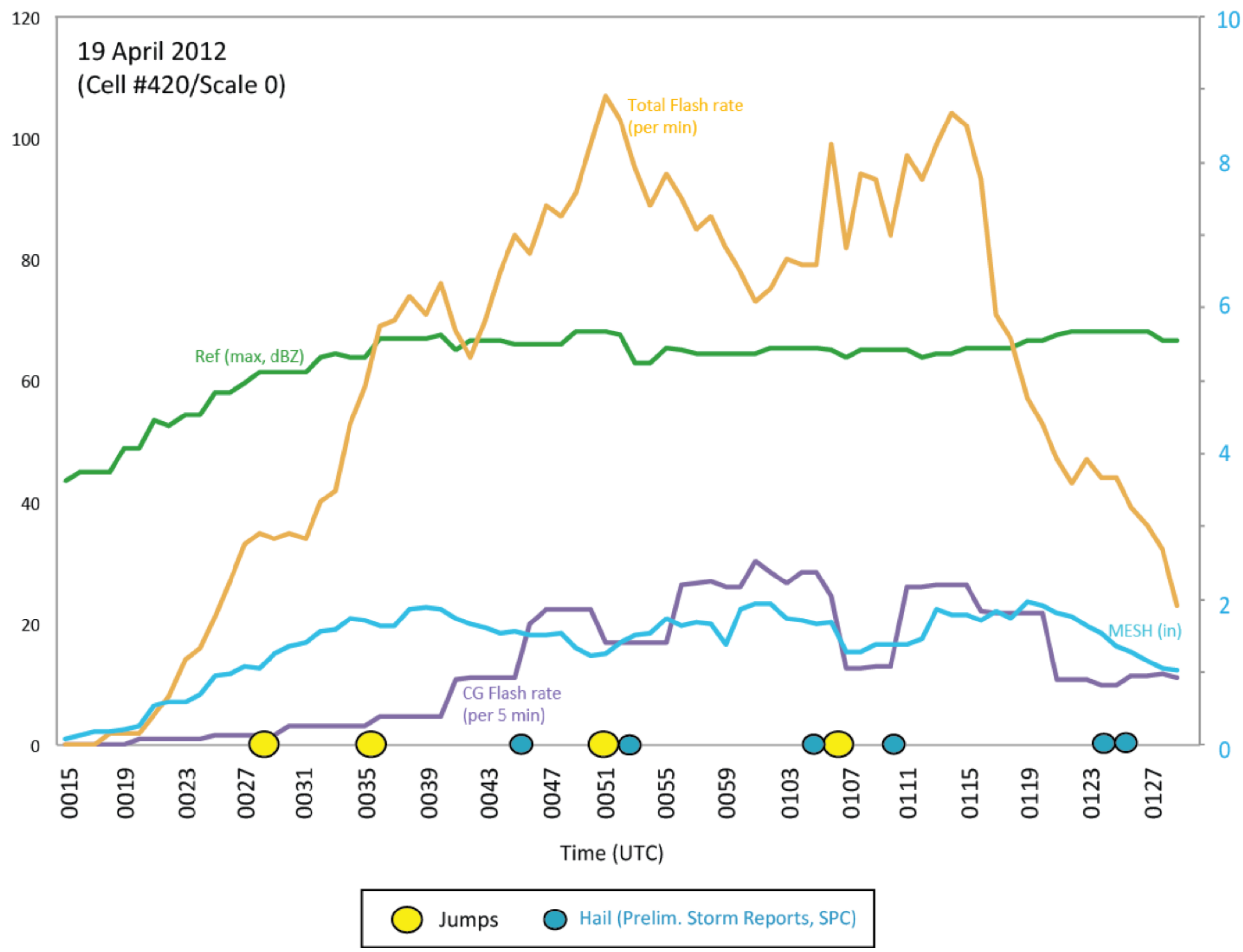

Cooperative Institute for Mesoscale Meteorological Studies

Annual Report

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

NA11OAR4320072

Fiscal Year – 2012

Cover figure – *Lightning jumps and associated storm trends from real-time cell tracking in Oklahoma. Plotted are time series of the total flash rate (orange), cloud-to-ground flash rate (purple), maximum reflectivity (green), and Maximum Expected Size of Hail (MESH, blue). Time of lightning jumps and preliminary severe hail reports are denoted on the x-axis by yellow and blue circles, respectively. More on this project can be found within the description for Multi-Radar/Multi-Sensor (MR/MS) Algorithm Development on p. 44.*

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COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES
THE UNIVERSITY OF OKLAHOMA

Annual Report of Research Progress under New Cooperative Agreement
NA11OAR4320072
During the 2012 Fiscal Year

Peter J. Lamb, Director
Randy A. Peppler, Associate Director
Tracy L. Reinke, Executive Director of Finance and Operations

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 weather radar, stormscale meteorological phenomena, regional climate variations, and related subject areas – all with the goal of helping to produce better forecasts and warnings that save lives and protect property.

CIMMS promotes cooperation and collaboration on problems of mutual interest among university researchers 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), NWS Norman Forecast Office (OUN), and NWS Training Center (NWSTC) in Kansas City, Missouri.

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 stormscale 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.

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 Norman Forecast Office (OUN)
- Oklahoma Climatological Survey (OCS)
- OU Center for Analysis and Prediction of Storms (CAPS)
- OU Atmospheric Radar Research Center (ARRC)
- OU College of Atmospheric and Geographic Sciences
- OU School of Meteorology
- OU Department of Geography and Environmental Sustainability

CIMMS, under the new cooperative agreement, concentrates its research and outreach efforts and resources on the following principal themes: (1) weather radar research and development, (2) stormscale and mesoscale modeling research and development, (3) forecast and warning improvements research and development, (4) impacts of climate change related to extreme weather events, and (5) societal and socioeconomic impacts of high impact weather systems.

This report describes NOAA-funded research and outreach progress made by CIMMS scientists at OU and those assigned to our collaborating NOAA units under new cooperative agreement NA11OAR4320072 during 1 October 2011 through 30 June 2012. NOAA-funded projects are explicitly identified in project titles. Publications written, awards received, and employee and funding statistics are presented in Appendices.

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

CIMMS was competed in 2010-11 and OU was awarded a new cooperative agreement beginning in October 2011, retaining the name CIMMS. A new Memorandum of Understanding is pending. An Executive Board and an Assembly of Fellows govern CIMMS under the new cooperative agreement.

The CIMMS Executive Board is to meet 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 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 as a Fellow, by the CIMMS Executive Board, 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 Executive Board. Fellows will review and suggest modifications of bylaws, participate in reviews of CIMMS activities, and elect two of their number to serve on the Executive Board. The Executive Board appoints Fellows.

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 Account and Budget Staff (Melanie Norris). Scientists, students, and post-docs are housed on the OU campus in its National Weather Center (NWC). Some CIMMS undergraduate students have duty stations off-campus at ROC in Norman.

Executive Summary Listing of Activities during FY2012 Under the New Cooperative Agreement

Weather Radar Research and Development

At the very center of NOAA's mission are the objectives of achieving a "reduced loss of life, property, and disruption from high-impact weather events", "improved transportation efficiency and safety", and "improved freshwater resource management" (*NOAA' s Next Generation Strategic Plan,* Long-Term Goal: Weather Ready Nation, pp. 10-14, December 2010). The weather systems involved include severe thunderstorms, tornadoes, tropical storms and hurricanes, and winter cyclones. Those systems produce the high intensity precipitation, strong winds, flooding, lightning strikes, freezing rain, and large snow accumulations that damage property, cost lives, disrupt transportation, and cause other economic dislocation. Reduction of these adverse impacts can result from the availability and use of accurate forecasts of the above weather systems and

their associated phenomena, for future periods ranging from several days down to a few minutes. One of the essential starting points for developing those forecasts is the detailed observation of the present state of the atmosphere.

For almost 60 years, remote sensing via weather radar has been a vital source of the necessary observations. The present national weather radar system (WSR-88D) uses reflectivity and Doppler velocity measurements to document the location and movement of the above weather systems, and indicate the time evolution of their precipitation intensity and wind strength. However, this radar system soon will be as old (30 years) as the chronologically and technologically ancient system (WSR-57) that it replaced in 1988. This situation has two crucial implications for NOAA's continued pursuit of its above objectives to achieve a "reduced loss of life, property, and disruption from high impact weather events", "improved transportation efficiency and safety", and "improved freshwater management". First, NOAA and its partners must complete the recently initiated development of the new Multi-Function Phased Array Radar (MPAR) system that will replace the WSR-88D and is incorporating all relevant technological advances during the last 20+ years. Second, since completion of this development activity will require another 7-12 years at its current rate of progression, the ongoing current WSR-88D upgrades (especially Dual-Polarization) must be brought to fruition as soon as possible.

During the past year, research was conducted at NSSL on:

- Evaluating Dual Pol Precipitation Estimates Using the Q2 Verification System
- Evaluating Dual Pol Precipitation Estimates vs. the Legacy Precipitation Processing System
- QPE Scheme for Merging Observations of Radars Operating at Different Wavelengths
- National Radar Mosaic and Quantitative Precipitation Estimation (NMQ) – Reflectivity Quality Control for the Canadian Radar Networks
- National Radar Mosaic and Quantitative Precipitation Estimation - Radar Bloom and Anomalous Propagation Quality Control
- National Radar Mosaic and Quantitative Precipitation Estimation - Non-Standard Blockage Mitigation
- National Radar Mosaic and Quantitative Precipitation Estimation – Seamless Hybrid Scan Reflectivity Algorithm
- Ground Radar Based QPE Improvement Using Satellite Radar Data

Stormscale and Mesoscale Modeling Research and Development

Research and development for stormscale and mesoscale modeling are essential for NOAA's aforementioned objectives. Use of stormscale and mesoscale models is a major ingredient of the forecasting and nowcasting procedures for high impact weather events, and is expected to grow in the future. The initialization of those prediction models is depending increasingly on wind and other observations from the current weather radar systems. This dependence also is anticipated to expand and therefore is

a principal motivation for the weather radar research and development proposed above -- to improve the initialization and hence performance of the prediction models. At the center of this radar-modeling interface is the manner in which radar data are ingested into the models, especially in combination with measurements from other platforms (e.g., satellite, rawinsonde, surface) via “assimilation” procedures. In addition to their predictive roles, stormscale and mesoscale models also are used extensively in a research mode to understand better the behavior of weather systems on those scales. The atmospheric processes that receive particular attention in these simulations include mesoscale dynamics, convective initiation, cloud dynamics and microphysics, and the precipitation process. Also investigated is the sensitivity of the simulation results to the data assimilation procedures. The ultimate goal of such stormscale and mesoscale simulation research is to improve the performance of the operational forecasting models.

During the past year, research was conducted on:

- Research was not conducted within this theme under the new cooperative agreement.

Forecast and Warning Improvements Research and Development

It is under this theme that the results of the research and development from the two preceding themes are integrated and converted into improved weather forecasts and warnings disseminated to the U.S. public. The ultimate outcome is to provide NWS forecasters routinely with enhanced information on which to base their forecasts. Two areas of highly innovative activity, anchored within the Hazardous Weather Testbed (HWT), dominate this effort – the Experimental Forecasting Program and the Experimental Warning Program. Activity within this theme also is dominated by the training activities of CIMMS scientists at the Warning Decision Training Branch.

During the past year, research and training was conducted on:

HWT Forecasting Experiments:
- Severe Desk Component
- Convective Initiation Component

HWT Warning Experiments:
- Warn-on-Forecast Real-Time Three-Dimensional Data Assimilation (3DVAR)
- GOES-R Component
- Multi-function Phased Array Radar (MPAR) Component
- AWIPS2 Integration

Additional NSSL Projects:
- The Multi-Year Reanalysis of Remotely Sensed Storms (MYRORSS)
- Warn-on-Forecast Real-Time Data Assimilation Experiment
- Multi-Radar/Multi-Sensor (MR/MS) Algorithm Development

- The Severe Hazards Analysis and Verification Experiment (SHAVE)
- 2012 OUNWRF Experiment

NWSTC Projects:
- Graphical Forecast Editor
- Advanced Training Development

CAPS Project:
- Development of a Short-Range Realtime Analysis and Forecasting System Based on the ARPS for Taiwan Region

Impacts of Climate Change Related to Extreme Weather Events

Here, we are concerned with the regional and global climate system context of mesoscale and stormscale weather variability, and especially the functioning of what now is termed the weather-climate interface. The genesis and trends of extreme events are of particular interest, given society's current concerns about climate maintenance and change. The optimum path forward will require an appropriate combination of observational (using fine resolution data) and modeling (emphasizing convection) research. This theme also addresses the NOAA objective of achieving "improved scientific understanding of the changing climate system and its impacts" and "assessments of current and future states of the climate system that identify potential impacts and inform science, services, and stewardship decisions" (*NOAA's Next Generation Strategic Plan*, Long-Term Goal: Climate Adaptation and Mitigation, pp. 5-10, December 2010).

During the past year, research was conducted on:

- Research was not conducted within this theme under the new cooperative agreement.

Societal and Socioeconomic Impacts of High Impact Weather Systems

This theme contributes to several of NOAA's objectives - - providing "mitigation and adaptation choices supported by sustained, reliable, and timely climate services"; achieving "a climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions"; and furnishing "services meeting the evolving demands of regional stakeholders" (*NOAA's Next-Generation Strategic Plan,* Long-Term Goal: Climate Adaptation and Mitigation, pp. 5-10, December 2010). Much of the effort here is motivated and fed by results obtained under the Forecast and Warning Improvements and Extreme Weather-Climate Change Impacts themes that, in turn, are built around the core of the more basic Weather Radar and Stormscale/Mesoscale Modeling Research and Development. The goal here is to facilitate the mitigation (enhancement) of the adverse (beneficial) social and socioeconomic impacts of high-impact weather systems and regional/seasonal-scale climate variations. Thus, our contributions to this theme are part of NOAA's crucial ultimate interface with society,

and therefore will reflect the continuing and increasing involvement of OU social scientists.

During the past year, research was conducted on:

- 2012 Phased-Array Radar Innovative Sensing Experiment (PARISE)

Public Affairs and Outreach

CIMMS education and outreach activities help NOAA achieve its objectives of providing "an engaged and educated public with an improved capacity to make scientifically informed environmental decisions" and making "full and effective use of international partnerships and policy leadership to achieve NOAA's mission objectives" (*NOAA's Next Generation Strategic Plan*, Engagement Enterprise Objective, pp. 30-32, December 2010). CIMMS location and role within the OU-NOAA National Weather Center (NWC) has embedded it within a wide-ranging and ongoing set of education and outreach activities that will draw continuously on the knowledge developed within the five above research themes. Those activities (a) involve local and national outreach to the general public, (b) extend across all levels of formal education, and (c) provide post-doctoral and professional development opportunities for individuals in careers related to the atmospheric sciences.

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

- No activity was conducted here under the new cooperative agreement.

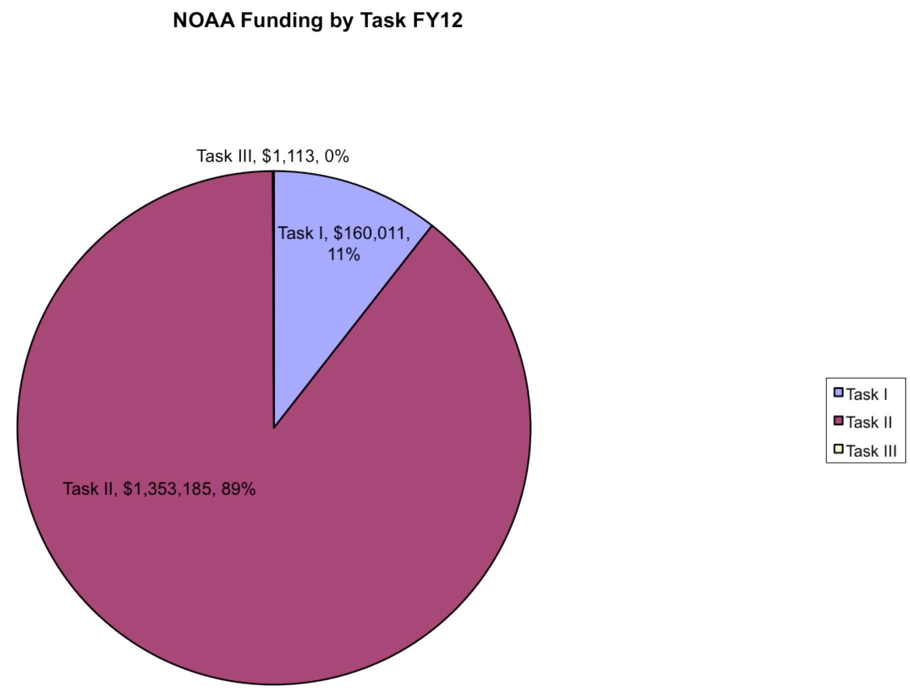
Awards

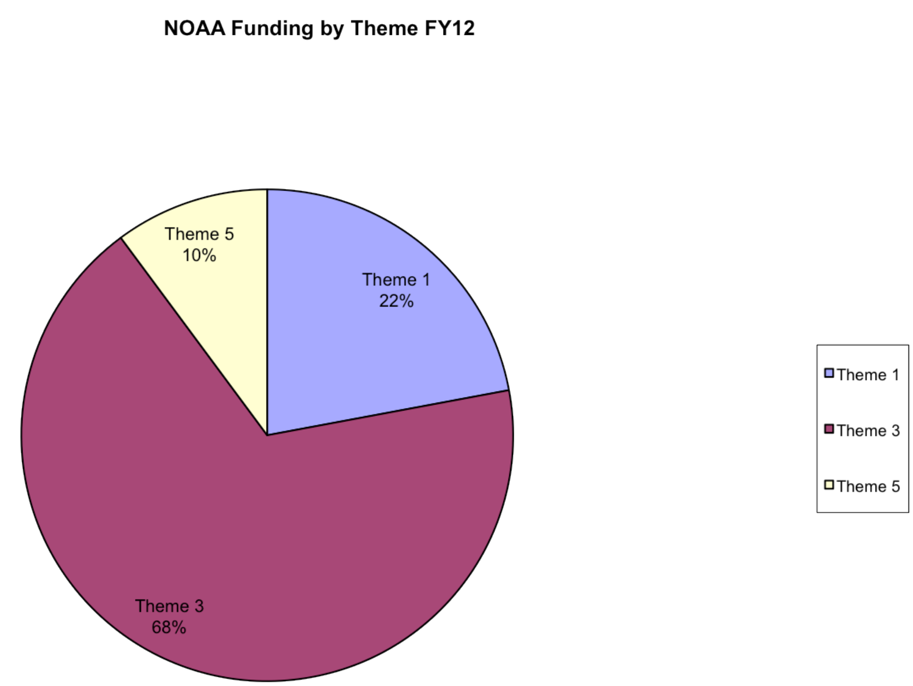
The following awards were bestowed in the past fiscal year:

- **CIMMS Scientist at NSSL Adam J. Clark** received an Editor's Award for the American Meteorological Society journal *Weather and Forecasting.*

- **CIMMS Scientists at NSSL Valliappa Lakshmanan (Leader), Jeffrey Brogden, Kimberly Elmore, Charles Kerr, Travis Smith, Lulin Song, Gregory Stumpf, Robert Toomey, and Thomas Vaughan, along with NSSL Scientists Kurt Hondl, Robert Rabin, and Jian Zhang,** received the ***Innovator Award from the OU Office of Technology Development***. The citation includes the following statement: "This groundbreaking (WDSS-II) software is used worldwide to help predict weather phenomena including hail, precipitation, mesocyclones, and tornadoes. Used by private companies, research labs, National and International governments across the globe, this technology provides users across the world with the information needed to make property and life-saving decisions in the event of hazardous weather."

