

Cooperative Institute for Mesoscale Meteorological Studies

Annual Report

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Cover figure - Schematic showing proposed effect of low-level mesovortices on quasi-linear convective systems (QLCS) structure and also their role in the production of damaging surface winds. Green barbed line indicates gust front, and red circles denote low-level mesovortices. Red area in vertical plane shows vertical extent and tilt of positive vertical vorticity and corresponding mesovortex. The implication is an associated downward-directed vertical pressure gradient force (bold blue arrow), which acts to locally eliminate or “fracture” the updraft above the mesovortex location. Black stippling on the south-southwest flank of this mesovortex shows the area of instantaneous damaging “straight-line” winds driven by the vortex circulation. A lesser area or narrow strip of such winds is indicated well southeast of the vortex, at the apex of the primary bowing segment. These winds are due to a rear-inflow jet that descends to the ground, represented by the black streamlines in the other vertical plane. For more on this project, see ***Tornadoes and Severe Winds with Quasi-Linear Convective Systems*** by Jeff Trapp, Kevin Manross, Greg Stumpf, and Chris Godfrey, under research theme ***Basic Convective and Mesoscale Research***.

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Executive Summary of Scientific Highlights and Accomplishments

Basic Convective and Mesoscale Research

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

During the past year, cloud research has been conducted to understand the effects of multi-dimensional radiative transfer on cloud system evolution, improve the parameterization of cloud microphysics and radiation, and develop statistical formulations of cloud parameterizations over the U.S Southern Great Plains. Lightning research has focused on the modeling of thunderstorm electrification, study of inverted polarity electrical structures in thunderstorms observed during the STEPS project, and an attempt to learn how lightning and other electrical storm properties depend on the structure, updrafts, and precipitation of the thunderstorms during the Thunderstorm Electrification and Lightning Experiment (TELEX). The Intermountain Precipitation Experiment (IPEX) was a field and research program conducted to improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain in Utah, including success at obtaining the first measurements of the electrical properties of continental U.S. winter storms. Tornado research has focused on the climatological distribution of tornadoes spawned by quasi-linear convective systems. Continued work on VORTEX data has allowed researchers understand the role played by the rear-flank downdraft in tornadogenesis, and the origins of the rear-flank downdraft itself, including a fundamental discovery regarding the rear-flank downdraft (RFD) and tornadogenesis was made using dual-Doppler analysis of the rear-flank region of a supercell 10 minutes prior to the Dimmitt, Texas, tornado. Researchers discovered that the vortex lines formed arches near the ground. The leading hypothesis prior to this discovery was that the RFD tilted vortex lines downward, leading to sagging lines connecting a counter-rotating pair of vortices. Instead, the vortex lines rise up in the developing tornado, proceed southward between the intense low-level updraft over the gust front and the trailing rear-flank downdraft, and then turn downward in an accompanying anticyclonic tornado. Work on deep convection has sought to determine how environmental factors, notably the forcing that initiates deep convection and the environmental wind and thermodynamic profiles, control the time-dependent behavior of deep convective storms. Research on mesoscale dynamics has explored new instability mechanisms that will provide possible explanations for some observed three-dimensional substructures, including severe storm elements, embedded in frontal rain bands. These include, but not limited to nearly-symmetric circulations and their stability and instability, and nonmodal growths and singular vector structures in the presence of symmetric stability and instability. Storm-scale data assimilation has received attention, along with development of state-of-art technologies and software for real-time applications of remotely sensed high-resolution measurements, especially those from Doppler radars. Effort has been made to improve and continue development of distant-dependent objective analysis techniques that are popular for real-time analysis and diagnostic studies. Three-dimensional, two-meter resolution boundary layer large eddy simulations (LES) have been conducted, the results of which exhibit vertical vortices with dust devil-scale motions. This is likely the first LES to resolve and simulate vertical vortices with dust devil characteristics. Other work on vertical vortices has examined their formation within idealized ellipsoidal convective elements in quiescent ambient flows, including the exploration of ambient winds, stratification, multiple convective elements, and other variables, on the formation of such vortices. Research has also been done to isolate the conditions under which mammatus clouds form and are detected, and to assess the role of dynamical and microphysical processes in their formation. New, innovative work is underway to develop software for photo-realistically renderings of hydrometeor data from numerical weather prediction models.

Forecast Improvements

The primary goal of this original thematic area is to accelerate the transfer of research knowledge and skills between the academic and NOAA operational mesoscale meteorological communities to both

improve the design and utilization of mesoscale weather observing systems and improve mesoscale weather prediction and warning.

Scientists continued to develop simulation capabilities to study warning decision making for severe convective weather and winter weather. Collaboration with NWS forecasters nationwide on warning decision making research and training continued with releases of the Weather Event Simulator (WES), which is now an active part of every NWS forecast office training and research plan. A number of new severe weather algorithms with data from multiple sensors have been developed for the Warning Decision Support System – Integrated Information (WDSS-II). Much effort has been expended to participate in operationally relevant research efforts and to act as liaisons between the numerical modeling and operational forecasting communities, such as manifested in the SPC/NSSL 2003 Spring Program. During this, an evaluation of the utility of Short-Range Ensemble Forecasts (SREF) for hazardous weather forecasting at the SPC was conducted. Efforts included improving numerical model forecasts, primarily by calibrating physical parameterizations, optimizing model configurations, and soliciting feedback from operational forecasters, as well as promoting the use of numerical models as educational and research guides among operational forecasters. The latter has included continued operation of an experimental version of the NCEP Eta model using the Kain-Fritsch convective parameterization and higher-order, reduced-magnitude horizontal diffusion. Scientists have also played a unique role in the development of the WRF model, not only contributing to specific elements of model design, debugging, and implementation, but also in establishing a framework for model evaluation and testing in an operational forecasting environment. Forecast verification work continued with the maintenance and expansion of a database of forecasts and observations and with the development of new and meaningful verification strategies. A pilot forecasting program in New England has generated model forecasts from different configurations of the Eta and the Penn State/NCAR (MM5) mesoscale research models that contribute as members of a multi-model ensemble. A rapid update version of the Severe Storms Analysis Program was evaluated to determine improved lead-time in detection of severe weather features and how best to disseminate severe weather feature information to users. A comprehensive climatology of the evolution of warm-season Mesoscale Convective Systems affecting the warning areas of Norman, OK and Dodge City, KS NWS Forecast Offices during late morning was developed, along with techniques to aid in their forecasting. A platform-independent interactive technique was created to allow forecaster visualization of a radar beam in a standard atmosphere and to show how that beam may interact with the surrounding terrain. Methods are being developed and tested to assimilate lightning flash data into a mesoscale prediction model. Work has been done to improve snowfall forecasting by developing techniques to forecast the density of snowfall. Displays of tropical weather on the Internet have been improved, allowing for better data dissemination. Additional basin boundary datasets, basin customization support, and data maintenance, enhancement, and better access were provided for the Flash Flood Monitoring and Prediction (FFMP) basin dataset. Scientists have assessed the ability of a high-resolution forecast model to depict icing and turbulence that are important to in-flight and terminal aviation operations. The effects of mesoscale cloud geometry and other characteristics have been explored when accounting for drizzle processes in marine stratocumulus using the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS).

Climatic Effects of/Controls on Mesoscale Processes

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

New insights have been gained into the winter storm track organization and behavior over the North Atlantic at different time-scales. Work on the response of the North Atlantic Oscillation to enhanced greenhouse gas forcing was conducted, highlighting the impact of using different greenhouse gas forcing scenarios (A2 and B2) on NAO trends in fully coupled models. Scientists also performed ensemble averaging of NAO under different forcing scenarios. The role of locally recycled versus advective origins of precipitating water have been examined over the agriculturally important Midwestern U.S. under different precipitation regimes and over different timescales. A quality controlled data set was developed

that involves meteorological and hydrologic observations from Oklahoma Mesonet sites to help obtain new insights into land-atmosphere interactions from diagnostic studies using the data, and to identify parameterizations in the NOAA land surface model that are sensitive to land surface conditions. An objective determination of the onset and cessation of June-September summer rains (Kiremt) in Ethiopia is underway; this work is important for agricultural applications as well as to enhance our understanding of the interannual variability of the rains in the region. Work continued to promote the scientific and educational benefits of the Atmospheric Radiation Measurement (ARM) Program Southern Great Plains site and to provide scientific guidance to strengthen the productivity of the operation of the site. Efforts also continued to inspect and assess ARM data from the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska on near real-time basis. Work continued to provide ocean rain gauge data sets to the global research community.

Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

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

Issues of seasonal forecasting and its underpinning climate research for the peoples of West Africa are being revisited, building upon work that began in response to the disastrous drought of 1968-73, impacting the West African Soudano-Sahel (10°-18°N). While these efforts have generated substantial information on a range of these topics, very little is known of the extent to which communities, activities at risk, and policy makers are aware of, have access to, or use such information. Factors are being identified that may help improve predictions of developing regional climate anomalies on sub-seasonal time scales, thereby reducing the social and economic impacts of such weather regime changes. Innovative work is being done to create a new database for tornado research with much greater resolution of storm paths by mapping tornado paths onto census tracts. This work suggests that census tract level resolution of tornado paths should allow estimation of improved models of tornado casualties.

Doppler Weather Radar Research and Development

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

Study of convective and mesoscale atmospheric processes to help improve forecasts of significant weather events such as flash floods, hurricanes, and tornadoes is being conducted with the Shared Mobile Atmospheric Research and Teaching Radar (SMART-R), created by the coalition of NSSL, OU, Texas Tech University, and Texas A&M University. Work has just begun to develop a phased array radar capability for weather surveillance research and applications, adapting SPY-1 radar technology currently deployed on Navy ships for use in spotting severe weather. Early tests of the phased array radar system have proved promising, and the technology has the potential to vastly improve the NEXRAD system for all weather radar applications. Continued development of the QPE SUMS algorithm took place to improve multisensor estimates of precipitation that will ultimately lead to improvements in operational flash flood monitoring and warning, watershed resources management, and model verification and initialization. Work is being done to establish a technique that ingests, quality controls, and analyzes

multiple weather radar data in real-time and produces a high-resolution 4-dimensional mosaic grid (three-dimensional in Cartesian space and one-dimensional in time) of radar data. Continued evaluation of the engineering design of polarimetric radar and demonstration of its utility took place within the Joint Polarization Experiment. As part of the dual polarization effort, new algorithms have been created that exploit the expanded capabilities of dual-polarimetric radar. Work continued to improve the interpretation of polarimetric radar data and the advance the understanding of microphysical processes associated with these radar signatures. To begin addressing the long-term needs for WSR-88D base (Level II) data transmission and archival, the Collaborative Radar Acquisition Field Test (CRAFT) has successfully demonstrated the real-time compression and Internet-based transmission of these data from multiple radars. A total of 62 radars now participate in CRAFT. Much work has been done over the past year on improving radar data acquisition and display, including modification of legacy WSR-88D algorithms to produce new high-resolution base datastreams, mitigation of range-velocity ambiguities, and improvement of spectral moment and polarimetric variable estimates. Accurate fields of single-Doppler divergent and rotational (azimuthal) shears have been provided that may be used as input into multi-sensor circulation or boundary detection algorithms that, in turn, should lead to improved algorithm guidance over the current Mesocyclone Detection Algorithm and Tornado Detection Algorithm. Work on mitigation of anomalous propagation has been done that provides guidance to the FAA and national air traffic controllers. The ability to obtain clear-air wind retrievals from the WSR-88D network, and determine usability of clear-air wind retrievals for the initialization of a mesoscale model, has also been evaluated.

Climate Change Monitoring and Detection

The goal of this relatively new (2001) research theme is to study the homogeneity or lack thereof of the historical station records in the U.S. and to use this information to help address the climate change questions, including those stemming from the Intergovernmental Panel on Climate Change (IPCC) process.

Determination of summertime temperature extremes in North America east of the Rockies using the Lamb/Richman data set is being conducted, looking at the number of days per summer and per summer month in which a threshold is met or exceeded in the daily maximum temperature. Future investigation will apply this information to energy usage and agricultural issues. Work is also being initiated to investigate the interannual variability of the climate system using the Lamb/Richman data set. Research is underway to determine the predictability of the NAO to understand its coupling with the other components of the North Atlantic climate system. The motivation behind this research is to investigate the temporal behavior of the seasonal signal of the NAO. Effort is also underway to document the long-term precipitation variability across coherent precipitation regimes in Africa using station and river discharge data.

**COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES
THE UNIVERSITY OF OKLAHOMA**

**Annual Report of Research Progress under Cooperative Agreement NA17RJ1227
During Fiscal Year 2003**

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INTRODUCTION

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) was established at the University of Oklahoma (OU) in 1978. Over the years, CIMMS has provided a mechanism to link the scientific and technical resources of OU and the National Oceanic and Atmospheric Administration (NOAA) to create a center of research excellence in mesoscale meteorology, regional climate studies, and related subject areas.

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

This report describes the research progress made by CIMMS scientists at OU and those assigned to our collaborating NOAA units during OU fiscal year 2003 (1 July 2002 through 30 June 2003), and as such represents the second of five annual reports to be written for the present cooperative agreement (NA17RJ1227). CIMMS concentrates its efforts and resources on the following principal research themes: (1) basic convective and mesoscale research, (2) forecast improvements, (3) climatic effects of/controls on mesoscale processes, (4) socioeconomic impacts of mesoscale weather systems and regional-scale climate variations, (5) Doppler weather radar research and development, and (6) climate change monitoring and detection. Activities in Public Affairs and Outreach and Computer Support are also presented, along with information on publications written and awards received.

RESEARCH PROGRESS

Basic Convective and Mesoscale Research

Effects of Multi-Dimensional Radiative Transfer on Cloud System Evolution

Mechem, Y. Kogan

Objectives

Assess the importance of horizontal radiative transfer on the evolution of radiatively-forced boundary layer clouds.

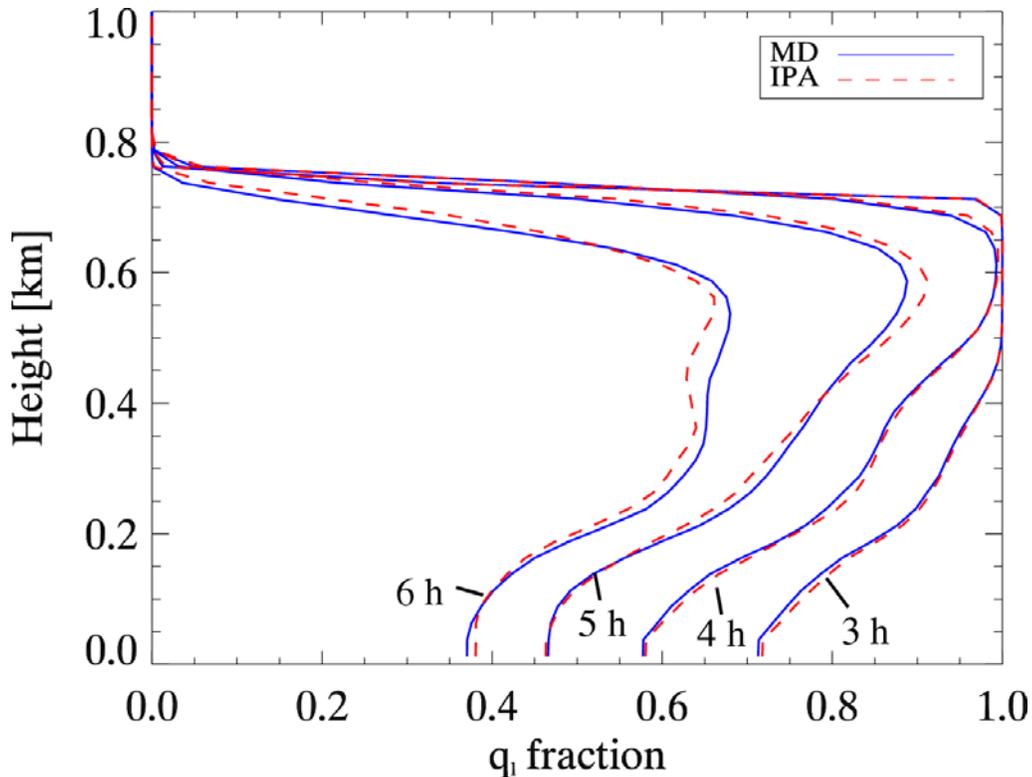
Accomplishments

Longwave Radiative transfer (RT) calculations for stratocumulus cloud fields indicate substantial differences in cloud-top cooling between a full multi-dimensional (MD) treatment of RT and typically used one-dimensional (1D) schemes. These differences arise from cloud top undulations, internal cloud liquid water content structure and overall cloud geometry (cloud fraction). Relative to 1D RT calculation, MD RT produces anomalous cooling over cloud top billows and anomalous warming in cloud top valleys. These heating (cooling) rate differences between MD and 1D RT treatments imply a possible effect on the cloud system evolution, especially for cloud types that are predominantly radiatively forced. Along with collaborators from Pacific Northwest National Laboratory (Mikhail Ovtchinnikov), The University of Colorado (Frank Evans), Florida State University (Ezra Takara and Bob Ellingson), Los Alamos National Laboratory (Anthony Davis), and NASA/GSFC (Bob Cahalan), we are exploring the evolutionary nature of this dynamic-radiative interaction. Coupling the CIMMS large eddy simulation (LES) model with Evans' SHDOM MD RT code enables us to explore the interactive effect of accounting for horizontal radiative transfer.

Differences between MD and 1D experiments develop but do not appear to exhibit any systematic bias in our relatively short (5-hour) simulation. Evolution of individual boundary layer elements can be markedly different, but this does not appear to be reflected in cloud fraction evolution between MD and 1D simulations (see figure). The slight reduction of cloud fraction in the 1D simulation seems to be opposite the sense that the MD cooling rates would imply, since enhanced lateral cooling at cloud top in the MD case should enhance negative buoyancy there and contribute to cloud breakup. Any differences in cloud fraction between MD and RT are likely well within the range of profiles that might be obtained simply from different realizations of initial turbulence that the LES employs; as such, the cloud fraction differences are probably not statistically significant. This result suggests that multi-dimensional radiative effects are not directly important for the evolution of stratocumulus clouds, even when they become broken.

Publications

- Mechem, D. B., M. Ovtchinnikov, Y. L. Kogan, K. F. Evans, A. B. Davis, R. F. Cahalan, E. E. Takara, and R. G. Ellingson, 2003: Implied dynamic feedback of 3D IR radiative transfer on simulated cloud fields. *Proc. of the Thirteenth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, 31 March-4 April 2003, Broomfield, CO.
- Mechem, D. B., M. Ovtchinnikov, Y. L. Kogan, K. F. Evans, A. B. Davis, R. F. Cahalan, E. E. Takara, and R. G. Ellingson, 2003: Simulation of PBL cloud fields with interactive multi-dimensional longwave radiative forcing. *Proc. of the Thirteenth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, 31 March-4 April 2003, Broomfield, CO.



Hourly mean cloud fraction profiles for MD RT and 1D RT simulations.

Parameterization of Cloud Microphysics and Radiation

Y. Kogan, Belochitsky, Mechem, Yang

Objectives

Understand feedbacks between cloud microphysical, radiative and dynamical processes, and develop cloud and radiation parameterizations for use in numerical weather prediction models.

Accomplishments

Integral Moment Parameterization. The development of an integral moment microphysics parameterization for stratiform clouds has been completed. The concept and design of the parameterization is described in a MS thesis defended by an OU graduate student in November 2002. The valuable feature of the new parameterization is its use and prediction of directly observable variables, such as radar reflectivity. The latter can be obtained from 24-hour routine Millimeter Wave Cloud Radar (MMCR) observations at the Atmospheric Radiation Measurement (ARM) Program Southern Great Plains data collection site.

Scale Dependence of the Near-Infrared Absorption Retrieval. The spectral dependence of the radiative horizontal transport and its effect on the accuracy of spectral and broadband absorption retrieval in the near-infrared wavelength range was investigated using a LES cloud model with explicit microphysics and a three-dimensional Monte Carlo radiative transfer model. Two typical types of marine clouds representing inhomogeneous overcast and broken stratocumulus clouds have been simulated. We demonstrated that the basic statistics (e.g., variance and correlation function) of the horizontal transport are wavelength dependent, and the estimates of spectral and broadband absorption with a given accuracy (e.g., root mean square error ~4%) may require the use of different spatial resolutions.

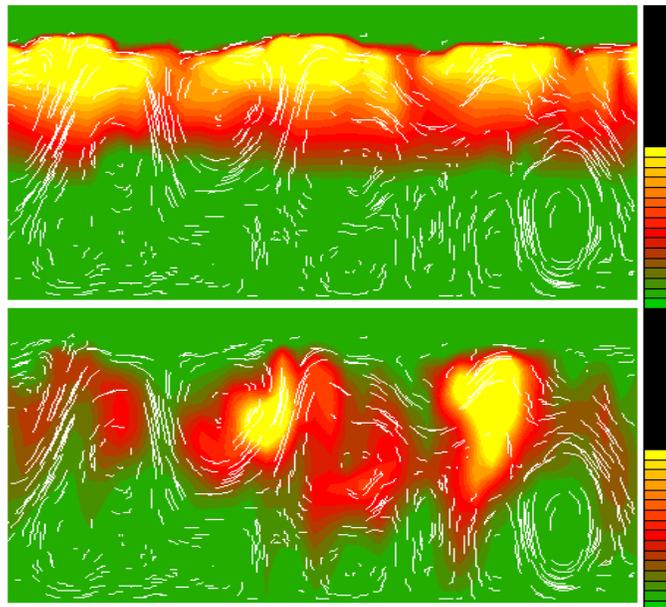
Warm Rain Initiation in Stratiform Clouds. The importance of cloud scale turbulent eddies on drizzle formation has been demonstrated using newly developed animation software. The new analysis technique allows tracking individual air parcels as they recycle through the cloud and mix with each other. As the figure below shows, air parcels rarely ascend in a simple isolated updraft, but rather continuously recycle and mix air volumes containing aged and newly activated cloud drops and aerosol particles. The CIMMS cloud microphysics and dynamics analysis technique reveals new features of rain formation that require a significant revision of the classical theory of rain initiation.

Drizzle Efficiency of Stratocumulus Clouds. We continued analysis of the feedbacks between drizzle, boundary layer thermodynamical parameters, surface winds, and horizontal advection of moisture. The objective is to determine sources that are responsible for maintaining cloud microstructure in numerical weather prediction (NWP) models. The dependence of drizzle on ambient aerosol and moisture sources has been studied in a series of over 50 experiments. It was found that quasi-stationary drizzle solutions exist when the cloud condensation nuclei (CCN) source exceeds the certain threshold value of the moisture source. It is interesting to note that a smaller CCN source is needed to maintain a quasi-stationary stratocumulus cloud layer at larger values of the moisture source. We also showed that turbulent mixing in the marine cloud topped boundary layer is as efficient in transporting sea-salt aerosols from the surface as the horizontal advection in the entire boundary layer.

Publications

Belochitsky A., 2002: Parameterization of Cloud Physics Processes Based on Integral Moments of Drop Spectra. M.S. Thesis, University of Oklahoma.

Kassianov, E.I., and Y.L. Kogan, 2003: Spectral dependence of radiative horizontal transport in stratocumulus clouds and its effect on near-IR absorption. *J. Geophys. Res. D. (Atmospheres)*, **107**(D23): Article No. 4712.



Air parcel trajectories (white lines) superimposed with isolines of cloud water (top) and drizzle water (bottom) mixing ratios. An animation movie of the LES simulation reveals extensive mixing occurring between new and aged cloud volumes. The mixing of parcels with different histories contributes to drop spectra broadening and drizzle initiation.

Statistical Formulations of Cloud Parameters over the U.S. Southern Great Plains

Z. Kogan, Mechem, Y. Kogan

Objectives

Determine cloud variability parameters for use in climate and numerical weather prediction models.

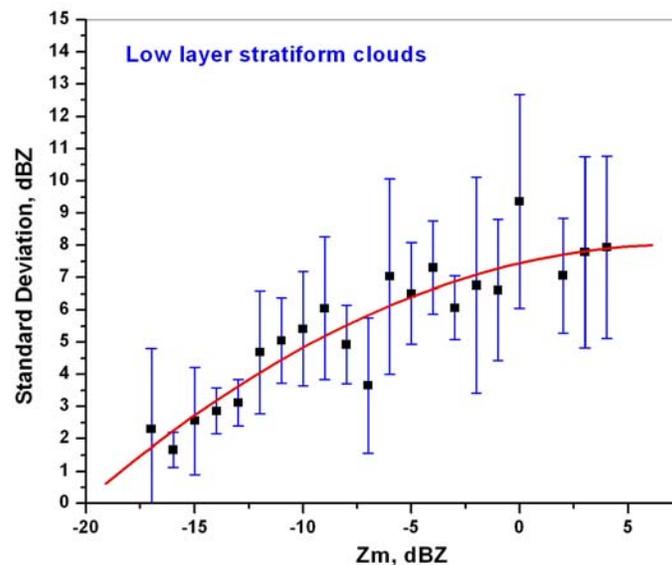
Accomplishments

Analysis of 953 hours of overcast low stratiform layers observed over the ARM SGP site during two winter seasons has shown distinct differences between probability distribution functions (PDF) of precipitating and non-precipitating cloud systems as well as between PDFs of two low stratiform cloud categories. Results indicate:

- The total duration of all precipitating boundary layer clouds is only one-third that of non-precipitating boundary layer clouds. On the contrary, all precipitating low altitude clouds have about 25% greater total duration than non-precipitating clouds. Precipitating clouds typically exhibit much greater variability than non-precipitating clouds. This effect is especially pronounced in the low altitude stratiform category (see figure). The variability of low altitude clouds is greater (3 times for precipitating clouds) than that of boundary layer clouds.
- For the boundary layer clouds, the PDFs of mean reflectivity are quite symmetrical for precipitating and non-precipitating cloud and in general can be well approximated by a two parameter Gamma function. PDFs of reflectivity for low altitude stratiform clouds demonstrate a different character. The non-precipitating category tends to be negatively skewed because of its shift towards greater reflectivity. PDFs in this category may be reasonably approximated with beta functions.
- Of the four categories studied, low altitude precipitating clouds would have the most pronounced effect on NWP forecast accuracy. The strong dependence of variability on radar reflectivity allows the formulation of a PDF in terms of only one parameter – radar reflectivity – which may be related to the resolved model variables or predicted by future parameterizations.

Publications

Kogan Z. N., D.B. Mechem, and Y. L. Kogan, 2003: The effect of precipitation on variability of low stratiform clouds over ARM SGP CART. *Proc. of the Thirteenth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, 31 March-4 April 2003, Broomfield, CO.



Standard deviation of segment reflectivity versus mean for precipitating low altitude clouds. Heavier precipitating stratiform clouds exhibit larger reflectivity variability.

Thunderstorm Electrification Modeling

Mansell, MacGorman, Straka, Ziegler, Kuhlman

Objectives

Test hypotheses about and gain insight into electrification processes and lightning behavior of thunderstorms.

Accomplishments

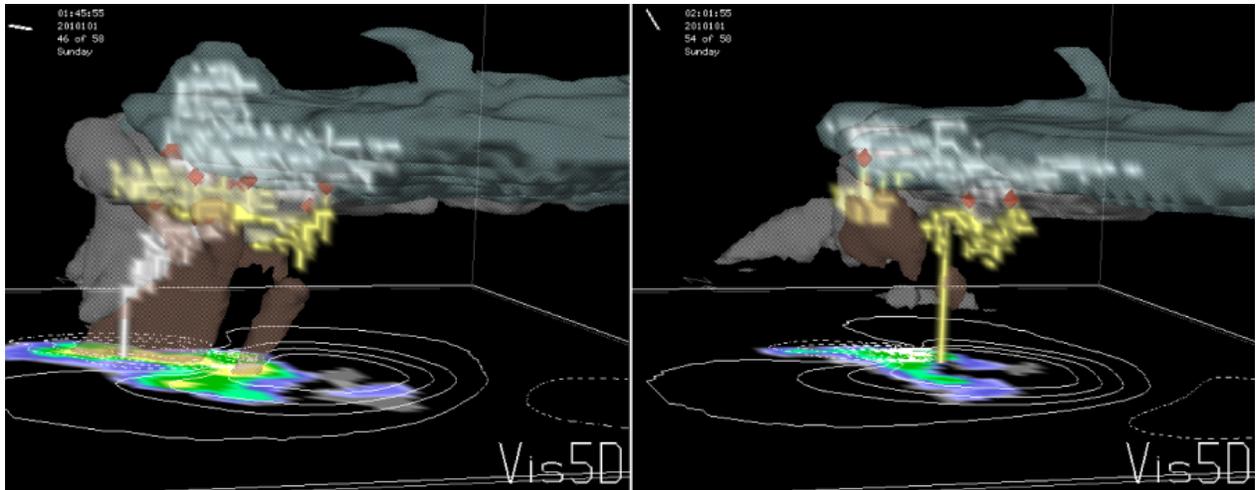
A sensitivity study has been completed for five different parameterizations of noninductive graupel-ice charge separation with varying efficiencies of inductive graupel-cloud droplet charging and variation of minimum cloud ice crystal concentration. The test case is an idealized continental multicell storm that has a lifetime of about two hours. Some sensitivity testing has been done with the other storm cases with generally similar results. Charge structure and lightning behavior are strongly influenced by the noninductive charge separation scheme, with two different parameterizations sometimes resulting in nearly opposite charge structure. Model results suggest a possible explanation for the delay between the first intracloud and first cloud-to-ground (CG) flashes that is often observed in continental thunderstorms. Simulated storms have exhibited the observed behavior of negative cloud-to-ground lightning flash production in and near the convective core but positive CG flashes from the forward flank/anvil. The phenomenon of the 'end of storm' positive CG flash is also being studied.

A simulation of the 29 June 2000 Severe Thunderstorm Electrification and Precipitation Study (STEPS) supercell storm shows similar dynamical and morphological characteristics as the observed storm. One charge separation parameterization stood out as resulting in lightning behavior most like what was observed. Both the observed and modeled storms had strong updrafts and midlevel rotation, and both produced many positive cloud-to-ground lightning flashes, which was a key interest in STEPS. A simulated balloon flight through the modeled storm updraft showed electric field structure similar to a flight through the observed storm. Simulated flash rate was also correlated with different microphysical parameters such as graupel mass and updraft volume to see which parameters may play the largest part in changes that occur during the storm lifetime. The 22 May 1981 Binger, OK, tornadic supercell storm has also been simulated. Again, different charge separation parameterizations have yielded dramatically different lightning characteristics.

An analysis of the electrical structure of the mesocyclone region of two supercell storms during STEPS was completed this year. This analysis confirms the hypothesis of MacGorman et al. (1989) that charge is elevated higher than usual in the strong rotating updrafts of supercell storms. It also confirms results of previous studies showing that the electrical structure in updrafts tend to be much simpler than in downdrafts and weak updrafts. However, the previous studies sampled updraft cores and weak updrafts at different times and usually in different storms. The new data set includes the up and down portions of the same flight in one storm and provides data on the rainy downdraft region of storms, a region that can be sampled well only by descending balloons.

Publications

- Beasley, W. H., E. R. Mansell, F. W. Gallagher, A. R. Bansenmer, L. G. Byerley, J. A. Swenson, and I. G. Bogoev, 2003: Simulations of spatial and temporal variations of electric-field contours at the surface beneath thunderstorms as would be observed by a network of solar-powered electric-field meters. *Proc. 12th International Conference on Atmospheric Electricity*, Versailles, France, 165-168.
- Gilmore, M. S., A. Fierro, E. R. Mansell, L. J. Wicker, and J. M. Straka, 2003: The influence of local environmental conditions upon supercell kinematics, microphysics, electrification, and lightning. *Proc. 12th International Conference on Atmospheric Electricity*, Versailles, France, 9-12.
- Kuhlman, K. M., E. R. Mansell, C. L. Ziegler, J. M. Straka, and D. R. MacGorman, 2003: Dynamical, microphysical and electrical simulations of the 29 June 2000 STEPS Supercell. *Proc. 12th International Conference on Atmospheric Electricity*, Versailles, France, 199-202.
- Mansell, E. R., D.R. MacGorman, C. L. Ziegler, and J. M. Straka, 2003: Electrification and lightning in simulated storms. *Proc. 12th International Conference on Atmospheric Electricity*, Versailles, France, 119-122.
- Straka, J. M., E. R. Mansell, C. L. Ziegler, D. R. MacGorman, and M. S. Gilmore, 2003: Electrification, lightning and microphysics in a simulated, 'bow echo' severe storm. *Proc. 12th International Conference on Atmospheric Electricity*, Versailles, France, 257.
- Ziegler, C., E. Mansell, D. MacGorman, and J. Straka, 2003: Electrification and lightning in a simulated tornadic supercell storm. *Proc. 12th International Conference on Atmospheric Electricity*, Versailles, France, 271-274.



Lightning in a simulated multicell storm. Each frame shows lightning in a 2-min time period. White channels carry negative charge, yellow channels have positive charge. Left: mature stage of the last cell in the storm with a negative cloud-to-ground flash and intracloud flashes. Right: dissipating stage of the last cell with a positive cloud-to-ground flash. Gray and bluish-gray surfaces show liquid droplets and small ice particles, respectively. The brown surface represents precipitation. At the surface are simulated reflectivity and electric field (dashed contours are negative values, increments of 2 kV/m).

