a shadow agreement (NA08OAR4320886). **NOAA-funded projects are explicitly identified in project titles.** This report also documents the NOAA-relevant research and outreach activities performed by core CIMMS scientists based at the university that may be funded by other agencies – these agencies are identified. Publications written, awards received, and employee and funding statistics are presented at the end.

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

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

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

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

The Mission and Vision Statements of CIMMS are as follows:

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

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

The organizational structure of CIMMS includes its Director (Peter Lamb), Associate Director and Assistant Director of NOAA Relations (Randy Peppler), Finance and Operations Director (Tracy Reinke), Administrative Assistant (Luwanda Byrd), and Staff Assistants (Melissa O'Brien and Rae Lynn Oliver). Scientists, students, and post-docs were housed on the campus of The University of Oklahoma at its National Weather Center (NWC). Some CIMMS undergraduate student staff was housed off-campus at the ROC at another location in Norman.

**Executive Summary Listing of Activities during FY2009**

**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:

- VORTEX2: A field experiment to study tornadoes from all angles
- Cloud microphysics and quantitative precipitation measurement using polarimetric radar
- Retrieval of drop size distribution parameters from polarimetric radar measurements
- Investigation of kinematic, microphysical and electrical signatures in convective storms
- Estimation of radial and vertical wind velocities in vortices from an analytical tangential model
- Doppler radar data quality control, analyses, and assimilation
- Synoptic-scale influences on outbreaks of severe convection
- Parameterization of drop size distributions in drizzling stratiform clouds
- Mesoscale dynamics and mesoscale applications of Information Theory
- Adaptive high-order methods for nonhydrostatic numerical weather prediction

**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:

- Dual-polarimetric WSR-88D development
- Hazardous Weather Testbed Experimental Warning Program
- Assimilation of radar observations in storm-scale NWP models
- Development of a WRF mesoscale ensemble data assimilation system for severe weather applications
- WRF model sensitivities to microphysical and planetary boundary layer parameterizations
- Optimizing probabilistic guidance from small, high-resolution ensembles
- Probabilistic forecasts for severe thunderstorms based on identification of extreme phenomena in convection-allowing model output
- Verification of European Severe Thunderstorm Forecast Experiment (ESTOFEX) products
- Communicating weather information to emergency managers
- Science and technology infusion in NWS operational systems
- Advanced storm-based warnings training
- Advanced Warning Operations Course
- AWIPS and WSR-88D improvements
- NOAA’s NWS Weather Event Simulator
- AWIPS-II and the Weather Event Simulator for AWIPS-II
- Distance Learning Operations Course
- Weather Event Simulator simulations to accompany COMET courses on Distance Learning Aviation Course Phase 2 and Numerical Weather Prediction
- WDTB Training and Research Toolkit
- WDTB Real-Time System
- Warning Decision Training Guide
- Optimizing WSR-88D VCP selection
- WSR-88D dual polarization upgrade
- WSR-88D dual polarization outreach and training for NWS partners
- Severe storm threats and large event venues
- Integrated warning team scenarios
- Manager’s guide to improve written communication
- Comprehensive severe storm environment database at SPC
- SPC’s GOES-R proving ground
- Probabilistic cloud-to-ground lightning forecasts at SPC
- Severe Hazards Analysis and Verification Experiment (SHAVE)
- National Sea Grant climate/weather extension specialist research and outreach with CI-FLOW
- Development of an integrated decision support system for quantifying water resources
- Evaluation of flash flood guidance
- Hydrometeorological research on the Fort Cobb Basin, Oklahoma
- Verification of QPF from convection-allowing configurations of the WRF model
- A partnership to develop, conduct, and evaluate real-time high-resolution ensemble and deterministic forecasts for convective-scale hazardous weather
- Integration and testing of advanced radar quality control algorithms for Hazardous Weather Testbed spring forecasting experiments
- An investigation on the importance of environmental variability to storm-scale radar data assimilation
- Advancing “Warn-on-Forecast” storm-scale analyses of VORTEX2 thunderstorms
- Parameterization of cloud microphysical processes in cumulus convective clouds
- Contribution to 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:

- Sensitivity of the modeled West African monsoon to convective parameterization
- Collaboration and cooperation within the ACMAD Core Demonstration Project in Climate Prediction between ACMAD and CIMMS
- RAINWATCH: A prototype geographic information system for daily and seasonal rainfall monitoring and visualization in West Africa
- Multidecadal variability of eastern Australian dust and northern New Zealand sunshine: Associations with the Pacific climate system
- Explaining the spatial variability of the mid-summer drought over the Inter-American seas region
- Assessing and improving regional climate modeling of mid-latitude, mid-continent cumulus convection
- Investigation of Southern Great Plains moisture budget for CLASIC: Recycling study
- Investigation of continental stratiform clouds using ARM observations and LES simulations

**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:

- Social Science Woven Into Meteorology (SSWIM)
- The Southern Climate Impacts Planning Program (SCIPP)
- Development and application of dynamic normals for investigation of climate variation and change
- The value of tornado watches and warning false alarms

**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:

- Real-time correlations of radar-derived QPE errors due to the bright band effect
- Improving precipitation estimates in complex terrain
- High-resolution and rapid update National 3-D Radar Mosaic
- Flash Flood Monitoring and Prediction (FFMP) GIS dataset support
- Display of multi-sensor datasets in virtual globes
- Polarimetric hydrometeor classification and rainfall estimation for better detecting and forecasting high-impact weather phenomena, including flash floods
• Investigation of microphysical processes in clouds and precipitation using polarimetric radar measurements
• Polarimetric rainfall measurements and attenuation correction at shorter radar wavelengths
• Drop size distribution retrieval using disdrometers
• Combined profiler, polarimetric WSR-88D, and disdrometer measurements to retrieve vertical velocities and microphysical signatures in precipitation systems
• Investigation of improved QPE using dual-polarimetric weather radar in the presence of partial beam blockage
• Sensitivity enhancement in the dual-polarization WSR-88D
• Assimilation of phased array radar data for the analysis of the 29 May 2004 Oklahoma City supercell
• Mitigation of range and velocity ambiguities
• Ground clutter detection and filtering
• Improvement of spectral moment and polarimetric variable estimates using range oversampling techniques
• Software upgrades for the National Weather Radar Testbed
• Phased Array Radar Innovation Sensing Experiment (PARISE)
• Radar Control Interface improvements
• Real-Time Controller improvements
• ROC research opportunities for undergraduate students
• Radar observations of severe convective weather
• Prototyping WSR-88D science and signal processing techniques
• Verification of the Hydrometeor Classification Algorithm in winter precipitation near the ground
• Advancements in phased array weather radar research at the University of Oklahoma ARRC
• A quantitative estimation of phased array radar polarimetry for the MPAR project
• Next generation QPE: Toward a multi-sensor approach for integration of radar, satellite, model, and surface observations to produce very high-resolution precipitation estimates
• Hail Size Discrimination Experiment (HaSDEx)
• Development of mobile X-band dual-polarization Doppler weather radar
• Development of C-band mobile polarimetric Doppler weather radar
• Storm-scale observations of supercells by mobile Doppler radar during VORTEX2
• Building the MPAR business case
• Dense radar feasibility study
• Wind turbine clutter research
• KTLX refractivity research

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:

• The use of kernel methods in data selection and thinning for satellite data assimilation in NWP models
• Meteorological patterns associated with variability of heavy precipitation in the United States
• Program support for the assimilation, analysis, and dissemination of Pacific rain gauge data: PACRAIN

Public Affairs and Outreach

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

• NOAA Norman Weather Partners educational outreach
- Outreach activities performed by CIMMS staff at WDTB
- NOAA Sector Applications Research Program/Climate Program Office Climate Training Workshops

Awards

The following awards were bestowed in the past year:

- **NSSL Scientists (formerly of CIMMS)** Pam Heinselman and Mike Coniglio were named as recipients of the 2008 Presidential Early Career Award for Scientists and Engineers (PECASE) for their work studying improvements in tornado forecasting and new radar systems, respectively. The award is the highest honor bestowed by the United States government on outstanding scientists and engineers in the early stages of their careers. An award ceremony is planned in Washington, D.C. in fall 2009.

- **NSSL Scientist (formerly of CIMMS)** Pam Heinselman and CIMMS Scientists at NSSL Dave Priegnitz, Kevin Manross, Travis Smith, and Richard Adams were awarded a NOAA OAR Outstanding Scientific Paper Award in the category of Weather and Water. Their paper, published in *Weather and Forecasting*, is titled “Rapid sampling of severe storms by the National Weather Radar Testbed phased array radar.”

- **CIMMS Scientist with SSWIM Eve Gruntfest** was awarded the Kenneth E. Spengler Award by the American Meteorological Society.

- **CIMMS Scientist at NSSL Suzanne Van Cooten** and others were awarded the U.S. Department of Interior Partners in Conservation Award for Protection of Aquifer Resources in Oklahoma.

- **PhD Student with SSWIM Monica Zappa** was awarded the Jeanne X. Kasperson Student Paper Award in the AAG Hazards Specialty Group at the AAG 2009 Annual Meeting in Las Vegas, NV.

- **PhD Student with NSSL Heather Moser** was awarded Third Place in the 2008 Oklahoma Water Symposium student poster competition in Oklahoma City, OK.

- **PhD Student with SSWIM Gina Eosco** was awarded a Top 5 Poster Award at the 2008 Society for Risk Analysis Annual Meeting in Boston, MA.

- **MS Student with NSSL Craig Schwartz** was awarded the Best MS Student Publication in the OU School of Meteorology.

- **Undergraduate Student with NSSL Jessica Erlingis** was the recipient of the American Meteorology Society Elbert W. “Joe” Friday Scholarship for Undergraduates.

- **Undergraduate Student with NSSL Zachary Flamig** was the recipient of Undergraduate Fellowship from the Astronaut Scholarship Foundation.
Distribution of NOAA Funding by CIMMS Task and Research Theme

NOAA Funding by Task FY09

- Task I: $345,000 (4%)
- Task III: $2,045,285 (24%)
- Task II: $6,027,900 (72%)

NOAA Funding by Theme FY09

- Theme 2: 58%
- Theme 5: 32%
- Theme 6: 8%
- Theme 4: 2%
- Theme 3: 0%
- Theme 1: 0%
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 3 September 2008, 26 February 2009, and 12 June 2009.

CIMMS Council membership for FY2009 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 of Electrical and Computer Engineering (Provost designated)
- Dr. Baxter E. Vieux, Presidential Professor of Civil Engineering and Environmental Sciences, OU (Provost designated)
- Dr. David J. Stensrud, Chief, Forecast Research & Development Division, NSSL, and Affiliate Professor of Meteorology (OAR designated)
- Mr. Kevin Kelleher, Deputy Director, NSSL (OAR designated)
- Dr. Russ Schneider, Chief, Science Support Branch, SPC (NWS designated)
- Mr. Richard Murnan, Radar Operations Center Applications Branch (NWS Designated)
- Dr. Michael L. Biggerstaff, Associate Professor of Meteorology, OU (Elected from CIMMS Assembly of Fellows)
- Mr. Doug Forsyth, Chief, Radar Research & Development Division, NSSL (Elected from CIMMS Assembly of Fellows)
- Dr. Frederick H. Carr, Director, OU School of Meteorology, McCasland Chair Professor of Meteorology, and Associate Director, CAPS (ex-officio member)
- Dr. James F. Kimpel, Director, NSSL, and Emeritus 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 NWS WFO (ex-officio member)
- Mr. William Proenza, Director, NWS Southern Region Headquarters (ex officio member)
- Dr. Tom Kari, Director, NSSL, and Emeritus Professor of Meteorology, OU

CIMMS Fellows membership for 15 August 2007 through 15 August 2009 is:

- Dr. Jeffrey B. Basara, Director of Research, OCS, and Adjunct Associate Professor of Meteorology, OU
- Dr. William H. Beasley, Professor of Meteorology, OU
- Dr. Michael I. Biggerstaff, Associate Professor of Meteorology, OU
- Dr. Howard B. Bluestein, George Lynn Cross Research Professor of Meteorology, OU
- Dr. David Bright, Research Meteorologist, SPC
- Dr. Harold E. Brooks, Research Meteorologist and Team Leader, Mesoscale Applications Group, NSSL, and Adjunct Professor of Meteorology, OU
- Dr. Frederick H. Carr, McCasland Chair Professor of Meteorology and Director, School of Meteorology, OU, and Associate Director, CAPS
- Dr. Phillip Chilton, Associate Professor of Meteorology, OU
- Dr. Gerald E. Crain, Professor of Electrical and Computer Engineering, OU
- Dr. Kenneth C. Crawford, Regents' Professor of Meteorology, OU, and Director, OCS
- Dr. Timothy D. Crum, NWS Radar Focal Point, ROC
- 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 and Weathernews Chair of Meteorology, OU, and OU Assistant Vice President for Research
- Dr. Claude E. Duchon, Emeritus Professor of Meteorology, OU
- Dr. Imke Durre, Scientist, NCDC
- Dr. David R. Easterling, Scientist, NCDC
- Dr. Evgeni Fedorovich, Professor of Meteorology, OU
- Mr. Douglas E. Forsyth, Chief, Radar Research & Development Division, NSSL
- Mr. Kurt Hondl, Research Meteorologist, NSSL
- Dr. Yang Hong, Associate Professor of Civil Engineering and Environmental Sciences, OU
- Mr. Michael Jain, Team Leader, Software Engineering and Technology Improvement, NSSL
- Dr. David P. Jorgensen, Chief, Warning Research & Development Division, NSSL
- Dr. David Karoly, Federation Fellow, University of Melbourne, Australia, and Affiliated Professor of Meteorology, OU
- Dr. Petra Klein, Assistant Professor of Meteorology, OU
- Dr. Kevin E. Kelleher, Deputy Director, NSSL
- Dr. James F. Kimpel, Director, NSSL, and Emeritus Professor of Meteorology, OU
• Mr. Paul Kirkwood, Scientist, NWS Southern Region Headquarters
• Dr. S. Lakshmivarahan, George Lynn Cross Research Professor of Computer Science, OU
• Dr. John Latham, Senior Research Associate, National Center for Atmospheric Research (NCAR)
• Dr. Lance M. Leslie, Robert E. Lowry Chair and Professor of Meteorology, OU
• Mr. Jason Levit, Techniques Development Meteorologist, SPC
• 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. Renee McPherson, Associate Director, Oklahoma Climatological Survey, and Adjunct Associate Professor of Meteorology, 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, Tommy Craighead Chair and Professor of Meteorology, OU, and Director, ARRC
• Dr. Ramkumar Parthasarathy, Associate Professor of Aerospace and Mechanical Engineering, OU
• Dr. Thomas C. Peterson, Scientist, NCDC
• Mr. John R. Reed, Chief, Radar Engineering Branch, ROC
• Dr. Michael B. Richman, E. K. Gaylord Presidential Professor of Meteorology, OU
• Dr. W. David Rust, Director, Field Observing Facilities and Services, NSSL, and Affiliate Professor of Meteorology and of Physics and Astronomy, OU
• Dr. Joseph T. Schaefer, Director, SPC, and Affiliate Professor of Meteorology, OU
• Dr. Russell Schneider, Chief, Science Support Branch, SPC
• Dr. David Schultz, Professor of Experimental Meteorology, University of Helsinki, Finland
• Dr. Alan M. Shapiro, American Airlines Associate Professor of Meteorology, OU
• Dr. James Sluss, Morris R. Pitman Professor and Director, School of Electrical and Computer Engineering, OU
• Dr. John T. Snow, Dean, College of Atmospheric and Geographic Sciences, and Professor of Meteorology, OU
• Dr. David J. Stensrud, Chief, Forecast Research & Development Division, NSSL, and Affiliate Professor of Meteorology, OU
• Dr. Jerry M. Straka, Associate Professor of Meteorology, OU
• Dr. Daniel S. Sutter, Associate Professor of Economics, University of Texas – Pan American
• Dr. Aondover A. Tarhule, Chair and Professor, Department of Geography, OU
• Dr. Susan Van Cooten, Research Meteorologist, NSSL
• Dr. Baxter E. Vieux, Presidential Professor of Civil Engineering and Environmental Sciences, OU
• Mr. Richard Vogt, Director, ROC
• Dr. Daniel B. Weber, Research Meteorologist, Tinker Air Force Base
• Dr. Louis J. Wicker, Research Meteorologist, Convective Weather Research Group, NSSL, and Affiliate Associate Professor of Meteorology, OU
• Dr. Qin Xu, Research Meteorologist, Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
• Dr. Ming Xue, Director, CAPS, and Associate Professor of Meteorology, OU
• Dr. Mark Yeary, Assistant Professor of Electrical and Computer Engineering, OU
• Dr. Tian-You Yu, Assistant Professor of Electrical and Computer Engineering, OU
• Dr. May Yuan, Professor of Geography, OU, and Director, Center for Spatial Analysis, OU
• Mr. Allen Zahrai, Team Leader, Radar Engineering and Development, NSSL
• Dr. Guifu Zhang, Associate Professor of Meteorology, OU
• Dr. Yan Zhang, Assistant Professor of Electrical and Computer Engineering, OU
• Dr. Conrad Ziegler, Research Meteorologist, Models and Assimilation Team, NSSL
• Dr. Dusan S. Zrnic, Senior Engineer and Group Leader, Doppler Radar and Remote Sensing Research Group, NSSL, and Affiliate Professor of Meteorology and of Electrical and Computer Engineering, OU
General Description of Task I Activities

Task I Expenditures
FY09

- $134,413; 39%
- $131,799; 38%
- $41,938; 12%
- $36,850; 11%

Legend:
- Administration
- Research Salaries
- Research Support
- Indirect Costs
RESEARCH PERFORMANCE

Basic Convective and Mesoscale Research

NSSSL Special Project/NSF/NOAA – VORTEX2: A Field Experiment to Study Tornadoes from All Angles
CIMMS Staff at NSSSL, WDTB, SPC and OU

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

Funding Agencies: NSF, NOAA, and NSSSL in-kind support

Objectives
Understand how, when and why tornadoes form with the ultimate goal of helping increase warning time for those in the path of tornadoes.

Accomplishments
VORTEX2 is the largest and most ambitious field experiment in history to explore tornadoes. Supported by National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), nearly 100 scientists and students from sixteen different universities and various other academic organizations in the United States are taking part in the experiment. The VORTEX2 teams will be looking to understand how, when and why tornadoes form. Answers to these questions will give researchers a better understanding of tornadoes and should help increase warning time for those in the path of these deadly storms. The first field phase of VORTEX2 took place during a five-week period from 10 May-13 June 2009 and a second six-week phase will take place in spring 2010.

From the VORTEX2 final Operations Summary issued 22 June 2009 by NSSSL, research vehicles each logged over 10,000 miles while visiting nine states (Oklahoma, Texas, Colorado, Kansas, Missouri, Wyoming, Nebraska, South Dakota and Iowa). Data were collected on 19 days out of 35 possible mission days. Teams deployed on 17 supercell thunderstorms and 12 ordinary storms. On 5 June 2009, VORTEX2 collected data on a significant tornado in Goshen County, Wyoming. Researchers claim this tornado is now the best-documented tornado in history, with comprehensive data collection beginning before the tornado formed and continuing through its demise.

Scientists had hoped to deploy on five tornadic storms this year, but 2009 was a historically low tornado year within the VORTEX2 domain. NSSSL and CIMMS scientists used the opportunity to refine deployment strategies, and felt by the experiment’s last week that all teams had learned to work together to cover a storm effectively. At the conclusion of 2009 operations, the principal investigators met to identify issues to address by 2010 operations, tentatively scheduled for 1 May-15 June 2010.

NSSSL and CIMMS used VORTEX2 as an opportunity to reach out to the public through social networking. Over 6,000 people became fans of the VORTEX2 facebook page and over 1,900 were following VORTEX2 on Twitter. For more on VORTEX2, see http://www.nssl.noaa.gov/vortex2/ and http://www.vortex2.org/home/. This project is ongoing.
NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Cloud Microphysics and Quantitative Precipitation Measurement using Polarimetric Radar
Zrnic (primary – NSSL), Melnikov (CIMMS at NSSL), Andric (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Understand microphysics of clouds and apply this understanding to the quantitative measurement of precipitation.

Accomplishments
Polarimetric radar data from stratiform and non-precipitating clouds have been collected with the KOUN radar and analysis is in progress. The data offer insight into poorly investigated bulk properties of ice crystals important for understanding precipitation formation and determining the amounts. The vertical profiles of polarimetric variables (reflectivity, differential reflectivity ($Z_{DR}$), cross-correlation coefficient ($\rho_{hv}$), and differential phase) have been examined. Several clouds exhibit maxima of $Z_{DR}$ of about few dBs near their tops. This is followed by gradual decrease to few tenths of a dB at the cloud bottom suggesting that $Z_{DR}$ mimics the growth of the ice crystals. As the crystals increase in the horizontal direction, $Z_{DR}$ increases and so does (ever slightly) their fall speed. It is hypothesized that beyond a certain size aggregation becomes the dominant growth process that causes the gradual decrease of $Z_{DR}$. The location of the maximum $Z_{DR}$ coincides with the location of the minimum in the cross-correlation coefficient ($\rho_{hv}$), which is about 0.95. One-dimensional model of ice crystal growth and aggregation is used to explain the observed profiles of the measured polarimetric values.

This project is ongoing.

Vertical Profiles at 45 km

Vertical profiles of reflectivity $Z_h$, differential reflectivity $Z_{DR}$ and cross correlation coefficient $\rho_{hv}$ between horizontally and vertically polarized returns. Upon formation at cloud top crystals grow primarily in the horizontal direction by deposition followed by accretion, so that $Z_{DR}$ reaches a maximum. As aggregation begins to take over $Z_{DR}$ decreases to a minimum just above the melting layer. Note the slight decrease of $\rho_{hv}$ in the region of max deposition.
NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Retrieval of Drop Size Distribution Parameters from Polarimetric Radar Measurements
Zrnic (primary – NSSL), G. Zhang (OU School of Meteorology), Bukovcic (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Study the spatial structure and time evolution of rain drop size distributions from disdrometer and polarimetric radar observations.

Accomplishments
The time evolution of drop size distribution, mass, and reflectivity were obtained with a disdrometer and also with polarimetric radar (KOUN) using constrained gamma distribution for drop size distribution retrievals. The vertical structure of time evolution of polarimetric variables at disdrometer site has been characterized and hydrometeor classification has been made. The disdrometer is used to validate the drop size distribution retrieval and to deduce microphysical properties of precipitations.

This project is ongoing.

Publications

Comparison of horizontal differential reflectivity, rainfall rate and median volume diameter obtained from disdrometer (2DVD) and polarimetric radar (KOUN), time series for 13 July 2007.
NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Investigation of Kinematic, Microphysical, and Electrical Signatures in Convective Storms

Schuur (primary – CIMMS at NSSL), MacGorman (NSSL), Rust (NSSL), Biggerstaff (OU School of Meteorology), Bruning (OU School of Meteorology), Kuhlman (CIMMS at NSSL), Lund (OU School of Meteorology), Payne (CIMMS at WDTB), LaBar (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives

Use data from the KOUN WSR-88D polarimetric radar and Oklahoma Lightning Mapping Array to investigate combined kinematic, microphysical, and electrical signatures of convective storms in Oklahoma.

Accomplishments

Data from the Thunderstorm Electrification and Lightning Experiment (TELEX) have been used to improve understanding of the interrelationships among microphysics, kinematics, electrification, and lightning in a broad spectrum of storms. The field program was built around two permanent facilities: the KOUN polarimetric radar and the Oklahoma Lightning Mapping Array. In addition, balloon-borne electric-field meters and radiosondes were launched together from a mobile laboratory to measure electric fields, winds, and standard thermodynamic parameters inside storms. Two mobile C-band Doppler radars also provided high-resolution coordinated volume scans for part of the experiment.

Data collected during the NSF-supported project have provided the foundation for the graduate research of several students. Work concluded in the past year has found that a ring of lightning activity previously observed in supercell storms is related to similar ring-like microphysical signatures as indicated by polarimetric radar data. A study of another supercell storm discovered that arcs of lightning activity developed in response to the storm’s updraft, where the evolution of the lightning activity in updraft pulses was found to follow an established model of precipitation formation and fallout in supercells. Another study examined the stratiform region of a Mesoscale Convective System and found that two layers of lightning activity were both associated with conditions favorable for a non-inductive charging mechanism, as inferred from polarimetric radar data.

This project is ongoing.

Publications


(a) Time-height plot of the density of locations at which lightning flashes were initiated and (b) time-height plot of VHF source density. Both plots include lightning within a 300 km x 300 km square centered on the KOUN radar. Densities were calculated by counting the number of data points that fell into each 2-minute by 250-m altitude bin. The bar across the top and the vertical dashed lines indicate the times for the organizing phase (phase 1), mature phase (phase 2), and the weakening phase (phase 3) of the MCS that passed through the observational network on 19 June 2004. From Lund et al. (2009).
NOAA/NWS – Estimation of Radial and Vertical Wind Velocities in Vortices from an Analytic Tangential Model
L. White (OU Department of Mathematics), V. Wood (NSSL), A. Shapiro (OU School of Meteorology)

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

Funding Type: CIMMS Task III

Objectives
Estimate radial and vertical components of vortex wind velocity from the tangential component for various tangential component models.

Accomplishments
The determination of radial and vertical components of vortex wind velocity given a model of the tangential component of the velocity was studied. The approach is to use the momentum equation for the tangential wind velocity component along with the continuity equation as a system the solution of which is the radial and vertical wind components. With the tangential component known, the vertical wind component is shown to satisfy a first-order hyperbolic partial differential equation with Cauchy data specified at \( z = 0 \). The vertical wind component is obtained by solving initial value problems for the system of ordinary differential equations that are the characteristic equations of the system. Radial components are then easily obtained from algebraic relations. Numerical studies also were carried out.

This project has been completed.

Publications

![Characteristic curves](attachment:characteristic.png)

Figure 1: Characteristic curves with \( k=1 \) and \( n=2 \)

![Tangential velocity component](attachment:tangential.png)

Figure 2: Tangential velocity component \( v \) for \( k=1 \) and \( n=2 \)
NOAA HPCC/NCEP/Other Agency – Doppler Radar Data Quality Control, Analyses, and Assimilation

Q. Xu (primary – NSSL), Nai (CIMMS at OU), P. Zhang (CIMMS at NSSL), Wei, Yao, Qiu (all three CIMMS at OU), and collaborators at NSSL, NCEP, NRL, Institute of Atmospheric Physics (IAP) at Beijing, and Lanzhou University

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

Funding Agencies: Office of Naval Research, FAA, NOAA High Performance Computing and Communications (HPCC), NCEP

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 data quality control.* A new dealiasing scheme has been developed for radar radial-velocity data quality control in the current wind analysis system. The new scheme upgrades and simplifies the previous three-step dealiasing method (Gong et al., 2003) in three aspects. First, the alias-robust VAD analysis (Xu et al., 2009a) is used in place of the modified VAD analysis (Tabary et al., 2001) for the preliminary reference check in the first step. Second, because the alias-robust VAD analysis is more accurate than the traditional VAD analysis for the refined reference check in the second step, the original second step becomes unnecessary and is thus removed. Third, a block-to-point continuity check procedure is developed to replace the point-to-point continuity check in the original third step. As the dealiasing scheme is developed for data analysis and assimilation, avoiding false dealiasing is the most important requirement. To meet this requirement, stringent threshold conditions have been used for alias corrections in each of the two steps.

The above VAD-based new scheme has been tested extensively and successfully with real-time radial velocities scanned by the KTLX radar under various weather conditions, except for severe winter storms scanned by using the VCP31 mode with the Nyquist velocity reduced below 12 m s$^{-1}$. In the latter case (VCP31), the reference radial velocities produced by the alias-robust VAD analysis do not have the required accuracy (relative to the Nyquist velocity) and horizontal variability (relative to the storm wind) to ensure the reference check to be absolutely free of false dealiasing. To solve this problem, the alias-robust variational analysis (Xu et al., 2009b; section 3.2) is used in place of the alias-robust VAD analysis for the reference check. This makes the new scheme VCP-adaptive and free of false dealiasing even for VCP31 with a small Nyquist velocity. As shown by the example in Fig. 2, the new scheme can correct almost all the alias errors without any false dealiasing, even though the raw radial velocities were severely aliased due to the strong wind and small Nyquist velocity. The operationally used algorithm (Eilts and Smith, 1990), however, cannot be free of false dealiasing.