Distribution of NOAA Funding by CIMMS Task and Research Theme





CIMMS Executive Board and Assembly of Fellows Meeting Dates and Membership

Under the new cooperative agreement, the Executive Board convened on 26 October 2011 and 21 May 2012. No Assembly of Fellows meetings have yet to take place.

Executive Board membership is:

- Dr. Peter Lamb (Chair), George Lynn Cross Research Professor of Meteorology, OU, and Director, CIMMS
- Dr. Robert Palmer, Professor and Tommy C. Craighead Chair, School of Meteorology, OU, and Director, Atmospheric Radar Research Center (ARRC), OU (Provost designated)
- Dr. Jerry Crain, Professor and Director, School of Electrical and Computer Engineering, OU (Provost designated)
- Dr. Baxter Vieux, Presidential Professor of Civil Engineering and Environmental Sciences, OU (Provost designated)
- Dr. David Stensrud, Chief, Forecast Research and Development Division, NSSL, and Affiliate Professor of Meteorology, OU (OAR designated)
- Mr. Kevin Kelleher, Deputy Director, NSSL (OAR designated)
- Dr. Russ Schneider, Director, SPC (NWS designated)
- Mr. Richard Murnan, Radar Operations Center Applications Branch (NWS designated)
- Dr. Michael 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. Steven Koch, Director, NSSL (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)
- Dr. David Parsons, Director, OU School of Meteorology, Mark and Kandi McCasland Professor of Meteorology (ex-officio member)
- Dr. Berrien Moore III, Dean, OU College of Atmospheric and Geographic Sciences, OU Vice President for Weather and Climate Programs, Director of National Weather Center, and Chesapeake Energy Professor of Meteorology (ex-officio member)

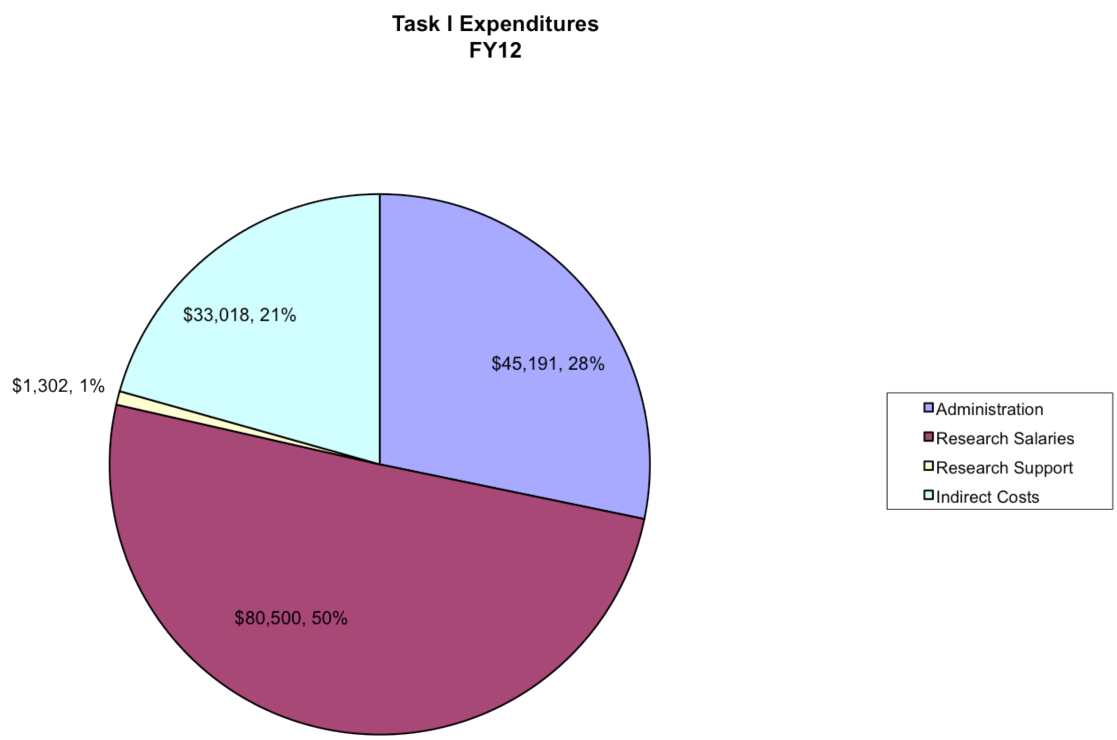
Assembly of Fellows membership for 16 August 2009 through 15 August 2011 is *(Fellows membership for the period beyond 15 August 2011 is pending approval by the OU Provost)*:

- 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. Keith Brewster, Senior Scientist and Associate Director, CAPS, OU
- 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 Chilson, Associate Professor of Meteorology, OU
- Dr. Michael Coniglio, Research Scientist, NSSL
- Dr. Gerald E. Crain, Professor of Electrical and Computer Engineering, OU
- Dr. Kenneth C. Crawford, Regents' Emeritus Professor of Meteorology, OU
- 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, Vice President for Research and Regents' Professor, OU
- Dr. Claude E. Duchon, Emeritus Professor of Meteorology, OU
- Dr. Imke Durre, Scientist, NCDC
- Dr. David R. Easterling, Scientist, NCDC

- Dr. Evegeni Fedorovich, Professor of Meteorology, OU
- Mr. Douglas E. Forsyth, Chief, Radar Research & Development Division, NSSL
- Dr. J.J. Gourley, Research Scientist, NSSL
- Dr. Pamela Heinselman, Research Scientist, NSSL
- Mr. Kurt Hondl, Research Meteorologist, NSSL
- Dr. Yang Hong, Associate Professor of Civil Engineering and Environmental Sciences, OU
- Mr. Ken Howard, Meteorologist, NSSL
- 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, Associate Professor of Meteorology, OU
- Mr. Kevin E. Kelleher, Deputy Director, NSSL
- Dr. James F. Kimpel, Director, Emeritus NSSL, and Emeritus Professor of Meteorology, OU
- Mr. Paul Kirkwood, Scientist, NWS Southern Region Headquarters
- Dr. Kevin Kloesel, Associate Director, College of Atmospheric and Geographic Sciences; Associate Professor, OU School of Meteorology; and Interim Director, Oklahoma Climatological Survey (OCS), OU
- Dr. S. Lakshmivarahan, George Lynn Cross Research Professor of Computer Science, OU
- Dr. Lance M. Leslie, Robert E. Lowry Chair and George Lynn Cross Professor of Meteorology, OU
- Dr. Donald R. MacGorman, Research Physicist, Convective Weather Research Group, NSSL, CIMMS Resident Fellow, and Affiliate Professor of Meteorology and of Physics and Astronomy, OU
- Mr. Ed Mahoney, Chief, WDTB
- Dr. Edward Mansell, Research Scientist, NSSL
- 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
- Dr. Robert Rabin, Research Scientist, NSSL
- 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. Russell Schneider, Director, SPC
- Dr. David Schultz, Professor of Experimental Meteorology, University of Helsinki, Finland
- Dr. Alan M. Shapiro, American Airlines 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, Professor of Meteorology, OU
- Dr. Aondover A. Tarhule, Chair and Associate Professor, Department of Geography and Environmental Sustainability, OU
- Dr. Susan Van Cooten, Research Meteorologist, NSSL
- Dr. Baxter E. Vieux, Brandt Professor and Presidential Professor of Civil Engineering and Environmental Sciences, and Director, Center for Natural Hazards and Disaster Research, OU
- Mr. Richard Vogt, Director, ROC
- Dr. Xuguang Wang, Assistant Professor of Meteorology, OU
- 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 Professor of Meteorology, OU
- Dr. Mark Yeary, Associate Professor of Electrical and Computer Engineering, OU
- Dr. Tian-You Yu, Associate Professor of Electrical and Computer Engineering, OU
- Dr. May Yuan, Brandt Professor and Edith Kinney Gaylord Presidential Professor of Geoinformatics, 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. Jian Zhang, Research Hydrometeorologist, NSSL
- 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



RESEARCH PERFORMANCE

Weather Radar Research and Development

NSSL Project 2 – Hydrometeorology Research

NOAA Technical Leads: Jian Zhang (NSSL), Kenneth Howard (NSSL)

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

Funding Type: CIMMS Task II

Objectives

Hydrometeorology Research objectives center on dual polarized radar and quantitative precipitation estimations (QPEs). Specifically:

- Evaluate the improvements in accuracy of precipitation estimates using dual-polarization radar parameters
- Enhance S-band single-polarization radar QPE and develop an optimal mosaic scheme for combining observations from S-band and C-band radars for the Taiwan Central Weather Bureau and Water Resources Agency
- Improve the quality of the base reflectivity fields for the Canadian radar networks
- Improve the quality of the base reflectivity fields for the WSR-88D network by removing Bloom/AP (anomalous propagation) clutter remove and mitigating non-standard beam blockage
- Improve the Seamless Hybrid Scan Reflectivity algorithm for better QPEs
- Evaluate possible improvements to radar based QPEs using satellite radar

Accomplishments

1. Evaluating Dual Pol Precipitation Estimates Using the Q2 Verification System

Brian Kaney (CIMMS at NSSL), Carrie Langston (CIMMS at NSSL), Steve Vasiloff (NSSL)

During the fiscal year, several single radar data products relevant to the evaluation of the WSR-88D's new dual polarization based precipitation estimating capabilities were fully incorporated into the Q2 Verification System (QVS). The QVS is a sophisticated suite of web applications for investigating weather data in both real time and in a long-term archive in a simple uniform manner.

In the previous fiscal year, initial work was done on a test machine with a few case studies and the real-time stream for a single radar. By the end of this fiscal year about 65 radars with dual pol data were entering the system. Since the QVS had previously only dealt with products defined on a Cartesian grid, a great deal of re-tooling was

needed to draw images and handle the menu navigational issues associated with single radar polar data. Single tilt based products added another level of complexity. In all about seven major new products were added. Four involve a single file per volume scan; the hydrometeor classification flag (HHC), the legacy hybrid scan reflectivity (DHR based HSR), the legacy precipitation estimate (DHR based PPS), the new dual pol precipitation estimate (DPR) and then three are tilt based; the differential reflectivity (ZDR), the specific differential phase (KDP), and the correlation coefficient (CC).

One of the strengths of the QVS is that it is supported by vast file storage resources. All the dual pol data we ingest are available at the click of a mouse whether minutes old or going back to the beginning of the archive months (and eventually years) ago. The QVS provides access to this huge archive with a simple and quick set of navigational tools for choosing regions and times of interest. All the dual products can be viewed on a map at any desired level of detail; as illustrated in the three sample panels in Figure 1.

A unique feature of the QVS is the Time Series tool. Any point in the continental US can be selected (by clicking on a map or entering coordinates or picking gauge locations) and then the data for a time series plot can be extracted for that point. The time series duration can range from 2–24 hours and can consist of plots of up to four of the variables stored by the system (five plots counting the hourly gauge amounts, if the location is specified by gauge location). Plots can be a mix of any of the single radar products mentioned above (and not confined to the same radar, although the radars must all have coverage at the point in question) along with mosaic reflectivity, precipitation, severe weather and model fields previously available in the QVS system. Again, the time series can cover any period in the archive. Figure 2 shows an example with a gauge near Tampa, FL and the 24 hour period ending 1200 UTC 25 June 2012. The Q2 precipitation mosaic value is shown along with the HHC, PPS and DPR single radar products for KTBW.

The primary focus of the QVS has always been on precipitation fields. Another possible image type is a difference field between two different precipitation fields. The three panels in Figure 3 show comparisons between the dual pol estimates of KTBW and KMLB (where they overlap), and between KTBW's dual pol and legacy precipitation products and finally between the KTBW dual pol and our groups Q2 radar only mosaic.

A key component of the QVS is the ability to lookup values from a precipitation estimate field to compare with co-located gauge reports. Scatter plots of the resulting gauge/QPE pairs can be made. Also maps can be made that show each gauge as a circle whose size codes for the gauge amount and that is color coded for the gauge/QPE bias value. Warm colors indicating a QPE that is too dry compared to the gauges and blues indicating a QPE that is too wet compared to gauges. A suite of statistics is generated from the scatter plot data pairs as well. These include maxima, average and minima values, average bias, average error, root mean square error, correlation coefficient, and contingency table functions for various yes/no event thresholds. The stats automatically adjust for the level of zoom selected and additional masking of regions can also be done. Amount thresholds for both the gauge and QPE

amounts can be applied independently as well as a 'distance from the radar' cut-off imposed. And then finally, arbitrary individual gauges can be removed from consideration via manual QC by the user simply clicking on the scatter plot point for that data pair. See Figure 4.

The design of the QVS attempts to balance this wealth of analysis options with an intuitive and easy to use navigational interface. Some relatively new techniques in coding web applications were explored to enhance the user's access to the data. The growing number of tabs in the traditional multi-tab QVS resulted in the inability of users to access all the desired onscreen elements at once. A new 'widescreen' version of the web tools was developed that takes advantage of the expanded 'screen real estate' of the increasingly common large flat panel monitor. This version combines all the key features of 3 or 4 QVS tabs into a single display were everything shows at once.

The dual pol products used for this evaluation are obtain in real-time via the NOAAPORT LDM data stream of Level III data. As products arrive, they are decoded and reformatted such that they are readable by QVS. In addition to decoding, the DHR product is used to derive a precipitation rate field. This DHR rate and the DPR product are used to derive 1 and 24-hour QPEs. Currently, 3 HP servers process 64 dual pol radars. Additional radars (and servers) will be added as more dual pol radars come on-line. This work is ongoing.

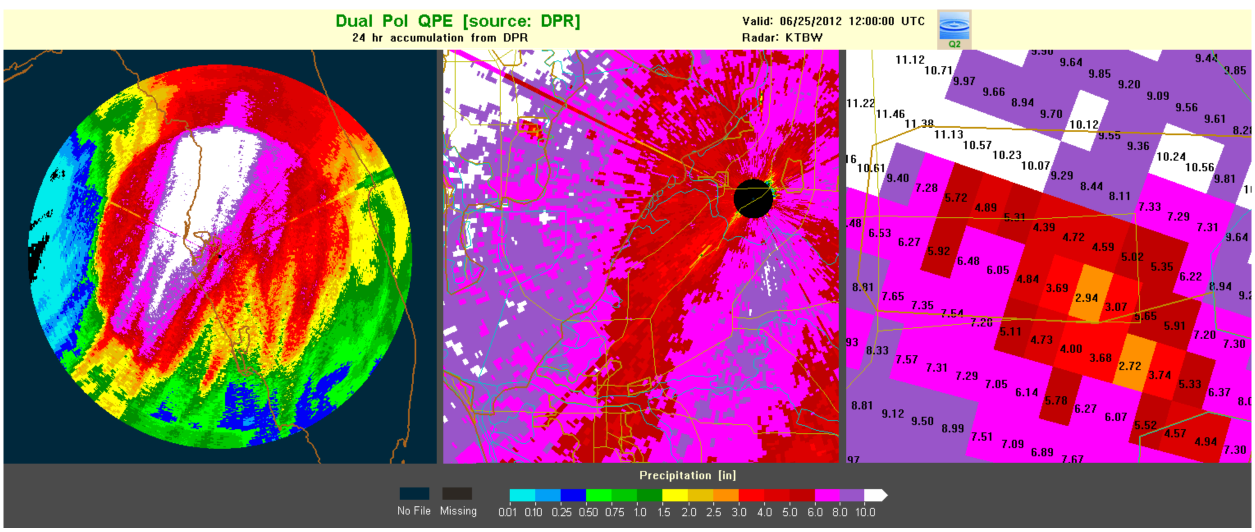


Figure 1. Three panels adapted from QVS imagery illustrating the wide level of zoom possible when examining the data. The specific event shown is central Florida during tropical storm Debby, 25 June 2012.

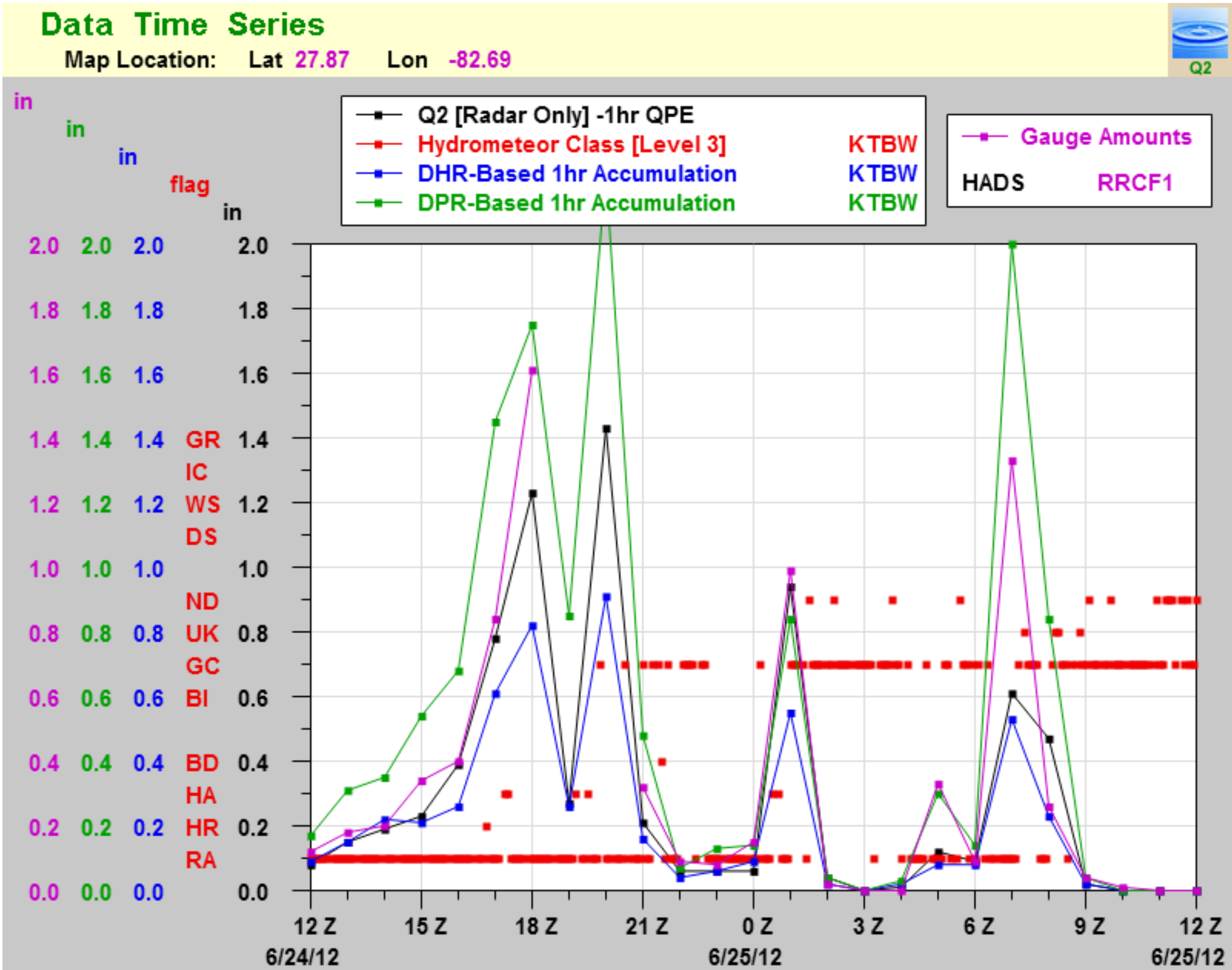


Figure 2. Sample time series plot from the QVS. Data is plotted for a location in central Florida for the 24 hrs ending 1200 UTC 25 June 2012. Up to four variables can be plotted together from any of the fields archived by the QVS system.