Inverted Polarity Electrical Structures in Thunderstorms during STEPS

Rust, MacGorman, Bruning, S. A. Weiss, New Mexico Institute of Mining and Technology collaborators

Objectives

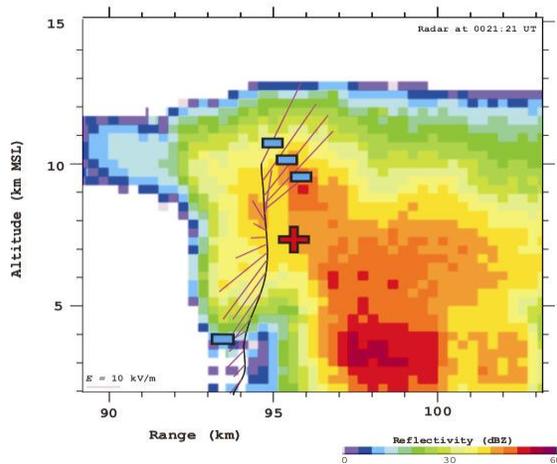
Basic study of thunderstorms whose electrical structure is inverted in polarity from most storms, using data obtained during the STEPS field program.

Accomplishments

Work continued to explore recently-discovered storms whose electrical structure is inverted in polarity from that of most storms. Analysis of additional data this past year confirms the previously preliminary conclusion that such storms exist.

Publications

- Lang, T., L. J. Miller, M. Weisman, S. A. Rutledge, L. J. Barker, III, V. N. Bringi, V. Chandrasekar, A. Detwiler, N. Doesken, J. Helsdon, C. Knight, P. Krehbiel, W. A. Lyons, D. MacGorman, E. Rasmussen, W. Rison, W. D. Rust, and R. Thomas, 2003: The Severe Thunderstorm Electrification and Precipitation Study (STEPS). *Bull. Amer. Meteor. Soc.*, submitted.
- Rust, W. D., and D. R. MacGorman, 2002: Possible inverted-polarity electrical structures in thunderstorms during STEPS. *Geophys. Res. Lett.*, **29** (12), 1571, doi: 10.1029/2001GL014303
- Rust, W. D., D. R. MacGorman, P. R. Krehbiel, R. J. Thomas, E. C. Bruning, and S. A. Stroman, 2003: The status of our search for inverted-polarity electrical structures in thunderstorms. *12th Intl. Conf. on Atmos. Elec.*, June 9-13, Versailles, France.



Representative electric field vectors and flight track of a balloon-borne electric field meter (and radiosonde) on vertical section of radar reflectivity of isolated thunderstorm. Only the first 10 km of ascent is shown for simplicity. The electric field vectors are attached to the balloon track and point away from the track in the plane of the radar image. The gross charge structure is inferred from the vectors. This storm structure from the bottom up is $-Q$, $+Q$, and $-Q$. This is one of only a few storms documented to have an apparently inverted-polarity electrical structure.

Thunderstorm Electrification and Lightning Experiment (TELEX)

MacGorman, Rust, Schuur, Straka, Wicker, Burgess, Bruning, Weiss, Doyle, Harris, Undergraduate students, South Dakota School of Mines and Technology collaborators

Objectives

Learn how lightning and other electrical storm properties depend on the structure, updrafts, and precipitation of the storms; this is needed, in part, to learn how new lightning observations can be used by the National Weather Service to improve forecasts and warnings of hazardous weather.

Accomplishments

CIMMS, OU, and NSSL conducted the Thunderstorm Electrification and Lightning Experiment (TELEX) in central Oklahoma in May 2003. It was the first of two sequential spring field programs for TELEX, the next to occur in May-June 2004.

The planning for TELEX took advantage of two new sensors now used routinely by OU and NSSL. One is the KOUN radar in Norman, a modified WSR-88D radar to which NSSL has added polarimetric parameters to provide information about the particle size and water phase of precipitation. The other is the Oklahoma Lightning Mapping Array, a network of ten stations in central Oklahoma that continuously maps the structure of all types of lightning in three-dimensions out to a range of 75 km and in two-dimensions out to a range of 200 km.

To these two systems, the TELEX team added balloon soundings to measure the electric field profile of storms. From an electric field profile, scientists can infer information about how a storm becomes electrified and about the forces responsible for lightning. This effort, funded partly by the National Science Foundation (NSF grant ATM-0233268) to CIMMS, was the maiden field program for NSSL's new mobile laboratory, used to collect the balloon data. The electric field sensor was custom-built by NSSL with assistance from the University of Oklahoma, New Mexico Institute of Mining and Technology, and NCAR. Temperature, pressure, and humidity were measured by an NCAR system that also provided GPS tracking of the balloon.

Whenever storms occurred, day or night, a crew of fourteen, including OU students, scrambled to get in position beneath storms to launch the instrumented balloons. They succeeded in flying fourteen balloons into nine storms during seven missions. Two of these storms were mesoscale convective systems (MCS), a specific target of TELEX. Now NSSL scientists have begun processing the raw measurements, and this fall they will begin analyzing the processed data to address the project's objectives.

The broad objective of TELEX is to learn how lightning and other electrical storm properties depend on the structure, updrafts, and precipitation of the storms. This is needed in part to learn how new lightning observations can be used by the National Weather Service to improve forecasts and warnings of hazardous weather. Three technologies now exist for routinely detecting all types of lightning over the U.S. Some studies have suggested that total lightning flash rates and other lightning characteristics provide useful information, unavailable from other measurements, about a storm's evolution and potential for severe weather. However, these studies have examined only a few storms, mostly in Florida and Alabama. The Oklahoma Lightning Mapping Array allows relationships with severe weather to be examined in a considerably broader spectrum of storms than has been done in detail so far.

TELEX observations will aid in testing hypothesized linkages between lightning and hazardous weather. Furthermore, in combination with numerical cloud modeling, TELEX observations will enable NSSL scientists to begin examining the physical mechanisms responsible for any observed linkages, to give forecasters understanding and confidence using the lightning relationships.



Students and scientists launch instrumented balloon into a morning mesoscale convective system during TELEX 2003 (right); balloon flight with instrument train (top to bottom) of parachute, GPS radiosonde (the cylinder), and electric field meter for determining storm electrical structure (left).

The Intermountain Precipitation Experiment

Schultz, Trapp

Objectives

Improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain, and to obtain the first measurements of the electrical properties of continental U.S. winter storms.

Accomplishments

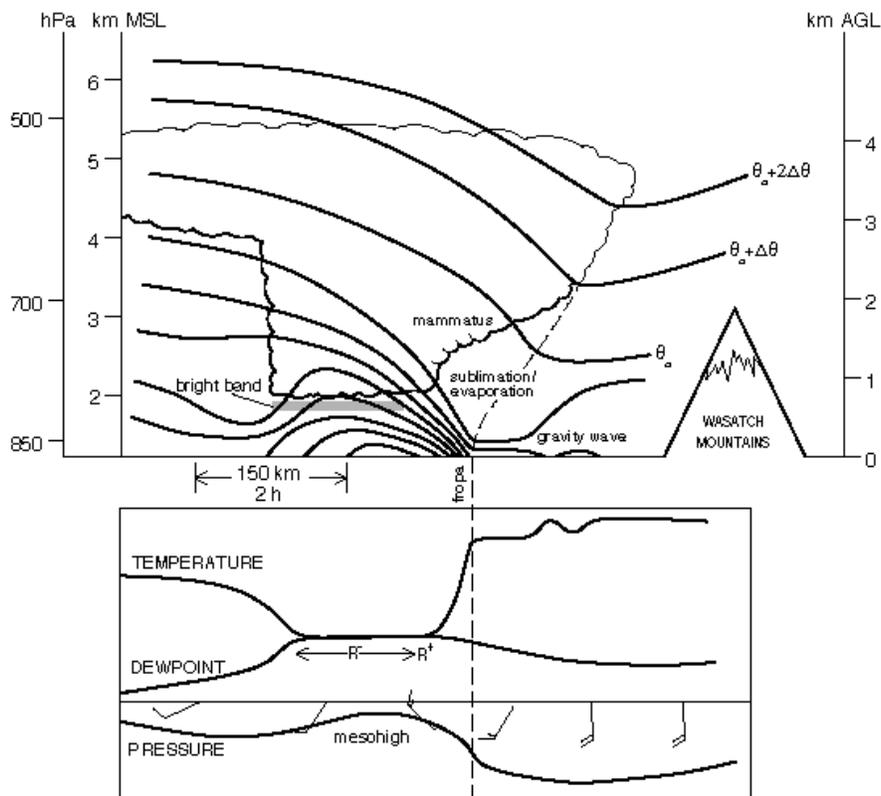
Instrumentation deployed during the field phase of the Intermountain Precipitation Experiment (IPEX) sampled a strong cold front and associated convection that moved through northern Utah on 14-15 February 2000. The surface cold front was characterized by a sharp temperature drop (8°C in 8 minutes), strong pressure rise (3 hPa in 30 minutes), and gusts to 40 ms^{-1} . The temperature drop at high-elevation

surface stations (2500-3000 m MSL) preceded the temperature drop at low-elevation surface stations (1290-2000 m MSL) by as much as an hour, implying a forward- or downshear-tilting frontal structure. Consistent with the cooling aloft, a hydrostatic pressure rise and wind shift preceded the temperature drop at the surface. Radar captured the rapid evolution of the wind shift line into a gravity current. A forward-sloping cloud with mammatus and a 20-hPa deep superadiabatic layer underneath were observed by radar and radiosondes, respectively. Shading from this forward-sloping cloud is believed to have produced a surface-based prefrontal inversion upon which a solitary gravity wave traveled. These and other observations reveal that the forward-sloping cloud generated by a shortwave trough aloft was producing precipitation that sublimated, melted, and evaporated in the dry subcloud air (dewpoint depression of 5-10°C), causing the cooling aloft and the nonclassical frontal structure.

Although the storm-total precipitation associated with this system was generally light (less than 20 mm at all observing sites), the amount of precipitation was strongly a function of elevation. During one 6-h period, precipitation at stations above cloud base (roughly 2000 m MSL) varied widely, mostly due to orographic effects; although precipitation amounts at most stations were about 7-11 mm. In contrast, precipitation amounts decreased with distance below cloud base, consistent with sublimation and evaporation in the dry subcloud air.

Publications

- Rust, W. D., and R. J. Trapp, 2002: Initial balloon soundings of the electric field in winter nimbostratus clouds in the USA. *Geophys. Res. Lett.*, **29**(20), 1969, doi:10.1029/2002GL015278.
- Schultz, D. M., and F. Sanders, 2002: Upper-level frontogenesis associated with the birth of mobile troughs in northwesterly flow. *Mon. Wea. Rev.*, **130**, 2593-2610.
- Schultz, D. M., and R. J. Trapp, 2003: Nonclassical cold-frontal structure caused by dry subcloud air in northern Utah during the Intermountain Precipitation Experiment (IPEX). *Mon. Wea. Rev.*, in press.



Conceptual model of the cold front from 14-15 February 2000. Top: schematic of cloud (scalloped lines), and potential temperature (thick solid lines). fropa=surface frontal passage. Bottom: time series of temperature, dewpoint, sensible weather, winds, and pressure at the surface.

Tornadoes and Severe Winds with Quasi-Linear Convective Systems

Trapp, Manross, Stumpf, Godfrey

Objectives

Determine the climatological distribution of tornadoes spawned by quasi-linear convective systems (QLCS), characterize the environmental conditions under which they occur, and determine their Doppler radar-derived attributes; also, determine the genesis mechanism of the mesovortices that may host tornadoes in QLCSs.

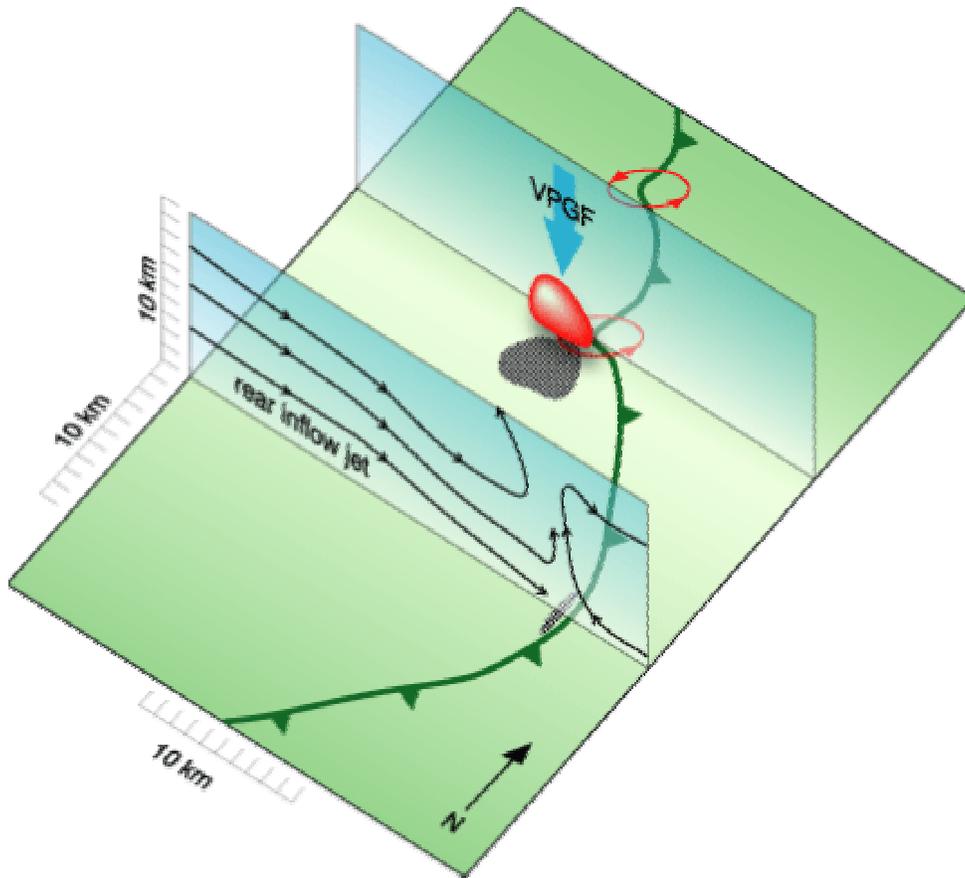
Accomplishments

Work was completed on the modeling part of this study. We determined the genesis mechanism of low-level mesovortices in QLCSs to be the tilting of crosswise horizontal baroclinic vorticity and the vertical stretching of the relative, and more notably, planetary vertical vorticity. In QLCSs simulated in environments of moderate-to-strong shear, we discovered that the simulated QLCSs evolved into bow echoes with “straight-line” surface winds found at the bow-echo apex and additionally in association with, and in fact induced by, the low-level mesovortices (see figure). Indeed, the mesovortex winds tended to be relatively stronger, more damaging, and larger in areal extent.

Significant progress was made in the three observational components of this study. Parent storm types of all U.S. tornadoes that occurred in 1998-2000 have been classified. 79% of the 3829 tornadoes were spawned by “cells,” 18% by “lines,” and 3% by “hurricane rainbands.” As anticipated, these percentages exhibit considerable geographic variation: in Illinois and Indiana, for example, the percentages of cell and line tornadoes are nearly equal. Statistical analysis of the QLCS tornadoes by F-scale and time of day of formation suggests that the number of weak tornadoes from QLCSs has likely been undersampled, owing to their relatively high frequency of occurrence during the overnight hours. Analysis of the Doppler-radar attributes of QLCS tornadoes during 1998-1999 shows that the QLCS circulations (mesocyclones and tornado vortex signatures – TVS) tend to be shallower and occur closer to the ground than supercell circulations. Additionally, low-level convergence leading to tornado formation tends to be greater within QLCS mesocyclones than in supercell mesocyclones. Finally, soundings in environments of tornadic QLCSs exhibit slightly more CAPE as well as low-level shear (0-3 km layer) than do environments of non-tornadic QLCSs. This result is consistent with the modeling study, which shows that only a relatively narrow range of environmental conditions promotes significant low-level mesovortices.

Publications

- Godfrey, E. S., R. J. Trapp, H. E. Brooks, and S. A. Tessendorf, 2003: A discussion of the F-scale of tornadoes from quasi-linear convective systems. *Preprints, Symposium on the F-scale and Severe-Weather Damage Assessment*, Long Beach, CA, Amer. Meteor. Soc.
- Manross, K. L., R. J. Trapp, and G. J. Stumpf, 2003: WSR-88D radar characteristics of quasi-linear convective system tornadoes using the NSSL Severe Storm Analysis Program. *Preprints, 31st Conf. on Radar Meteorology*, Seattle, WA, Amer. Meteor. Soc.
- Trapp, R. J., and M. L. Weisman, 2003: Low-level mesovortices within squall lines and bow echoes. Part II: Their genesis and implications. *Mon. Wea. Rev.*, in press.
- Weisman, M. L., and R. J. Trapp, 2003: Low-level mesovortices within squall lines and bow echoes: Part I. Overview and dependence on environmental shear. *Mon. Wea. Rev.*, in press.



Schematic showing proposed effect of low-level mesovortices on QLCS structure and also their role in the production of damaging surface winds. Green barbed line indicates gust front, and red circles denote low-level mesovortices. Red area in vertical plane shows vertical extent and tilt of positive vertical vorticity and corresponding mesovortex. The implication is an associated downward-directed vertical pressure gradient force (bold blue arrow), which acts to locally eliminate or “fracture” the updraft above the mesovortex location. Black stippling on the south-southwest flank of this mesovortex shows the area of instantaneous damaging “straight-line” winds driven by the vortex circulation. A lesser area or narrow strip of such winds is indicated well southeast of the vortex, at the apex of the primary bowing segment. These winds are due to a rear-inflow jet that descends to the ground, represented by the black streamlines in the other vertical plane.

Tornadogenesis Studies

Rasmussen, Straka, Gilmore, Davies-Jones

Objectives

Understand the role played by the rear-flank downdraft in tornadogenesis, and the origins of the rear-flank downdraft itself.

Accomplishments

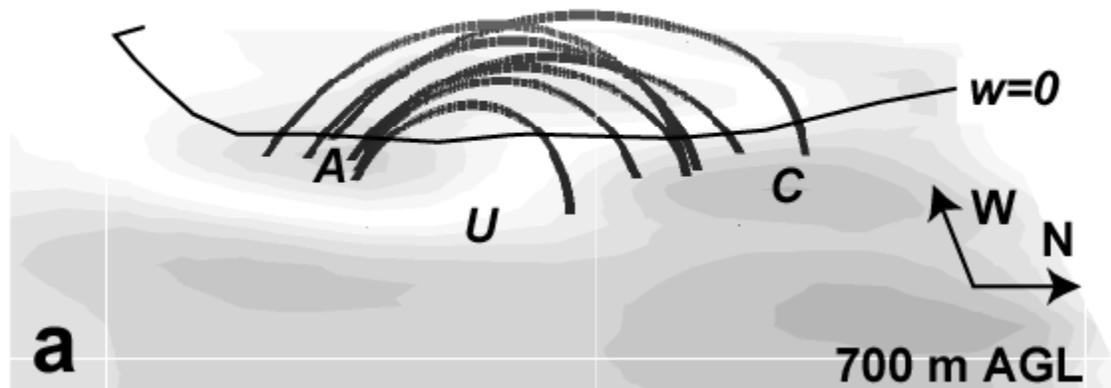
We have made a fundamental discovery regarding the rear-flank downdraft (RFD) and tornadogenesis. Using dual-Doppler analysis of the rear-flank region of a supercell 10 minutes prior to the Dimmitt, Texas, tornado, we discovered that the vortex lines formed arches near the ground. The leading hypothesis prior to this discovery was that the RFD tilted vortex lines downward, leading to sagging lines connecting a counter-rotating pair of vortices. Instead, the vortex lines rise up in the developing tornado, proceed southward between the intense low-level updraft over the gust front and the trailing rear-flank downdraft, and then turn downward in an accompanying anticyclonic tornado. The pair of vortices can be seen in

almost every observational study of tornadogenesis, but the anticyclonic vortex has been ignored, and prior research did not analyze the actual vortex line distribution.

The most obvious explanation for the arches is that rotation is generated in annuli surrounding a negative buoyancy region at the rear of the storm. Flow relative to this region brings the vortex rings forward where they are subsequently tilted upward above the gust front and stretched intensely.

Publications

- Davies-Jones, R., 2003: Reply to Comments on "Linear and nonlinear propagation of supercell storms" by R. Rotunno and M. L. Weisman. *J. Atmos. Sci.*, accepted.
- Davies-Jones, R., 2003: Comments on "A generalization of Bernoulli's theorem". *J. Atmos. Sci.*, accepted.
- Davies-Jones, R., 2003: An expression for effective buoyancy in surroundings with horizontal density gradients. *J. Atmos. Sci.*, in review.
- Markowski, P. M., 2002: Hook echoes and rear-flank downdrafts: A review. *Mon. Wea. Rev.*, **130**, 852-876.
- Markowski, P. M., J. M. Straka, and E. N. Rasmussen, 2003: Tornadogenesis resulting from the circulation transport of a downdraft: idealized numerical simulations. *J. Atmos. Sci.*, **60**, 795-823.
- Rasmussen, E. N., 2003: Refined supercell and tornado forecast parameters. *Wea. Forecasting*, in press.
- Rasmussen, E. N., R. Davies-Jones, and R. L. Holle, 2003: Terrestrial photogrammetry of weather images acquired in uncontrolled circumstances. *J. Atmos. Oceanic Technol.*, in press.
- Rasmussen, E. N., J. M. Straka, R. Davies-Jones, and M. S. Gilmore, 2004: The Dimmitt, Texas tornadic storm of 2 June 1995: Morphology and evolution during tornadogenesis. *Mon. Wea. Rev.*, **132**, in review.



Vortex line analysis in perspective view looking west prior to the Dimmitt, TX, tornado. The lines rise from the cyclonic region, labeled "C" (gray shading represents vertical vorticity at 700 m AGL), then turn southward near the zero vertical motion contour between updraft to the east, and downdraft to the west. They then turn downward in the anticyclonic vertical vorticity region labeled "A". This arch-like pattern has not been previously reported but is fundamental to understanding tornadogenesis.

Numerical Modeling Study of the Time-Dependent Behavior of Convection

Doswell, Weber

Objectives

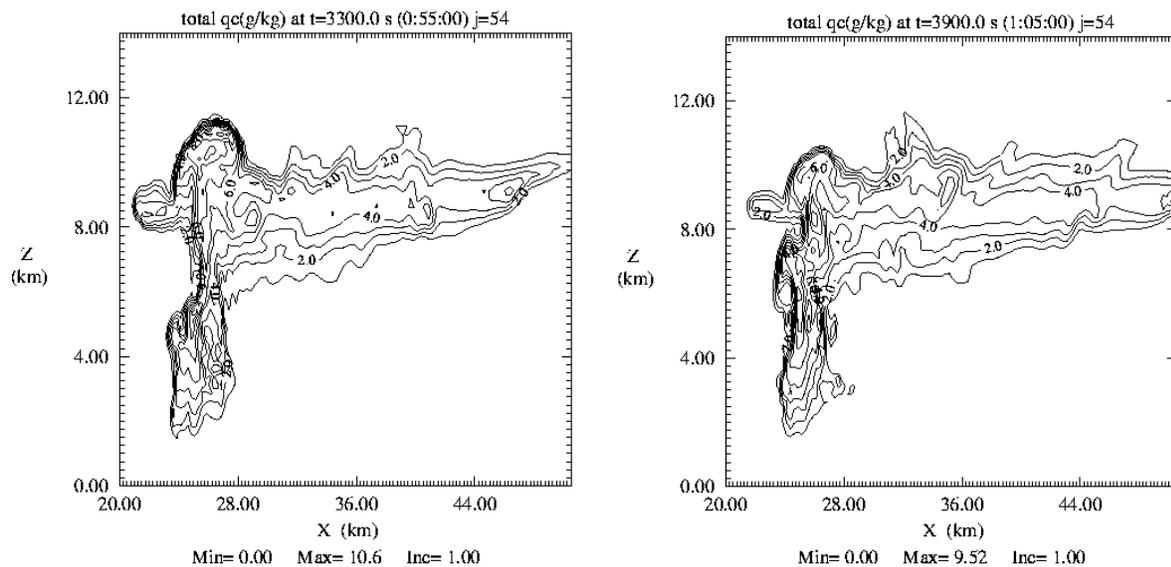
Determine how environmental factors, notably the forcing that initiates deep convection and the environmental wind and thermodynamic profiles, control the time-dependent behavior of deep convective storms.

Accomplishments

Early simulation study results can be viewed at: <http://www.caps.ou.edu/~dweber/bubbles.html>. As anticipated, we have been able to produce simulations that strongly resemble observed isolated multicell convective storms.

Publications

- Brooks, H., C. Doswell III, D. Dowell, R. Holle, B. Johns, D. Jorgensen, D. Schultz, D. Stensrud, S. Weiss, L. Wicker, and D. Zaras, 2003: Severe thunderstorms and tornadoes. Chapter 29, Handbook of Weather, Climate, and Water: Dynamics, Climate, Physical Meteorology, Weather Systems, and Measurements (B. R. Colman and T. D. Potter, Eds.), John Wiley and Sons, 575-619
- Doswell III, C.A., 2002: Flooding. *Encyclopedia of Atmospheric Sciences* (J. Holton, J. Curry, and J. Pyle, Eds.), Academic Press (New York), 769-776.
- Doswell III, C.A., 2002: Severe Storms. *Encyclopedia of Atmospheric Sciences* (J. Holton, J. Curry, and J. Pyle, Eds.), Academic Press (New York), 2054-2061.
- Doswell III, C.A., 2003: Comments on "Extraction of geopotential height and temperature structure from profiler and rawinsonde winds." *Mon. Wea. Rev.*, **131**, 1502-1503.
- Doswell, III, C.A., 2003: *A Guide to F-Scale Assessment*. U.S. Department of Commerce, NOAA, Silver Spring, MD, 94 pp.
- Doswell III, C.A., D.V. Baker and C.A. Liles, 2002: Recognition of negative mesoscale factors for severe weather potential: A case study. *Wea. Forecasting*, **17**, 937-954.
- Monteverdi, J.P., C.A. Doswell III and G.S. Lipari, 2003: Shear parameter thresholds for forecasting California tornadic thunderstorms. *Wea. Forecasting*, **17**, 357-370.



Simulated isolated multicell storm, showing an east-west cross section of the cloud water content (with precipitation turned off), showing a new cell developing at 3300 sec (left) and 3900 sec (right) into the simulation. These show the development and ascent of a discrete cell within an ongoing multicell storm.

Evaluation of Synoptic-Scale Controls on Tornado Outbreaks

Doswell, Thompson, Hart, Crosbie, Edwards

Objectives

Collect and categorize past tornado events in order to relate them to synoptic-scale controlling factors.

Accomplishments

An important tornado forecasting problem is whether or not a particular synoptic-scale is going to produce a significant outbreak of tornadoes. Although much work has been done on individual case studies over the decades since tornado forecasting began in the 1950s, this issue remains problematic for forecasters. In collaboration with Mr. Richard Thompson, Mr. John Hart, Mr. Casey Crosbie, and Mr. Roger Edwards of the SPC, an effort has begun to collect and categorize past events and build a database for the study.

Objective Analysis Studies and Improvements

Spencer, Stensrud, Fritsch, Gao

Objectives

Improve upon and continue to develop distant-dependent objective analysis techniques that are popular in real-time analysis and diagnostic studies.

Accomplishments

A comprehensive study using analytic data to compare a proposed variational technique for the analysis of scalar variables to more traditional analysis techniques has been completed. The traditional methods for objective analysis (e.g. Barnes and Cressman) assign grid point values based on the distance from the grid points to each member of the set of observations. Spatial derivatives are derived by applying a finite differencing scheme to the gridded observations. Traditional methods generally provide acceptable scalar analyses, but in the presence of highly irregularly-distributed observations, they may provide unsuitable derivative analyses. Triangle methods for data analysis, on the other hand, generally provide superior derivative analyses, but inferior scalar analyses.

The proposed variational analysis technique combines the best aspect of the traditional method with that of the triangle method. Specifically, the variational analysis technique is formulated such that the scalar analysis resembles that from the traditional method, whereas its derivative analysis resembles that of the triangle method. By using derivative information at points between observing stations in addition to the observations themselves, the variational method is able to generate analyses that are generally superior to those from both the traditional and triangle methods.

Work has begun to develop an improved variational technique for the analysis of scalar variables. A previous variational procedure combined scalar analyses from the "traditional" method with derivative analyses from the "triangle" method to provide analyses that were superior to those from both the traditional and triangle methods. The cost function of a new variational method is similar to that from the old method, except that analyses from the traditional and triangle methods are no longer required – only the observations themselves and first-derivative estimates at triangle centroids are required.

Initial results suggest that the new variational analysis scheme provides markedly improved analyses of scalar observations when compared to the earlier version of the variational analysis scheme and to more traditional analysis methods.

Publications

Spencer, P.L., 2002: A Variational Method for Improved Analyses of Scalars and their Derivatives. Ph.D. Dissertation, Pennsylvania State University, 121 pp.

Mesoscale Dynamics

Xu, Liu, P. Zhang

Objectives

Explore new instability mechanisms that should provide possible explanations for some observed three-dimensional substructures, including severe storm elements embedded in frontal rain bands; these include, but not limited to, nearly-symmetric circulations and their stability and instability, and nonmodal growths and singular vector structures in the presence of symmetric stability and instability.

Accomplishments

The structures and energetics of the nearly symmetric and nearly baroclinic modes are analyzed in detail to examine their instability mechanisms. It is shown that the nearly symmetric modes have their cross-band circulations slanted largely between the along-band absolute momentum surface and buoyancy surface of the basic state. Their growth is thus supported mainly by the symmetric-type energy conversion that transports energy from the basic-state along-band velocity and buoyancy to the perturbation along-band velocity and buoyancy, respectively, and then to the cross-band circulation. However, as the band

orientations are tilted slightly away from the basic shear, the growth is also assisted by the baroclinic-type energy conversion that transports energy from the basic-state buoyancy to the perturbation buoyancy via the along-band advection and then to the cross-band circulation. When the band orientation is tilted to the warm (or cold) side of the basic shear, the baroclinic-type energy conversion smoothes (or sharpens) the near-boundary structures and thus reduces (enhances) the effect of diffusive damping, especially near the non-slip boundaries. This explains why in the presence of diffusivity the symmetric instability yields to the nearly symmetric instability with the band orientation tilted slightly to the warm side of the basic shear.

Publications

Xu, Q., 2003: Nearly symmetric and nearly baroclinic instabilities in the presence of diffusivity. Part I: Growth Rate Patterns. *J. Fluid Mech.*, in press.

Xu, Q., and W. Gu, 2002: Semigeostrophic frontal boundary layer. *J. Bound.-Layer Meteor.*, **104**, 99-110.

Mesoscale Data Analyses and Data Assimilation

Xu, Liu, Nai, Wang, P. Zhang

Objectives

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

Accomplishments

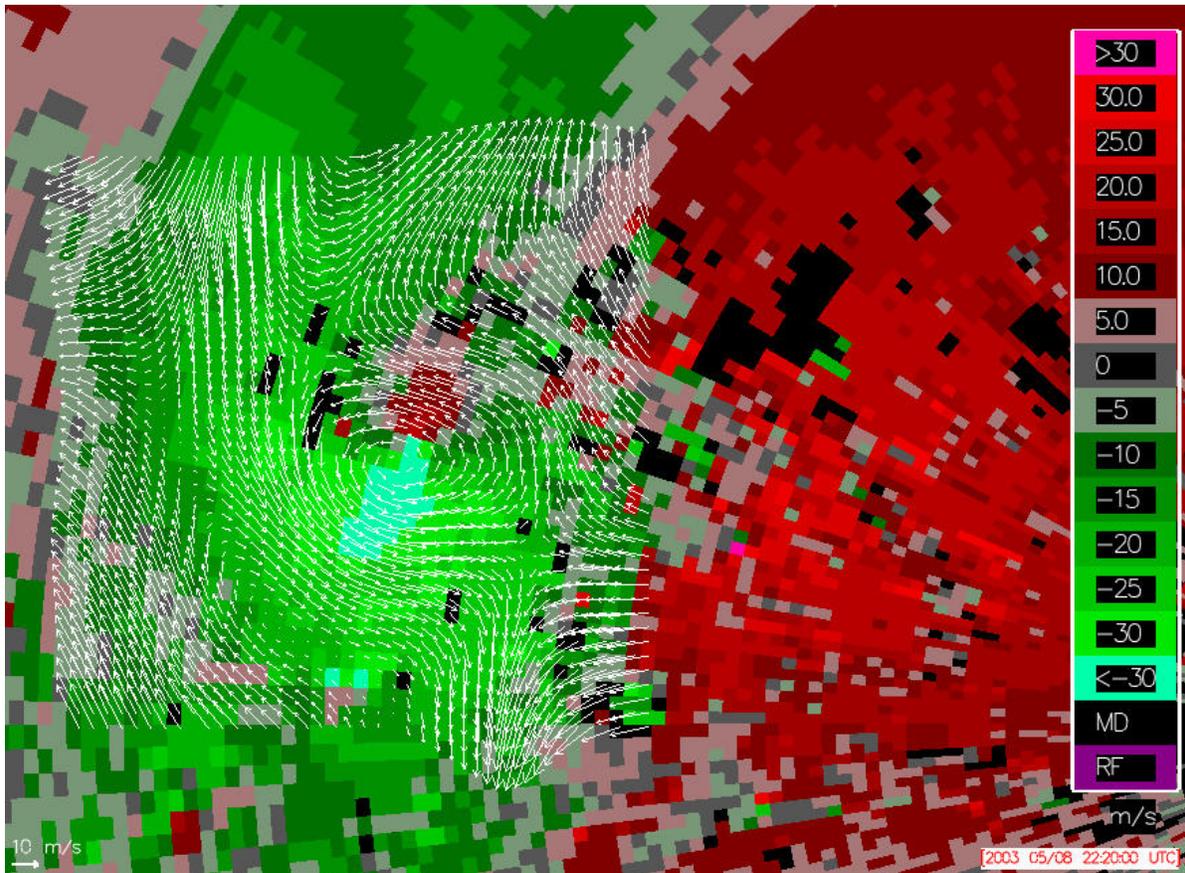
Doppler Radar Data Assimilation. The 2DSA method of Xu et al. (2001, *J. Appl. Meteorology*, 1485-1499) was extended for retrieving high-resolution winds on the conical surfaces of radar scans. The method was then further improved by incorporating the B-spline filter and developed into a stand-alone package to retrieve storm winds from WSR-88D Level-II wind data in a storm-following moving frame. The package was tested with Level-II data for Oklahoma tornadic storms on 11 May 1992, 3 May 1999, and 20 May 2001 (see <http://gaussian.gcn.ou.edu:8080/research.shtml>), and then coded into FORTRAN 90 (from FORTRAN 77) and installed on a PC-based workstation with Linux operating system for semi-automated real-time applications. This semi-automated package was then tested during the 2003 spring storm season for operational demonstrations at the Norman WFO. It produced real-time high-resolution winds on 1 km grid within storms on the severe-weather active dates during the demonstration period: April 15, 19, 23; May 6, 7-8 (overnight), 8-10, 15-16 (overnight), 16, 19; June 11-12 (overnight). The retrieved storm winds agreed closely with the radial velocities around 70% of the time. It produced real-time high-resolution vector winds on 1 km grid within storms and on 250 m grid in the vicinities of tornadic vortices overlaid with the radar radial-wind image. The test results were very encouraging. An example is shown in the figure below.

