COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES
THE UNIVERSITY OF OKLAHOMA

Annual Report 2001: Fiscal Year 2001 Research Progress/Fiscal Year 2002 Research Plans

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I. INTRODUCTION

The University of Oklahoma (OU) and NOAA established the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) in 1978. Through mid-1995, CIMMS promoted cooperation and collaboration on problems of mutual interest among research scientists in the NOAA Environmental Research Laboratories (ERL) National Severe Storms Laboratory (NSSL), and faculty, postdoctoral scientists, and students in the School of Meteorology and other academic departments at OU.

The Memorandum of Agreement (MOA) between OU and NOAA that established CIMMS was updated in mid-1995 to also include the National Weather Service (NWS). This expanded the formal OU/NOAA collaboration to the Radar Operations Center (ROC) for the WSR-88D (NEXRAD) Program, the NCEP (National Centers for Environmental Prediction) Storm Prediction Center (SPC), and our local NWS Forecast Office, all located on the OU campus in Norman, Oklahoma.

Management of the NSSL came under the auspices of the NOAA Office of Atmospheric Research (OAR) in 1999. The Norman NOAA groups at that time became known as the NOAA Weather Partners.

In the new five-year cooperative agreement that recently took effect on July 1, 2001, NOAA/NESDIS, and specifically its National Climatic Data Center, became a formal CIMMS partner to work on problems of climate change monitoring and detection, which is a new sixth CIMMS research theme. In addition, the NWS Southern Region Headquarters (SRH) and the NWS Warning Decision Training Branch (WDTB) became CIMMS partners on July 1, 2001 to work on problems of mutual interest related primarily to forecast and warning improvements.

Through CIMMS, OU faculty and NOAA OAR/NWS/NESDIS scientists collaborate on research supported by NOAA programs and laboratories as well as other agencies such as the National Science Foundation (NSF), the U.S. Department of Energy (DOE), the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA).

The period of this report covers the transition between the five-year cooperative agreement between OU and NOAA for CIMMS funding that spanned July 1, 1996 through June 30, 2001 and the new cooperative agreement that spans the period July 1, 2001 through June 30, 2006. Under these agreements, CIMMS concentrates its efforts and resources on the following principal research themes, the sixth of which pertains to the new period: (1) basic convective and mesoscale research, (2) forecast improvements, (3) climate effects of/controls on mesoscale processes, (4) socioeconomic impacts of mesoscale weather systems and regional-scale climate variations, (5) Doppler weather radar research and development, and (6) climate change monitoring and detection.

This document describes the significant research progress made by CIMMS scientists at OU and detailed to our cooperative NOAA units during fiscal year 2001 (July 1, 2000 through June 30, 2001) and presents research plans for fiscal year 2002 (July 1, 2001 through June 30, 2002), and as such represents the fifth annual report of five written for the recently expired cooperative agreement. A final report for that entire five-year period will be produced on September 30, 2002. Also on that date, the first annual report for the new cooperative period will be published.

II. RESEARCH PROGRESS AND PLANS

1. Basic Convective and Mesoscale Research

Progress - FY01

Parameterization of Cloud Microphysics and Radiation (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

The work on an integral moment microphysics parameterization for stratiform clouds has continued. New formulations of drop activation, CCN regeneration, as well as coagulation processes, have been implemented into the CIMMS LES model. A series of experiments has been performed to evaluate the accuracy of each individual process formulation, including drop activation, regeneration and condensation/evaporation. Based on these experiments, the existing formulations were considerably refined and improved. The main focus now is on the testing of the coagulation formulation within the entire 3D LES dynamical framework. Once the development of the whole parameterization is complete, it will provide a new and powerful tool to formulate cloud physics processes in numerical forecast models. An especially valuable feature of the new parameterization is its use of directly observable variables such as radar reflectivity. These radar reflectivity values can be obtained from 24-hour routine millimeter cloud radar (MMCR) observations at the ARM Program Southern Great Plains (SGP) site.

The prediction of cloud microstructure in NWP models is of paramount importance to accurate weather and precipitation forecasts. We continued the analysis of the feedbacks between precipitation, boundary layer thermodynamical parameters and surface winds in defining the cloud microstructure. In a series of LES experiments it was found that surface winds affect the stratocumulus drop concentration in a complex way, involving many feedbacks between the intensity of boundary layer turbulence, drizzle, total concentration and shape of the background CCN sulfate spectra. Model simulations showed that the total background sulfate concentration does not uniquely define the effect of surface winds. An accurate formulation of this effect should account for the shape of the background sulfate spectrum; in particular, it is important to account for the number concentration of Aitken nuclei in the radius range from 0.04 μ to 0.1 μ. The latter are activated at supersaturation in the range 0 – 0.2%, which is the prevailing range of occurrence in stratocumulus-topped marine boundary layers characterized by moderate turbulence. The effect of surface winds on cloud microstructure was described in a M.Sc. thesis written by an OU graduate student. The major findings of the research were presented at the 13th International Conference on Clouds and Precipitation.

The Statistical Formulations of Cloud Parameters over the Southern Great Plains (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

Lack of data on cloud variability is the main reason why most current models consider clouds as plane-parallel, horizontally homogeneous combinations of cloudy and clear portions defined by cloud fraction. Unique information on cloud variability can be obtained using data from profiling observational instruments, in particular using cloud reflectivity data from the ARM Program MMCR. The cloud inhomogeneity may be described in terms of probability distribution functions (PDFs) and dominant scales of the wavenumber spectra, as well as employing scale invariance analysis. The latter has been widely used over the last few decades to study turbulent flows, including atmospheric turbulence.

We analyzed the usefulness of various statistical tools in describing cloud inhomogeneity. The PDFs provide the sub-grid information on cloud parameters and are an important part of cloud physics and radiative parameterizations in meso- and large-scale models. Spectral and scale invariance analyses are additional tools to characterize cloud internal structure. The spectral analysis locates the dominant wavenumbers, while the scale invariance analysis determines the upper and lower scales that bound scale-invariant regimes of the flow. By combining spectral and scale invariance analysis we can classify atmospheric datasets within the scale-invariant range scale as stationary or nonstationary. The stationarity is fundamental for obtaining meaningful spatial statistics. It indicates the minimal length and resolution of datasets that is needed to obtain reliable statistics. Many commonly used statistical procedures produce ambiguous or even meaningless results for nonstationary datasets.

We performed a preliminary statistical analysis of two cloud systems, representing a low and a mid-level stratocumulus cloud layer, observed over the ARM SGP site on 2 December 2000 and 16 May 2000, respectively. The low stratus layer was capped by a strong inversion at 1200–1300 m with a temperature jump of 7-13° C. The rather small values of radar reflectivity Z with maximum less than –10 dBZ within the layer indicate the absence of significant drizzle. Therefore, the variability of Z reflects most likely the variability of surface fluxes and inhomogeneity in convective organization, rather than drizzle patchiness. In this case, the PDFs are broader at cloud top and more uniform at cloud base.

The 16 May 2000 case represented a powerful alto-stratocumulus cloud system spanning in height from 5.5 to about 11 km. The system developed slightly ahead of a warm front and lasted for one and a half days, producing showers on the second day. The maximum radar reflectivities (about 10 dBZ) are near cloud base, indicating accumulation of drizzle, although the drizzle drops were not large enough to reach the ground. Plots of PDFs show broader distributions at cloud base compared to cloud top. The width of the distribution and its shape has important implications for determining cloud microphysical and radiative properties. For instance, a more homogeneous field of cloud reflectivity near cloud top (represented by a narrow PDF) will result in a more homogeneous cloud reflectance field.

In addition to the MMCR data, the one km resolution AVHRR satellite reflectance field for the low stratocumulus case observed on 2 December 2000 was analyzed to compare the dominant scales of variability for radar reflectivity and satellite reflectance fields. A preliminary Fourier analysis indicates that both fields have major common variability features, demonstrating congruence between surface and satellite observational analyses.

The Effects of Horizontal Radiative Transport on Cloud Thermodynamical Evolution (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

This project is a collaborative effort between CIMMS and scientists from Florida State University (Bob Ellingson), Los Alamos National Laboratory (Anthony Davis), and NASA (Bob Cahalan). CIMMS scientists funded by the ARM Program will link a 3D longwave radiative code developed at FSU with the CIMMS LES model. The objective of the study is to investigate the 3D radiation effects on cloud layer dynamics and boundary layer evolution and to evaluate the potential and limitations of the commonly used two-stream delta approximation for radiative transfer models. At present, we have performed a set of timing tests with the FSU 3D longwave radiative code using CIMMS workstations. The conclusion so far is that the computer time to run the 3D code is prohibitively large and makes the runs with the combined model impractical. In the coming months, we plan to have an Internet teleconference with all colleagues involved in the project and discuss other models available for solving the problem. It is hoped that the discussion will evaluate current, state of the science radiative tools that are practical to use to achieve the objective of the project.