This project is ongoing.
a) Raw radial-velocity image scanned by the KTLX radar with VCP31 mode and Nyquist velocity = 11.51 m s⁻¹ at 0.5° tilt for the Oklahoma ice storm at 043637 UTC on 27 January 2009. (b) Dealiased radial-velocity image by the new scheme. (c) Dealiased radial-velocity image by the operational algorithm.

Radar data assimilation. Assimilation experiments were carried out with simulated radar radial-velocity observations to examine the impacts of observation accuracy and resolutions on storm-scale wind assimilation with an ensemble square root filter (EnSRF). The background covariance was estimated from an ensemble of 40 imperfect-model predictions. The results show that the analysis is not significantly improved when the measurement error is overly reduced (from 4 to 1 m s⁻¹) and becomes smaller the representativeness error. The analysis can be improved by properly coarsening the observation resolution (to 2 km in the radial direction) with an increase in measurement accuracy and further improved by properly enhancing the temporal resolution of radar volume scans (from every 5 to 2 or 1 min) with a decrease in measurement accuracy. There can be an optimal balance or trade-off between measurement accuracy and resolutions (in space and time) for configuring radar scans, especially phased-array radar scans, to improve storm-scale radar wind analysis and assimilation (Liu and Xu 2009).

This project is ongoing.

Publications
Xu, Q., 2009: Bayesian perspective of the unconventional approach for assimilating aliased radar radial velocities. Tellus (accepted).
Newsom, R. K., W. Shaw1, J. Rishel, W. Wang, Qin Xu, and P. Zhang, 2008: Development and validation of a real-time wind field retrieval system, 12th Annual George Mason University Conf. on Atmospheric Transport and Dispersion Modeling. George Mason University, Fairfax, VA.
Other Agency – Synoptic-Scale Influences on Outbreaks of Severe Convection

Doswell (CIMMS at OU), Leslie (primary – OU School of Meteorology), Richman (OU School of Meteorology), Leslie (OU School of Meteorology), C. Shafer (OU School of Meteorology), Mercer (OU School of Meteorology)

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
Recent studies have suggested that tornado outbreaks are linked to synoptic-scale processes, with lead times of at least 72 hours. However, many questions remain regarding the precise nature of these links. For example, the ability of mesoscale models to discriminate outbreak types using synoptic-scale input may be diminished for cases in the spring and fall. Furthermore, many severe weather outbreaks cannot be classified as primarily tornadoic or primarily nontornadoic. A mesoscale model’s ability to distinguish these “nearly major” tornado outbreaks from tornadoic and nontornadoic outbreaks remains unknown. To explore these uncertainties, numerical simulations are proposed, using synoptic-scale initial conditions and test cases of the three outbreak types occurring in the spring and fall seasons.

Two mesoscale models, WRF and MM5, will be initialized using NCEP/NCAR reanalysis data, which has an effective horizontal grid spacing of about 200 km. Simulations will be analyzed using meteorological covariates as the explicit prediction of tornadoes, because even with the most sophisticated mesoscale models, it is not possible to predict tornadoes starting from synoptic-scale environmental conditions now or in the foreseeable future. A combination of subjective and objective techniques will be employed to analyze the predicted covariates. These techniques will determine the degree to which the outbreak types can be discriminated and what severe weather parameters can be exploited to distinguish the outbreaks. If mesoscale models are shown to be capable of distinguishing outbreak type using synoptic-scale input, implications for future research are profound, as further study aimed at the diagnosis of processes connecting the synoptic scales to tornado outbreaks is likely to prove fruitful.

A comparison of the WRF model’s ability to forecast covariates that can be used to discriminate between tornado outbreaks (TOs) and outbreaks of predominantly nontornadoic severe weather (PNOs) has been completed; this comparison is with previous work that included a majority of summer season PNOs. The result is that the discrimination ability is reduced somewhat over what was previously reported. And the accuracy of the discrimination falls off with the time of the projection more rapidly than previously reported. These results are the basis for a formal journal publication, in preparation at this time.

A new way to rank outbreaks has been developed that is not limited to TOs and PNOs. Using a weighted linear combination of outbreak variables (such as the number of tornadoes, the number of nontornado severe weather reports, etc.), it has been found that the ranking overall is relatively resistant to the choice of weights, especially for the highest- and lowest-ranked events. For the events of intermediate rank, it has been found that the events tend to cluster in a 4-dimensional vector space (T, H, W, O), where T is the sum of the weighted tornado-related variables, H is the sum of the weighted hail-related variables, W is the sum of the weighted wind-related variables, and O is the sum of the weighted “other” variables. A manuscript describing this new ranking scheme is in preparation.

This project is ongoing.

Publications

Other Agency – Parameterization of Drop Size Distributions in Drizzling Stratiform Clouds

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

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

Funding Agencies: Office of Naval Research, NOAA

Objectives

Develop parameterization of cloud processes for NWP and climate models.

Accomplishments

The development of cloud microphysical retrievals and cloud microphysics parameterizations rely heavily on the knowledge of the shape of drop size distributions (DSDs). Many investigations assume that DSDs in the whole, or parts of the drop size range, may be approximated by known analytical functions. The most frequently employed approximations are gamma, lognormal, Khrgian-Mazin, and Marshall-Palmer type functions. At present, little is known about the accuracy of each of these approximations, especially their ability to successfully simulate the higher moments of the DSD. We have evaluated the applicability and accuracy of DSD approximations using a combination of lognormal and gamma-type functions for stratocumulus and shallow convective clouds. The DSDs were generated using the new version of the CIMMS LES explicit microphysics model (SAMEX) in simulations of cases observed during the ASTEX and DYCOMS-II field projects. Special emphasis in the analysis was placed on the fidelity of representing the higher moments of the drop spectra, such as precipitation flux and radar reflectivity.

We found that approximating drop spectra in drizzling stratocumulus by Gamma-type distributions proves to be much more accurate than approximation by the lognormal distribution. In drizzling stratocumulus the two mode approximations provided better accuracy than the one-mode approximations. We also concluded that in numerical models which use two-moment microphysical parameterization schemes, the six parameters defining the two-mode Gamma distribution can be expressed through the four predictive microphysical variables describing concentrations and mixing ratios of cloud and rain drops. The latter approach requires parameterization of the drizzle mode dispersion that was developed as part of this project.

This project has been completed.

Publications

The vertical cross-section of radar reflectivity field: a) radar reflectivity $Z$ calculated from the full LES predicted DSDs; b) $Z$ defined from the 3-parameter gamma fit; c) $Z$ defined by the 2-parameter gamma fit with parameterized drizzle drop dispersion; d) $Z$ defined from the $Z$ – $R$ relationship.

Other Agency – Mesoscale Dynamics and Mesoscale Applications of Information Theory
Q. Xu (primary – NSSL), Wei (CIMMS at OU), Cao (OU School of Meteorology), and collaborators at NSSL and the Institute of Atmospheric Physics (IAP) at Beijing

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

Funding Agencies: NSF, Office of Naval Research, FAA, NSSL Director’s Discretionary Research Fund, NOAA High Performance Computing and Communications (HPCC), NCEP

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; diagnose balanced and unbalanced dynamics in synoptic-scale and mesoscale domains and study their interactions and impacts on mesoscale data assimilation and predictability.

Accomplishments
Theoretical formulations and numerical methods were developed based on the semi-balanced equation system of Xu (1994) for diagnosing nonlinearily-balanced dynamics from observed and full-model simulated flow fields flow in a terrain-following coordinate. An implicit scheme was designed for the time
integration of the primary nonlinearly balanced flow with the secondary flow solved by minimizing its associated quadratic functional.

Modal and nonmodal growths of nonhydrostatic symmetric perturbations in unbounded domain were examined in comparison with their hydrostatic counterparts. The total perturbation energy norm was used to measure the nonmodal growths. It is found that the modal growth rate and maximum instantaneous nonmodal growth rate are functions of a single internal parameter $s$ – the slope of the cross-band wave pattern, and the hydrostatic approximation inflates the modal and nonmodal growth rates significantly when the basic-state Richardson number $Ri$ is smaller than 0.5. Analytical relationships were derived to quantify the maximum nonmodal growths in connection with the orthogonality measured by the normalized energy inner products between the free modes.

The relative entropy and Shannon entropy formulations for measuring information content from observations were revisited and extended for four-dimensional data assimilation. The extended formulations were shown to be potential useful for designing optimum phased-array radar scan configurations to maximize the extractable information contents from radar observations.

This project is ongoing.

**Publications**


**Other Agency – Adaptive High-Order Methods for Nonhydrostatic Numerical Weather Prediction**

Wicker (NSSL), Mavriplis (formerly CIMMS at NSSL), Williams (OU School of Meteorology), Crowell (OU Department of Mathematics)

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

**Funding Agency:** NSF

**Objectives**

Create collaboration between mathematicians who have developed numerical modeling methods and meteorologists who have used them to study weather events to yield more efficient and accurate models.

**Accomplishments**

Across the globe weather modelers are striving to increase model resolution, but they are limited in their methodology to only reducing grid spacing, which increases computer time significantly. This project seeks others solutions. To this end, a comparison was completed on various test problems using high-order finite differences, discontinuous galerkin, and spectral finite differences. Dr. Mavriplis and S. Crowell have written a draft paper detailing these results. Also, a mini-symposium was held at the ICOSAHOM Meeting in June 2009 in Norway to bring together numerical analysis scientists from the engineering and mathematics communities with modelers from the meteorological community. The results of this symposium are in preparation.

This project is ongoing.

**Publications**

**Forecast Improvements**

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

Burgess (primary – CIMMS at NSSL), Manross (CIMMS at NSSL), Roberts (OU School of Meteorology), Meyer (OU School of Meteorology)

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

**Funding Type:** CIMMS Task II

**Objectives**

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

**Accomplishments**

Testing of new dual-polarization algorithms (Hydrometer Classification Algorithm and Quantitative Precipitation Estimation Algorithm) continued during the year. Extensive preparations were made for upcoming testing: first operations testing on the dual-polarization contractor-upgraded KOUN (Norman, OK) radar, and later beta testing on the KICT (Wichita, KS) Radar. Initial KOUN data will be compared to KCRI (Norman baseline WSR-88D) data to ensure basic radar observation quality is maintained. Validated KOUN data will be compared to KICT data during the beta test. Input has and is being made into training materials being developed by WDTB and the ROC.

Database and case study activities continued during the year. A large number of radar data sets (baseline WSR-88D, experimental KOUN, and TDWR) were collected, including Level 1 (time series) data and dual-polarization data. These data sets were enhanced by addition of supplemental data from other sensors (surface mesonetwork, satellite, balloon soundings, lightning detection, numerical model, etc). The data sets were added to an extensive archive of data sets maintained as a resource for application development and testing. In addition, the data set was used to carry out case studies of events of interest in helping determine WSR-88D performance.

This project is ongoing.

**NSSL Project 3 – Severe Weather Warning Research and Application Development: Hazardous Weather Testbed Experimental Warning Program**

T. Smith (primary – CIMMS at NSSL), Adams (CIMMS at NSSL), Burgess (CIMMS at NSSL), Heinselman (NSSL), Hluchan (OU School of Meteorology), Kerr (CIMMS at NSSL), Kolodziej (OU School of Meteorology), Kuhlman (CIMMS at NSSL), Manross (CIMMS at NSSL), Ortega (CIMMS at NSSL), Lakshmanan (CIMMS at NSSL), Newman (OU School of Meteorology), Priegnitz (CIMMS at NSSL), A. Smith (OU School of Meteorology), Stumpf (CIMMS at MDL), Young (OU School of Meteorology), Andra (NWS), Baranowski (CIMMS at WDTB), R. Brown (NSSL), Hondl (NSSL), Kingfield (CIMMS at NSSL), Scharfenberg (NWS), Witt (NSSL)

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

**Funding Type:** CIMMS Task II

**Objectives**

Improve the nation’s hazardous weather warning services by bringing together forecasters, researchers, trainers, developers, and user groups to test and evaluate new techniques, applications, observing platforms, and technologies.
Accomplishments
The Experimental Warning Program (EWP) conducted its third spring project in 2009, with collaborating meteorologist from NSSL, CIMMS, WDTB, and the Norman NWSFO locally, as well as 24 visiting meteorologists from across the United States, Canada and Europe. A total of over 60 participants were involved for at least one week each. Two primary areas of research in the EWP are in the application and evaluation of new remote sensing tools as well as 0-120 minute nowcasting applications and techniques. Several experiments were conducted in the EWP in the spring of 2009, including:

Multi-radar/multi-sensor (MRMS) severe weather algorithms – These diagnostic tools were found to aid forecasters in decision-making, in the management of situation awareness, and in the creation of better warning polygons. The NWS has requested that these applications be integrated into warning operations as soon as possible.

Lightning mapping array – 1-km lightning mapping array data were evaluated, and compared to simulated GOES-R 10 km resolution total lightning data, for severe weather threat assessment. This project is a collaborative effort with NESDIS and NASA.

Advanced radar platforms – Participants evaluated data from the Multi-function Phased Array Radar (MPAR) and Collaborative Adaptive Sensing of the Atmosphere (CASA) radar testbed network. This included the exploration of needed visualization and decision support tools for large volumes of rapidly updating radar data.

HWT technology enables forecasters to examine locally produced and CONUS-wide data sets both in real-time and post-event. CIMMS personnel also led the development of software applications and provided technical support for the experiments.

This project is ongoing.

Publications

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

Funding Type: CIMMS Task II

Objectives
Document the impact of assimilating high temporal frequency Phased Array Radar data in storm analysis and prediction using the Observation System Simulation Experiments (OSSE).

Accomplishments
The conventional Weather Surveillance Radar-1988 Doppler (WSR-88D) scans a given weather phenomenon in approximately 5 minutes and past results suggest that it takes 30-60 min to initialize a storm into a model using these data. Severe weather events, however, can develop and evolve very rapidly. Therefore assimilating observations for a 30 to 60-min period prior to the availability of accurate analyses may not be feasible in an operational setting. A shorter assimilation period also is desired if forecasts are produced to increase the warning lead-time. With the advent of the emerging phased array radar (PAR) technology, it is now possible to scan the same weather phenomenon in less than a minute. Therefore it is of interest to see if the faster scanning rate of PAR can yield improvements in storm-scale analyses and forecasts from assimilating over a shorter period of time. Observing system simulation experiments (OSSEs) are conducted to evaluate the ability to quickly initialize a storm into a numerical model using PAR data in place of WSR-88D data. Synthetic PAR and WSR-88D radar observations of a splitting supercell storm are created from a storm-scale model run using a realistic volume averaging technique in native radar coordinates. These synthetic reflectivity and radial velocity observations are assimilated into the same storm-scale model over a 15-min period using an ensemble Kalman filter (EnKF) data assimilation technique followed by a 50-min ensemble forecast. Results indicate that assimilating PAR observations at 1-min intervals over a short 15-min period yields significantly better analyses and ensemble forecasts than those produced using WSR-88D observations. Additional experiments are conducted in which the adaptive scanning capability of PAR is utilized for thunderstorms that are either very close to or far away from the radar location. Results show that the adaptive scanning capability improves the analyses and forecasts when compared to the non-adaptive PAR data. These results highlight the potential for flexible rapid-scanning PAR observations to help quickly and accurately initialize storms into numerical models yielding improved storm-scale analyses and very short-range forecasts.

One of the major sources of error in storm-scale data assimilation and forecasts is the microphysical scheme used in the model. Several observational studies indicate that the particle densities and intercept parameters of hydrometeor distributions can vary widely within a single storm and among storms. Assuming the same precipitation particle parameters for all precipitation events can lead to significant errors in the analyses and forecasts of severe storms. Therefore, the selection of a microphysics scheme in storm-scale modeling has profound impact on the analyses and forecasts of severe weather events. In an effort to explore the impact of variations in parameters within the same microphysics scheme, Observing System Simulation Experiments (OSSEs) are conducted using a range of different realizations of the intercept and density parameters using EnKF data assimilation technique. Using a realistic volume averaging technique, two sets of synthetic WSR-88D radar observations of a splitting supercell storm are created from two truth runs using LFO and 10 ICE microphysics schemes respectively. Two sets of experiments are conducted that assimilates the synthetic observations for a 30-min period. The first set of experiments are conducted in a perfect model setup in which both the truth run and the ensemble system uses the same LFO microphysics scheme, while in the second set of experiments the truth run uses 10 ICE microphysics schemes and the ensemble system uses the LFO microphysics scheme. In each sets, one ensemble system uses the same intercept and density parameters for all the ensemble members while the other experiments uses a variety of intercept and density parameters to the ensemble members.
Results obtained are then compared to see the value of variations of intercept and density parameters within the same microphysics scheme in the analyses and forecasts.

This project is ongoing.

**Publications**


The rms errors of ensemble mean analyses vs. time(s) for the 30-min assimilation experiment from the imperfect model experiment starting at t = 25 min and ending at t = 54 min for (a) u (m s\(^{-1}\)), (b) v (m s\(^{-1}\)), (c) w (m s\(^{-1}\)), (d) t (K) and (e) total precipitation mixing ratios (g kg\(^{-1}\)) for the control (black lines) and multi-parameter (gray lines) ensemble system. Values are averaged over the domain at grid points where the total precipitation mixing ratios (sum of qr, qh and qs) in the truth run is greater than 0.10g kg\(^{-1}\).
NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Development of a WRF Mesoscale Ensemble Data Assimilation System for Severe Weather Applications

Stensrud (primary - NSSL), Wheatley (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Explore the impact of conventional observations on mesoscale analyses and forecasts of severe weather.

Accomplishments
An ensemble-based data assimilation system using the Weather Research and Forecasting (WRF) model has been developed to explore the impact of conventional observations on mesoscale analyses and forecasts of severe weather events. Routinely available observations from surface stations, rawinsondes, and automatic aircraft reports are assimilated into a 30-member ensemble that is constructed from initial and boundary conditions provided by the North American Mesoscale (NAM) forecast cycle starting at 1200 UTC. This ensemble accounts for initial condition and model physics uncertainties.

Performance of the assimilation system is assessed through comparison to mesoscale objective analyses of observational fields. Special emphasis is placed on the system’s ability to produce realistic mesoscale structures (e.g., dry lines, cold pools) that affect convective development, but are often not present in models without data assimilation. Also examined are the impacts of the assimilation on environmental characteristics such as CAPE and shear, as well as other severe weather parameters (e.g., supercell motion forecast algorithms). This project is ongoing.

MCS maintenance probability (MMP; %) based on WRF model ensembles a) without and b) with data assimilation, valid at 1200 UTC 12 June 2009. Significant tornado parameter (STP) based on WRF model ensembles c) without and d) with data assimilation, valid at 0200 UTC 25 June 2009.

Kain (primary - NSSL), Schwartz (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Examine daily WRF model forecasts over a 7-week period during the peak severe convective weather season and determine sensitivities to model physics.

Accomplishments
Daily model forecasts generated by CAPS from a seven-week period in the spring of 2007 were analyzed to assess the sensitivity of the WRF model to different physical parameterizations. In all, ten forecasts were generated each day as part of an ensemble forecasting initiative. The ensemble diversity included perturbations in initial and lateral boundary conditions, but it also involved three different microphysical (MP) parameterizations and two different planetary boundary layer (PBL) parameterizations. Systematic variations in the MP and PBL schemes allowed us to evaluate the sensitivity of QPF forecasts to individual schemes and their specific combinations.

The forecasts revealed significant sensitivities MP and PBL schemes. For example, over the 7-week experiment, the Mellor-Yamada-Janjic PBL and Ferrier MP parameterizations were associated with relatively high precipitation totals, while members configured with the Thompson MP or Yonsei University PBL scheme produced comparatively less precipitation. These results have been shared with model developers from both NCEP/EMC and NCAR and additional work continues at these institutions in an effort to better understand the causes of specific biases in the physical parameterizations.

This project has been completed.

Publications


Variations in frequency bias as a function of accumulation threshold for the ten members of the CAPS 2007 ensemble, indicating strong sensitivity to PBL and MP parameterizations in the WRF model. Statistics are derived from an aggregate of daily forecasts over a seven-week period.
Kain (primary - NSSL), Schwartz (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Explore methods that optimize probabilistic guidance derived from ensembles that have high resolution but relatively small membership.

Accomplishments
During the seven-week 2007 NOAA Hazardous Weather Testbed Spring Experiment, CAPS produced daily a 10-member 4 km horizontal resolution ensemble forecast covering approximately three-fourths of the continental United States. This ensemble was utilized as guidance for the production of probabilistic forecasts for severe convective weather during the experiment. Real time analysis during the experiment provided insight into the strengths and weaknesses of the ensemble dataset and informed a strategy for optimizing probabilistic guidance derived from it. This strategy was explored during 2008-2009 and involved a “neighborhood” approach in which probabilistic forecasts were generated for each member of the ensemble then combined to produce unique “neighborhood” ensemble probabilities (NEP). NEP forecasts were shown to provide much more skillful guidance than ensemble probabilities generated using traditional approaches, yielding an important cost-effective way to enhance the value of high-resolution ensembles. This project has been completed.

Publications


ROC-curve areas as a function of QPF threshold for forecasts associated with traditional ensemble probabilities (EP) and neighborhood ensemble probabilities (NEP) (using different smoothing radii). Also shown are areas associated with probabilistic forecasts derived from a single ensemble member (cn).
Kain (primary - NSSL), Sobash (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Develop a guidance product that provides calibrated probabilistic outlooks for severe convective weather based on deterministic high-resolution model output.

Accomplishments
Output from convection allowing high resolution model forecasts, generated on a daily basis at NSSL, was examined for the presence of potentially useful surrogates for severe convective weather. Five surrogates were identified, including measures of 1) mid-level rotating updrafts, 2) updraft strength, 3) downdraft strength, 4) graupel concentration, and 5) strong low-level winds associated with convection.

For each day’s model forecast, surrogate events were aggregated (1200-1200 UTC, corresponding to operational Outlook time period used at the SPC) and a Gaussian function was used to create density fields based on each daily aggregate. Corresponding density fields were created for observations, based on the daily occurrence of severe weather reports. The correspondence between each pair of simulated and observed density fields was determined using a variety of spatial verification metrics, providing valuable information about the potential utility of each surrogate phenomena/process as a predictor of severe convection. Density fields associated with each phenomenon are currently being calibrated based on one year of forecasts and reports so that this technique can be used to produce reliable probabilistic guidance for severe convection on a daily basis.

This project is ongoing.

Publications
Density fields for model-generated surrogate reports (top) and observed severe weather reports (bottom), for the 24h period ending 8 May 2008.

**NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Verification of European Severe Thunderstorm Forecast Experiment (ESTOFEX) Products**

Brooks (primary - NSSL), Marsh (OU School of Meteorology)

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

**Funding Type:** CIMMS Task II

**Objectives**
Test new approaches for displaying forecast performance; establish baselines of quality for ESTOFEX forecasts.

**Accomplishments**
Three years of ESTOFEX forecasts have been analyzed. These forecasts resemble SPC categorical forecasts of severe thunderstorm threat and lightning occurrence. Several important aspects of the forecast performance have been identified. First, there is a significant annual cycle in performance.
Second, there are no statistically significant differences in the forecast quality between different forecasters, beyond that expected by the different distributions of forecast issuance during different times of year. And third, the quality of severe thunderstorm forecasts improved from year to year, but the lightning forecasts from the final year were not better than those in the second year.

Recently developed display ideas were tested and it was found that they provided insight into the temporal progression of forecast performance. It will be straightforward to apply these techniques to SPC forecasts.

This project is ongoing.

### Level 1 Severe Forecast Performance Variability

Forecast performance diagram for level 1 severe weather forecasts. Blue squares show annual averaged performance, red triangles the average performance for each of the five forecasters, and black dots the different seasons. Forecasts improved in both Probability of Detection and Frequency of Hits between each year. The severe weather forecasts were best in the summer with the worst forecasts in the fall. The curved black line represents a line of constant Critical Success Index.

**NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Communicating Weather Information to Emergency Managers**

Brooks (primary - NSSL), Erickson (OU School of Meteorology), O’Hair (OU Department of Communication)

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

**Funding Type:** CIMMS Task II

**Objectives**

Study how information flows between weather services and emergency management.
Accomplishments
Somer Erickson met extensively with emergency managers and spent time in the Norman Emergency Management Center during severe weather events in order to gain a better understanding of the decision-making process for emergency managers. This led to the development of a draft survey for emergency managers. The survey will measure how managers collect information, use it, and make decisions with it.

This project is ongoing.

NSSL Project 9 – Research on Integration and Use of Multi-Sensor Information in Weather Forecasting: Science and Technology Infusion in NWS Operational Systems
Stumpf (primary – CIMMS at NWS/MDL), S. Smith (NWS/MDL)

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

Funding Type: CIMMS Task II

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

Accomplishments
The fifth full year of the CIMMS/NWS-Meteorological Development Laboratory (MDL) collaboration was completed during this review period. During this year, this Mr. Stumpf maintained his position as Operations Coordinator for the Experimental Warning Program’s (EWP) 2009 spring experiment in the NOAA Hazardous Weather Testbed (HWT). The NWS/Meteorological Development Laboratory and OAR/NSSL jointly fund this position. The EWP is a proving ground for evaluating new applications, technology, and services designed to improve NWS short-fused (0-2 hour) hazardous convective weather warning decisions. Mr. Stumpf was responsible for the logistical coordination of a six-week real-time operational experiment in which visiting forecasters from across the United States, as well as other countries, traveled to the NWC to evaluate these specific new innovations: 1) multiple-radar/multiple-sensor severe weather algorithms; 2) 3D lightning mapping array; 3) phased array radar; and 4) Collaborative Adaptive Sensing of the Atmosphere (CASA) radar. He also collaborated with other CIMMS, NSSL, WDTB, and OU scientists on projects related to the EWP. The results from EWP evaluations are being used to further develop these potential improvements to NWS warning services. For 2010, we expect to begin the first experimental test of a 3D radar assimilation system that might be a component of a future “Warn on Forecast” system.

MDL continues to support an Advanced Weather Information Processing System (AWIPS) workstation in the HWT. The WDTB augmented the system with a second AWIPS workstation. Together, these two workstations provide server-client capabilities to provide “localizations” for any NWS forecast office in the nation with live radar, satellite, lightning, surface, upper air, and numerical model data in support of real-time operations in the HWT spring experiments. For 2010, HWT operations will most likely continue to rely on the legacy AWIPS, owing to the readiness status of the next-generation AWIPS (AWIPS2). However, there are plans to have an experimental AWIPS2 workstation available within the HWT during 2010 playing a minor supporting role to the activities. We expect AWIPS2 to take on the primary workstation role during the 2011 experiments.

Close collaboration was maintained with severe weather warning research and development activities at CIMMS and NSSL in the area of multiple-radar/multiple-sensor (MRMS) severe weather warning algorithms, which will eventually be transferred to NWS operations. During 2009, the MRMS algorithms that were tested within the HWT were identified as the most promising new technique for transition to
WFO operations from all of NSSL's spring experiments. As such, we have inserted the MRMS algorithms into the NWS Operational and Services Improvement Process (OSIP), with hopes that the MRMS algorithms will be included in an early release of AWIPS2.

Mr. Stumpf continues to serve as the project lead for the Four-Dimensional Stormcell Investigator (FSI), the project that adapted the NSSL Warning Decision Support System II (WDSSII) 3D/4D base radar display application into AWIPS. During the past year, he worked with other MDL scientists to provide additional display capabilities for Terminal Doppler Weather Radar (TDWR) data. The new version of the software has been delivered to the National Weather Service, and was included in the AWIPS Operational Build 9.0 (OB9.0), which was deployed during 2009. Beyond OB9, Mr. Stumpf will lead the effort to begin the transition of the FSI and other advanced visualization techniques under development at NSSL into AWIPS2.