In collaboration with scientists at the Naval Research Laboratory (NRL), the previously-delivered 3.5DVar radar data assimilation package was further developed and incorporated into a data assimilation system for the Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). This system was used, together with other data fusion technologies, to retrieve three-dimensional cloud and wind fields from radar observations of radial velocity and reflectivity from multiple radars inside an analysis domain. The system also used satellite data and surface observations for retrieving cloud and precipitation information. The products from this system have been used to initialize the high-resolution COAMPS model, and at the same time, to provide detailed dynamical and hydrological structures of the three-dimensional atmosphere for the NOWCAST program at NRL.

Publications

Liu, S., C. Qiu, and Q. Xu, 2002: A variational method for dual-Doppler Radar retrievals of wind and thermodynamic fields. *Preprints, 21st Conference on Severe Local Storms*, 2 - 16 August, 2002, San Antonio, TX, Amer. Meteor. Soc., J145-146.

Zhao, Q., J. Cook, L. Phegley, K. Sashegyi, Q. Xu, P. Harasti, and M. Frost, 2003: Assimilation of radar observations into a high-resolution numerical weather analysis and prediction system at NRL. *Preprints, 31st Conference on Radar Meteorology*, 6-12 August 2003, Seattle, Washington, Amer. Meteor. Soc.



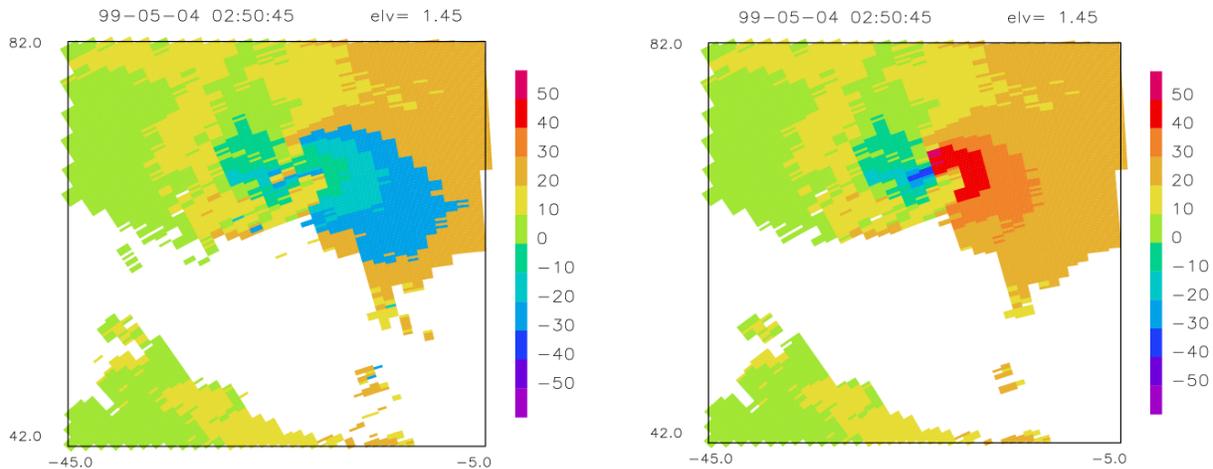
Mesocyclone winds (arrows) retrieved by 2dSA package in a moving frame, with $(U, V) = (8.3, 5.3) \text{ ms}^{-1}$ relative to the ground, from KTLX radial-wind observations (color imagery at 0.5°) for the time period from 2215 to 2220 UTC on 8 May 2003. The grid resolution is 250 m for the retrieved winds and the arrow scale is in ms^{-1} .

Doppler Radar Data Quality Control (in collaboration with NSSL scientists). A three-step method was developed for Doppler radar velocity dealiasing. This method uses the modified velocity azimuth display (VAD) method, in the first step, to estimate the horizontal mean winds from raw (aliased) radar velocity data. These mean winds are used as preliminary references for pre-dealiasing. Then, the traditional VAD method is applied to the pre-dealiased data to produce refined reference velocities for refined dealiasing in the second step. After these two steps, flagged data points are confined in small areas (often associated with strong shear and/or convergence flows), so the dealiased velocities along the boundary of each small area provide reliable starting points for the continuity check in the third step. The method was tested with Doppler radar data collected during 3 May 1999 Oklahoma tornado outbreak, the tornadic storm on 20 May 2001, the severe thunderstorm on 27 August 2002, and the tornadic storm on 8 May 2003. All of them were difficult cases for dealiasing. The results showed that the method is efficient and effective even in the areas of mesocyclones (see figure below).

The radar wind retrieval (RWR) system was upgraded with enhanced quality controls to process Level-II Doppler velocity data scans after the system started its real-time run in June 2002. A post quality control was also added for the retrieved vector wind fields. This system has been applied to nine WSR-88D radars in the Oklahoma and New England areas (<http://gaussian.gcn.ou.edu:8080/rtime.shtm>). This system has not only produced real-time displays of vector wind fields but also demonstrated important utilities in detecting data quality problems, and thus led to recent progress in quality control with expected deliverables to NCEP for radar data assimilation.

Publications

- Gong, J., L. Wang, and Q. Xu, 2003: A three-step dealiasing method for Doppler velocity data quality control. *J. Atmos. & Oceanic Technology*, accepted.
- Liu, S., P. Zhang, L. Wang, J. Gong, and Q. Xu, 2003: Problems and solutions in real-time Doppler wind retrievals. *Preprints, 31th Conference on Radar Meteorology*, 6–12 August 2003, Seattle, Washington, Amer. Meteor. Soc., 308-309.
- Zhang, P., S. Liu, L. Bi, and Q. Xu, 2003: Real-time WSR-88D velocity data quality control on bird detection. *Preprints, 31th Conference on Radar Meteorology*, 6–12 August 2003, Seattle, Washington, Amer. Meteor. Soc., 473-474.
- Zhang, P., Q. Xu, and A. V. Ryzhkov, 2002: Identification of biological scatters and Radar data quality control. *Preprints, 21st Conference on Severe Local Storms*, 2 - 16 August, 2002, San Antonio, TX, Amer. Meteor. Soc., 208-209



Raw data field (a) and dealiasing data field (b) of radial velocity on 1.5° tilt at 02:51 May 4, 1999, displayed over the vicinity area of the mesocyclone.

Error Covariance Estimation using Innovation Techniques (in collaboration with NSSL scientists). To optimally assimilate Doppler radar radial-velocity observations into a numerical model, it is necessary to estimate their error statistics. Since no method existed for this, a new statistical method was developed to estimate the required error covariances from Doppler radial-wind innovation (observation minus background) data. This method is an extension and re-formation of the innovation method of Xu and Wei (2001, *Mon. Wea. Rev.*, 2939-2954) based on the non-isotropic form of radial-velocity error covariance. Unlike the conventional innovation method, this method does not require the observation errors be non-correlated in the horizontal, so observation error correlations between neighborhood gates can be revealed and assessed. The new method was applied to radar data from the TDWR at the Oklahoma City, OK, Airport, while the background vector velocity fields were produced by the two-dimensional Doppler wind analysis package (Liu et al. 2003) running real-time with input radial-velocity data from NWS KTLX radar.

Publications

- Xu, Q., and L. Wei, 2002: Estimation of three-dimensional error covariances. Part III: Height-wind error correlation and related geostrophy. *Mon. Wea. Rev.*, **130**, 1052-1062.
- Xu, Q., and J. Gong, 2002: Background error covariance functions for Radar wind analysis. *Preprints, 19th Conference on Weather Analysis and Forecasting and 15th Conference on Numerical Weather Prediction*, 2 - 16 August, 2002, San Antonio, TX, Amer. Meteor. Soc., 286-287.
- Xu, Q., and J. Gong, 2003: Background error covariance functions for Doppler radial-wind analysis. *Quart. J. Roy. Meteor. Soc.*, **129**, 1703-1720.
- Xu, Q., L. Wang, and Kang Nai, 2003: Error covariance estimation for Doppler wind data assimilation. *Preprints, 31th Conference on Radar Meteorology*, 6–12 August 2003, Seattle, Washington, Amer. Meteor. Soc., (in press).

Convective Boundary Layer Vertical Vortices

Kanak, Lilly, Snow

Objectives

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

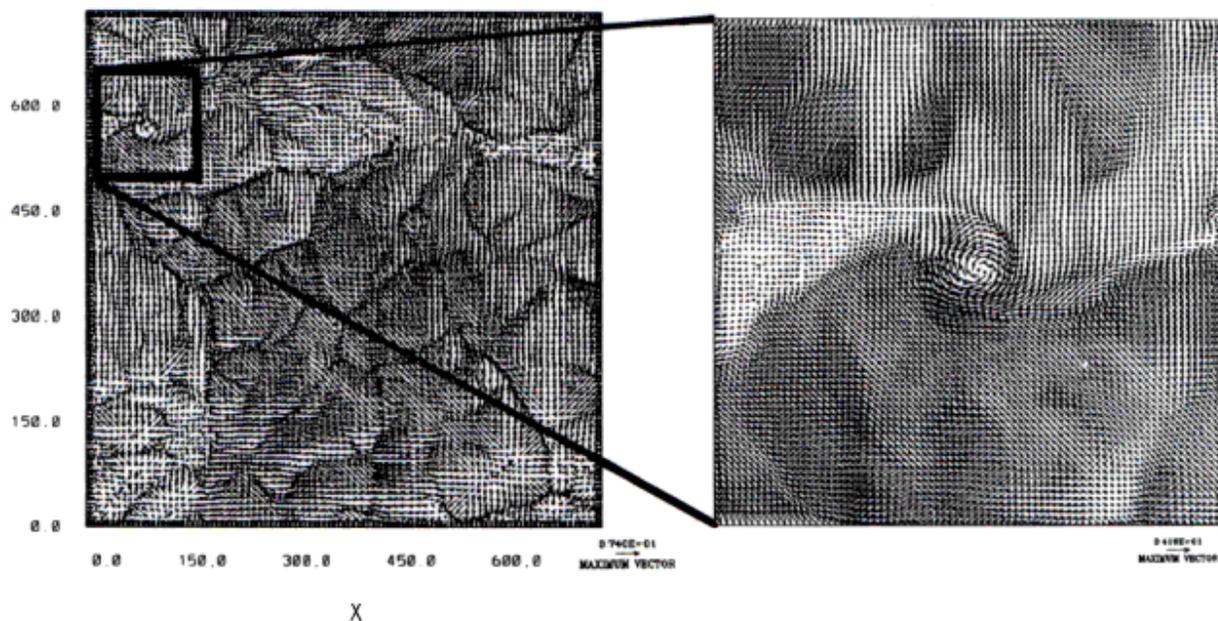
Accomplishments

Three-dimensional, two-meter resolution boundary layer LESs have been conducted, the results of which exhibit vertical vortices with dust devil-scale motions. This is likely the first LES to resolve and simulate vertical vortices with dust devil characteristics. The vortices' structure and intensity are compared to those of dust devil field observations by Sinclair and others. A paper on these experiments and their comparison with observations will soon be submitted to *Monthly Weather Review*.

Experiments that extend these results to consider the effects of ambient winds and wind shears on such vortices have been carried out and the results have been written for submission to the *Quarterly Journal of the Royal Meteorological Society*. Work in progress includes the continuing development of FORTRAN codes to detect and quantify vertical vortices in the run-time simulations using two different quantification algorithms.

Publications

Kanak, K. M., D. K. Lilly, and J. T. Snow, 2002: The formation of vertical vortices in the convective boundary layer. *International Symposium on boundary layers and turbulence*, The Netherlands, July 2002, Amer. Meteor. Soc. 76-79.



XY Cross-section of horizontal velocity vectors from 2m resolution LES at $z = 2.1$ m and $t = 2000$ s. Total domain with every fourth vector plotted (left). Maximum vector length is 7.4 m s^{-1} . Expanded view of the boxed region in left panel (right). Maximum vector is 4.2 m s^{-1} . The box corresponds to a 160 m^2 region.

Idealized Convective Elements and Vertical Vortex Formation

Shapiro, Kanak

Objectives

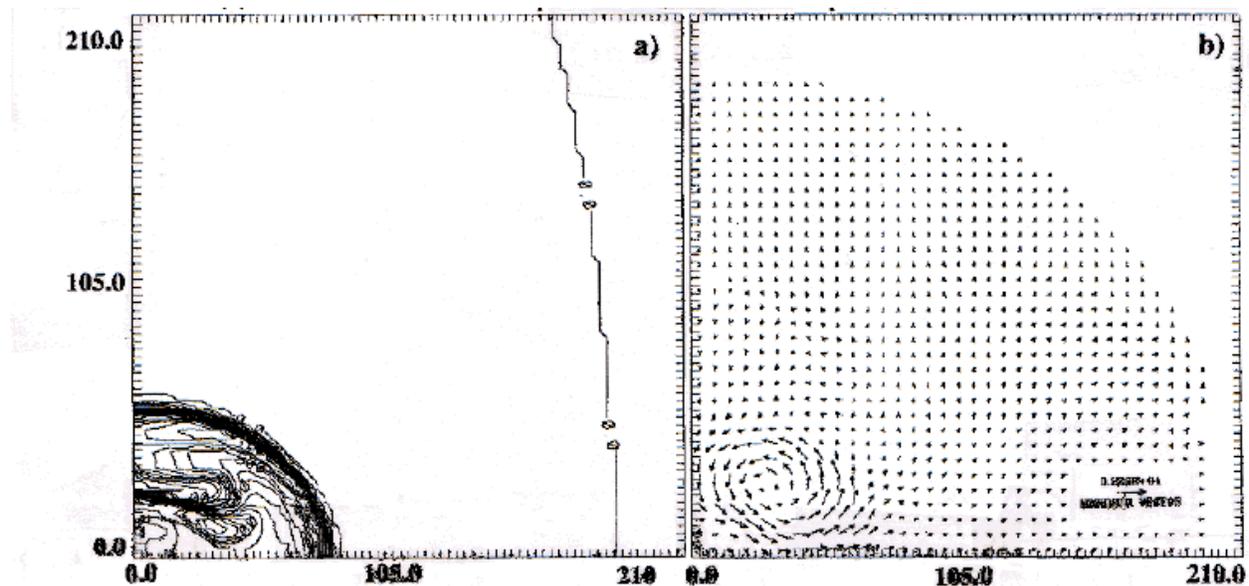
Examine the formation of vertical vortices within idealized ellipsoidal convective elements in quiescent ambient flows, and explore the effects of ambient winds, stratification, multiple convective elements, and other variables on the formation of these vertical vortices.

Accomplishments

Study of the formation of vertical vortices in elliptical buoyant bubbles has been conducted. Analytical and numerical works are described that demonstrate the formation of vertical vortex circulations in isolated elliptical bubbles in quiescent ambient flows. These basic fluid dynamic results can be readily generalized to many flows and should be intriguing in the context of the development of rotation in supercell convection. The inclusion of the effects of ambient winds, surface heat fluxes, variations in thermal stratification and the effects of viscosity will also be investigated.

Publications

Shapiro, A., and K. M. Kanak, 2002: Vortex formation in ellipsoidal thermal bubbles. *J. Atmos. Sci.*, **59**, 2253-2269.



XY cross-sections of potential temperature and horizontal velocity vectors. Horizontal cross-sections of selected fields at $t = 168$ s for the EXPT1 ellipsoidal thermal bubble. (a) Perturbation potential temperature contours at $z = 418.5$ m. Contour interval is 0.05° K. (b) Horizontal velocity vectors at $z = 418.5$ m.

Cloud Morphology and Mammatus

Schultz, Kanak, Straka, Trapp, Garrett, Gordon, Zrnica, Lilly

Objectives

Isolate the conditions under which mammatus clouds form and are detectable, and make case studies of mammatus events and null events to help assess the role of dynamical and microphysical processes in mammatus cloud formation.

Accomplishments

An observational study using existing data and new data collected with new mammatus events is underway to study of the formation mechanisms and dynamics of mammatus clouds.

Two Dimensional Video Disdrometer Data Collection and Analysis

Schuur, Duchon

Objectives

Collect and study disdrometer measurements of precipitation.

Accomplishments

The NSSL 2D Video Disdrometer was moved to a newly constructed subterranean pit at the Norman, OK Mesonet site in December 2002. Since then, 44 precipitation events have been sampled. These data are used to investigate the influence of airflow disturbances on disdrometer measurements, investigate the precipitation physics of precipitation systems over the Southern Great Plains, and provide crucial measurements on natural drop size distribution variability that can be used to improve NSSL dual-polarization radar rainfall estimation algorithms.

Evaluation of Historical Trends in the SPC Wind and Hail Reports Database

Levit

Objectives

Evaluate all reports of wind and hail damage logged in a database spanning 1955-2002.

Accomplishments

This research examines the trends in severe hail and wind reports contained in an SPC database spanning 1955-2002. The data show that, as expected, reporting differences over the years and population biases contribute to particular trends in the data. However, even with these problems, climatology still mainly prevails and seasonality still has the most effect on the location, distribution, and intensity of hail and wind reports.

Publications

Schaefer, J., S. Weiss, and J. Levit, 2003: The frequency of severe thunderstorm winds over the contiguous United States. *Preprints, 11th International Conference on Wind Engineering*, Lubbock, Texas, IGWE, 237-244.
Schaefer, J., S. Weiss, J. Levit, and D. McCarthy, 2003: The frequency of severe hail over the contiguous United States. *Preprints, 14th Conference on Applied Climatology*, Seattle, Washington, Amer. Meteor. Soc., accepted.

Advanced Weather Data Visualization

Levit, Purdue University and University of Utah collaborators

Objectives

Develop software for photo-realistically renderings of hydrometeor data from numerical weather prediction models.

Accomplishments

This three-year research project, sponsored by the National Science Foundation, began on 1 October 2002. Collaborators include Kirk Riley and David Ebert of Purdue University, and Charles Hansen of the University of Utah. To date, our research team has developed initial software to render data from the Weather Research and Forecasting (WRF) model, and a simulated supercell data set has been used to test the system. At Purdue, Riley has created a Windows-based software package to test different methods for rendering the hydrometeor data in the WRF model (cloud water, rain, ice, snow, and graupel) and initial results show that examining the data in this photo-realistic sense adds value to the overall scientific visualization. In the future, much more capability will be added to the software system, along with improved rendering of the various hydrometeor fields.

Publications

Riley, K., D. Ebert, C. Hansen, and J. Levit, 2003: Visually-Accurate Multi-Field Weather Visualization. *Proc., 2003 IEEE Visualization Conf.*, Seattle, Washington, accepted.



Test visualization of a simulated supercell thunderstorm, rendered using new computer graphics techniques. This image was rendered using the new software package developed by Riley, and is from a simulated supercell thunderstorm using the WRF model.

Forecast Improvements

Warning Simulation

Magsig, Wood, Yu, Hoggard, Mohammed Said, Ferree, Quoetone, Page

Objectives

Develop simulation capabilities to enhance warning decision making research and training.

Accomplishments

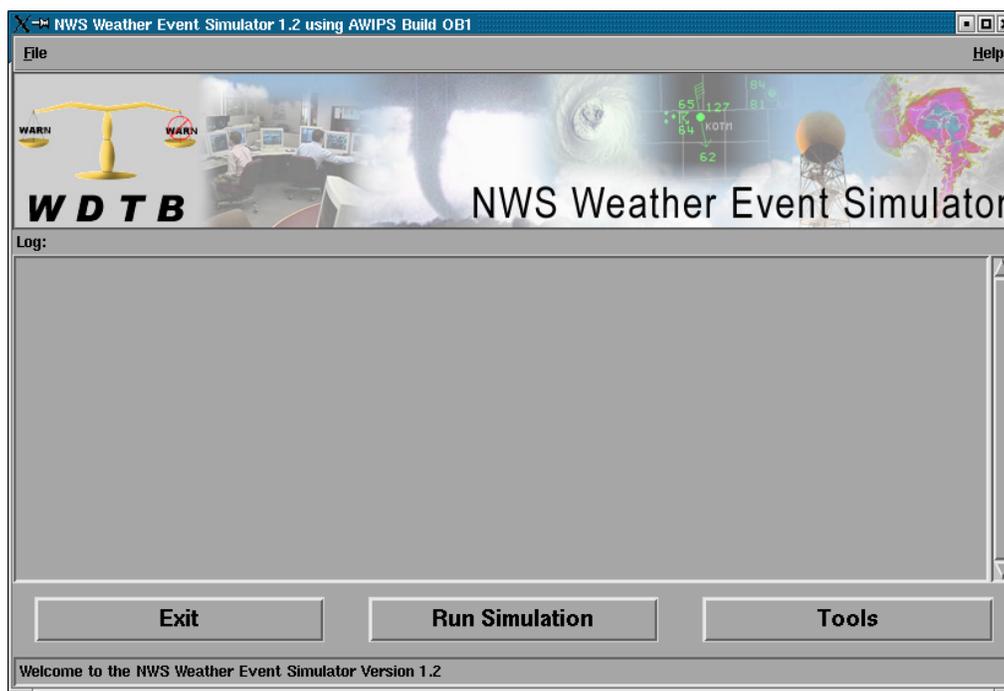
CIMMS scientists, working with WDTB instructors and NWS software developers, continue to develop simulation capabilities to study warning decision making for severe convective weather and winter weather. The simulation capabilities have been expanded to include more relevant software builds of the Advanced Weather Interactive Processing System (AWIPS) that contain the new 8-bit radar data products, mesoscale ensemble model data, and unique techniques to aid forecaster communication. Simulation capability has also been improved with the addition of version 2 of the Flash Flood Monitoring and Prediction System (FFMP2.0). This has allowed investigation into flash flooding decision making and the role of these systems in providing guidance to the forecaster.

Collaboration with NWS forecasters nationwide on warning decision making research and training continued with releases of the Weather Event Simulator (WES), which contain some of the simulation capabilities developed by CIMMS that can run on Linux-based training workstations. The WES has become an active part of every NWS forecast office training and research plan, and numerous WES cases and research findings have been shared with CIMMS researchers and incorporated into NWS training at the WDTB. WES capabilities have been further enhanced by a collaborative project with the Radar Operations Center to extract historical events archived on optical disks and import them into WES.

Publications

Ferree, J.T., E.M. Quoetone, and M.A. Magsig, 2002: Weather event simulator best practices. *Preprints, 21st Conf. on Severe Local Storms*, 12-16 August 2002, San Antonio, TX, Amer. Meteor. Soc.

Magsig, M.A., and E. M. Page, 2003: Weather Event Simulator implementation and future development, *Preprints, 19th Interactive Symposium on AWIPS*, 9-13 February 2003, Orlando, FL. Amer. Meteor. Soc.



Web interface for the Weather Event Simulator version 1.2.

Warning-Related Forecast Improvements

Magsig, Yu, Wood, Hoggard, Mohammed Said, Carroll, LaDue, Ferree, Burgess, Dowell, Richardson, Wurman

Objectives

Improve understanding of warning related issues.

Accomplishments

The warning decision making process is multi-faceted, often being improved directly by unique observing systems, analysis techniques, data analysis techniques, human factors, or improvements in forecast verification. Progress is being made in warning-related forecast improvements with the application of unique radar sensors. The Doppler on Wheels (DOW) is a mobile radar sensor with high temporal and spatial resolution data that has been used to illustrate the structure and evolution of the hook echo as it relates to tornadogenesis in multiple tornadic storms. Considerable variability exists in precipitation structure surrounding the tornado between events, and in one of the more complete data sets it was shown that the low-level hook echo structure was strongly influenced by the structure and evolution of the vortex pairs aloft.

Publications

Carroll, K. D., J.G. LaDue, A.C. Wood, and J.T. Ferree, 2003: Nonmeteorological factors in warning verification. *Preprints, 2nd Annual AMS Student Conference*, 9-13 February 2003, Long Beach, CA.
Magsig, M.A., D.W. Burgess, D. Dowell, Y. Richardson, and J. Wurman, 2002: The structure and evolution of hook echoes during tornadogenesis as revealed by high resolution radar data. *Preprints, 21st Conf. on Severe Local Storms*, 12-16 August 2002, San Antonio, TX.

Warning Decision Making Analysis

Magsig, Wood, Yu, Hoggard, Mohammed Said, Jones (SA Technologies), NWS/WDTB collaborators

Objectives

Investigate warning decision making issues with NWS forecasters, and evoke a better understanding of the warning decision making process.

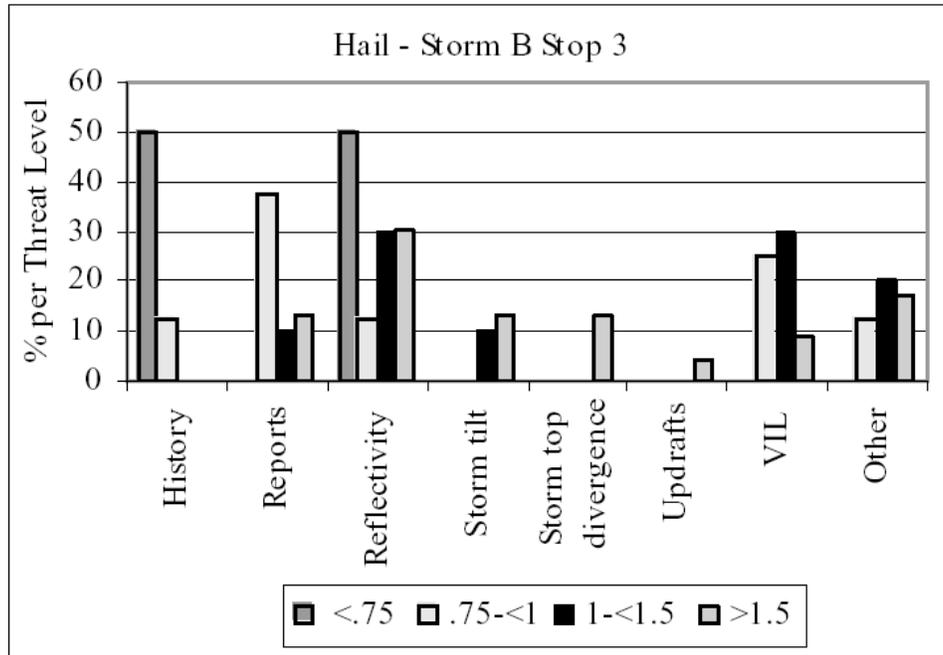
Accomplishments

Warning decision making analysis continues to be an area of active collaborative research between CIMMS and the WDTB. CIMMS staff has been heavily involved in WDTB workshops on analysis of warning decision making for severe weather, including flash flooding, and winter weather. The workshops incorporate subject matter experts and warning forecasters from around the country to discuss many facets of the warning decision making process. The workshops are an opportunity to share knowledge and experience as well as to test new experimental techniques for issuing and evaluating warnings. A Level III follow-up evaluation of the winter weather workshop indicates that the research and experiences of the workshop have been particularly valuable to NWS forecasters.

Collaboration on warning decision making analysis has recently been expanded to include Dr. Debra Jones from SA Technologies, Inc. For each of the three 90-minute simulations in the severe weather/flash flood workshops, students are asked a series of questions about their perceptions at random intervals during the simulation. Audio recordings of the warning operations are transcribed and combined with the warnings and statements issued to create the data sets needed to investigate warning decision making issues. Dr. Jones is using these data sets to collect information on cognitive mechanisms that enable a person to project how a system changes over time. A detailed investigation of one simulation has found evidence supporting both pattern matching and mental simulation as mechanisms for mental projection.

Publications

Jones, D.G., E.M. Quetone, J.T. Ferree, M.A. Magsig, and W.F. Bunting, 2003: An initial investigation into the cognitive processes underlying mental projection, submitted to *Human Factors and Ergonomics Society*, 47th Annual Meeting, Oct. 13-17, 2003, Denver, CO.



Simulation group participants' rationale for hail forecast decision making organized by maximum expected hail size and percent distribution per threat level. Comparison with an expert opinion and ground truth illustrates biases in the decision making process that may be related to the mental simulations forecasters use when making forecasts.

Assimilation of Lightning Data into Mesoscale Models

Mansell, Ziegler, MacGorman, Fiedler, Beasley

Objectives

Develop and test a method to assimilate lightning flash data into a mesoscale prediction model.

Accomplishments

Lightning data assimilation is being tested in COAMPS using information from the 19 June 2000 Kansas storm that occurred during the STEPS field program. A simple assimilation scheme helps the model turn on the convection parameterization (Kain-Fritsch) in the correct times and places where convection actually occurred according to lightning data. Convection is not directly suppressed, but the modification to the environment appears to help remove some incorrect activations of the convection parameterization. Four-day spin-up cycles have been run with and without lightning data assimilation. The test case shows a slight improvement in a 3-h pure forecast when lightning is assimilated.

Improving Snowfall Forecasting by Diagnosing Snow Density

Schultz, Cortinas

Objectives

Improve snowfall forecasting by developing methods to forecast the density of snowfall.

Accomplishments

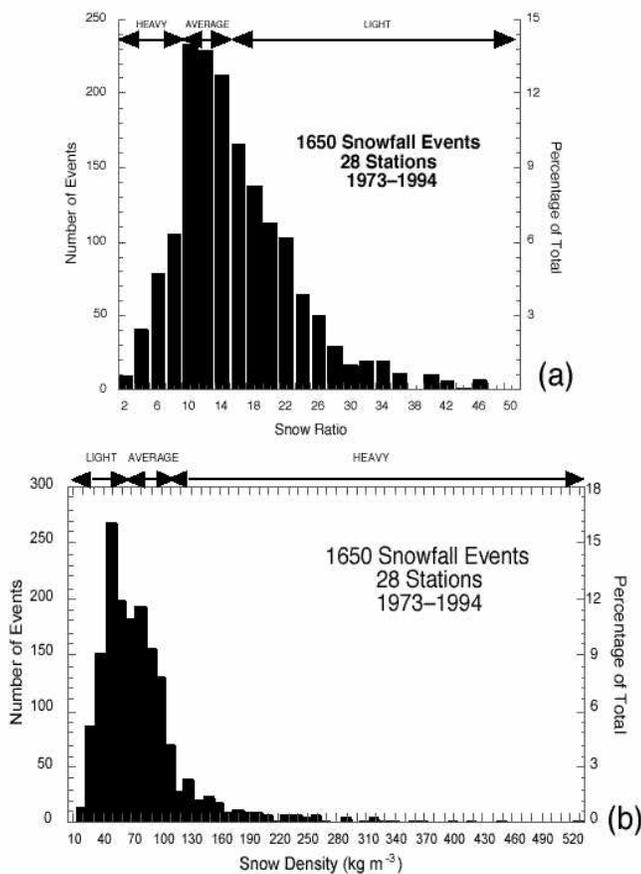
Current prediction of snowfall amounts is accomplished either by using empirical techniques that have questionable scientific validity, or by using a standard modification of liquid equivalent precipitation such as the ten-to-one rule. This rule, which supposes that the depth of the snowfall is ten times the liquid equivalent (a snow ratio of 10:1, reflecting an assumed snow density of 100 kg m^{-3}), is a particularly popular technique with operational forecasters, although it dates back to a limited nineteenth century

study. Unfortunately, measurements of freshly fallen snow indicate that the snow ratio can vary on the order of 3:1 to 100:1. Given this variability, quantitative snowfall forecasts could be substantially improved if a more robust method for forecasting the density of snow (i.e., the snow ratio – the ratio of the depth of the snow to the melted equivalent precipitation rate) were available. A review of the microphysical literature reveals that many factors may contribute to snow density, including in-cloud (crystal habit and size, the degree of riming and aggregation of the snowflake), sub-cloud (melting and sublimation) and surface processes (compaction and snowpack metamorphism). Despite this complexity, our work explores the sufficiency of surface and radiosonde data for the classification of snowfall density.

A principal component analysis isolates seven factors that influence the snow ratio: solar radiation (month), low- to mid-level temperature, mid- to upper-level temperature, low- to mid-level relative humidity, mid-level relative humidity, upper-level relative humidity, and external compaction (surface wind speed and liquid equivalent). A ten-member ensemble of artificial neural networks is employed to explore the capability to determine snow ratio in one of three classes: heavy ($1:1 < \text{ratio} < 9:1$), average ($9:1 \leq \text{ratio} \leq 15:1$), and light ($\text{ratio} > 15:1$). The ensemble correctly diagnoses 60.4% of the cases, which is a substantial improvement over the 25.8% correct using the 10:1 ratio, 41.7% correct using the sample climatology, and 51.7% correct using the NWS "new snowfall to estimated meltwater conversion" table. Given the improvement over presently used techniques for diagnosing snow ratio, this study indicates that the neural network approach can lead to advances in forecasting snowfall depth.