Mesoscale Dynamics (Contributors: Xu et al.)

A spectral model was developed to study the stability and instability of baroclinically sheared flows in three-dimensional space in the presence of diffusivity. This model was used to search for unstable modes over wide ranges of wavelengths (from mesoscale to synoptic scale) and all possible orientations. It is found that in the presence of moderate diffusivity, the most unstable mode changes gradually from a nearly symmetric-type to nearly baroclinic-type as the basic state Richardson number increases (and thus the basic state became less unstable). This fills the gap between the two classic instabilities: the baroclinic instability and the symmetric instability, ranging from synoptic scale to the mesoscale.

Mesoscale Data Analysis and Data Assimilation (Contributors: Xu et al.)

<u>Doppler radar data assimilation</u> (in collaboration with scientists at NSSL, CAPS, Naval Research Lab – NRL – and Lockheed-Martin). Because the NEXRAD radar network provides only single-Doppler scanning over most areas in the U. S., research efforts have been undertaken to develop various methods for meteorological parameter retrievals from single-Doppler observations. These previous efforts, however, were focused mainly on retrievals with no

background information. To optimally use the background field provided by high-resolution model forecasts, basic research was conducted to examine (i) how the previous retrieval methods should be upgraded in consistency with the general formulation derived for the conditional maximum likelihood estimate based on theoretical considerations, and (ii) how the theoretical formulations should be simplified under certain assumptions to make the analyses and related computations feasible. Along with these studies, prototype 3.5dVAR and simple-adjoint 4dVAR (S4dVAR) packages were developed for Doppler radar data assimilation in combination with other observations. The packages were tested with NEXRAD and SPY1 radar data for several cases. The results were very encouraging and reported at AMS conferences.

Statistical analysis of innovation vectors (in collaboration with scientists at NSSL and NRL). The statistical technique of innovation (observation minus forecast) analysis was further improved and applied to both height and wind innovation data collected for each season from the Navy Operational Global Atmospheric Prediction System (NOGAPS). The major products of the analysis include (i) observation error variances and vertical correlations, (ii) forecast error variances and correlations in three-dimensional space and their spectra as functions of pressure levels and horizontal wavenumber, and (iii) forecast error geostrophy measured, at each pressure level and horizontal wavenumber, by the ratio between the geopotential-streamfunction cross-covariance spectrum and the streamfunction power spectrum.

Using GOES satellite data to improve cloud analysis and forecasts (in collaboration with scientists at NSSL and NRL). The 3D cloud analysis package was further developed to utilize both radar and GOES satellite observation with background fields generated by the Navy's Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS). The package was delivered to NRL Monterey and tested successfully for operational nowcast applications. The package was also used to initialize the COAMPS cloud and moisture fields for several squall line cases. The forecasts were verified against GOES images, NEXRAD radar images, and the products of the National Precipitation Analysis for squall line cases. The results showed positive impacts on short-term forecasts.

Further improving and testing COAMPS soil-vegetation physics using ARM data (in collaboration with scientists at NSSL and NRL). The soil-vegetation physics based on Noilhan was upgraded by introducing a skin layer. The upgraded physics was tested with ARM data for two (wet and dry) periods and showed improvements in soil water content and soil temperature predictions. The upgraded physics was also coded into the Navy's COAMPS and delivered to NRL Monterey for further tests under operational conditions.

Duct parameter data assimilation (in collaboration with scientists at NSSL, NRL and U.S. Navy). Low-altitude radar electromagnetic (EM) propagation can be strongly affected by the presence of surface-based and elevated ducts formed by capping inversions in the atmospheric boundary layer. In the presence of an inversion, the refractivity profile is often characterized as being tri-linear, and is determined by three key variables: the base height, the intensity, and the thickness of the inversion. To estimate these duct variables for inversion layers detected from radiosonde observations and/or model forecasts, a 2dVAR package was developed. The error statistics required by the 2dVAR were estimated from the innovations (observations minus forecasts) obtained from the Variability of Coastal Atmospheric Refractivity (VOCAR) field experiment.

This 2dVAR may open a new path for boundary layer data assimilation in which vertical phase errors can be corrected based on the analyzed inversion base height field.

Vertical Profiles of the Electric Field in Severe Storms During the Severe Thunderstorm Electrification and Precipitation Study (STEPS) and in Mesoscale Convective Systems (Contributors: Rust, MacGorman et al.)

Our goal in STEPS (conducted on the High Plains during May-July 2000) was to determine the electrical structure of the observed storms, and to improve understanding of electrification and of unusual lightning, such as cloud-to-ground flashes that lower positive charge to ground. We obtained soundings of one tornadic supercell storm, a non-tornadic strong supercell storm, a marginal supercell storm, a mesoscale convective system, and smaller, less severe storms on roughly ten days. A total of approximately 20 useful soundings were obtained. The analysis is still underway and we are now just beginning to get results. However, we (in collaboration with other STEPS PIs) have found two results in our preliminary analyses that will have a significant impact on our understanding of storm electrification:

Effect of mesocyclones on the storm's charge distribution. We obtained a few soundings in mesocyclones to supplement the one sounding we had obtained previously in 1998. In all cases in which the balloon was in strong updrafts in a mesocyclone, significant charge density was absent below a height of approximately 8 km mean sea level, though outside of the mesocyclone, charge was present at the lower altitudes where it is usually observed. Our initial hypothesis, needing verification by model studies and by additional data, is that the strong updraft shifts graupel formation to higher altitudes and the vorticity and strong updraft combine to interfere with re-circulation of graupel into the updraft. Together these two effects prevent charge from occurring at lower altitudes in mesocyclone updrafts.

Inverted-polarity storms. By 'inverted-polarity storms' we mean that the normal polarities of charge in two or more vertically separated regions of a storm are reversed. One previously suggested hypothesis as to why storms produce positive, instead of the usual negative, cloud-to-ground lightning is that the charge structure of the storm is inverted. Preliminary analyses both of our soundings and of the lightning mapping data suggest that this occurs in some storms. However, it does not appear to be true of all storms that produce many positive cloud-to-ground lightning flashes. Additional data analysis is needed to verify that the storms have inverted charge structure and to try to understand why.

STEPS Thunderstorm Electrification Modeling (Contributor: Mansell)

We recently submitted a revised manuscript describing the new lightning parameterization that simulates the three-dimensional branched structure of lightning channels. Model results indicate that positive cloud-to-ground (CG) lightning flashes can initiate only when a region of negative charge exists below the positive charge region tapped by the flash. This requirement is analogous to the necessity of a lower positive charge region to initiate negative CG lightning from the negative region above.

Charge conservation in the thunderstorm model has been dramatically improved, allowing us to investigate ties between cloud-to-ground lightning polarity with the overall thunderstorm charge polarity. We are also investigating correlations between lightning and thunderstorm quantities such as updraft mass flux and precipitation ice mass. The growth and decay of the graupel volume appears to correlate well with lightning activity, but this result needs to be tested for full life cycles of a wider variety of storm types.

Retrieval and Assimilation of Storm Characteristics from Both In-Cloud and Cloud-to-Ground Lightning Data to Improve Mesoscale Model Forecasts (Contributors: MacGorman, Ziegler, Beasley, Fiedler, Mansell, Showell, Nealson, van der Velde, Askelson)

During this past year, work focused on getting infrastructure in place for this project. A lightning-mapping array was ordered from New Mexico Institute of Mining and Technology, sites were found for the stations in the mapping system, and a powerful workstation was ordered for the modeling effort. Preparations were on track to complete installation of the lightning mapping system by the end of July 2001, but a fire in early July 2001 at NSSL destroyed all of the equipment for the stations, some of which had just been delivered. Intense work on lightning data assimilation into numerical forecast models was awaiting installation of the lightning mapping system, and this has been delayed by the fire that destroyed the mapping stations. However, the delay thus far has not been great, because data assimilation work was not scheduled to begin until April or May 2002. In May we began working on techniques for ingesting the lightning mapping data into the forecast model and made significant progress on this point. Furthermore, some work has been done on the element of the project that is to investigate relationships between lightning characteristics detected by mapping systems and storm characteristics that are potentially useful for data assimilation into models. An undergraduate senior from The Netherlands was supported to work on a research project in Oklahoma for his degree and he chose to investigate relationships between lightning data from a mapping array operated during the MEaPRS field project in 1998 and microphysical data inferred from a polarimetric radar. He found that trends in graupel mass and lightning rates were similar and that rising regions of lightning that appeared to be indicative of updrafts occurred before or at approximately the same time as tornadogenesis.