Mr. Stumpf continues collaboration on behalf of MDL and the HWT with the Weather and Society Integrated Studies (WAS*IS) movement and the new Social Science Woven Into Meteorology (SSWIM) program in the NWC. These collaborations will serve to help integrate innovative applications of social science techniques into HWT experiments in order to make the transition to operations even more socially relevant.

This project is ongoing.

Publications


The "Hail Swath" product from the NSSL Multiple-Radar/Multiple-Sensor system for a supercell event in southeast New Mexico on 28 April 2009. The figure on the left shows the experimental warnings (orange = severe; red = tornado) issued by forecasters during exercises in the 2009 HWT Spring Experiment. The figure on the right shows the official NWS warnings for the same event. Note that the experimental warning polygons (left) are more closely aligned with the motion of the storm tracks, leading to better representation of the weather hazard. This was an important finding of the 2009 experiments.
WDTB Project 10 – Warning Decision-Making Research and Training: Advanced Storm-Based Warnings Training

A. Wood (primary – CIMMS at WDTB), Spannagle (CIMMS at WDTB), NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives
Research the best practices developed by NWS forecast offices since the implementation of storm-based warnings and develop training for all forecasters on these practices.

Accomplishments
Since October 2007, the NWS has been issuing polygon, or storm-based, warnings for short-fused convective events that put the general public at risk (e.g., tornado warnings, severe thunderstorm warnings, and flash flood warnings). These new warnings were designed to depict the specific meteorological threat areas for severe weather warnings and allow NWS forecasters to better serve the public.

During the first 12-18 months of implementation, several best practices were identified that were not addressed in the original training on storm-based warnings. The practices involved one of three categories: internal operational practices, external practices, and the role of management. CIMMS staff
and WDTB instructors developed a training course to inform all NWS forecasters of these practices (primarily involving internal operational practices) in order to help improve NWS service nationwide. The course involved both lecture material (delivered via web modules) as well as several “stories from the field” reports that highlight lessons learned from particularly challenging events. This training was developed and delivered to support NWS forecasters prior to the 2009 convective season.

This project is completed.

A slide from the Advanced Storm-Base Warnings Course showing a limitation of the Advanced Weather Interactive Processing System (AWIPS) geographic shape files used to create warning polygons.

WDTB Project 10 – Warning Decision-Making Research and Training: Advanced Warning Operations Course (AWOC)

Kingfield (primary – all listed are CIMMS at WDTB), Lemon, Martinaitis, Morris, Payne, Sessing, Spannagle, Van Den Broeke, A. Wood, NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives
Improve understanding of warning related issues, helping the NWS achieve GPRA Goals 1-5.

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

In collaboration with WDTB instructors, CIMMS scientists updated existing (from FY08) AWOC Core, Severe, and Winter Track material to add some new material and better fit with other existing curriculum of new hires to the National Weather Service. This work included adding new lessons to the course on user needs (with a focus on ground transportation and road weather), preparing new or better graphics and animations, applying past research to training content, conducting new research relevant to operational forecasters (e.g., analysis of new super-resolution radar versus the previous WSR-88D spatial resolution), and developing interactivity for the modules. Because of the upgrade to super-resolution radar, research associates at WDTB are currently working on new modules, simulations, and websites for the AWOC Severe Track in FY10.

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

This project is ongoing.

Publications
WDTB AWOC official site: http://www.wdtb.noaa.gov/courses/awoc/

AWIPS D2D screen capture of super-resolution versus previous radar resolution for a tornadic supercell as seen by KDDC at 0326 UTC on 24 May 2008.
WDTB Project 10 – Warning Decision-Making Research and Training: AWIPS and WSR-88D Improvements

Van Den Broeke (primary – all listed are CIMMS at WDTB), Lemon, Payne, A. Wood, NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives
Improve understanding of warning-related issues as they relate to upgrades of the AWIPS and WSR-88D radar product generator (RGP) software systems.

Achievements
Upgrades have been made to two software systems available to NWS forecasters for warning operations: 1) the Advanced Weather Interactive Processing System (AWIPS), and 2) the WSR-88D Radar Product Generator (RPG). AWIPS was upgraded to Operational Build 9.0 (OB9.0) and the WSR-88D RPG was upgraded to Build 11.0.

AWIPS OB9.0 introduced many new tools to forecasters: the High-Resolution Precipitation Nowcaster (HPN); data from some Air Route Surveillance Radars (ARSR-4) and Airport Surveillance Radars (ASR-11); Feature Following Zoom (FFZ); and Panel Combo Rotate with All Panel Sampling. CIMMS personnel worked in conjunction with WDTB instructors as subject matter experts to help develop and test training material released to the NWS. RPG Build 11.0 introduced the Clutter Mitigation Decision (CMD) algorithm for real time detection of clutter. CIMMS personnel also assisted WDTB instructors on the development of the training materials released to the NWS.

This project is ongoing.

Publications
RDA/RPG Build 11.0: http://www.wdtb.noaa.gov/buildTraining/Build11/index.html

An example of a one-hour forecast of rainfall rate produced by the High-Resolution Precipitation Nowcaster.
NOAA Strategic Goal 3 (Serve Society’s Need for Weather and Water Information)

Funding Type: CIMMS Task II

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

Accomplishments
Now in its eighth year since the initial release, NOAA’s NWS Weather Event Simulator (WES) continues to play an important role in NWS training. Every NWS forecaster with warning responsibility is required by NWS Directive 20-101 to complete two simulations using the WES prior to each significant weather season per year. The WES has also been a key part of the WDTB’s major training initiatives, allowing students to apply lessons in an operational context. These included Advanced Warning Operations Course (AWOC), Winter Weather Advanced Warning Operations Course (WWAWOC), the Distance Learning Operations Course (DLOC), the Distance Learning Aviation Course (DLAC2), Storm-Based Warnings training, Terminal Doppler Weather Radar (TDWR) training, and AWIPS Delta Training.

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

In the past year, CIMMS scientists collaborated with the WDTB, the Meteorological Development Laboratory (MDL), and the Office of Science and Technology (OST) to develop and release several new versions of WES:

<table>
<thead>
<tr>
<th>BUILD RELEASE</th>
<th>RELEASE DATE</th>
<th>MAJOR IMPROVEMENTS</th>
</tr>
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<tr>
<td>WES 9.0</td>
<td>February 2009</td>
<td>High-Resolution Precipitation Nowcaster (HPN), TDWR in FSI, ARSR-4/ASR-11/Dual-Pol Display</td>
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<tr>
<td>WES 9.0 Tropical Update</td>
<td>June 2009</td>
<td>Support for OB9 ATAN 974 Components as part of the 2009 Tropical GFE Training</td>
</tr>
</tbody>
</table>

This project is ongoing.

Publications

WDTB WES official site: http://www.wdtb.noaa.gov/tools/wes/index.htm
The WES graphical interface – it provides a simulation and data playback capability for NWS forecasters and interested researchers. The interface is used to run simulations for training and research.

WDTB Project 10 – Warning Decision-Making Research and Training: AWIPS-II and the Weather Event Simulator for AWIPS-II

Anderson (primary – all listed are CIMMS at WDTB), Baranowski, Kingfield, Morris, A. Wood, NWS/WDTB and INDUS staff

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

Funding Type: CIMMS Task II

Objectives
Prepare NWS Stakeholders (e.g., AWIPS Focal Points, forecasters) in how to localize and customize the new AWIPS-II software and to educate on the differences from the legacy AWIPS system through on-line training; develop simulation and case review capabilities to enhance NWS warning decision making training and research using the new AWIPS-II platform.

Accomplishments
NOAA’s NWS has embarked on a redevelopment of its AWIPS platform. The major focus of this AWIPS Technology Infusion project is the development of AWIPS-II by Raytheon Technology Services, initially consisting of a conversion of the legacy AWIPS software into a modern services oriented architecture. Based in Java, this new software paradigm features a modular design with loosely-coupled components that communicate using an enterprise service bus and new data storage mechanisms, including the creation and usage of metadata. Three consequences of this new architecture are: (1) new processes are required to localize and customize infrastructure; (2) small functional changes introduced under new platform; and (3) and obsolescence of the existing Weather Event Simulator (WES).
CIMMS staff at WDTB, in collaboration with other NWS training centers, are designing and developing training materials for both AWIPS Focal Points and Forecasters in preparation for the migration to AWIPS-II. The training for AWIPS Focal Points is focused on how to localize and configure the new system while the training for forecasters is to instruct them on the small functional changes (variances) from the legacy AWIPS system so they may efficiently utilize the new system in daily operations. The process of developing aforementioned training also has allowed WDTB to extensively test the new platform and submit trouble tickets on problems found and to make recommendations for improvement of the software and documentation. To date WDTB has submitted 18 trouble ticket reports identifying problems found.

To preserve existing case-review and displaced real-time simulation functionality provided by WES and to support the NWS Directive 20-101 for completion of two simulations by every forecaster prior to each significant weather season, WDTB is designing and developing a WES-II, based on the AWIPS-II software platform. This design may also serve as a prototype method of incorporating training functionality into the “baseline” AWIPS-II system.

The WES-II development will also feature a case converter and an upgrade of WESSL. The case converter will allow training and research activities based on the AWIPS-I data storage methodology to continue in the new system. WES-II will be used to deliver training on any variances between AWIPS-I and AWIPS-II. The new WESSL will provide a method to control the simulation, display non-AWIPS information important to the warning process, and the ability to gather feedback from forecasters as they complete simulations.

CIMMS staff at WDTB have developed a real-time ingest of data into an AWIPS-II platform. Hence, all WDTB staff have the capability of learning the new software environment and discovering any effects AWIPS-II may have on existing and new training and research initiatives.

This project is ongoing.

CAVE, the Common AWIPS Visualization Environment, the display and user-interface component of AWIPS-II.
WDTB Project 10 – Warning Decision-Making Research and Training: *WSR-88D Distance Learning Operations Course (DLOC)*

A. Wood (primary – all listed are CIMMS at WDTB), Anderson, Davis, Kingfield, Lemon, Martinaitis, Morris, Payne, Said, Sessing, Spannagle, Van Den Broeke, NWS/WDTB and INDUS staff

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

**Funding Type:** CIMMS Task II

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

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

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

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

This project is ongoing.

**Publications**
WDTB DLOC information page: [http://www.wdtb.noaa.gov/courses/dloc/](http://www.wdtb.noaa.gov/courses/dloc/)
WDTB Project 10 – Warning Decision-Making Research and Training: WES Simulations to Accompany COMET Courses “Distance Learning Aviation Course Phase 2” (DLAC2) and “Numerical Weather Prediction” (NWP)

Sessing (primary – CIMMS at WDTB), Davis (CIMMS at WDTB), NWS/WDTB staff and COMET collaborators

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

Funding Type: CIMMS Task II

Objectives
Improve forecast abilities of NWS aviation forecasters using DLAC2 and demonstrate effective the use of numerical weather prediction in the forecast process using NWP.

Accomplishments
CIMMS staff members have been working over the past year to develop simulations for COMET’s DLAC2 and NWP courses.

DLAC is a series of courses designed to improve the aviation forecasting abilities of NWS forecasters. The role of CIMMS staff in DLAC is to assist in the research and creation of these hazardous weather simulations. The current phase of DLAC (DLAC 2) began in late FY07. Collaboration among CIMMS staff and other NOAA/NWS employees during FY09 occurred in Norman to strengthen knowledge about aviation forecasting and to work with the other members of the DLAC team to create Module 4 and receive guidance in creating the accompanying simulations. This past year, CIMMS staff at WDTB created three sets of simulations (Las Vegas, St. Louis, and New York), each consisting of two 40-minute
simulations. These simulations will be delivered in August 2009 in conjunction with the release of the accompanying COMET module. The deliverable will consist of multiple DVDs and three guides for the training facilitator at each NWS forecast office to provide direction in setting up the simulations.

The Numerical Weather Prediction (NWP) course is aimed to improve forecasters’ ability to use numerical weather prediction when creating forecasts through several instructional components and WES simulations. Like DLAC2, the role of CIMMS staff for the NWP course is to assist in the research and creation of the WES simulations to give a well-rounded approach to the training. CIMMS staff at WDTB are currently working on producing those simulations from different WFOs throughout the country, and will continue to do so into FY10.

This project is ongoing.

Publications

Distance Learning Aviation Course 2:

Producing Customer-Focused TAFs

Winter Weather Simulation Guide: 12/17/2008 Case

Presented by the Warning Decision Training Branch

DLAC2 Winter Weather Simulation Guide cover.
WDTB Project 10 – Warning Decision-Making Research and Training: WDTB Training and Research Toolkit

Said (primary – CIMMS at WDTB), Kingfield (CIMMS at WDTB), NWS/WDTB and INDUS staff

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

Funding Type: CIMMS Task II

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

Accomplishments
The warning decision making process is multi-faceted, often being improved directly by analysis tools or data analysis techniques. CIMMS staffs have developed some applications to apply these new tools and techniques into the operational forecasting, training and research environment. The WDTB Research and Training (WRAT) Lab Toolkit is one of those applications which has been successfully used for the past few years. CIMMS staff also developed an advanced, automated, efficient and flexible platform, WRAT Lab Control, as part of the application. With this platform, the time consuming setting up and managing of the lab with two servers and twenty-five workstations became very handy, fast, efficient and flexible.

The WRAT toolkit also provides some new functions, including but not limited to pause, resume, forward and grouping workstations to support and enhance resident training strategies. This tool has been performing an important role in setting up the lab’s configuration and enhancing the interactive learning for workshops, such as the NOAA’s NWS Distance Learning Operations Course (DLOC) and for other foreign meteorologist’s visits. This toolkit has made the setting and configuring of the lab easier and more flexible after every major release of Weather Event Simulator (WES).

This project is ongoing.
WDTB Project 10 – Warning Decision-Making Research and Training: WDTB Real-Time System
Baranowski (primary – CIMMS at WDTB), Kingfield (CIMMS at WDTB), NWS/WDTB and INDUS staff

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

Funding Type: CIMMS Task II

Objectives
Investigate warning decision making issues with 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 continue to collaborate with the WDTB on a project that provides various meteorological products, such as satellite data, radar data, model grid data, point data (including METAR, upper air, profiler, maritime, 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 warning decision making skills and archive these events for future training. The system can be used for real-time display, case studying, or as an introduction to AWIPS for students at the University of Oklahoma.

Owing to the unique data requirements of the training community, the CIMMS staff created a unique solution that broke up a transcendent real-time system consisting of multiple LDM and AWIPS servers with different priority levels. In addition, a machine dedicated to housing the Radar Product Generators (RPGs) allowed raw Level II data to be processed for any NWS radar in the CONUS area. These implementations and configurations enhanced the AWIPS, so that users were able to view 8-bit Legacy and Super-Res data across the country.

The system itself is being updated with new AWIPS and RPG builds which provide users with the same software as the forecast offices. The real-time system continues to test the experimental capabilities of the AWIPS II software. Also, RPG build 12 (with dual-polarization radar capabilities) is being tested. This allows WDTB trainers to begin planning training modules while giving them a first look at how data will be displayed with these new systems.

The real-time system has expanded beyond the borders of WDTB and was used heavily in the 2009 Hazardous Weather Testbed Experimental Warning Program (HWT-EWP) and the NWS Polygon Warning Improvement Project, providing all the capabilities of the WDTB real-time system. The LDM and AWIPS decoders were run on one workstation along with up to 5 RPGs. This technology also was incorporated on a laptop and used in collaboration between WDTB and the Norman, OK, forecast office.

This project includes continuing updates and improvements to both the AWIPS I and II software packages and the RPG software. Also, we continue to collaborate with the HWT-EWP to improve system stability for the 2010 experiment.

This project is ongoing.

Publications
The real-time system at work. Pictured setup has 5 Radar Product Generators (RPGs): one RPG is playing back Dual-Pol data for training case build while the other four are processing real time Level II data for four WSR-88D sites across the country. The output products are viewable immediately in AWIPS along with all other ingested data from any workstation in the WDTB.


Davis (primary – all listed are CIMMS at WDTB), Anderson, Martinaitis, A. Wood, NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives

Allow NWS Forecast Office employees to easily reference information regarding courses offered by WDTB as well as information about WDTB team members.

Accomplishments

This document lists the courses offered by WDTB in the coming fiscal year as well as a brief description of the course, performance goals, target audience, time requirements and points of contact. The document also contains a directory for all WDTB team members. The first Training Guide released was an FY09 prototype that was sent to the Science and Operations Officer at each Forecast Office in March 2009. In July 2009 the full FY10 version was released.

This project is ongoing with annual release and possible mid-year release.

Publications

WDTB Project 10 – Warning Decision-Making Research and Training: Optimizing WSR-88D VCP Selection
A. Wood (primary – all listed CIMMS at WDTB), Payne, Spannagle, Van Den Broeke, NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives
Familiarize NWS forecasters with the available Volume Coverage Patterns (VCP) and provide decision support for VCP selection.

Accomplishments
Over the past several years a number of different VCPs have been developed for use on the WSR-88D radar. With the increased number of VCPs available, a number of misconceptions and some confusion over which VCP to use for a particular situation have developed.
WDTB and CIMMS staff members worked together to create an online course describing available VCPs to NWS forecasters, clarifying misconceptions about certain VCPs and their use, and showing examples of how VCP use can affect warning operations. CIMMS staff created multiple graphics showing the advantages and limitations of each VCP at various distances from radar targets. CIMMS staff also created a decision aid tool to help NWS forecasters quickly assess which VCP would be most advantageous for a given forecast scenario.

This project is ongoing.

**VCP 12**

![Graphic showing the beam center lines associated with VCP-12.](image)

**WDTB Project 10 – Warning Decision-Making Research and Training: WSR-88D Dual Polarization Upgrade**  
Payne (primary – all listed are CIMMS at WDTB), Sessing, Van Den Broeke, NWS/WDTB staff

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

**Funding Type:** CIMMS Task II

**Objectives**
Prepare the NWS for the upgrade of the WSR-88D to dual-polarization capability.

**Accomplishments**
The upgrade to dual-polarization on the WSR-88D network is comparable to the upgrade to the WSR-88D network itself back in the 1990s. New variables, in addition to the current ones, will be introduced to all NWS forecasters. These new variables have been shown to improve radar-derived precipitation estimates, discriminate between hydrometeor types (i.e. hail, rain, snow, etc.), and identify new storm signatures (i.e. $Z_{DR}$ column) that can help a forecaster better interrogate storms for issuing warnings to the public.
CIMMS personnel have been working in close collaboration with WDTB instructors to gather and consolidate all of the research on dual-polarization into a two-part course introducing NWS forecasters to dual-polarization and how to best use it in warning operations. Prior to this two-part course, however, CIMMS personnel have helped assemble some cursory presentations on dual-polarization applications in warning operations. Additionally, CIMMS employees have been actively acquiring dual-polarization data from the research radar in Norman, OK to begin developing a database of cases for training purposes.

This project is ongoing.

**Publications**


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**AWIPS 4-panel display showing dual-polarization data of a supercell moving over the Oklahoma City metropolitan area.** The top left panel is reflectivity (Z), top right is differential reflectivity (Z\_DR), bottom left is specific differential phase (K\_DP), and bottom right is correlation coefficient (CC).
WDTB Project 10 – Warning Decision-Making Research and Training: WSR-88D Dual Polarization Outreach and Training for NWS Partners

A. Wood (primary – all listed are CIMMS at WDTB), Lemon, Morris, Payne, Spannagle, Van Den Broeke, NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives
Prepare NWS partners (e.g., emergency managers, government decision makers, media weather broadcasters, and America’s Weather Enterprise) effectively to incorporate dual-polarization data into their decision making process through outreach presentation materials and on-line training.

Accomplishments
Starting in 2010, the entire fleet of WSR-88Ds (Weather Surveillance Radar – 1988 Doppler) is scheduled to undergo a major software and hardware upgrade that will greatly expand the collection of data types and radar products. This upgrade, known as dual-polarization, will allow each radar to collect data with information about the horizontal and vertical properties of weather (e.g., rain, hail) and non-weather (e.g., insect, ground clutter) targets. As part of this system upgrade, CIMMS staff and WDTB instructors are developing outreach and on-line training for emergency managers, media weather broadcasters, and forecasters in America’s Weather Enterprise to help NWS partners effectively incorporate these new data into their decision making.

The work to date on this project has consisted of planning to define the overall scope and instructional design of the training in this project. CIMMS staff created a questionnaire for NWS partners to complete on-line. This needs assessment, completed by over 350 people, helped CIMMS researchers gauge the understanding of dual-polarization radar technology in the targeted communities and, among other things, helped identify key misconceptions that will need to be addressed. Outreach material development will commence in the fall of 2009 and be available for Warning Coordination Meteorologists to use in their spring outreach talks by early 2010. The on-line training, which will be developed during late 2009 and into 2010, will be available for beta testing of the WSR-88D in June 2010 with a final version available sometime in August 2010.

This project is ongoing.
Example of the Hydrometeor Classification Algorithm (HCA) that will be included with the WSR-88D Dual-Polarization upgrade scheduled to start in 2010. Products such as the HCA have a large potential for misuse by NWS partners who don’t understand the details of how the product is generated.

WDTB Project 10 – Warning Decision-Making Research and Training: Severe Storm Threats and Large Event Venues
Lemon (primary – CIMMS at WDTB), Bailey (NWS, Pleasant Hill, MO)

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

Funding Type: CIMMS Task II

Objectives
Educate large venue operators to the severe storm threats and produce protocols for venue operators and train NWS Warning Coordination Meteorologists to assist.

Accomplishments
We have teamed with the International Association of Assembly Managers (IAAM) on this topic and are teaching biannually at their Academy for Venue Safety and Security (AVSS). The IAAM and has developed a strong severe storm emphasis within the AVSS with basic and advanced classes. The students are venue managers and safety managers. With the IAAM and AVSS we have also produced version 1 of the Severe/Hazardous Weather Preparedness Plan and Guideline for venue managers.
This project is ongoing.

**Publications**


**WDTB Project 10 – Warning Decision-Making Research and Training: Integrated Warning Team Scenarios**

Morris (primary – all listed are CIMMS at WDTB), Davis, D. Ladue, Spannagle, NWS/WDTB and External collaborators (SPC, Norman Forecast Office, NWS/OCCWS, Oklahoma Climatological Survey, Broadcast Media, and Emergency Managers)

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

**Funding Type:** CIMMS Task II

**Objectives**

Improve situational awareness, teamwork, and understanding among integrated warning team partners who are NWS forecasters, broadcast meteorologists, and emergency managers

**Accomplishments**

A role-playing scenario was conducted at the 2009 National Hydrologic Warning Council meeting in Vail, CO. This scenario was an interactive simulation of an actual severe weather event that featured river flooding, flash flooding, severe thunderstorms, and tornadoes in a metropolitan area. A fictitious event (an NCAA Division I football game) at a large outdoor venue was added to focus attention on a major societal impact. Workshop attendees (typically water managers) played the part of NWS forecasters to gain a better understanding of communications and teamwork challenges involved in the warning process. The scenario featured a mock NWS Weather Forecast Office (WFO) designed with as much realism as possible. Watches, warnings, and advisories were created using the Weather Event Simulator and were monitored using situation awareness display system software. Warning decisions were determined through audience input gathered using an electronic voting system. Customer interactions were simulated using “NWSChat” including both incoming reports and requests for additional information.

A similar scenario will be developed for a land falling tropical system in the Carolinas in conjunction with the CI-FLOW project. This scenario will likely feature a mock WFO as well as an emergency operations center and television station. Outcomes from a live version of the scenario will be captured and used as the basis for distance learning versions developed for NWS forecasters, broadcast meteorologists, and emergency managers. The distance learning versions will be eventually incorporated as part of the Advanced Warning Operations Course. Project progress includes significant planning and recruitment of team members/advisors from the following organizations: WFOs in Raleigh and Morehead City, Southeast River Forecast Center (Atlanta), OU Sea Grant, NC Sea Grant, SC Sea Grant, OU SSWIM, NC-FIRST, and WRAL-TV.

This project is ongoing.

**Publications**


Photograph of the delivery of the scenario at the 2009 National Hydrologic Warning Council. Screens facing the audience include a situation awareness display (not pictured) and (left to right) NWSChat, the Weather Event Simulator, and the voting system. Five laptops are shown in the foreground for NWSChat and a situation awareness display. The situation awareness display indicates two flash flood warnings and a tornado warning issued and currently in effect. The rightmost NWSChat laptop provides interaction between the WFO and the remaining NWSChat clients (which simulate a TV station and two emergency operations centers). The table in the background has a laptop for the voting software and the Weather Event Simulator workstation. Photo credit: Jim LaDue

WDTB Project 10 – Warning Decision-Making Research and Training: Hazardous Weather Testbed

Lemon (primary – CIMMS at WDTB), Davis (CIMMS at WDTB), NWS/WDTB staff

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

Funding Type: CIMMS Task II

Objectives
Test and evaluate phased array and CASA radars, multi-sensor/multi-radar and the Lightning Mapping Array contributions to nowcasting.

Accomplishments
Lemon and Davis participated as forecasters during the HWT Spring Experiment, each for five days. We issued warnings during both live and canned cases using phased array radar, CASA radars, multi-sensor/multi-radar and Lightning Mapping Array. We then discussed the advantages and disadvantages of each and took a survey to document our thoughts.

This project is ongoing.
SPC Project 12 – Advancing Science to Improve Knowledge of Mesoscale Hazardous Weather: Comprehensive Severe Storm Environment Database at SPC

Dean (CIMMS at SPC), Schneider (SPC)

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

Funding Type: CIMMS Task II

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

Accomplishments
Our main focus continued to be the development of a comprehensive severe storm environment database, which links SPC forecast products and severe weather reports with environmental parameters such as CAPE, vertical wind shear, helicity, and many others. Several projects that use this database are underway:

- A severe storm environment climatology (developed from the database) highlights the differences in tornadic environments in the Plains, which are typically associated with high CAPE and moderate deep-layer shear, versus those in the Southeast and Ohio Valley, which are characterized by relatively low CAPE and strong shear (Schneider and Dean 2008).

- Analysis of SPC forecast performance indicates a strong relationship between watch POD and FAR and the frequency of favorable severe storm environments (Dean and Schneider 2008).

- Conditional probabilities of severe convection and tornadoes (given the presence of deep convection) have been developed from a combination of severe storm reports, lightning data, and environmental parameters such as CAPE, CIN, LCL height, deep-layer shear, and 0-1 km storm-relative helicity. These probabilities show potential utility both in providing real-time operational guidance and in providing further context to SPC forecast verification (Dean et al. 2009).

- High resolution population data from the 2000 U.S. Census has been incorporated into the database; this data, in conjunction with archived SPC forecast products and severe storm reports, is being used to analyze potential human impacts associated with the expected magnitude and location of a severe weather event (Schneider et al. 2009).

This project is ongoing.

Publications


Conditional tornado probability estimate generated from SPC's severe storm environment database, valid for 2200 UTC, 8 May 2003, around 30 minutes before an F4 tornado struck the Moore/Oklahoma City, OK, area.

SPC Project 12 – Advancing Science to Improve Knowledge of Mesoscale Hazardous Weather: SPC’s GOES-R Proving Ground
Siewert (CIMMS at SPC), Rabin (NSSL), Schneider (SPC)

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

Funding Type: CIMMS Task II

Objectives
Assist in successful GOES-R product testing and integration into SPC operations; develop experiments conducive to testing and providing product feedback to developers.