Publications

Roebber, P. J., S. L. Bruening, D. M. Schultz, and J. V. Cortinas Jr., 2003: Improving snowfall forecasting by diagnosing snow density. *Wea. Forecasting*, **18**, 264-287.



Histograms for the dataset used in this paper (1650 snowfall events over 28 stations during 1973-1994). The y-axis is the number of events on the left and the percentage of total events on the right. Light, average, and heavy are defined in the text. (a) Snow ratio (in 2-unit bins); (b) snow density (in 10 kg m⁻³ bins).

Collaborating With the Operational Forecasting Community

Baldwin, Kain, Levit

Objectives

Cultivate and participate in operationally-relevant research efforts and act as liaisons between the numerical modeling and operational forecasting communities.

Accomplishments

Active interactions between NSSL and SPC continued with daily map discussions, collaborative research projects, and the 2003 SPC/NSSL Spring Program. A core group of CIMMS, SPC, and NSSL scientists gathered each day to discuss the current day's weather, forecast "problems of the day", and related scientific and operational issues. These discussions cultivate and maintain a casual and working relationship between researchers and forecasters. Numerous operationally-relevant collaborative research projects have been inspired by these discussions. Among the collaborative projects to emerge this year is a study to understand rapid changes in convective inhibition (CIN). Since the onset of deep convection is modulated by CIN, better understanding and prediction of the processes that change this field could substantially improve forecasts of thunderstorm initiation. This project involves both observational analysis and the use of numerical models.

The 2003 Spring Program explored two promising applications of numerical models in forecasting severe weather: the use of Short-Range Ensemble Forecast (SREF) prediction systems, and the use of high-resolution deterministic models. As in previous years, forecast/research teams were anchored by SPC forecasters and NSSL/CIMMS researchers. The teams were rounded out with visiting scientists from numerous institutions, including the NCEP Environmental Modeling Center, the NOAA Forecast Systems Laboratory, the Norman, OK, and White Lake, MI, NWS Forecast Offices, the University of Arizona, OU, the University of Washington, Iowa State University, the Massachusetts Institute of Technology, the United Kingdom Meteorological Office, and the Meteorological Service of Canada. In addition, observers from COMET and the US Weather Research Program participated. The SREF system was developed in collaboration with Dave Stensrud (NSSL), and involved the aforementioned forecast teams preparing the perturbations for the SREF through a novel graphical user interface and the MM5 adjoint system. The real-time 32-member MM5 ensemble was created on a Linux supercomputer located at the OU Oklahoma Supercomputing Center for Education and Research (OSCER), and the dedicated time on that machine was provided through an OSCER grant to CIMMS. In the second area of focus, participants compared mesoscale model forecasts using parameterized convection to cloud resolving forecasts (i.e., without parameterized convection) from the WRF model. The goal was to provide a preliminary assessment of the forecast value of high-resolution models compared to the current generation of operational and experimental forecast models, including the WRF, Eta, EtaKF, RUC, and NCEP's new Nonhydrostatic Mesoscale Model (NMM). The program ran weekdays from 14 April through 6 June.

Publications

- Carbin, G. W., J. S. Kain, J. S., M. S. Bukovsky, and M. E. Baldwin, 2003: Mesoscale processes associated with rapid erosion of the "cap". *Preprints, Tenth Conference on Mesoscale Processes*. Portland, OR, Amer. Meteor. Soc.
- Kain, J. S., M. E. Baldwin, and S. J. Weiss, P. R. Janish, M. P. Kay, and G. Carbin, 2003: Subjective verification of numerical models as a component of a broader interaction between research and operations. *Wea. Forecasting*, in press.
- Kain, J. S., P. R. Janish, S. J. Weiss, M. E. Baldwin, R. S. Schneider, and H. E. Brooks, 2003: Collaboration between forecasters and research scientists at the NSSL and SPC: The Spring Program. *Bull. Amer. Meteor. Soc.*, in press



Members of a forecast team evaluate deterministic model output during the 2003 SPC/NSSL Spring Program.

Improving Numerical Guidance for Mesoscale Forecasting

Baldwin, Kain

Objectives

Improve numerical model forecasts, primarily by calibrating physical parameterizations, optimizing model configurations, and soliciting feedback from operational forecasters, and promote the use of numerical models as educational and research aids for operational forecasters.

Accomplishments

Experimental Version of the Eta Model. CIMMS scientists continue to run an experimental version of NCEP's Eta model at NSSL. Our model configuration differs from the operational version in that it uses the Kain-Fritsch convective parameterization and higher-order, reduced-magnitude horizontal diffusion. Model parameters have been calibrated and optimized through collaboration with forecasters at the SPC. Over the last several years this configuration of the model has earned the confidence of forecasters at the SPC, the Hydrometeorological Prediction Center, and many local NWS Forecast Offices, and has become a part of their routine forecast-preparation process. In addition, CIMMS researchers have incorporated this model into SPC training programs, promoting a better understanding of numerical models among local forecasters. Furthermore, the model has been used as a diagnostic technique in various collaborative research studies. As a consequence of these efforts, forecasters at the SPC have become more confident and knowledgeable users of all numerical models.

Development of the WRF Model. Over the past year CIMMS scientists have played a unique role in the development of the WRF model. Not only have they contributed to specific elements of model design, debugging, and implementation, they have also established a framework for model evaluation and testing in an operational forecasting environment. In particular, they have worked closely with the SPC and the Norman NWS Forecast Office to promote awareness, education, operational usage, and critical

examination of WRF output by operational forecasters. In turn, forecasters have provided valuable feedback on WRF model performance. Specific contributions include the following:

- Active participation as members of various WRF development teams.
- Development of post-processing software to convert WRF output into a format compatible with NCEP operational model output. This software provides a crucial link between the operational and research elements in the WRF program, enabling WRF output to be processed by standard NCEP post-processing procedures and facilitating side-by-side comparisons of output from WRF and operational NCEP models.
- Inclusion of quantitative precipitation forecasts output from WRF runs at NCAR and CIMMS/NSSL into verification databases for NCEP models, providing a comparative benchmark for WRF performance based on equitable-threat and bias scores (<http://www.nssl.noaa.gov/etakf/verf>).
- Increasing awareness and education of SPC and Norman WFO forecasters through daily interactions, training seminars, and lectures on the WRF model.
- Encouraging forecasters to provide feedback about WRF performance so that their insight can influence model development trends.
- Procuring funding for a new state-of-the-art computing cluster and establishing a high resolution real-time forecasting system for daily WRF predictions using this cluster.
- Real-time forecasting on high resolution (3 km spacing) and mesoscale resolution (12 km spacing) grids as a central component of the 2003 SPC/NSSL Spring Program (http://www.spc.noaa.gov/exper/Spring_2003)

Publications

- Baldwin, M. E., J. S. Kain, and M. P. Kay, 2002: Properties of the convection scheme in NCEP's Eta Model that affect forecast sounding interpretation. *Wea. Forecasting*, **17**, 1063-1079.
- Kain, J. S., 2003: The Kain-Fritsch convective parameterization: An update. *J. Appl. Meteor.*, in press.
- Kain, J. S., M. E. Baldwin, and S. J. Weiss, 2002: WRF model evaluation at the SPC and NSSL. *Preprints, 15th Conference on Numerical Weather Prediction*, San Antonio, TX, Amer. Meteor. Soc., 256-259.
- Kain, J. S., M. E. Baldwin, and S. J. Weiss, 2003: Parameterized updraft mass flux as a predictor of convective intensity. *Wea. Forecasting*, **18**, 106-116.
- Kurkowski, N. P., D. J. Stensrud, and M. E. Baldwin, 2003: Assessment of implementing satellite-derived land cover data in the Eta model. *Wea. Forecasting*, **18**, 404-416.
- Stensrud, D., J., N. P. Kurkowski, and M. E. Baldwin, 2003: An evaluation of using real-time, satellite derived vegetation fraction in the Eta model. *Preprint CD, Symp. On Variability of Water in Weather and Climate*, Long Beach, CA, Amer. Meteor. Soc., paper J8.3.

Forecast Verification

Baldwin, Kain, Elmore, Schultz

Objectives

Maintain and continue building a database of forecasts and observations for ongoing verification, and develop new and meaningful verification strategies.

Accomplishments

Automated data collection procedures have continued for quantitative precipitation forecasts from NCEP's operational models, an experimental version of the Eta model running twice-daily at NSSL, and experimental versions of the WRF model running at NSSL and NCAR. These data are verified against analyses of both raingage observations and the so-called "Stage IV" high-resolution multi-sensor precipitation fields from NCEP using equitable threat (ET) and bias scores. These scores are compiled on a monthly basis and updated daily on the web at <http://www.nssl.noaa.gov/etakf/verf/>.

Development of new verification techniques has also continued at NSSL. In order to obtain more meaningful verification information, such as verifying the characteristics of interesting meteorological phenomena, an automated procedure for classifying rainfall systems has been developed. Forty-eight cases from the "Stage IV" precipitation analysis are used to create a training data set. Essential attributes are determined from the training data set by comparing an expert classification with results from

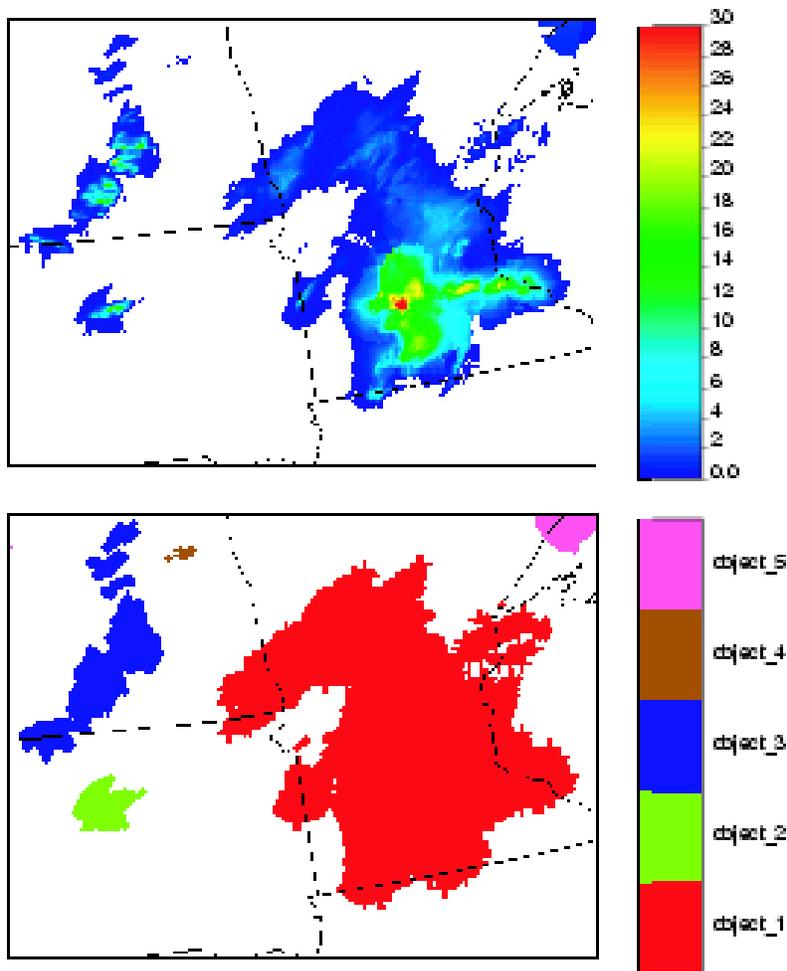
hierarchical cluster analysis experiments. The parameters of the gamma probability distribution are fit to observed rainfall amounts using the generalized method of moments technique. These parameters are used as attributes related to the rainfall intensity. Attributes related to the degree of linear organization of each rainfall system are obtained via geostatistical measures. Automated procedures for identifying, analyzing, and classifying rainfall systems have been developed. The automated classification procedure was used to analyze all rainfall systems for 2002. To test the performance of the automated classification procedure, results are validated against an expert classification based upon objective criteria. From an independent random sample, the automated classification procedure accurately classifies events into stratiform, linear, and cellular classes 85% of the time.

A long-term archive of several forecast fields, such as winds and temperatures on mandatory pressure levels, from daily runs of NCEP's operational Eta model and NSSL's experimental version of the Eta model has continued. These data are verified against operational Eta analyses and forecast error fields for 24-h forecasts over a 14-month period have been studied in detail. By applying basic statistical techniques, appropriate corrections are made for temporal and spatial degrees of freedom, yielding the spatial distribution of 95% confidence intervals about the mean error at each grid point. These 2D plots of mean error can be used by forecasters to improve the model guidance that they use in the preparation of their forecasts. The 500-hPa height errors for mobile shortwave troughs are usually localized and positive (under forecast); errors are believed to mostly be associated with initial-condition errors. On the other hand, the 500-hPa height errors for longwave ridges usually cover a much larger area comparable to the size of the ridge and are also negative (under forecast); errors are believed to mostly be associated with errors in the model, likely the radiation scheme.

In order to determine whether the spatial structure and variability of precipitation fields is predicted in a manner consistent with observations, Fourier energy spectra of precipitation observations and forecasts from various mesoscale models (NCEP Eta, NSSL Eta, NCAR WRF, etc) were analyzed. These results showed that the spectra from the NSSL Eta and NCAR WRF matched the observed spectra up to around the 5 delta-x scale, where the explicit and implicit energy dissipation mechanisms in the models become dominant. However, the energy dissipation in the operational NCEP Eta began to dominate the results at a much larger scale, approximately 10-20 delta-x. These results are useful to developers of numerical weather prediction models in determining what aspects of the model physics or dynamics are producing the energy spectra. This information is also useful to forecasters to allow them to realize what spatial scales are actually being resolved by the model forecasts.

Publications

- Baldwin, M. E., 2003: Automated Classification of Rainfall Systems using Statistical Characterization. PhD Dissertation, University of Oklahoma, 195pp.
- Baldwin, M. E., and M. S. Wandishin, 2002: Determining the resolved spatial scales of Eta Model precipitation forecasts. *Preprints, 15th Conf. Numerical Weather Prediction*. San Antonio, TX, Amer. Meteor. Soc., 85-88.
- Baldwin, M. E. and S. Lakshmiarahan, 2002: Rainfall classification using histogram analysis: An example of data mining in meteorology. *Intelligent Engineering Systems Through Artificial Neural Networks*, 12, C.H. Dagli, A.L. Buczak, J.Ghosh, M.J. Embrechts, O. Ersoy, S.W. Kercel, Eds., ASME Press, 429-434.
- Baldwin, M. E., S. Lakshmiarahan, and J. S. Kain, 2002: Development of an "events-oriented" approach to forecast verification. *Preprints, 15th Conf. Numerical Weather Prediction*, San Antonio, TX, Amer. Meteor. Soc., 210-213.
- Baldwin, M. E., and S. Lakshmiarahan, 2003: Development of an events-oriented verification system using data mining and image processing algorithms. *Preprints, 3rd Conf. Artificial Intelligence*, Long Beach, CA, Amer. Meteor. Soc.
- Ebert, E. E., U. Damrath, W. Wergen, and M. E. Baldwin, 2003: The WGNE assessment of short-term quantitative precipitation forecasts. *Bull. Amer. Meteor. Soc.*, **84**, 481-492.
- Elmore, K. L., M. E. Baldwin, and D. M. Schultz, 2002: Spatial bias errors in the operational NCEP Eta Model. *Preprints, 15th Conf. Numerical Weather Prediction*. San Antonio, TX, Amer. Meteor. Soc., 93-96.



An example of the automated rainfall system identification process, which is part of the automated classification procedure. Top panel shows 1-h rainfall valid 2300 UTC 28 July 2002, bottom panel shows rainfall object labeling. Each contiguous region of measurable rainfall is considered an object; these regions are expanded in area by 15%. Objects within 20 km of each other are connected to form a single rainfall object.

New England Forecasting Pilot Program: High Resolution Temperature and Air Quality Study

Baldwin, Kain, Yussouf

Objectives

Generate model forecasts from different configurations of the Eta and the Penn State/NCAR (MM5) mesoscale research models to contribute as members of a multi-model ensemble; collaborate and coordinate with scientists at NCEP and FSL to collect the model output, prepare the full ensemble, and produce and display ensemble forecasts on the web for future analysis; and create and test new methods for improving the forecasts of temperature and dewpoint temperature in the New England region from the ensemble of model forecasts.

Accomplishments

A multi-model short-range ensemble forecasting system created as part of a NOAA pilot program on temperature and air quality forecasting over New England during the summer of 2002 has been evaluated. The ensemble forecasting system consists of 23 total forecasts from four different models out of which six forecasts are generated by the CIMMS/NSSL scientists. Two of these forecasts are from the

20-km EtaKF model (NKF). It started from both the operational Eta model and the operational aviation run of the medium-range forecast (MRF) model initial conditions, but uses a smaller domain than the operational Eta model. The remaining four forecasts are from MM5 that uses the Eta model initial and boundary conditions for the control run and a random coherent structure approach to generate another three initial conditions for the 32-km grid.

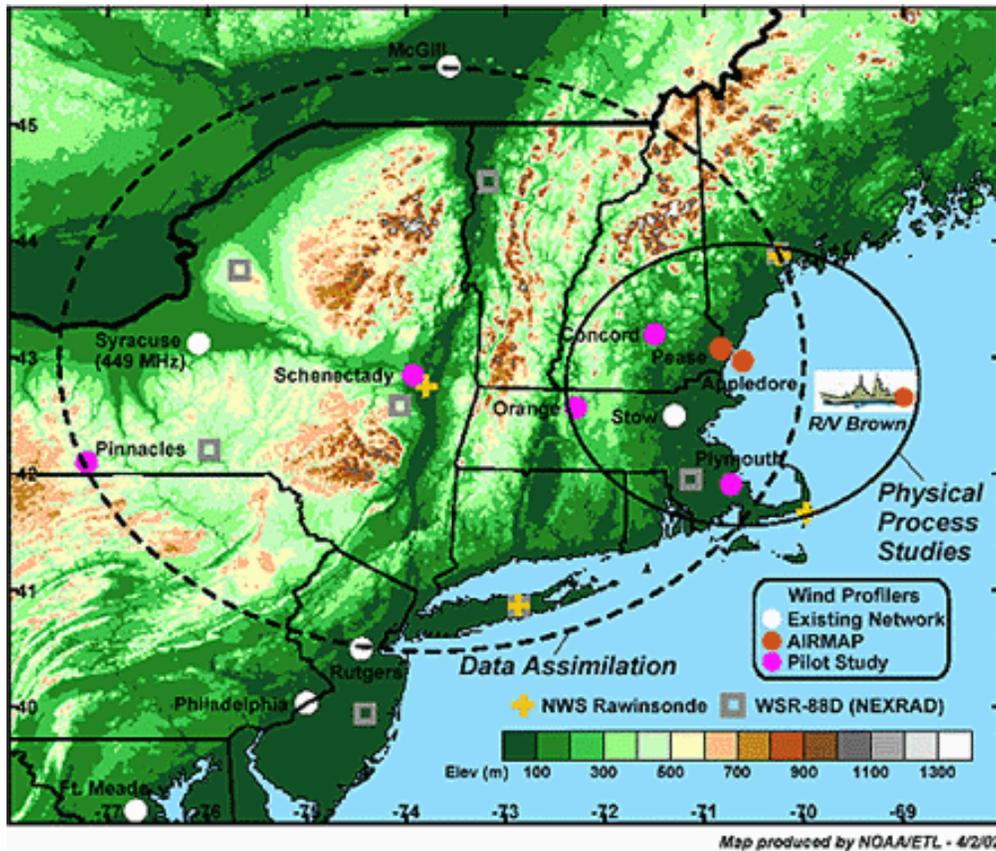
CIMMS researchers have developed an automated process that ran from 15 July to 31 August 2002 to (1) collect the forecast data by collaborating with NCEP and FSL scientists, (2) produce the bias-corrected temperature and dewpoint temperature and (3) update the website on a daily basis. This web site at NSSL displayed horizontal plots of ensemble mean of both 2-m temperature and dewpoint temperature. The website also displayed the time series of raw and bias corrected ensemble mean temperature for 10 selected cities.

In addition, CIMMS researchers have developed a cluster analysis software package in FORTRAN 90 that ingests ensemble member data and performs cluster analysis on the forecast data. Forecasts of 2-m temperature, 850-hPa u-component wind speed, 500-hPa temperature, and 250-hPa u-component wind speed are bilinearly interpolated to a common grid and a cluster analysis is conducted using a hierarchical clustering approach. Results from the analysis indicate that the forecasts largely cluster by model, with these intra-model clusters occurring more often near the surface and less often at higher levels in the atmosphere. Results also indicate that model physics diversity provides for more diverse solutions, which has been found to be valuable.

Furthermore, a simple 7-day running mean bias correction is applied individually to each of the 23 ensemble members. Various measures of accuracy are used to compare these bias-corrected ensemble predictions of 2-m temperature and dewpoint temperature with those available from the Nested Grid Model (NGM) Model Output Statistics (MOS). Results indicate that the bias-corrected ensemble mean prediction is as accurate as the NGM MOS for temperature predictions, and is more accurate than the NGM MOS for dewpoint temperature predictions, for the 48 days studied during the warm season. Results also indicate that the ensemble has some ability to predict forecast skill for temperature with a correlation between ensemble spread and the error of the ensemble mean of greater than 0.7 for some forecast periods. The use of a multi-model ensemble clearly helps to improve the spread-skill relationship.

Publications

- Stensrud, D. J., and N. Yussouf, 2003: Short-range ensemble predictions of 2-m temperature and dewpoint temperature over New England. *Mon. Wea. Rev.*, in press.
- Yussouf, N., D. J. Stensrud and S. Lakshmirarahan, 2003: Cluster analysis of multimodel ensemble data over New England. *Mon. Wea. Rev.*, submitted.



Profiler network for the New England Temperature and Air Quality Forecasting Pilot Study. The study domain of the pilot program, although the forecast domains being created are larger.

Multiple-Sensor Severe Application Development using WDSS-II

Stumpf, Smith, Manross, Lakshmanan, McCoy, Myers, Thomas, Elmore, Song, Bailor, Toomey, Cooper, Hondl

Objectives

Improve the accuracy and timeliness of severe weather warning applications for the NWS and other users by integrating multiple-radar and multiple-sensor data.

Accomplishments

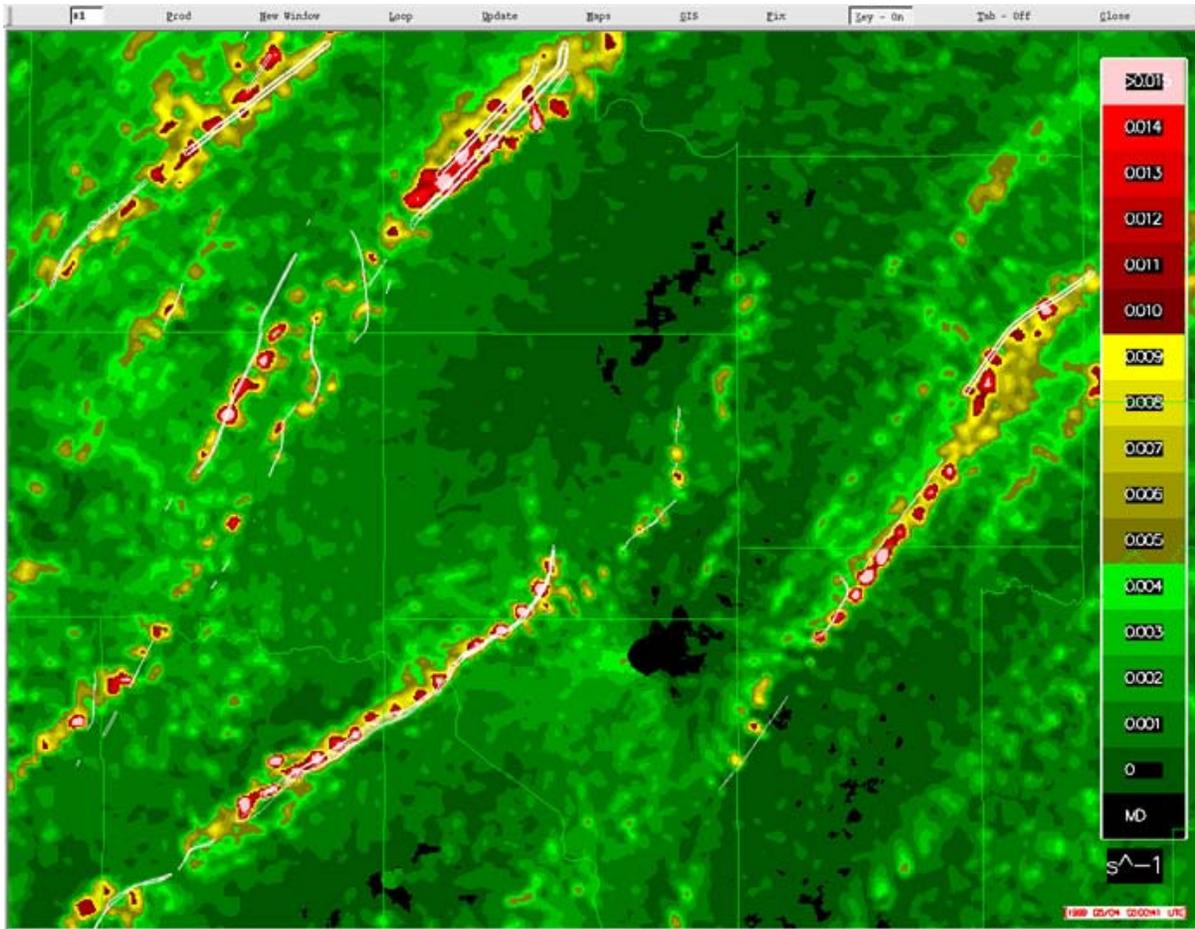
CIMMS has played the primary role in the prototype development and evaluation of severe weather warning applications used to analyze storm information using Doppler radar. During the previous year, CIMMS scientists continued to make improvements to these algorithms. Most severe weather algorithms have been designed for use with a single-radar data source. Our research has shown that effective warning decisions can only be made via the integration of information from many sources, including input from multiple remote sensors (e.g., multiple radars, mesoscale models, satellite, and lightning). Therefore, the traditional single-radar severe weather algorithms are being updated to take advantage of additional data sources in order to reduce the uncertainty of the measurements and increase the accuracy of the diagnoses of severe weather.

A variety of new multiple-radar and multiple-sensor severe weather warning applications were improved or developed during this year. The research and development process was greatly facilitated by use of the Warning Decision Support System - Integrated Information (WDSS-II) infrastructure. These warning applications have included making the Multiple-Radar Severe Storms Analysis Program (MR-SSAP) more

robust. We have included near-storm environment thermodynamic information for multiple-radar hail diagnosis, and mean wind information for storm cell component drift. The high-resolution (in time and space) gridded hail algorithm and hail swath products have been also been made more robust with the addition of mesoscale model thermodynamic data. We have also improved our multiple-radar shear diagnosis algorithms and developed a rotation tracks mosaic (see figure) to diagnose histories of thunderstorms containing mesocyclones. We are also working toward improved multiple-sensor radar echo segregation, reflectivity motion estimates, and lightning prediction. Many of the new severe weather warning applications were tested in real-time NWS operations at Jackson, MS, and Wichita, KS.

Publications

- Lakshmanan, V., 2002: An extensible, multi-source meteorological algorithm development interface. *Preprints, 21st Conference on Severe Local Storms*, Amer. Meteor. Soc., San Antonio, TX.
- Lakshmanan, V., 2002: Real-time merging of multisource data. *Preprints, 21st Conference on Severe Local Storms*, Amer. Meteor. Soc., San Antonio, TX.
- Lakshmanan, V., 2002: Statistical clustering for hierarchical storm identification. *Preprints, 21st Conference on Severe Local Storms*, Amer. Meteor. Soc., San Antonio, TX.
- Lakshmanan, V., 2003: Motion estimator based on hierarchical clusters. *Preprints, 19th IIPS Conference*, Amer. Meteor. Soc., Long Beach, CA.
- Lakshmanan, V., 2003: Real-time merging of multi-source data. *Preprints, 19th IIPS Conference*, Amer. Meteor. Soc., Long Beach, CA.
- Lakshmanan, V., K. Hondl, G. Stumpf, and T. Smith, 2003: Quality control of WSR-88D data. *Preprints, 31st Radar Conference*, Amer. Meteor. Soc., Seattle, WA, 522-525.
- Smith, T. M., G. J. Stumpf, K. L. Manross, and C. Thomas, 2003: Warning Decision Support System - Integrated Information (WDSS-II). Part I: Multiple-sensor severe weather applications development at NSSL during 2002. *Preprints, 19th International Conf. on Interactive Information and Processing Systems (IIPS) for Meteor., Oceanography, and Hydrology*, Long Beach, CA, Amer. Meteor. Soc., 14.8 - CD preprints.
- Smith, T. M., K. E. Elmore, G. J. Stumpf, and V. Lakshmanan, 2003: Detection of rotation and boundaries using two-dimensional, local, linear least squares estimates of velocity derivatives. *Preprints, 31st Conf. on Radar Meteor.* Seattle, Amer. Met. Soc.
- Stumpf, G. J., T. M. Smith, and C. Thomas, 2003: The National Severe Storms Laboratory's contribution to severe weather warning improvement: Multiple-sensor severe weather applications. *Atmos. Research*, **66**, accepted.
- Stumpf, G. J., T. M. Smith, K. L. Manross, and A. E. Gerard, 2003: Warning Decision Support System - Integrated Information (WDSS-II). Part II: Real-time test at Jackson Mississippi NWSFO. *Preprints, 19th International Conf. on Interactive Information and Processing Systems (IIPS) for Meteor., Oceanography, and Hydrology*, Long Beach, CA, Amer. Meteor. Soc., P1.36-CD preprints.



Linear least-square derived azimuthal shear within a 6-hour history ("rotation tracks") over central Oklahoma during the 3 May 1999 tornado outbreak. The white contour lines indicate tornado damage paths, while the yellow and red shades indicate areas where the strongest radar-detected circulations were located during the period.

Mesocyclone Climatology Revision and Quasi-Linear Convective System Radar Study

Manross, McCoy, Stumpf, Trapp

Objectives

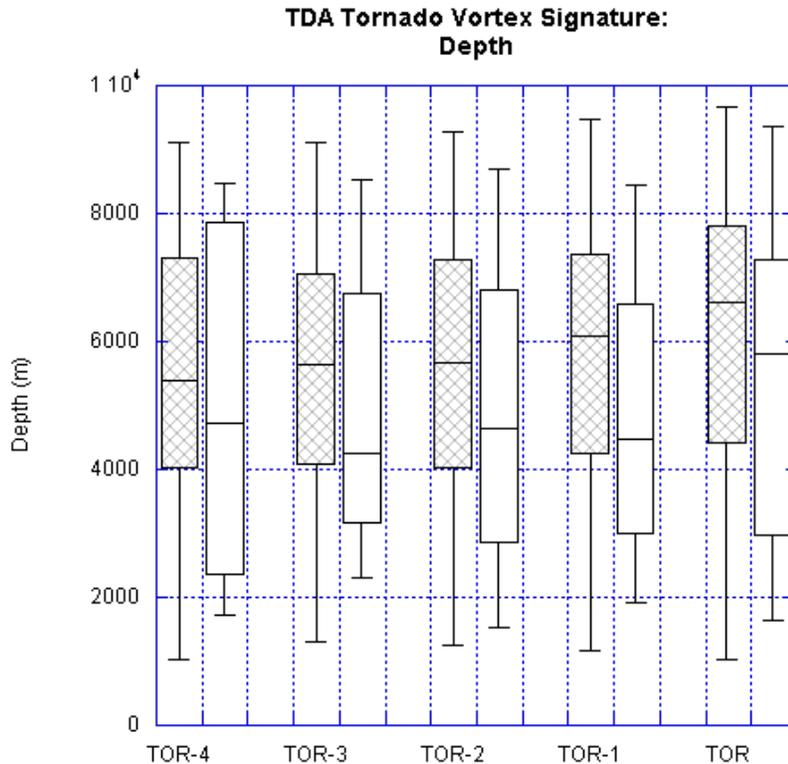
Update the radar detected mesocyclone climatology, and obtain climatology of radar attributes associated with parent vortices of QLCS tornadoes, comparing these attributes to those found in supercell tornadoes.

Accomplishments

We are attempting to duplicate Burgess' work on a mesocyclone climatology, used the Tornado Warning Guidance (TWG) database to identify Mesoscale Detection Algorithm (MDA) detections associated with verified tornadoes. This involves identifying a mesocyclone's lifespan (formation to demise) and recording all MDA detections associated with that feature as well as recording whether or not the mesocyclone produced a tornado. For the QLCS study, radar data were processed in a similar fashion to past TWG projects. The attributes of the parent vortices associated with QLCS tornadoes were compared to those of supercells.

Publications

Manross, K.L., R.J. Trapp, and G.J. Stumpf, 2003: WSR-88D radar characteristics of quasi-linear convective system tornadoes using the NSSL severe storm analysis program. *Preprints, 31st Conf. on Radar Meteorology*, Seattle, WA, Amer. Meteor. Soc., P2C.4.



Box-and-whiskers plot of TDA detected TVS depth (m AGL) for supercells (hatched) versus QLCS (open). X-axis is radar volume scans prior to tornadic volume scan.

Implementation of the CIMMS Stratiform Cloud Parameterization in a Regional Forecast Model

Mechem, Y. Kogan

Objectives

Explore the effect of accounting for drizzle processes in marine stratocumulus on mesoscale cloud geometry and other characteristics.