The Effects of Pyrgeometer Dome Heating on Calculated Longwave Radiation (Contributor: Richardson)

To obtain accurate measurements from the Eppley Precision Infrared Radiometer (PIR), it is necessary to account for a number of factors because the sensitivity of the PIR to thermal effects. Ideally, three different temperatures should be measured in the PIR system: the temperature of the top of the thermopile, and the temperatures of the PIR dome and case. The standard instrument does not measure the temperature of the thermopile but does measure the dome and case temperatures. The PIR instrument case has a large thermal mass, so the case temperature can be used as a surrogate for the thermopile temperature. However, the thermal conductivity of the glass dome is much lower, indicating that a single dome temperature measurement may not be sufficient.

This study was concerned with the effect of the dome temperature on the calculated longwave radiation. Typically, a single thermistor mounted on the inside edge of the glass dome is used to estimate the dome temperature. Delany and Semmer had three dome thermistors installed by the manufacturer to measure the dome temperature but used circuitry to average the three temperatures and did not have access to the individual temperature measurements. In this study, the manufacturer installed three thermistors on the base of the PIR dome and wired them so that each dome temperature could be measured separately. The three dome thermistors were mounted at 120° increments around the base of the dome.

This sensor was deployed in the field and data from 1 January to 31 December 2000 were analyzed. Each day was subjectively categorized as cloudy or clear; for the year there was 66 clear and 66 cloudy days. Results from the cloudy days should resemble the effects of dome heating when the sensor is shaded, as is done in the ARM Program. Therefore, this work suggests that in the ARM Program, the effects of dome temperature inhomogeneities on calculated long wave radiation should be less than about 2 Wm^{-2}. If the PIR sensor is not shaded (e.g., results from the clear days) but is ventilated, the effects of dome temperature inhomogeneities could be as large as 8 Wm^{-2}. When the PIR sensor is not shaded or ventilated, the effects of dome temperature inhomogeneities could exceed 11 Wm^{-2}.

Radiosonde Intercomparison During the Fall 2000 Water Vapor IOP (Contributor: Richardson)

One hundred sixty dual-radiosonde soundings (i.e., two sonde packages attached to the same balloon) were conducted during the fall 2000 ARM Program Water Vapor Intensive Operations Period (WVIOP). The soundings were made every three hours at the SGP central facility from 1430 on 18 September 2000 through 1130 on 8 October 2000. The dual soundings included Vaisala RH-80H radiosondes from four different calibration lots as well as Vaisala RS-90 radiosondes, the newest sondes produced by Vaisala. The radiosondes were distributed during the experiment so as to conduct pair-wise comparisons between RS-80s, RS-90s, and RS-80s/RS-90s. Prior to the WVIOP we tested the calibration of these radiosondes in the ARM humidity chamber. Some of the radiosondes that were chamber-tested were later flown in dual-soundings made during July 2000. The results of these intercomparisons will be used to evaluate both the proposed RS-80H dry-bias correction algorithm and the advantages of the RS-90 radiosonde humidity sensor.

The Formation and Climatological Distribution of Tornadoes within Quasi-Linear Convective Systems (Contributor: Trapp)

Research during the fiscal year focused on the formation and implications of low-level, meso-gamma scale vortices within quasi-linear convective systems (QLCSs) like squall lines and bow echoes. Such QLCS vortices, also referred to as mesovortices, are observed frequently, at times in association with tornadoes. Idealized experiments with a numerical cloud model show that low-level mesovortices develop in simulated QLCSs only when the environmental vertical wind shear is within a relatively narrow range of values and when the Coriolis forcing is nonzero. As illustrated by a QLCS simulated in an environment of moderate vertical wind shear (20 ms^{-1} over a 2.5-km depth), mesovortexgenesis is initiated at low levels by the upward tilting, in downdrafts, of horizontal baroclinic vorticity. Such relative vertical vorticity is vertically stretched, as is also planetary vorticity. In fact, in terms of circulation tendency, the time-integrated contribution to positive circulation by the flux of planetary vorticity is, over a period of less than an hour, comparable to or larger than that due to fluxes of horizontal and/or vertical vorticity.

In moderate-to-strong environmental shear, the simulated QLCS evolves into a bow echo whose strongest low-level winds surprisingly are found about 20 km to the northwest of the bow-echo apex rather than just behind the apex, as is typically conceptualized. In other words, what are regarded as the most damaging 'straight-line' winds are induced by the low-level mesovortices. The swath of these winds expands with time, owing apparently to a mesovortex amalgamation, or 'upscale' vortex growth. As with the mesovortex formation, the system-relative location of the damaging winds is dependent on the system-scale dynamics, which in turn is dependent on characteristics of the larger-scale environment.

Concentrating Vorticity Near the Ground: An Investigation of the Interaction of Precipitation Processes and Flow Dynamics in Supercells and Other Severe Thunderstorms (Contributors: Gilmore, Rasmussen, Askelson)

A significant observational study was completed on the low-level thermodynamic state of tornado cyclones. These are vortices of 1-3 km scale that are present at the ground in most of the supercells that we have observed with mobile mesonet equipment. In a sample of about 30 tornado cyclones, it was found that tornado formation was more likely and tornado longevity greater if the near-ground air in the tornado cyclone is buoyant and potentially buoyant with respect to the storm inflow. The near-ground air within the tornado cyclone is hypothesized to originate in the rear-flank downdraft (RFD). These results and hypotheses were further explored using idealized axisymmetric numerical simulations of tornado cyclones containing peripheral downdrafts. The simulations demonstrated that angular momentum-rich downdraft air penetrated closer to the axis of the vortex, leading to larger tangential velocities, when the downdraft arrived at the ground with buoyancy relative to the inflow base state.

Based on these findings, we have developed deployment strategies for obtaining a new generation of near- and in situ tornado observations. These included design of an all-weather UAV in collaboration with the Aerospace Engineering department at the University of Colorado. This remotely controlled, instrumented aircraft should be capable of making state measurements within tornado cyclones and weak tornadoes. In collaboration with the National Geographic Society, we also evaluated strategies for deployment of in-situ optical and state sensors in tornadoes, including a next-generation 'turtle' and a multi-camera digital imaging system. These preliminary investigations are being conducted in preparation for the next VORTEX (Verification of the Origins of Rotation in Tornadoes EXperiment) that may be held in the 2005-2008 timeframe.

We continued to refine and enhance our observational analysis tool set. Roughly 90% of our analysis, visualization, and Doppler processing software were ported to Interactive Data Language (IDL) for greater compatibility across our research group and with other groups. Enhancements included the addition of a high-resolution terrain data set for the entire central

U.S., allowing us to perform pressure reduction of mobile mesonet data for any experiment we have participated in.

Formation Flying of Rapidly Deployable Remotely Piloted Vehicles for Mesoscale Meteorological Observations (Contributor: Rasmussen)

The primary purpose of this project is to develop the capability to fly Unmanned Aerospace Vehicles (UAVs) in formation to gather mesoscale meteorological observations. Working with Wyndemere, Inc. we established the goal of producing a small UAV (~1.5 m wingspan, < 15 lb weight) that is capable of autonomous flight. This requires a state engine that can determine the attitude of the aircraft, as well as a flight computer that can direct the aircraft control surfaces based on the combination of attitude information and requested flight path. We established the goal of producing an aircraft that would cost less than $5,000 in materials so that we could easily replace lost or damaged aircraft. Hence, we have utilized concepts such as a GPS-only state engine that does not require accelerometers, magnetometers, or other expensive equipment. During the reporting year, several off-the-shelf 'almost ready to fly' (ARTF) aircraft were built, and the rudimentary state engine and flight computer were tested.

The Intermountain Precipitation Experiment (Contributor: Schultz)

The Intermountain Precipitation Experiment (IPEX) is a research program designed to improve the understanding, analysis, and prediction of precipitation over the complex orography of the Intermountain West of the United States. The goals of IPEX are to advance knowledge of the structure and dynamics of Great Salt Lake effect and orographic precipitation, especially in and adjacent to the Wasatch Mountains of northern Utah; to better understand the relationships between orographic circulations and cloud microphysics; to verify and improve data assimilation, numerical weather prediction, and radar-derived quantitative precipitation estimates over the Intermountain West; to explore the electrical structure of continental winter storms; and to raise awareness of mountain meteorology and the associated scientific and forecasting challenges at the public, K-12, undergraduate, and graduate levels.

The field phase of this research program was carried out in northern Utah in February 2000, employing, among other instrumentation, a heavily instrumented P-3 research aircraft, two Doppler on Wheels mobile radars, two mobile research laboratories with sounding capabilities (one equipped with electric-field meters), a vertically pointing Doppler radar, the MesoWest cooperative networks, and special radiosonde releases from the National Weather Service. In a first review paper, the weather of the Intermountain West is summarized and preliminary results from the field phase are presented. Lessons learned in the planning and execution of this field program are also discussed.