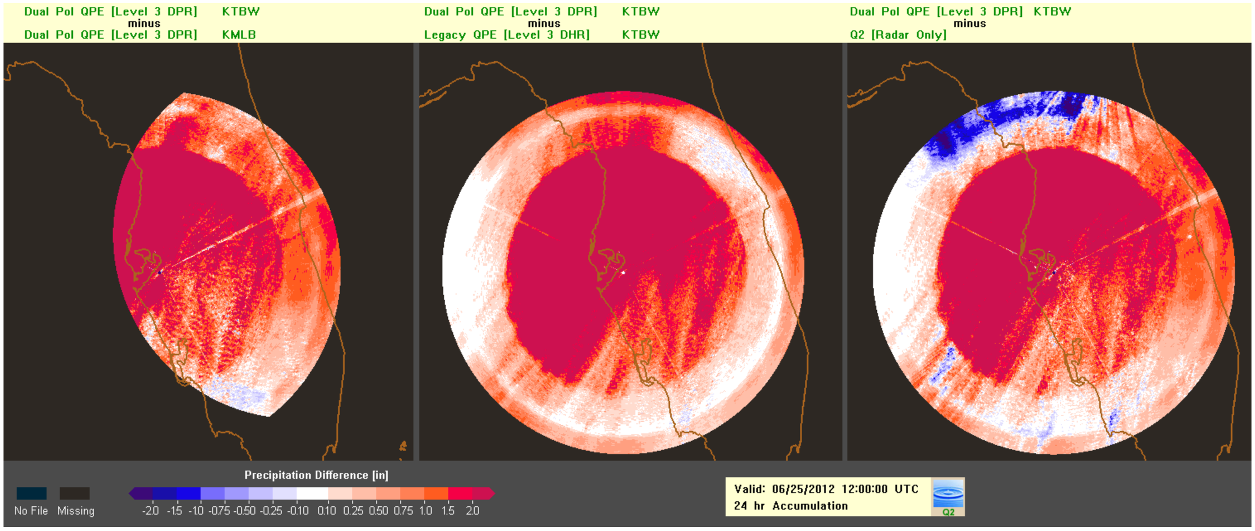


Figure 3. Three panels adapted from QVS imagery showing samples of precipitation difference fields. Left: dual pol precipitation at KTBW vs. the same from KMLB, center: KTBW dual pol vs. KTBW legacy precipitation fields, and right: LTBW dual pol vs. our groups Q2 radar only mosaic.

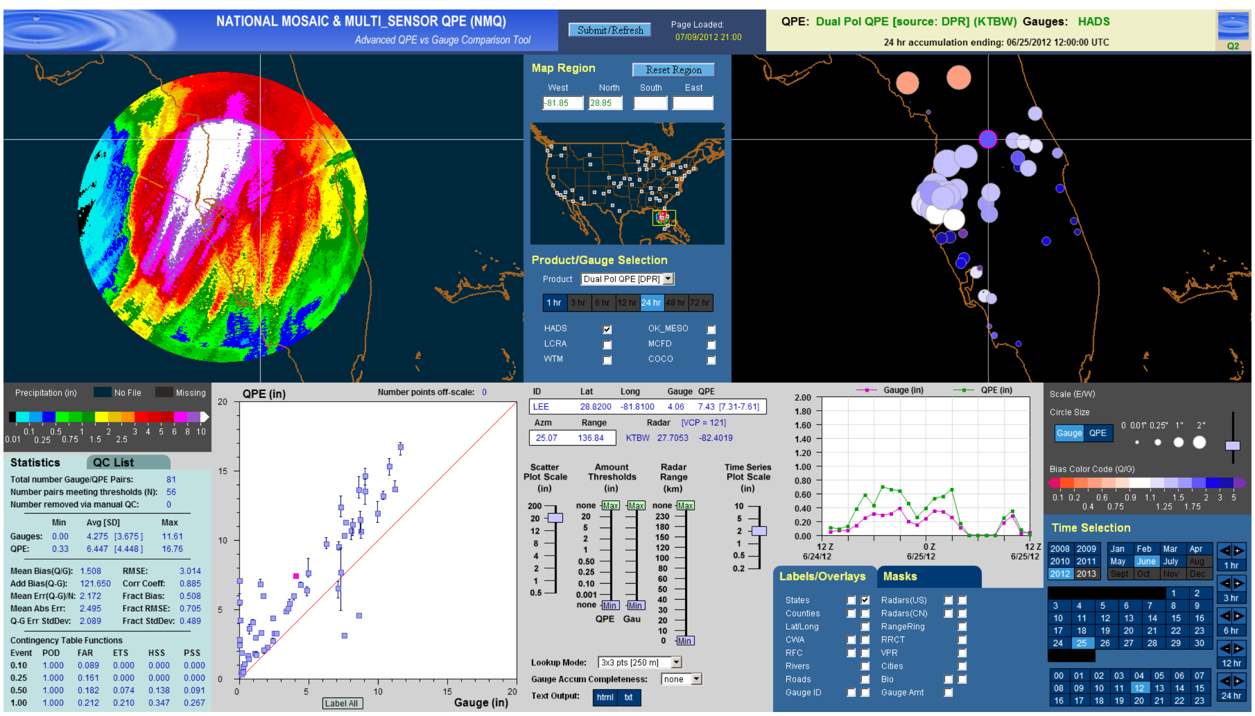


Figure 4. Screen shot of the latest QVS tool referred to as the 'Advanced QPE vs. Gauge Comparison Tool'. A precipitation field product map, a gauge circle map color coded for bias, a scatterplot, statistics and a time series (for whatever gauge is selected by mouse hover over event) can all be seen at once for an event of interest.

2. Evaluating Dual Pol Precipitation Estimates vs. the Legacy Precipitation Processing System

Kim Elmore (CIMMS at NSSL), Steve Vasiloff (NSSL)

During 2012, the primary goal was to compare polarimetric radar quantitative precipitation estimation (DP QPE) to the prior legacy precipitation processing system (PPS) QPE algorithm. The question that needed to be answered centered on whether the DP QPE algorithm was significantly (in a statistical sense) better than the PPS QPE algorithm. To that end, errors between storm total precipitation rain gauge amounts are compared between the DP and PPS QPE algorithms in both a bias sense as well as in a root-mean-square error (RMSE) sense.

In total, 4133 radar-gauge (RG) pairs are extracted by the Radar Operations Center (ROC) staff from the KOUN, KVNX, KICT, and KMHX radars over 16, 16, 11, and 10 cases, respectively. These radars are chosen because they are among the earliest radars to be upgraded to polarimetric capability. Due to spatial correlation between radar-gauge each pair could not be treated as an independent error source but instead had to be grouped within events. In some cases, two radars shared some of the same events, (such as KOUN and KVNX) but the errors from each case are considered to be independent from case to case.

Because the above considerations define radar-case pairs (instead of radar gauge pairs) as the fundamental sampling element, the number of cases is considerably smaller than the number of RG pairs. Even so, the number of cases is sufficient for an overall assessment of DP QPE compared to PPS QPE, though the data set is insufficient for a radar-by-radar assessment. To assess the statistical difference between the DP and PPS QPE, a matched-pairs, Monte Carlo form of Fisher's Exact Permutation Test is implemented using 3000 permutations. Some assessment of each radar's contribution is made using a leave-one-out analysis, wherein all cases from one radar are removed and the remaining data are reanalyzed to check the stability of any statistical inference (a form of jackknife analysis). In addition, cases are separated into "warm" and "cool" seasons, where warm-season cases are April to September and cool-season cases are October through March. Even with the small number of cases available, some compelling statistics result.

Overall, the DP QPE displays significantly less bias (at the $p = 0.05$ threshold) and smaller RMSE than the PPS QPE. However, there is some range dependence that appears keyed to the range at which the lowest elevation scan intersects the freezing level. In particular, while DP QPE has a significantly smaller bias and lower RMSE than PPS QPE at ranges inside the freezing level range, the improvement is even greater at ranges beyond the freezing level.

Some radar-dependent variability was noted within the jackknife analysis, but the nature of the variability remains unknown. Meaning, it is unknown whether the variability results from something different about the radar or from some pathological characteristic in

the available cases (e.g., cases dominated by virga). The 2011-2012 precipitation seasons have been climatologically anomalous and so assessments of individual radars must await more data.

A final report, due out in the near future, is being prepared within the ROC and will provide in-depth detail of these statistical comparisons.

3. QPE Scheme for Merging Observations of Radars Operating at Different Wavelengths

Yadong Wang (CIMMS at NSSL), Carrie Langston (CIMMS at NSSL), Jian Zhang (NSSL), Kenneth Howard (NSSL)

During the year of 2011-2012, the main effort was focused on the refinement of the R-Z relations for the S-band single-polarization radars in Taiwan. Three R-Z relations were implemented on the S-band single-polarization radars; stratiform, convective and tropical precipitation. However, these three relations were derived for continental precipitations, which have different drop size distribution (DSD) and drop shape relations (DSR) from maritime precipitations, as in Taiwan. The R-Z relations in Taiwan were optimized using the data collected by four Joss-Waldvogel Disdrometers (JWD) located in north of Taiwan. The new derived R-Z relations were tested with various precipitation types including winter, typhoon, and monsoon precipitations. Significant improvements resulted from the newly derived R-Z relations. This is especially true for those precipitation events underestimated by the old R-Z relations. Figure 5 provides an example of improved QPE using the new R-Z relations.

Taiwan's radar network includes both S-band single-polarization and C-band dual polarization radars. Both radar types are used to create single radar rain rate fields, which are later mosaicked to create multi-radar rate and QPE products. The original mosaic scheme assumed all rate fields have the same accuracy; no matter the radar type. Assessments of the S- and C-band QPEs for several heavy rain events indicated that the C-band radar rate field is more accurate than the S-band radar. Therefore, a new mosaic scheme was developed such that more weight is given to C-band radars when merging them with S-band. Using the new mosaic scheme, the advantages of C-band dual-polarization radars can be fully utilized to improved QPE accuracy. This work is ongoing.

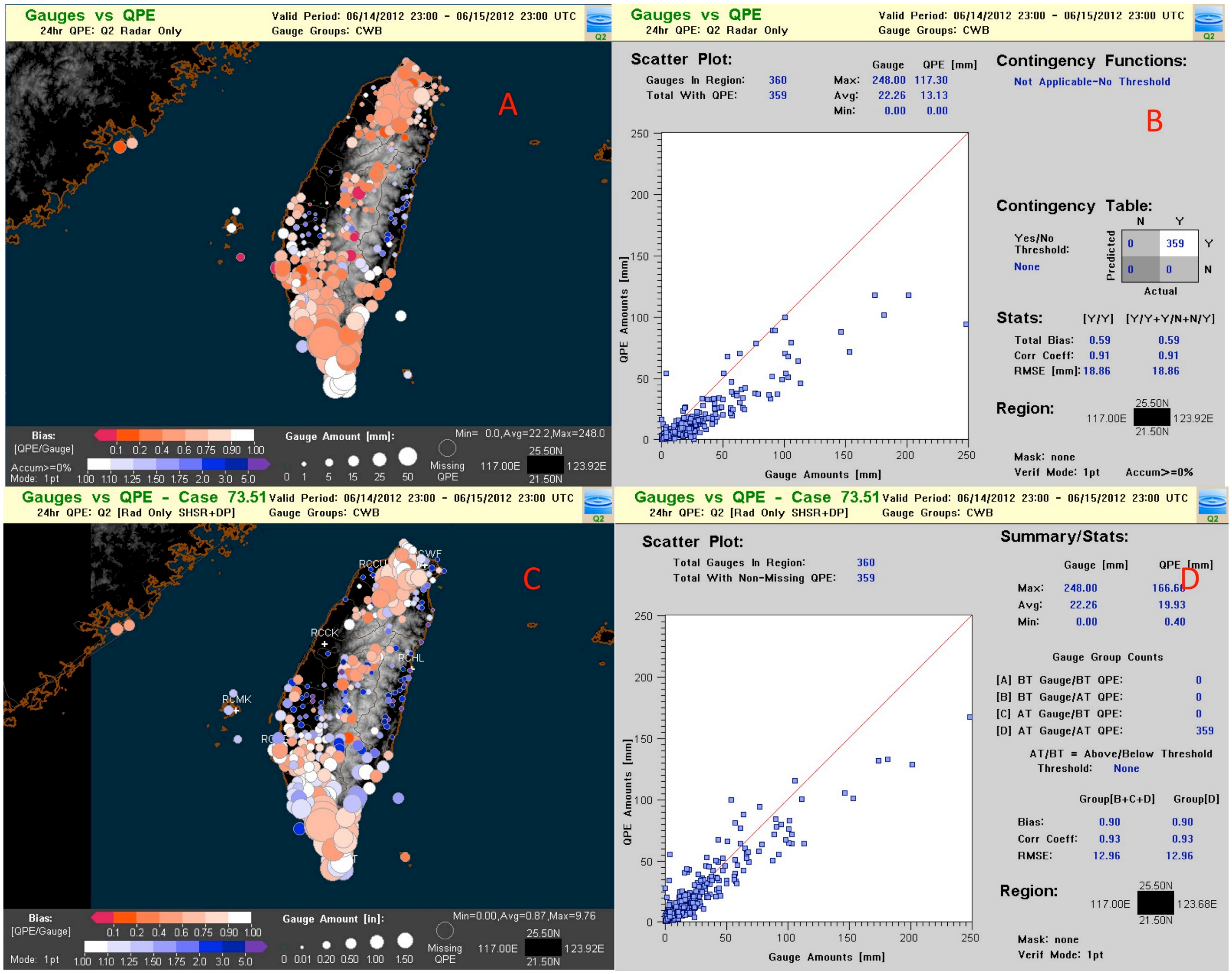


Figure 5. Comparison of accumulated rainfall using old (panel A and B) and new (panel C and D) R-Z relations. 24 hours of data (ending 2300 UTC 15 June 2012) were used in this example. The bubble charts (A and C) show bias ratios between the QPEs and independent gauge observations, where the size of the circles represents the gauge observed rainfall amount and the color shows the bias. The scatter plots (B and D) show distributions of the 24-hour radar QPEs vs. gauge observations. Improved QPE is obtained from the new R-Z relations in terms of more close to "1" bias ratio (0.90 vs. 0.59), more close to "1" correlation coefficient (0.93 vs. 0.91), and more close to "0" root mean square error (12.96 mm vs. 18.86).

4. National Radar Mosaic and Quantitative Precipitation Estimation (NMQ) – Reflectivity Quality Control for the Canadian Radar Networks

Lin Tang (CIMMS at NSSL), Carrie Langston (CIMMS at NSSL), Jian Zhang (NSSL), Valliappa Lakshmanan (CIMMS at NSSL)

NMQ quality controls Canadian radar data, in part, by applying clutter maps, which are used to remove persistent or semi-persistent ground clutter. The Canadian network

changes each radar's volume coverage plan (VCP) twice a year, winter and summer. Ground clutter maps will change if scan strategies are altered. Thus, two sets of maps are required for Canadian radars (summer and winter). Work from the previous year generated summer clutter maps for Canada. Activities during this period were focused on the creation and installation of winter clutter maps for 30 Canadian radars, based on reflectivity observations.

Using the same methodology that was applied for the summer scans, the winter clutter maps were created for every elevation angle for each of the 30 radars. The resulting winter maps differ slightly from the summer maps due to seasonal changes and different VCPs.

The winter clutter maps are able to effectively mitigate the strong echoes from persistent ground clutter during clear weather conditions and winter storm precipitation. Figure 6 is a set of cropped images from the NMQ real time system with and without clutter maps applied. The clutter echoes surrounding radars XPG and WHG are successfully removed during clear-air weather conditions. The application of the clutter maps greatly reduces the number of erroneously high QPE values caused by persistent strong echoes from ground clutter.

The winter clutter maps were installed on the NMQ real time system in early November 2011. This work is ongoing.

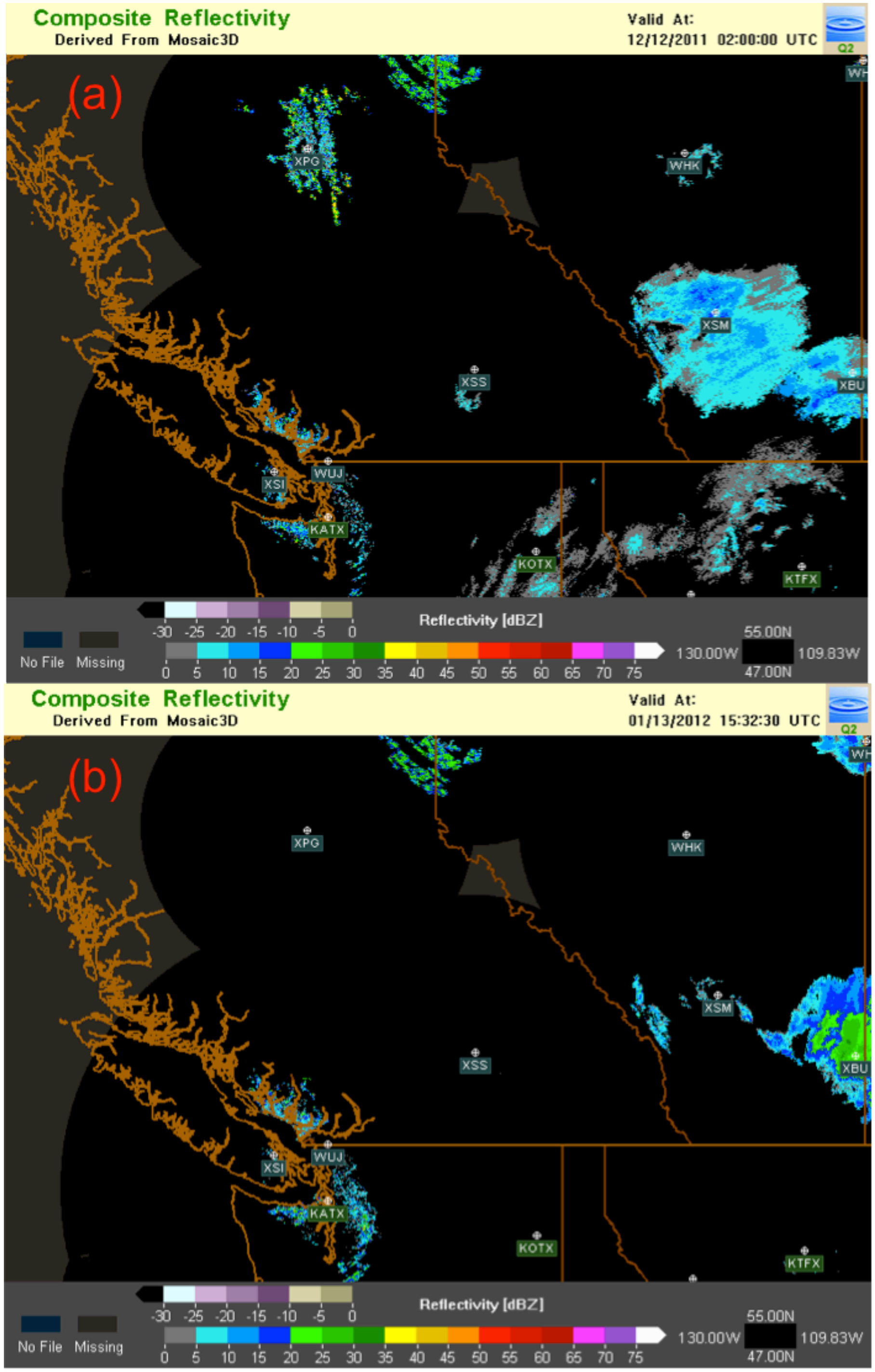


Figure 6. Reflectivity echoes of persistent ground clutter for the Canadian/US West coast before (a) and after (b) the implementation of the clutter maps for winter VCPs. Images from 0200 UTC 12 December 2011 during clear air conditions.