Accomplishments

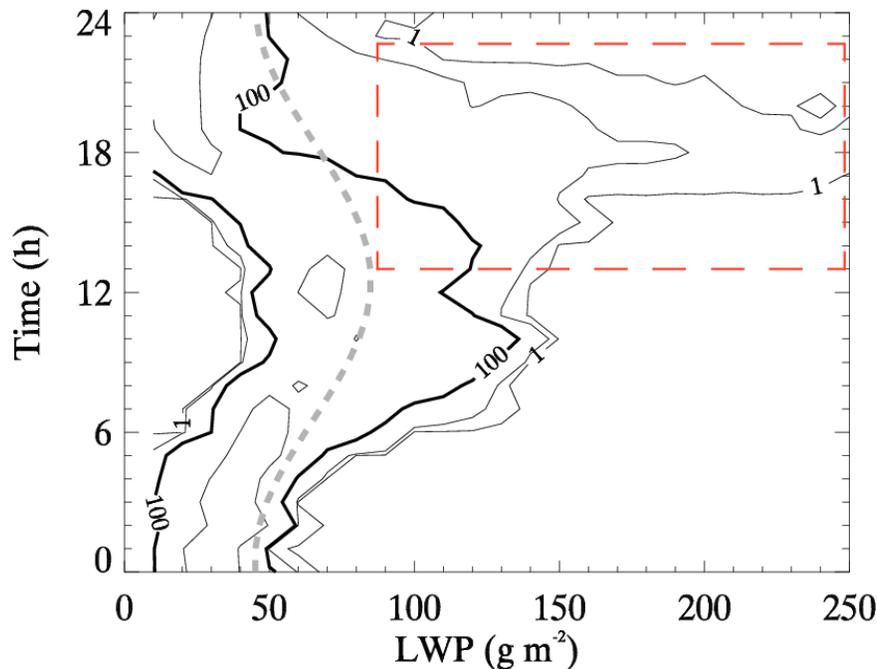
A case of coastal California summer season boundary layer stratocumulus has been simulated using the Naval Research Laboratory COAMPS and the results analyzed in the context of consistency with conclusions derived from large eddy simulation-based studies. Results show a pronounced diurnal cycle and fair agreement with satellite-derived observations of liquid water path. When using the CIMMS bulk drizzle parameterization, a significant degree of mesoscale organization emerges in the form of cloud bands, accompanied by a transition from a well mixed boundary layer topped by unbroken stratocumulus cloud into a more potentially unstable, convective boundary layer regime. The transition and subsequent development of mesoscale variability is analogous to the drizzle-induced cloud breakup produced in large eddy simulation studies. The dynamics of the pure stratocumulus are dictated by the model's subgrid parameterization, while the more convective regime exhibits appreciable vertical velocities characteristic of an ensemble of cumulus clouds. Convective updrafts are tied to a decoupling of the cloud and

subcloud layers, after which air of higher equivalent potential temperature can pool at the surface. Some similarities to the propagation of deep convection are noted.

We believe our results are the first to demonstrate mesoscale organization arising from the effects of drizzle, a process that has only been hinted at from observational and LES studies. We expect that operational use of the CIMMS bulk drizzle scheme will lead to improvements in regional forecasts of boundary layer cloud systems, especially when supplied with accurate aerosol data.

Publications

Mechem, D. B., and Y. L. Kogan, 2003: Simulating the transition from drizzling marine stratocumulus to boundary layer cumulus with a mesoscale model. *Mon. Wea. Rev.*, in press.



Evolution of hourly liquid water path probability density function, composited and contoured on a logarithmic scale. Light gray dashed line represents TMI-derived June-August satellite climatology supplied by Robert Wood. The tail of the distributions is outlined by the dashed box and shows emergence of mesoscale variability in the form of organized convective structures. This variability is only present in the simulation that includes drizzle.

High Resolution Radar Analysis for Aviation Weather Hazard Characterization

Brewster, Gao, Shapiro, Kemp, Thomas, Robinson

Objectives

Assess the ability of a high-resolution forecast model to depict icing and turbulence that are important to in-flight and terminal aviation operations.

Accomplishments

Operational radar data, aircraft, surface and satellite are combined in an analysis on a 3-km grid. They are then brought into a non-hydrostatic forecast model in a ten-minute assimilation window using the incremental analysis updating technique. This allows the model fields, including the hydrometeors and turbulence, to gradually adjust to the new information from the current observations.

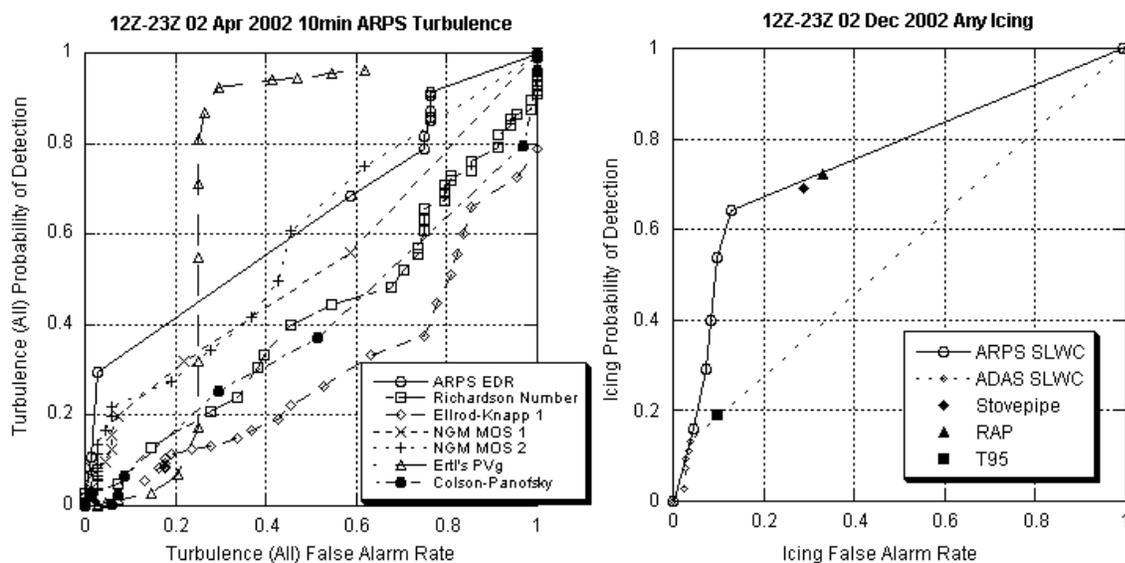
The real-time assimilation and web-based display have been updated for changes to the ADAS and ARPS, and were run using operational data for a second test period, from late October to early December 2002. The most notable event in the test period was a storm on 2 December that featured long delays at Chicago O'Hare Airport and many in-flight icing reports. Some of the displays from this autumn test period remain available online on our archive website, <http://inflow.caps.ou.edu/wx/p2>.

Software was developed to process manual PIREP data and automated MDCRS reports to verify icing and turbulence against model hydrometeors and eddy dissipation rate (EDR) from the model's turbulent kinetic energy (TKE). Code for six turbulence and three icing indicators was written or adapted from other sources in order to compare to the explicit predictors. Comparisons were done using several threshold values so that a receiver operating characteristics curve could be obtained. The result of this comparison for a day with turbulence hazards (2 April) and a day of icing hazards (2 December) are shown in the figure below. It is apparent the assimilation system demonstrates skill on par with the best index in each case, although some threshold values of the Ertl's potential vorticity do show better skill for turbulence. This is likely due to the synoptic-scale turbulence generating mechanism present on this day.

Separately, software was completed to ingest operational radial velocity data in the ARPS 3DVAR system, and an adaptation of a velocity-volume processor technique was completed to provide transverse wind information to ADAS. Analyses using these techniques were produced for the December case described above. Comparisons of verification statistics will be done using these analysis methods for the turbulence and icing cases in the ARPS incremental analysis updating assimilation system.

Publications

- Brewster, K., 2002: Recent advances in the diabatic initialization of a non-hydrostatic numerical model. *Preprints, 21st Conf. on Severe Local Storms, and Preprints, 15th Conf. Num. Wea. Pred. and 19th Conf. Wea. Anal. Forecasting*, San Antonio, TX, Amer. Meteor. Soc., J51-J54.
- Brewster, K., A. Shapiro, J. Gao, E. Kemp, P. Robinson and K. Thomas, 2003: Assimilation of radar data for the detection of aviation weather hazards, *Preprints, 31st Intl. Conf. on Radar Meteor.*, Seattle, WA, Amer. Meteor. Soc., 118-121.
- Gao, J., M. Xue, K. Brewster, F. Carr, and K. K. Droegemeier, 2002: New development of a 3DVAR system for a nonhydrostatic NWP model. *Preprints, 15th Conf. Num. Wea. Pred. and 19th Conf. Wea. Anal. Forecasting*, San Antonio, TX, Amer. Meteor. Soc., 339-342.
- Gao, J., Xue, M., Brewster, K., and K.K. Droegemeier, 2003: A three-dimensional variational data analysis method with recursive filter for Doppler radar. *J. Atmos. and Oceanic Tech.*, Amer. Meteor. Soc., in press.
- Gao, J., M. Xue, K. Brewster, and K. K. Droegemeier, 2003: A 3DVAR method for Doppler radar wind analysis with using recursive filters. *Preprints, 31st Intl. Conf. on Radar Meteor.*, Seattle, WA, Amer. Meteor. Soc., 114-117



Turbulence relative operating characteristics curve for 2 April 2002 (left) and icing relative operating curve for 2 December 2002 (right) based on gridded data from 10-minute incremental analysis updating, except for ADAS SLWC, which is from the static analysis.

Contribution to WRF Model Development

Xue, Gao, Brewster, Ren, Xiao

Objectives

Develop radar data assimilation components for the WRF 3DVAR system; develop a 4DVAR-based soil temperature and moisture retrieval system for use in mesoscale models and improve land surface models; and contribute to the development and testing of the WRF model system.

Accomplishments

Accomplishments to date include the further development and testing of radar data assimilation components to be used in the WRF 3DVAR system, development of new single Doppler radar retrieval techniques, development of a wind profile retrieval technique from radar data, development of a variational 4DVAR system for retrieving soil model initial conditions and model parameters, and improvement to the force-restore model used in land surface models.

Publications

Gao, J., M. Xue, K. Brewster, F. Carr, and K. K. Droegemeier 2002: New developments of a 3DVAR system for a nonhydrostatic NWP model, *Preprints, 15th Conf. on Numerical Weather Prediction*, 12-16 August, Amer. Meteor. Soc.

Gao, J., K. K. Droegemeier, J. Gong and Q. Xu 2003: Retrieval of vertical wind profiles from Doppler radar radial velocity data, *Mon. Wea. Rev.*, conditionally accepted.

Gao, J., M. Xue, K.K. Droegemeier, A. Shapiro, 2003: A three-dimensional variational single-Doppler velocity retrieval method with single conservation equation constraint, *Quart. J. Roy. Meteor. Soc.*, in review.

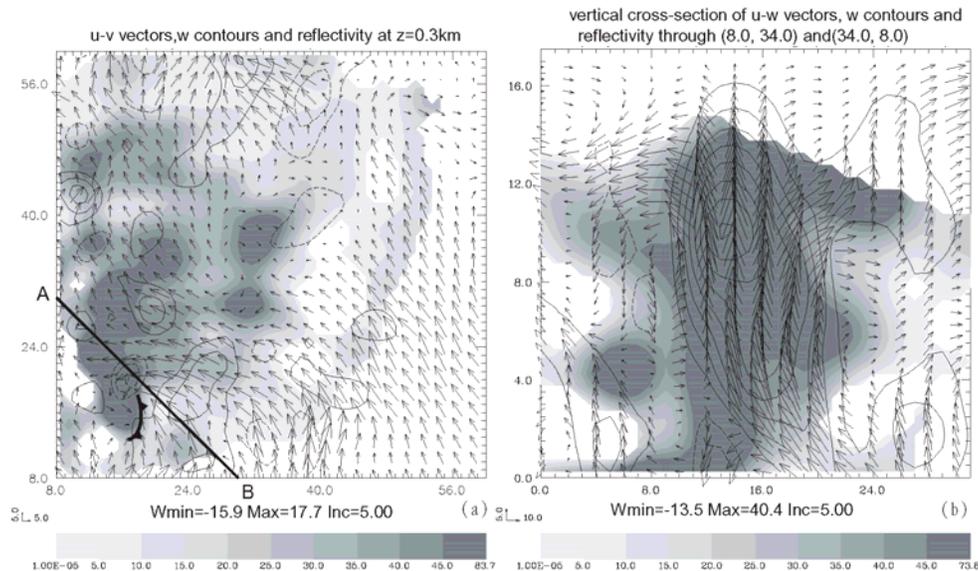
Gao, J., K. K. Droegemeier, J. Gong and Q. Xu 2003: A wind profile retrieval method from azimuthal gradients of radial velocity, *Preprints, 31th Conf. on Radar Meteorology*, Amer. Meteor. Soc.

Gao, J., M. Xue, K. Brewster, and K. K. Droegemeier 2003: A 3DVAR method for Doppler radar wind analysis with using recursive filter, *Preprints, 31th Conf. on Radar Meteorology*, Amer. Meteor. Soc.

Ren, R., M. Xue, 2003: An improved force-restore model for land-surface modeling, *J. Appl. Meteor.*, in review.

Ren, D., M. Xue, and J. Gao, 2002: Parameter retrieval in a land-surface model. *Preprint, 15th Conf. on Num. Wea. Pred. and 19th Conf. on Wea. Anal. Forecasting*, San. Antonio, TX, Amer. Meteor. Soc.

Shapiro, A., P. Robinson, J. Wurman, and J. Gao, 2003: Single-Doppler Velocity Retrieval with rapid-scan radar data, *J. Atmos. Oceanic. Technol.*, in press.



Wind vectors, vertical velocity (contours) analyzed from data sampled by two Doppler radars (located at Norman and Cimarron in Oklahoma) using the variational method for Arcadia, OK at 16:34 CST, 17 May 1981 tornadic storm. Also shown are shaded contours of the reflectivity field. a) Horizontal cross-section at $z = 0.3\text{km}$; b) Vertical cross-section through A-B line in panel a). Rear flank gust front at this level is indicated by the cold front symbol in a).

Ray Path Java Explorer

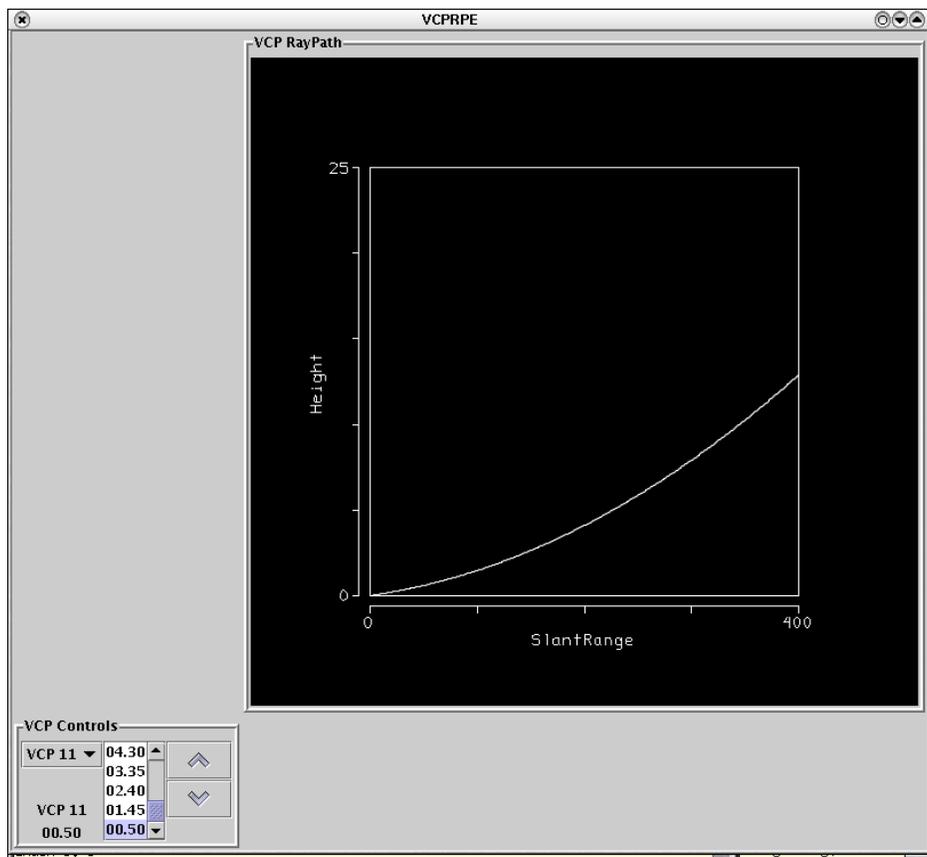
Manross, Stumpf

Objectives

Create a platform-independent interactive technique to allow visualization of a radar beam in a standard atmosphere and show how that beam may interact with the surrounding terrain.

Accomplishments

A number of software languages have been applied to perform new ways of visualizing data. A partial working model has been produced. The eventual goal will be to produce a platform-independent interactive technique to allow visualization of a radar beam in a standard atmosphere, and in time show how that beam interacts with terrain.



Ray Path Explorer (without terrain).

The Morning Convection Project

Hane, Haynes, Andra, Rabin, Berry, Carr

Objectives

Develop a comprehensive climatology of the evolution of warm-season Mesoscale Convective Systems (MCSs) affecting the warning areas of Norman, OK and Dodge City, KS NWS Offices during late morning, and develop techniques to aid in the forecasting of these systems.

Accomplishments

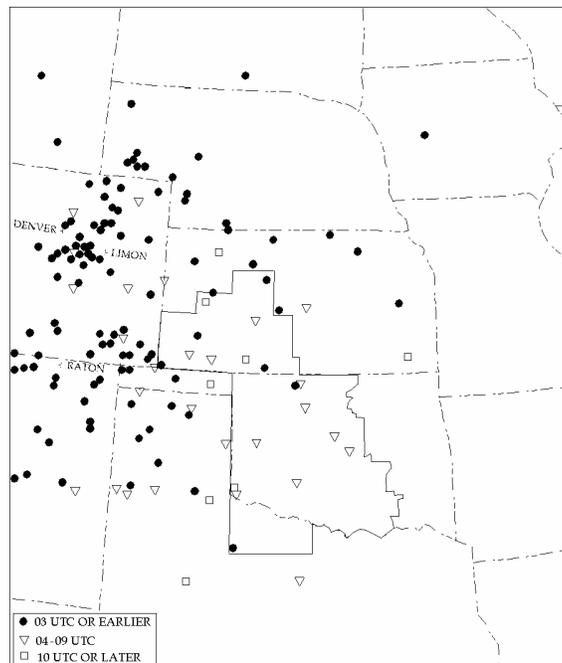
A 5-year climatology was completed that included 145 MCSs. Initiation locations were identified for each system. The majority of systems formed during the previous afternoon or evening along ridges that

extend eastward from the Rockies in Colorado and New Mexico. It was found that 72% of these systems either decreased in intensity or dissipated during the late morning.

To evaluate the influence of various environmental factors on the evolution of these systems, for a subset of 48 systems hourly soundings were extracted from RUC analyses at locations in advance of each system as it moved through the area of interest. Scatter diagrams were constructed to assess the influence of pairs of environmental factors on system evolution. Certain combinations of such quantities as CAPE, deep-layer wind shear, and water vapor flux toward the system show promise in helping to discriminate between classes of evolution.

Publications

- Hane, C.E., J.D. Watts, D.L. Andra, Jr., J.A. Haynes, E. Berry, R.M. Rabin, and F.H. Carr, 2003: The evolution of morning convective systems over the Great Plains during the warm season. Part I: The forecast problem. *Wea. Forecasting*, **18**, in press.
- Hane, C.E., J.A. Haynes, and D.L. Andra, Jr., 2003: A search for environmental factors important in the evolution of morning Great Plains MCS activity during the warm season. *Preprints, 10th Conf. on Mesoscale Processes*, Portland, OR, Amer. Meteor. Soc., (CD ROM).
- Haynes, J. A., 2002: Analysis of Warm Season Morning Convection Across the Southern Great Plains. M.S. Thesis, University of Oklahoma, 119 pp.



Initiation locations for the MCSs included in the climatology. The key at lower left indicates the time period of initiation for the location markers. The area bounded by the solid line encloses the county warning areas of the Dodge City and Norman NWS offices.

Flash Flood Monitoring and Prediction Basin Dataset Legacy Issues

Howard, Cox, Arthur

Objectives

Provide additional basin boundary datasets, basin customization support, and data maintenance, enhancement, and access for Flash Flood Monitoring and Prediction (FFMP) basin dataset users.

Accomplishments

During the past year, Alaska basins have been delineated based on elevation data in the USGS EROS Data Center's National Elevation Dataset (NED). These basins are currently being used to assemble

FFMP basin datasets for the seven Alaskan region radars. In addition, new or updated FFMP basin datasets have been assembled for four continental U.S. radars (KDGX, KVWX, KBMX, and KHTX).

Basin customization support has been offered in the form of training and ongoing assistance to FFMP dataset users. It was the intent of the original delineation project that the FFMP basin datasets would be created at NSSL and edited or customized at the NWS Forecast Offices. To familiarize forecast staff with the basin dataset and with the ArcView scripts and extensions created to assist with customization tasks, a 3-day Basin Customization course has been offered through COMET. This course has been taught six times during the past year by several instructors including FFMP Basin Dataset Legacy Issues project staff. In addition, ongoing assistance and data access has been provided to 16 forecast offices and River Forecast Centers since March 2003.

A portion of the basin customization process involves the addition of hydrologic connectivity attributes to the original FFMP basin dataset shapefiles. These attributes indicate the upstream or downstream location of a particular basin or stream segment relative to other basins or streams. This information helps to ensure that certain customization tasks are accomplished in a hydrologically correct manner, as well as aiding forecasters in understanding the hydrology involved in a flash flooding situation. One of the tasks of the FFMP Basin Dataset Legacy Issues Project is the addition of these attributes to enhance the existing FFMP basin datasets.

Support of Case Study Research

Levit

Objectives

Provide support for research severe weather case studies.

Accomplishments

During 2003, several significant weather events were noted, and data from these events were saved to disk and magnetic tape through Perl scripts. These case studies are part of an ongoing project to collect data from and document significant weather days. For example, nearly 200 gigabytes of weather information (radar, satellite, surface observations, and NWP data) were saved during the tornado outbreaks of 4-10 May 2003. Additional severe weather cases, including winter weather, were saved throughout 2003.

Advanced Hydrological Processing of Tropical Weather

Minton, Kirkwood

Objectives

Improve the dissemination of meteorological information on the Internet.

Accomplishments

A project has been completed to improve displays of meteorological data on tropical weather on the Internet. This allows for real-time access of critical information during periods of intensified tropical activity.

Climatic Effects of/Controls on Mesoscale Processes

North Atlantic Winter Surface Extratropical Cyclone Track Variability

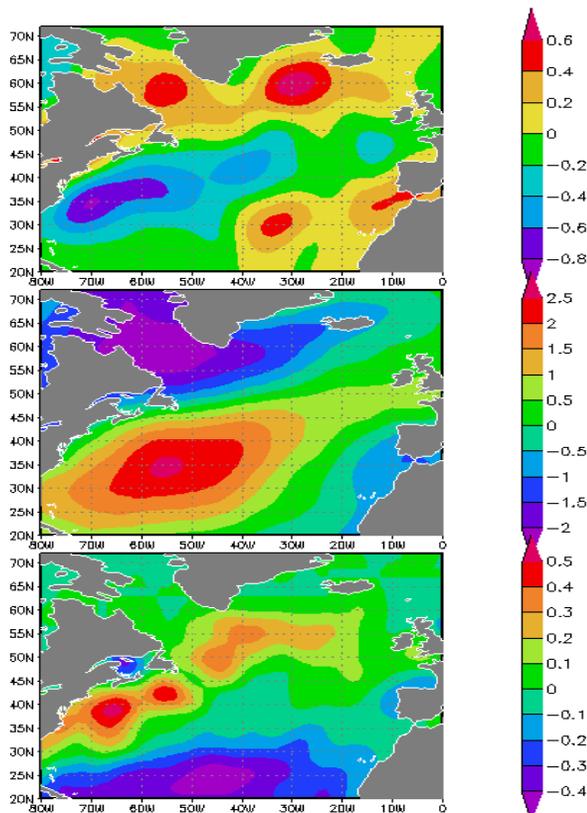
El Hamly, Lamb, Portis

Objectives

Provide new insight into the winter storm track organization and behavior over the North Atlantic on interannual-to-decadal time-scales.

Accomplishments

A new hybrid space- and time-smoothed surface extratropical cyclone track density function (CDF) has been developed over the North Atlantic on a $2^\circ \times 2^\circ$ grid for winter semesters (October-March) of 1948-99 provides the foundation for this and future research. The following lines of investigation have been performed: (1) compilation of previously unavailable long-term mean climatological features (including persistence) of cyclone activity; (2) use of a novel aspect of wavelet analysis of CDF permitted (a) separation of the high-frequency and low-frequency components of cyclone activity and (b) full 2-D grid analyses that document the spatial heterogeneity of cyclone behavior, rather than areal averaging; (3) analysis of the interannual variability of cyclone activity and its associations with regional climate variations; (4) a new classification of cyclone behavior into three major circulation regimes based on VARIMAX Rotated Principal Component Analysis (VRPC) of CDF anomalies; (4) relationships of short-term variability in cyclone activity to short-term variability in regional teleconnections patterns (e.g., NAO, ENSO); (5) use of CDF for immediate application to Morocco; and (6) analysis of cyclone activity at decadal-to-multidecadal time-scales involving ocean-atmosphere interactions.



SOI-based high-minus-low composite difference fields of the following North Atlantic winter semester (October-March) anomalies for 1948-99. Top – cyclone track density function (CDF, cyclones/day/250 km x 250 km area); middle – SLP (hPa); and bottom – SST (°C). In particular, this figure reveals a southward shift of the North Atlantic low-pressure systems in the winter semester during El Niño events.

Coupled Ocean-Atmosphere GCM Simulation of Low-Frequency NAO under Different Greenhouse Gas Scenarios

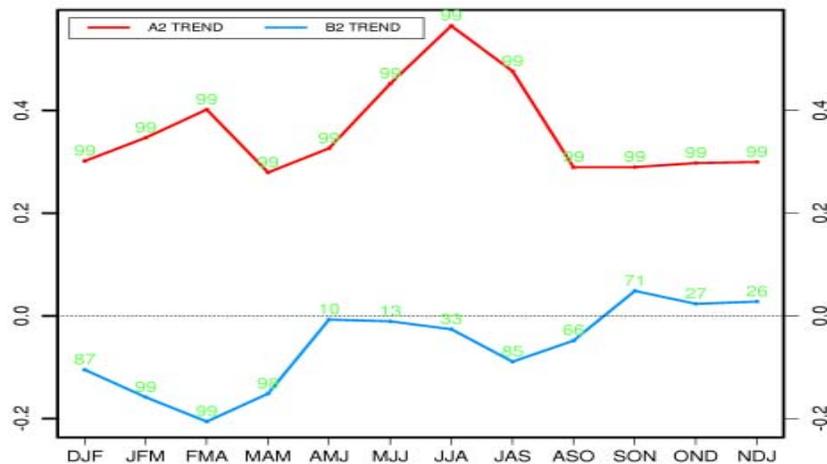
El Hamly, Lamb, Portis

Objectives

Investigate the response of the North Atlantic circulation to enhanced greenhouse gas forcing.

Accomplishments

Since the North Atlantic Oscillation (NAO) is highly correlated to the leading mode of CDF anomalies, this analysis builds on the results of the above project. Specifically, as a new contribution to climate change studies, this analysis highlights the impact of using different greenhouse gas forcing scenarios (A2 and B2) on NAO trends in fully coupled models. A prerequisite for such NAO prediction is a realistic simulation of the present NAO variability in coupled models; many recent studies (e.g., Meehl et al. 2000) have already explored this issue and shown that these coupled models in general do a reasonably good job. In this project, trends in low frequency (LF) NAO were computed and compared and contrasted: between different NAO types (traditional NAO, mobile NAO, and PCA-based NAO), between coupled models, and between forcing scenarios. Since ensemble averaging reduces the noise level in model-simulated climate changes (e.g., Dai et al. 2001), we also performed ensemble averaging of NAO under different forcing scenarios. Moreover, a complete picture of the seasonal variations of predicted trends in LF NAO under different scenarios has been provided.



Seasonal variations of predicted - via ensemble averaging of different global coupled ocean-atmosphere GCM runs and three NAO types (i.e., traditional NAO, mobile NAO, and PCA-based NAO) - trends in low-frequency NAO under IPCC forcing scenario A2 (solid line) and B2 (dashed line). Values on top of points indicate statistical significance levels (in percent) of these trends according to a two-sided Student's t-test. Based on this ensemble averaging, this figure clearly shows that the response to enhanced greenhouse forcing is a marked tendency for a positive trend in NAO index (i.e., a strengthening of the westerlies) during all seasons.

Investigation into the Role of the Recycling of Local Evapotranspiration on Different Timescales Over the Agriculturally Important Midwestern U.S.

Zangvil, Portis, Lamb

Objectives

Document the role of locally recycled versus advective origins of precipitating water over the agriculturally important Midwest under different precipitation regimes and over different timescales.

Accomplishments

Using a recycling formula that was developed by Zangvil, we expanded on our previous investigation of the large-scale moisture fields in the generation of summertime precipitation over the agriculturally important and largely non-irrigated central United States. Our research focused on four seasons with widely varying precipitation, including the very dry summer of 1988 and the very wet summer of 1979. Evidence from crop yield data, solar radiation data, satellite derived NDVI, and the timing of the precipitation deficit strongly indicate that the extremely poor crop status in 1988 was the forcing behind the large reduction in recycled moisture for the agriculturally important precipitation categories of greater than 4 mm/day. Our approach and results have yielded considerable physical insight into the complex land-atmosphere interactions involved, including plant behavior and the apparent paradox between monthly/seasonal and daily time-scale results.

Publications

Zangvil, A., D. H. Portis and P. J. Lamb, 2003: Investigation of the large-scale atmospheric moisture field over the Midwestern United States in relation to summer precipitation. Part II: Recycling of local evaporation and association with crop yields. *J. Climate*, submitted.

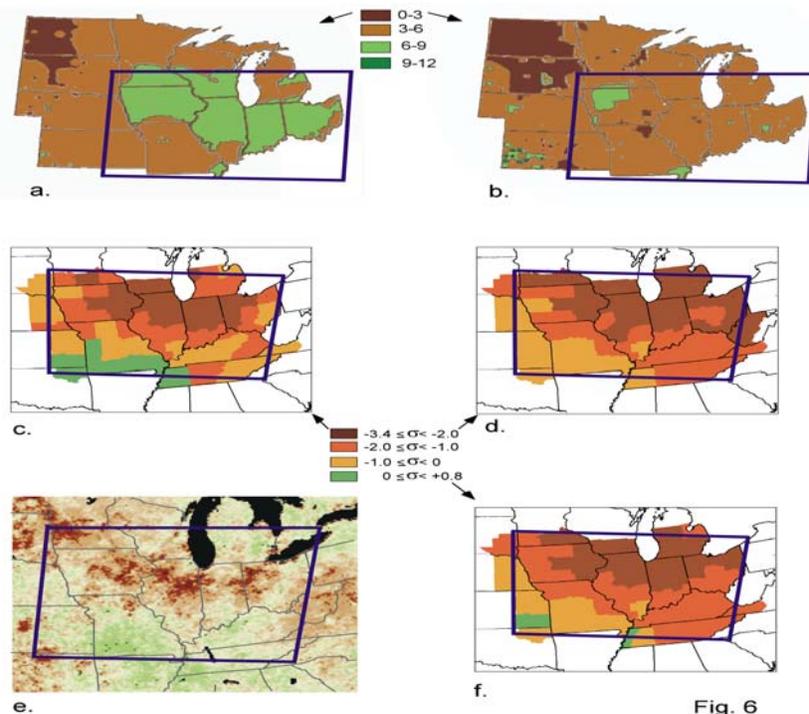


Fig. 6

Patterns of crop yield, crop yield anomalies, and Normalized Difference Vegetation Index (NDVI, “greenness” index) anomalies for the study region for 1988. Rectangular boxes enclose the study region. (a) Average corn yield (Tonnes Ha⁻¹) for USDA North Central Region for 1972-91 (from Gage 2003). (b) 1988 corn yield (Tonnes Ha⁻¹) for USDA North Central Region (from Gage 2003). (c) 1988 soybean yield anomaly (from detrended 1972-90 mean). (d) 1988 corn yield anomaly (from detrended 1972-90 mean). (e) NDVI anomaly for August (from NASA/Goddard Space Flight Center Scientific Visualization Studio; <http://svs.gsfc.nasa.gov/stories/drought/na.html>), where deeper brown (green) indicates lesser (greater) “greenness”. (f) 1988 combined corn-soybean yield anomaly (from detrended 1972-90 mean).

Land Atmosphere Memory Quantified Using Observations from the Oklahoma Mesonet and the Noah Land Surface Model

Basara, Crawford, Nemunaitis, Monroe, Illston

Objectives

Develop a quality controlled data set that contains meteorological and hydrologic observations from Oklahoma Mesonet sites; obtain new insights into land-atmosphere interactions from diagnostic studies using Mesonet data; and identify parameterizations in the Noah land surface model that are sensitive to land surface conditions.