Objective Analysis Studies (Contributor: Spencer)

Previous research has shown that line integral (triangle) techniques are superior to traditional methods for creating gridded estimates of kinematic quantities such as divergence and vorticity. Line integral techniques involve calculating kinematic quantities directly from the observations and then mapping those estimates onto a uniform grid, whereas traditional techniques involve applying a finite difference scheme to the analyzed horizontal wind components. This same philosophy of calculating derivatives directly from the observations has been applied to scalar variables, as well, producing gridded derivative fields that are superior to those that are generated by traditional analysis/differencing techniques. The comparisons were made using an analytic input field such that the true solution is known at all points in the domain.

Although the scalar derivative information derived via the triangle technique is superior to that derived by traditional methods, the scalar amplitude of the analysis typically is damped somewhat. This deficiency has been overcome by applying a variational technique whereby differences between the analysis and the traditional analysis are minimized under the constraint that the horizontal derivatives of the analysis obtained by finite differencing are equal to those obtained directly from the observations. This results in an analysis that has a very accurate amplitude as well as excellent gradient information.

Plans - FY02

Parameterization of Cloud Microphysics and Radiation (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

The work on an integral moment microphysics parameterization for stratiform clouds will continue. It is planned that the new parameterization will be part of a M.Sc. thesis.

We will continue the analysis of the feedbacks between drizzle, boundary layer thermodynamical parameters and surface winds in defining the cloud microstructure with the aim of identifying the parameter set that determines the cloud drop concentration. Another part of this research will be directed at finding the factors that control cloud base height and visibility in the marine boundary layer.

The Statistical Formulations of Cloud Parameters over the Southern Great Plains (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

This project will be the major thrust of our ARM Program research. The goal of the project is to determine the statistical descriptions of stratiform cloud parameters using ARM observational platforms, including the MMCR. We will analyze multiyear MMCR observations to determine statistics of cloud inhomogeneity over the ARM SGP site during various seasons and for various cloud types (low clouds vs. midlevel clouds) and environmental conditions (e.g., precipitating vs. non-precipitating clouds). The LES simulations will also be started based on ARM IOP data to relate PDFs obtained from the two-dimensional (time-height) MMCR data to the ones obtained from the fully 3D spatial cloud data.

The Effects of Horizontal Radiative Transport on Cloud Thermodynamical Evolution (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

We plan to organize a teleconference between our collaborators from FSU, LANL, and NASA. As a result of the ensuing discussion we will reach a conclusion about the practicality of currently available 3D radiative tools that are appropriate to address the problem of evaluating the role of horizontal radiative transport in dynamical evolution of the cloud.

Mesoscale Dynamics (Contributors: Xu et al.)

We will continue the current theoretical study on synoptic-mesoscale instabilities and examine the non-modal growths of perturbations in terms of singular vectors.

Mesoscale Data Analysis and Data Assimilation (Contributors: Xu et al.)

We will continue the current studies on mesoscale data assimilation in the areas of Doppler radar data assimilation; error covariance estimation using innovation techniques; GOES satellite cloud data analysis and data assimilation; soil-vegetation data analyses and assimilation; and duct parameter data assimilation.

Vertical Profiles of the Electric Field in Severe Storms During the Severe Thunderstorm Electrification and Precipitation Study - STEPS (Contributors: Rust, MacGorman et al.)

Plans call for extensive analyses of STEPS data. Of particular focus will be the interrelationships among the three-dimensional lightning mapping, the dual-polarization radar observations, and the balloon profiles of electric field structure. These analyses will address objectives listed previously. Papers that are currently in preparation deal with specific subsets of the broader goals that will be completed. They address inverted-polarity electrical structures and charge location in updraft and non-updraft regions of the storm.

Retrieval and Assimilation of Storm Characteristics from Both In-Cloud and Cloud-to-Ground Lightning Data to Improve Mesoscale Model Forecasts (Contributors: MacGorman, Ziegler, Beasley, Fiedler, Mansell, Showell, Nealson, van der Velde, Askelson)

A major effort planned for this year is to try to recover from the fire that destroyed the lightning mapping system. We are optimistic that sufficient funds will be found and the New Mexico Institute of Mining and Technology will be able to deliver a replacement system in spring 2002 so that this aspect of the research can begin. Work on lightning data assimilation is continuing. We are planning to start working on this by using lightning mapping data from the STEPS field project. During the year, we expect to examine at least one case and to examine the effect of lightning data assimilation on the forecasted outcome. By the end of the following year, we expect to complete the proposed research.

Numerical Modeling Study of the Time-Dependent Behavior of Convection (Contributor: Doswell and Weber)

This work involves the use of a 3-d cloud model based on the ARPS model, developed by Dr. Daniel Weber. The goal is 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. Of particular interest are the factors that determine the frequency of "bubbles" within such storms. Preliminary simulations showing the capability of a simplified cloud model to reproduce this behavior have been completed. Support is being sought for a comprehensive parameter study using the model.

Theoretical Study of Thermal Buoyancy (Contributor: Doswell)

Pure parcel theory, as developed in textbooks, treats the pressure perturbation in a conceptual way that can be misleading. Moreover, the diagnosis of "buoyancy" in either operations or in numerical simulations ignores the important role that buoyancy has on perturbation pressure, even in the absence of finite airflow. A theory has been developed that shows more clearly than the traditional textbook explanations what role the pressure field has on buoyancy. This work is being done in collaboration with Prof. Paul Markowski (Pennsylvania State University). Work is underway on a publication that will present this theoretical development.

Evaluation of Synoptic-Scale Controls on Tornado Outbreaks (Contributor: Doswell, Thompson, Edwards, Leslie)

A classic 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 and Mr. Roger Edwards of the Storm Prediction Center, an effort to clarify this with a large number of case studies, including ‘null’ cases where a significant tornado outbreak did not occur, we hope to determine whether or not there is a clear signal at synoptic scales that would permit an improvement in forecasting significant tornado outbreaks. We are exploring the possibility that a parallel modeling study of this problem, in collaboration with Prof. Lance Leslie (incoming Lowry Chair at the OU School of Meteorology) will begin with his arrival.

Automated Tornado Video Photogrammetry (Contributors: Doswell and Rasmussen)

Even with pairs of mobile Doppler radars, tornadic wind fields near the surface are not readily observed. Therefore, many details of the time- and space-dependent wind field in tornadoes have remained unknown near the surface, where structures exist. The proliferation of inexpensive video cameras means that many tornadoes are captured on video during their interaction with human structures. The data that can be derived from photogrammetric analysis of these videos could be revolutionary in adding to our understanding of tornadic airflow, but there remains a need for a system that would provide rapid photogrammetric analysis of such videos. Given the rapid progress in automated image analysis, it should be possible to use these videos to provide tangential wind speed estimates at hundreds of points in space at high temporal frequency. In collaboration with Dr. Erik Rasmussen (CIMMS), funding will be sought to develop such an analysis system.

A Radiosonde Correction Using Prelaunch Sonde Data (Contributor: Richardson)

The ARM Program uses Vaisala radiosondes to measure the vertical profile of wind, pressure, temperature, and relative humidity. The surface point (i.e., first point in the sonde data files) is taken as an instantaneous reading from the sonde ground station and manually entered by the sonde operator. This research seeks to develop an alternate method for obtaining the surface point observation, which involves averaging data from the radiosonde prior to sonde launch while it is in an aspirated shelter. This method eliminates human errors (e.g., transposing digits) and improves the resolution of the surface humidity reading (the sondes output relative humidity in one percent increments).

In addition, corrections to the radiosonde dry bias and batch-to-batch variability have been examined using SGP central facility dual sonde launches from the third Water Vapor IOP. Past attempts have been made to correct sondes by scaling them using a single reference point (in time) observation. These single point adjustments have not successfully brought agreement between microwave radiometer and sonde precipitable water vapor estimates. In this study, radiosonde prelaunch data, i.e., data collected prior to sonde launch, is used to scale the sondes instead of the instantaneous launch value. It appears possible to account for batch-to-batch variability using several minutes of prelaunch sonde data whereas the single point observation contains too much variability.

Formation of Vertical Vortices in Large Eddy Simulations of the Convective Boundary Layer (Contributors: Kanak, Lilly, Snow, Fiedler)

We are currently working on the development of a vertical vortex algorithm (after McWilliams) to identify and quantify the formation of vertical vortices in large eddy simulations of the convective boundary layer. Earlier results were published in 2000.

New work will include higher resolution simulations and application of the algorithm to assess the effects of various parameters such as wind shear on the existence of vertical vortices and the properties associated with them, such as vertical heat and momentum fluxes. The results of this work may contribute to the improvement of boundary layer parameterizations in larger scale numerical models and promote understanding of the role of vertical vortices (visible as dust devils and non-visible in the absence of tracers) in convective boundary layer processes. A proposal to NSF to support this research is currently in review. Another related paper, with B. Fiedler, is in review at *Atmospheric Science Letters*.