Accomplishments
This year represented the spin-up for the introduction of the GOES-R Proving Ground to SPC-Hazardous Weather Testbed Spring Experiment, in which four products from three core GOES-R product developers across the country were tested. The main goal during the experiment was to set up data flow from the three core developers such that integration of new products into the SPC system was made more straightforward. We also began key interactions with the product developers by bringing them to the Testbed during the 2+ month Spring Experiment campaign. Interactions with the HWT’s Experimental Forecasting Program, Experimental Warning Program, and the VORTEX2 field program also took place.
as a way to include more members of the forecasting community into the GOES-R proving ground mission. Feedback was obtained from SPC and visiting forecasters on the four GOES-R products and it was provided to the product developers for improvements. Presentation of the initial results was given at the COMET Satellite Workshop in Boulder, CO, in May 2009 and at NWS headquarters in Silver Spring, MD, in early July.

This project is ongoing.

Example of one of the four GOES-R products that were tested during the 2009 GOES-R Proving Ground Spring Experiment, showing 15-minute cloud-top cooling rates along a dryline in central Texas at 2032 UTC on 29 April 2009. Cloud-top cooling rates exceeding -4°K/15 min. can be an indication of convective initiation, which is defined as the first occurrence of a radar echo of more than 35 dBZ. Signals can been seen in satellite cloud-top cooling rates up to 45 minutes prior to the first occurrence of a 35 dBZ echo on radar.

**SPC Project 12 – Advancing Science to Improve Knowledge of Mesoscale Hazardous Weather: Probabilistic Cloud-to-Ground Lightning Forecasts at SPC**

Buckey (CIMMS at SPC), Bothwell (SPC)

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

**Funding Type:** CIMMS Task II

**Objectives**

Lightning forecast verification using a variety of methods

**Accomplishments**

Lightning forecasts made during the summer of 2008 were verified using a variety of forecast verification methods. Also, a lightning climatology on a 10 -m basis was developed. The previous 45-km climatology and the forecasts results from the 2008 season were presented at the AMS Annual Meeting in January
2009 and David Buckey’s thesis was defended in July 2009. Lastly, forecast equations on a 10-km grid were derived for different phases of the lightning season in Alaska. Within these phases, unique forecast equations were derived for different time periods of the day. A brief guide describing the various programs used, their locations, and the files they created also were created for any future work that might be done on the subject.

This project is completed.

**NSSL Special Project and NSSL Project 3 (Severe Weather Warning Research and Application Development) – Severe Hazards Analysis and Verification Experiment (SHAVE)**

Ortega (primary – CIMMS at NSSL), T. Smith (CIMMS at NSSL), Manross (CIMMS at NSSL), Scharfenberg (NWS), Witt (NSSL), and Kolodziej, Irwin, Erlingis, Frey, Meyer, Mulder (all OU School of Meteorology)

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

**Funding Type:** CIMMS Task II

**Objectives**

Improve the verification of severe weather events (tornadoes, hail, damaging wind, flash flooding) in the United States through the use of very high resolution multi-sensor/multi-radar data, and verification phone calls, integrated within a geographic information system; improve the verification of tornadoes and wind events using digital photographs integrated within a geographic information system.

**Accomplishments**

The Severe Hazards Analysis and Verification Experiment (SHAVE) is a unique project that has utilized the latest GIS technology to develop techniques used to improve severe storm verification. While the primary objective for SHAVE is to collect high temporal and spatial resolution data that describe the distribution of hail sizes, wind damage and flash flooding by severe thunderstorms, SHAVE participants also have surveyed a number of tornadoes occurring near the National Weather Radar Testbed phased array radar. These data have and will enable several goals, including to:

- Provide the tornado track paths and other high resolution verification data for the National Weather Radar Testbed phased array radar;
- Use the high-resolution verification data in the development of techniques for probabilistic warnings of severe thunderstorms;
- Evaluate the performance of multi-sensor, multi-radar severe weather algorithms—especially their use as a synthetic verification tool;
- Build a large database to associate changes in hail size and wind damage with storm evolution;
- Enhance climatological information about severe storm threats in the United States.

The high spatial and temporal resolution of the dataset collected during the project will facilitate the development of decision-making tools that improve forecasts and warnings of severe thunderstorms and tornadoes, and pave the way for improvements to the historical severe storms database. The 2009 data collection period was from mid-May to end of July, and included:

- 47 operational days
- 33757 verification phone calls
- 10402 “good” data points
- 6200 hail data points
- 1179 wind data points
- 3023 flood data points
The project also surveyed tornado and straight-line wind damage events in support of the phased array radar during the spring of 2009.

This project is ongoing.

**Publications**


**SHAVE** collected high-resolution hail reports via phone calls on a storm that passed over Oklahoma City on 16 July 2009. Further, ground damage surveys completed by participants in SHAVE revealed damage from two microbursts: one in southwestern Edmond and the other in Midwest City. Pictured is the swatch of radar-estimated, maximum hail size along with the reports of hail and wind damage collected via phone surveys.
NOAA/Sea Grant – National Sea Grant Climate/Weather Extension Specialist Research and Outreach with CI-FLOW

Van Cooten (primary – CIMMS at NSSL), Moser (OU School of Meteorology), Kelleher (NSSL), Neumanitis (CIMMS at OU), Peppler (CIMMS at OU)

NOAA Strategic Goals 3 (Serve Society’s Need for Weather and Water Information) and 1 (Protect, Restore, and Manage the Use of Coastal and Ocean Resources through Ecosystem-Based Management)

Funding Type: CIMMS Task III (Program Manager – Leon Cammen)

Objectives
Connect National Sea Grant research and outreach programs with NOAA’s NSSL and other NWC organizations; lead the CI-FLOW research project to improve hydrologic information for coastal watersheds.

Accomplishments
The OU/National Sea Grant Research Program continues to lead NOAA’s CI-FLOW project activities and actively participate in all facets of NSSL’s interdisciplinary hydrometeorological research portfolio. In FY09, the OU/National Sea Grant Extension Specialist accepted an invitation to serve on the NOAA Coastal Estuary River Information Services (CERIS) Vision Team which crafted an initial outline of how NOAA will provide an integrated suite of water information to residents of coastal watersheds very much in the model of the CI-FLOW project. From this activity, the OU/National Sea Grant Extension Specialist was nominated by the NSSL Deputy Director to serve as a representative to NOAA’s Integrated Water Forecast (IWF) program which was approved in FY09 for inclusion in the NOAA planning and budgeting process. In this capacity, OU/National Sea Grant worked to establish project justification and budgets for the FY12-16 NOAA budget planning process for NSSL research program activities in CI-FLOW, QPE, Field Research deployments (Debris Flow and Hydrometeorological Testbed), and assimilation of QPE into NWP to improve short term QPF. The OU/National Sea Grant Research Program continues to develop and strengthen partnerships including those with NOAA Regional Teams, NWS offices, NWS Warning Decision Training Branch, and other Sea Grant organizations especially those in North and South Carolina, Texas, and Louisiana.

In CI-FLOW, FY09 research foci have accomplished hindcast streamflow simulations for over 50 USGS gauging sites in the Tar-Pamlico and Neuse River basins of North Carolina for Hurricane Isabel (2003) and Tropical Storm Alberto (2006). QPE produced by the NSSL Q2 system provided the high temporal and spatial resolution needed to force the National Weather Service (NWS) Hydrologic Lab-Research Distributed Hydrologic Model (HL-RDHM) and the Vflo Hydrologic model. These hydrologic models are currently producing streamflow simulations in real-time at the NWC as a result of the OU College of Engineering’s School of Civil Engineering and Environmental Science and NSSL’s hydrometeorological research collaboration.

The streamflow discharge produced by the two hydrologic models is being used as input for ocean hydrodynamic models to create a seamless suite of water quantity information from the headwaters of the Tar-Pamlico and Neuse Rivers to the Pamlico Sound in North Carolina. At a designated point on the Tar-Pamlico and the Neuse Rivers, river discharge information is being passed off to a research team at the University of Oklahoma and University of North Carolina-Chapel Hill collaborating on the ADCIRC (A (Parallel) Advanced Circulation) Model and researchers at North Carolina State University (NCSU) for their Coast Estuary model. This river discharge serves as the upstream boundary input for each of these ocean hydrodynamic models to incorporate freshwater contributions into coastal water level simulations. Assessments of hindcast simulations of coastal water levels for Hurricane Isabel (2003) and Tropical Storm Alberto (2006) will be available on line in the first quarter of FY10.

CI-FLOW’s unique interdisciplinary team of scientists includes outreach and education specialists to increase the utility and thus value of CI-FLOW research outcomes for coastal watershed stakeholders. In FY09, the CI-FLOW web page was redesigned to be able to highlight research outcomes from the Isabel
and Alberto case studies and results from a possible real-time test of the system. From funding provided in FY09 from NOAA’s Southeast and Caribbean Regional Team (SECART) and NOAA’s Integrated Water Resources Services (IWRS) office, NOAA’s nowCOAST data portal development team partnered with CI-FLOW to tailor data visualization tools for the CI-FLOW river and coastline water level simulations. In the 4th Quarter of FY09, efforts began to ramp up under an NWS Warning Decision Training Branch (WDTB) and OU/National Sea Grant partnership to develop a realistic simulation of NWS operations and products for a landfalling Hurricane in the CI-FLOW project area. A project team consisting of Carolina broadcasters, emergency managers, WFO forecasters, Sea Grant outreach leaders, and NWC social scientists and WDTB instructors are in the planning and data collection phase to construct a storm scenario which will be used to build an interactive exchange of information between project scientists and local stakeholders on current NWS products and those emerging from the CI-FLOW research activities to understand local needs for decision making especially in coastal locations with evacuation considerations and flash flood vulnerabilities.

This project is ongoing.

Publications


The Project CI-FLOW area of focus. Highlighted areas are the Tar-Pamlico and Neuse river basins whose lower reaches are influenced by the Pamlico Sound tidal interaction.

NOAA/Sea Grant – Development of an Integrated Decision Support System for Quantifying Water Resources
Moser (OU School of Meteorology), Van Cooten (primary – CIMMS at NSSL)

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

Funding Type: CIMMS Task III (Program Manager – Leon Cammen)

Objectives
Establish an ensemble of distributed hydrologic models in the Blue River basin of south-central Oklahoma
that uses multiple precipitation inputs, two models, and multiple initial surface parameter estimates. The purpose of the ensemble is to capture the uncertainty of the inputs and generate an event-based probabilistic forecast of streamflow. Also, create a GIS-based decision support interface that displays all rainfall and streamflow-related information in real-time for water resources applications. The information would encompass the complete hydrologic system of a basin, including (but not limited to) observed streamflow, the short term probabilistic forecast of streamflow, rainfall accumulations from both multisensor QPE and rain gauge networks, QPF, soil moisture conditions, ET, and groundwater levels.

**Accomplishments**

As of December 2008 the hydrologic model ensemble was set up for the basin and had been run for eight different rainfall events. The results were presented in a student poster competition at the Oklahoma Governor's Water Conference in October 2008. Work is ongoing to develop temporally varying parameter estimates for the ensemble members that account for changing soil moisture conditions (initial results were presented at the 2009 AMS Annual Meeting). The Center for Spatial Analysis will assist with the creation of the decision support interface. A conceptual design was created in November 2008. This work also is being conducted as part of the Oklahoma Water Bank Project involving the Chickasaw Nation.

This work is ongoing.

**Publications**


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**NOAA/NWS Advanced Hydrologic Prediction Service – Evaluation of Flash Flood Guidance**

Gourley (primary – NSSL), Erlingis (OU School of Meteorology)

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

**Funding Type:** CIMMS Task II

**Objectives**

Evaluate legacy flash flood guidance thresholds and newer, gridded approaches.

**Accomplishments**

To date, we have collected a 2-year archive of flash flood guidance values, gridded flash flood guidance thresholds, precipitation, and observations of flash floods over the Arkansas-Red Basin. All data have been sampled to the same analysis grid. We have developed software to compute statistics on the algorithm performance based on observations of NWS Storm Data reports, USGS streamflow observations, and data collected during the Severe Hazards and Verification Experiment (SHAVE).

A separate analysis of the SHAVE flash flood observations collected during the summer of 2008 has been completed. SHAVE operations continued during the summer of 2009 with a successful data collection effort.

This project is ongoing.

**Publications**

NSSL Special Project – Hydrometeorological Research on the Fort Cobb Basin, Oklahoma

Gourley (primary – NSSL), Flamig (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Evaluate rainfall algorithms from satellite and dual-polarization radar using USDA/ARS Micronet and improve hydrologic prediction.

Accomplishments
We compiled a comprehensive dataset of KOUN polarimetric rainfall estimates covering 9 hydrologic events on the Ft. Cobb basin. Several dual-polarization algorithms have been evaluated using the dense rain gauge network for the 3-year study period. In addition, the Hydrology Laboratory – Distributed Hydrologic Model (HL-DHM) has been set up and rigorously calibrated on the Ft. Cobb basin. A technique was developed to objectively evaluate the polarimetric rainfall algorithms as inputs to hydrologic model simulations. Preliminary results indicated a long-term bias removal was needed for the polarimetric algorithms. Following this simple correction, all polarimetric rainfall algorithms outperformed the conventional R(Z) estimator.

We also collected an archive of rainfall estimates from GOES satellite, TRMM satellite, radar, rain gauges, and merged radar/rain gauge for the summer of 2007. We conducted a study to evaluate the various rainfall estimates at different space and time scales. Results from this study will be used to guide future research in multisensor quantitative precipitation estimation.

This project is ongoing.
Publications

Accumulated rainfall from Jun-Aug of 2007 for (a) TRMM-3B42RT, (b) TRMM-3B42V6, (c) PERSIANN-CCS-RT, (d) PERSIANN-CCS-MW, (e) Radar, (f) Gauge, and (g) Stage4.

**NOAA/OHD – Verification of QPF from Convection-Allowing Configurations of the WRF Model**
Schwartz (OU School of Meteorology), Kain (primary – NSSL)

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

**Funding Type:** CIMMS Task II

**Objectives**
Determine and compare the QPF skill of convection-allowing configurations of the WRF-ARW model with 4km and 2km grid spacing; assess the added value of convection-allowing configurations of the WRF-ARW model compared to the operational NAM
Accomplishments
Model forecasts generated by CAPS from a seven-week period in the spring of 2007 were analyzed using objective verification of mean hourly precipitation and visual comparison of individual events, primarily during the 21- to 33 hour forecast period to examine the utility of the 00Z-initialized model forecasts as next-day guidance. On average, both the 2 and 4 km model forecasts showed substantial improvement over the 12 km NAM. However, although the 2 km forecasts produced more detailed structures on the smallest resolvable scales, the patterns of convective initiation, evolution, and organization were remarkably similar to the 4 km output. Moreover, on average, metrics such as equitable threat score, frequency bias, and fractions skill score revealed no statistical improvement of the 2 km forecasts compared to the 4 km forecasts. These results, based on the 2007 dataset, corroborate previous findings, suggesting that decreasing horizontal grid spacing from 4 to 2 km provides little added value as next-day guidance for severe convective storm and heavy rain forecasters in the United States.

As an extension of this work, similar statistics were computed for another set of 4km WRF-ARW forecasts, this time for much longer time period. In this case the output came from 4km forecasts generated at NSSL over a continuous two-year period (April 2007 – April 2009) and once again these convection-allowing forecasts were compared to operation guidance from the NAM. The NSSL forecasts showed remarkably good skill in terms of frequency bias and were more skillful than the NAM at moderate to high precipitation thresholds – the range in which QPFs are particularly relevant to the prediction of heavy rains and flooding.

This project has been completed.

Publications


Frequency bias, threat score, and equitable threat score as a function of hourly accumulation threshold for WRF-NSSL and NAM forecasts from April 2007 – April 2009.
**NOAA/NWS/CSTAR – A Partnership to Develop, Conduct, and Evaluate Real-Time High-Resolution Ensemble and Deterministic Forecasts for Convective-Scale Hazardous Weather**

Xue (primary – OU CAPS), Droegeiemer (OU CAPS and School of Meteorology), Kong (OU CAPS), Thomas (OU CAPS), Wang (OU CAPS), Gao (OU CAPS), Brewster (OU CAPS)

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

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

**Objectives**

Demonstrate the value and cost-benefits of storm-scale ensembles versus coarser-resolution short-range ensembles and even-higher-resolution deterministic forecasts; the value and impact of assimilating high-resolution data including those from WSR-88D radars; and the impact of storm-scale ensemble product on real-time forecasting and warning of high impact weather events.

**Accomplishments**

In the third year under this CSTAR project, CAPS produced 20-member real-time storm-scale, convection allowing, ensemble forecasts at 4-km horizontal grid spacing as contributions to the NOAA SPC/NSSL Hazardous Weather Testbed (HWT) 2009 Spring Experiment. One major advance from the 2008 season is the inclusion of 10 additional members from two different NWP modeling systems – 8 members from WRF-NMM and 2 from ARPS, in addition to the 10 WRF-ARW members, resulting in a multi-model storm-scale ensemble. As in 2008, Level-II data from over 120 WSR-88D radars were assimilated through ARPS 3DVAR and cloud analysis package into all members but one from each model.

All members ran daily during the weekdays from 20 April through 5 June 2009, for a domain covering most of the continental U.S as in 2008. Thirty-hour forecasts were produced starting at 0000 UTC through 0600 UTC the next day. The ensemble system was constructed with hybrid perturbation members with a combination of perturbed initial conditions (extracted from selected NCEP SREF members) and various microphysics, shortwave radiation, and planetary boundary layer physics parameterization schemes. At the same time, a single 30-hour 1-km WRF-ARW deterministic forecast was produced over the same domain and with radar data assimilation. All ensemble forecasts were run overnight on **Bigben**, a Cray XT3 cluster at the Pittsburgh Supercomputing Center, using 2000 cores, while the 1-km deterministic forecast was run on **Kraken**, a newly commissioned 66,000 core Cray XT5 cluster system at the National Institute for Computing Science (NICS), using 10,000 cores.

The unprecedented assimilation of WSR-88D radar data on the native grid over the national scale has once again proved, as in the 2008 season, to help boost the forecast scores (such as ETS) for the first 6-12 hours, and for some case dates the impact lasts for the entire 30 hours. The multi-model ensemble shows improvement in dispersion and reliability.

This project is ongoing.

**Publications**


Kong, F., and co-authors, 2008: Realtime storm-scale ensemble forecast experiment. 9th *WRF User’s Workshop*, NCAR Center Green Campus, 7-3.


30 h forecast of composite reflectivity products, valid at 0600 UTC 6 May 2009. (a) Probability Matching (PM) composite reflectivity, (b) probability of composite reflectivity ≥35 dBZ, (c) spaghetti chart of composite reflectivity = 35 dBZ, and (d) NSSL observed composite reflectivity mosaic.

NSSL Special Project – Integration and Testing of Advanced Radar QC Algorithms for Hazardous Weather Testbed Spring Forecast Experiments

Xue (primary – OU CAPS), Brewster (OU CAPS), Lei (CIMMS at OU), Xu (NSSL), Nai (CIMMS at OU)

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

Funding Type: CIMMS Task III

Objectives

Compare operational and research Doppler radar radial velocity dealiasing/quality-control algorithms between CAPS and CIMMS/NSSL research groups; use the results of the comparison to improve the quality control algorithms used for analyses and forecasts in the Hazardous Weather Testbed for the real-time spring forecast experiments and for other research projects.
Accomplishments
Software and some documentation were shared between the CAPS and CIMMS/NSSL research groups and the quality control methods that are used in the CAPS NEXRAD processing and remapping program, known as 88d2arps, were implemented. The groups discussed candidate cases for benchmarking and testing, settling on a handful of cases based on case studies and recent events.

One case being used is the 8 May 2003 Moore/Midwest City tornado that had a strong mesocyclone, using data from Oklahoma City KTLX radar. The result of a sample comparison from this case using the operational thresholds of the schemes is shown in the figure below. The raw observed data are shown in the upper left quadrant (a), the result of the standard operational NEXRAD de-aliasing algorithm is shown in the upper right (b), the result of the CIMMS two-step method (Xu et al. 2009) is shown the lower right (c), and the result of the algorithm in the CAPS ARPS system (Brewster et al. 2005) is shown the lower right (d). The ARPS and the two-step methods do a very good job with the de-aliasing in this radar tilt. The ARPS method has some trouble with the highest velocities in the center of the mesocyclone whereas the two-step method deletes a number of those gates. This suggests the need for an improved data fitting model or a tightening of the CAPS QC thresholding within such features.

This project is ongoing.

Publications
Xu, Q., K. Nai, L. Wei, P. Zhang, Q. Zhao and P. R. Harasti, 2009: A real-time radar wind data quality control and analysis system for nowcast application. WSN09 – WMO Symposium on Nowcasting, Whistler, BC, Canada, WMO.

Comparison of Doppler radial velocity from the Norman, Oklahoma NEXRAD radar (KTLX) for the 3.35 degree tilt from 2230 UTC 8 May 2003. a) raw velocity, b) classic NEXRAD de-aliasing algorithm, c) CIMMS two-step de-aliasing/QC algorithm, d) CAPS ARPS de-aliasing algorithm.

NSSL Special Project – An Investigation on the Importance of Environmental Variability to Storm-Scale Radar Data Assimilation
Xue (primary – OU CAPS), Gao (OU CAPS), Stensrud (NSSL)

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

Funding Type: CIMMS Task III

Objectives
Explore the importance of environmental variability to storm-scale radar data assimilation by including explicit environmental information from a mesoscale ensemble data assimilation system.
Accomplishments
In this study we investigated the importance of horizontal environmental variability to very short-range (0-1 h) convective-scale ensemble forecasts initialized using Doppler radar observations for the 4-5 May 2007 Greensburg, KS, tornadic thunderstorm event. Radar observations of reflectivity and radial velocity from the operational Doppler radar network at 0230 UTC 5 May 2007, during the time of the first large tornado, are assimilated into each ensemble member using a three-dimensional variational data assimilation system (3DVAR) developed at CAPS. Very short-range forecasts are made using the nonhydrostatic Advanced Regional Prediction System (ARPS) model from each ensemble member and results compared with observations. Explicit three-dimensional environmental variability information is provided to the convective-scale ensemble using analyses from a 30-km mesoscale ensemble data assimilation system. Comparisons between convective-scale ensembles with initial conditions produced by 3DVAR using a) background fields that are horizontally homogeneous but vertically inhomogeneous (i.e., have different vertical environmental profiles), and b) background fields that are horizontally and vertically inhomogeneous are undertaken. Results show that the ensemble with horizontally and vertically inhomogeneous background fields provides improved predictions of thunderstorm structure, mesocyclone track, and low-level circulation track than the ensemble with horizontally homogeneous background fields. This suggests that knowledge of horizontal environmental variability is important to successful convective-scale ensemble predictions and needs to be included in real data experiments.

This project has been completed.

Publications


Vorticity counts (isolines every 5, starting at 5) from 30 member ensemble for (a, c) 3-km grid spacing and (b, d) 1-km grid spacing between 0230 and 0330 UTC 5 May 2007. Counts valid at 2 km MSL are in the top panels, and valid at 1 km MSL (300-400 m above ground level) are in the bottom panels. Vorticity counted when it exceeds 0.004 s⁻¹ for the 3-km runs and 0.01 s⁻¹ for 1-km runs at each grid point. Shading denotes approximate region of observed mesocyclone track at 2 km MSL from 3DVAR analyses.
NSSL Special Project – Advancing Warn-on-Forecast Storm-Scale Analyses of VORTEX2 Thunderstorms
Xue (primary – OU CAPS), Gao (OU CAPS), Stensrud (NSSL)

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

Funding Type: CIMMS Task III

Objectives
Assimilate WSR-88D observations of reflectivity and radial velocity for the thunderstorms targeted during VORTEX2 field operations using the ARPS 3DVAR system.

Accomplishments
As a first step, we have initiated testing on the relative importance of assimilating radial velocity and reflectivity using ARPS 3DVAR. We have conducted two case studies. For the idealized case, a set of experiments that differ in the type of data used are performed to identify the impact of radial velocity and reflectivity data when using different numbers of NEXRAD radars. It is found that by assimilating radial velocity data only, the model can predict the timing and evolution of a simulated supercell thunderstorm with great accuracy. In contrast, large errors emerge when only reflectivity data are assimilated. These errors are produced during the updating of hydrometer-related variables and the temperature adjustment that occurs in the cloud analysis package. For the observed Greensburg tornadic thunderstorm case of 4-5 May 2007, two preliminary experiments are performed. One uses only radial velocity and the other uses both radial velocity and reflectivity from several nearby radars. It is found that by assimilating only radial velocity data, the model can reconstruct the supercell thunderstorm that produced Greensburg tornado very well, while assimilating reflectivity does not add much value. These initial results suggest that the assimilation of radial velocity data is essential for the prediction of supercell thunderstorms within the 3DVAR and cloud analysis framework, likely due to their helical updrafts that play such an important dynamic role in storm development and evolution. Though reflectivity data is fundamental to storm tracking and QPE, the assimilation of such data into NWP models may be not as effective as radial velocity for supercell storms, because reflectivity is related to more inactive model variables, and a lot of uncertainties in model microphysics and with the cloud analysis package used further complicates its usage in storm scale NWP. However, for weaker thunderstorms reflectivity data may be important. The reported experiments used 1-km horizontal grid spacing.

This project is ongoing.

Publications
Gao, J., G. Ge, D. J. Stensrud, and M. Xue 2009: The relative importance of assimilating radial velocity and reflectivity data to storm-scale analysis and forecast. 23rd Conf. on Weather Analysis and Forecasting/19th Conf. on Numerical Weather Prediction, Omaha, NE, Amer. Meteor. Soc., 16A.3.

Other Agency – Parameterization of Cloud Microphysical Processes in Cumulus Convective Clouds
Y. Kogan (CIMMS at OU)

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

Funding Agency: Office of Naval Research, NOAA

Objectives
Development and improvement of cloud microphysical parameterizations in cumulus convective clouds for use in numerical weather prediction models
Accomplishments
We continued development of a new bulk microphysical parameterization for cumulus convective clouds using an explicit (drop spectrum resolving) microphysical model as a data source and a benchmark for comparison. Our previous research emphasized that the development of an accurate parameterization requires the use of the dynamically balanced cloud drop spectra dataset. The best tool to create such dataset is an LES model with explicit microphysics, since it is able to provide a full range of drop spectra generated by realistically represented dynamics and turbulence. Several case studies based on Rain in Cumulus over the Ocean (RICO) field project have been conducted and results analyzed by comparison with available observational studies. In order to verify the model, several new software packages have been developed in collaboration with Prof. S. Gutman from the Department of Mathematics at OU. These new analysis tools will allow selective data sampling for cloud cells with varying intensity. We also developed parameterizations for main conversion rates, such as autoconversion/accretion of cloud water into/by drizzle, as well as drizzle drop concentration and mixing ratio fall velocities. The testing of the developed parameterization will continue in the framework of the bulk version of SAMEX that will be developed during the next year.

This project is ongoing.

Publications


Other Agency – Contribution to WRF Model Development by CAPS
Xue (primary – CAPS), Zhu (OU CAPS), Yang (OU CAPS), Brewster (OU CAPS)

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

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

Objectives
Develop and test radar data assimilation capabilities within the GSI data assimilation framework, and test and improve the capabilities for planned 13-km Rapid Refresh (RR) and 4-km High-Resolution Rapid Refresh configurations (HRRR).

Accomplishments
A large number of data assimilation and forecast experiments were performed for the 2007 land-falling tropical storm Erin case, assimilating reflectivity and/or radial velocity data from multiple WSR-88D radars together with other observations routinely used by GSI and RUC system. The experiments used NAM or RUC as analysis background and boundary conditions. Different assimilation window lengths and data assimilation frequencies were tested. The track and intensity forecasts are generally improved by assimilating radar data, but the degree of improvement is dependent on the data assimilation configuration. Due to incomplete coverage of radar data even in the core vortex region, the radar data impact appears to be smaller than some of the strong hurricane cases studied by this group. Objective oriented verification methods were also applied to the precipitation verification of Erin forecasts.

The radar data assimilation procedure based on ARPS complex cloud analysis, adapted to work within the GSI framework, together with variations of its implementation in the digital-filter-based initialization procedure of Rapid Refresh, were compared to the standard Diabatic Digital Filter Initialization (DDFI) procedure of RR for limited cases. The results suggest that it is the temperature adjustment in either the
cloud analysis or DDFI that plays the most important role. More systematic comparisons will be performed to arrive at an optimal procedure.