5. National Radar Mosaic and Quantitative Precipitation Estimation – Radar Bloom and Anomalous Propagation Quality Control

Lin Tang (CIMMS at NSSL), Jian Zhang (NSSL), Carrie Langston (CIMMS at NSSL), Valliappa Lakshmanan (CIMMS at NSSL), Kenneth Howard (NSSL)

The Bloom and Anomalous Propagation Quality Control algorithm (BloomAPQC) was developed to address two issues affecting the radar QPE; ground clutter due to anomalous propagations and non-precipitation echoes due to insects and migrating birds. This scheme includes multiple steps of tilt test, entity test and spectrum test to classify and clean up biological and AP echoes from stratiform and convective precipitation using base level radar reflectivity data.

Continuing the work from the previous year, more case studies were performed to test the scheme during this research period. The automated algorithm was refined to reduce the false alarm rate of the clutter detection. It was implemented on the NMQ real-time system in February 2012 as an additional quality control step.

Figure 7 provides an example of bloom clutter for radar KMAF. Figure 7a, shows the asymmetric shape of the strong power return that might be mistaken for precipitation, 7b shows the new scheme is able to identify the clutter and completely remove them, and 7c shows the satellite infrared field to prove the echoes were clutter. This work is ongoing.

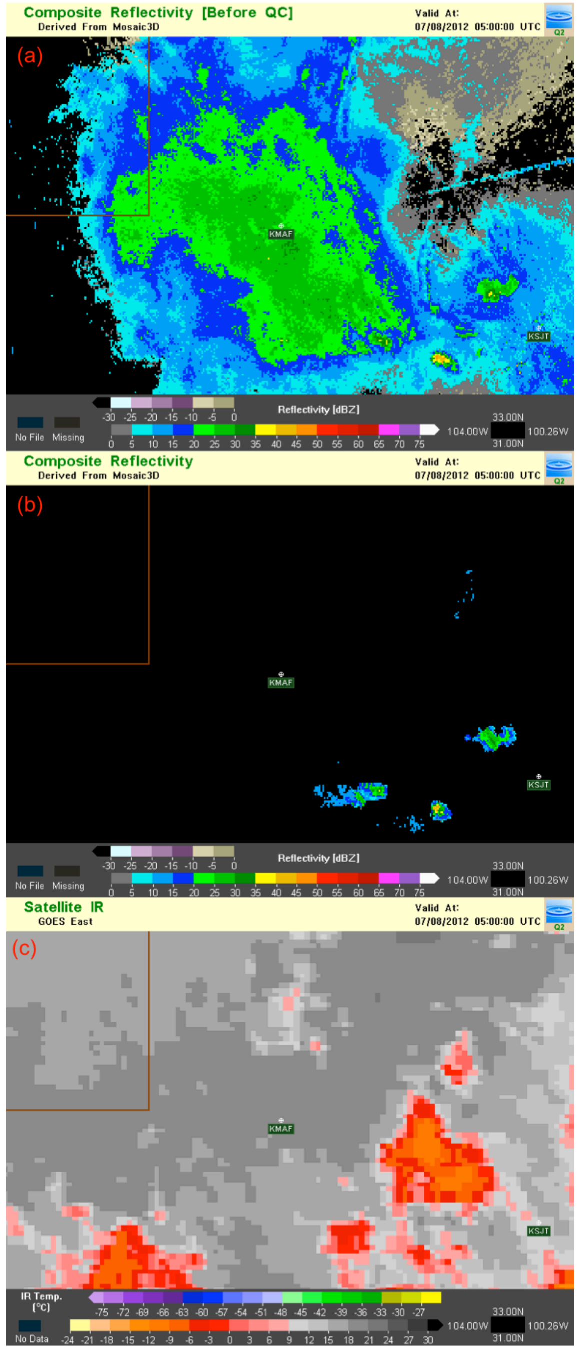


Figure 7. (a) The clutter echoes from migrating birds near KMAF during clear air weather conditions; (b) The BloomAPQC algorithm is able to identify the bloom clutters and remove them; (c) The satellite infrared information at that moment. Images from 0500 UTC 8 July 2012.

6. National Radar Mosaic and Quantitative Precipitation Estimation – Non-Standard Blockage Mitigation

Lin Tang (CIMMS at NSSL), Carrie Langston (CIMMS at NSSL), Youcun Qi (CIMMS at NSSL), Jian Zhang (NSSL), Kenneth Howard (NSSL)

In fields of radar based accumulated precipitation, artificial gaps or sharp discontinuities along the radial direction are often caused by terrain blockage (standard blockage) or outdated blockage information. Non-Standard Blockages (NSB) are undocumented blockages (e.g., buildings, trees) that lead to discontinuities in the hybrid reflectivity scan, which directly affect radar based QPEs. To help mitigate the effects of NSB on QPEs, a series of NSB reference tables were created. These tables are used to recover the continuous characteristic of real precipitation fields.

The reference tables define areas of NSB and also provide a method for mitigating them. The following actions may be applied to the hybrid scan generally based on the blockage-sector size and also the unique characteristics of individual cases:

1. Cross-azimuth interpolation
2. Use data from higher tilts for hybrid scan
3. Apply azimuthal or radial smoothing across tilt boundaries in the hybrid scan

The NSB reference tables were manually created for each radar by examining radar based QPEs for discontinuities. Observed NSB can change with different volume coverage patterns (VCP). Thus, one table is needed for each radar for each VCP. Approximately 60% of all the US WSR-88D radar-VCP pairs have a NSB table at this time. Note these tables are based on single pol data, and were installed on the real time NMQ system in mid June 2012.

The NSB characteristics for a radar differ between single and dual pol data. This is due to different terrain blockage files used for single and dual pol applications and different criterion for addressing partially blocked beams. For example, the information obtained from a radar bin with over 50% blockage is considered meaningless for single polarization radars. In such cases, the information from a higher tilt is used instead. For dual pol radars, the blockage threshold is 70%. Figure 8 shows the accumulated QPE for selected storms on single polarization radar KGWX (8a and 8b) and dual polarization radar KAMA (8c and 8d) before and after the application of NSB mitigation. It is demonstrated that NSB mitigation is effective in mitigating discontinuities in the QPE field due to inaccurate terrain information and the use of the echoes from various tilts in the hybrid-scan field. This work is ongoing.

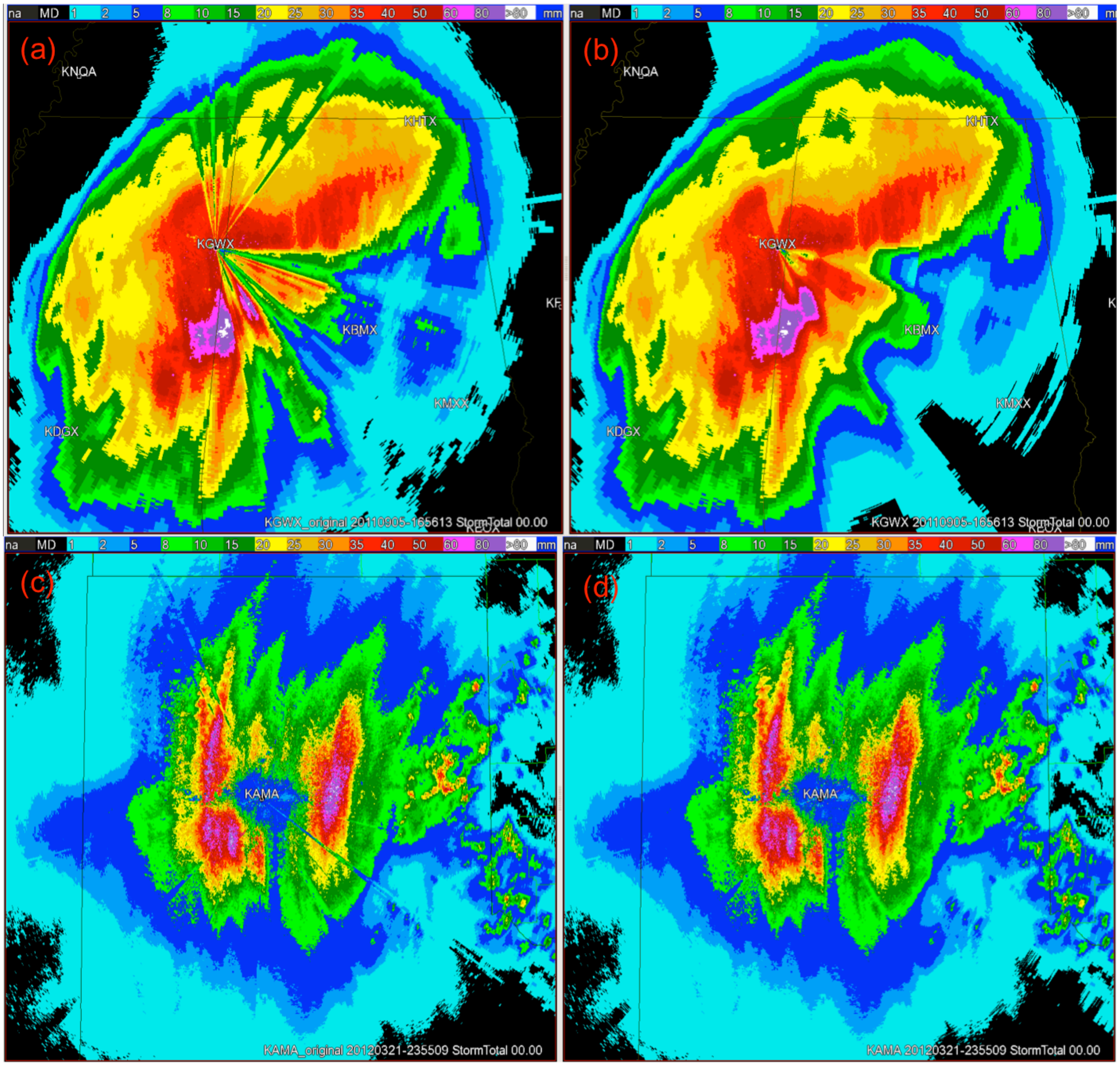


Figure 8. Accumulated precipitation fields for single pol radar KGWX (a, b) at 1656 UTC 5 September 2011 and dual pol radar KAMA (c, d) at 2355 UTC 21 March 2012. Fields show before (a, c) and after (b, d) the application of NSB tables.

7. National Radar Mosaic and Quantitative Precipitation Estimation – Seamless Hybrid Scan Reflectivity Algorithm

Youcun Qi (CIMMS at NSSL), Carrie Langston (CIMMS at NSSL), Jian Zhang (NSSL), Kenneth Howard (NSSL)

Radar QPEs are commonly calculated from the lowest radar bins that are not significantly blocked. Those bins constitute a 2-D polar grid called "hybrid scan". The

reflectivity values in partially blocked bins are adjusted to compensate for the amount of power blockages. However, the compensation is not sufficient when the radar wave propagates differently under super-refractive conditions. This often results in discontinuities in radar rainfall accumulations over a period of time (e.g., several hours).

The Seamless Hybrid Scan Reflectivity (SHSR) algorithm was developed to mitigate discontinues in the hybrid scan based on known standard blockages (e.g., terrain). However, undocumented non-standard blockages (e.g., buildings, trees) continue to be a problem. To mitigate these blockages, a series of non-standard blockage mitigation (NSBM) tables was created (see part 6), and new techniques were developed to address them. Sectors with non-standard blockage are updated with an upper tilt or undergo linear interpolation or smoothing. The new NSBM algorithm has largely reduced discontinuities caused by blockages, as shown in Figure 9.

The improved SHSR algorithm was installed on the real time NMQ system in mid June 2012.

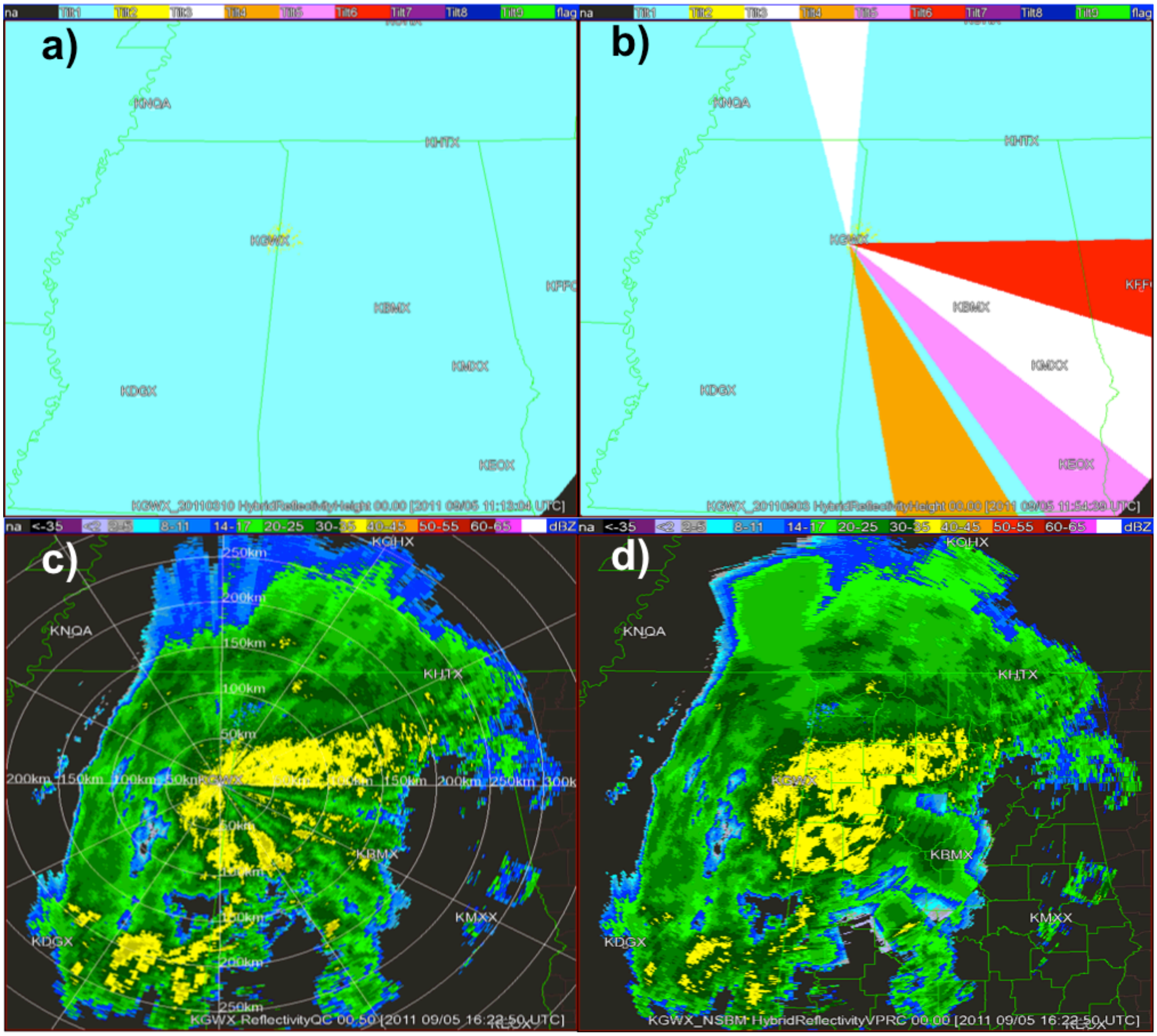


Figure 9. A hybrid scan tilt: a) containing standard blockages and b) standard plus non-standard blockages; reflectivity: c) before VPR correction with the standard hybrid scan tilt and d) after VPR correction with new non-standard hybrid scan tilt (NSBM).

8. Ground Radar Based QPE Improvement Using Satellite Radar Data

Youcun Qi (CIMMS at NSSL), Jian Zhang (NSSL), Kenneth Howard (NSSL)

A new vertical profile of reflectivity (VPR) correction algorithm based on Tropical Rainfall Measuring Mission Precipitation Radar (TRMM PR) observations was developed to improve existing VPR correction methodologies. The TRMM PR observations were converted from Ku-band to S-band based on the empirical polynomial relations between Ku- and S-band radar reflectivity.

The new correction scheme was tested on three meso-scale convective system (MCS) precipitation events from different geographical regions in the United States and was compared against VPR corrected results using the technique described in Zhang and Qi 2010 (ZQ10). The TRMM based technique showed improvement in areas where the bright band (BB) affected radar QPE. The improvement is mainly due to the more accurate VPRs derived from TRMM. This is especially true for areas below the BB peak or BB bottom. Figure 10 and 11 show the comparison results of ZQ10 and TRMM based VPR correction schemes. This work is ongoing.

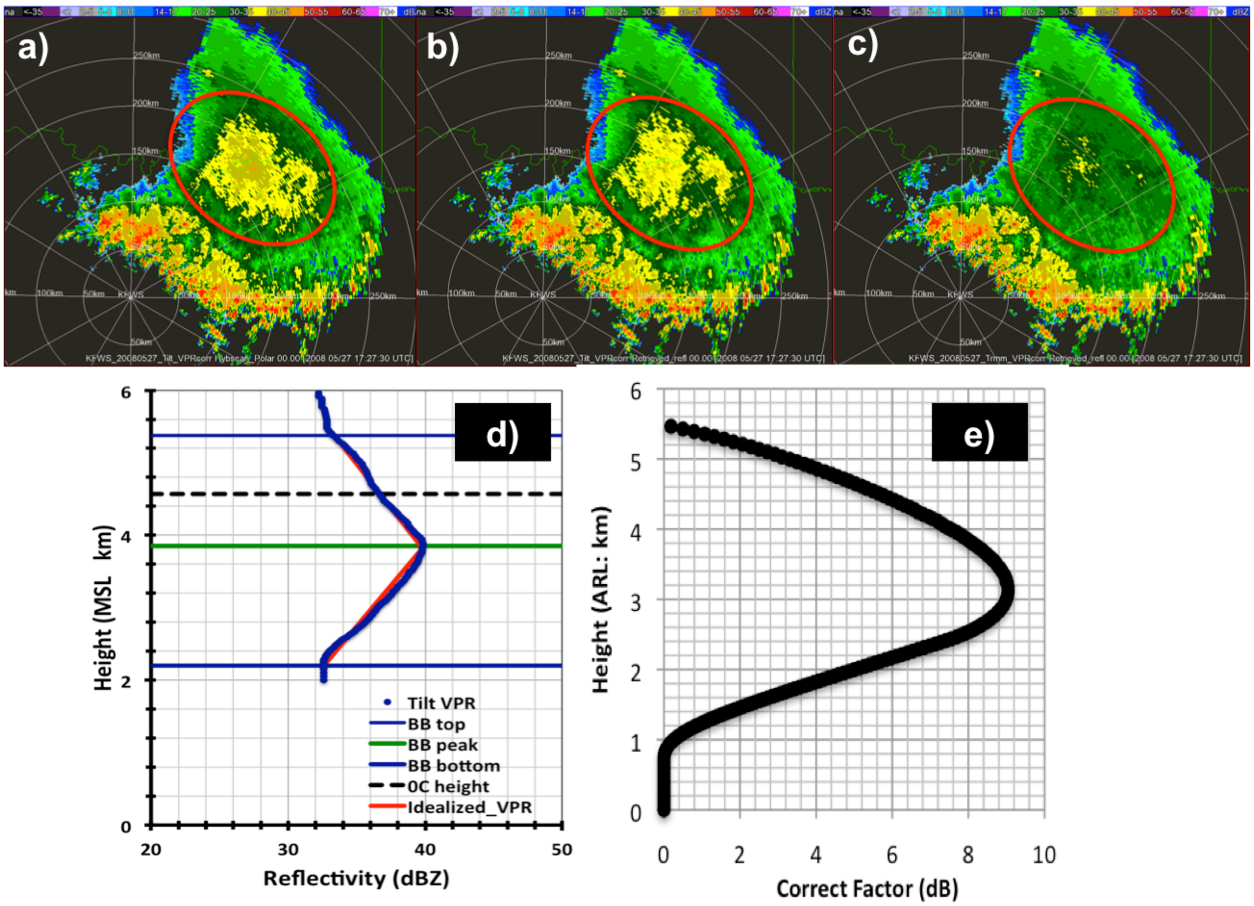


Figure 10. Base level reflectivities 0.5^o: (a) before apparent vertical profile of reflectivity (AVPR), (b) after the AVPR correction with ZQ10, and (c) after the VPR correction with new TRMM VPR correction. These images are from KFWS at 1727 UTC 27 May 2008. d) the AVPR derived from (a) with ZQ10, and (e) Reflectivity correct factor.