Vertical Vortex Formation in Ellipsoidal Thermal Bubbles (Contributors: Kanak, Shapiro)

We are continuing to conduct an analytical and numerical study of vertical vortex formation in isolated elliptical thermal bubbles. A paper submitted to *J. Atmos. Sci*. is currently in review and we have received approval from NSF to write a proposal to extend these results to higher resolution and to incorporate mean winds.

Thunderstorm Cirrus Outflow Dynamics and Mammatus Formation (Contributors: Kanak, Straka, Lilly)

An effort is beginning to study thunderstorm cirrus outflow dynamics and mammatus formations.

Martian Dust Devils (Contributors: Kanak, Edgett, Cantor)

An effort is also just beginning to study Martian dust devils.

The Formation and Climatological Distribution of Tornadoes within Quasi-Linear Convective Systems (Contributor: Trapp)

Efforts during the new fiscal year will be concentrated on the climatological component of this project. Specifically, we plan to classify all tornadoes reported in the contiguous U.S. in 1999 by their respective parent storm type of 'cell', 'QLCS', or 'other'. This analysis will complement a similar classification for tornadoes reported in 1998, and when complete, will allow us to compute the geographical, seasonal, and temporal distributions of the sampled tornadoes, as a function of parent storm. Additionally, we will stratify the QLCS tornadoes according to, for example, damage-based intensity (Fujita-scale), estimated duration, number of fatalities, and dollar amount of property damage. Statistical tests will be applied to these and other results to determine their robustness.

To help characterize the larger-scale environment that supports the formation of QLCS tornadoes, composite thermodynamic and wind profiles will be constructed using data from radiosonde observations taken in proximity to a sub sample of tornadic QLCSs in our dataset. For comparative purposes, we will gather data and perform a similar analysis for an equivalent number of non-tornadic QLCSs. An OU graduate student will be responsible for this task. Another task to be initiated is the computation of radar-based attributes of the tornadic and non-tornadic QLCSs in our dataset. Relevant WSR-88D Level II data will be processed and analyzed, using the suite of automated algorithms developed at NSSL. Algorithmic output showing, for example, the size distribution of the parent vortices of QLCS tornadoes will help characterize tornadic QLCSs, and also point to any unique radar signatures that may have nowcasting utility.

Concentrating Vorticity Near the Ground: An Investigation of the Interaction of Precipitation Processes and Flow Dynamics in Supercells and Other Severe Thunderstorms (Contributors: Gilmore, Rasmussen)

We will continue case study analysis of numerous tornadic and non-tornadic supercells observed during VORTEX. An angular momentum budget analysis will be utilized with a thermodynamic analysis of each case to infer the relative importance of angular momentum versus buoyancy in tornado formation and longevity. Also, we will continue our work testing deployment strategies for obtaining new generation measurements in tornado cyclones and tornadoes. In particular, the all-weather UAV will be tested in the coming year in preparation for the next VORTEX experiment. Analysis of these datasets will be performed with our suite of observational analysis tools. These tools will be completely ported to IDL this year.

We will also continue our numerical simulation work by studying the sensitivity to supercell morphology and evolution from variations in the hail size spectra using traditional three-ice-category Lin-Farley-Orville (LFO) microphysics. Specific sensitivities of interest include quantitative precipitation (hail and rain reaching ground), baroclinic production of vorticity at low-levels, and timing/intensity of mesocyclogenesis. Understanding the sensitivity to variations in the three-category schemes will be helpful in understanding and will help motivate the use of more advanced (many-category) ice microphysics schemes developed by OU School of Meteorology professor Jerry Straka.

Formation Flying of Rapidly Deployable Remotely Piloted Vehicles for Mesoscale Meteorological Observations (Contributor: Rasmussen)

The following development milestones have been established. We expect autonomous straight-and-level flight commanded by the flight computer onboard the aircraft to be obtained by 1 August 2001. Autonomous flight following ground-commanded patterns will be demonstrated by 1 September 2001. The flight of two aircraft in formation will be demonstrated by 15 September 2001. Prior to the May 2002 International H_2O Project (IHOP) experiment, if the foregoing efforts are successful, we will produce a total of six UAVs to be utilized for observations of fronts, boundaries, and the atmospheric boundary layer during IHOP.

The Intermountain Precipitation Experiment - IPEX (Contributor: Schultz)

Preliminary research by NSSL/CIMMS scientists involves examining the organization of precipitation in IPEX IOPs 4 and 5. Dave Rust, Jeff Trapp, and collaborators are examining the electrification of clouds during IOPs 5 and 6, making this the first observations of electrified winter storms over the continental United States. A severe-weather climatology of Idaho is also being performed, in collaboration with Jon Racy of the Storm Prediction Center.

Objective Analysis Studies (Contributor: Spencer)

The utility of the improved objective analysis scheme involving the variational technique described earlier will be tested within a numerical modeling framework. Traditional methods for objective analysis currently in place for the MM5 modeling system will be replaced by the improved analysis technique to assess potential forecast improvements, especially regarding precipitation forecasts.

2. Forecast Improvements

Progress - FY01

Implementation of CIMMS Stratiform Cloud Parameterization into a NWP Regional Model (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

The U.S. Navy COAMPS, run with the CIMMS bulk drizzle scheme, has been shown to be able to produce the breakup of marine stratocumulus for short timescales at a horizontal grid spacing of 2 km. The presence of drizzle accelerates the breakup compared to that seen when stratocumulus clouds are advected over water with progressively warmer sea surface temperatures. Cloud breakup is manifested as a transition from unbroken stratocumulus to a broken, boundary layer cumulus regime. Modifications to the model's turbulence parameterization produce a more physically plausible boundary layer structure that results in a more realistic treatment of the cumulus regime, specifically more reasonable values of liquid water path, surface drizzle rate, cloud base height, and convective element intensity. COAMPS shows a sensitivity to the depletion of CCN by the drizzle processes, though the lack of an in-situ boundary layer CCN source is somewhat offset by entrainment of CCN as the boundary layer grows with time. Patches of moistened and cooled surface air arising from evaporating drizzle produce a complex structure in the surface flux fields, though COAMPS appears to exhibit only a weak sensitivity to these transient features. Results have been convincing enough that much of the CIMMS drizzle parameterization has been included as part of an effort by the Naval Research Laboratory to systematically improve the treatment of microphysical processes in COAMPS. This work should ultimately lead to improved short-term forecasts (3-24 hours) of marine boundary layer cloud behavior.

A simple treatment of sub-grid variability for the autoconversion process has been derived and implemented into COAMPS. The autoconversion inside a grid is obtained by integrating the process rate over the probability distribution function (PDF) of the cloud variables, and is equivalent to spatial integration of local process rates inside the grid. Sub-grid PDFs are unknown and are represented by gamma distributions. The distribution means are taken to be the grid point values, and the shape parameters are constrained by PDFs of broken and solid stratocumulus cloud fields taken from the CIMMS LES. On the 2 km mesh, including information about sub-grid variability results in increased autoconversion rates that lead to enhanced drizzle production and a reduction in liquid water path. The enhanced breakup is particularly obvious in values of cloud fraction, 0.93 for the control run and 0.78 for the sub-grid PDF treatment. Stronger drizzle ultimately leads to a more robust convective mode that acts in the model as a positive feedback on cloud breakup, with increased subsidence outside the resolved convective elements resulting in increased dissipation of the stratocumulus deck. This demonstration study shows that accounting for sub-grid heterogeneity can ultimately have a significant impact on the mesoscale characteristics of a stratocumulus cloud system.

The Advanced Weather Prediction Prototype – AWPP (Contributors: Droegemeier et al.)

The AWPP project has four distinct but related components: 1) expansion of the Project CRAFT testbed; 2) further development of the OK-FIRST decision support system for public safety officials; 3) development of radar and related moisture data assimilation strategies for the Weather Research and Forecast (WRF) Model; and 4) development of convective parameterization techniques and forecast verification strategies for storm- and mesoscale models.

<u>Component 1</u>: Results from Project CRAFT are described in the section "Doppler Weather Radar Research and Development".

<u>Component 2</u>: During the past 3-4 years, with support from a U.S. Department of Commerce TIAAP grant, the Oklahoma Climatological Survey (OCS) developed and operationally fielded its OK-FIRST decision support system for emergency managers and other public safety officials. The original version of OK-FIRST was based upon NIDS data and thus was limited to the products provided therein. The Level II data provided by the CRAFT network afforded an opportunity for the OCS to explore a broader and arguably more effective utilization of radar information for OK-FIRST. OCS completed Version 8.0 of the WxScope Plugin software,

which allows for the incorporation of multiple data file formats for the integration of multiple radars, as well as multiple meteorological data formats. This feature results in the capability to integrate surface data (such as NWS ASOS) with the radar data into a single interactive display. OCS also completed a radar-training workshop for 18 additional emergency managers who tested the WxScope v8.0 software.