This project is ongoing.

Equitable threat scores of predicted composite reflectivity, at 20 dBZ threshold, for four experiments (Exp-All, Exp-VR, Exp-RF and Exp-CTL) that assimilated, respectively, both radial velocity and reflectivity, reflectivity, radial velocity, and conventional data only. Assimilating both velocity and reflectivity data gives the best forecast.
Climatic Effects of/Controls on Mesoscale Processes

NOAA/NWS/International Activities Office – Sensitivity of the Modeled West African Monsoon to Convective Parameterization
Lélé (CIMMS at OU), Lamb (primary – CIMMS at OU), Leslie (OU School of Meteorology)

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

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

Objectives
Document characteristics of modeled West African Monsoon Systems.

Accomplishments
The West African monsoon system (WAMS) has been extensively studied on the large scale, where it was often described in terms of the variability of the Intertropical Convergence Zone (ITCZ) and its associated regional circulations. However, on the synoptic and mesoscale, WAMS structure and variability involve complex interactions between organized mesoscale convective systems (MCS), wave patterns, deep convection, diurnal variations and associated rainfall. Hence, General Circulation Models (GCM) have had difficulties in simulating these WAM features. Consequently, Numerical Weather Prediction (NWP) and Regional Climate Models (RCM) currently are being increasingly used to simulate the important climate components of WAMS. Therefore, there is a need to extensively test these models before using them for real time operational forecasting. While the simulation of mesoscale and synoptic features of the WAMS using some RCMs has been documented, little work has been done with the Weather Research and Forecasting (WRF) model which is another regional and weather climate model. The research reported is investigating the sensitivity of the modeled evolution and diurnal variation of the WAMS to convective parameterization schemes in terms of thermodynamic and circulation characteristics, stability profiles, and rainfall. Unlike previous studies that used coarser resolutions in simulating WAMS features, we are using the WRF model with a high resolution (12 and 4 km) in a three nested domain configuration. Model results for the 2006 monsoon season are compared with surface meteorological station observations and key AMMA radiosonde sites. The preliminary results show substantial differences in the modeled rainfall and atmospheric stability between the different simulations.

This project is ongoing.

Difference between modeled and observed equivalent potential temperature in domain 2 (12 km) for Dakar (Senegal), Bamako (Mali) and Niamey (Niger) stations.
NOAA/NWS/International Activities Office – Collaboration and Cooperation within the ACMAD Core Demonstration Project in Climate Prediction between ACMAD and CIMMS  

Lamb (primary – CIMMS at OU), Lélé, Segele, Mtainayel (all CIMMS at OU)

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

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

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

Accomplishments
Research and development collaboration and cooperation between the African Centre of Meteorological Applications for Development (ACMAD, Niamey, Niger) and CIMMS was sustained strongly in the past year. CIMMS continued to fund and supervise three graduate students and one Post-Doctoral scientist from Africa whose research focuses on key weather- and climate-related problems of their countries. Those scientists come from Ethiopia (Zewdu Segele, Ph.D. in Meteorology, completed; now a Post-Doc), Niger (Issa Lele, M.S. in Meteorology, completed, and Ph.D. in Meteorology, started; Rahama Beida, M.S. in Meteorology, started), and Chad (Samuel Mtainayel, M.S. in Meteorology, almost completed). During the first half of 2009, three large papers derived from Dr. Segele’s Ph.D. Dissertation were published in the International Journal of Climatology and the Journal of Climate. A paper from Mr. Lele’s M.S. Thesis was submitted to the Journal of Climate in mid-2009.

CIMMS played a major role in the deployment of 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 subsequently to analyze ARM data collected in Niamey. That funding is supporting Dr. Segele to visit the University of Niamey and ACMAD during July-October 2009, and a University of Niamey scientist to spend six months at CIMMS beginning in late 2009. The leader of the University of Niamey team (Professor Abdelkrim Ben Mohamed) also serves as Chair of the ACMAD Scientific Advisory Council. In support of the ARM Mobile Facility deployment in Niamey, CIMMS issued monthly and seasonal reports on the progress and quality of the West African monsoon at Niamey for 2005 and 2006. This work was incorporated into an overview paper on the Niamey deployment that was published in the Journal of Geophysical Research-Atmospheres in late 2008, again with CIMMS coauthorship. The CIMMS Director visited ACMAD in July-August 2009.

This project is ongoing.

Publications


NOAA/NWS/International Activities Office and CIMMS – RAINWATCH: A Prototype Geographic Information System for Daily and Seasonal Rainfall Monitoring and Visualization in West Africa

Tarhule (primary – OU Department of Geography), Saley-Bana (OU Department of Geography), Lamb (CIMMS at OU)

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

**Funding Type:** CIMMS Task III (Program Manager – Dan Thompson)

**Objectives**

Provide tools to monitor rainfall and track critical rainfall attributes beneficial to farmers in West Africa.

**Accomplishments**

RAINWATCH is a stand alone, prototype Geographic Information System (GIS) application that automates and streamlines key aspects of rainfall data management, processing, and visualization for West Africa. It was implemented at the African Centre of Meteorological Applications for Development (ACMAD, Niamey, Niger) during the 2009 monsoon season. This initial demonstration was for 7 stations in Niger. Next year, RAINWATCH will be run at ACMAD for a similar number of stations in each of several other West African nations (at least Mali, Burkina Faso, Senegal)

RAINWATCH is an interactive Map Objects Visual Basic application that monitors rainfall and tracks critical rainfall attributes beneficial to farmers. Using the simple to understand concept of cumulative rainfall plots, the program allows users to compare rainfall for any year against six percentile thresholds for a historical reference period (1965-2000). These thresholds separate dry, normal, and wet conditions. Users also can compare rainfall data between stations for a given season or between seasons for a particular station, and spatially interpolate rainfall for a single event, defined period, or an entire season. The system is dynamic and automatically updates all charts and tables as new data are added to the database. Thus, for this poor and drought-prone region, RAINWATCH can reduce delay in rainfall data processing, facilitate communication between data collection agencies, and generally make rainfall data more accessible and meaningful. A paper describing the characteristics and utility of RAINWATCH will appear in the “Insights and Innovations” section of the *Bulletin of the American Meteorological Society* in November 2009. This project is ongoing.

![RAINWATCH display for Niamey, Niger.](image)
NOAA CPO/Insurance Group Australia – Multidecadal Variability of Eastern Australian Dust and Northern New Zealand Sunshine: Associations with the Pacific Climate System

Lamb (primary – CIMMS at OU), Leslie (OU School of Meteorology), Timmer (OU School of Meteorology), Speer (University of New South Wales, Australia)

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

Funding Type: CIMMS Task III

Objectives
Study the impact of central Eastern Australian dust on sunshine in New Zealand, and the role of the Pacific climate system.

Accomplishments
Central eastern Australia is a major global source region for atmospheric dust. Time series of surface dust observations show that a striking multidecadal oscillation of dust frequency has occurred in this large region since the late 1950s. From 1959 to 1973, there was a pronounced and consistent dust maximum, after which a sharp decline was followed by a much more dust-free 1977-2006. Time series of surface and 925 hPa (~725 m) winds reveal that the dust oscillation was associated locally with strengthening and then weakening of the southerly component of the low level wind over the dust-prone region.

Composite maps for 1959-1973 (dusty) and 1977-2006 (more dust-free) indicate that these local wind changes reflected the relative speed of the southerly-southeasterly airflow into southeastern Australia. Correlation analyses show that this multidecadal regional wind oscillation was associated with similar timescale changes in the behavior of the Pacific climate system, including the latitudinal displacement of the South Pacific Convergence Zone, and more remotely with the sea surface temperature changes of the Pacific Decadal Oscillation (tropical North Pacific and extratropical North-Northeast Pacific) and North Pacific Oscillation (central subtropical North Pacific). Further correlation analyses suggest these Pacific climate system oscillations modulated other key environmental conditions (cloud regime, sunshine duration, rainfall rate) across the Southwest Pacific, including northern New Zealand sunshine.

This work has been completed.

Publications
Environmental variability in central eastern Australian dust-prone region enclosed by broken line panel f for September – February periods of 1957 – 2006. Each point in each time series represents a single season. (a) Dust frequency (days per season) calculated from 24 monitoring stations (open circles in panel f). (b) Surface scalar wind speed anomaly (m s\(^{-1}\)) from 1957 to 2006 mean averaged over 13 stations (solid dots in panel f). (c) Surface meridional wind component anomaly (m s\(^{-1}\), southerly anomalies positive) from 1957 to 2006 mean averaged over 13 stations (solid dots in panel f). (d) 925 hPa (725 m) meridional wind component anomaly (m s\(^{-1}\), southerly anomalies positive) from 1949 to 2006 mean averaged over 29 grid points in NCAR-NCEP reanalysis data from dust-prone region (orange crosses in panel f). (e) Rainfall total anomaly (normalized, \(s\)) from 1957 to 2006 mean averaged over 13 stations (solid dots in panel f). In panels a – e, broken blue (solid red) curves give raw (9-year running mean, i.e., low frequency, LF) values, year markers are for first year of each September – February, and dash-dotted vertical lines separate dusty (1959 – 1960 to 1972 – 1973), transition (1973 – 1974 to 1976 – 1977), and relatively dust-free (1977 – 1978 to 2005 – 2006) periods. According to two-tailed t tests, raw (LF) correlation magnitudes in panels a – e exceeding 0.28 (0.67) are significant at the 5% level, and those exceeding 0.36 (0.80) are significant at 1% level [Wilks, 2006, pp. 117 – 118; Holland and Webster, 2007]. One/two/three asterisks indicate correlation coefficients significant at 10%/5%/1% level. In panel g, solid red and broken green lines respectively enclose areas of maximum SST variance explained by Pacific Decadal Oscillation (PDO) and North Pacific Oscillation (NPO [Barlow et al., 2001]) modes computed here, and the dotted black line is the location of South Pacific Convergence Zone (SPCZ) given by Griffiths et al. [2003]. Also in panel g, A (Apia, Samoa) and Su (Suva, Fiji) locate nodes of SPCZ index used [Griffiths et al., 2003], and Sy (Sydney, Australia), T (Taumarunui, New Zealand), and K (Kaitaia, New Zealand) are stations for which sunshine duration and rainfall rate time series are developed.
NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Explaining the Spatial Variability of the Mid-Summer Drought over the Inter-American Seas Region

Douglas (primary – NSSL), Mejia (CIMMS at NSSL), Beida (OU School of Meteorology), Dominguez (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Describe spatial variations of the mid-summer dry period over Central America; explain interannual variations in dry season intensity and geographical. Extent.

Accomplishments
We have continued to use 16 years of 3-hrly GOES satellite imagery to map the spatial extent of the mid summer dry season over the Caribbean Sea region and northern South America. Several new indices for defining the dry season have been used to determine the timing of the onset and decay of the dry season, but no best index has yet been identified.

On a related project John Mejia completed his PhD dissertation and is preparing the results for publication.

This project is ongoing.

Publications

Douglas, M and J. Mejia, 2008: Mapping the spatial extent of the Central American Mid-summer drought. 2008 Climate Prediction Program for the Americas Principal Investigators Meeting, Silver Spring, MD.
Mejia, J., and M. Douglas, 2008: Synoptic variability of rainfall and cloudiness along the coasts of northern Peru and Ecuador during the 1997-8 El Niño event. 2008 Climate Prediction Program for the Americas Principal Investigators Meeting, Silver Spring, MD.
Multyear (1990 to 2006) mean of June minus July cloud-tops colder than -38°C illustrating unprecedented details of the cloudiness changes during the onset of the Mid-Summer Drought (MSD). The large monsoonal increase in cloudiness (negative MSD index) along the Sierra Madre Occidental in NW Mexico is obvious, as is the decrease in cloudiness (positive MSD index) over the central and western US. What is normally termed the MSD is associated with the decrease in cloudiness over the Pacific slopes from southern Mexico to northern Cost Rica. Of note are also the maritime MSD-like structures over the Caribbean and E. Pacific.

Other Agency – Assessing and Improving Regional Climate Modeling of Mid-Latitude, Mid-Continent Cumulus Convection

Segele (CIMMS at OU), Lamb (primary – CIMMS at OU), Leslie (OU School of Meteorology), E. White (OU School of Meteorology)

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

Funding Agency: U.S. Department of Energy

Objectives
Assess and improve the representation of mid-latitude mid-continent cumulus convection in regional climate models.

Accomplishments
Work on this project commenced in June 2008 by examining the ability of the WRF model to reproduce the observed cloud properties and convection characteristics in the vicinity of the ARM Southern Great
Plains (SGP) Central Facility. Initial emphasis was given to assessing the impacts of WRF microphysics on warm-season convection and cloud characteristics. Accordingly, nine nested WRF simulations, corresponding to each of the model's alternative microphysical schemes, were conducted for the SGP domain for the warm-season heavy precipitation case of 27-31 May 2001. For model validation we used precipitation data from the SGP Surface Meteorological Observation System (SMOS), precipitable water vapor from the ARM Climate Modeling Best Estimate (CMBE), cloud fraction data from the continuous baseline microphysical retrieval (MICROBASE) VAP, liquid water content (LWC), ice water content (IWC), and MMCR radar reflectivity best estimates from the Mace et al. (2006) SGP Atmospheric State, Cloud Microphysics, and Radiative Flux Divergence VAP. The QuickBeam radar simulator (Haynes et al. 2007) was used to convert WRF-simulated profiles of thermodynamic, microphysical, and hydrometeor variables to the equivalent radar reflectivities measured by the MMCR. Substantial differences were observed in simulated precipitation rates and convection onsets at the SGP Central Facility for the different microphysical schemes. Comparison of the observed and simulated fields revealed that all WRF microphysics schemes underestimate LWC (especially) and IWC, with the largest simulated LWC being less than 1.4 g m$^{-3}$ compared to the observed 4.5 g m$^{-3}$ maximum. In addition, examination of simulated and observed cloud fraction and cloud radar reflectivity profiles revealed large discrepancies at low levels for all 9 WRF microphysical parameterizations.

To minimize differences in observed and simulated convection onset and cloud microphysical properties and assess the impacts of data simulation, hourly SGP SMOS measurements and 6-hourly upper air sounding data from the SGPCF were assimilated using 3DVAR and 4DVAR techniques for the Thompson et al. microphysics scheme. Additional model simulations were performed by nudging model results to a SGP surface-only analysis (SFC-NUDGING) and to surface and upper air SGP meteorological data analyses (OBS-NUDGING). For the 3DVAR analysis, surface (rawinsonde) measurements within 1 hr of 0600 UTC on 27 May 2001, were assimilated for 15 Extended Facility sites. Rawinsonde data for SGP Boundary Facilities were not available for this simulation period. For all other analyses, observations from 0600-1200 UTC on 27 May 2001 were assimilated. For the Control Run (CTRL), the integration was performed without data assimilation. The same microphysics and model configuration were used for all sensitivity simulations. The analysis nudging and variational data assimilation experiments showed improvements compared to the CTRL run, with observable increases in the simulated LWC and especially IWC more than 50 hours into the simulations (~1700 UTC 29 May 2001).

Compared to the 3DVAR simulation, the SFC-NUDGING, OBS-NUDGING, and 4DVAR experiments produced IWC profiles that are more consistent with observations. Of all the simulations, the 4DVAR experiment performed best although it overestimated LWC/IWC near the start of the simulation. In particular, there is a good agreement between observed IWC and 4DVAR-simulated values for the first major convection event near 0600 UTC on 28 May 2001. Very similar 4DVAR results were obtained when the number of iterations of the tangent linear and adjoint model executions (inner iteration) was reduced from 30 to 5 within a WRF nonlinear model execution (outer iteration). This finding is useful as it provides the basis for reducing the large computational cost of the 4DVAR analysis for future sensitivity experiments.

This project is ongoing.
Height-time profiles of observed (left) and best-simulated (right) hourly liquid water content (top row, g m$^{-3}$), ice water content (second row, g m$^{-3}$), cloud fraction (third row, %), and cloud radar reflectivity (bottom, dBZ) in the vicinity of the SGP Central Facility for 27-31 May 2001. Simulation results are shown only for the WRF Single-Moment 6-class, WRF Single-Moment 5-class, and Lin et al. microphysics schemes, which respectively produced the best-simulated liquid and ice water concentration, cloud fraction, and reflectivity profiles that are closest to the observations. Observed cloud fraction profile is from MICROBASE VAP, while observed ice and liquid water concentrations and cloud radar reflectivities are Mace et al.’s (2006) Best-Estimates. Gray vertical bars in left column denote missing observations. Scale for each observed and simulated variable pair (g m$^{-3}$) is shown between columns in the corresponding row. Tick marks on the abscissa are every 12 hours beginning at 0000 UTC on 27 May 2001.
Other Agency – Investigation of Southern Great Plains Moisture Budget for CLASIC: Recycling Study

Portis (primary – CIMMS at OU), Lamb (CIMMS at OU)

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

Funding Agency: U.S. Department of Energy

Objectives

Provide larger-scale background for the interpretation of results from the Cloud and Land Surface Interaction Campaign (CLASIC) program that was conducted over the SGP ACRF during June 2007, with emphasis on the relative contributions to regional precipitation of locally evaporated and transpired (i.e. recycled) moisture versus externally advected atmospheric water vapor; assess the uniqueness of the CLASIC land-atmosphere-interaction results especially in regards to precipitation moisture sources; build on our insights from a recently-completed investigation of the moisture budget over the Midwest (Zangvil et al. 2001, 2004) regarding the physical interpretation of the relationships among the moisture budget components.

Accomplishments

Our moisture budget analysis over an expanded region surrounding the SGP during CLASIC was expanded to include two other May-June periods with contrasting rainfall regimes: 1998 with upstream dryness over Texas and 2002 with near normal rainfall over the entire region. These study periods along with the extreme wetness during CLASIC and the extreme dryness during 2006 over the SGP provided a data set with large variations in rainfall and land surface cover. These large variations enable us to focus on land-atmosphere interactions over the Southern Great Plains within our moisture budget framework where linkages among atmospheric dynamics, water vapor, surface conditions, and precipitation are constrained by the moisture continuity equation.

Despite these contrasting study periods, our investigation revealed fundamental commonalities among their moisture budget components and related variables. The figure below shows these moisture budget terms composited by rainfall amounts (P). For daily P<4 mm/day (the P categories of most relevance to CLASIC), there is moist horizontal advection (HA<0) and horizontal divergence in the presence of moisture (HD>0). As P rises above this level, HD decreases dramatically and becomes convergent, indicating stronger synoptic forcing. This increase in the HD contribution to the total moisture convergence is accompanied by a decrease in HA contribution. This paradoxical decrease in moist horizontal advection with increasing P can be explained by the finding that there is a very small phase difference between HA and P. Also included in this figure is a recycling estimate (PE/P) that uses the equation developed in our recent Midwestern moisture budget study (Zangvil et al. 2004) where PE is the P derived from local evapotranspiration.

Our moisture recycling methodology involves the advected and locally evapotranspired origins of P being expressed in terms of an inflow/outflow (“bulk”) formulation that is defined at the boundaries of the study area and not in terms of the more traditional moisture flux divergence (“process”) formulation. The recycling ratios for P<4 mm/day are consistently higher for 2007 when there was copious rainfall and a saturated land surface.

This project is ongoing.
Other Agency – Investigation of Continental Stratiform Clouds using ARM Observations and LES Simulations
Y. Kogan (primary – CIMMS at OU), Mechem (University of Kansas)

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

Funding Agencies: Office of Naval Research, Department of Energy, and NOAA

Objectives
Improve our understanding of low altitude continental clouds and their representation in climate models.

Accomplishments
Low-altitude continental boundary layer stratus clouds constitute a significant climatological signal that is important to understand for correct representation of these clouds in climate models. Most of the previous studies focused on marine boundary layer clouds, with very few explicitly addressing low layer clouds over the continent. Our study has capitalized on the suite of observational instruments centered at the Atmospheric Radiation Measurement Program (ARM) Climate Research Facility (ACRF) Southern Great Plains site in northern Oklahoma that includes a millimeter-wave Doppler cloud radar (MMCR) in addition to the ground-based passive (shortwave, longwave, and microwave) radiometers, as well as active remote sensors (ceilometers and micropulse lidar).

In order to identify the influence of large scale forcing on the structure and evolution of continental stratocumulus clouds, we complement the observational study with LES simulations. We found that LES simulation is quite sensitive to changes in forcing, with even modest changes in the large-scale forcings, particularly the large-scale temperature and moisture advection, producing significant differences in LWP. This implies an important difference from marine stratocumulus, where the evolution of the boundary layer is driven mostly by cloud top inversion parameters. The result is of important significance for climate models that resolve horizontal advection much more accurately than cloud top entrainment.

This project is ongoing.
Publications

Mechem D. B. and Y. L. Kogan, 2008: Scalings for precipitation and coalescence scavenging obtained from simulations of trade cumulus. 15th *Int. Conf. on Clouds and Precipitation*, Cancún, Mexico.

*Simulated liquid water path overlaid on LWP obtained from the microwave radiometer. Dark line corresponds to the mean, while the two outer lines correspond to an interval of ±2s.*
Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

NOAA/NWS and NSSL – Social Science Woven Into Meteorology (SSWIM)

Grunfest (primary – CIMMS at OU), Lazrus (CIMMS at OU), Eosco (OU Department of Communication), Zappa (OU Department of Geography)

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

Funding Type: CIMMS Task III

Objectives

Weave social science concepts and methodologies into the fabric of weather and climate applications in the National Weather Center and beyond. This will entail raising the awareness of social science in the NWC and conducting original research with partners in the NWC and elsewhere on problems of mutual interest that ultimately relate to the societal impacts of hazardous weather. In pursuing this objective we will work to increase the appreciation of the value of qualitative as well as quantitative approaches, including archival, ethnographic, statistical, and participatory methods.

Accomplishments

Year 1 of the SSWIM program involved program initiation, partnership building, academic, governmental and public outreach, and proposal writing. Most importantly, two PhD students and a post-doc joined SSWIM. SSWIM expects to grow a relationship with the NWC Hazardous Weather Testbed (HWT) that will yield numerous future fruitful partnerships between researchers, product developers, forecasters, and a wide variety of stakeholders. During Year 2 SSWIM will foster on-campus collaborations and will continue to respond to calls for social science from NOAA and its partner agencies. Innovative research approaches are being planned with the HWT that will incorporate social science methodologies to examine the potential of probabilistic hazard information for aiding decision-making with the ultimate goal of reducing the vulnerability of the public to hazardous weather.

Specifically during Year 1, Dr. Heather Lazrus joined SSWIM in February 2009 to fill the post-doctoral position. Doctoral students Gina Eosco and Monica Zappa joined SSWIM in August 2008 and August 2009, respectively. More than two-dozen presentations were given and on 1 June 2009 SSWIM submitted its first annual report. SSWIM also established an Advisory Council and will engage it beginning in October 2009. During 15-17 September 2008 SSWIM helped host the Advanced WAS*IS Workshop at OU, titled “Beyond Storm-Based Warnings: Communication of Probabilistic Hazard Information.” This workshop gathered approximately 50 stakeholders and forecasters interested in the potential for probabilistic warnings of severe weather. SSWIM also helped host the “NWS Next Generation Warning Services Workshop” during 2-4 December 2008 at OU and the OU K-20 Center Workshop on “Consideration of the Future Weather Workforce” on 4 December 2008. Planning discussions have been held with NSSL on incorporating behavioral methodologies in research on flash floods within the Severe Hazards Analysis and Verification Experiment (SHAVE) project, and with NCAR and NWS on developing a Flash Flood Risk Analysis project that would involve mapping, observation, and monitoring protocols related to risky travel patterns and low water crossings. SSWIM can be found at http://cimms.ou.edu/sswim/.

This project is ongoing.

Publications


Lazrus, H., 2009: “Sea Change: Anthropology and Climate Change in Tuvalu, South Pacific.” In Anthropology and Climate Change: From Encounters to Actions, S. Crate and M. Nuttall, eds. Left Coast Press, Walnut Creek, CA.

Lazrus, H., 2009: “Perspectives on Vulnerability to Climate Change and Migration in Tuvalu.” In Anthropology and Climate Change: From Encounters to Actions, S. Crate and M. Nuttall, eds. Left Coast Press, Walnut Creek, CA.


Lazrus, H. 2009: The intersection between social science and meteorology. Keynote address to the *National Press Foundation Severe Weather Workshop III*, Norman, OK.


NOAA/CPO – Southern Climate Impacts Planning Program (SCIPP)
M. Shafer (primary – Oklahoma Climatological Survey – OCS), Keim (co-primary – LSU), Hocker (OCS), T. James (Political Science), Carter (LSU), Blackburn (OCS), Brehe (LSU), Brown (LSU), Campbell (OCS), Crawford (OCS), Demko (OCS), Eosco (OU Department of Communication), Erickson (OU School of Meteorology), Lamb (CIMMS), McManus (OCS), McPherson (OCS), Meo (OU Department of Geography), Needham (LSU), O’Hair (OU Department of Communication), Robbins (LSU), Roberts (LSU), Romolo (LSU), Sathiaraj (LSU), Shao (LSU), Shrivastava (OCS), Tovstiadi (OU Department of Communication), Trevino (LSU), Yuan (OU CSA), and Norton (OU Undergraduate Student)

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

Funding Type: CIMMS Task III

Objectives
Promote consideration of climate change in community hazard planning processes; engage decision-makers and stakeholders region-wide to determine climate-related information and education needs.

Accomplishments
The first year of SCIPP focused significantly on program start-up activities, including the hiring of several program staff members, development of a program website, the creation of a program advisory committee (and holding the first annual meeting), the initiation of seven applied climatological research projects, and initial product and database development for an all-climate hazards decision support and planning tool.

The SCIPP team also hosted a major climate applications workshop at the National Weather Center during March 2009 titled the “Climate Prediction Applications Science Workshop” (co-hosted by NOAA) with 85 national and international attendees. Additional efforts during the first half of 2009 focused on planning for other workshops and SCIPP engagement activities that will be occurring during the second half of 2009.

For more details on SCIPP activities in Year 1, please see our NOAA Climate Program Office (CPO) annual report available at http://www.southernclimate.org/publications.php.

This project is ongoing.

Publications
NOAA/CPO – Development and Application of Dynamic Normals for Investigation of Climate Variation and Change
Timmer (OU School of Meteorology), Lamb (primary – CIMMS at OU), Richman (OU School of Meteorology), Mjelde (Texas A&M)

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

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

Objectives
Use the results of this research to help maximize crop yields and hedge climate-related risk, bridging the gape between the climatologist and the farmer.

Accomplishments
A Farm-Scale Yield Index (FYI) is introduced in the present study; it is the first index of its kind that combines the unique impacts of a multitude of crop-specific climate variables (growing degree days, precipitation, Palmer Z Index, extreme mid-summer heat, and other crop-specific variables) based on feedback from local farmers and exhibits statistically significant correlations with crop production. Given
the high correlations exhibited between the FYI and local crop yield, analyses of long-term trends in the FYI also provide insight on the impacts of climate change on crop production.

Utilizing the derived relationships between region/local climate variables and crop yield, as well as their lagged teleconnections with Pacific Ocean SST patterns, this study develops with recommendations for farmers on how to adapt their farming strategies to maximize crop yield. For example, planting dates could be adjusted based on localized climate information such that probability of climate extremes negatively impacting crops during weather-sensitive growing season time windows is reduced. Other farming strategies during the growing season such as fertilizer application, irrigation, and seed populations at planting could be adjusted based on newly discovered climate-agriculture relationships presented here to maximize the farmer’s effectiveness in improving crop maturation, and also mitigate the stress placed on crops during periods of extreme climate.