Accomplishments

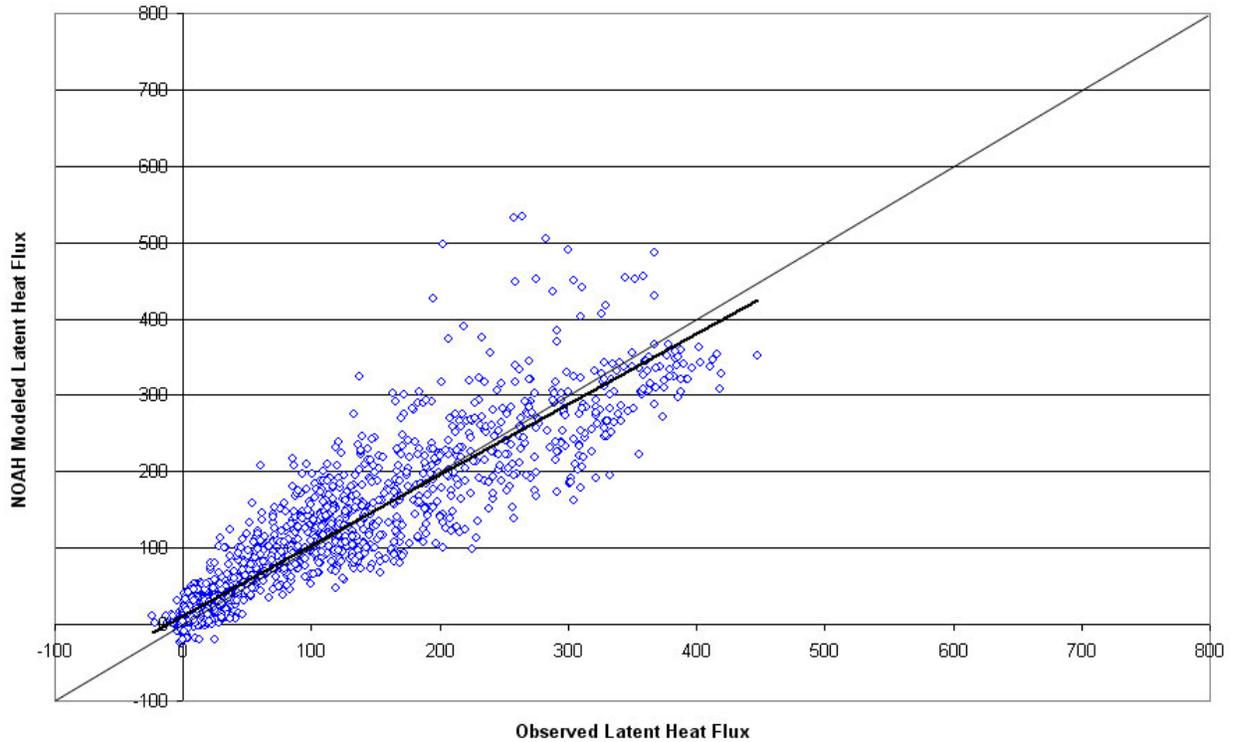
A number of diagnostic studies involving Oklahoma Mesonet data have been accomplished. One such effort investigated the impacts of short-term droughts in Oklahoma, which focused on droughts occurring during years of above-annual precipitation (1998 and 2000). Another study investigated the surface skin temperature measurements installed at Oklahoma Mesonet sites using infrared temperature sensors. These sensors had been deployed at 89 Mesonet environmental monitoring stations in 1999. A 3-year dataset provided a unique opportunity to analyze longer-term, continuous, mesoscale observations of skin temperature across a large area.

A retrospective simulation data set for the Noah land-surface model (LSM) was provided in collaboration with Dag Lohmann at NCEP for the 1999-2000 period. Noah stands for **N**CEP **O**regon State University **A**ir Force **H**ydrologic Research Laboratory (NWS). Model-simulated energy fluxes were compared with the OASIS surface flux data set, which includes net radiation, latent heat flux, sensible heat flux, and ground heat flux for the following days in 2000: 23 May, 29 May, 30 May, 10 July, 13 August, 14 August, 25 August, and 29 August. Time series plots were created for each day at each OASIS Super Site to compare the time-averaged hourly output to the hourly averaged flux observations. The preliminary validation of the Noah modeled surface energy fluxes using OASIS data provides a blueprint for future work. In terms of a regional approach, these preliminary results show that net radiation is captured very well, sensible heat flux is overestimated, latent heat flux is underestimated, and ground heat flux is slightly overestimated.

Publications

- Basara, J. B., R. A. McPherson, D. S. Arndt, B. G. Illston, M. J. Haugland, C. A. Fiebrich, and K. C. Crawford, 2002: The Oklahoma Mesonet: An infrastructure for quantifying land-atmosphere interactions, *Mississippi River Climate and Hydrology Conference*, New Orleans, LA, 17.
- Basara, J. B. and D. R. Cheresnick and P. K. Hall, Jr. 2003: The representativeness of skin temperature measurements at Oklahoma Mesonet Sites. *Preprints, 12th Symposium on Meteorological Observations and Instrumentation*, Long Beach, CA, Amer. Meteor. Soc.
- Fiebrich, C. A., J. E. Martinez, J. A. Brotzge, and J. B. Basara, 2003: The Oklahoma Mesonet's skin temperature network. *J. Atmos. Oceanic Tech.*, in press.
- Illston, B. G. and J. B. Basara, 2003: Analysis of short term droughts in Oklahoma. *EOS, Trans.*, AGU, **84**, 157, 161.
- Illston, B. G. and J. B. Basara. 2003: Climatology of soil moisture variables using the Oklahoma Mesonet. *Preprints, 17th Conference on Hydrology*, American Meteorological Society, Long Beach, California, February 9-13.
- Nemunaitis, K. L. and J. B. Basara, 2003: The Validation of a Land Data Assimilation System (LDAS) Using Data from the Oklahoma Mesonet. *Preprints, 17th Conference on Hydrology*, American Meteorological Society, Long Beach, California, February 9 - 13.

Latent Heat Flux at the OASIS Super Sites



Noah-modeled and observed surface fluxes for all OASIS Super Sites. While the modeled and observed latent heat fluxes follow the same temporal pattern, it was not uncommon for the modeled latent heat flux curve to reach its peak value earlier than the observed. The results also reveal a slight underestimation of latent heat flux by the model when compared to observations collected in Oklahoma.

Characteristics of the Kiremt Rainy Season in Ethiopia

Tessema, Lamb

Objectives

Examine the interannual variability of the onset and cessation of summer rains in Ethiopia.

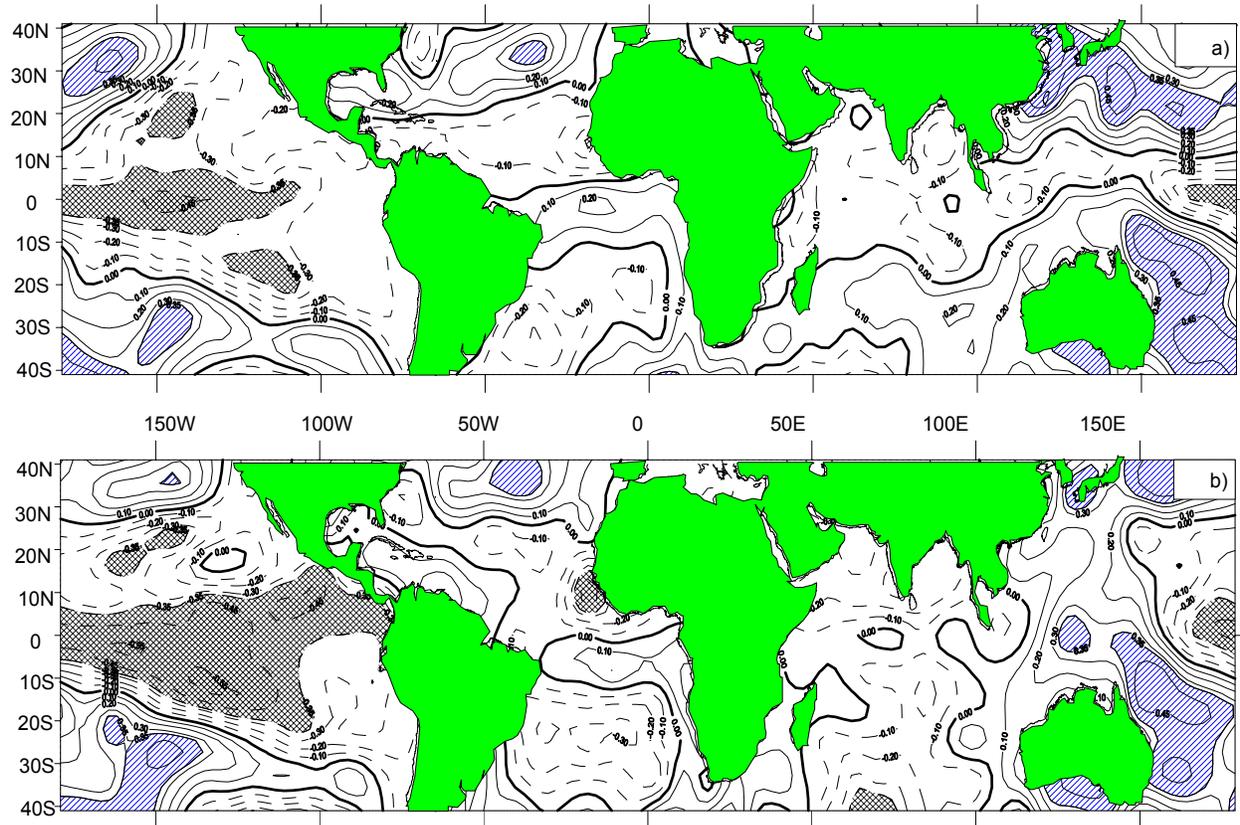
Accomplishments

An objective determination of the onset and cessation of the June-September summer rains (Kiremt) of Ethiopia is important for agricultural applications as well as to enhance our understanding of the interannual variability of the rains in the region. Based on a quantitative study of daily rainfall data for 121 stations, the onset and cessation dates and dry spells at different thresholds have been determined and their statistical properties studied. The interannual variability of these parameters was examined in association with local upper air sounding and global sea surface temperature data.

The study shows that the highest variability in Kiremt onset and cessation is in regions where the rains start early in the year. Prior to the onset, low level westerlies build up for at least two pentads, while upper level strong easterlies exceeding 10 ms^{-1} develop at least 3 pentads before the onset of the season over central Ethiopia. Lower tropospheric cooling, upper tropospheric and lower stratospheric warming, and tropospheric moisture increase are the major seasonal changes that accompany the onset of the season. These changes reverse sign after the rain ceases.

Dry spells are more frequent during the last one- third of the Kiremt during which time the tropical easterly jet (TEJ) and the surface westerlies become more infrequent or weak. During years when long dry spells occur, easterly winds prevail throughout the troposphere and the TEJ becomes weak, whereas in years when dry spells are short, westerlies prevail at lower levels and the TEJ becomes strong.

The onset and the effective length of the Kiremt growing season correlate strongly with Pacific sea surface temperature (SST). In particular, El Niño events are associated with delayed onset and shorter effective growing length. On the other hand, the cessation of Kiremt correlates more strongly with SST over the Arabian Sea and Indian Ocean than the Pacific Ocean.



Correlation isopleths between effective growing length of Kiremt over eastern and northeastern Ethiopia and (a) April-June SST and (b) July-September global SST anomalies. Monthly SST anomalies are averaged over a 3-month period for a 2 degree by 2 degree grid box. Positive (negative) correlations are denoted by solid (broken) isopleths. Areas of positive (negative) correlations significant at 95% probability level are hatched (cross hatched).

ARM Program Southern Great Plains Site Scientist Team Activities

Bahrman, Bond, Lamb

Objectives

Promote scientific and educational benefits of the ARM Program Southern Great Plains site, and provide scientific guidance to site operators to strengthen the productivity of the site and the quality of data produced by it.

Accomplishments

The first objective was accomplished by providing scientific guidance and weather forecasting support (see visual) during intensive observing periods (IOPs), particularly within this fiscal year during the Aerosol IOP of May 2003. We also conducted site tours and provide educational outreach through the Oklahoma Climatological Survey. The second objective was achieved by working closely with personnel at the SGP Central Facility in northern Oklahoma to provide scientific guidance for the data collection process. We also served as the instrument mentor for the Soil Water and Temperature System (SWATS), participated in annual site quality inspections (called the Continuous Quality Improvement Program), and oversaw the SGP portion of the Data Quality Problem Reporting system.

Forecast

11Z Thursday May 29'03 Scenario: Cold front from n.central OK extending East. High in w.Kansas. Low in SE Colo. with warm front across TX panhandle. Region: Dewpts around 60 and sfc wind light/variable. Today Scattered clouds with best chance of clearing in late afternoon hours. Cirrus still expected to be a problem.

[Forecast Page](#)

[Skip down to IAP \(Cessna 172\) Flight Status](#)

Twin Otter Flights

[Add new Twin Otter flight](#)

Edit/update a Twin Otter flight-choose flight number: [Update](#)

Flight No.	Date	Flight Plan	Meeting Time	Status	Notes
17	May 29	6b	7:00 am	Scheduled	Take-off time: 9:12 CDT. Payload ops: Anthony Bucholtz. Purpose of this flight was to survey a ground-based net of sunphotometers/MFRSR's towards the south of the CART site. Most instruments performed well. AATS-14 failed to track properly for about 1 hour in the middle of the flight, recovered for about 1.5 hours and tracked intermittently again for the last 30 minutes of the flight. Cloud conditions: only occasional scattered Ci towards the end of the flight.

Aerosol IOP forecast and flight information database provided by the Site Scientist Team to Aerosol IOP 2003 participants. The database was accessible and modifiable through a web browser.

ARM Program Data Quality Office

Dean, Peppler, Shafer, Sonntag

Objectives

Inspect and assess ARM data from the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska sites on a near real-time basis, and provide support to site operators, site scientists, and instrument mentors to solve problems.

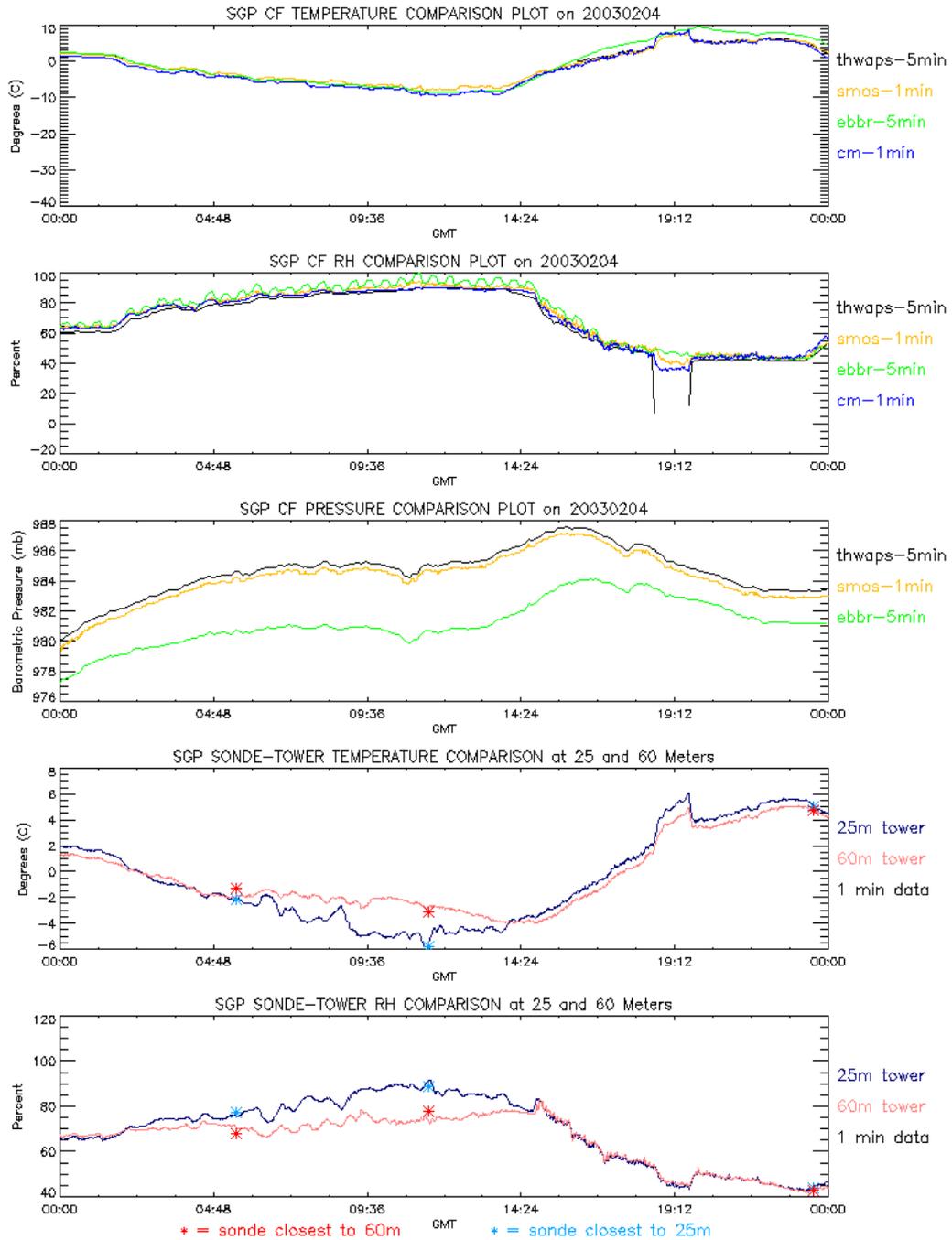
Accomplishments

During the past year the Data Quality Office has participated in a number of special activities beyond its day-to-day charge to inspect, assess, and report on ARM data quality from observations collected at the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska sites. These activities have included spearheading the Data Quality Reporter project, identifying primary and recommended measurements for use in a new on-line data browser, refining instrument web pages, increasing our participation in the verification of reprocessed data, re-examining automated flagging routines, and further developing graphical aides for use in our Data Quality Health and Status system (<http://dq.arm.gov/>).

The Data Quality Reporter project was initiated to streamline the reporting of data quality results to (1) ARM infrastructure to ensure quick repairs and (2) ARM data users so that they may make informed decisions when using the data. Our group specifically participated in the development of several parts of the project, including the Data Quality Assessment Report, the Data Quality Problem Report, and a search mechanism to compile and display all known quality metadata for a given site/date/instrument scenario.

Publications

- Sonntag, K.L., Dean, A.R., Shafer, C.M., Peppler, R.A., and C.P. Bahrmann, 2003: Automated quality control of Atmospheric Radiation Measurement Program (ARM) data from the Southern Great Plains (SGP), North Slope Alaska (NSA), and Tropical Western Pacific (TWP) Cloud and Radiation Testbed (CART) sites. *Proceedings, 12th Symposium on Meteorological Observations and Instrumentation*, 10-14 February 2003, Amer. Meteor. Soc.
- Peppler, R.A., C. Bahrmann, D. Bond, C. Choudhari, D. Cook, A. Dean, K. Doty, R. McCord, G., Palanisamy, S. Richardson, K. Sonntag, D. Stampf, and R. Wagener, 2003: The Data Quality Reporter System. *Proc., 13th ARM Program Science Team Meeting*, 31 March-4 April 2003, U.S. Dept. of Energy.



Surface meteorological intercomparison plots. This series of plots allows data quality analysts to compare the data from various instruments measuring like variables (in this case, temperature, pressure, and relative humidity) at the ARM SGP Central Facility near Lamont, Oklahoma.

Assimilation, Analysis, and Dissemination of Global Rain Gauge Data

Morrissey, Postawko, Greene

Objectives

Provide ocean region rain gauge data sets to the global research community.

Accomplishments

Efforts have been expanded to increase the rain gauge climate observing data base for specific, environmentally critical locations. While it is not our intention to collect all rain gauge data world-wide, it is possible to assimilate rain gauge data in environmentally critical locations where dense rain gauge networks exist, and where agreements can be made to help construct rain gauge networks in these critical locations. An experimental effort focused on the latter objective with the government of Niue and Kiribati has resulted in a network of approximately 25 new rain gauges located on atolls and islands managed by local meteorological services. The success of this effort has motivated us to expand this effort to other environmentally important countries. To this end, approximately 100 rain gauges were sent to the meteorological service of Vanuatu. Vanuatu weather service personnel are in the process of setting up a network of these gauges across this group of 83 islands in the South Pacific. It is also our intention to experiment with new and innovative verification methods which attempt to extract as much information from a data set as possible. These 'data mining' methods are currently being utilized in many fields and are still being developed.

The collaborative effort with the Meteorological Director of Niue Island in the South Pacific has resulted in the placement of six new manual read gauges spanning the island. Niue is located within the climatological average position of Southern Pacific Convergence Zone and is very isolated. Thus, these data are extremely important. We receive monthly reports of daily data that are then analyzed and incorporated into the Comprehensive Pacific Raingauge Data Base (Pacrain; <http://srdc.evac.ou.edu>). In addition, 10 rain gauges and related material were requested by the Meteorological Director of the country of Tuvalu. Tuvalu consists of three main atolls located in the primary climatological rain zone in the Pacific. The gauges and material have been sent to Tuvalu for set up. This collaboration is a direct result of efforts made by the SPaRCE program. Our collaborative arrangement with Mr. Tom Christian on Pitcairn Island is continuing. We are receiving regular reports of daily data from this isolated island. To our knowledge these data exist nowhere else. In addition to data received directly from the Pacific Meteorological Services, we continue to receive data from many strategically-located schools participating in the SPaRCE program. These data, from schools on islands and atolls with few or no other weather-reporting sites, are important supplements to the Pacific rainfall database.

Another primary focus of effort has been to compute daily averaged rainfall in $1^\circ \times 1^\circ$ degree grid boxes for Tropical Rainfall Measuring Mission (TRMM) Florida validation sites. This task, which included construction of box averages and error statistics, has been completed and is available at <http://www.evac.ou.edu/srdc>. The error statistics include the standard error and signal-to-noise ratio for each box for the years 1997 through 2001. The results indicate that, due to poor gauge instrumentation and data maintenance, only several boxes in Florida are reliable enough to use as validation sites.

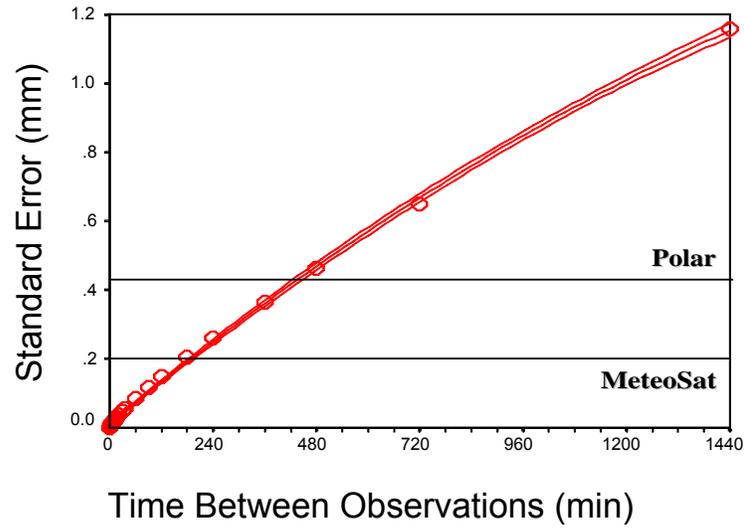
We have developed a new mathematical expression for the signal-to-noise ratio for areal averaged rainfall. This expression relates the time variance of box averages (with zero sampling error) to the error variance. Newly developed and existing validation technology has been derived using the *Mathematica* symbolic software package. Several techniques have been developed and the *Mathematica* notebooks are available for downloading on our web page. Two examples of this work are ordinary kriging and the signal-to-noise ratio.

An additional research effort assessed the impact of Meteosat 5 satellite estimates of precipitation over the Indian Ocean when compared to lower orbit satellite data, such as from pre-Meteosat 5 polar orbiters. This work consisted of two main objectives. The first was to determine the standard error associated with different temporal sampling rates (see figure), and the second was to compute and analyze the difference in precipitation estimates between satellites. Results indicate that the standard error increases approximately 0.2 mm based on the difference in the temporal sampling. A spatial analysis of the mean

values, conditional amounts, and frequency of occurrence of precipitation as measured by the two different satellites illustrates regional differences. This difference in the frequency and amount of precipitation between satellites can perhaps be explained by a difference in the estimation of diurnal variability.

Publications

Mahmood, R. M. Meo., D. R. Legates, and M. Morrissey, 2002: The CERES-Rice model-based estimates of potential monsoon season rainfed rice productivity in Bangladesh. *Professional Geographer*, **55**, 259-273.



Standard error associated with different temporal sampling rates for Meteosat 5 and polar orbiter satellites.

Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

Climate Research and Seasonal Forecasting for West Africans: Perceptions, Dissemination, and Use

Tarhule, Lamb

Objectives

Revisit the issue of seasonal forecasting and its underpinning climate research for West Africa.

Accomplishments

Beginning in response to the disastrous drought of 1968-73, considerable research and monitoring have focused on the characteristics, causes, predictability, and impacts of West African Soudano-Sahel (10°-18°N) rainfall variability and drought. While these efforts have generated substantial information on a range of these topics, very little is known of the extent to which communities, activities at risk, and policy makers are aware of, have access to, or use such information. This situation has prevailed despite Glantz' 1977 provocative paper on the use and value of seasonal forecasts for the Sahel more than a quarter-century ago. We now provide a systematic re-evaluation of these issues based on questionnaire responses of 566 participants (in 13 communities) and 26 organizations in Burkina Faso, Mali, Niger, and Nigeria. The results reveal that rural inhabitants have limited access to climate information, with NGOs being the most important source. Moreover, the pathways for information flow are generally weakly connected and informal. As a result, utilization of the results of climate research is very low to non-existent, even by organizations responsible for managing the effects of climate variability. Similarly, few people have access to seasonal climate forecasts, although the vast majority expressed a willingness to use such information when it becomes available. Those respondents with access expressed great enthusiasm and satisfaction with seasonal forecasts. The results suggest that inhabitants of the Soudano-Sahel savanna are keen for changes that improve their ability to cope with climate variability, but the lack of information on alternative courses of action is a major constraint. Our study thus essentially leaves unchanged both Glantz' negative "tentative conclusion" and more positive "preliminary assessment" of 25 years ago. Specifically, while many of the infrastructural deficiencies and socioeconomic impediments remain, the great yearning for climate information by Soudano-Sahelians suggests the time is finally ripe for fostering increased use. Therefore, a simple model for improved dissemination of climate research and seasonal climate forecast information is proposed.

Publications

Tarhule, A., and P. J. Lamb, 2003: Climate research and seasonal forecasting for West Africans: Perceptions, dissemination, and use? *Bull. Amer. Meteor. Soc.*, accepted.

Multiscale Evolution and Predictability of Warm Season Climate Anomalies

Nutter, Leslie, Lamb, Chambers

Objectives

Identify factors that may help improve predictions of developing regional climate anomalies on sub-seasonal time scales, with the goal of reducing the social and economic impacts of such weather regime changes.

Accomplishments

To help satisfy the objective, the onset and maintenance of a seasonal climate anomaly that developed over the U.S. Southern Great Plains during summer 2002 was examined. The onset of cooler and wetter than average weather was caused by flooding rains in the vicinity of San Antonio, TX, on 1-2 July 2002 which resulted in damages worth about \$1 billion. The origins of this flooding event can be traced to a mesoscale convective vortex that formed over Kansas and Oklahoma on 15 June 2002. This case provides a unique opportunity to study the multiscale predictability of sub-seasonal climate change over a well-observed region.

NCEP/NCAR reanalyses have been used to show that the regional climate anomaly is detectable on weekly and monthly timescales. The analyses also highlight the multiscale evolution of conditions leading to the onset and persistence of the anomaly. Furthermore, we have demonstrated that enhanced evaporation from areas near the Texas flood provided strong moisture transport and greater cloud cover over Oklahoma. Numerical model studies will be used to understand how soil moisture feedback processes influence the maintenance of the climate anomaly within the context of the existing large-scale circulation. We are now exploring the impact of model resolution on the predictability of this event by studying variance spectra from operational NCEP 15-day global model forecasts.

Matching Tornado Tracks with Census Tracts

Sutter, Yuan, Simmons (Oklahoma City University)

Objectives

Create a new database for tornado research by mapping tornado paths on to census tracts.

Accomplishments

The mapping of tornado paths to census tracts was completed under the supervision of Professor May Yuan, Department of Geography, University of Oklahoma. All U.S. tornadoes in the SPC's tornado archive for 1950 to 1999 were mapped on to 1990 and 2000 census tracts. About one third of the tornadoes in the archive had distinct latitude and longitude start and end points, and were successfully mapped. Supporting documentation was created and this data base is now available at NSSL for use by other tornado researchers.

Census tract level variables for Oklahoma for 1990 and 2000 censuses were obtained and matched with the census tract level paths of tornadoes in the state between 1990 and 1998. This allowed for comparison of census tract storm paths with county level storm paths, the resolution currently available in the SPC tornado archive. The comparison reveals that the census tract paths of tornadoes that caused fatalities and injuries in Oklahoma during this period had significantly higher population density and numbers of mobile homes as a percentage of housing units than the county level paths of these tornadoes. This suggests that census tract level resolution of paths should allow estimation of improved models of tornado casualties. The data set and the Oklahoma comparisons were described in a report submitted to NSSL.

Comparison of County and Census Tract Paths of Oklahoma Casualty-Producing Tornadoes 1990-1998			
		Mean of County Level Variables	Mean of Census Tract Variables
Fatality Tornadoes	Population Density	152.3	200.0
	Median Income	\$41,084	\$37,212
	Percent Mobile Homes	14.20	20.59
Injury Tornadoes	Population Density	103.1	162.9
	Median Income	\$37,859	\$39,052
	Percent Mobile Homes	13.74	19.00

Doppler Weather Radar Research and Development

Shared Mobile Atmospheric Research and Teaching Radar (SMART-R)

Rasmussen, Ziegler, Wicker, Biggerstaff, Straka, Texas Tech and Texas A&M collaborators

Objectives

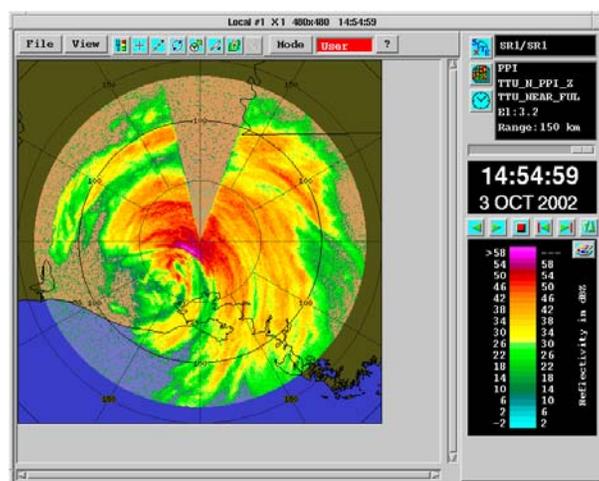
Study convective and mesoscale atmospheric processes to help improve forecasts of significant weather events such as flash floods, hurricanes, and tornadoes.

Accomplishments

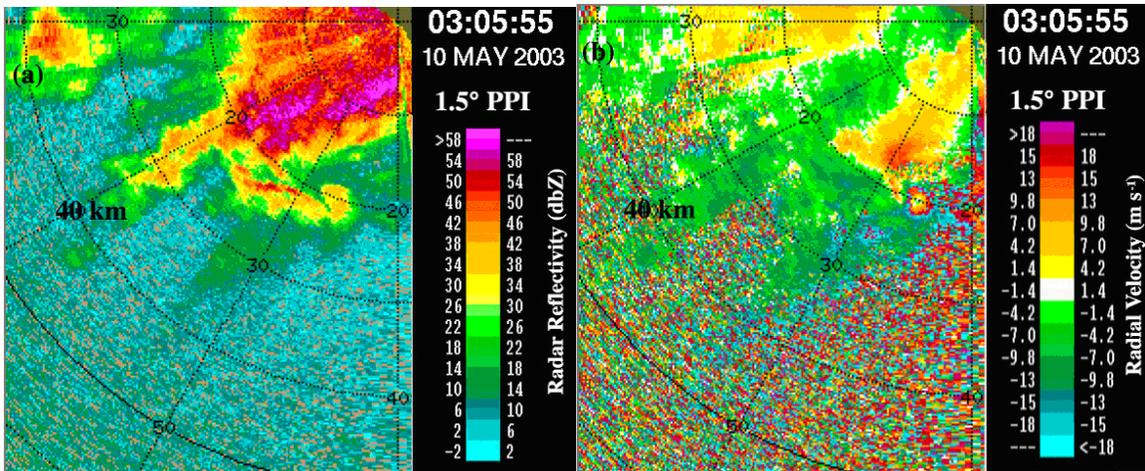
The Shared Mobile Atmospheric Research and Teaching Radar (SMART-R) had several milestone events during 2003. First, Texas Tech meteorologists used SMART-R #1 (SR-1) to intercept Hurricane Lili as she made landfall in Louisiana on 3 October 2002 (first figure below). SR-1 was used to study boundary layer structure in the rainbands as the hurricane made landfall in conjunction with multiple tower measurements that were deployed along the coast of Louisiana. This research was part of a wind engineering study at Texas Tech to investigate the turbulence associated with the landfalling storm.

The second milestone was the use of SR-1 to study tornadic storms. During the first two weeks of May 2003, with OU's Drs. Mike Biggerstaff and Howard Bluestein, the SR-1 system was deployed several times onto tornadic supercells in conjunction with the OU X-POL radar and the Doppler on Wheels project. Simultaneous data collection occurred on three days, 8 May in northeast Kansas, 9 May in central Oklahoma, and 15 May in the eastern Texas Panhandle. Importantly, the tornadic storm that struck downtown Oklahoma City on the evening of 9 May was sampled by five mobile Doppler radars as well as 3 fixed-site radars. This unprecedented data set will be used to extensively study the Oklahoma City tornado of 2003. The rapid evolution of the storm makes it a potentially important case for understanding cyclic tornadogenesis processes (second figure below).