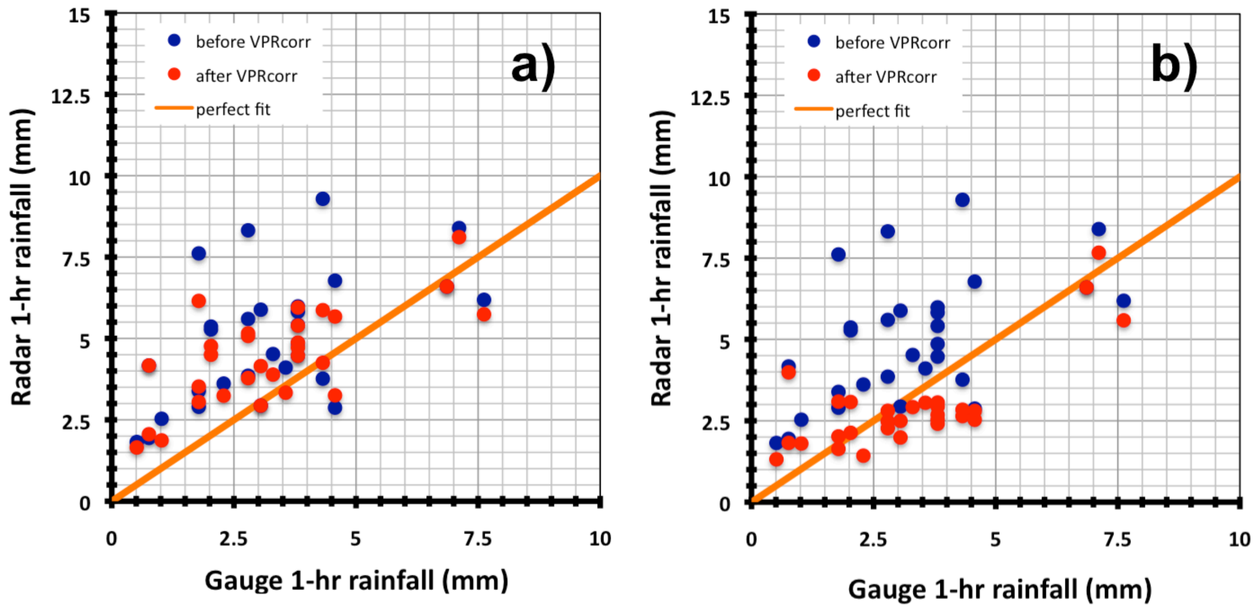


Figure 11. Scatter plots of hourly radar precipitation estimates versus gauge observations before (blue dots) and after (red dots) a VPR correction using the ZQ10 (a) and the new TRMM (b) methods. The data are from KFWS 1300–2000 UTC 27 May 2008.

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Van Cooten, S., K. Kelleher, K. Howard, J. Zhang, and Coauthors, 2011: The CI-FLOW Project: A system for total water level prediction from the summit to the sea. *Bulletin of the American Meteorological Society,* **92,** 1427-1442.

Zhang, J., K Howard, C. Langston, and Coauthors, 2011: National Mosaic and multi-sensor QPE (NMQ) system: Description, results and future plans. *Bulletin of the American Meteorological Society*, **92,** 1321-1338.

Zhang, J., Y. Qi, D. Kingsmill, and K. Howard, 2012: Radar-based quantitative precipitation estimation for the cool season in complex terrain: Case studies from the NOAA hydrometeorology testbed. *Journal of Hydrometeorology*, Accepted.

Zhang, J., Y. Qi, K. Howard, C. Langston, and B. Kaney, 2011: Radar Quality Index (RQI) – A combined measure of beam blockage and VPR effects in a national network. *Proceedings, International Symposium on Weather Radar and Hydrology*, IAHS Publ. 351-25.

Stormscale and Mesoscale Modeling Research and Development

Nothing to report here for the new cooperative agreement.

Forecast and Warning Improvements Research and Development

NSSL Project 5 – Hazardous Weather Testbed

NOAA Technical Leads: Jack Kain (SPC), Steve Weiss (SPC), David Andra (OUN)

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

Funding Type: CIMMS Task II

Objectives
Two major experiments were conducted in the HWT in 2012, both in May and June during the climatological peak for severe weather in the United States. These experiments brought together over 100 scientists and forecasters from NWS forecast offices, the Storm Prediction Center, CIMMS, NSSL, international weather services, universities, and other government agencies. These experiments are annual.

The Experimental Forecast Program's objective is to evaluate the utility of high-resolution ensemble forecast systems for convection initiation and severe storms by:

- Developing diagnostics and visualizations for convection initiation forecasting using object based methods for storm identification and transition detection; and
- Developing diagnostics and visualization for severe storms and their environments using object-based methods.

The Experimental Warning Program's objectives include testing and evaluating new applications, techniques, and products to support Weather Forecast Office (WFO) severe convective weather warning operations, including:

- Evaluation of 3DVAR multi-radar real-time data assimilation fields being developed for the Warn-On-Forecast initiative;
- Evaluation of multiple CONUS GOES-R convective applications, including pseudo-geostationary lightning mapper products when operations are expected within the Lightning Mapping Array domains (OK-TX, AL, DC, FL); and
- Evaluation of model performance and forecast utility of the OUN WRF when operations were expected in the Southern Plains.

Accomplishments

1. Forecasting Experiments

<u>*Severe Desk Component*</u> – Adam J. Clark (CIMMS at NSSL), Patrick Marsh (CIMMS at NSSL), Valliappa Lakshmanan (CIMMS at NSSL)

Object based identification of model storms and their environments was accomplished but the move to do this in real time during the forecast and evaluation process was not. This was due to insufficient computing resources (decoding and processing data took 6 hours and mostly was due incoming data format conversion) and adjustments will be made to remedy this issue leveraging NSSL resources. In a similar manner, a smaller 6-hour period of verification of the CAPS control member with versus without data assimilation (DA) was conducted in real time. The preliminary results show a lasting impact of the DA driven control member, verifying nearly 4 percent more convective storms than the without DA through 6 hours.

Additionally, using similar object based algorithms, a method to extract simulated storm reports focusing on Hourly Maximum Updraft Helicity to construct full period Day 1 probabilities of Severe weather was performed. This method was applied to 3 ensembles (CAPS, AFWA, and NCEP SSEO) and verified daily during the experiment. All three ensembles use vastly different strategies (e.g. radar data assimilation with NAM input, multiple global model forecast input, NAM input and different WRF and NEMS based dynamic cores) and could be tested head to head. Initial analysis of these data show:

- A strong relationship (correlation coefficients as high as 0.86) between the total path lengths of simulated rotating storms and the total path lengths of tornadoes was found by applying time-domain diagnostics to members of the Storm-Scale Ensemble Forecast system provided by the Center for Analysis and Prediction of Storms (CAPS) to the HWT.
- Based on the results from 1), visualization of simulated rotating storm tracks was developed and displayed in real-time during the 2012 EFP Spring Forecasting Experiment (see example in Figure 1).
- A technique based on time-domain diagnostics was used to diagnose attributes from observed rotating storm tracks from the 27 April 2011 tornado outbreak based on 5-minute analyses from a 1.25 km grid-spacing 3DVAR data assimilation system used for the 2010-2012 HWT Experimental Warning Program Real-time 3D Radar Data Assimilation Experiment.
- Time-domain diagnostics were developed to objectively identify convective initiation in models and observations. These CI-diagnostics were applied in real-time and used as both a forecasting and verification tool during the 2012 Spring Forecasting Experiment.

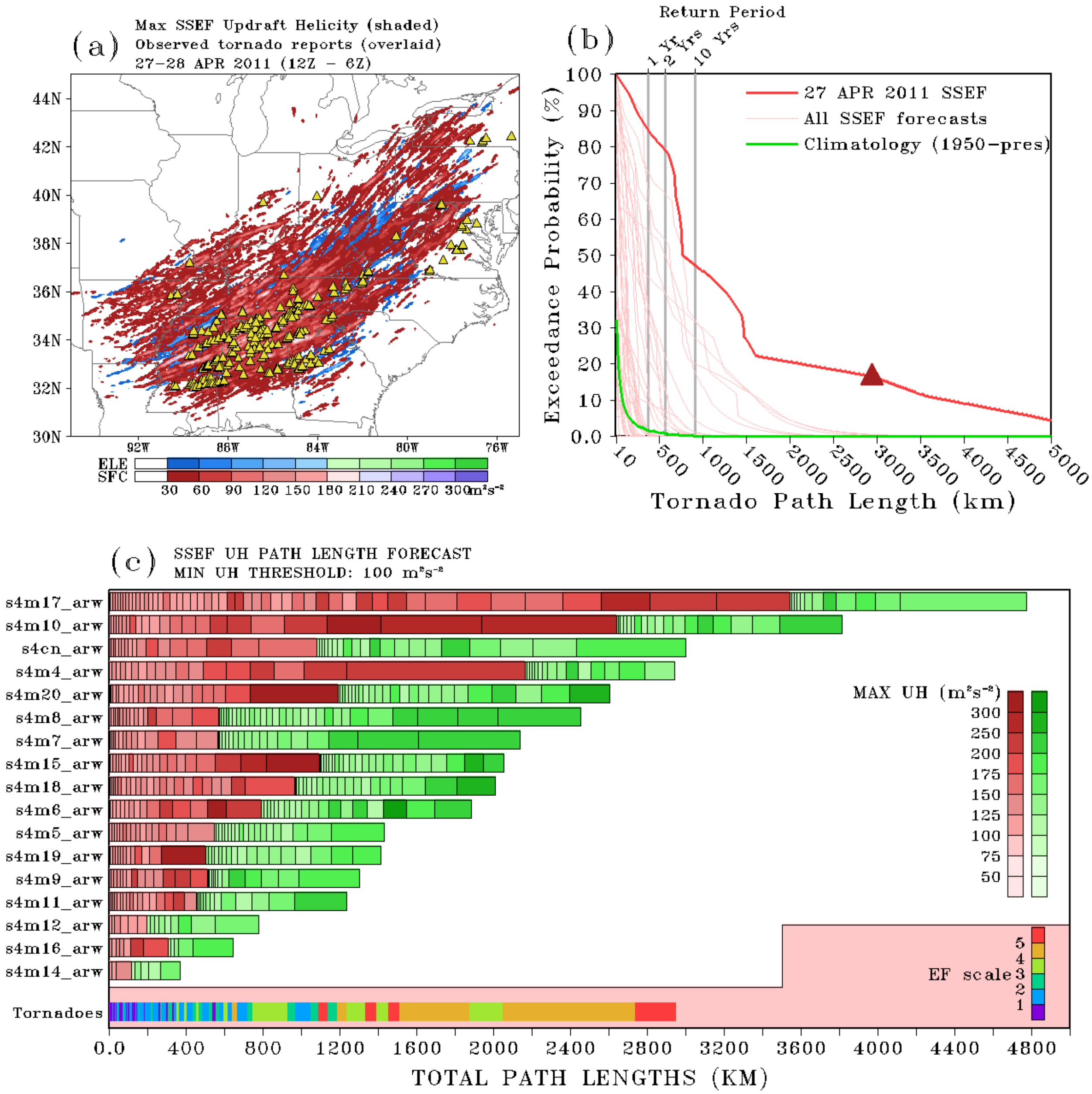

(a)
Max SSEF Updraft Helicity (shaded)
Observed tornado reports (overlaid)
27-28 APR 2011 (12Z - 6Z)
44N
42N
40N
38N
36N
34N
32N
30N
92W
88W
84W
80W
76W
ELE
SFC
30 60 90 120 150 180 210 240 270 300 m²s⁻²
(b)
Return Period
1 Yr
2 Yrs
10 Yrs
27 APR 2011 SSEF
All SSEF forecasts
Climatology (1950-pres)
Exceedance Probability (%)
Tornado Path Length (km)
10 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
100 90 80 70 60 50 40 30 20 10 0.0
(c)
SSEF UH PATH LENGTH FORECAST
MIN UH THRESHOLD: 100 m²s⁻²
s4m17_arw
s4m10_arw
s4cn_arw
s4m4_arw
s4m20_arw
s4m8_arw
s4m7_arw
s4m15_arw
s4m18_arw
s4m6_arw
s4m5_arw
s4m19_arw
s4m9_arw
s4m11_arw
s4m12_arw
s4m16_arw
s4m14_arw
Tornadoes
MAX UH (m²s⁻²)
300 250 200 175 150 125 100 75 50
EF scale
5 4 3 2 1
0.0 400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800
TOTAL PATH LENGTHS (KM)

Figure 1 (a) Maximum UH from any SSEF system member initialized 0000 UTC 27 April 2011 for forecast hours 13 to 30 (valid 1200 to 0600 UTC 27-28 April). The red/purple shading scheme is for UH produced by surface-based storms, while the blue/green shading scheme is for UH produced by elevated and/or high-based storms. Tornado reports (yellow triangles) for the corresponding period are overlaid. (b) Exceedance probabilities as a function of total tornado path length computed from the distribution of SSEF member UH path length forecasts. The dark red line is for 27 April, the light red lines are for the 47 other cases in the dataset, and the green line is climatological exceedence probabilities computed from Storm Data for the period 1950 – 2011 (legend provided at top). The dark red triangle marks the actual total tornado path length for 1200 to 0600 UTC 27-28 April. (c) Total length of UH objects for each SSEF member using a minimum threshold of 100 m^2s^{-2}. The length of the individual colored bars that comprise each column indicate the length of each UH object for each member. The colors within these bars indicate the maximum value of UH within the corresponding object, with red/pink shades corresponding to objects produced by surface-based storms and green shades to objects produced by elevated and/or high-based storms (color bars provided on right side). The bars in the bottom column similarly indicate path lengths and maximum intensities, but for observed tornadoes where maximum intensities correspond to enhanced-Fujita scale ratings.

<u>Convection Initiation Component</u> – James Correia, Jr. (CIMMS at SPC), Patrick Marsh (CIMMS at NSSL)

Recent efforts in the NOAA HWT in Norman, OK have centered on how best to utilize convection-allowing ensembles to glean information regarding Convection Initiation (CI)/Convective Activity (CA). Building off results from the 2011 HWT Spring Forecasting Experiment (SFE), efforts in the 2012 SFE centered on using model reflectivity values at the -10C level to determine if a grid point was convectively active (dBZ >= 35) or not (dBZ < 35). Once CA grid points were identified two separate CI identification algorithms, one object-based and the other grid-point-based, were used to identify CI grid points. Once the CI grid points were determined for each member of the ensemble, various aspects of CI (e.g., timing, probability, evolution) were calculated and used as guidance for probabilistic forecasts of CI location and timing.

A multi-faceted strategy was developed for rigorous diagnosis of CI/CA, applied in a convection-allowing ensemble, and used to generate probabilistic guidance for experimental forecasts of the CI timing and location. This strategy was complex, requiring implementation in the WRF model of 1) simulated reflectivity calculations that were uniquely linked to different microphysical parameterizations, and 2) run-time diagnostic code that extracted simulated reflectivity fields using a sampling interval comparable to that of observed reflectivity (5 min). Outside of the WRF model, the ensemble output was ingested into sophisticated algorithms that determined the timing and location of CI points in all model runs. These data were further processed to generate probabilistic guidance for both the timing and location of CI (and CA). Finally, the guidance was presented to forecasters in a series of simple, easy to interpret displays that were used for preparation of probabilistic forecasts of CI and CA.

2. Warning Experiments

The NOAA Hazardous Weather Testbed's (HWT) Experimental Warning Program's (EWP) purpose is to integrate National Weather Service (NWS) operational meteorologists, and National Severe Storms Laboratory (NSSL) researchers to test new science, technologies, products, and services designed to improve short-term (0-2 hour) warnings and nowcasts of severe convective weather threats wherever they occur in the U.S. and worldwide. The EWP has been conducting these Spring Experiments at the National Weather Center in Norman, OK. This was the sixth year for EWP activities in the testbed. EWP2012 took place across five weeks (Monday – Friday), from 7 May through 15 June. There were no operations during Memorial Day week (28 May – 1 June).

Real-time operations were conducted across two shifts Monday through Thursday, with an end-of-week summary debriefing taking place on Friday. New for 2012, we added an extra training shift that was taken at the forecaster's office prior to their arrival to Norman. Also new for 2012 was the addition of an end-of-week national "Tales from the Testbed" Webinar hosted by the NWS Warning Decision Training Branch (Clarke Payne, Mark Sessing, and Steve Martinaitis – all CIMMS at NSSL). In addition, this was the first year of operations in the HWT using AWIPS2. Feedback was obtained from the forecasters during operations through the use of live blogging, online surveys, and post-event discussions.

Overall management of warning experiments was provided by Travis Smith (CIMMS at NSSL) and NWS Forecast Office relations and coordination was provided by Greg Stumpf (CIMMS at MDL).

Warn-on-Forecast Real-Time Three-Dimensional Data Assimilation (3DVAR) – Kristin Calhoun (CIMMS at NSSL), Chenghao Fu (CIMMS at NSSL), Travis Smith (CIMMS at NSSL)

A weather-adaptive three-dimensional data assimilation system was included in the Experimental Warning Program as a first step in the progress to a Warn-on-Forecast system. NWS forecasters were asked to incorporate the data in conjunction with single-radar and multi-sensor products in AWIPS-2 as part of their warning-decision process for real-time events across the United States. During the 2012 experiment, forecasters examined events in real-time each day, including tornadic supercells, severe squall lines, and multi-cell storms.

The product of 3DVAR analysis was available to forecasters at 1km horizontal resolution every 5 min, with a 4-5 min latency, incorporating data from the national WSR-88D network and the North American Mesoscale (NAM) model. Four different 200x200 km domains were used to run the 3DVAR program throughout the experiment; the location of each was determined by default via an automated algorithm that chose where severe weather most likely happened, but this process could be over-ridden by forecasters/scientists using a web-map interface. Initial products provided to the

forecasters included: vertical velocity, synthesized (or mosaic) reflectivity, vertical vorticity, and 3D wind vectors. Following feedback from early forecaster evaluations, additional products for updraft helicity and storm-top divergence (max-divergence above 8 km) were provided in 2012 experiments. The forecasters found the vertical vorticity, storm-top divergence, and updraft products the most useful for storm interrogation and quickly visualizing storm trends, often using these tools increase the confidence in a warning decision and/or issue the warning slightly earlier. See Figure 2.

The addition of AWIPS-2 during the 2012 experiment also allowed forecasters to overlay 3D wind vectors, barbs, or streamlines on other 3DVAR or radar products at multiple levels from near surface to storm-top. The 3DVAR analysis was most consistent and reliable when the storm mode was supercellular, though forecasters were still able to utilize the data in multiple scenarios. The analysis was also better when the storm of interest was in close proximity to one of the assimilated 88-D radars, or data from multiple radars were incorporated in the analysis. The latter was extremely useful to forecasters when helping to fill in the gaps of having to analyze multiple radars separately, especially where storms from one or more radars were in the "purple haze" of the range-folded obscuration. The largest hurdle for realtime use of 3DVAR or similar data assimilation products by forecasters is the data latency, as even 3-5 minutes reduces the utility of the products when new radar scans are already available. Future additions in the HWT include reducing the data latency, cycling the 3DVAR analysis to improve the estimates for other variables, like temperature, water vapor etc., and adding short term forecast (0-1 hour) as computational speed increases.