Component 3: The OU Center for Analysis and Prediction of Storms (CAPS) is one of four core institutions, along with NCEP, NCAR, and the NOAA/FSL, involved in developing the NOAA/NCEP next generation forecast system known as WRF (Weather Research and Forecast). This system, designed as a dual research and operational model with emphasis on grid resolutions of 1-10 km, is expected to become operational around 2004 and also is anticipated eventually to replace the RUC and Eta models. The primary role of CAPS in the WRF effort is to develop techniques for the assimilation of radar data; particularly those based upon 3D and 4D variational approaches. CAPS has fine-tuned and refined its phase-correction data assimilation schemes, and two manuscripts were submitted for publication. NIDS0-based forecast experiments of the April 2000 Fort-Worth tornadic storms continued, with emphasis given to the initialization of microphysical and thermodynamic variables as well as reductions in model spin up. The results obtained thus far are rather spectacular, and initial retrieval experiments using simulated data in the 3DVAR system also are encouraging. Efforts are now underway to generalize the Doppler radar data-oriented 3DVAR system and to conduct comparisons against non-variational techniques.

Component 4: The first portion of this component of the AWPP was aimed at developing more appropriate verification strategies and methods for meso- and finer- scale NWP models. The second part focused on improving convective parameterizations for operational forecast models utilizing the new verification tools and other diagnostic techniques to guide the development of improved formulations. CIMMS/NSSL continued to execute semi-operational, experimental runs of the Eta model in parallel with operational runs at EMC. The experimental version of the Eta utilized the Kain-Fritsch parameterized convection and 4th order horizontal diffusion (compared to BMJ convection and 2nd order diffusion in operational configuration), and was run four times per day. These four numerical predictions were comprised of two runs using a 00Z initialization time and two runs at 12Z. For each initialization time, the model was first run over a limited domain with 22 km grid spacing, and then it was run over a larger domain with 32 km grid spacing. Output from all of these runs was made available to the general public via anonymous ftp, supplied to the Storm Prediction Center for viewing on their workstations, and selected fields are posted on the web. Using output from these runs, CIMMS/NSSL developed verification techniques designed to measure the value gained by using higher resolution in the Eta model. CIMMS/NSSL continued to investigate and diagnose the role played by parameterized convection in the Eta model. In collaboration with SPC forecasters and research scientists, parameterized convective effects were examined and compared in the operational Eta and RUC models, as well as in our experimental version of the Eta model, during a six-week intensive study period last April and May. This study concentrated on model forecasts of grid-point soundings, convective initiation and convective evolution. The results of this study are being used to guide current efforts to improve methods for parameterizing convection in operational forecast models.

Quantitative Precipitation Estimation Using Multiple Sensors - QPE SUMS (Contributors: Gourley, Maddox, Arthur, Zhang)

The QPE SUMS precipitation algorithm is now running operationally in four NWS offices as well as the Salt River Project in Phoenix, Arizona. Several improvements have been made to the QPE SUMS rainfall algorithm. The algorithm is now capable of ingesting real-time sounding data, surface observations, and rain gauge data. These additional data sources have been integrated in the rainfall estimation scheme. Secondly, a verification package has been added to the algorithm suite. This package posts statistical comparisons between QPE SUMS gridded rainfall fields and co-located gauges on the Internet daily.

Supercell Identification Algorithm (Contributor: Lynn)

An algorithm to identify supercells based on the base radar reflectivity data and the outputs of Severe Storms Analysis Program (SSAP) and the Bounded Weak Echo Region (BWER) detection algorithm was developed. This algorithm combines the outputs of several algorithms to classify the radar echo as being a supercell thunderstorm.

Storm Cell Identification Through K-Means Clustering of Base Radar Data (Contributor: Lakshmanan)

We have designed an algorithm to segment radar data to identify storms cells. The segmentation uses a novel hierarchical K-Means clustering algorithm developed at CIMMS to segment images. The algorithm was implemented and runs in real-time on the WDSS-II testbed at NSSL.

Three-dimensional Multiple Radar Reflectivity Mosaic (Contributors: Zhang, Gourley)

Major improvements have been made to the 3D multiple radar reflectivity mosaic scheme. A gap-filling scheme was developed for removing ring-shaped discontinuities on horizontal cross sections of the interpolated reflectivity fields. The discontinuities are due to the large elevation gaps in WSR-88D data samplings. The mosaic algorithm has been optimized and computational efficiency is greatly increased. The optimizations are realized through 1) using lookup tables for the polar-to-Cartesian and Cartesian-to-polar coordinates transformation; and 2) better handling of large 3D data arrays. A data compression scheme is developed for the mosaic products. The compression procedure saved the disk storage resources and speeded up archive processes significantly. The mosaic algorithm has been documented in detail using a well-organized format. The documentation includes functional descriptions, variable tables, pseudo code and computational formulas. Extensive in-code documentation has also been added to the mosaic programs to improve readability of the code. These documentation efforts can help users to better understand the algorithm logic, and they can serve as useful references for further development/improvement.

Warning Decision Making Analysis (Contributors: Magsig, Wood, Yu, Hoggard, Tan)

Warning decision-making analysis continues to be an area of active collaborative research between CIMMS and the Warning Decision Training Branch (WDTB). CIMMS staff have been heavily involved in WDTB workshops on analysis of warning decision-making. 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 between the research and operational sectors as well as to test new experimental techniques for issuing and verifying warnings.

Warning-Related Forecast Improvements (Contributors: Magsig, Wood, Yu, Hoggard, Tan)

The warning decision making process is multi-faceted, often being improved directly by unique observing systems, analysis tools, data analysis techniques, human factors, or improvements in forecast verification. Progress has been made in warning-related forecast improvements with the application of unique radar and satellite sensors and new data analysis techniques. The Terminal Doppler Weather Radar (TDWR) and OU's Doppler On Wheels (DOW) are two radar sensors that have been used to illustrate the sampling limitations of the operational WSR-88D radar and the potential improvement in warning decision making using these new tools and knowledge gained from analysis of their data. The TDWR data from Salt Lake City, UT were incorporated into an online module which featured how TDWR data could have significantly improved the detection and warning of the 11 August 1999 F-2 tornado that struck downtown Salt Lake City. The DOW data for the 3 May 1999 Oklahoma City area tornado were used to illustrate operational radar sampling limitations of tornadoes and the implications for warning decision making. In the 3 May radar analysis, a new technique was developed to infer significant tornado damage using debris signatures in the reflectivity fields. High-resolution satellite data was another unique sensor source used in an analysis of the 3 May tornado outbreak to develop a new technique for detecting tornado tracks remotely that can improve the verification of tornado forecasts. Other warning-related forecast improvements include evaluating satellite-based lightning data during the 3 May tornado outbreak, evaluating how to best use new warning decision analysis tools such as the System for Convection Analysis and Nowcasting (SCAN) and the Flash Flood Monitoring and Prediction System (FFMP), developing a Java-based technique for visualizing boundary relative flow, and developing techniques to ensemble precipitation forecasts.

Warning Simulation (Contributors: Magsig, Wood, Yu, Hoggard, Tan)

Time is a critical factor in issuing warnings. To effectively research the warning process on many events requires the ability to adequately reproduce as many of the components of the warning decision making process as possible. To this end, CIMMS scientists collaborated with the National Weather Service to develop a research tool called the Warning Event Simulator on a Linux platform to simulate warning events. The simulator has allowed study on the warning decision making process for many recent significant severe weather events across the country, including Birmingham, AL; Columbia, MO; Salt Lake City, UT; Granite Falls, MN; Des Moines, IA; Broome County, NY; and Lancaster County PA. In addition to its use as a research tool, the Warning Event Simulator can be used as an effective training tool for CIMMS scientists and National Weather Service forecasters.

National Basin Delineation (Contributors: Cox, Arthur, Kuhnert, Slayter)

NSSL has partnered with the USGS Earth Resources Observation Systems (EROS) Data Center (EDC) to delineate flash flood basins for the conterminous U.S. These basins are a necessary component of the Flash Flood Monitoring and Prediction (FFMP) Program to be included in AWIPS Build 5.1.2. The FFMP will include functionality similar to the Areal Mean Basin Estimated Rainfall (AMBER) Program for assisting forecasters in flash flood warning decisions. The FFMP will calculate average rainfall rates and accumulations from radar precipitation estimates for every flash flood basin within a radar coverage area.

The basin delineation is being performed using the ArcView and ARC/INFO Geographic Information Systems (GIS), and is based on digital elevation data from the National Elevation Dataset (NED). Produced at the EDC, the NED is a seamless mosaic of the highest resolution, best-quality elevation data for the U.S. To date, approximately 95% of the basin delineation has been completed, and the remaining task of assembling the FFMP basin and stream data sets for each radar coverage area is underway.