Finally, May 2003 closed a significant chapter in the SMART-R story. The second radar, SR-2, was delivered by Texas A&M to the coalition (NSSL, OU, Texas Tech, Texas A&M) on 20 May 2003 by A&M SMART radar engineer Jerry Guynes. The delivery of this radar, originally destroyed by the 2 July 2001 fire at the NSSL balloon barn, marks the end of the 21-month period of rebuilding. The rebuild was made possible by the generous support of all four coalition members, including also CIMMS and the NOAA Office of Oceanic and Atmospheric Research. Each of these institutions contributed significant financial and in-kind support for the rebuild effort. SR-1 and SR-2 are scheduled to be used in a landfalling hurricane experiment in the fall of 2003 by Texas Tech and OU.

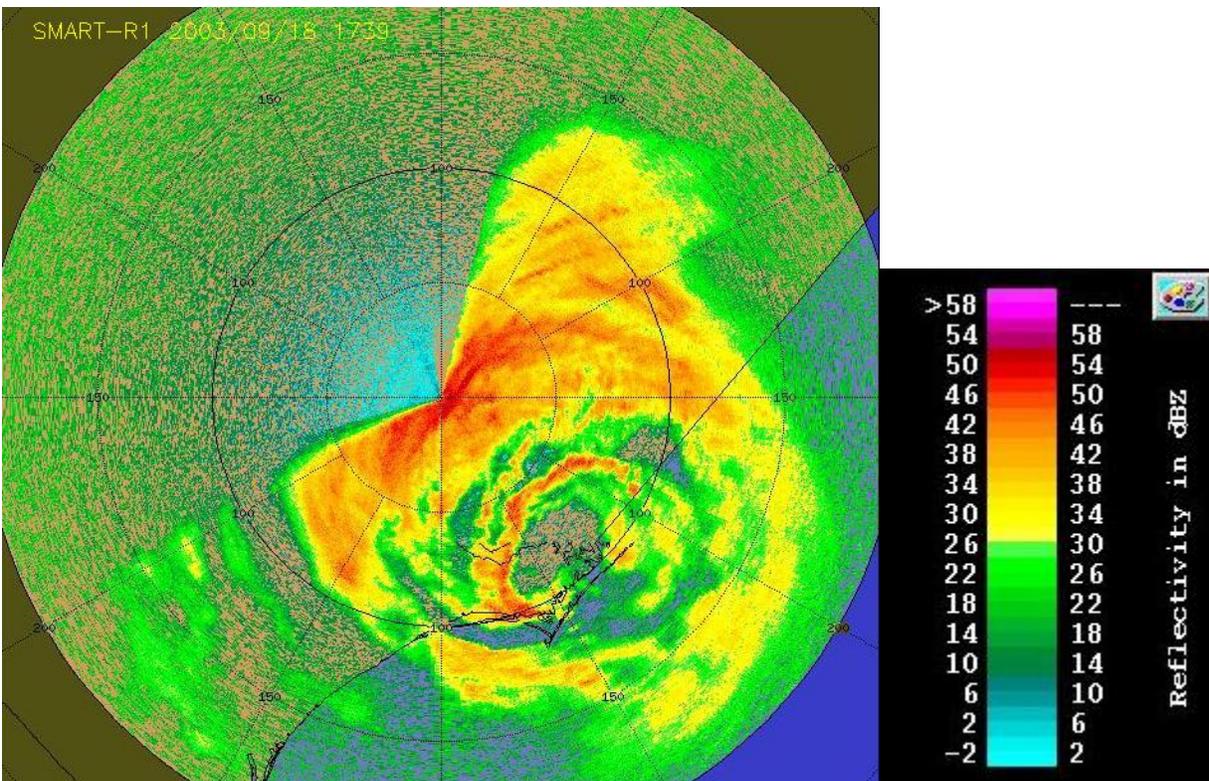


Hurricane Lili reflectivity from SR-1 deployed at Monroe LA on 3 October 2002 as she makes landfall. The eye of the hurricane is located southwest of the radar.



Radar reflectivity and Doppler velocity of a tornadic supercell thunderstorm observed by the SMART-radar on 10 May 2003 at 0305 UTC over Oklahoma City. The circulation associated with the hook echo at a range of 20 km and azimuth angle of 200 degrees was producing F1 damage at this time.

[Editor' Note: The SMART radars were also deployed with fairly short notice to North Carolina in September 2003 (after the reporting period) to capture Hurricane Isabel as she made landfall. A complete set of Images can be found at <http://www.nssl.noaa.gov/smartradars>. The radars were deployed such that a dual-Doppler lobe was concurrent with the hurricane landfall near Atlantic, NC. Thirteen hours of continuous data, containing two-minute volume scans, were collected. The image below is from SR-1 at 1739 UTC on 18 September. Mike Biggerstaff reports that there is some "mighty interesting stuff" contained in these images, which will be the subject of much research.]



SR-1 reflectivity of Hurricane Isabel in North Carolina at 1739 UTC on 18 September 2003.

Phased Array Radar – Fundamental Research Studies

Staples, Benner, Carter, Kimpel, Zrnicek, Zahrai, Schmidt, Wahkinney, Forsyth; many others beginning in FY04

Objectives

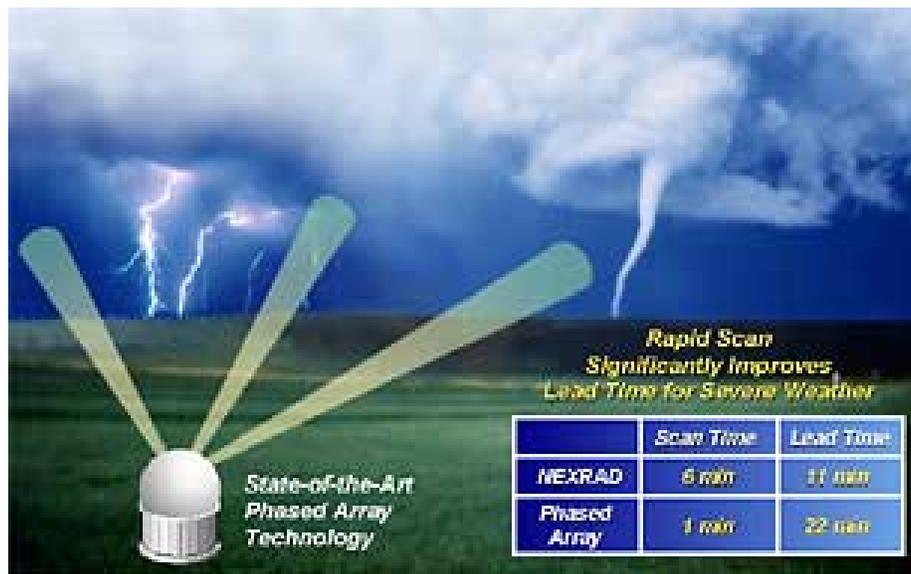
Develop a phased array radar capability for weather surveillance research and applications.

Accomplishments

Researchers have started adapting SPY-1 radar technology currently deployed on U.S. Navy ships for use in detecting severe weather. Early tests of the phased array radar (PAR) system have proved promising, and the technology has the potential to vastly improve upon the NEXRAD system for all weather radar applications. Using multiple beams and frequencies that are controlled electronically, PAR reduces the scan time of severe weather from six minutes for NEXRAD radar to only one minute, producing quicker updates of data and thereby potentially increasing the lead time for tornado warnings well beyond the current average of 11 minutes. Other technology being developed will extend lead times even more.

A National Weather Radar Testbed is being established at NSSL, which will provide the first surveillance PAR facility available on a full-time basis to the radar meteorological research community. The new system will be able to scan the atmosphere with more detail than the current radar. It will also be able to re-scan areas of severe weather very quickly, improving forecasters' warning capability. In addition, the new technology will gather storm information not currently available, such as rapid changes in wind fields, to provide forecasters with better conceptual storm models and to initialize stormscale forecast models.

A unique federal, private, state and academic partnership is developing the PAR technology. Participants include NOAA's NSSL and ROC, Lockheed Martin, the U.S. Navy, OU's School of Meteorology and School of Electrical and Computer Engineering, CIMMS, the Oklahoma State Regents for Higher Education, the Federal Aviation Administration, and Basic Commerce and Industries. The project, from research and development to technology transfer and deployment throughout the U.S., is expected to take 10 to 15 years at an initial cost of approximately \$25 million for the Norman facility.



Phased Array Radar rapid scan capability conceptual schematic.

Quantitative Precipitation Estimation and Segregation Using Multiple Sensors

J. Zhang, Xia, Qin, Clarke, Young, Gourley

Objectives

Continue development of the QPE SUMS algorithm to improve multisensor estimates of precipitation that will ultimately lead to improvements in operational flash flood monitoring and warning, watershed resources management, and model verification and initialization.

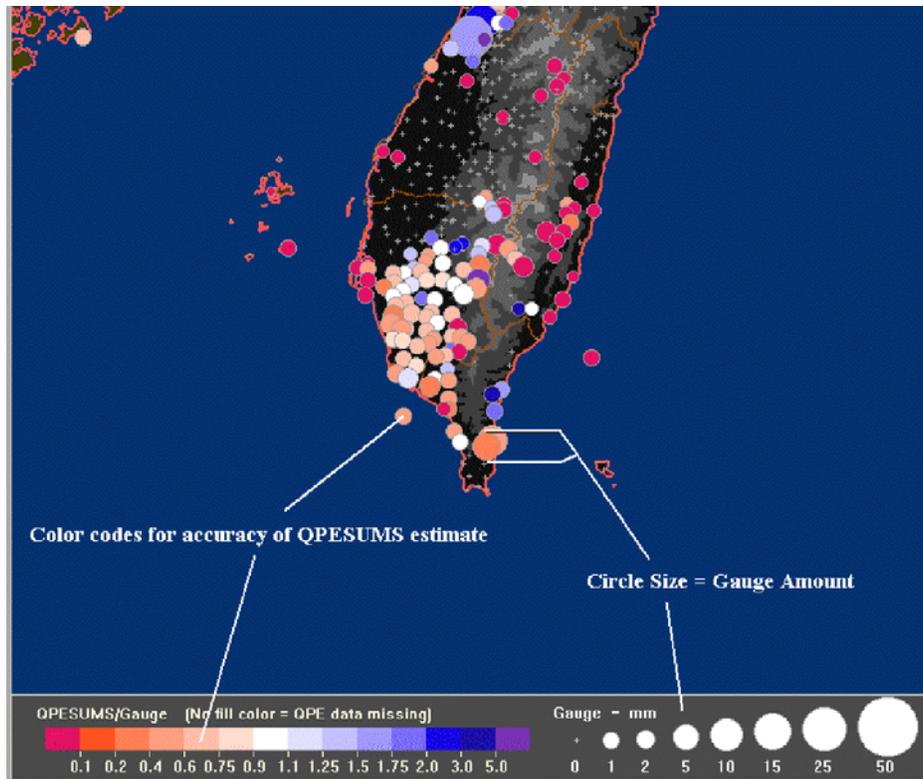
Accomplishments

Heretofore, rain gauge data have been withheld from our internal estimation scheme so that scheme evaluation could be made possible. These estimates have now been included to yield gridded gauge analyses of rainfall. Moreover, the rain gauge data have been combined with the multisensor estimates to adjust the rainfall magnitudes while maintaining their spatial variability. The results have been made available to operators who work the NWS ROC Hotline.

A significant effort was also made toward evaluating the QPE SUMS products for the 2003 winter season in Arizona. These findings have been summarized in a report and submitted to the Salt River Project. In addition, QPE SUMS products in the Carolinas and California have been archived or regenerated so that they can be evaluated and compared to operational NWS products in the near future. A verification web page was designed to display all QPE SUMS precipitation products and a full suite of intermediate output. A unique gauge comparison technique provides the user the ability to evaluate the performance of precipitation products statistically and qualitatively with a graphical representation. A flexible, web-based interface allows the user to choose the verification region as a function of geography (e.g., a specific basin), elevation, and range from the nearest radar. The user can also choose units to be in metric or English. The web page is updated hourly with the latest QPE SUMS graphics and rain gauge verification data.

Publications

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- Gourley, J.J. and B.E. Vieux, 2002: The effects of radar-derived rainfall uncertainties on forecasts from a distributed hydrologic model. *Red Book Symposium on Information from Weather Radar and Distributed Hydrological Modeling*, Sapporo, Japan, Intl. Assoc. of Hydro. Sci., 130-137.
- Gourley, J.J., and C.M. Calvert, 2003: Automated detection of the bright band using WSR-88D radar data. *Wea. Forecasting*, **18**, 585-599.
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- Gourley, J. J., B. Kaney, and R. A. Maddox, 2003: Evaluating the calibrations of radars: A software approach. *Preprints, 31st Intl. Conf. on Radar Meteor.*, Seattle, WA, Amer. Meteor. Soc., 459-462.
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An example of a QPE SUMS/gauge map for a rainfall event in Taiwan. The circles, with areas proportional to gauge accumulation, are color coded to indicate the ratio of QPE SUMS/gauge as shown in the lower left-hand legend.

Four-Dimensional Dynamic Multi-Radar Mosaic

J. Zhang, Langston, Xia, Gourley, Qin

Objectives

Establish a method to ingest, quality control, and analyze multiple weather radar data in real-time and produce a high-resolution 4D mosaic grid (3D in Cartesian space and 1D in time) of radar data.

Accomplishments

The focus of this project has been on developing optimal spatial analysis schemes that can produce a physically sound, high-resolution (1km) radar data mosaic grid in real-time (updated every 5 minutes). Various objective analysis schemes were tested on radar data from different weather regimes. Cases from convective storms and wintertime stratiform precipitation were used to study WSR-88D sampling characteristics. Each radar datum is not a point observation but a weighted integral of returns from a volume of targets. The size of the volume grows rapidly with range and results in extremely non-uniform resolution in radar data. The non-uniformity causes widely varying responses in radar data sampling to different weather systems. Because of the different responses, different analysis schemes are needed for different weather regimes. For instance, a vertical interpolation scheme can produce a consistent and representative analysis for upright convective storms. For a stratiform precipitation system with horizontally extended layers and strong vertical gradients, however, a vertical interpolation scheme results in ring-shaped artifacts because of the conical reference frame of radar sampling. For these weather systems, a horizontal interpolation is needed to reconstruct the physical structure of stratiform weather echoes.

The spatial resolution will be $\leq 1\text{km}$ in space ($\leq 500\text{m}$ in the vertical) and $\leq 5\text{min}$ in time. The 4D multi-radar mosaic will be able to combine multiple radars of different types such as WSR-88D, TDWR, mobile

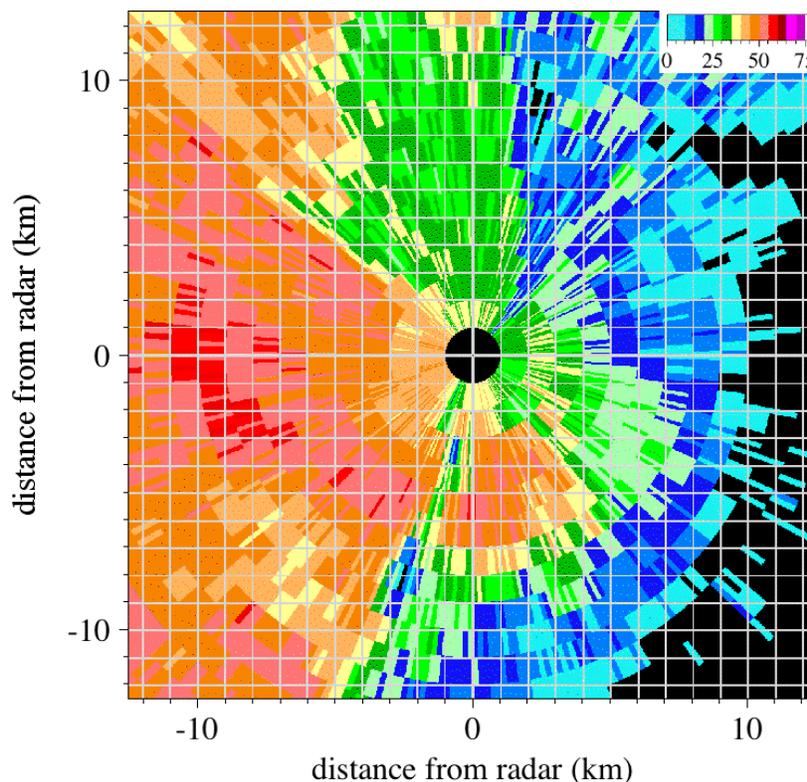
Doppler, and gap-filling radars. The mosaic grid in a Cartesian reference frame can provide a better database for severe storm algorithms than single radar data in a conical reference frame. It can also be used in diabatic initializations for numerical weather prediction models to improve quantitative precipitation forecasts.

Damping of storm intensities in the 4D multi-radar mosaic has been studied and special algorithms were developed to prevent the damping. This is very important for severe storm applications when storm intensity is a key parameter. When storms are very close to a radar, their structure is sampled by the radar at such high resolution that a 1km x 1km Cartesian grid will undersample the radar data (see figure). In this situation, any weighted mean analysis scheme could result in a reduction of the maximum storm intensities. The amount of the reduction depends on size of the storm cells and gradient of reflectivity field. To avoid this reduction, a “taking maximum” analysis scheme should be used for grid cells at close ranges.

Progress has been made in terrain-based radar data quality control. Very high-resolution (~30m) terrain data and the radar power density function are used to compute beam blockages by topography and to determine places where radar data are prone to ground clutter contaminations. The quality control scheme has been generalized for application to different radar data (e.g., WSR-88D, TDWR, mobile Doppler such as DOW, gap-fill radars, etc).

Publications

Zhang, J., J. J. Gourley, W. Xia, and K. Howard, 2002: 3D multi-radar reflectivity mosaic for the CIWS domain. *Preprints, 10th Conference on Aviation, Range, and Aerospace Meteorology*. May 13-16, Amer. Meteor. Soc., Portland, OR, J107-J109.
 Zhang, J., K. Howard, W. Xia, and J.J. Gourley, 2003: Comparison of Objective Analysis Schemes for the WSR-88D Radar Data. *Preprints, 31st Conference on Radar Meteorology*. August 5-12, Amer. Meteor. Soc., Seattle, WA. 907-910.



A reflectivity PPI image shows relative size of WSR-88D radar bins (1deg x 1km, color shaded) and Cartesian grid cells (1km x 1km, white lines). At ranges of 10 and 15km, one grid cell can cover ~6 and ~3-4 bins, respectively. Damping of storm intensities can occur in these regions when a weighted mean analysis scheme is used.

Joint Polarization Experiment – Engineering and Data Utility

Schuur, Ryzhkov, Zrnice, Heinselman, Scharfenberg, Burgess, Melnikov

Objectives

Evaluate the engineering design of polarimetric radar and demonstrate its utility.

Accomplishments

Over the past year, CIMMS scientists at NSSL played a leading role in conducting the Joint Polarization Experiment (JPOLE), which was designed to evaluate the engineering design of the polarimetric KOUN research WSR-88D radar, and demonstrate the utility of polarimetric radar data and products to operational users. Data collection with the KOUN radar began in late spring 2002. Since then, data have been collected for a wide variety of precipitation systems (e.g., widespread warm- and cold-season rainfall, isolated convective cells, supercell thunderstorms, tornadoes, MCSs, and winter storms) and for non-meteorological echoes (anomalous propagation, birds, insects, and chaff). A comprehensive summary of this data set is presented at <http://cimms.ou.edu/~heinsel/jpole/database.html>. In all, data have been collected and archived for approximately 80 days of observations. These data will be invaluable for research and for attaining Doppler weather radar improvements for the entire scientific community, and the skills learned in collecting and archiving the data will be invaluable during the development of PAR.

Publications

Schuur, T.J., D.W. Burgess, and A.V. Ryzhkov, 2003: The Joint Polarization Experiment - an operational demonstration of the polarimetric KOUN WSR-88D radar. *Preprints, 31st International Conference on Radar Meteorology*, Seattle, 952-955.

Dual-Polarimetric Radar Research

Krause, Schuur, Heinselman, Ryzhkov, Melnikov

Objectives

Create new algorithms that exploit the expanded capabilities of dual-polarimetric radar, and collect, deliver, and archive dual-polarimetric radar data to demonstrate its capabilities to end users

Accomplishments

A new winter precipitation algorithm was developed that differentiates between frozen precipitation and non-frozen precipitation. This was accomplished by the identification of the bright band from within the dual-polarimetric moment pHV. By identifying locations with frozen precipitation, we are better able to forecast snow and rain accumulations, and snow amounts can be estimated much more accurately. This can allow state and local services to respond better to locally heavy snow squalls.

Publications

Alberoni, P.P., D. Zrnice, A. Ryzhkov, and L. Guerrieri, 2002: Use of fuzzy logic classification scheme with a C-band polarimetric radar: first results. *Proc., Second European Conference on Radar Meteorology (ERAD)*, Delft, The Netherlands, 324 – 327.

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Melnikov, V.M., and R.J. Doviak, 2002: Spectrum widths from echo power differences reveal meteorological features. *J. Atmos. Oceanic Technol.*, **19**, 1793-1810.

Melnikov, V. M., D. S. Zrnice, J. K. Carter, A. V. Ryzhkov, R. J. Doviak, 2003: Evaluation of polarimetric capability on the research WSR-88D. *Preprint CD, 19th Internat. Conf. IIPS*, paper 2.7. Amer. Meteor. Soc., Long Beach, CA., Amer. Meteor. Soc.

Miller, D.J., and K. Scharfenberg, 2003: Polarimetric radar signatures in microburst-producing thunderstorms. *Preprints, 31st Intl. Conf. on Radar Meteor.*, Seattle, WA, Amer. Meteor. Soc., Vol. II, 976-979.

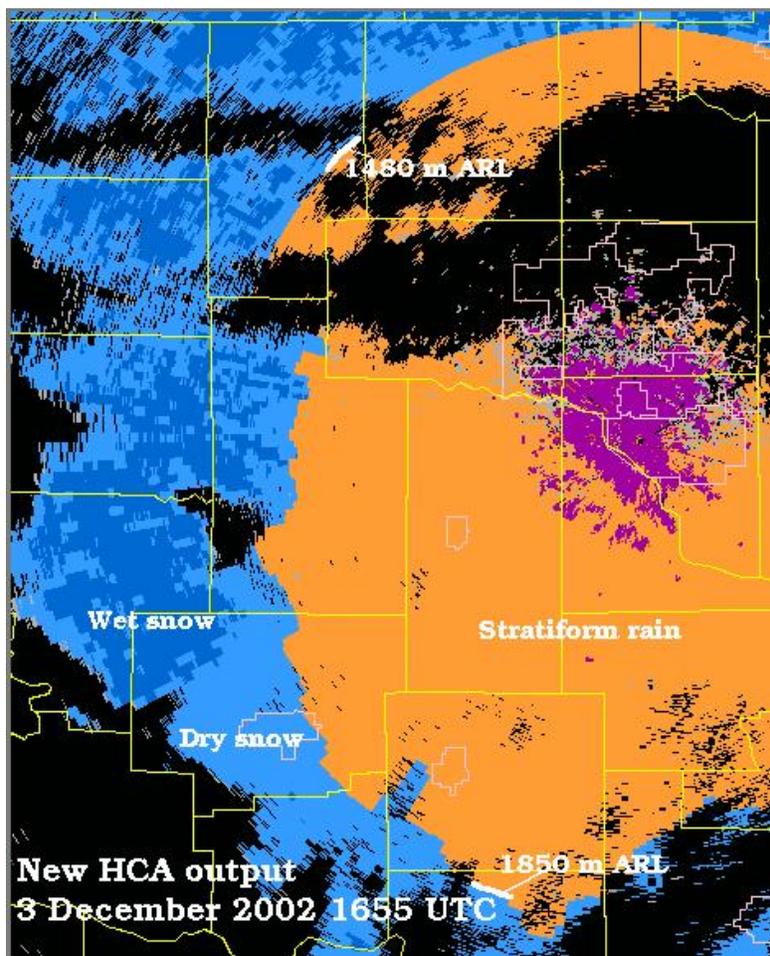
Ryzhkov, A., D. Burgess, D. Zrnice, T. Smith, and S. Giangrande, 2002: Polarimetric analysis of a 3 May 1999 tornado. *Preprints, 21st Conference on Severe Local Storms*, Amer. Meteor. Soc., San Antonio, TX, 515 – 518

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Ryzhkov, A.V., and T.J. Schuur, 2003: Effective shape of raindrops. Polarimetric radar perspective. *Proc. IGARSS 2003*, Toulouse, France, CDROM.

Ryzhkov, A.V., D.S. Zrnice, R. Doviak, P. Zhang, 2003: Development of a classification algorithm for operational polarimetric NEXRAD radar. *Proc. IGARSS 2003*, Toulouse, France, CDROM.

- Ryzhkov, A.V., S. Giangrande, and T.J. Schuur, 2003: Rainfall estimation with a polarimetric prototype of the operational WSR-88D radar. *Preprints, 31st International Conference on Radar Meteorology*, Amer. Meteor. Soc., Seattle, WA, 208 - 211.
- Ryzhkov, A.V. and D.S. Znic, 2003: Discrimination between rain and snow with a polarimetric NEXRAD radar. *Preprints, 31st International Conference on Radar Meteorology*, Amer. Meteor. Soc., Seattle, WA, 635 - 638.
- Scharfenberg, K.A., 2003: Polarimetric radar signatures in microburst-producing thunderstorms. *Preprints, 31st Intl. Conf. on Radar Meteor.*, Amer. Meteor. Soc., Seattle, WA, Vol. II, 581-584.
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- Scharfenberg, K.A., and E. Maxwell, 2003: Operational use of a hydrometeor classification algorithm to detect the snow melting level. *Preprints, 31st Intl. Conf. on Radar Meteor.*, Amer. Meteor. Soc., Seattle, WA, Vol. II, 639-641.
- Schuur, T., D. Znic, and R. Saffle, 2003: The Joint Polarization Experiment – an overview of initial data collection with a polarimetric WSR-88D radar. *Preprint CD, 19th Internat. Conf. IIPS*, paper 2.6. Amer. Meteor. Soc., Long Beach, CA.
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Winter hydrometeor classification. The dual-polarimetric radar's hydrometeorological classification routine has been adapted to differentiate between rain and snow.

Zdr Columns and Microphysical Processes

Straka, Kanak

Objectives

Continue to improve the interpretation of polarimetric radar data and the advance the understanding of microphysical processes associated with these radar signatures.

Accomplishments

Zdr columns are documented in at least three different convective flow regimes. We examined the differences based on distinguishing microphysical processes that may lead to similar appearing Zdr columns for very different convective systems. Results have been obtained on the interpretation of Zdr columns in polarimetric radar data and the associated microphysical processes and is near submission.

Internet-Based Delivery of WSR-88D Level II Data in Near Real-Time

Droegemeier, Sinclair, Jahn, Hill, Kelleher, Crum

Objectives

Real-time compression and Internet-based transmission of WSR-88D Level II data from multiple radars, and real-time delivery of such data.

Accomplishments

To begin addressing the long-term needs for WSR-88D base (Level II) data transmission and archival, the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma joined forces in late 1998 with the NOAA/NSSL, UCAR, the NEXRAD Radar Operations Center, and the NCDC to establish the Collaborative Radar Acquisition Field Test. Funded by grants from the State of Oklahoma, NSF EPSCoR, and NOAA (total funding to date of \$2.6 million), CRAFT has successfully demonstrated the real time compression and Internet-based transmission of WSR-88D Level II data from multiple radars. A total of 62 radars now participate in CRAFT (see figure), and data are being delivered by CAPS, in real time, to more than 30 IP addresses, including numerous private companies.

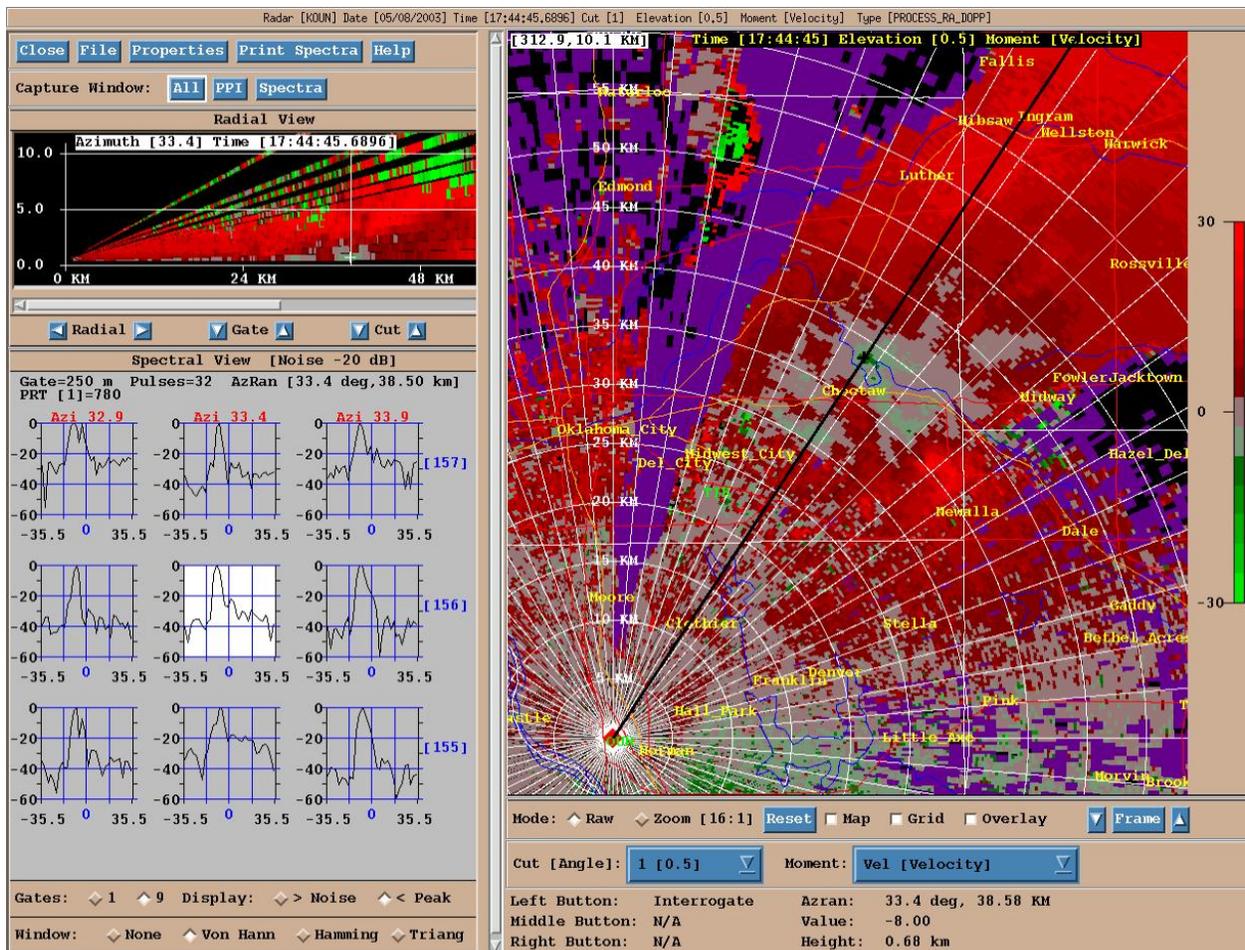
During the past 12 months, funding from NOAA for Project CRAFT has been leveraged against \$100,000 from private industry partners, \$50,000 from the NSF, and \$10,000 from NRL to continue supporting continuous delivery and to expand delivery to the academic community. Another dozen radars have been added, including the two USAF WSR-88D radars in Korea.

The success of CRAFT, which won the 2002 NOAA Tech award, has resulted in considerable cost savings to NOAA via the suspension of 8 mm data recording at all CRAFT sites, and the development of an entirely new archived data delivery system at NCDC. Introduced late last year, the NCDC system is now delivering about three times as much Level II data to the community, via automated ftp, as all other data sets, with the .edu community representing 60% of the volume. Prior to the new system, 53% of the Level II data requests at NCDC were made by NOAA/NWS, with only 12% from academia. Consequently, the demand by academia for Level II data, both archived and in real time, is exploding.

Based upon the success of CRAFT, the NWS now is establishing an Internet-based delivery system for Level II data that will serve its needs as well as those of the corporate and academic communities. It is expected to be fully operational in late calendar year 2004.

Publications

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- Crum, T., D. Evancho, C. Horvat, M. Istok, and W. Blanchard, 2003: An update on NEXRAD program plans for collecting and distributing WSR-88D base data in near real time. *Preprints, 19th Conf. on Interactive Information Processing Systems for Meteorology, Oceanography and Hydrology*, Amer. Meteor. Soc., Long Beach, CA.



RRAT display for the 8 May 2003 tornado outbreak in central Oklahoma.