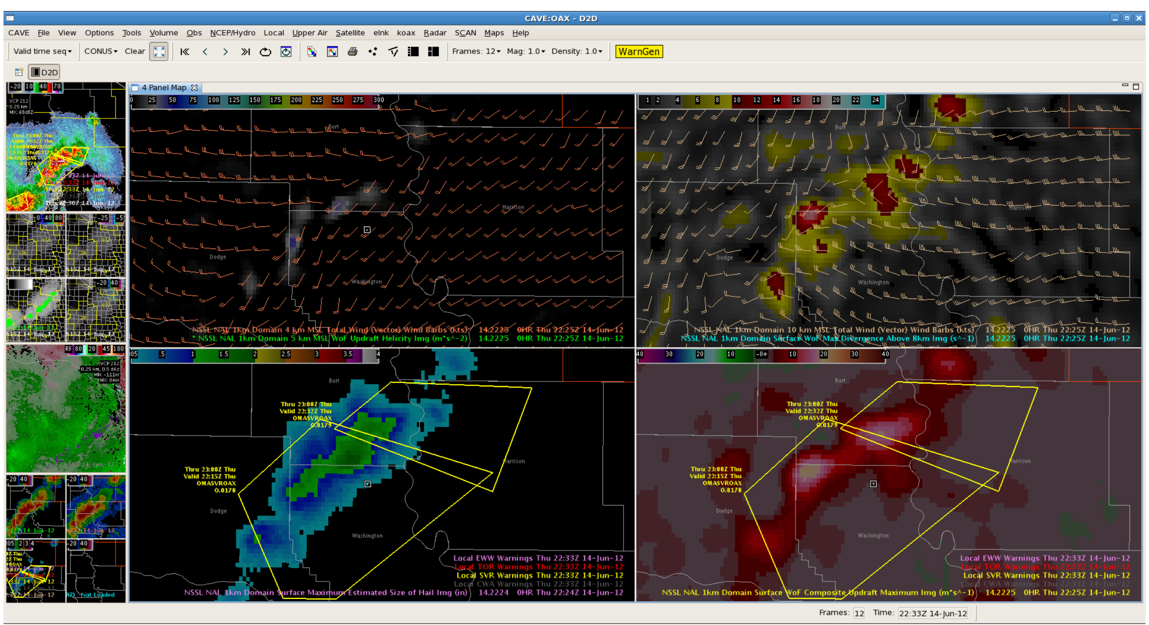


Figure 2: An AWIPS2 display captured in real-time by one of the participating forecasters. The four large panels show the 3DVAR 4-km AGL wind field/updraft helicity (upper left), 10-km AGL wind field / 1 km-AGL near-surface divergence (upper right), Maximum Expected Size of Hail(lower-left), and 3DVAR maximum updraft speed (lower right).

GOES-R Component – Kristin Calhoun (CIMMS at NSSL), Kiel Ortega (CIMMS at NSSL), Chris Siewert (CIMMS at SPC)

During 2012, CIMMS scientists were responsible for developing and synthesizing training for the multiple GOES-R products (contributed by CIRA/CIMSS/NASA SPoRT as well as CIMMS) to be evaluated by forecasters as well as implementing the various GOESR products into AWIPS2 in the HWT (see table below for the specific GOESR products included in 2012 HWT activities). A Weather Event Simulator training case was developed using data from the 24 May 2011 tornadic outbreak in central Oklahoma to introduce forecasters to the various GOESR products and was completed by visiting forecasters as part of the pre-arrival training. Surveys, discussions, and daily operations during the EWP were all synthesized and led by CIMMS scientists in order to assess use and understanding of GOES-R products prior to launch of the satellite.

Demonstrated Product [development]	Category
Cloud and Moisture Imagery [CIRA and UW-CIMSS]	Baseline
Lightning Detection (PGLM) [CIMMS & NASA SPoRT]	Baseline
Convective Initiation [UAH]	Future Capabilities
Nearcasting Model [UW-CIMSS?]	GOES-R Risk Reduction
Weather Research and Forecasting (WRF) based lightning threat forecast [NASA SPoRT / NSSL]	GOES-R Risk Reduction
Cloud Top Cooling [UW-CIMSS]	GIMPAP
Sounder RGB Airmass [NASA SPoRT / CIRA?]	
Category Definitions: **Baseline Products** - GOES-R products that are funded for operational implementation as part of the ground segment base contract. **Future Capabilities Products** - New capability made possible by ABI as option in the ground segment contract. Option 1 in the ground segment contract will provide reduced product latency. **GOES-R Risk Reduction** - The purpose of Risk Reduction research initiatives is to develop new or enhanced GOES-R applications and to explore possibilities for improving the AWG products. These products may use the individual GOES-R sensors alone, or combine data from other in-situ and satellite observing systems or models with GOES-R. **GIMPAP** - The GOES Improved Measurement and Product Assurance Plan provides for new or improved products utilizing the current GOES imager and sounder	

Multi-function Phased Array Radar (MPAR) Component – Darrel Kingfield (CIMMS at NSSL)

This component of the HWT is described in NSSL Project 9 below.

AWIPS2 Integration – Darrel Kingfield (CIMMS at NSSL)

CIMMS scientists at NSSL and external collaborators developed the ingest and display environment for the EWP using the Advanced Weather Interactive Processing System-2 (AWIPS-2) framework. The HWT AWIPS system allows forecasters to display a full suite of operational datasets from any office in the nation, maximizing the potential number of domains during real-time operations. Alongside the operational datasets, CIMMS scientists (along with guidance from HWT partners) implemented over 70 experimental products for evaluation. This AWIPS environment provides a familiar platform to the forecaster as it is their baseline software package in some form at their local Weather Forecast Office. As a result, forecasters can spend less time learning the system and more time evaluating the experimental datasets during their tenure in the HWT.

Week 4 EWP participants Chris Siewert, Rich Grumm, Kristen Schuler, Jennifer Palucki, Gary Skwira, Marc Austin, Chris Leonardi, Gabe Garfield, Kathrin Wapler, Travis Smith, Greg Stumpf, Chris Karstens, and Steven Martinaitis. Photo by Jim LaDue.

This research is in progress.

Publications

Bikos, D., and Coauthors, 2012: Synthetic satellite imagery for real-time high-resolution model evaluation. *Weather and Forecasting*, **27**, 784–795.

Clark, A.J., and Coauthors, 2012: An overview of the 2010 Hazardous Weather Testbed Experimental Forecast Program Spring Experiment. *Bulletin of the American Meteorological Society*, **93**, 55–74.

Clark, A.J., J.S. Kain, P.T. Marsh, J. Correia, Jr., M. Xue, and F. Kong, 2012: Forecasting tornado path lengths using a 3-dimensional object identification algorithm applied to convection-allowing forecasts. *Weather and Forecasting*, **27**, Early Online Release, http://dx.doi.org/10.1175/WAF-D-11-00147.1

Goodman, S.J., and Coauthors, 2012: The GOES-R Proving Ground: Accelerating user readiness for the next-generation Geostationary Environmental Satellite System. *Bulletin of the American Meteorological Society*, **93**, 1029–1040.

Marsh, P.T., and H.E. Brooks, 2012: Comments on "Tornado Risk Analysis: Is Dixie Alley an extension of Tornado Alley?". *Bulletin of the American Meteorological Society*, **93**, 405–407.

Marsh, P.T., J.S. Kain, V. Lakshmanan, A.J. Clark, N.M. Hitchens, and J. Hardy, 2012: A method for calibrating deterministic forecasts of rare events. *Weather and Forecasting,* **27**, 531–538.

Awards

Adam J. Clark received an Editor's Award for the American Meteorological Society journal *Weather and Forecasting.*

NSSL Project 6 – Development of Technologies and Techniques in Support of Warnings

NOAA Technical Lead: Lans Rothfusz (NSSL)

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

Funding Type: CIMMS Task II

Objectives

The primary objects for this reporting period include:

1. Developing the capability to re-process and analyze 15 years worth of WSR-88D data for use in severe local storms, hydrological, and climatological research;
2. To conduct a real-time evaluation of data assimilation for the Warn-on-Forecast project;
3. Continue development of Multi-Radar/Multi-Sensor algorithms for use in warning decision-making;
4. Conduct enhanced verification of severe weather events.

Accomplishments

1. The Multi-Year Reanalysis of Remotely Sensed Storms (MYRORSS)

Valliappa Lakshmanan (CIMMS at NSSL), Madison Miller (CIMMS at NSSL), Kiel Ortega (CIMMS at NSSL), Travis Smith (CIMMS at NSSL), Jon Cintineo (CIMMS at NSSL)

The foundation for the data processing of MYRORSS was completed. This included debugging processing software, generating necessary miscellaneous data and developing and establishing a workflow. The workflow was designed to: 1) minimize the need for a human to be involved at every step of the processing, 2) easily track where in the data processing chain a particular day and/or radar is at; this minimizes the effort needing to find errors and restart the processing, 3) allow dozens of machines to easily pass data between themselves, automatically, to accomplish the necessary steps to complete the processing. The computer infrastructure was set up at the end of April, with development and testing of the workflow and debugging of software occurring in May and June. The final infrastructure set up is nearly complete, and processing is ongoing.

2. Warn-on-Forecast Real-Time Data Assimilation Experiment

Kristin Calhoun (CIMMS at NSSL), Darrel Kingfield (CIMMS at NSSL), Kiel Ortega (CIMMS at NSSL), Travis Smith (CIMMS at NSSL), Greg Stumpf (CIMMS at MDL), Kevin Manross (CIMMS at NSSL)

The accomplishments for this sub-project overlap with NSSL Project 5 on the Hazardous Weather Testbed, and are detailed above in that report. In summary, a successful experiment was conducted in Spring 2012.

3. Multi-Radar/Multi-Sensor (MR/MS) Algorithm Development

Kristin Calhoun (CIMMS at NSSL), Darrel Kingfield (CIMMS at NSSL), Valliappa Lakshmanan (CIMMS at NSSL), Madison Miller (CIMMS at NSSL), Kiel Ortega (CIMMS at NSSL), Travis Smith (CIMMS at NSSL), Greg Stumpf (CIMMS at MDL)

A Lightning Jump Algorithm described by Schultz et al. (2009) and employed by Schultz et al. (2011) identifies rapid increases in the rate of total lightning (intra-cloud plus cloud-to-ground). These jumps have been shown to be pre-cursors of severe weather in thunderstorms and there may be potential to incorporate lightning jump algorithm data to significantly improve severe weather warning accuracy. NSSL/CIMMS is working with scientists at the University of Alabama-Huntsville and NWS/MDL to lead the effort to confirm the findings of Schultz et al (2009, 2011) for the NWS implementation of a similar product, including possible future use of the GOES-R Geostationary Lightning Mapper (GLM) technology for NWS warning operations. NSSL/CIMMS scientists created a real-time algorithm for testing and evaluation using

lightning data from multiple lightning mapping arrays and integrating it with other multi-radar/multi-sensor products created within the WDSS-II platform (Figure 1). This process removes the human element from storm cell identification and lightning jump association and makes it possible to use the algorithm in real-time warning operations. In addition, a number of enhanced verification methods will be employed, owing to the use of a robust high-resolution storm report database from the Severe Hazards Analysis and Verification Experiment (below, subsection 4).

Ongoing improvements to the MR/MS "Rotation Tracks" products have significantly improved the data. Figure 2 shows the maximum azimuthal shear over a 3-day outbreak event in the southeastern United States. A combination of improved velocity dealiasing techniques developed by the WSR-88D Radar Operations Center and improved time matching via a multiple hypothesis tracking technique have vastly reduced errors in the data sets. Although still experimental, these data are widely used by the National Weather Service and emergency response organizations such as the Red Cross to help in the aftermath of major tornado events.

MR/MS data sets were used during the HWT real-time experiments as well, and included in the HWT AWIPS2 system (see NSSL Project 5). This work is ongoing.

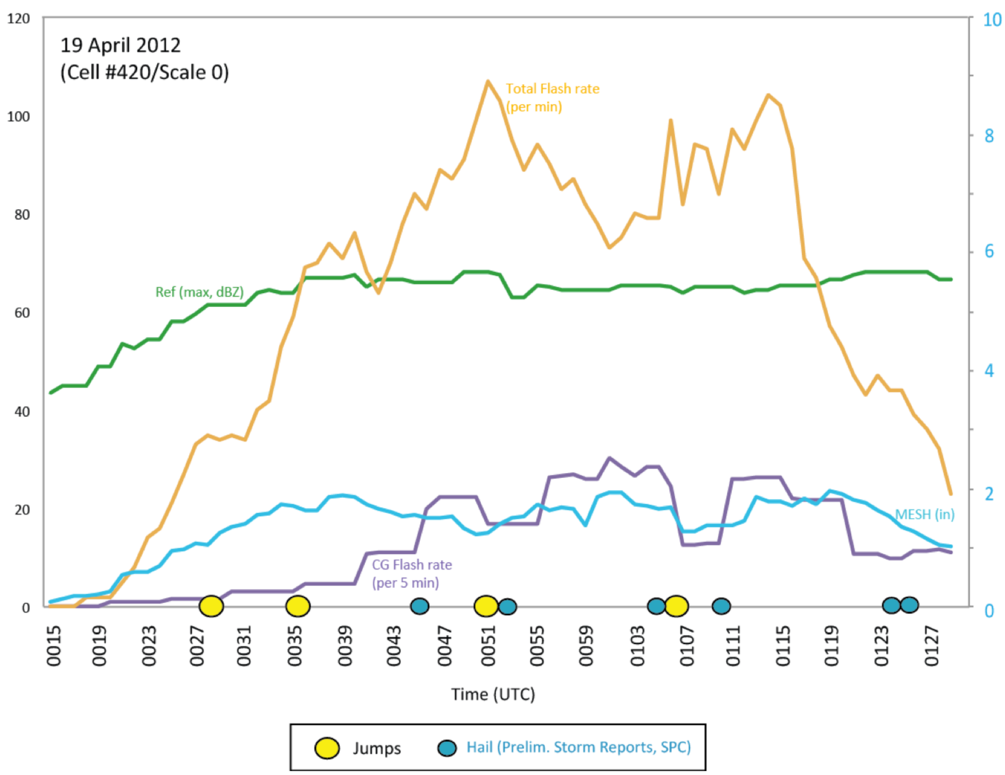


Figure 1. Lightning jumps and associated storm trends from real-time cell tracking in Oklahoma. Time series of the total flash rate (orange), cloud-to-ground flash rate (purple), maximum reflectivity (green), and Maximum Expected Size of Hail (MESH, blue) are plotted. Time of lightning jumps and preliminary severe hail reports are denoted on the x-axis by yellow and blue circles, respectively.

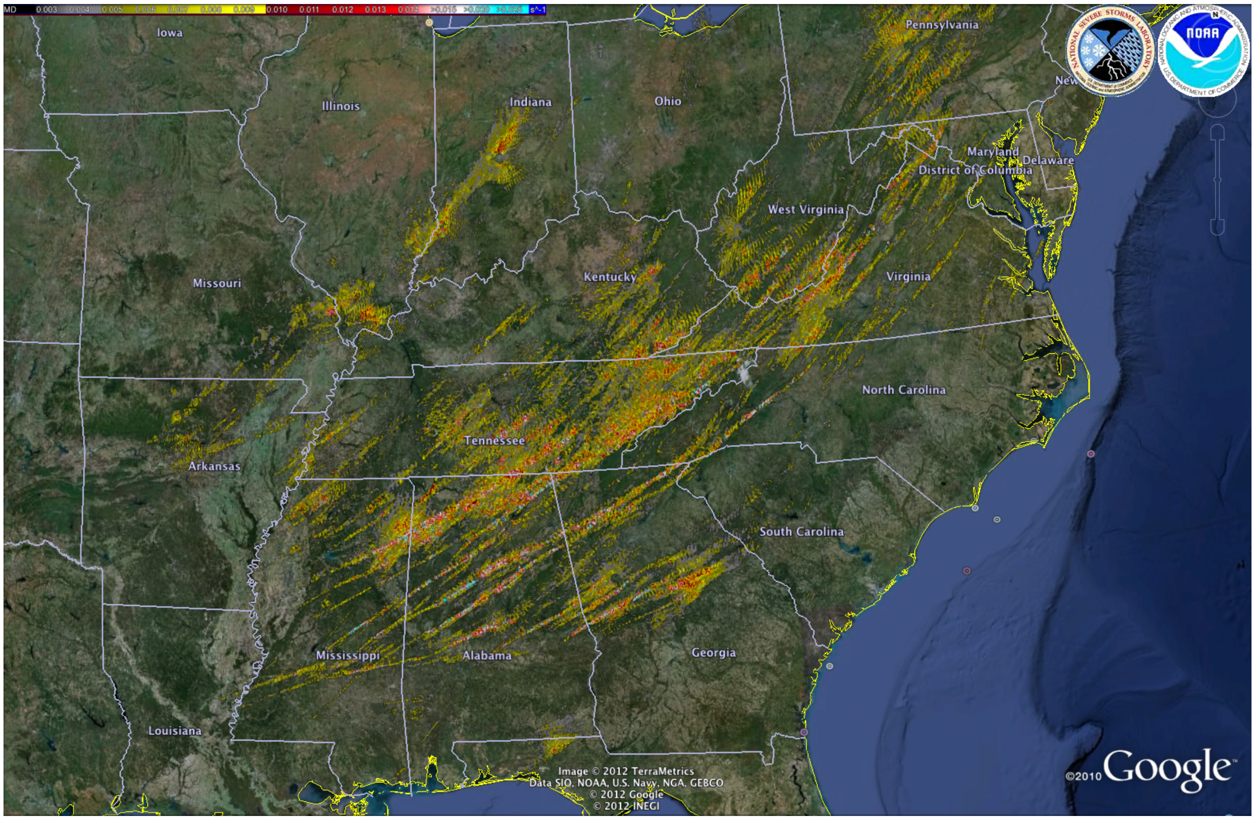


Figure 2. "Rotation Tracks" – a time accumulation of the maximum azimuthal shear from the WDSS-II MR/MS system for the 25-27 April 2011 tornado outbreak event.

4. The Severe Hazards Analysis and Verification Experiment (SHAVE)

Kiel Ortega (CIMMS at NSSL), Kristin Calhoun (CIMMS at NSSL)

SHAVE changed its operations schedule this year and became a year-round experiment. During the early winter months of 2012, SHAVE focused on collecting winter precipitation reports from around the country. The winter precipitation reports are currently being used in a study to improve a new multi-sensor hydrometeor classifier which uses model analyses and dual-polarized radar data. SHAVE then shifted focus in the spring and summer to the typical convective verification of hail and wind damage. The focus this year was in areas near lightning mapping arrays (LMAs). There are seven areas with available LMA data in 2012: Northern Colorado (centered east of Greeley, CO), West Texas (centered near Lubbock, TX), Southwest Oklahoma (centered near Altus, OK), Central Oklahoma (centered near Chickasha, OK), Northern Alabama and Central Tennessee (centered near Huntsville, AL), Eastern Florida (centered over Cape Canaveral) and the Mid-Atlantic (centered over Washington, DC). SHAVE has collected around 5,600 reports within the LMA areas, which includes data from past years' data collection which was within active LMA areas. SHAVE's convective verification efforts also are focused on areas surrounding dual polarized

WSR-88Ds. The hail data collected will be used to help verify a new hail size algorithm being developed at NSSL that uses dual polarized WSR-88D data. Thus far SHAVE has collected a little over 6,600 reports near 41 dual polarized 88Ds. Overall, thus far in 2012, SHAVE has operated 60 days collecting a total of 5,291 reports with 1,200 being related to the winter precipitation study, 3,992 related to hail and 99 related to wind damage. This experiement is ongoing.