Evaluation of the Areal Mean Basin Estimated Rainfall (AMBER) Program at the Sterling, Virginia NWS Forecast Office (Contributors: Cox, Arthur, Kuhnert, Slayter)

A formal evaluation of the AMBER flash flood warning decision program was conducted as a follow-up to NSSL's AMBER evaluation from February 2000. The purpose was to conduct an objective evaluation of the algorithm to obtain quantitative feedback on its performance. The 2001 evaluation focused on three flash flood case studies in the Sterling, VA, County warning area. The Digital Hybrid Scan Reflectivity (DHR) product was derived from KLWX Archive Level II data. From this, the 1-km by 1-degree precipitation estimates were derived and used to generate average basin rainfall rates and accumulations in AMBER. The flash flood potential as indicated by the rates and accumulations was analyzed with respect to the occurrence of flash flooding as reported in the publication *Storm Data.* The general conclusions drawn from this evaluation were 1) basins should be delineated with a minimum drainage area threshold less than 10 square miles, 2) flash flooding indicated by AMBER is only as reliable as the precipitation estimate input, 3) average basin rainfall rates are more indicative of flash flood potential in a timely manner than average basin accumulations, and 4) the addition of hydrologic parameters such as basin slope, elevation difference, hydraulic roughness, infiltration characteristics, and antecedent moisture conditions would assist in determining meaningful threshold rates and accumulations as well as improve the detection of flash flood potential. The methodology and results of this evaluation have been provided in a formal report.

Implementation of SCAN/FFMP into the NWS AWIPS System (Contributor: Xin)

The FFMP 1.0 was been released to NWS weather forecast office and river forecast center sites in 2000. New features of FFMP 2.0 have included the Areal Mean Basin Estimated Rainfall (AMBER) concept to issue the flash flooding warning on small basins that are delineated using River Reach Files Version 3 (RF3) from US EPA. On the FFMP Image and Table displays, all precipitation and flash flood information will be shown for all CWA areas and further so all of the basins for one specific county.

RIDDS Support, Maintenance, and Installation (Contributors: Benner, Cooper, Sinclair)

In cooperation with the Radar Operations Center (ROC), the NWS, the FAA, and OU, NSSL/CIMMS continued to support, maintain and install Radar Ingest and Data Dissemination Systems (RIDDS) during the reporting year. The RIDDS objective is to support the diverse warning/forecast improvement projects of the cooperating organizations by providing high-resolution WSR-88D and other radar data in real time. Currently, there are 56 RIDDS sites in the United States, 2 in Australia, and 1 in Taiwan. New sites installed during the reporting year include Eureka, CA, Slidell, LA, Cedar City, UT, Wilmington, NC, Fort Wayne, IN, Cleveland, OH, Chicago, IL, Cincinnati, OH, Buffalo, NY, Detroit, MI, Wakefield, VA, Columbia, SC, Morehead City, NC, Charleston, SC, and Wu-Fen-Shan, Taiwan. In addition to the installations, maintenance was performed at nine other RIDDS sites.

Improving Numerical Guidance for Mesoscale Forecasting (Contributors: Kain, Baldwin)

We continued 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. These differences promote the generation of more detailed mesoscale structures in the model. In addition, several unique output fields are produced. Many of these specific characteristics have been designed in collaboration with SPC forecasters, thus they are tailored to the needs of mesoscale forecasters.

We have become active contributors to the development of the next generation Weather Research and Forecasting (WRF) model as members of the model physics, post-processing and model verification working groups. CIMMS, NSSL, SPC, and the rest of the Oklahoma Weather Center are uniquely positioned to provide expert feedback to WRF developers on the value of this model as a high resolution forecast tool. We have procured funding from COMET to evaluate the model at the SPC and provide this feedback to the development team over the next two years.

Collaborations with the Operational Forecasting Community (Contributors: Kain, Baldwin)

From 17 April to 8 June 2001, a real-time forecast and research experiment called the Spring Forecast and Research Program was conducted in the Science Support Area of the NSSL/SPC facility. This program was a collaborative effort, organized by Mike Baldwin and Jack Kain (CIMMS) of NSSL's Mesoscale Applications Group and Paul Janish and Steve Weiss of the SPC. A diverse group of forecasters and scientists participated, including individuals from NSSL and SPC as well as the Norman NWS/WFO, NCEP's Environmental Modeling Center (EMC), NOAA's Forecast Systems Laboratory, OU, and Iowa State University.

The primary goal of the program was to investigate whether operational and experimental numerical weather prediction (NWP) models could be utilized more effectively to predict the initiation and development of severe convection. This overriding objective was mutually beneficial to NSSL and SPC because it incorporated important mission priorities from both sides. Specifically, it promoted NSSL's efforts to evaluate and improve NWP models while it supported the SPC's exploration of ways to reliably increase the projection time for severe thunderstorm and tornado watches. External participants provided very positive feedback from their experiences in this program, inspiring us to believe that collaborations between research and operational groups at the NSSL/SPC can emerge as a model for the rest of the weather service.

Our group also collaborated with Paul Janish of the SPC to mentor two ORISE students during summer 2001. We also served as guest lecturers at COMET symposia on several occasions this year. This program plays a critically important role in educating and training NWS personnel by transferring knowledge and applications from the research to the operational communities.

Verification Issues in Forecasting (Contributors: Kain, Baldwin)

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 an experimental version of the WRF model running twice daily at 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. In addition, a long-term archive of forecasts and analyses from both the operational and NSSL's experimental version of the Eta model has been established. This archive contains parameters besides precipitation that are important factors in the prediction of convective initiation and intensity, and will be used for future verification research. Additionally, other measures of ground truth for convective activity, including hourly gridded fields for lightning frequency and various fields derived from radar were collected and archived during the NSSL-SPC spring research program and will be used for additional verification studies.

WSR-88D Algorithm Testing And Display System (Contributor: Cooper)

NSSL/CIMMS in cooperation with the ROC continued support of the WSR-88D Algorithm Testing and Display System (WATADS) during the reporting year. WATADS software, developed during previous reporting years, makes it possible to play back high-resolution WSR-88D data tapes to test and compare baseline and experimental algorithms to improve forecasts/warnings. During the reporting year there were: 2950 hits on the WATADS Homepage; 482 direct communications with users; 254 different users; and 125 problems identified, 97% of which were solved. A list of WATADS users during the reporting year included: NWS (79 Offices) - 131 (52%); universities - 62 (24%); Department of Defense - 14 (6%); ROC/Other Government - 24 (9%); and Other - 23 (9%).

May 3, 1999 Tornado Outbreak (Contributor: Schultz)

Despite the relatively successful long-lead forecasts of the storms during the 3 May 1999 tornadic outbreak in Oklahoma and Kansas, considerable uncertainty among forecasters with regards to the timing, location, and mode of convection persisted through the time of convective initiation. Despite this uncertainty, the forecasters identified three crucial elements that they monitored for clues as to how the event would unfold. These elements were (a) the absence of strong surface convergence along a weak dryline in western Oklahoma and the Texas panhandle;

(b) the presence of a cirrus shield that was hypothesized to limit surface heating (except under holes in the cloud deck); and (c) the arrival of an upper-level wind-speed maximum into Oklahoma that was responsible for favorable synoptic-scale ascent and the cirrus shield.

The Pennsylvania State University/National Center for Atmospheric Research Mesoscale Model Version 5 (MM5) is used to explore the sensitivity of the outbreak to these features using simulations down to 2-km horizontal grid spacing. The 30-h control simulation reproduces the observed long-lived, long-track nature of the supercell outbreak, although errors in timing, location and longevity exist. Convective initiation occurred along the leading edge of the cirrus shield and within holes in the shield, suggesting the importance of incoming solar radiation to the development of the 3 May storms. Consequently, the simulation is adequate for evaluating the importance of the above processes identified by forecasters.

During this project, two processes are evaluated using factor-separation techniques: the opaqueness of the clouds to solar radiation and the upper-level wind-speed maximum associated with a potential-vorticity (PV) filament. Synoptic regulation of the 3 May 1999 event was imposed by the effects of the PV filament. Two pulses of convective activity occurred, the first tied to initiation within holes in the cirrus shield, and the second with the passage of the PV filament. The PV filament was responsible for forcing the upper-level synoptic-scale ascent that produced the cirrus shield and for enhancing boundary layer convergence well to the east of the dryline, where convection initiated. The joint effects of the PV filament and cloud-radiative processes acted to focus the convection in particular locales, associated with holes in the cirrus shield. Although the presence of the PV filament inhibited rather than enhanced deep-layer shear, through interactions with a stronger PV anomaly in the northern stream, sufficient shear and storm-relative helicity existed to produce supercell storms for PV filaments of 0, 1 and 2 times the magnitude of the analyzed feature at 0000 UTC 3 May.