This study is beneficial for the farming end-user and supplements previous literature involving applied climatology research for agriculture by combining the positive aspects of these previous studies into one body of work, as well as providing a number of unique, innovative analyses that quantify climate-crop production relationships. This research is supplemental for the field of North American agricultural climatology for a multitude of reasons. First, the climate analyses are not only focused on one spatial scale, but begin with the regional level and also quantify impacts on the farm-scale. Also, the time periods of the Pacific Ocean SST patterns are specifically selected to provide lead-time for the identified teleconnections with North American climate such that farmers can effectively adapt their strategies during the growing season, which has not been similarly considered in previous studies. Further increasing the uniqueness and utility of research for the Agriculture Sector, the selection/computation of the North American climate variables was based entirely on statistical relationships with crop maturation as well as input from the five AAPEX farmers that initiated the work. Finally, recommendations are presented on how the results here can be effectively utilized to maximize crop yields and hedge climate-related risk, thus bridging the gap between the climatologist and farmer.

This project is ongoing.
NSSL Special Project – The Value of Tornado Watches and Warning False Alarms
Sutter (primary – Univ. of Texas-Pan American), Simmons (Austin College)

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

Funding Type: CIMMS Task III

Objectives
Develop a method of modeling tornado-warning false alarms on tornado casualties; explore the impact of tornado watches on casualties.

Accomplishments
A variety of variables have been created to model false alarms, using warnings from different geographical areas and time periods. The different variables all affect fatalities and injuries similarly, with a one standard deviation in the false alarm ratio (FAR) increasing fatalities and injuries by between about 10 and 30 percent. The reduction in the false alarm rate observed between 1986 and 2004 is responsible for a 4-10 percent reduction in casualties, or about 10-25 percent of the reduction in casualties attributable to installation of Doppler weather radar by the NWS. Calculations indicate that there is no exploitable tradeoff between the probability of detection and false alarm ratio; if the NWS tried to reduce the FAR, the resulting decrease in the probability of detection (POD) would increase casualties and basically offset the reduction in casualties due to the lower FAR. Another way of putting this is that the NWS is currently optimizing the choice between FAR and POD to minimize tornado casualties. The false alarm effect is stronger when the recent, local FAR is based on more warnings, consistent with Bayesian updating of confidence in NWS warnings by residents.

This project is completed.

Publications

![Effect of a one-standard deviation increase in FAR on fatalities.](image-url)
**Doppler Weather Radar Research and Development**

NSSL Project 2 – National Radar Mosaic and Quantitative Precipitation Estimation – Real-Time Corrections of Radar-Derived QPE Errors due to the Bright Band Effect

J. Zhang (primary – NSSL), Qi (CIMMS at NSSL), Langston (CIMMS at NSSL)

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

**Funding Type:** CIMMS Task II

**Objectives**

Develop a method that automatically corrects for large errors due to bright band effects in a real-time national radar quantitative precipitation estimation (QPE) product.

**Accomplishments**

A real-time algorithm for the correction of bright band (BB) effects in radar precipitation estimation was developed. The correction was based on mean observed vertical profiles of reflectivity (VPR) from volumetric radar data. The VPR was computed for each single tilt, and only in the bright band area that was delineated according to radar reflectivity distributions and atmospheric environmental data. A linear model was fitted to the mean observed VPR and then the linear BB VPR was used to correct for BB effects in the observed reflectivity field.

The BB VPR correction scheme was tested for eight heavy precipitation events from different geographical regions and seasons in the United States. The linear BB VPR model was found to be representative and stable for various BB structures. High reflectivities associated with BB were correctly reduced in most of the cases and the corrected reflectivity field showed physically continuous distributions. The overestimation errors in radar-derived QPE were largely reduced after the VPR correction, and the VPR corrected radar-derived QPE agreed well with rain gauge observations. The VPR correction is most effective and robust for radars in flat terrains because of relative uniform spatial distributions of BB. For radars in mountainous region, the performance of the correction is mixed because of large spatial variations of VPRs caused by underlying topography. The current convective and stratiform segregation still needs further refinement. And delineations of tropical and orographically enhanced rain from the BB-impacted stratiform precipitation are very important.

This project is ongoing.

**Publications**


Scatter plots of one-hour radar precipitation estimates before (blue dots) and after (red triangles) the VPR correction versus gauge observations. The data are from (a) KCLE (Cleveland, OH) 05-10Z Nov. 15, 2008, (b) KUXD (Rapid City, ND) 00-09Z May 27, 2008, (c) KATX (Seattle, WA) 14Z Jan. 7 to 16Z Jan. 8, 2009. The significant overestimations in radar-derived QPE were successfully reduced by the VPR correction.
NSSL Project 2 – National Radar Mosaic and Quantitative Precipitation Estimation – Improving Precipitation Estimates in Complex Terrain

J. Zhang (primary – NSSL), Pickens (OU School of Meteorology), Langston (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Improve the accuracy of real-time estimates of precipitation in the complex terrain of the western United States with high spatial (1km) and temporal 1-hour) resolution.

Accomplishments
A gauge-based precipitation estimation technique similar to the so-called “Mountain Mapper” (MM), has been developed. The MM was developed at the US National Weather Service (NWS) River Forecast Centers (RFC), which combines rainfall climatology, terrain distributions, and real-time rain gauge observations and produces regional hourly rainfall maps. Sensitivities of parameters in the Mountain Mapper, including the radius of influence (roi), were tested.

Several cool season precipitation events were selected from mountainous regions in the states of Arizona, California and Washington, and corresponding radar and rain gauge data were collected. The rain gauge data were divided into two groups, one was used for creating rainfall maps using the MM technique and another for evaluations. Initial evaluations results for the MM were obtained and documented. Evaluations of radar rainfall estimates will be performed in the next year. The performance of gauge-based (MM) and radar-based QPEs will be analyzed and an optimal merging strategy will be developed.

This project is ongoing.
Hourly rainfall maps, valid at 0700 UTC on 18 December 2008, from the MM using different radius of influence. The 50 km roi is insufficient, as this small radius produces large gaps in the QPE field. The same is true for the 100 km roi, which still has gaps, though not as big. The 200 and 300 km roi’s have no gaps in them, and going from 200 to 300 km smoothed out some artifacts (e.g. the medium blue areas in the extreme southwest of Arizona). In areas with dense gauge distributions, the rainfall estimates from the 200 and 300 km roi are very similar.

NSSL Project 2 – National Radar Mosaic and Quantitative Precipitation Estimation – High-Resolution and Rapid Update National 3-D Radar Mosaic
J. Zhang (primary – NSSL), Langston (CIMMS at NSSL), Lakshmanan (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Develop for operational utilization a seamless high-resolution national 3-D grid of radar reflectivity for data assimilation, numerical weather prediction model verification, and aviation product development.
Accomplishments
The real-time 3-D mosaic combining the US and Canada radar network has been implemented, and a web-based display of the new 3-D mosaic products has been developed in the National Severe Storms Lab's National Mosaic and multi-sensor QPE (NMQ) system (http://nmq.ou.edu). Various hardware and software tests were carried out for increasing the update cycle frequency of the NMQ products from 5- to 2.5-minute. Based on the test results, new hardware has been purchased and computational infrastructure is configured. Other activities during this year include continued research and development for mitigating radar QPE errors due to non-precipitation echoes from migrating birds and insects. The NMQ research team has also established initial collaborations with radar meteorologists in Environment Canada to develop static clutter suppression maps for the Canadian radars. The clutter maps will be used to reduce ground clutter in the base level Canada radar reflectivity data.

This project is ongoing.

Publications


This figure shows example composite reflectivity and 24-hr precipitation accumulation images from the real-time system with and without the Canadian radar data. The integration of Canadian radar data significantly improved the radar coverage in the Great Lakes area.
NSSL Project 2 – National Radar Mosaic and Quantitative Precipitation Estimation – *Flash Flood Monitoring and Prediction (FFMP) GIS Dataset Support*

Arthur (CIMMS at NSSL)

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

**Funding Type:** CIMMS Task II

**Objectives**

Provide tools, training, and technical assistance to NWS forecasting staff on issues related to the FFMP basin and stream datasets, and manage the online FFMP Basin and Customization repositories.

**Accomplishments**

During the summer of 2008, all WFOs successfully completed the acquisition and processing of FFMP flash-flood-scale basin and stream shapefile datasets for use in the updated Flash Flood Monitoring and Prediction Advanced (FFMPA) system that was fielded in AWIPS OB8.3. This was the result of many months of close interaction among project staff, the WFOs, and NWS regional contacts, and was facilitated by training webinars and technical assistance provided by project staff. Since the time of completion, many WFOs have taken the initiative to begin local customization of their datasets. This includes stream name verification and updates, basin boundary checking and editing, and exclusion of lakes and other water body areas. Project staff has continued to provide customization assistance, as well as general GIS assistance, to these WFOs. This assistance has ranged from developing various sets of instructions to assistance with actual customization tasks.

In January 2009, the FFMP Basin Customization Repository was officially online. This repository, developed and managed by project staff, provides a national location for the storage and sharing of locally customized FFMP datasets, including version metadata. This allows neighboring WFOs to benefit from each other’s enhancements and avoid duplication of effort. Ongoing tasks for this project include developing training materials for a series of upcoming webinars in Fall 2009. The webinars will be hosted by project staff and will cover in detail various basin customization tasks for WFO staff. This project is ongoing.

*Locally customized FFMP basin and stream datasets can be shared with neighboring WFOs through the online FFMP Basin Customization Repository.*
NSSL Project 4 – Investigation into the Use of Warning Decision Support Systems for Improving Hazardous Weather Detection, Warnings, and Forecasts: Display of Multi-Sensor Datasets in Virtual Globes

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

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

Funding Type: CIMMS Task II

Objectives
Integrate multi-source and multi-sensor data into a display system; develop image processing and expert systems to analyze the multi-source, multi-sensor data; investigate methods and procedures for handling polarimetric and phased array data.

Accomplishments
Progress has been made in several aspects of displaying multisensor datasets in virtual globes. Algorithm products are converted into open map standards for display in off-the-shelf clients such as Google Earth. Changes of storm cell attributes with time have been successfully extracted in real-time and displayed in browser plugins. In addition, progress has been made in displaying isosurfaces of radar data in combination with GIS information. This was carried out by extending a virtual globe client called World Wind, from NASA.

Several new algorithms have been developed that operate on multisensor data. An algorithm that predicts cloud-to-ground lightning activity within 30 minutes on a 1-km grid has been developed and is now run routinely. A storm type classification algorithm has been developed and is now being refined. A clustering and motion estimation algorithm has been enhanced to permit extraction of storm attributes. The storm identification and tracking part of that algorithm has also been improved. These algorithms were refined on satellite infrared images and are now being used for satellite-based precipitation nowcasting.

Research versions were implemented for several polarimetric radar algorithms that are scheduled for operational implementation, so as to allow the testing of potential improvements. A virtual volume algorithm has been developed to properly sequence adaptive scans of phased array radar data, to permit analysis by automated algorithms. Storm cell identification and tracking algorithms have been developed for reflectivity and azimuthal shear fields from phased array radar data.

This project is ongoing.

Publications


Lakshmanan, V., 2009: The simpler the better. 6th Conf. on Artificial Applications to the Environmental Sciences, Phoenix, AZ, Amer. Meteor. Soc., P3.5.


Real-time algorithm that predicts the probability of lightning 30 minutes later.

NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Polarimetric Hydrometeor Classification and Rainfall Estimation for Better Detecting and Forecasting High-Impact Weather Phenomena, Including Flash Floods
Ryzhkov (primary – CIMMS at NSSL), Park (CIMMS Visiting Scientist), Krause, P. Zhang, Melnikov, and Schuur (all CIMMS at NSSL), Gu (CIMMS Visiting Scientist)

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

Funding Type: CIMMS Task II

Objectives
Refine polarimetric hydrometeor classification algorithm (HCA) for warm season and develop the basics of HCA for winter weather.

Accomplishments
The latest version of NEXRAD polarimetric HCA was tested in the case of typical mesoscale convective system. The algorithm slated for operational implementation on polarimetric WSR-88D distinguishes between 10 classes of radar echo using 6 radar variables. It takes into account the differences in the classification power and measurement quality of various radar variables and effects of beam broadening at longer distances from the radar. A detailed description of the algorithm is published in the June 2009 issue of *Weather and Forecasting*.

An experimental version of polarimetric HCA suited for winter transitional weather has been developed and tested for the storm on 30 November 2006 in central Oklahoma. The algorithm discriminates between different types of precipitation at the surface including rain, freezing rain, sleet / ice pellets, dry snow, and wet snow. Class designation is based on the analysis of vertical profiles of radar variables and thermodynamic parameters (temperature and humidity) retrieved either from RUC or WRF numerical weather prediction models.
The capability of dual-polarization radar to detect fire plums has been confirmed and documented in several cases. It was shown that utilization of the one-lag estimators for differential reflectivity and cross-correlation coefficient is crucial for distinguishing fires from meteorological echoes with low reflectivity.

This project is ongoing.

**Publications**


Classification of precipitation types on the surface for the storm on 11/30/2006 in central Oklahoma. The results of classification are updated every hour. Discrimination is made between rain (red color), freezing rain (green), freezing rain / iced pellets mixture (orange), ice pellets (yellow), wet snow (dark shade of blue), and dry snow (light shade of blue). Shown in the images are locations of four ASOS stations that were used to validate results of classification.

Ryzhkov (primary – CIMMS at NSSL), and Kumjian, Ganson, Picca (all OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Develop cloud microphysics / scattering models capable to reproduce observed polarimetric signatures in clouds and precipitation. Investigate polarimetric signatures in tornadic and nontornadic supercell storms for better understanding microphysical aspects of tornadogenesis and hail formation.

Accomplishments
One-dimensional models with explicit microphysics for melting snow and graupel/hail have been developed for interpreting radar polarimetric signatures within the melting layer. Two-dimensional cloud model with spectral bin microphysics owned by The Hebrew University of Jerusalem was modified to produce the fields all polarimetric radar variables within the storm.

Data collection of polarimetric data in supercell storms continued. The origins of such polarimetric attributes of supercells as “ZDR arc” and midlevel rings of differential reflectivity and cross-correlation coefficient were studied using explicit microphysical modeling.

Preliminary analysis of polarimetric variables in the rear flank downdraft area of supercell storms indicates that ZDR tends to be lower and ρHV to be higher in the storms which eventually produce a tornado as opposed to nontornadic storms. This finding is consistent with the fact that evaporative cooling is weaker in tornadic supercells compared to their nontornadic counterparts.

This project is ongoing.

Publications


NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Polarimetric Rainfall Measurements and Attenuation Correction at Shorter Radar Wavelengths

Ryzhkov (primary – CIMMS at NSSL), Gu (CIMMS Visiting Scientist), Melnikov (CIMMS at NSSL), Borowska (CIMMS Visiting Scientist)

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

Funding Type: CIMMS Task II

Objectives
Develop and test polarimetric schemes for attenuation correction and rainfall measurements at C and X bands.

Accomplishments
The ability of C-band polarimetric radar to account for severe attenuation/differential attenuation and to produce robust rainfall estimation is demonstrated in the case of extreme rain event which occurred in the Chicago metropolitan area on 5 August 2008. A new polarimetric attenuation correction scheme separates relative contributions of “hotspots” (i.e., strong convective cells) and the rest of the storm to the path-integrated total and differential attenuation. It is shown that reliable attenuation correction is possible if radar signal is attenuated as much as 40 dB. This analysis is presented in the journal article submitted to the Journal of Applied Meteorology.

Validation of the attenuation correction algorithms at C and X bands was performed via direct comparisons of S-band polarimetric observations (which are weakly affected by attenuation) with the ones from C-band OU PRIME radar and the X-band XEREX polarimetric radar in central Oklahoma. Availability of simultaneous multi-frequency polarimetric measurements using closely located radars and the presence of dense rain gauge networks in Oklahoma provides a unique chance to verify different methods for attenuation correction and rainfall measurements.

This project is ongoing.
Publications


Fields of measured and corrected C-band radar reflectivity, differential phase measured at C band, and reflectivity factor measured by S-band WSR-88D radar for the Chicago storm on 08/05/2008. Corrected Z at C band is in good agreement with S-band Z, whereas uncorrected C-band Z is heavily underestimated due to attenuation.

NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Drop Size Distribution Retrieval using Disdrometers
Schuur (primary – CIMMS at NSSL), G. Zhang (OU ARRC), Cao (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Characterize rain microphysics in the southern Great Plains using measurements from multiple disdrometers; use this information to develop improved techniques of retrieving drop size distributions and estimating rainfall from polarimetric radar data.
Accomplishments
With support from a grant from the National Science Foundation, data from three 2-dimensional video disdrometers (2DVDs) and the KOUN WSR-88D polarimetric radar were used to characterize rain microphysics in Oklahoma. Sampling errors from the 2DVD measurements were then quantified through side-by-side comparisons, refine a shape–slope ($\mu$–$\Lambda$) relation of a constrained gamma (C-G) model, and develop an adjustable term (based on observed radar reflectivity ($Z$) and differential reflectivity ($Z_{DR}$)) to make the C-G Drop Size Distribution (DSD) model more applicable.

A Bayesian approach to retrieve DSDs and estimate rainfall rates from polarimetric radar data was also developed and tested. Long-term 2DVD measurements were used to construct a prior probability density function of DSD parameters estimated using truncated gamma fittings of the 2nd, 4th, and 6th moments. A forward model for $Z_H$ and $Z_{DR}$ was then developed based on T-matrix calculations of raindrop back-scattering amplitudes. The algorithm was tested on KOUN WSR-88D polarimetric radar data for a rain event on 13 May 2005. Retrieved rainfall rates and one-hour rain accumulations were compared with the in-situ measurements from one 2DVD and six Oklahoma Mesonet rain gauges, located at distances of 28-54 km from KOUN. Results of comparisons with measurements from a 2DVD and six Oklahoma Mesonet rain gauges demonstrated that algorithm rain estimation agreed well with in-situ measurements at the different sites. This project is ongoing.

Publications

Retrieval results from radar observations at 0830 UTC on 13 May 2005. Four panels represent (a) rainfall rate from Bayesian retrieval, (b) rainfall rate from $Z_H$ retrieval, (c) $SD(L')$ from Bayesian retrieval, and (d) $SD(N'\phi)$ from Bayesian retrieval. From Cao et al. (2009).
NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Combined Profiler, Polarimetric WSR-88D, and Disdrometer Measurements to Retrieve Vertical Velocities and Microphysical Signatures in Precipitation Systems

Schuur (primary – CIMMS at NSSL), Chilson (OU School of Meteorology), Teshiba (OU School of Meteorology), Morris (OU School of Meteorology), G. Zhang (OU ARRC), Luchs (OU School of Meteorology), Ryzhkov (CIMMS at NSSL), Krause (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Develop techniques to use combined profiler and polarimetric radar measurements to gain insight into the vertical motions and vertical evolution of drop size distributions in warm season precipitation systems.

Accomplishments
KOUN WSR-88D polarimetric weather radar and UHF wind profiler observations of precipitation have been used to extract the properties of liquid phase hydrometeors and the vertical velocity of the air through which they are falling. Doppler spectra, which contain the air motion and/or fallspeed of hydrometeors, were estimated using the vertically pointing wind profiler. Complementary to these observations, spectra of raindrop size distribution (DSD) were estimated using the polarimetric parameters of radar reflectivity (Z_H) and differential reflectivity (Z_DR). These DSDs were then mapped into equivalent Doppler spectra (fallspeeds) using an assumed relationship between the equivolume drop diameter and the drop's terminal velocity. The work was conducted using observations collected by combined NSSL and OU facilities at the Kessler Farm Field Laboratory (KFFL).

Overall, the study found that vertical air motions (updrafts / downdraughts) can be estimated using such combined measurements. In stratiform precipitation where the vertical wind motion is typically small, fallspeeds obtained from the spectra of the rain DSD agreed well with those of the Doppler velocity estimated with the profiler. On the other hand, owing to vertical air motions and atmospheric turbulence, Doppler spectra of the rain DSD and the Doppler velocity in convective precipitation often exhibited significant differences. Height dependencies of Doppler spectra measured by the profiler combined with vertical profiles of Z, Z_DR, and the cross-correlation (\(\rho_{HV}\)) were also found to provide unique insight into the microphysics of precipitation. Combined, these observations provide valuable information that might be used to improve polarimetric rainfall estimation techniques, particularly at distant ranges from the radar where rainfall must be estimated from observations that are collected well above the surface.

Mixed precipitation during winter transitional weather events was also studied with KOUN WSR-88D polarimetric radar and 2DVD disdrometer at KFFL with special emphasis on the impact of variability in snow size distributions and snow density on polarimetric radar variables.

This project is ongoing.

Publications


Time-height plot of vertical profiles of KOUN radar reflectivity (Z), differential reflectivity (Z_{DR}) and correlation coefficient (r_{HV}) over the Kessler Farm Field Laboratory (28.5 km range from KOUN) on 11 March 2007. Arrow represents location of thunderstorm updraft while solid red dashed line indicates time on plot of the UHF wind profiler spectra (see insert) at 1124 UTC. Dashed black line on KOUN data indicates height of the OC isotherm on 11 March 2007. Vertical panels on inset, from left to right, represent vertical profiles of KOUN Z, Z_{DR}, r_{HV}, and profiler spectra, respectively.

**NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Investigation of Improved Quantitative Precipitation Estimation (QPE) using Dual-Polarimetric Weather Radar in the Presence of Partial Beam Blockage**

P. Zhang (co-primary – CIMMS at NSSL), Ryzhkov (co-primary – CIMMS at NSSL), P.F. Lin (Taiwan Central Weather Bureau)

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

**Funding Type:** CIMMS Task II

**Objectives**

Improve QPE accuracy using dual-polarimetric radar measurements in the presence of partial beam blockage.

**Accomplishments**

The performance of different radar algorithms for estimation of tropical rain in the presence of significant beam blockage caused by mountains has been examined using S-band polarimetric radar measurements
in Taiwan in June 2008. Four different QPE algorithms, including two standard R(Z) relations and two R(Z, ZDR, KDP) relations, are utilized to estimate accumulated rainfall amounts in the different periods for these events and validated with the dense network of 175 rain gages located in the mountainous area.

Data quality control that includes differential reflectivity ZDR calibration and mitigation of ground clutter on radar data was executed before rainfall estimation. The results are divided into 6 categories in the degrees of beam blockage to examine the performance of the QPE algorithms. It was shown that polarimetric algorithms (R3 and R4 in the following figure) including the "synthetic" one which is optimal for Oklahoma outperform the standard R(Z) relations in tropical rain if beam blockage is less than 60 percent. This demonstrates that polarimetric radar relations can automatically account for the differences between tropical and continental rain. Simple correction of radar reflectivity based on geometrical considerations and utilization of the data collected at multiple elevation angles help to reduce the error in estimation of rainfall amount in the situations with substantial beam blockage. In addition to blocking microwave radiation, the mountains act as a significant source of ground clutter which can be easily detected (and potentially mitigated) using polarimetric measurements. This project is ongoing.

Average rainfall amounts in the categories with different degrees of beam blockage estimated by using 4 radar QPE algorithms (R1, R2, R3, R4) at the elevation angles of a) 0.5° and b) 1.8° and rain gage measurements (RG) in the period from 10:00 to 13:00 UTC on 14 June 2008. The algorithms of R1 and R2 are standard and R3 and R4 are polarimetric.
NSSL Project 5 – Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts: Sensitivity Enhancement in the Dual-Polarization WSR-88D

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

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

Funding Type: CIMMS Task II

Objectives
Develop and demonstrate a method to mitigate the 3 dB loss in sensitivity per channel inherent to the simultaneous transmission and reception of H,V waves.

Accomplishments
A hybrid approach has been developed to mitigate the loss of sensitivity. It is based on the sum of the cross-correlation estimates as well as the powers and autocorrelations from each of the dual-polarization returns. The estimate of the uniform sum is compared to a threshold to determine the presence of a signal. We have shown that this procedure improves detection of weather features on the dual-polarized radars. To make this technique operational an economical method has been devised that efficiently produces the threshold value resulting in a desired low false alarm rate. Even with this efficiency, the computation of the thresholds are very time consuming hence regression coefficients from which these thresholds can be quickly obtained have been pre-computed for all operational parameters of the WSR-88D radar. The thresholds are computed from simple functions, exponential and linear along with noise powers in channels for vertical and horizontal polarizations. This is suited for a real-time implementation.

The procedure, with the set of the coefficients, has been delivered to the NWS for implementation on the dual polarization WSR-88D radars. To assess the performance of the novel censoring technique, the noise is artificially doubled to simulate the SNR drop caused by the dual-polarization upgrade. The proposed scheme is used on such data and each detection is classified with respect to the legacy censoring applied to the original data (i.e., where noise is not doubled).

This project has been completed.

Publications

Classification of detections obtained after doubling the noise power, and using the proposed algorithm for detection. 
Additional detections are data classified as signals by the proposed scheme but not by the legacy censoring. Missed detections are data discarded as noise by the proposed scheme but detected as signals by the legacy censoring. 
Data classified as signals by both schemes are shown in green.

**NSSL Project 6 – Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather: Assimilation of Phased Array Radar Data for the Analysis of the 29 May 2004 Oklahoma City Supercell**

Wicker (primary - NSSL), T. Thompson (OU School of Meteorology), Biggerstaff (OU School of Meteorology)

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

**Funding Type:** CIMMS Task II

**Objectives**
Determine whether the increased time sampling from PAR data improves convective-scale radar data assimilation for Warn on Forecast applications.

**Accomplishments**
The first phased array radar (PAR) adapted to observe weather via its unique scanning capabilities became operational in spring 2004, as part of the National Weather Radar Testbed (NWRT) located in Norman, Oklahoma. On 29 May 2004 the PAR observed a tornadic supercell as it traversed central Oklahoma.
Oklahoma, producing 10 tornadoes and significantly impacting Geary, OK and the greater Oklahoma City metropolitan area. This data set represents the first tornadic supercell observed using volumetric rapid-scan 10 cm radar. The PAR radial velocity and reflectivity data are available every 20-30 seconds during an approximately three hour period when the storm was less than 150 km from the radar. Using Ensemble Kalman Filtering (EnKF) data assimilation methodology (Dowell and Wicker 2009), the PAR observations are assimilated to generate storm-scale analyses representing the three-dimensional thermodynamic and kinematic structure of the tornadic supercell during a fifty-minute period. The impacts of rapid-scan data assimilation on the analyses are examined.

Comparing analyses produced from assimilating PAR data approximately every minute, with analyses produced from assimilating PAR data approximately every five minutes (i.e., more conventional weather radar observational frequencies), show that rapid-scan data improves the analysis of the storm. Results indicate that analyses produced from rapid-scan PAR data yield quicker spin-up times and better fit the radar observations. Results also show the difficulties of maintaining ensemble spread and the impacts on analyses. The sensitivities to the length of initialization period and microphysics parameters are discussed.

This study also investigates a method that uses volumetric PAR data at five-minute intervals more than once, which produces analyses comparable to those from the rapid-scan PAR data. These results suggest that the current approach used in EnKF algorithms to assimilate radar data may not be fully exploiting the available information. Finally, analyses produced using high and low time frequency PAR data are used to initialize forecasts. Results indicate that the forecast problem is not yet understood and model error leads to poor forecasts.

This project has been completed.

Publications
Thompson, T., L. Wicker, K. Kuhlman, M. Biggerstaff, 2008: Comparison of three-dimensional winds derived from assimilated phased array radar data with mobile dual-Doppler analyses from a tornadic storm. 23rd Conf. on Severe Local Storms, Savannah GA, Amer. Meteor. Soc.

Thompson, T., L. Wicker, M. Biggerstaff, D. Forsyth 2008: EnKF analysis of the 29 May 2004 Oklahoma City supercell using rapid-scan phased array radar data. 5th European Conf. on Severe Storms. Munich Germany.
NSSL Project 7 – Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings: Mitigation of Range and Velocity Ambiguities

Torres (primary – CIMMS at NSSL), Warde (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Resolve WSR-88D range and Doppler velocity ambiguities to the levels required for the efficient observation of severe weather, culminating in significantly improved WSR-88D data quality when implemented on the Open Radar Data Acquisition (ORDA) system; better data quality will result in an improved ability for the radar 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. Efforts in this area are expected to culminate 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.