5. 2012 OUNWRF Experiment

Gabe Garfield (CIMMS at OUN), Kristin Calhoun (CIMMS at NSSL), Chenghao Fu (CIMMS at NSSL), Darrel Kingfield (CIMMS at NSSL), Kiel Ortega (CIMMS at NSSL), Clarke Payne (CIMMS at WDTB), Chris Siewert (CIMMS at SPC), Travis Smith (CIMMS at NSSL), Greg Stumpf (CIMMS at MDL)

The 2012 OUNWRF Experiment sought to understand how forecasters use convection-allowing models in operational forecasting. It also sought to ascertain the impact of its use by comparing a priori conceptual models of convective evolution – obtained through hourly personal interviews – with the actual verification. Another objective was to develop best practices in using high-resolution modeling in severe weather operations – based upon the completion of the first two objectives. During the 2012 Spring Experiment, 42 interviews, 51 surveys, and countless blog and discussion comments were logged for 10 severe weather days. Analysis of these data is underway.

Publications

Gallo, K., T. Smith, K. Jungbluth, and P. Schumacher, 2012: Hail swaths observed from satellite data and their relation to radar and surface-based observations: A case study from Iowa in 2009. *Weather and Forecasting*, **27**, 796-802.

Hobson, A., V. Lakshmanan, T. Smith, and M. Richman, 2012: An automated technique to categorize storm type from radar and near-storm environment data. *Atmospheric Research*, **111**, 104-113.

Lakshmanan, V., 2012: Image processing of weather radar reflectivity data: Should it be done in Z or dBZ? *EJSSM*, **7**, 1-4.

Smith, T. M., and V. Lakshmanan, 2011: Real-time, rapidly updating severe weather products for virtual globes. *Computers and Geosciences*, **37**, 3-12.

Awards

CIMMS scientists Valliappa Lakshmanan (Leader), Jeffrey Brogden, Kimberly Elmore, Charles Kerr, Travis Smith, Lulin Song, Gregory Stumpf, Robert Toomey, and Thomas Vaughan, along with NSSL Scientists Kurt Hondl, Robert Rabin, and Jian Zhang received the Innovator Award from the OU Office of Technology Development. The citation includes the following statement: "This groundbreaking (WDSS-II) software is used worldwide to help predict weather phenomena including hail, precipitation, mesocyclones, and tornadoes. Used by private companies, research labs, National and International governments across the globe, this technology provides users across the world with the information needed to make property and life-saving decisions in the event of hazardous weather."

OST Project 13 – Research on Integration and Use of Multi-Sensor Information for Severe Weather Warning Operations

Greg Stumpf (CIMMS at MDL)

NOAA Technical Lead: Stephan Smith (NWS/OST/MDL/DAB)

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

Funding Type: CIMMS Task II

Objectives

Work with CIMMS and NSSL scientists in developing multiple-radar/sensor severe weather warning applications and advanced display systems and transferring that technology to NWS operational systems; collaborate with the NOAA Hazardous Weather Testbed - Experimental Warning Program at the National Weather Center in Norman.

Accomplishments

The eight full year of the CIMMS/NWS-Meteorological Development Laboratory (MDL) scientist position was completed during this review period. During this year, the scientist maintained his position as Operations Coordinator for the Experimental Warning Program's 2012 spring experiment (EWP2012) in the NOAA Hazardous Weather Testbed (HWT). 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. The CIMMS scientist was responsible for the logistical coordination of a five-week real-time operational experiment in which twenty-five (25) visiting forecasters from across the United States (and three from other countries) traveled to the NWC to evaluate these specific new innovations: 1) 3DVAR Radar Assimilation for Warn-On-Forecast), 2) the "OUN WRF", a version of the WRF numerical nowcast model developed by the NWS forecast office in Norman, OK, and 3) GOES-R Proving Ground convective nowcast and warning products. The CIMMS scientist also collaborated with other CIMMS, NSSL, WDTB, and university scientists. The results from these evaluations are being used to further develop these potential improvements to NWS warning services. This project also reported in NSSL Project 5 above.

The CIMMS/MDL scientist continues to collaborate with the severe weather warning R&D activities at CIMMS and NSSL and served as the co-principle investigator for the multiple-radar / multiple-sensor (MRMS) severe weather warning algorithm experiment in the testbed. During FY12, the CIMMS/MDL scientist continued to support a limited capability to import and display several popular MRMS products to all NWS forecast offices in Southern, Central and Eastern Region. Presently, the NWS is scoping out the requirements to move MRMS into official operations. The CIMMS/MDL scientist was

loosely involved in this activity, with more involvement to increase perhaps for FY13. This project is also reported in NSSL Project 6 above.

A project to develop innovative methods to quantitatively evaluate severe weather warnings continued in FY12. The technique includes geospatial (gridded) verification methods that can be used to better determine the "goodness" of severe weather warnings. In addition, a continuous hazard system ("threat-in-motion" or TIM) was developed for potential future evaluation in the HWT. The system was evaluated against the Tuscaloosa-Birmingham tornado supercell from 27 April 2011; new verification measures such as location-specific lead- and departure times, and accumulated false alarm area and time were computed for TIM versus the actual warnings issued by the NWS. Results indicate that for this event, location-specific lead times more than doubled, departure-times were reduced to near zero, and false alarm time was cut nearly in half. In addition, the scientist adapted the probabilistic THESPA technique developed by Dance et al. (2011) to the threat-in-motion concept (see figure). We hope that these Probabilistic Hazard Information (PHI) concepts can be evaluated in real-time in the HWT sometime in the future (see below).

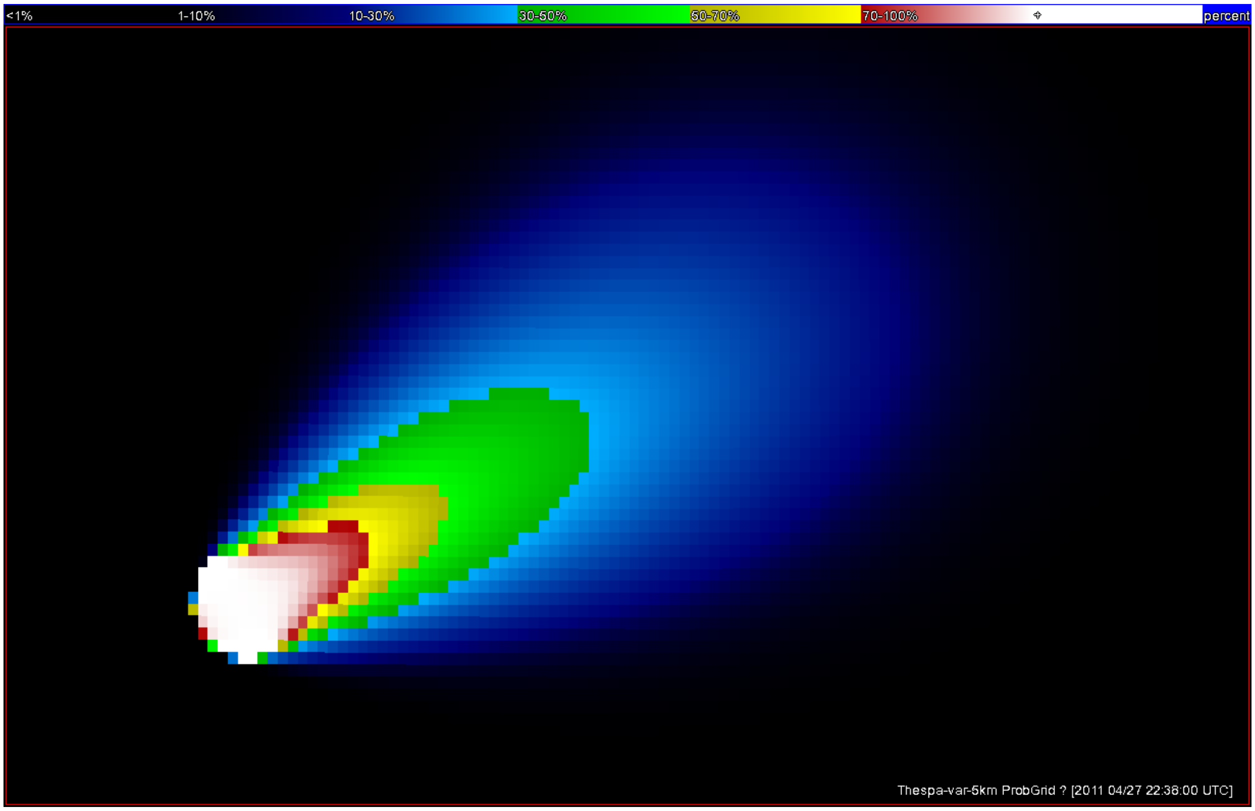
The CIMMS scientist continues to serve as the project lead for the Four-Dimensional Stormcell Investigator (FSI), the project that adapted the NSSL Warning Decision Support System II (WDSSII) 3D/4D base radar display application into AWIPS. In the next few years, the CIMMS scientist will lead the effort to begin the transition of the FSI and other advanced visualization techniques under development at NSSL into AWIPS2.

The CIMMS scientist began collaboration with other CIMMS and external scientists to evaluate a Lightning Jump Algorithm (LJA; Schultz et al. 2009) for the National Weather Service. The scientist developed the test plan for the project, and is involved in the verification of the algorithm. He was also co-mentor for a NSF Research Experiences for Undergraduates (REU) student who was working on evaluating the LJA during the summer of 2012. This project is also reported in NSSL Project 6 above.

From a weather and society perspective, the CIMMS/MDL scientist participated in two NWS Weather-Ready Nation (WRN) "Vital Conversation" workshops, in Norman and Birmingham, respectively. In addition, the CIMMS/MDL scientist attended the second Integrated Hazards Information System (IHIS) workshop in Boulder, and began to be involved in the adaptation of the PHI concepts of "threats-in-motion" into the AWIPS2 Hazard Services software, in collaboration with the NOAA Global Systems Division (GSD).

The CIMMS scientist began developing and providing training on the operational AWIPS severe weather warning algorithms and decision support systems to Taiwanese meteorologists at the Central Weather Bureau in Taipei, to be delivered the next fiscal year.

Work is ongoing.



Gridded probabilistic tornado threat field at one time during the Tuscaloosa-Birmingham tornadic supercell from 27 April 2011. The technique was adapted from Dance et al. (2011). Values are the probability that the specific location at the grid point will be within 5 kilometers of the tornado within the next 45 minutes.

NWSTC Project 14 – Forecast Systems Optimization and Decision Support Services Research Simulation and Training

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

Funding Type: CIMMS Task II

Objectives

Create a new Learning Management System (LMS) distance-learning course for the AWIPS-2 version of the Graphical Forecast Editor (GFE); this includes development of a course for Boise Verify (BOIVerify), which is a forecast verification program built into the AWIPS-2 version of GFE – this course will be the first of its kind. Assist the NWSTC team and staff with educational support, including for the LMS component called Taleo/Learn.

Accomplishments

1. Graphical Forecast Editor

Justin Schultz (CIMMS at NWSTC), Hattie Wiley (NWSTC), Teresa Murphy (NWSTC), Megan Taylor (CIMMS at NWSTC), Kevin Freeman (NWCTC), Scott Tessmer (NWSTC)

NOAA Technical Lead: Jeffrey Zeltwanger NWSTC

The Graphical Forecast Editor (GFE; Figure 1) software is used by NWS forecasters to produce weather element forecast grids for dissemination to the public. This course is currently named “Using GFE in the Forecast Process”. The reason for creating this course is because there does not exist nationally adopted basic GFE user training. The process used to develop this course is outlined next.

Adobe Dreamweaver was used to code the course web pages. The software Camtasia Studio 7 and Snagit 10 were used to take images and video for the training course material. A visit was made to the Pleasant Hill/Kansas City, Missouri NWS Forecast Office to observe the GFE in an operational setting. Based on this experience, we developed a lesson list for the Using GFE in the Forecast Process course. During the process of writing the lesson plan, we consulted GFE Focal Point Course material, including, Basic Concepts, GFE Configuration, Command Line Scripts, Server Configuration, Intersite Coordination mode, BOIVerify, and Service Backup. In March we completed the Using GFE in the Forecast Process project plan document, used as a layout of course lessons and topics. Additional media hardware was installed, including the Epiphan image capture tool. We then began developing the Using GFE in the Forecast Process detailed design document, which lays out all relevant information we planned to put in the course, including images, text, and special presentations (video and interactive media). In April two new documents were created for the Using GFE in the Forecast Process course, GFE Components and GFE Simulations. The GFE Components document contains a detailed outline and explanation of the primary parts of the GFE interface, including the Menu Bar, Button Bar, Spatial Editor, Grid Manager, Temporal Editor, Formatter Launcher and the Publish to Official dialog. The GFE Simulations document contains details for the GFE User Training simulations (videos) that will be created during summer 2012. Once the detailed design document was completed, HTML programming began for the course web pages, which were completed by May.

Programming for the BOIVerify course was completed in May (Figure 2). This included development of interactive presentations for the BOIVerify components and review quizzes for both BOIVerify and GFE courses using Articulate Engage and Quizmaker e-learning software. After completion, both courses were edited. In June, training was completed on Adobe Captivate, which was then used to make the training simulations interactive. To create interactive simulations that students can take at their own pace, screenshots of the steps for each procedure outlined in the GFE Simulation document

were made (Figure 3). The goal of these simulations is to show the student how to perform each task by allowing them to click on the necessary buttons and menus to accomplish a task. We then began recording audio for each simulation. The audio directs the students on how to perform a certain task and gives him or her a real-world example of how each task is useful. A timeline was established for when the Using GFE in the Forecast Process course will be completed (tentatively, a 20 July 2012 deadline). This summer, team members will look through each simulation to ensure that they are of sufficient quality. Once completed, each simulation will be coded into its respective HTML pages.

This work is ongoing.

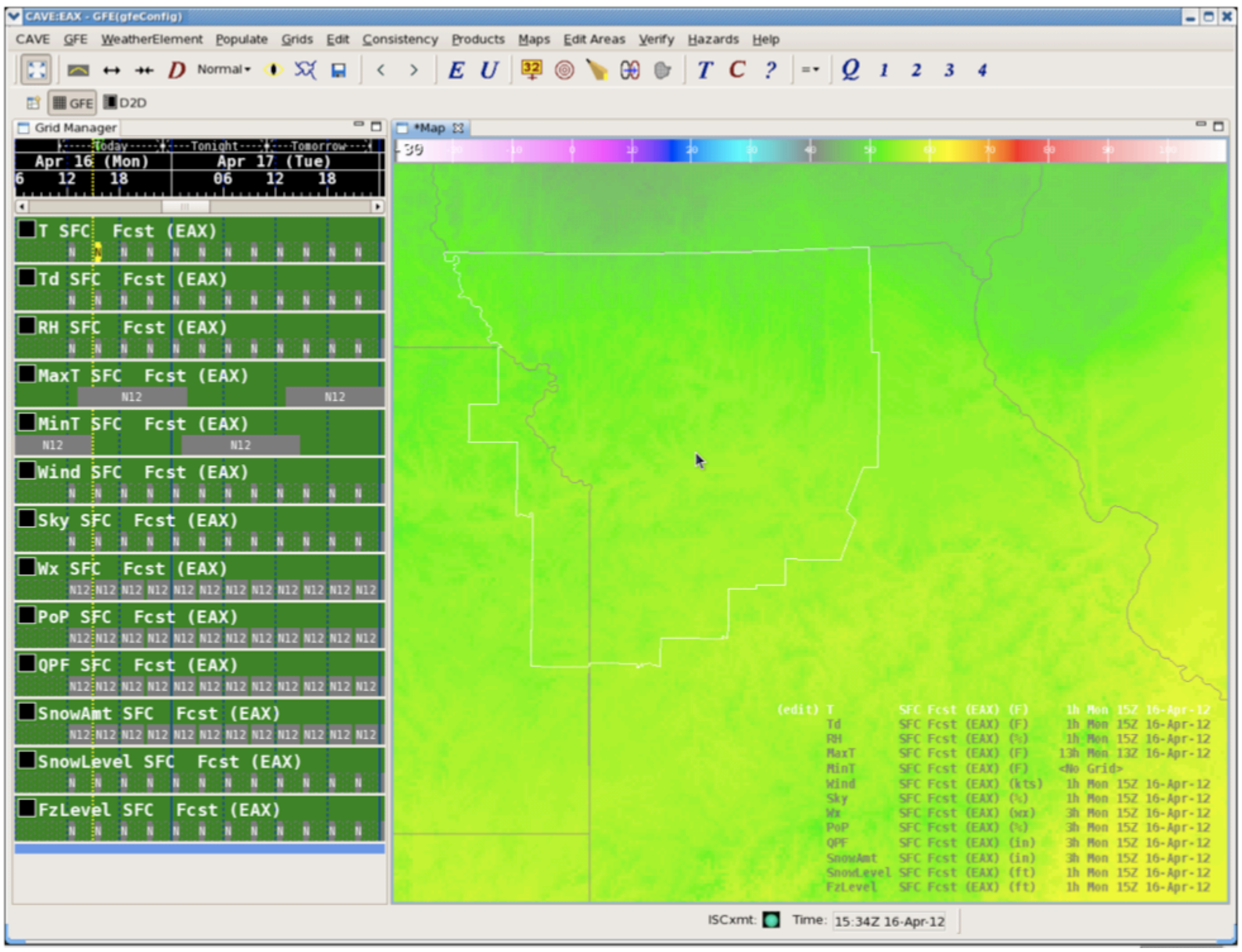


Figure 1: Graphical Forecast Editor terminal.

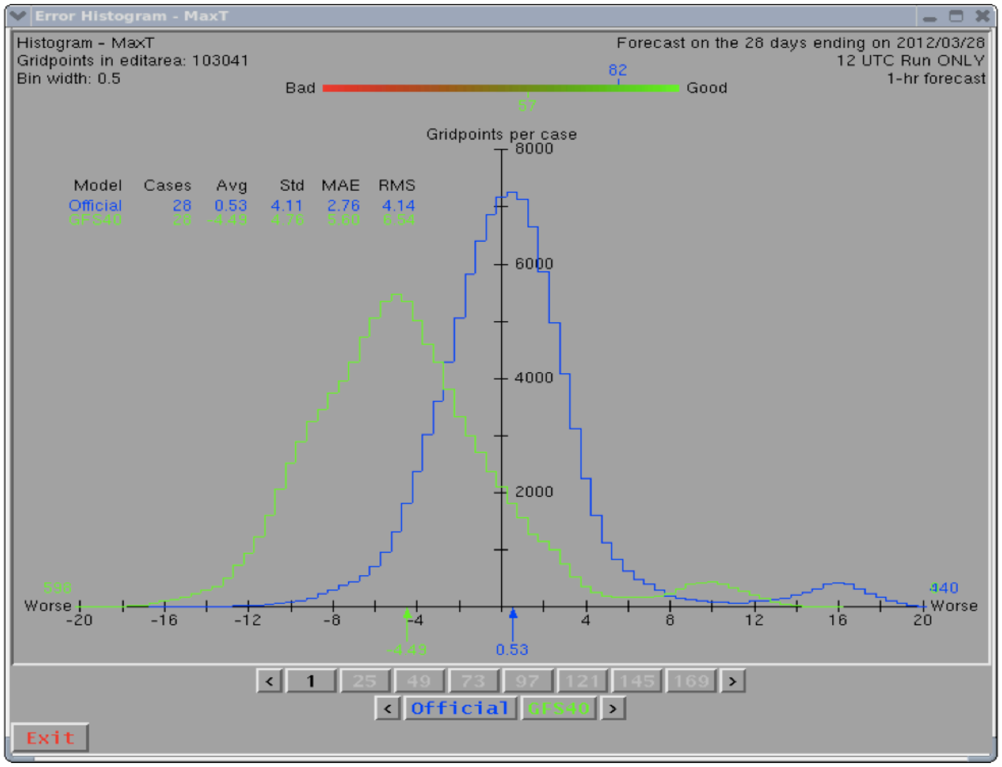


Figure 2: BOIVerify error histogram.