Radar Data Acquisition Research

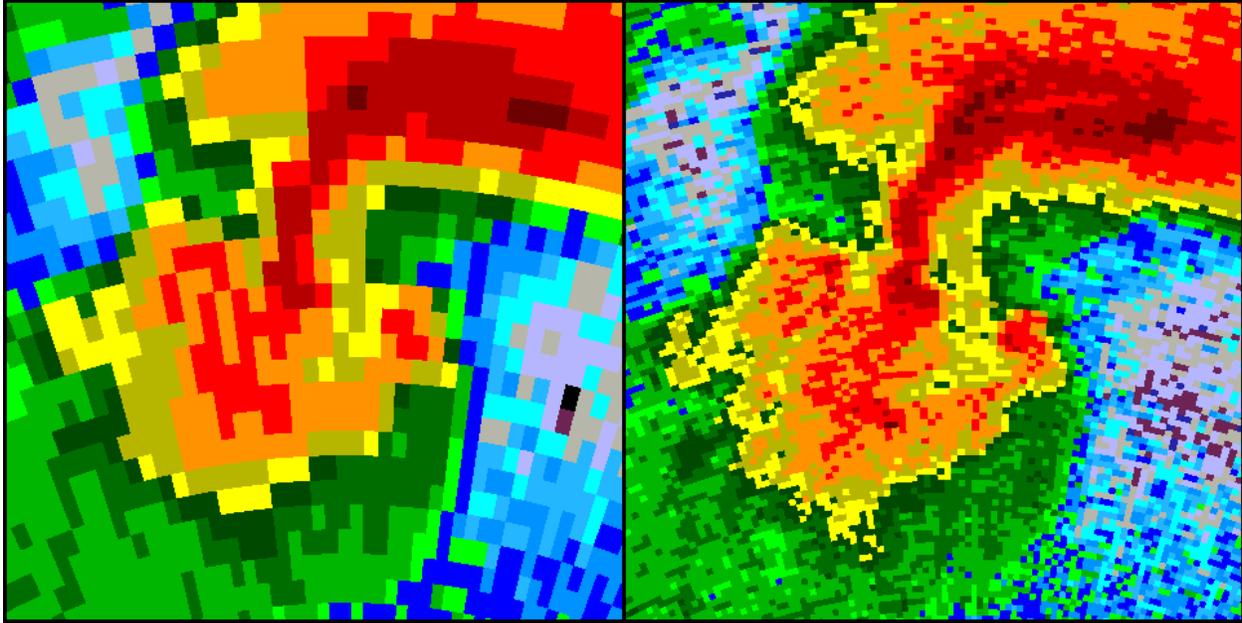
Curtis, Torres, Forren, Ivic, Dubel, Brown, Wood

Objectives

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

Accomplishments

High-Resolution WSR-88D Base Data. Legacy WSR-88D algorithms were modified for the KOUN research radar to produce a new high-resolution base data stream. These high-resolution data are collected at 0.5 deg. intervals with 250 m resolution for all of the spectral moments. A new capability was also added to allow visual inspection by the user.

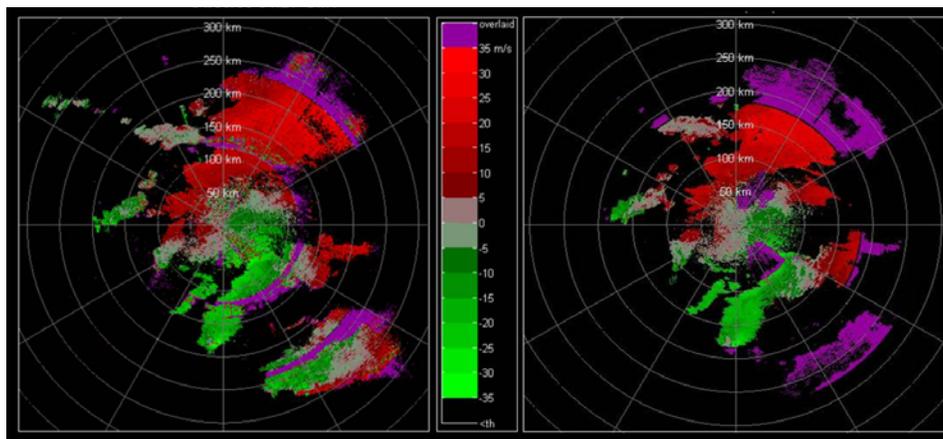


Current low-resolution reflectivity data (left) and high-resolution reflectivity data (right) collected during the 9 May 2003 Oklahoma City tornado.

Publications

- Curtis, C., S. Torres, and E. Forren, 2003: High-resolution WSR-88D base data on the KOUN research radar. *Preprints, 31st Intl. Conf. on Radar Meteor.*, Seattle, WA, Amer. Meteor. Soc. 964-966.
- Torres, S., 2003: Processing of staggered PRT sequences on the KOUN research radar. *Preprints, 31st Intern. Conf. on Radar Meteor.*, Seattle, WA, Amer. Meteor. Soc., 746-748.

Mitigation of Range-Velocity Ambiguities. Systematic phase coding was implemented and evaluated on the KOUN research radar. This was thoroughly analyzed with a MATLAB-based signal processor simulator. An algorithm proposed previously was refined using this process, and an algorithm recommendation was made to the NWS ROC for operational radars. The staggered Pulse Repetition Time (PRT) method was also tested on the KOUN radar. The system was modified to generate staggered pulse sequences and the signals were processed in real time using this algorithm. Again, several tests were performed using the MATLAB signal processing simulator. These included statistical analyses of estimate errors and algorithm refinement.



Doppler velocity fields retrieved using the phase coding (left) and the staggered PRT (right) techniques. Data was acquired using KOUN research radar on 6 April 2003 at approximately 0427 UTC. The antenna elevation is 1.5 deg in both cases.

Mitigation of Anomalous Propagation within WSR-88D Composite Reflectivity Products

Porter

Objectives

Provide the Federal Aviation Administration with guidance on the accuracy of anomalous propagation-mitigated composite reflectivity products.

Accomplishments

Guidance has been provided to the FAA and, in turn, to the National Air Traffic Controllers Association on the use of anomalous propagation (AP) mitigated products. Subjective examination of AP-mitigated products suggests smoothing of reflectivity data is occurring, causing a reduction in magnitude and areal coverage of maximum reflectivity returns. This can produce a potentially dangerous situation for air traffic controllers when supplying guidance to airline pilots. An investigation of the AP-mitigated code is ongoing to determine if the smoothing is inherent to the AP algorithm. Moreover, improvements to the current AP algorithm are being examined to provide a robust method of removing non-precipitation returns from radar data for a variety of AP events.

Clear-Air Adjoint Method Wind Retrievals

Porter

Objectives

Evaluate the ability to obtain clear-air wind retrievals from the WSR-88D network, and determine the usability of clear-air wind retrievals for the initialization of a mesoscale model.

Accomplishments

A clear-air adjoint-method (CAAM) wind retrieval scheme has been developed to accurately depict wind flow over a mesoscale domain using WSR-88D data. In particular, clear-air or precipitation-free wind retrievals were examined. The CAAM is based upon the simple adjoint method that incorporates predictive equations for reflectivity and radial wind, treating them as passive scalars. These equations have been used to retrieve the horizontally varying time-mean wind that gives the best estimate of the observed fields during the retrieval period. The optimal simulation of the observed field is obtained through minimizing, in a least squares sense, a cost function representing discrepancies between the estimated and observed quantities such as reflectivity and radial wind.

The CAAM has been applied to both idealized atmospheric regimes and real-data cases containing various configurations of atmospheric structures. Accurate retrieval solutions have been shown to depend on the initial conditions of the technique and the existence of coherent gradients within the radar observation fields. When using retrieved information to initialize a mesoscale numerical weather prediction model, observation information from multiple CAAM wind retrievals over a mesoscale region must be spread across the entire model domain. This has been accomplished using a Cressman successive correction method of objective analysis with an "air mass" weighting scheme. The weighting scheme does not allow retrieved wind information to be spread across a detected boundary. Thus, wind information is distributed only within the same air mass in which it resides.

Application of the assimilation technique has been demonstrated in a numerical simulation of a MCS initiated along a stationary boundary in weak, synoptic flow using retrieved wind information from seven WSR-88D radars. The assimilated retrieved winds significantly affect the horizontal convergence along the stationary boundary producing a more realistic spatial distribution of precipitation in the first couple of hours of the simulation. Furthermore, the orientation of the resultant cold pool and outflow boundary generated by the convective system is modified. Hence, the location and amount of lift along the outflow boundary is altered resulting in a more accurate simulated evolution of subsequent convection.

Publications

Porter, C. W., 2003: Using Clear-Air Adjoint-Method Wind Retrievals from the WSR-88D Network to Initialize a Mesoscale Model in a Pre-Convective Environment. Ph.D. Dissertation, Pennsylvania State University, 171 pp.

Climate Change Monitoring and Detection

North Atlantic Climate Variability

Portis, El Hamly, Lamb

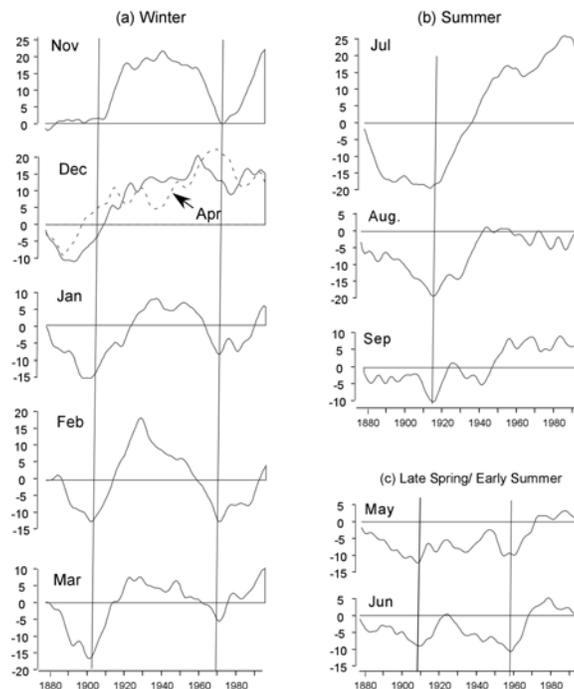
Objectives

Investigate the temporal behavior of the seasonal signal of the NAO.

Accomplishments

Determining the predictability of the NAO is ultimately tied to understanding any coupling it has with the other components of the North Atlantic climate system. The motivation behind this research is to investigate the temporal behavior of the seasonal signal of the NAO. This is a first step in exploring any seasonal coordination between the NAO and the ocean/cryosphere. Seasonal coordination has been theorized to provide the mechanism for the ocean/cryosphere to feedback on the NAO. If there is evidence of 1) seasonal coherences in the NAO signal; 2) low-frequency variability that is reflected in other components of the climate system; or 3) months which dominate low-frequency variability; then such results could be used as a frame of reference to study coupling between the NAO and other components of the North Atlantic climate system.

To address the seasonal aspects of the NAO signal, our analysis used a mobile NAO index that better captures its seasonality by following the seasonal migration of the centers of action (Portis et al. 2001). This seasonal inclusivity of the NAO expands on previous research (e.g., Hurrell and van Loon 1997) that has concentrated on the wintertime study of the NAO signal. Our research analyzes many facets of the time series behavior of the NAO signal, including the strength of the monthly NAO signal, persistence across consecutive months over interannual, decadal and interdecadal timescales, the seasonal evolution of the NAO signal, and the temporal variability of the NAO signal through wavelet analysis.



Monthly cumulative sum plots for NAO in (a) winter, (b) summer and (c) late spring/early summer. The cumulative sum time series for April (dashed line) is also shown with December. Maximum and minimum values of the cumulative sum curves represent a change in a persistent tendency for the time series. Maximum values represent a phase change from persistent negative and conversely minimum values represent a phase change from persistent negative to persistent positive.

Investigation of Long-Term Precipitation Variability across the African Continent

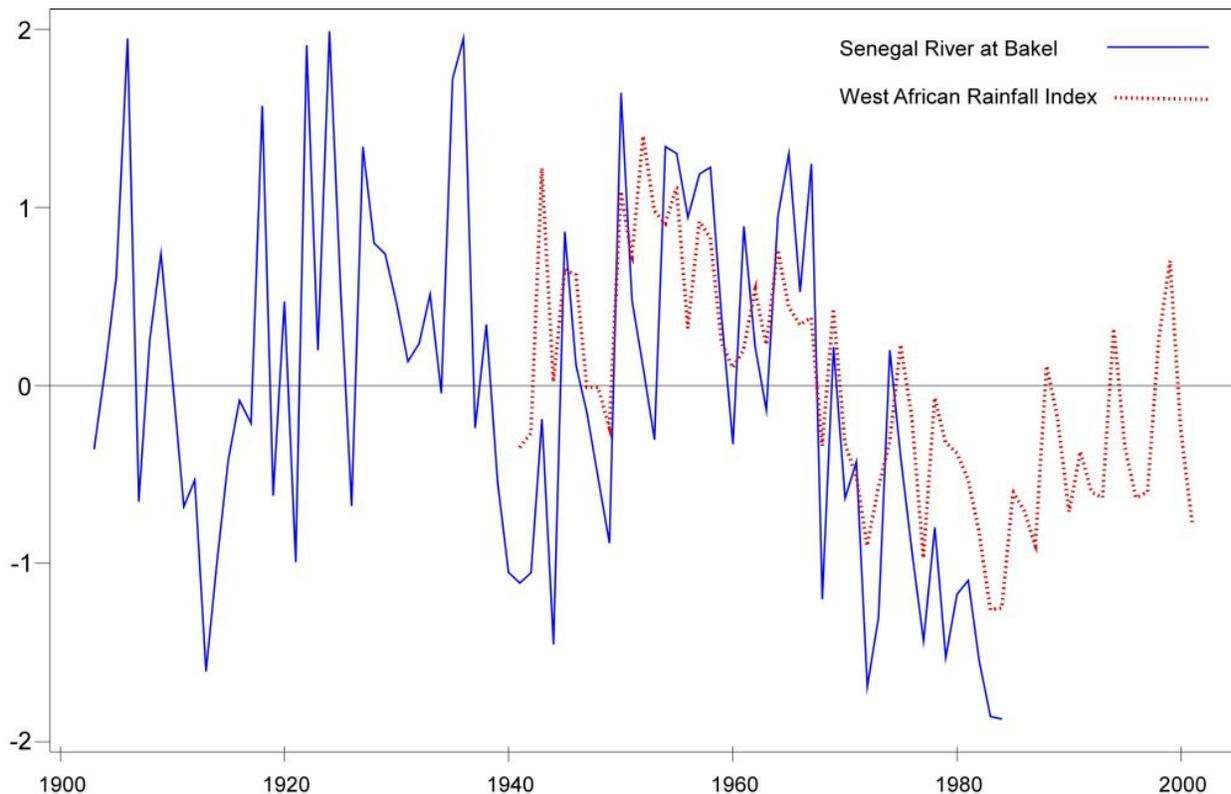
Lamb, Portis, Winstanley (Illinois State Water Survey)

Objectives

Document long-term precipitation variability across coherent precipitation regimes in Africa using station and river discharge data.

Accomplishments

Winstanley (1985) documented three coherent precipitation regions within the African continent that are characterized by a single-season, two-season, or all-season precipitation regime. In our study, we are expanding on his previous analysis with much larger datasets of river discharge and station data. We currently have available to us 64 time series of river discharge data on a monthly basis, 50 long-term monthly precipitation time series across the sub-Sahara, and 17 monthly time series from Morocco. After documenting the compatibility of these different data sources by analyzing their characteristics across overlapping observational periods, we will then have a basis for establishing precipitation proxies for studying longer-term variations for each of the African precipitation regimes. Investigation of the long-term variations will be made in the context of documented variations in other parts of the climate system, such as the NAO and Atlantic sea surface temperatures.



Time series of the annual discharge data from the Senegal River at Bakel, Senegal (1903-1984) and the West African rainfall index (Lamb, 1985) for 20 sub-Saharan stations over the period 1941-2001. The normalization period for the Senegal River is from 1903-1984; the normalization period for the West African rainfall index is from 1941-2000.

Summer Temperature Extremes in North America East of the Rockies

Rogers, Lamb

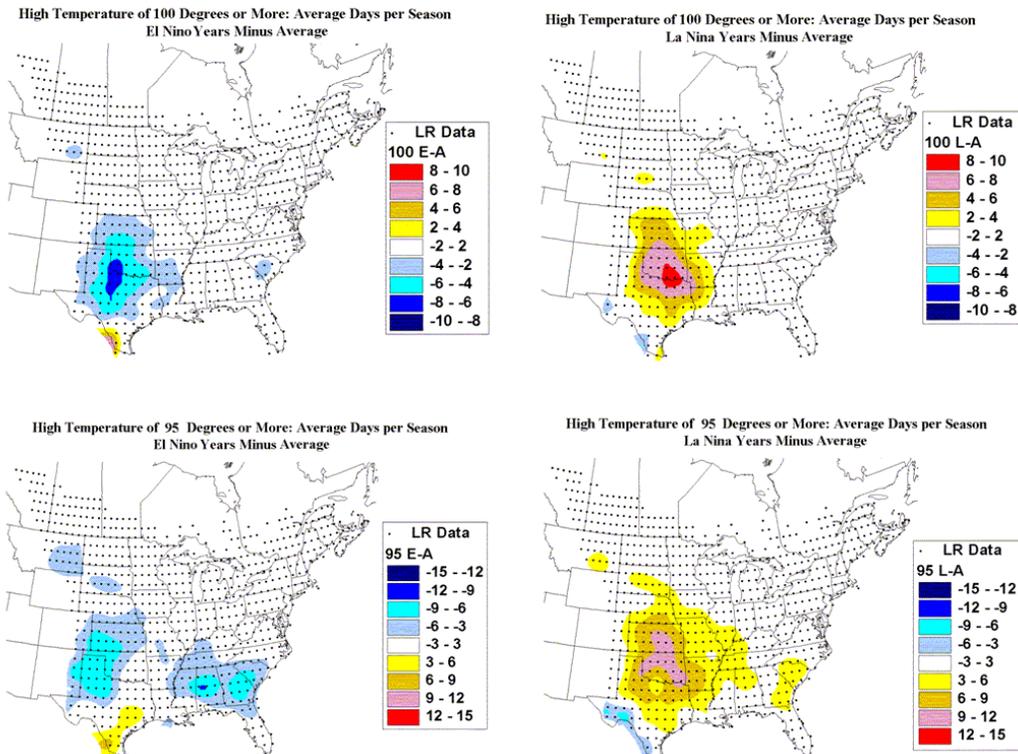
Objectives

Determine summertime temperature extremes in North America east of the Rocky Mountains.

Accomplishments

Extreme summertime temperatures in North America east of the Rocky Mountains are being examined using the Lamb/Richman dataset. It consists of 764 grid points in the United States and southern Canada, with a 1° spatial resolution. The daily maximum temperatures available in this dataset are analyzed with respect to equatorial Pacific sea-surface temperature, resulting in computation of the differences between El Niño and La Niña years from an overall average year. The analysis period covers the North American summer months of June-September. Analyses thus far are based on defined extreme thresholds, both absolute (90, 95, 100°F) and relative (5, 10, 15°F above/below average).

The most striking results thus far have been found with absolute temperature thresholds of 95 and 100°F. The analyses performed look at the number of days per summer and per summer month in which the threshold is met or exceeded in the daily maximum temperature. For the 100°F La Niña anomaly (upper right figure panel), we see that nearly all of Oklahoma experiences six to eight more 100° days during a La Niña summer, when compared to a 52-year average. The area of additional 100° days extends over much of the Southern Plains. This pattern is also consistent for 95° and 100°, for both El Niño and La Niña summers (though El Niño summer anomalies are of the opposite sign), as shown below. Other patterns are also being investigated, including 90° anomalies in the Midwest, and above/below average anomalies in the Northeast. Future investigation will look into energy usage and agriculture applications.



Created by James Rogers (2003)

Average number of days per season with high temperatures of 100°F and 95°F or more, respectively, for both El Niño and La Niña years.

Interannual Variability of the Climate System

Richman, Lamb

Objectives

Investigate the interannual variability of the North American climate system.

Accomplishments

The interannual variability of the climate system is being investigated with the aid of a recent expansion to the Lamb/Richman dataset. Mean and modal patterns of NCEP/NCAR reanalysis data are investigated for seasons that coincide with extreme temperature and precipitation anomalies. Trends in precipitation and extreme temperature occurrences are examined. The resulting patterns and time series provide the information necessary to diagnose recent climate fluctuations.

PUBLIC AFFAIRS AND OUTREACH

ARM Program Outreach Activities

Melvin, Kloesel

Objectives

Provide outreach support for the ARM Program to K-12 teachers and students throughout Oklahoma, Kansas, and the U.S.

Accomplishments

Year 11 of ARM Program/SGP educational outreach activities was marked most notably by the July 2002 EarthStorm workshop for Oklahoma K-12 teachers and the 10th Anniversary Mesonet/ARM Science Fair. ARM/SGP Outreach staff presented papers or posters at the American Meteorological Society Annual Meeting in Long Beach, CA; the National Science Teachers Association Regional Meeting in Albuquerque, NM; the Oklahoma Science Teachers Association State Meeting in Oklahoma City, OK; and at regional and local teacher in-services and workshops throughout Oklahoma and Kansas.

Another feature accomplishment was the completion of the “Magic School Bus Kicks up a Storm” traveling children’s museum exhibit. The exhibit is a joint effort between the Oklahoma Climatological Survey (OCS) and numerous other entities. ARM data are used heavily in the training of teachers and students so that they may get the most out of their field trip experience. OCS staff trained personnel from 10 different children’s museums this year, and will do likewise in each of the next five years.



Children enjoy working with radiometric thermometers at the “Magic School Bus Kicks up a Storm” exhibit at the Children’s Museum of Houston.

For the fourth consecutive year, ARM teacher Marilyn McComber invited OCS Outreach staff to present a workshop for Kansas teachers at Emporia (KS) High School. The workshop provided scientific knowledge to help the Emporia teachers modify an online environmental course. The online course provides teachers with increased scientific knowledge, infuses multidisciplinary concepts, promotes integration of

technology into classrooms, and encourages teacher networking and peer mentoring. The OCS workshop covered all facets of measurements at the ARM SGP site and the Oklahoma Mesonet, remote sensing, Earth's seasons and atmosphere, the electromagnetic spectrum, and global warming.

The ARM/SGP outreach staff and OCS "Storm Team" teacher-consultants traveled throughout Oklahoma and Kansas conducting workshops on how to use ARM and Oklahoma Mesonet data in the classroom. The workshops focused on the OCS Outreach web site and how to use the WxScope Plugin visualization software to display interactive maps and graphs. In addition, a short course entitled "Thermodynamics of Pizza" was created and presented at the NSTA meeting in Albuquerque, and the 2002 EarthStorm workshop in Norman. Evaluations from the teachers taking the short course were unanimously positive.



Teachers at EarthStorm 2002 view a radiosonde launch.

The OCS Weather Series is a collection of educational activities intended for use with real-time or archived ARM and Mesonet data. There are two main components of the OCS Weather Series: reference materials and lessons. Teachers use the reference materials as refresher information prior to teaching a given subject. The OCS Weather Series lessons are aimed at the middle school grade level, but can be modified by the teacher to be more or less difficult. The lessons typically require environmental data and many can be used with recent or real-time data. The lessons contain a list of prerequisites for the activity, suggested grade levels, an overview of the lesson content, ideas for the teacher to apply the lesson, the experiment, and several questions. Each lesson is reviewed yearly and new data cases are added. OCS is now expanding these activities to a national focus.

Newly developed OCS lessons continue to be added to the Aurora Project's GeogWeb site (<http://www.auroraok.org>). Aurora is a statewide educational project whose mission is to create an interactive collaborative learning community among teachers and students, homes and towns, and public and private organizations across Oklahoma. Aurora uses a geography-based curriculum full of real problems and relevant experiences to integrate several educational disciplines. Learning activities in GeogWeb take advantage of resources in local communities of Oklahoma. Aurora is funded by the U.S. Department of Education.

Oklahoma Weather Center Research Experiences for Undergraduates Program

Zaras, Schultz, Elmore, Sonntag, Dean, Peppler, Stumpf, Lakshmanan

Objectives

Provide a rich intern experience to ten bright college students from across the U.S. by guiding each of them through a unique research project.

Accomplishments

CIMMS researchers continue to manage, serve as mentors, and participate in the Oklahoma Weather Center Research Experiences for Undergraduates (REU) program at OU, funded by NSF. Ten meteorology, physics, and math college students from across the country participated in the 2003 program. Each student was paired with a CIMMS, OU, or NOAA mentor who guided them through project decision making, the writing of a 10-page paper, and the presentation of a 15-minute conference-style talk. Lectures, workshops, and field trips supplemented the students' experiences to provide an experience much like that of professional scientists. Past participants consistently report their experience is the best of all those available in meteorology. CIMMS scientists mentored four of the 10 students.



Students from two summer programs, REU and ORISE, gather with their mentors for the annual group photo.

Outreach Activities of CIMMS Staff at NSSL

Zaras, Rasmussen, Tarp, Schultz, Spencer, Baldwin, Benner, Cox, Manross, Staples, Mansell, Elmore, Farmer, J. O'Bannon

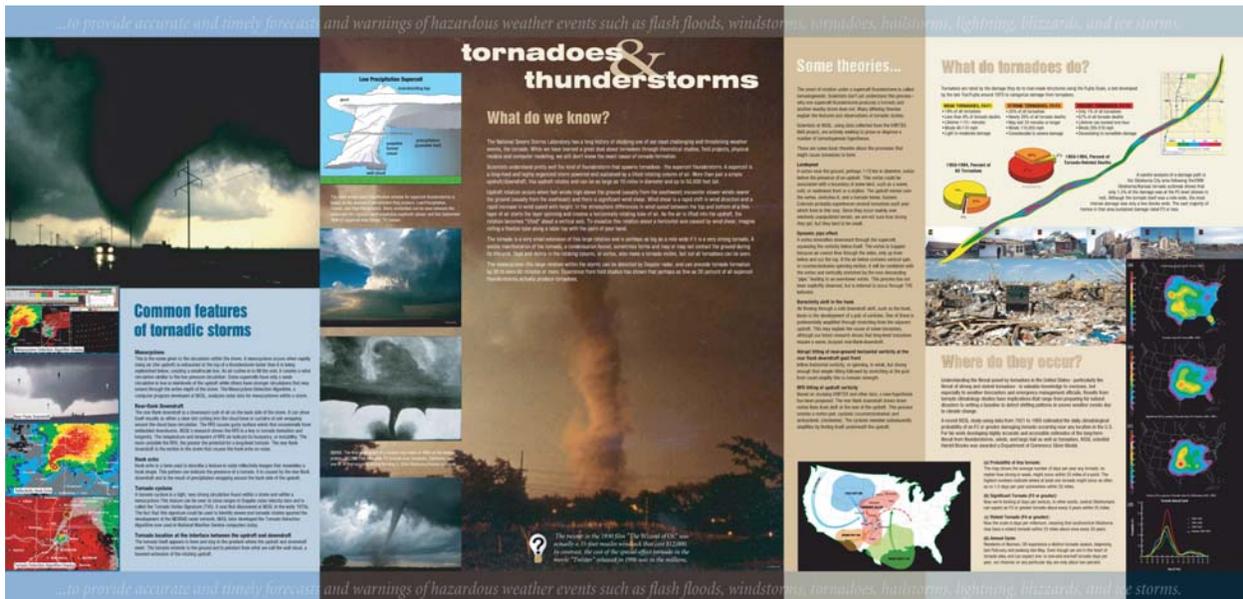
Objectives

Inform an interested public about our research activities and how those activities impact their daily lives, sharing the task of providing outreach among many uniquely-skilled staff members.

Accomplishments

A number of activities have been conducted during the fiscal year. They include:

- Completion of an extensive wall displays about the science and research of CIMMS (see figure)
- Served as professional liaisons for K-12 and university students
- Mentored high school students working on local and national science fair projects
- Responded to requests for information about our work received via phone, email, and mail
- Wrote "Weather Watch" column in *Canoe & Kayak Magazine*
- Installed NOAA weather radios in local elementary schools
- Met with visitors, including many college students majoring in meteorology or related fields
- Served as professional staff during job shadow days for local high school students
- Spoke at local schools and clubs about our science and weather safety
- Spoke to local aviation committee about our aviation-related research
- Organized and taught local Girl Scout Weather Badge Workshop
- Spoke at American Meteorological Society's WeatherFest public event in Long Beach, CA
- Coordinated exhibits for the American Meteorological Society's Annual Meeting
- Recruited students for a summer student internship program at the American Indian Science and Engineering Society's Annual Meeting in Tulsa, OK
- Maintained and updated the CIMMS web page (<http://www.cimms.ou.edu/>)



Informational display explaining the current understanding and ongoing research on tornadoes.

Enlightening Lightning: Lightning Education Project (Safety and Science)

Mansell, Texas A&M University and Tarleton State University collaborators

Objectives

Develop a planetarium-based educational program about lightning science and safety.

Accomplishments

Collaboration with Texas A&M and Tarleton State (TX) is resulting in the "Enlightening Lightning" project. It aims to introduce 6th-8th graders to lightning research and safety through a planetarium-based presentation. A detailed outline of science content has been developed, and a preliminary narration and script have been drafted. A storyboard has been generated to direct the flow of the program with animated sequences and live-action video.

COMPUTER SUPPORT

Computer Support Activities for CIMMS Researchers Located at NSSL

G. Skaggs and Staff

The management and administration of computers, networks, and computer-related security for CIMMS scientists at NSSL is accomplished by the Information and Technology Services (ITS) group. Equipment consists of Linux-based systems, a significant number of Windows-based and Macintosh clients, as well as a number of UNIX systems (most of which are Solaris-based), remote access systems, firewalls, and computational clusters.

CIMMS scientists have completed development of two computational 'clusters' to support meteorological and hydrologic modeling. This has enabled our scientists to develop and enhance these models in a more cost-effective environment than with traditional computational systems.

Much time was spent this year by ITS in the development and implementation of security policies that help make our work environment safer from technological threats. Remote access technology was enhanced this year to allow our scientists to work away from the office in as transparent a way as possible, while maintaining necessary security controls.

CIMMS AWARDS

Mike Baldwin (at NSSL)

- Received the 2003 **AMS Editor's Award** for the journal *Weather and Forecasting* "for his thoughtful, helpful, and detailed reviews that consistently assisted in improving submitted manuscripts."

Leon Minton (at NWS Southern Region Headquarters)

- With Southern Region Headquarters colleagues, received a **Certificate of Appreciation** "for outstanding efforts in support of the National Weather Service Spaceflight Meteorology Group and NASA [Space Shuttle] Columbia accident investigation".



IN APPRECIATION

For outstanding efforts
in support of the
National Weather Service
SPACEFLIGHT METEOROLOGY GROUP
and NASA
Columbia Accident Investigation

NWS Southern Region Headquarters

Frank C. Brody
Frank C. Brody, Chief
Spaceflight Meteorology Group



Michael Magsig, Kenyon Hoggard, Xuning Tan (at WDTB)

- With NWS colleagues (Mike Foster, David Andra, Liz Quoetone, John Ferree), received the 2003 **U.S. Department of Commerce NWS Gold Medal** “for contributions to improved warning performance as a result of concept design and development of a warning event simulator”. The program citation reads as follows: “The Weather Event Simulator Concept and Development Team is recognized for its pioneering work leading to nationwide implementation of simulators that greatly improved the training of forecasters who are responsible for making critical severe weather warning decisions. Working independently the team conceived, designed and developed a successful prototype for what would become known as the Weather Event Simulator. The success and skillful persistence of the team members resulted in a fundamental change in how the National Weather Service would approach training for warning operations. The simulator has become a vital training tool.”

Jian Zhang, Wenwu Xia, Sharon, Qin, Carrie Langston (at NSSL)

- Received the 2002 U.S. Department of Transportation’s Federal Aviation Administration **Aviation Weather Research Program Excellence in Aviation Award** for their three-dimensional NEXRAD algorithm mosaic work. The Excellence in Aviation designation is a highly competitive, non-monetary award presented each year to individuals and/or institutions that show how their past research benefits the aviation community today. Through this award, the FAA formally recognizes significant accomplishments as a result of aviation-related research efforts. FAA-funded organizations provide applied research to solve critical operational aviation weather issues. Working as part of multi-discipline teams, the researchers’ efforts are enhanced through collaboration with industry, other national laboratories, government agencies, academia, and trade associations.

GENERAL DESCRIPTION OF CIMMS

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-supported scientists and students conduct research in mesoscale dynamics, radar research, development, and analysis, atmospheric electricity, severe storms, cloud microphysics, and boundary layer studies, with increasing emphasis in recent years on the climatic effects of/controls on mesoscale processes, the socioeconomic impact of such phenomena, and climate change monitoring and detection.

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

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

In addition to CIMMS, National Weather Center organizations include:

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

EMPLOYEE SUMMARY (for those having some component of NOAA funding)

Title	# of Employees	Terminal Degree		
		Bachelor	Masters	Doctorate
Research Associate	21	0	21	0
Research Scientist	18	0	0	18
Visiting Scientist	4	2	1	1
Post Docs	0	0	0	0
Information Technology Analyst II	8	2	5	0
Information Technology Analyst III	16	12	4	0
Information Technology Specialist	4	2	1	0
Graphic Designer	1	0	0	0
Administrator II	1	1	0	0
Managerial Associate	2	0	0	0
Financial Associate	1	0	1	0
Secretary	2	1	0	0
Associate Director	1	0	1	0
Total	79	20	34	19
		Student Level		
Graduate Research Assistant	7		5	2
Undergraduate	9			

In all, there are 144 employees of CIMMS; the balance receives funding from other sources.

PUBLICATION SUMMARY

	JI Lead Author			NOAA Lead Author			Other Lead Author		
	FY01	FY02	FY03	FY01	FY02	FY03	FY01	FY02	FY03
Peer Reviewed	31	26	24	3	7	12	21	18	19
Non-Peer Reviewed	54	37	52	12	7	17	7	11	21

FY03 Summary			
Author	Peer Reviewed	Non-Peer Reviewed	Total
CIMMS Lead Author	24	52	76
NOAA Lead Author	12	17	29
Other Lead Author	19	21	40
Total	55	90	145
Theses	5 (3 Ph.D., 2 M.S.)		