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 (SZ-2) and staggered pulse repetition time (SPRT). The two techniques are complementary since they offer advantages at specific elevation angles; hence, they can be simultaneously incorporated into the same volume coverage pattern (VCP).

The first stage of upgrades is complete and has been operational with great success for a couple of years. The second stage of NEXRAD upgrades dealing with range and velocity ambiguities involves the operational implementation of SPRT. During this year, we focused on designing operational Volume Coverage Patterns (VCP) using SPRT. Also, we completed the analysis of a spectral clutter mitigation algorithm that can meet NEXRAD operational system specifications. Additionally, we introduced a range-overlaid recovery algorithm that allows increased range coverage of the Doppler moments in SPRT. Both, the clutter filter and the range-overlaid algorithms were merged into the algorithm as a complete SPRT solution capable of meeting NEXRAD operational needs.

This project is ongoing.

Publications
Torres, S., 2008: Range and velocity ambiguity mitigation on the US NEXRAD network: Performance and improvements of the SZ-2 phase coding algorithm. Fourth European Conf. on Radar Meteorology and Hydrology (ERAD), Helsinki, Finland.

Reconstructed velocity displays from KOUN data collected on June 26, 2008 show how velocity obscurations in the image on the left are recovered in the image on the right using the Range-Overlaid SPRT technique.
NSSL Project 7 – Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings: *Ground Clutter Detection and Filtering*

Torres (primary – CIMMS at NSSL), Warde (CIMMS at NSSL)

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

**Funding Type:** CIMMS Task II

**Objectives**
The goal of this project is to develop efficient techniques that provide both automated detection and application of ground clutter filtering.

**Accomplishments**
A common dilemma in obtaining quality meteorological-variable estimates using Doppler weather radar is the application (or misapplication) of ground clutter filters (GCF) to mitigate contamination from ground returns. Typically, weather radars use static clutter maps (i.e., pre-identified clutter contaminated regions) to control the application of the GCF. Ideally, the GCF should only be applied if the ground clutter contamination obscures the weather estimate. However, the problem of applying the GCF becomes very complex considering the dynamic atmospheric effects on radar beam propagation.

During the past year, we suggested a spectral technique for automatic detection and mitigation of ground clutter contamination: the Clutter Environment Analysis using Adaptive Processing (CLEAN-AP) filter. We have shown the clutter detection and mitigation performance of the CLEAN-AP filter using time-series data from the national network of weather surveillance radars (WSR-88D). Compared to current technologies used for ground clutter suppression, the CLEAN-AP filter provides a real-time, integrated clutter mitigation solution with: (a) improved ground clutter suppression, (b) effective ground clutter detection, and (c) dynamic ground clutter suppression characteristics optimally matched to the existing atmospheric environment. All of this is achieved with modest computational complexity and increased quality of meteorological estimates.

This project is ongoing.

**Publications**
Example of clutter suppression exhibited by the CLEAN-AP filter. Note that the filter provides over 60 dB of clutter suppression without biasing the weather signal power estimate. To place this into context, the filter easily provides the clutter suppression requirements of 50 dB required for operations in the U.S. network of weather surveillance radars (i.e., the NEXRAD network of WSR-88D radars).

**NSSL Project 7– Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings: Improvement of Spectral Moment and Polarimetric Variable Estimates using Range Oversampling Techniques**

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

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

**Funding Type:** CIMMS Task II

**Objectives**
Exploit range oversampling followed by a decorrelation transformation for faster data temporal acquisition and denser spatial sampling as needed to satisfy some of the evolutionary requirements for the WSR-88D.

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

During the past year, we continued our focus on practical issues involving the implementation of oversampling and pseudo-whitening techniques within the WSR-88D operational environment. The National Weather Radar Testbed (NWRT) is a natural platform for range oversampling research because, by default, the system oversamples in range. A simple pseudowhitenning strategy was implemented and tested on the NWRT using a fixed transformation matrix. This work represents a step towards establishing range-oversampling techniques as operationally viable on weather surveillance radars.

This project is ongoing.

Publications


(a) Non-range oversampled  (b) Range oversampled

Reflectivity field of storms in central Oklahoma collected with the NWRT phased-array radar and processed using standard sampling (left) and range-oversampling (right). As expected, “smoother” fields obtained with range oversampling techniques are an indication of reflectivity estimates with lower statistical errors than those obtained with standard processing.

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

Torres (primary – all listed are CIMMS at NSSL), Curtis, Ivic, Warde, Forren, J. Thompson, Priegnitz, Adams, Suppes, Burcham

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

Funding Type: CIMMS Task II

Objectives

Improve the quality of meteorological data produced by the NWRT PAR, to demonstrate adaptive scanning capabilities for weather observations, and to demonstrate dynamic scheduling of multi-function scanning strategies.
Accomplishments

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

The real-time digital signal processing software was completely redesigned and rewritten to run on a cluster of personal computers. An innovative parallel processing design allows for significant processing power beyond the equivalent digital signal processors on NEXRAD radars. More processing power can easily be added by adding cheap, mainstream personal computers.

We continued to develop and maintain the MATLAB DSP environment that allows for fast implementation, testing, and validation of new algorithms. These include schemes to effectively remove artifacts from meteorological signals, methods to mitigate range and velocity ambiguities, and techniques that allow for faster data collection. Among the current signal processing functionality, some are standard signal processing techniques and some are novel techniques that go beyond those found in the NEXRAD system. Techniques such as coherency-based data censoring, clutter-residue censoring, automatic bias correction, and interference removal were designed and implemented to improve data quality. The implemented CLEAN-AP clutter filter does not require clutter maps and is a significant improvement over current NEXRAD clutter filtering algorithms. Because of our available processing power, we were also able to implement and test a prototype version of range oversampling techniques.

An initial version of an adaptive scanning algorithm (ADAPTS) that dynamically modify the scanning area of the PAR based on the existence or non-existence of weather was implemented to reduce scan times to get faster updates. Our open systems/distributed computing infrastructure was leveraged to allow adaptive algorithms to communicate with the real-time controller. The work required in the real-time controller and in the algorithms was significant. Toward the end of the year, we started the process of designing more advanced adaptive scanning algorithms to relax some of the limitations of the current implementation.

We started the design and implementation of a multi-function scheduler that will allow multiple scans to be scheduled and executed on the PAR “simultaneously.” This will be a key step in demonstrating successful multi-function use of the PAR for weather, aircraft, and other needs. Implemented infrastructure such as collection tags and pre-processor filtering by tag will allow dynamic selection of processing paths depending on the application.

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

This project is ongoing.

Publications
Example of software upgrades implemented during this past year on the NWRT. (a) Data quality improvements gained through successive upgrades of the signal processing functionality. (b) Infrastructure improvements that allowed successful demonstration of adaptive scanning for weather observations.

**NSSL Project 8 – Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings:** Phased Array Radar Innovation Sensing Experiment (PARISE)

Heinselman (primary – NSSL); Hluchan (OU School of Meteorology), T. Smith (CIMMS at NSSL)

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

**Funding Type:** CIMMS Task II

**Objectives**

Explore, develop, and evaluate phased array radar capabilities that may improve scientific understanding of severe storms and severe weather warnings. A related objective is the development and evaluation of high-temporal resolution scanning strategies.
Accomplishments
Since spring 2007, the NSSL has invited NWS forecasters to participate in experiments designed to demonstrate and provide user feedback on phased array radar (PAR) weather surveillance capabilities. These initial experiments focused on the operational use of high-temporal resolution data on the analysis and warning of severe storms. During the 2009 Phased Array Radar Innovative Sensing Experiment (PARISE), this focus was enhanced by the implementation of adaptive scanning of weather echoes.

The PARISE ran from 27 April – 14 June 2009, with the exception of the week beginning with Memorial Day. During that period, 16 National Weather Service (NWS) forecasters evaluated the operational utility of PAR technology during real-time operational warning situations and playback of archived cases. The two key objectives of PARISE were to demonstrate and obtain feedback on: 1) basic adaptive electronic scanning of weather echoes and 2) storm-type scanning strategies for surveillance of storm initiation and severe storms. Forecaster evaluations of PAR weather data were obtained through an eight-item questionnaire; analysis of forecaster responses is underway. Preliminary analysis of participant responses indicate that for cases examined, high-temporal resolution PAR data provides improved depiction of the temporal evolution of severe storms, which results in higher confidence in interpretation of potential storm severity, and a few minutes earlier lead time in simulated warnings. These preliminary findings agree with results from the 2008 PAR spring experiment.

In 2009, more than 15 events were sampled by the PAR, including a heat burst, three supercell events, including one supercell that produced a tornado within ~ 15 mi of the PAR, multiple squall lines and hail storms, and 2 winter ice storms. Detailed analyses of three of these events, the heat burst and two tornadic supercells, are in progress to assess the impact of employed scanning strategies on depicted storm evolution, improve understanding of storm dynamics, and explore a potential new precursor of tornadic storms.

This project is ongoing.

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

Priegnitz (CIMMS at NSSL)

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

Funding Type: CIMMS Task II

Objectives
Continue to enhance the phased array radar remote interface to support new capabilities.

Accomplishments
Improvements were made to the Radar Control Interface (RCI) that supported data collection operations in the spring and summer of 2009, including the Phased Array Radar Innovative Sensing Experiment (PARISE) conducted in the Hazardous Weather Testbed (HWT). An auto RTC reboot feature was added to the controlling RCI client to help minimize down time during data collection. Without this feature, the RCI operator would have to closely monitor the Real Time Controller (RTC) status to determine if a reboot was required. During data collection, an operator’s focus is usually on the moment data display so when an RTC problem occurs, several valuable minutes may have passed before corrective action is taken resulting in a loss of data during that time. In past projects in the HWT a number of outside forecasters expressed a desire to be able to adjust the pulse repetition time (PRT) in order to minimize the obscuration of radial velocities in specific regions. A new “PRT Adjust” selection was added so forecasters can adjust the unambiguous range outward in 10-kilometer intervals. This featured proved very useful during the PARISE project. To support the new post processing adaptive scanning algorithm,
Improvements were made to the RCI to control when it is run and how often it performs a full scan. In addition, a new tab window was added to display a map of active beams in the current scan. This project is ongoing.

Sample RCI client system control/status window display.

Sample RCI client ADAPT algorithm beam window display.
NSSL Project 8 – Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings: Real Time Controller Improvements

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

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

Funding Type: CIMMS Task II

Objectives
Continue to enhance the phased array real time controller component to support new capabilities and reduce failures.

Accomplishments
The Real Time Controller (RTC) of the NWRT is the physical component that interacts directly with the radar hardware (i.e., antenna array, pedestal, transmitter, and GPS). It is a time critical component that accepts commands from and sends status to the Radar Control Interface (RCI). During the fiscal year, significant improvements have been made to the RTC software. Since the initial installation of the NWRT, periodic RTC failures resulted in the loss of critical data during severe weather operations. Significant modifications have been made to the main stimulus processing function that has greatly reduced digital receiver failures and RTC lockups, resulting in higher quality data sets for future analysis.

To support the new adaptive scanning post processing algorithm (ADAPTS), a number of changes were made to the RTC software. To provide direct feedback from the algorithm to the RTC, linear buffer support (which was developed by NSSL/CIMMS engineers during the ORPG project) was added to the RTC. This feedback specifies which beams are determined to contain significant and non-significant information. During scan processing, when the ADAPTS algorithm is active, the RTC only transmits pulses for significant beam positions; reducing overall scan time in most cases.

This project is ongoing.
ROC Project 13 – Analysis of Weather Radar Observations of Severe Convection to Understand Severe Storm Processes and Improve Warning Decision Support: Research Opportunities for Undergraduate Students

Langlieb, Madaus, Richardson (all OU School of Meteorology undergraduate students), Saul (primary – ROC)

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

Funding Type: CIMMS Task II

Objectives
Provide research opportunities for students at the University of Oklahoma by allowing them to work with federal scientists at the NWS Radar Operations Center; improve the quality of radar observations and improve and validate the detection and forecast ability of WSR-88D severe weather algorithms.

Accomplishments
The students assisted in the comparison and evaluation of radar data from the Radar Operations Center (ROC) testbed radar (KCRI) and the NSSL research radar (KOUN) both before and after the retrofit of KOUN to a standard WSR-88D system. The comparison is essential to the success of the dual-polarization upgrade of the entire WSR-88D network as KOUN is the first baseline radar that will undergo the upgrade. Data sets were collected and compared and the two radars were deemed similar for operational purposes. The next phase of our work is to evaluate and compare data from the two radars after the upgrade of KOUN.

These activities are ongoing.

A comparison of the base reflectivity from KOUN and KCRI after KOUN retrofit to baseline WSR-88D.
ROC Project 13 – Analysis of Weather Radar Observations of Severe Convective Storms to Understand Severe Storm Processes and Improve Warning Decision Support: Radar Observations of Severe Convective Weather

Burgess (primary – CIMMS at NSSL), Manross (CIMMS at NSSL), Scharfenberg (NWS), Roberts (OU School of Meteorology), Meyer (OU School of Meteorology)

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

Funding Type: CIMMS Task II

Objectives
Obtain better understanding of radar observations of severe convective weather; improve radar input into severe thunderstorm and tornado warnings.

Accomplishments
Progress has been made on this project in two areas. First, data were analyzed on problem radar cases identified by the ROC Data Quality Group. Causes of unusual/atypical radar data were investigated and discussions/presentations took place at this group’s weekly meetings. Diagnosed reasons for atypical data included anomalous beam propagation, multi-path, multi-trip radar returns, 3-body scatter signatures, and very strong reflectivity and velocity gradients in and around severe and tornadic thunderstorm echoes. Second, the operational utility of dual-polarization data from the KOUN experimental WSR-88D was investigated for data quality improvement and severe/tornadic storm detection purposes.

Dual-polarization data are useful in discriminating between precipitation and non-precipitation radar returns. The data were examined in conjunction with determining locations and sizes of hail fall and storm structure related to hail formation and location. Dual-polarization hail locations appeared accurate. There are currently limitations in the use of dual-polarization data to uniquely determine hail size. Further research on hail size estimation is in progress.

This project is ongoing.

Publications

Conceptual model of 1 km AGL (top) and mid-level (bottom) polarimetric radar features for a tornadic classic supercell storm based on observations of the 8 May 2003 OKC tornadic storm. Adapted from composite of Doswell and Burgess (1993) Fig. 3a and Lemon and Doswell (1979) Fig. 7. Tornado (T) and mid-level mesocyclone (M) are marked.

ROC and NSSL Special Project - Prototyping WSR-88D Science and Signal Processing Techniques
Melnikov (CIMMS at NSSL)

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

Funding Type: NOAA NWS

Objectives
Continue development of spectral processing techniques for WSR-88D radars; estimate turbulence from measured radar spectral widths.
Accomplishments
Weather radar observations of stratiform precipitation often reveal regions having very large measured Doppler spectrum widths, exceeding 7 and sometimes 10 m$^{-1}$. These widths are larger than those typically found in thunderstorms; widths larger than 4 m$^{-1}$ are associated with moderate or severe turbulence in thunderstorms. We have found that stratiform precipitation has layers of widths larger than 4 m$^{-1}$ in more than 80 percent of cases studied, wherein shear of wind on scales large compared to the dimensions of radar resolution volume is the dominant contributor to spectrum width. Analyzed data show that if width exceeds 7 m$^{-1}$, and if the layers are not wavy or patchy, these layers have weak turbulence. On the other hand, regions having widths 4 m$^{-1}$ in patches or in wave-like structures are likely to have moderate to severe turbulence with the potential to be a hazard to safe flight.

To separate contributions to spectrum width from wind shear and turbulence, and to evaluate the errors in turbulence estimates, data have been collected with elevation increments much less than a beam width. Despite beam width limitations, the small elevation increments reveal impressive structures in the fields. For example, the “cat's eye” structure associated with Kelvin-Helmholtz waves is clearly exhibited in the fields of spectrum width observed at low elevation angles, but not in the reflectivity or velocity fields. Reflectivity fields in stratiform precipitation are featureless compared to spectrum width fields.

This project is ongoing.

Publications

NOAA/HPCC and NSSL Project 3 (Severe Weather Warning Research and Application Development) – Verification of the Hydrometeor Classification Algorithm (HCA) in Winter Precipitation Near the Ground
Elmore (CIMMS at NSSL)

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

Funding Type: NOAA HPCC and CIMMS Task II

Objectives
Determine how well the NSSL HCA performs in winter precipitation using KOUN radar data; verify precipitation type using observations provided by the public during winter events and submitted through a web-based interface.

Accomplishments
To date, three main winter events have occurred. Within these three events, the public provided about 2600 observations. Of these, quality control efforts identified about 100 observations that are obviously problematic and they were excised. Of the remaining 2500 observations, those within 300-1200 m above the ground were extracted. These height limitations are used to insure that the radar is highly likely to observe the same hydrometeor types than will be observed on the ground.

The HCA and observed precipitation types are reduced to three classes: frozen (snow, sleet, graupel), liquid (rain, drizzle, freezing rain and freezing drizzle) and none. When examined in this way, the NSSL HCA displays a Peirce Skill Score of 0.115. Further examination reveals that this is due to a misapplication of the NSSL HCA. The NSSL HCA was developed for warm season convection, with very different particle concentration and size distribution. To test if there is information about hydrometeor type in the radar data alone, these data are divided into training and testing sets. A linear discriminant analysis is then performed on the training data and its performance is evaluated with the testing data. In that case, the skill score was doubled, to about 0.236. If environmental data are added, and the new data are then subjected to purely statistical classification methods, a skill score of nearly 0.37 results. Thus,
there is considerable information about hydrometeor type contained within a combination of polarimetric radar and environmental data.

This project is ongoing.

The Peirce Skill Sores, and 95% confidence intervals for those scores, based on various techniques tested in the 2009 AMS Artificial Intelligence Competition, in which these data are used. The last two values, labeled LDA and HCA show the linear discriminant performance and NSSL HCA performance, respectively. Other labels identify competitor entries in the competition. HCA performance in winter precipitation is worse than any other method, with statistical significance greater than 99%.

NSSL Special Project – Advancements in Phased Array Weather Radar Research at the University of Oklahoma ARRC
Palmer (primary – OU ARRC), Crain, Yu, Yeary, Chilson, G. Zhang, Y. Zhang, and Hong (all OU ARRC), and Li, Kurdzo, Le, Root, Smith, Cao, and Reinoso (all OU School of Meteorology)

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

Funding Type: CIMMS Task III

Objectives
Study the advantages of phased array radar for weather observation; fully utilize the National Weather Radar Testbed (NWRT) for advanced measurements of severe storms.

Accomplishments
The multi-mission phased array radar (MPAR) program is ambitious with its goal of transforming the aging radar infrastructure across the United States into a modern system exploiting phased array technology. By using a single phased array radar for aircraft surveillance/tracking and weather observations, it is possible to reduce the total number of needed radar systems, provide better service, and reduce the maintenance costs of the entire network. Over the past several years, the National Severe Storms
Laboratory (NSSL) has led this initiative, which has seen tremendous progress. Members of the Atmospheric Radar Research Center (ARRC) at the University of Oklahoma have partnered with NSSL to conduct fundamental research needed to prove the feasibility and advantages of the MPAR concept. During the first years of this active collaboration, contributions have been made related to rapid refractivity retrieval, adaptive sensing, crossbeam wind theory, pulse compression, aircraft tracking, beam multiplexing, and adaptive clutter mitigation using spatial filters with 13 archival journal publications to-date. The S-band Phased Array Radar (PAR) is a unique system operated by NSSL and has been used for several aspects of the project. In addition, an advanced phased array radar simulator has been developed and refined for testing of the more technically sophisticated research thrusts. Recently, the simulator has been upgraded with polarimetric capabilities. Continuing research topics include spaced antenna/interferometry, multi-pattern clutter mitigation, adaptive resource management, optimized scanning strategies, storm cell tracking, and detailed scattering experiments. In addition, recent thrusts have been started in satellite-based precipitation estimation, and a detailed coverage study of the CONUS using both S-band and X-band phased array radar systems.

Although all aspects of OU's phased array research are making significant progress, we will highlight our electromagnetic modeling and controlled laboratory experiments led by Dr. Yan Zhang. The goal of this work is to combine laboratory measurements and numerical simulations to find out 'deeper knowledge' of hydrometeor scattering and apply such knowledge to artificial-intelligence type sensing schemes. First, simulated dual-polarization radar signatures of hydrometeors at X-band have been obtained from a unique 'single radar resolution cell' approach, in which both analytical equations about hydrometeor scattering and Monte-Carlo simulation are combined together in a small scale. Hydrometeors including rain, snow (dry and melting) and hail (dry and melting) are placed into this small cell according to the outputs from the Advanced Regional Prediction System (ARPS). Scattering amplitude of a single hydrometeor whose shape is assumed to be spheroid is computed based on T-Matrix technique. Scattering fields from hydrometeors with different sizes, shapes (axis ratios), dielectric constants and canting angles are then added together forming the radar return of the small cell. The results from the 'single cell' can be extended to the entire radar scanning volume based on the simulated weather field output from ARPS. Also, by artificially setting the parameters, which were controlled by ARPS within a reasonable range, we can control the number, size, and type even melting of hydrometeors in the cell. Knowledge gained from this simulation is pure and clean since only one species exists in the cell, therefore more suitable for classification algorithms. Currently, equivalent reflectivity factor, differential reflectivity and specific differential phase are simulated. Other dual-polarization variables can be easily obtained via this simulation. The figure attached gives an example of simulated radar signature for rain, snow, hail, melting snow and melting hail (500 scenarios for each species).

Of course, natural hydrometeors have different shapes other than simply spheroids. To further verify the numeric predictions from Monte-Carlo simulations and improve the quality of the simulation result, lab measurements of man-made and natural hydrometeors has been carried out to modify scattering amplitude calculated from T-matrix. Also, more measurements on melting particles are to be performed in order to improve the calculations of equivalent dielectric constant of a melting particle. 'Scaled' particle measurements are being performed with the consideration of nonlinear change of dielectric constants to 'emulate' the volume scattering in the laboratory environment.

The overall project is ongoing.

**Publications**


Zh-ZDR ‘cluster map’ for simulated X-band radar observations.

NSSL Special Project – Advancements in Phased Array Weather Radar Research at the University of Oklahoma: A Quantitative Estimation of Phased Array Radar Polarimetry for the MPAR Project

G. Zhang (primary – OU ARRC), Y. Zhang (OU ARRC), Zrnic (NSSL), Lei (CIMMS at OU)

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

Funding Type: CIMMS Task III

Objectives
Understand the principle of phased array polarimetric radar for weather observations and measurements of precipitation; quantify the effects of cross-polar coupling in the radar system on estimates of rainfall.

Accomplishments
In this project, the principle of phased array radar polarimetry is studied through establishment of a relation between electric fields at the antenna of phased array radar and the fields in a resolution volume filled with hydrometeors. It is shown that polarimetric measurements with an electronically steered beam can cause measurement biases that are comparable to or even larger than the intrinsic polarimetric characteristics of hydrometeors. Nonetheless, these biases can be corrected if the transmitted electric fields are known. A theoretical formulation is developed for the bias correction to the measured scattering matrix so that meteorological variables are unbiased. Laboratory experiment to verify this assertion is being conducted.

This project is ongoing.
Publications

Dependence of differential reflectivity bias for an Alternate Transmission but Simultaneous Reception (ATSR) Phased Array Radar (PAR) system on the electronically steered beam direction.

NSSL Special Project – Next Generation QPE: Toward a Multi-Sensor Approach for Integration of Radar, Satellite, Model, and Surface Observations to Produce Very High-resolution Precipitation Estimates
Hong (primary – OU ARRC), Wang (OU Department of Civil Engineering and Environmental Studies)

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

**Funding Type:** CIMMS Task III

**Objectives**
Implement a satellite-based multi-sensor rainfall estimation algorithm on NSSL National Mosaic Q2 website (*http://nmq.ou.edu*).

**Accomplishments**
We have comprehensively evaluated the NSSL’s Q2 radar, gauge-corrected Q2 radar, satellite QPE hydro-estimator, and PERSIANN-CCS algorithms over CONUS using Stage IV data. In addition, we have implemented a cloud motion wind vector algorithm to detect cloud wind speed and wind direction in real-time using GOES infrared cloud images every 15 minutes at 4-km resolution. And, we are implementing
a satellite-based multi-sensor QPE algorithm that advects the combined microwave QPE from five satellite sensors using the cloud motion wind vector approach.

This project is ongoing.

Upper panel: wind speed and wind direction calculated from GOES IR cloud images at real-time every 15 minutes using cloud motion wind vector algorithm. Middle panel: daily rainfall accumulation from the satellite-based multi-sensor QPE algorithm that advects the combined Microwave QPE from 5 satellite sensors using the Cloud Motion Wind Vector approach. Bottom: corresponding daily rainfall accumulation from Stage IV.
NSSL Special Project and Project 3 (Severe Weather Warning Research and Application Development) – Hail Size Discrimination Experiment (HaSDEx)

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

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

Funding Type: CIMMS Task II

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

Accomplishments
This project remains active. Data collection continues for as long as the KOUN radar remains available. New methods for computing some radar parameters (specific differential phase, Kdp and total differential phase, PHIdp) that use monotonic regression techniques along with robust least squares, are being examined to enhance the quality of these parameters over that of the current system. In addition, a new parameter, differential attenuation or Adp, is also being considered. These data, along with the SHAVE data, and data from the Norman NWSFO storm reports, will be quality checked and merged into a single data set. Various parameters will be extracted RUC analysis data centered on the observations and, together with the radar parameters, will be used for a first attempt at creating a new hail detection and hail size algorithm. This project is expected to continue over the next two to three years.

This project is ongoing.

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

Biggerstaff (primary – OU School of Meteorology), Straka (OU School of Meteorology), Wicker (NSSL), Ivic (CIMMS at NSSL), Curtis (CIMMS at NSSL)

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

Funding Type: CIMMS Task III

Objectives
Build radar subsystems and integrate them to complete a dual-polarimetric X-band weather radar; test the new radar.

Accomplishments
The NSSL-OU X-band dual-polarization (“NOXP”) radar was finished just before the landfall of Hurricane Ike in Houston, TX, on 14 September 2008. The radar was tested during Ike, and several problems affecting data quality and antenna control were discovered and rectified. NOXP was then deployed as part of the NOAA and NSF-sponsored VORTEX2 field campaign to study tornadogenesis during May-June 2009; the radar performed well. Currently the radar is in New Mexico in support of a hydrometeorology project.

This project has been completed.
The NOXP radar deployed at Brazoria County Airport in advance of Hurricane Ike.

NSSL Special Project – Development of C-Band Mobile Polarimetric Doppler Weather Radar
Biggerstaff (primary – OU School of Meteorology), Wicker (NSSL), Zahrai (NSSL), Zrnic (NSSL), Straka (OU School of Meteorology), Ivic (CIMMS at NSSL), Curtis (CIMMS at NSSL)

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

Funding Type: CIMMS Task III

Objectives
Build radar subsystems and integrate them to form a completed dual-polarimetric C-band weather radar system, and test it.

Accomplishments
The transmitter, reflector, feed horn, signal processor, and antenna controller were installed and tested in a single-polarimetric (horizontal-only) mode during the NSF and NOAA-sponsored VORTEX2 field campaign held during May-June 2009. Problems affecting the data quality were noted and the transmitter chain was modified to alleviate them. Completion of the system is awaiting specialized waveguide components and a RF notch filter to reduce interference from other C-band radars. The radar is scheduled for completion by October 2009 and is slated to participate in a NOAA-sponsored Debris Flow project this coming winter in California.

This project is ongoing.
The C-band dual-polarimetric weather radar deployed at Pine Bluffs, WY, during the VORTEX2 field campaign. Double-rainbow in the background occurred after the passage of a tornado-warned, but non-tornadic, supercell thunderstorm.