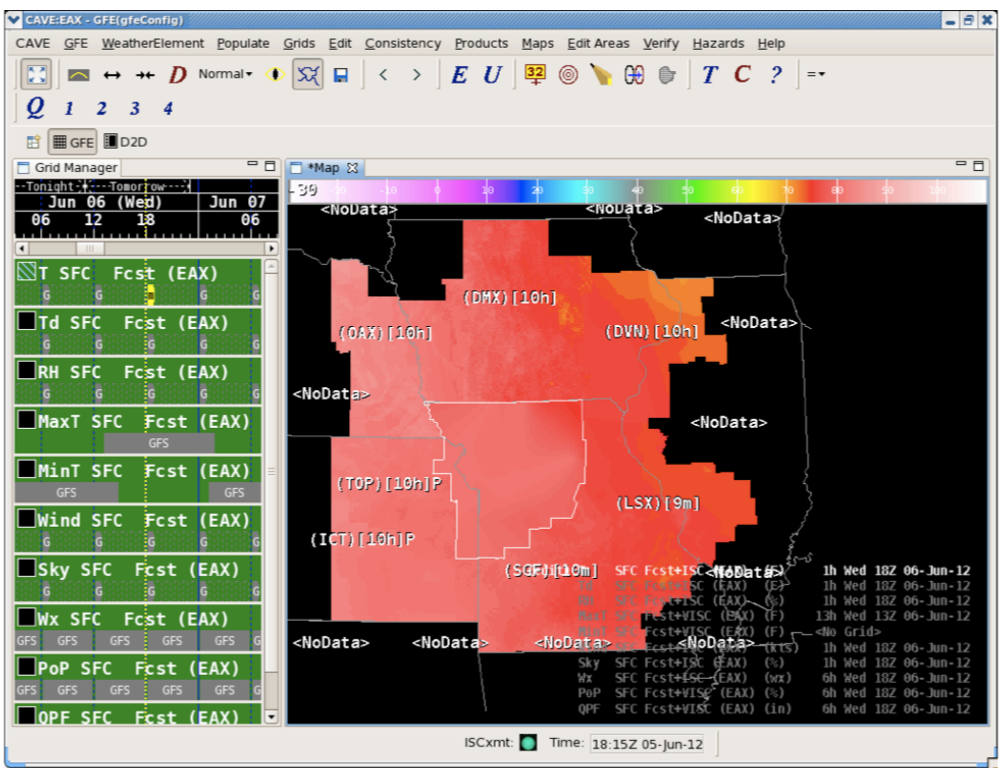


Figure 3: Screenshot from the "Toggling Intersite Coordination Grids" simulation.

2. Advanced Training Development

Kori Schmieding (CIMMS at NWSTC), Jim Poole (NWSTC), Jerry Griffin (NWSTC), Hattie Wiley (NWSTC), Cathy Burgdorf (NWSTC), Robert Hatch (NWSTC), Jim Jones (NWSTC)

NOAA Overall Technical Lead: Scott Tessmer (NWSTC)

Administration of LMS (NOAA Technical Lead: Jerry Griffin)

We have completed several assessments and evaluations of online courses, both for courses commercially produced and those created at NWSTC. For the review process of these modules, we assessed the course work for learning elements, grammar, navigation, as well as utilization of adult learning standards. We then built the learning assessments for these courses, preparing the courses, questions and level one evaluations. NWSTC had been three years behind in making some of the commercial courseware available to the personal, so we loaded 2010 and 2012 courses into the LMS and made them available for NWS personal. We also assisted in the redesign of the LMS commercial catalog. Currently, there are so many courses available that the system has become quite cumbersome, so we are working to streamline the system to make it easier to navigate. We hope that this redesign will assist more NWS managers in knowing what is available in creating lesson plans and course maps for their personal.

Crisis Communication/The Heart of Communicating (NOAA Technical Leads: Scott Tessmer, Hattie Wiley, Cathy Burgdorf, and Richard Brundage)

During the pre-production phase of this project, we provided guidance on how to record the presentation and other production related information; conducted research on topic of Crisis Communications; and checked and prepared equipment that was used during this session. During the production and post-production phases, we recorded the seminar presenter; assisted in individual assessments for participants; performed digital editing; provided a transcription for assisted learners; developed video learning modules of the Crisis Communication course using Adobe Premiere, Camtasia; and performed digital editing of graphics/photos used in the learning module.

Portal/Intranet (NOAA Technical Lead: Hattie Wiley)

We participated in a Dreamweaver web-authoring course in January. The Taleo/Learn LMS uses Dreamweaver and a built-in HTML editor. The NWSTC portal and Intranet are all updated and maintained using Dreamweaver.

Directives/New Hire Orientation (NOAA Technical Leads: Jerry Griffin and Hattie Wiley)

We have written and are currently developing the NWS directives training for new hires. This course will include video and other multimedia elements. We will use Articulate, as

well as Camtasia, to do this. Additionally, to ensure that this learning module is completed in a cost efficient and timely matter, we have evaluated commercial courses that could be included into the orientation that include professional development, team building, communications, verbal and written communications, and diversity.

WRIP Training (NOAA Technical Leads: Robert Hatch and Jim Poole)

The Weather Radar Impact Processor (WRIP) is a part of the NOAA National Weather/All Hazards Radio system. This system is equipped not only to handle weather related events and/or emergencies but also incorporates other matters of public safety such as Amber Alerts, environmental warnings and post event information, and any other information deemed necessary by Federal, State and Local Emergency Managers. We created the learning materials for WRIP to be used in the training of NWS personnel. Objectives of this training include familiarizing NWS technicians with installation compliance and needs; establishing the launch procedures and then the operational procedures; and performing quality control/basic troubleshooting. After completing the video portion of the training module, the WRIP system install was subsequently cancelled.

Radar Conference (NOAA Technical Lead: Cathy Burgdorf and Scott Tessmer)

We recorded the radar conference and assisted in interviews, production, and postproduction editing. Emergency personal, police, fire fighters, Emergency Managers, Red Cross officials, and others attended the conference. The goal of this conference was to educate participants on radar interpretations, forecasting, and emergency notifications to the public.

Nautel (NOAA Technical Leads: Cathy Burgdorf and Robert Hatch)

Pre-production and production was conducted of learning modules called Nautel, for NOAA Weather Radio. Inclusion of this material into learning content is in pre-planning stages.

Sutron Fisher Porter Gauge (NOAA Technical Leads: Cathy Burgdorf and Jim Jones)

Pre-production and production of training for the Sutron Fisher Porter Gauge has been conducted; this will be included in learning content to be determined at a later date.

Co-Op Program (NOAA Technical Leads: Jim Jones, Hattie Wiley, Scott Tessmer, and Cathy Burgdorf)

The Community Observational (Co-Op) Program involves volunteers that collect data in the field and report them to the National Weather Service. The program is facing multiple mission related problems. One problem is a lack of volunteers: many current observers are retiring. Additionally, volunteers who are coming into the program now are meteorology interns who are only temporary volunteers for the program. The other

problem is budget cuts, as there is a lack of funding to conduct residential courses for the program. The curriculum needs to move to a Web Basted Training (WBT) program in order to keep the program functioning. Timing also is crucial – volunteers in the field are already feeling the impact from the lack of training and are communicating with the program director regarding the urgency of moving these learning materials to an online environment. Our objective is to ensure that the course which once was predominantly classroom facilitated will be converted to a web based instructional learning course. How to do this is under discussion. Among ideas discussed are using video, audio, and e-learning authoring tools and how they could be applied to the materials. Project timelines have been discussed for how to meet both content and time constraints. We also discussed the possibility of using some current online learning materials by updating and moving them into the LMS to assist current volunteers in the training problems they are currently experiencing.

These projects are ongoing.

CIMMS Task III Project – Development of a Short-Range Realtime Analysis and Forecasting System Based on the ARPS for Taiwan Region

Ming Xue (OU CAPS), Fanyou Kong (OU CAPS), Keith Brewster (OU CAPS), Chong-Chi Tong (OU CAPS), Michael Hernandez (OU CAPS)

NOAA Technical Lead: Fanthune Moeng (GSD)

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

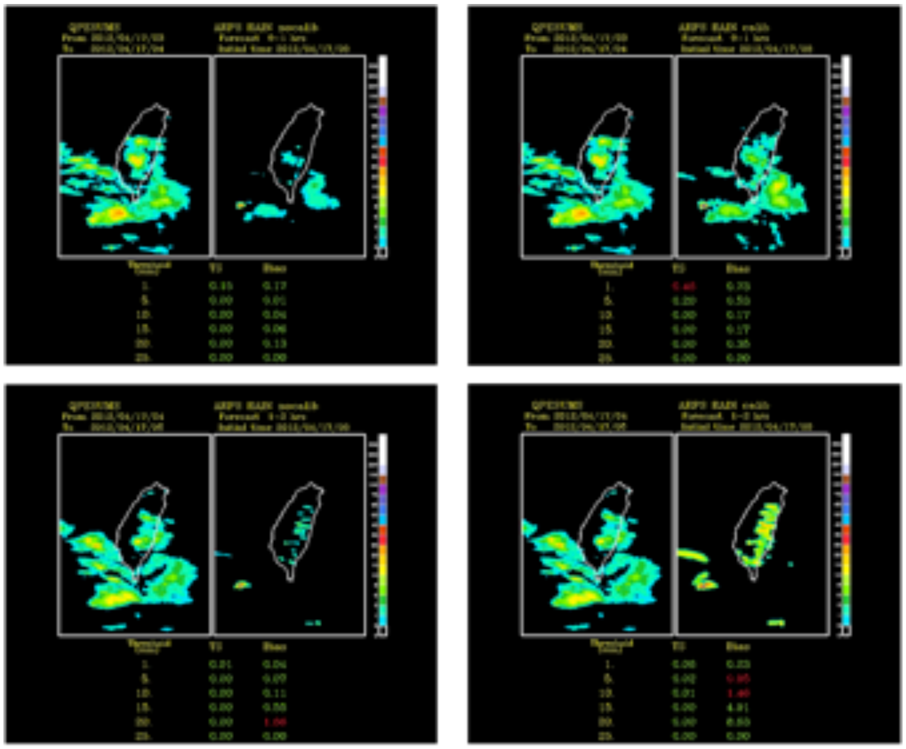
Funding Type: CIMMS Task III (Taiwan Central Weather Bureau; NOAA/NSSL and NOAA/GSD)

Objectives
Develop an ARPS-based short-range real-time analysis and forecasting system for the Taiwan Central Weather Bureau (CWB).

Accomplishments
CAPS fulfilled all tasks proposed for the period, including adding capability to ingest CWB surface and upper air observations into the ARPS 3DVAR data assimilation system and performing case studies to examine their impact on storm and QPF forecast skill. The two cases used are the Morakot Typhoon case of 7 August 2009 and a Meiyu heavy rainfall case of 28-29 May 2010. For the first half of 2012, two more tasks were completed: a baseline bias correction capability, and code development and case study analyzing AWS data in the Meiyu heavy rainfall case. Code packages of all non-radar observation data capability, including conventional surface observation and upper air soundings, surface AWS data analysis, and bias correction, were delivered to CWB, including technical support to help CWB implement them.

The CAPS performance in this period was approved at the annual acceptance review meeting held in November 2011 at CWB, and at the semi-annual review meeting held in May 2012 at the National Weather Center in Norman.

Research is completed.



Examples of bias corrected precipitation forecasts in the CWB ARPS forecasting system.

Impacts of Climate Change Related to Extreme Weather Events

Nothing to report here for the new cooperative agreement.

Societal and Socioeconomic Impacts of High Impact Weather Systems

CIMMS Task III Project – 2012 Phased-Array Radar Innovative Sensing Experiment (PARISE) *AND* NSSL Project 9 – Evaluating the Impact of New Technologies, Data, and Information in the Operational Forecasting Environment

Daphne LaDue (OU CAPS), Darrel Kingfield (CIMMS at NSSL), James Murnan (INDUS),

NOAA Technical Lead: Pam Heinselman (NSSL)

NOAA Strategic Goal 2 – *Weather-Ready Nation – Society is Prepared for and Responds to Weather-Related Events*

Funding Type: CIMMS Task III (NOAA/NSSL)

Objectives

Identify key judgments and decision points of NWS forecasters when using data from the experimental multi-function phased array radar (MPAR); test for improvement in tornado warning performance.

Accomplishments

Six forecasters have worked through four weather cases each while their desktops were recorded in an experimental setting. Forecasters completed the NASA Task Load Index for each case. The researchers then reviewed each case with each forecaster to understand their actions and decision processes, scan-by-scan, throughout the case. Researchers also collected data on the forecasters' knowledge and career. Data collection period is at the midpoint; at least six additional forecasters will participate to complete the data collection phase of this project. A peer-reviewed manuscript describing previous, related research for this experiment has been published.

Publications

Heinselman, P. L., D. S. LaDue, and H. Lazrus, 2012: Exploring impacts of rapid-scan radar data on NWS warning decisions. *Weather and Forecasting,* **27**, Early Online Release, *http://dx.doi.org/10.1175/WAF-D-11-00145.1*

Public Affairs and Outreach

Nothing to report here for the new cooperative agreement.

Appendix A

CIMMS AWARDS AND HONORS

CIMMS Scientist at NSSL Adam J. Clark received an ***Editor's Award*** for the American Meteorological Society journal *Weather and Forecasting.*

CIMMS Scientists at NSSL Valliappa Lakshmanan (Leader), Jeffrey Brogden, Kimberly Elmore, Charles Kerr, Travis Smith, Lulin Song, Gregory Stumpf, Robert Toomey, and Thomas Vaughan, along with NSSL Scientists Kurt Hondl, Robert Rabin, and Jian Zhang received the ***Innovator Award from the OU Office of Technology Development***. The citation includes the following statement: "This groundbreaking (WDSS-II) software is used worldwide to help predict weather phenomena including hail, precipitation, mesocyclones, and tornadoes. Used by private companies, research labs, National and International governments across the globe, this technology provides users across the world with the information needed to make property and life-saving decisions in the event of hazardous weather."

Appendix B

PUBLICATION SUMMARY*

	CIMMS Lead Author				NOAA Lead Author				Other Lead Author			
	2004-05	2005-06	2006-07	2007-08	2004-05	2005-06	2006-07	2007-08	2004-05	2005-06	2006-07	2007-08
Peer Reviewed	40	40	55	55	15	20	15	16	31	32	33	37

	CIMMS Lead Author				NOAA Lead Author				Other Lead Author			
	2008-09	2009-10	2010-11	2011-12**	2008-09	2009-10	2010-11	2011-12**	2008-09	2009-10	2010-11	2011-12**
Peer Reviewed	52	32	28	9	13	25	22	5	45	40	44	4

**Publication numbers are approximate.*

***Note that this listing is partial because publications for CIMMS projects conducted during the fiscal year under the old Cooperative Agreement will be tallied and listed in the report for that agreement and as such are not included here.*

Appendix C

PERSONNEL SUMMARY – NOAA FUNDED RESEARCH ONLY

NOAA-Funded Research

Category	**Number**	**B.S.**	**M.S.**	**Ph.D.**
Research Scientist	15		10	5
Visiting Scientist				
Postdoctoral Fellow	3			3
Research Support Staff	3			
Administrative				
Total (> 50% NOAA support)	**21**		**10**	**8**
Undergraduate Students	10			
Graduate Students	3	2	1	
Employees that receive < 50% NOAA Funding (not including students)	4		1	3
Located at a NOAA unit	SPC-1 NSSL-17 Norman WFO-1 NWSTC-2			
Obtained NOAA employment within the past year				

Appendix D

COMPILATION OF CIMMS-RELATED PUBLICATION 2011-12

Publications compiled here were reported for projects funded under the *new* Cooperative Agreement (NA11OAR4320072).

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

Bikos, D., and Coauthors, 2012: Synthetic satellite imagery for real-time high-resolution model evaluation. *Weather and Forecasting*, **27**, 784–795.

Clark, A.J., and Coauthors, 2012: An overview of the 2010 Hazardous Weather Testbed Experimental Forecast Program Spring Experiment. *Bulletin of the American Meteorological Society*, **93**, 55–74.

Clark, A.J., J.S. Kain, P.T. Marsh, J. Correia, Jr., M. Xue, and F. Kong, 2012: Forecasting tornado path lengths using a 3-dimensional object identification algorithm applied to convection-allowing forecasts. *Weather and Forecasting*, **27**, Early Online Release, *http://dx.doi.org/10.1175/WAF-D-11-00147.1*

Gallo, K., T. Smith, K. Jungbluth, and P. Schumacher, 2012: Hail swaths observed from satellite data and their relation to radar and surface-based observations: A case study from Iowa in 2009. *Weather and Forecasting*, **27**, 796-802.

Goodman, S.J., and Coauthors, 2012: The GOES-R Proving Ground: Accelerating user readiness for the next-generation Geostationary Environmental Satellite System. *Bulletin of the American Meteorological Society*, **93**, 1029–1040.

Heinselman, P. L., D. S. LaDue, and H. Lazrus, 2012: Exploring impacts of rapid-scan radar data on NWS warning decisions. *Weather and Forecasting,* **27**, Early Online Release, *http://dx.doi.org/10.1175/WAF-D-11-00145.1*

Hobson, A., V. Lakshmanan, T. Smith, and M. Richman, 2012: An automated technique to categorize storm type from radar and near-storm environment data. *Atmospheric Research*, **111**, 104-113.

Kitzmiller, D, S. Van Cooten, F. Ding, K. Howard, C. Langston, J. Zhang, and Coauthors, 2011: Evolving multisensor precipitation estimation methods: Their impacts on flow prediction using a distributed hydrologic model. *Journal of Hydrometeorology,* **12,** 1414-1431.

Lakshmanan, V., 2012: Image processing of weather radar reflectivity data: Should it be done in Z or dBZ? *E-Journal of Severe Storms Meteorology*, **7**, 1-4.

Lakshmanan, V., J. Zhang, K. Hondl, and C. Langston, 2011, A statistical approach to mitigating persistent clutter in radar reflectivity data,' *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, **5**, Issue 2, 652-662.

Marsh, P.T., and H.E. Brooks, 2012: Comments on "Tornado Risk Analysis: Is Dixie Alley an extension of Tornado Alley?" *Bulletin of the American Meteorological Society*, **93**, 405–407.

Marsh, P.T., J.S. Kain, V. Lakshmanan, A.J. Clark, N.M. Hitchens, and J. Hardy, 2012: A method for calibrating deterministic forecasts of rare events. *Weather and Forecasting,* **27**, 531–538.

Qi, Y., J. Zhang, D. Kingsmill, J. Min, and K. Howard, 2011: VPR corrections of cool season radar QPE errors in the mountainous area of northern California. *Proceedings, International Symposium on Weather Radar and Hydrology*, IAHS Publ. 351- 34.

Smith, T. M., and V. Lakshmanan, 2011: Real-time, rapidly updating severe weather products for virtual globes. *Computers and Geosciences*, **37**, 3-12.

Van Cooten, S., K. Kelleher, K. Howard, J. Zhang, and Coauthors, 2011: The CI-FLOW Project: A system for total water level prediction from the summit to the sea. *Bulletin of the American Meteorological Society,* **92,** 1427-1442.

Zhang, J., K Howard, C. Langston, and Coauthors, 2011: National Mosaic and multi-sensor QPE (NMQ) system: Description, results and future plans. *Bulletin of the American Meteorological Society*, **92,** 1321-1338.

Zhang, J., Y. Qi, D. Kingsmill, and K. Howard, 2012: Radar-based quantitative precipitation estimation for the cool season in complex terrain: Case studies from the NOAA Hydrometeorology Testbed. *Journal of Hydrometeorology*. Accepted.

Zhang, J., Y. Qi, K. Howard, C. Langston, and B. Kaney, 2011: Radar Quality Index (RQI) – A combined measure of beam blockage and VPR effects in a national network. *Proceedings, International Symposium on Weather Radar and Hydrology*, IAHS Publ. 351-25.