**NSSL Special Project – Storm-Scale Observations of Supercells by Mobile Doppler Radar During VORTEX2**

Biggerstaff (OU School of Meteorology), Wicker (NSSL)

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

**Funding Type:** CIMMS Task III

**Objectives**

Participate in the 2009 field phase of the NSF and NOAA-sponsored Verification of the Origin of Rotation in Tornadoes EXperiment (VORTEX2) and collect storm-scale observations with the two C-band Shared Mobile and Atmospheric Research and Teaching (SMART) radars.

**Accomplishments**

Both C-band radars were successfully deployed during the 2009 tornado season in support of VORTEX2. Several supercell storms were sampled, including a tornadic storm near La Grange, WY, on 5 June 2009. Data analysis has started.

This project is ongoing.
Low-level radar reflectivity from the dual-polarimetric C-band radar at 2215 UTC on 5 June 2009 during the tornadic phase of the La Grange, WY supercell thunderstorm observed during VORTEX2. The white stippled region is the area in which three-dimensional winds can be retrieved using dual-Doppler methods. The other C-band radar was deployed 48.2 km away to the east-northeast.

NSSL Special Project – Building the Multi-Function Phased Array Radar Business Case
LaDue (primary – CIMMS at WDTB), Heinselman (NSSL), Newman (NSF REU student)

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

Funding Type: CIMMS Task III

Objectives
Illustrate the critical capabilities and deficiencies of current radar systems for two key stakeholder groups in the Southern Plains: National Weather Service forecasters and TV broadcasters.

Accomplishments
In order for the outcomes of radar research and development to be the most beneficial to users, an understanding of user needs must be established early in the process and considered throughout. As an important early step in addressing this need, this study explored the strengths and limitations of current radar systems for nine participants from two key stakeholder groups: NWS and broadcast meteorologists. Critical incident interviews revealed the role of each stakeholder group and attained stories that exemplified radar strengths and limitations in their respective roles.

NWS forecasters emphasized using radar as an essential tool to assess the current weather situation and communicate hazards to key stakeholder groups. TV broadcasters emphasized adding meaning and value to NWS information and using radar to effectively communicate weather information to viewers. The stories told by our participants vividly illustrated the advancing nature of weather detection with radar, and why there are still issues with weather radar and radar-derived information. Analysis of the stories, that ranged from severe to winter weather, revealed four underlying radar needs: 1) clean, accurate data without intervention, 2) higher spatial and temporal resolution data than that provided by the WSR-88D, 3)
consistent and low-altitude information, and 4) more accurate information on precipitation type, size, intensity, and distribution.

This project has been completed.

Publications


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How a) 4–6 min update limitations, and b) strength of clear air scanning and limitations of current sampling were manifested in the lived experience of participants, and what those experiences implied about the need for higher-temporal or higher-spatial resolution data. Small boxes to the right indicate how many (shaded) of the five forecasters and four broadcasters talked about that item.
NSSL Special Project – Dense Radar Feasibility Study
Brotzge (primary – OU CAPS), Brewster (OU CAPS), Contreras (UMass), Philips (UMass)

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

Funding Type: CIMMS Task III (Program Manager – Kevin Kelleher)

Objectives
Assess the meteorological need for and the feasibility of deploying additional radars to augment the current radar observing system in northeastern and southwestern Wyoming and coastal Washington, including to compare existing needs with current weather observing networks and identify what, if any, critical gaps existed, and, once any gaps in the system had been identified, explore the feasibility of deploying additional weather radars to the area.

Accomplishments
The project report has been completed. Data needs for each state were defined. Project investigators then visited local NWS offices, state university researchers, local and state Congressional and governmental staff, local media, and private weather data companies in both Wyoming and Washington. Once the weather data needs were established, the current weather infrastructure was evaluated. Quantitative maps were generated showing current radar coverage at multiple elevations above ground, and the geospatial distribution and sampling of in situ sensors were mapped. The distribution of weather data and warning services was examined next, with special consideration for public safety and economic impact. Together, these steps quantified, as best as possible, any gaps in the existing weather observing infrastructure. Next, the feasibility of additional weather radars was explored. Two potential solutions were considered. The first solution examined the addition of one to two long-range radars (e.g., WSR-88D) to each region. The second solution examined the deployment of a dense network of short-range radars (e.g., CASA-type radars) to each region. The infrastructure requirements and integration needs were explored for each solution. The final report was provided both to NOAA and to relevant Congressional staff. This project has been completed.

Publications

A critical part of this study was to quantify gaps in the current observational network. Low-level weather radar coverage as provided by the existing WSR-88D network is shown. Shades of color represent the areas where weather radar coverage is available at or below 1 km, 2 km and 3 km AGL (orange, red and blue, respectively). Areas with no color shading represent areas with no weather radar coverage below 3-km AGL.
ROC and NSSL Special Projects – Wind Turbine Clutter Research

Palmer (primary – OU ARRC), Torres (CIMMS at NSSL), G. Zhang (OU ARRC), Isom (OU School of Electrical and Computer Engineering - ECE), Cheong (OU ARRC), Hood (OU ECE), Le (OU ECE), Kong (OU ECE), Huston (OU ECE), Wang (OU ECE), Nai (CIMMS at OU), Secrest (ROC), Rhoton (ROC), Saxion (ROC), Reed (ROC), Vogt (ROC)

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

Funding Type: CIMMS Task III

Objectives
Identify wind farms that interfere with WSR-88D systems; mitigate corruption due to wind farms on these systems.

Accomplishments
Several large radar datasets were utilized to test effective wind turbine clutter (WTC) detection algorithms. Identification of contaminating wind farms is an essential step toward understanding the WTC signal and potential mitigation. Such mitigation studies are underway in a laboratory setting via the use of a working scaled model of a wind turbine. The model turbine, coupled with similar-scale radar, provides a controlled environment for WTC measurement and evaluation. With complete control of the laboratory setup, total understanding of the WTC signal (RCS, Doppler) will be achieved and will aid in the development of mitigation algorithms. In addition to laboratory experiments, software radar simulators were used to explore possible solutions that lie in emerging technologies such as phased array radars. Adaptive beam-forming techniques show promise in reducing interference due to wind turbines.

This overall project is ongoing.

Publications


An illustration depicting the many areas of wind turbine clutter expertise at the Atmospheric Radar Research Center. Wind turbine clutter detection is essential to mitigation techniques being developed with both laboratory experiments and technologically relevant radars.

**ROC Special Projects – KTLX Refractivity Research**
Palmer (co-primary – OU ARRC), Heinselman (co-primary – NSSL), Cheong (OU ARRC), Bodine (OU School of Meteorology), Michaud (OU School of Meteorology)

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

**Funding Type:** CIMMS Task III and NSF

**Objectives**
Obtain and assess forecaster evaluations of radar refractivity retrievals; develop new forecasting and research applications for radar refractivity retrievals and study role of moisture in convection initiation and boundary layer processes

**Accomplishments**
Forecaster evaluations of radar refractivity data from the Norman, OK, NWS Forecast Office were obtained from 18 April – 22 June 2007 and 15 April – 20 June 2008. Over forty forecaster evaluations from the experiment were analyzed to assess the benefits and limitations of radar refractivity retrievals. This study found that forecasters did not obtain significant new benefits from refractivity retrievals, and one forecaster suggested that new applications of refractivity data are needed for operational retrievals of refractivity on the WSR-88D network.

The second part of the project focused on developing new applications of radar refractivity retrievals, and studying the role of moisture in convection initiation. New radar refractivity retrievals were presented for convection initiation, supercells, and boundary layer processes in two conference papers. One application includes assessing the impact of small-scale moisture variability on convection initiation by reanalyzing soundings. The 30 April 2007 case showed that a small-scale maximum in the moisture field contributed to convection initiation by lowering the level of free convection and convective inhibition where convection initiation occurred (see figure). These projects have been completed.
Publications


Plot showing a) refractivity, and b) scan-to-scan refractivity at 1726, 1736, 1745, and 1755 UTC, and c) 4.5º-tilt radial velocity at 1723, 1733, 1743, 1752 UTC. The Oklahoma Mesonet data within the refractivity domain are plotted on the refractivity images. The black circle shows the location of the convergent signature associated with the developing storm, which is collocated with a moisture maximum in refractivity and scan-to-scan refractivity.
Climate Change Monitoring and Detection

NOAA/NESDIS/JCSDA – The Use of Kernel Methods in Data Selection and Thinning for Satellite Data Assimilation in NWP Models
Leslie (primary – OU School of Meteorology), Richman (OU School of Meteorology), C. Shafer (OU School of Meteorology), Gilbert (OU Department of Industrial Engineering)

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

Funding Type: CIMMS Task III (Program Managers – Dr. Fuzhong Weng and Dr. Lars Peter Riishojgaard)

Objectives
Development of an improved algorithm for thinning satellite data; reduction of forecast errors in numerical models that assimilate satellite wind data.

Accomplishments
The kernel-based thinning algorithms developed in the first two years of the project were sent to Dr. Mike Morgan working with PhD candidate Li Bi for incorporation into assimilation algorithms used in forecast models. Given the interest in the methodology expressed by the U.S. Navy and Australian Bureau of Meteorology, we have applied kernel methods to a trajectory model (highly deterministic) and the Lorenz/Emanuel model (chaotic) and compared the results to traditional data assimilation techniques used operationally (EnKF) as well as advanced nonlinear assimilation techniques that have not been deployed operationally (EKF). Despite their popularity, Kalman filters and ensemble Kalman filters are suboptimal in the sense that they make unrealistic assumptions (e.g., linearity, prior knowledge of the “correct” atmospheric model, properties about the error covariances and questions about the “correct” number of ensemble members) and are not particularly efficient when the datasets become large. Machine learning may provide an alternative to Kalman filtering to predict the future of a dynamic system without any knowledge of the underlying physical model and make minimal assumptions about the data and error properties.

Results show that for highly deterministic systems, kernel methods can learn the relationships among the data to make predictions as well as the best data assimilation methods. As the chaotic component gets large, relative to the deterministic signal, if the model is assumed known a priori, the kernel methods are close to EKF (see figure below).

This project is ongoing.

Publications
Comparison of kernelized data assimilation to the extended Kalman filter.

NOAA/NCDC – Meteorological Patterns Associated with Variability of Heavy Precipitation in the United States

Crawford (primary – OU Oklahoma Climatological Survey), Lamb (CIMMS at OU), Richman (OU School of Meteorology), Godfrey (OU School of Meteorology)

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

Funding Type: CIMMS Task III (Program Manager – David Easterling)

Objectives
Investigate the climate record archived during the past 60 years and determine whether the observed increased frequency and intensity of extreme rainfall events has been accompanied by changes in atmospheric dynamic forcings on either the national or the regional scale.

Accomplishments
The increasing regularity and intensity of heavy precipitation events in the United States during the latter part of the 20th century is widely recognized. To evaluate heavy precipitation events on a regional scale, the principal component analysis (PCA) technique is applied using the expanded version of the evenly-distributed Richman-Lamb dataset. The PCA technique identifies climatically similar regions with respect to rainfall in the United States east of the Rocky Mountains between 1949 and 2000. Results show 13 regions of coherent precipitation patterns across the eastern two-thirds of the continental U.S.

This project is ongoing.
Average total annual precipitation (inches) at the stations in the expanded Richman and Lamb (1985) precipitation dataset across the eastern two-thirds of the U.S. from 1949–2000.

**NOAA/OCO – Program Support for the Assimilation, Analysis and Dissemination of Pacific Rain Gauge Data: PACRAIN**

Morrissey (primary – OU School of Meteorology), Postawko (OU School of Meteorology), Greene (OU Department of Geography)

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

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

**Objectives**

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

Accomplishments

**Deliver vital rainfall data to the research community through on-line access of the PACRAIN database.**
Rain rate measurements over open ocean regions are very important in the assessment of satellite rain algorithms climate change and modeling of physical processes. Until recently, no Pacific island rainfall measurements have been available at resolutions less than one hour. Our new MetONE rain gauges tipping bucket gauges are equipped with data loggers and have been donated by the University of Oklahoma for this project. In turn, they have been given to the PI-GCOS Coordinator, headquartered at SPREP, for distribution to the various PNMS. We have deployed over 50 of these gauges throughout the Pacific region during 2008. We are currently receiving rainfall tip data back from many PNMS and these data are inserted into the PACRAIN database. These data are particularly important in the understanding of basic tropical rain systems and consequently, more accurate global climate models. These data are all included in the PACRAIN database. The achievement of this objective could not be accomplished without the close collaboration of the PI-GCOS Steering Group and the current PI-GCOS Coordinator. Other important collaborative groups are the Global Ocean Observing System (GOOS), the New Zealand Meteorological Service, and the New Zealand Institute for Research in Water and Atmosphere, the Australian Bureau of Meteorology, Meteo-France and the US National Weather Service.

**Provide high spatial density world regional rain gauge datasets for use in satellite rainfall algorithm verification.** EVAC maintains a database of selected high-density rain gauge network data for use in satellite rainfall algorithm assessment. Parts of our responsibilities include operating the Surface Reference Data Center (SRDC), which is associated with the Global Precipitation Climatology Project (GPCP). Our tasks in this capacity include identifying and collecting these data sets and making them available to researchers for this purpose. We also conduct studies on the errors involved when comparing satellite and rain gauge data. During 2008 we began research on the rain rate characteristics of tropical rainfall by developing a tropical point process model. The fit of the model at various temporal scales was tested using the data from the tipping bucket gauges. The results of our research indicate that the model is able to reproduce the rain rate statistics computed from Tongan MetONE gauges quite well. This study would not have been possible without the tipping bucket data. The model now can be further tested at other sites that will allow the assessment the statistical characteristics unique to tropical rainfall. The results have used to produce a point process rainfall model for the tropics and a manuscript is now published in the AMS Journal of Hydrometeorology.

**Maintain and improve an error-assessed PACRAIN database.** The core asset of PACRAIN and SPaRCE programs is the online rainfall database. This database contains historical data from several sources, and is updated monthly with the latest data from three sources: the National Climatic Data Center (NCDC), the National Institute for Water and Atmospheric Research (NIWA) in New Zealand, and the SPaRCE program. Additional updates are done as needed. The pacusers mailing list is maintained as a way to disseminate information and provide support to PACRAIN users (http://pacrain.evac.ou.edu/pacusers.html). Database changes are also cataloged online (http://pacrain.evac.ou.edu/changes.html). Some database statistics:

- ~2.5 million observations
- ~8 thousand observations added each month
- 855 sites
- monthly data with some records beginning in 1874
- daily records begin in 1942

Over the past few years the PACRAIN database has undergone a number of upgrades, and this trend continued in FY 2009. Previous upgrades focused on infrastructure, but the most recent improvements have been to the underlying data. The quality control of PACRAIN data is an ongoing process, and errors are corrected as they are discovered. A comparison of PACRAIN records to satellite data was performed in May to evaluate the accuracy of PACRAIN timestamps. In addition to specific database upgrades,
other routine activities continued throughout the year. The PACRAIN database continues to be upgraded on a monthly basis with data from the Schools of the Pacific Rainfall Climate Project (SPaRCE) project, the National Climatic Data Center, New Zealand Institute for Research in Water and Atmosphere (NIWA), and directly from the individual PNMS. Also, several journal articles have been accepted into print which details the PACRAIN operations and objectives.

Current status of PACRAIN database. More than 150,000 records have been added to the PACRAIN database, including almost 50,000 tipping bucket rain gauge observations. The PACRAIN data base was modified to allow for high-resolution tipping bucket gauge data; such gauges incorporating data loggers are now operational in these countries:

- Cook Islands: 4
- Kiribati: 6
- Tuvalu: 4
- Samoa: 3

A total of 200 plastic rain gauges have been sent to various Pacific Island Meteorological Services. New software (a Microsoft Excel add-in) has been developed for use by the individual meteorological services for easy download of tip data from these gauges. Enhanced support of the PI-GCOS tipping bucket gauge network has been achieved through technical support and the distribution of supplies (data loggers, batteries, etc.).

Enhancement of the educational outreach component of the SPaRCE Program. For the past 15 years the Schools of the Pacific Rainfall Climate Experiment (SPaRCE) project at the University of Oklahoma has worked directly with elementary and high school teachers around the Pacific. During this time, we have also worked informally with the Pacific island meteorological services to aid them with their own local educational outreach projects. However, given the age of the SPaRCE materials there is a need to upgrade them to include more relevant information, e.g. the PI-GCOS program, global warming, cyclones, cyclone preparation brochure, etc.

As the meteorological services in the Pacific islands continue to expand and enhance their technological capabilities, there is an increased awareness and appreciation by meteorological service personnel for the need of an educated public. For example, more cooperative climate observer networks are being proposed and implemented in these countries, modeled after the U.S. Cooperative Observers Network (e.g. in Vanuatu, Samoa, and Tonga). There are many challenges in implementing a sustainable cooperative observer program in the developing tropical Pacific island nations, one of which is the availability of easily understood educational materials that can be used by meteorological service personnel in recruiting and training potential observers. In addition, disasters such as the December 2004 tsunami have emphasized the need for a basic understanding of any potentially dangerous phenomenon, such as hurricanes, by the general public. The SPaRCE program is uniquely situated to be able to both continue collaborating directly with schools, and to aid the meteorological personnel in the islands to develop easily understood educational materials that can be used in a variety of circumstances. Additional funding for the SPaRCE program will be used to provide Pacific island meteorological services with low-cost rain gauges for their cooperative observer networks, and to hire a student to work with meteorological service personnel to develop and deliver educational materials aimed at both potential cooperative observers as well as the general public. In addition, these additional materials would be available through the Pacific-RANET project’s satellite/internet broadcasts.

This project is ongoing.

Publications
PUBLIC AFFAIRS AND OUTREACH

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

NOAA Cross-Cutting Priority (Promote Environmental Literacy)

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

Accomplishments
NOAA offers scheduled tours of the National Weather Center (NWC) throughout the week for groups interested in learning more about the five NOAA organizations in Norman. These tours are offered to anyone from 3rd grade and up. Between 1 July 2008 and 30 June 2009, 84 tours were given to more than 1,600 people who visited the building. These include public school groups, homeschoolers, private schools, church groups, engineering groups, senior citizen groups and many others. Tours additionally provided by OU’s National Weather Center Program were given to nearly 30,000 people.

A tour of the NWC includes a presentation about the NOAA National Severe Storms Lab along with a weather safety lesson followed by another presentation on the Science on a Sphere. Visitors then see the 7th floor observatory where the distant NSSL and NOAA Radar Operations Center radars located in north Norman are pointed out. The training done by the NOAA WDTB also is discussed. On the second floor, the NOAA SPC and Norman NWS Forecast Office are shown so that visitors can see forecasters at work and learn about the watch/warning process.

Besides scheduled tours, another important event where we are able to show the public the various science and forecasting done by the NOAA Weather Partners is the National Weather Festival, which was held on 8 November 2008; it was attended by about 3,000 people. Additional highlights included tours provided to over 180 students attending the Jr. ROTC Honors Camp at the University of Oklahoma.

This activity is ongoing.
WDTB – Outreach Activities of CIMMS Staff
Davis, Lemon, Morris, Payne, Sessing, A. Wood

NOAA Cross-Cutting Priority (Promote Environmental Literacy)

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

Accomplishments
A number of outreach activities were conducted during the fiscal year. These include:

• Participated in University of Oklahoma Career Fairs
• Provide personal tours of the National Weather Center and the Warning Decision Training Branch
• Participated in the National Weather Center Open House in October of 2008
• Participated in the United Way Day of Caring
• Active in the Central Oklahoma Chapter of the American Meteorological Society
• Attended Norman Chamber of Commerce, Weather Committee meetings
• Participated in board and annual membership meetings of the National Weather Museum and Science Center
• Volunteered at National Weather Festival
• Spoke on National Weather Center activities at Norman PEO International chapter meeting
• Make WDTB course description pages and training modules available for use by non-NOAA personnel
• Participated in the 2009 portion of the VORTEX2 project

These activities are ongoing.

Clark Payne working at the WDTB booth during the 2008 National Weather Festival. Photo courtesy Mary Murnan.
NOAA Sector Applications Research Program/CPO – Climate Training Workshops
M. Shafer (primary – OCS), T. James (OU Department of Political Science), Giuliano (OCS), Hall (OCS), McManus (OCS), Arndt (OCS)

NOAA Cross-Cutting Priority (Promote Environmental Literacy)

Objectives
Enhance climate literacy, including understanding basic principles, among non-technical audiences; facilitate participants’ ability to locate weather and climate information from the Internet; quantitatively document learning that is directly attributable to the workshops

Accomplishments
Six one-day workshops were conducted at facilities across Oklahoma, reaching 62 individuals. Workshops included a combination of PowerPoint presentations, hands-on activities, and computer exercises (locating climate information on the web). Each workshop included a pre-test and post-test to evaluate what participants already knew prior to the workshop and what they learned during the day’s presentations.

Overall test scores increased from 60 percent correct prior to the training to 69 percent correct at the completion of the workshops. All participants indicated they were very or somewhat satisfied with the workshop and nearly all found the materials useful. The evaluation identified areas in which instructional materials and procedures need to be revised. A follow-up survey to document retention and use of the information is ongoing. Additional workshops are planned for Colorado and Vermont to test replication of materials in different settings.

This project is ongoing.

Publications

Example of training materials presented to participants in the Climate Training Workshops (NOAA SARP).
Appendix A

CIMMS AWARDS AND HONORS

NSSL Scientists (formerly of CIMMS) Pam Heinselman and Mike Coniglio were named as recipients of the 2008 Presidential Early Career Award for Scientists and Engineers (PECASE) for their work studying improvements in tornado forecasting and new radar systems, respectively. The award is the highest honor bestowed by the United States government on outstanding scientists and engineers in the early stages of their careers. An award ceremony is planned in Washington, D.C. in fall 2009.

NSSL Scientist (formerly of CIMMS) Pam Heinselman and CIMMS Scientists at NSSL Dave Priegnitz, Kevin Manross, Travis Smith, and Richard Adams were awarded a NOAA OAR Outstanding Scientific Paper Award in the category of Weather and Water. Their paper, published in *Weather and Forecasting*, is titled “Rapid sampling of severe storms by the National Weather Radar Testbed phased array radar.”

CIMMS Scientist with SSWIM Eve Gruntfest was awarded the Kenneth E. Spengler Award of the American Meteorological Society

CIMMS Scientist at NSSL Suzanne Van Cooten and others were awarded the U.S. Department of Interior Partners in Conservation Award for Protection of Aquifer Resources in Oklahoma

PhD Student with SSWIM Monica Zappa was awarded the Jeanne X. Kasperson Student Paper Award in the AAG Hazards Specialty Group at the AAG 2009 Annual Meeting in Las Vegas, NV

PhD Student with NSSL Heather Moser was awarded Third Place in the 2008 Oklahoma Water Symposium student poster competition in Oklahoma City, OK

PhD Student with SSWIM Gina Eosco was awarded a Top 5 Poster Award at the 2008 Society for Risk Analysis Annual Meeting in Boston, MA

MS Student with NSSL Craig Schwartz was awarded the Best MS Student Publication in the OU School of Meteorology

Undergraduate Student with NSSL Jessica Erlingis was the recipient of the American Meteorology Society Elbert W. “Joe” Friday Scholarship for Undergraduates

Undergraduate Student with NSSL Zachary Flamig was the recipient of Undergraduate Fellowship from the Astronaut Scholarship Foundation
Appendix B

PUBLICATION SUMMARY

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Theses: M.S. – 5 in meteorology; PhD – 1 in meteorology

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

**PERSONNEL SUMMARY – NOAA FUNDED RESEARCH ONLY**

### NOAA-Funded Research

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### Located at a NOAA unit

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### Obtained NOAA employment within the past year

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Appendix D

COMPILATION OF CIMMS-RELATED PUBLICATION 2007-2008

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


Lazrus, H., 2009: “Sea Change: Anthropology and Climate Change in Tuvalu, South Pacific.” In Anthropology and Climate Change: From Encounters to Actions, S. Crane and M. Nuttall, eds. Left Coast Press, Walnut Creek, CA.


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


C. Other Publications


158


Crowell, S., D. Williams, C. Mavriplis and L. Wicker, 2009: Comparison of traditional and novel discretization methods for advection models in numerical weather prediction. ICCS Conf. on Numerical Methods, Baton Rouge, LA.


Douglas, Michael W., 2008: Progress towards development of the glidersonde: A recoverable radiosonde system. WMO Technical Conf. on Meteorological and Environmental Instruments and Methods of Observation (TECO), St. Petersburg, Russian Federation.


Douglas, M and J. Mejia, 2008: Mapping the spatial extent of the Central American Mid-summer drought. 2008 Climate Prediction Program for the Americas Principal Investigators Meeting, Silver Spring, MD.


Eosco, G., 2009: Toward a simple science: Comparing popular visual and verbal science messages in meteorology. 59th International Communication Association Annual Meeting, Chicago, IL.


Gao, J., D. J. Stensrud, and M. Xue, 2009: The relative importance of assimilating radial velocity and reflectivity data to storm-scale analysis and forecast. 23rd Conf. on Weather Analysis and Forecasting/19th Conf. on Numerical Weather Prediction, Omaha, NE, Amer. Meteor. Soc., 16A.3.


Kong, F., and co-authors, 2008: Realtime storm-scale ensemble forecast experiment. 9th WRF User's Workshop, NCAR Center Green Campus, 7.3.


Lazrus, H., 2009: The simpler the better. 6th *Conf. on Artificial Applications to the Environmental Sciences*, Phoenix, AZ, Amer. Meteor. Soc., P3.5.


Lazrus, H., 2009: The intersection between social science and meteorology. Keynote address to the *National Press Foundation Severe Weather Workshop III*, Norman, OK.

Lazrus, H., 2009: Weathering the waves: Anthropology and climate change in Tuvalu. *Association for Social Anthropology in Oceania, Santa Cruz, CA.*


Mechem, D. B., and Y. L. Kogan, 2008: Scalings for precipitation and coalescence scavenging obtained from simulations of trade cumulus. 15th *Inter. Conf. on Clouds and Precipitation*, Cancun, Mexico.
Mejia, J., and M. Douglas, 2008: Synoptic variability of rainfall and cloudiness along the coasts of northern Peru and Ecuador during the 1997-8 El Niño event. 2008 Climate Prediction Program for the Americas Principal Investigators Meeting, Silver Spring, MD.


Newsom, R. K., W. Shaw1, J. Rishel, W. Wang, Qin Xu, and P. Zhang, 2008: Development and validation of a real-time wind field retrieval system, 12th Annual George Mason University Conf. on Atmospheric Transport and Dispersion Modeling. George Mason University, Fairfax, VA.


Thompson, T., L. Wicker, K. Kuhlman, M. Biggerstaff, 2008: Comparison of three-dimensional winds derived from assimilated phased array radar data with mobile dual-Doppler analyses from a tornado storm. 23rd Conf. on Severe Local Storms, Savannah, GA, Amer. Meteor. Soc.

Thompson, T., L. Wicker, M. Biggerstaff, D. Forsyth 2008: EnKF analysis of the 29 May 2004 Oklahoma City supercell using rapid-scan phased array radar data. 5th European Conf. on Severe Storms. Munich Germany.

Torres, S., 2008: Range and velocity ambiguity mitigation on the US NEXRAD network: Performance and improvements of the SZ-2 phase coding algorithm. Fourth European Conf. on Radar Meteorology and Hydrology (ERAD), Helsinki, Finland.


Xu, Q., K. Nai, L. Wei, P. Zhang, Q. Zhao and P. R. Harasti, 2009: A real-time radar wind data quality control and analysis system for nowcast application. WSN09 – WMO Symposium on Nowcasting, Whistler, BC, Canada, WMO.


Zappa, M., 2009: Social, economic, and cultural impacts on hurricane vulnerability in Bluefields, Nicaragua. AAG 2009 Annual Meeting, Las Vegas, NV.

Zhang, G., R. J. Doviak, D. Zrnic, and J. Crain, 2008: Phased array radar polarimetry for weather sensing: challenges and opportunities. IGARSS’08, Boston, MA.