Finally, the potential usefulness of high-resolution mesoscale modeling was assessed. In particular, it was found that the forecast data would have provided useful guidance that could have assisted forecasters in formulating and evaluating conceptual models of the event, enhancing situation awareness, and reducing forecast uncertainty.

Hazardous Winter Weather Climatologies (Contributor: Cortinas)

Hazardous winter weather is responsible for many fatalities and injuries, and millions of dollars of property damage every year. Currently, few studies have documented the climatology of these events across North America. During the previous year, research was completed that examined the variability of synoptic and local meteorological conditions associated with freezing rain across the United States. Results from this study indicate that there are common conditions typically associated with freezing rain at most locations across the U.S.: (1) subfreezing surface layer, (2) nearly-saturated air near the surface, (3) upward motion, and (4) elevated mid-level warm layer. However, the magnitude of these conditions is variable from location to location because of topographical effects. These results are significant to forecasters who may expect a specific combination of meteorological conditions to produce freezing rain for any location.

Additional research associated with this project also examined the distribution of freezing rain, freezing drizzle, and ice pellets across North America. These data have been analyzed and basic climatological information (e.g., frequency, variability, etc.) regarding these distributions has been created.

Creation, Evaluation, and Implementation of a Precipitation-Type Forecasting System (Contributor: Cortinas)

During the past year, resources for this project have been devoted to: 1) creating a procedure to run experimental precipitation-type algorithms and distribute the numerical output to NOAA/NWS forecasters; 2) developing an evaluation form for forecasters to submit; and 3) creating a website for the project. Currently, six algorithms are being run and the output data are being distributed from a workstation at the Hydrometeorological Prediction Center (HPC). The data are distributed in a format that is easy to view on forecaster workstations and include numerous plots that show the hourly output from each algorithm as well as ensemble products that show the most likely type of precipitation and a risk assessment (e.g., low, medium, and high) of each precipitation type.

Forecaster evaluation forms were created with the assistance of the Science and Operations Officer at the HPC and a forecaster from the SPC to provide forecaster feedback on the usefulness of the algorithm output, the format of the products, and the forecaster's perceived accuracy of the products. Between October 2000 and March 2001, 138 (66 from SPC forecasters and 72 from HPC forecasters) evaluations were submitted, with over 92% of those that evaluated the usefulness of the output stating that it had been useful (27%), very useful (27%), or extremely useful (39%) in creating the current NWS product. The evaluations show that HPC forecasters used the algorithm output most often for the first 12-h Winter Weather Forecast and the 24-h Day Two Winter Weather Forecast. SPC forecasters used the output for their Mesoscale Discussion product. The evaluations also indicate that forecasters used the algorithm output based on the Eta solution more often than output from the RUC. Most (> 95%) of the forecaster evaluations that commented on the presentation format of the output indicated that it was presented in a useful way.

NSSL/ROC Level II Database (Contributors: Smith, Palmer)

The WSR-88D Level II database continues to be an important source for Level II data for the Oklahoma Weather Center community. CIMMS scientists, with support from the Radar Operations Center, continue to collect Level II data for the purposes of various research needs and algorithm development and evaluation. These two organizations represent the largest users of WSR-88D Level II data. Work completed during the past year includes the addition of Level II data sets for use in a variety of application evaluation and applied research exercises. These include Tornado Warning Guidance statistical analysis, a Radar Signature Climatology investigation, and new WSR-88D Volume Coverage Pattern (VCP) studies. In addition to the Level II data, upper air data have also been collected and made available via anonymous ftp or the web.

NWS Tornado Warning Guidance (Contributors: Stumpf, Marzban, Burke, Cheresnick, Hannon, McCoy)

CIMMS employees, in collaboration with the ROC Applications Branch and the Warning Decision Training Branch developed the 1999 NWS Tornado Warning Guidance document (TWG99). In anticipation of updating this document, the TWG database was greatly expanded from 43 to 123 cases. Eighty-three of these cases have associated Near-Storm Environment (NSE) algorithm data, and all 123 cases have associated BWER data.

During FY01, CIMMS employees completed a statistical analysis of this expanded database in preparation for an update to the Tornado Warning Guidance document to occur in FY02 (TWG02).

Climatology of Radar Signatures Using the WSR-88D (Contributors: Stumpf, Marzban, Cheresnick, Hannon, Palmer)

Since 1995, Level II data have been routinely collected at WSR-88D sites and archived at the National Climatic Data Center. As a result, climatologies of radar observed signatures (hail, mesocyclones, tornadic vortex signatures [TVS], etc.) using a relatively large Doppler radar data set are now possible. In 1998, CIMMS scientists embarked upon a pilot study to ultimately determine a more reliable estimate of the frequency of these radar signatures and how often they are associated with tornadoes and other severe/hazardous weather.

This pilot study incorporated the use of the NSSL Severe Weather Warning Applications and Technology Transfer (SWAT) team enhanced severe weather and tornado detection algorithms for two radars (Pittsburgh, PA and St. Louis, MO) for a continuous three-year data set (1996-1998). CIMMS scientists processed all Level II data (precipitation data only, i.e. Volume Coverage Patterns – VCPs – 11 and 21) collected by the Pittsburgh WSR-88D (KPBZ) for these three complete years of data collection. Approximately 350 KPBZ 8mm Level II data tapes spanning 1996 trough 1998 have now been processed by NSSL's severe weather detection algorithms. Also, CIMMS scientists have nearly completed similar processing for the same three-year period for the St. Louis WSR-88D (KLSX).

The output of radar signatures was compared to storm reports from *Storm Data* and their attributes were prepared for spatial (geographical) and statistical analysis. CIMMS scientists completed the statistical analysis using the KPBZ data and presented the results at the 20th Conference on Severe Local Storms in September 2000.

CIMMS scientists also developed a study to determine whether radar-observed storm-scale vortex signatures (e.g., mesocyclones and TVSs) can be used as a proxy to synthesize tornado climatologies where verification is problematic. Tornado verification can be problematic in certain locations, such as those with low population density, in mountainous and forested regions, and where storm verification is not as actively pursued (such as in Europe and other foreign countries).

Starting with a database of "well-verified" tornado events (43 cases with about 207 tornado reports), and the associated output from both mesocyclone and TVS detection algorithms, we determined the likelihood that particular detections are tornadic based on a variety of detection attributes (such as rotational velocity, depth, etc.). We then apply the posterior probabilities of the well-verified dataset to a test data set that is assumed to be poorly verified (the poorly-verified data set is actually a three-year nearly-conclusive set of all the storm-scale vortex detections collected from the Pittsburgh radar during 1996-1998). The resulting synthetic climatological values for the number of tornadoes are quite similar to the actual number of reported tornadoes within the domain of the radar for the poorly verified data set.

New Volume Coverage Pattern (VCP) Development and Testing (Contributor: Janish)

CIMMS has worked with NSSL to analyze six new optimized WSR-88D Volume Coverage Patterns (VCP). Three of these will replace the four operational VCPs (11, 21, 31, and 32). The three new VCPs have been developed with an angle selection that allows for less uncertainty of echo height measurement between adjacent elevation scans. By selecting a slightly faster antenna rotation, the new VCPs also include more elevation angles for the entire volume scan, including much more dense coverage at the lowest elevation scans (3 or 4 elevations scans between 0.5 and 1.5 degrees, when there used to be only 2). A brand new "Fast-VCP" has been developed which basically is a "half" VCP – it updates at 2.3-minute intervals to allow for the observation of quickly evolving low-altitude phenomena such as tornadoes and downbursts. Two more VCPs, which incorporate a Multiple-Pulse Repetition Frequency (PRF) Dealiasing Algorithm (MPDA), have also been developed. The experimental KCRI WSR-88D in Norman Oklahoma is being used to collect experimental data using all six new VCPs.

CIMMS scientists helped NSSL scientists identify radar coverage problems by simulating "cone of silence" problems with the six experimental VCPs throughout the contiguous US. Terrain blockage was taken into account at WSR-88D sites near mountains. CIMMS worked with NSSL to simulate the spatial coverage provided within the three composite layers (0-24,000 ft, 24-33,000 ft, 33-60,000 ft) and the spatial coverage that would be available to detect storms that extend to heights of 30,000 ft and 60,000 ft. The findings will be used to answer how well they provide the data needed to produce the WSR-88D composite layer products and the echo top product.

Working with NSSL, CIMMS also continues to research optimal scanning strategies for mountaintop radar sites. These strategies employ the use of elevation angles below 0.5 degrees such that the lowest elevation angles skim the valley surfaces and maximize full volume coverage for the densest population centers. Since elevation angles below 0.5 degrees are currently not authorized, these new mountaintop VCPs are not expected to be implemented until this restriction is lifted.

Comparison of WSR-88D Data to the 3 May 1999 Oklahoma City Tornado Damage Path (Contributors: Stumpf, McCoy)

CIMMS scientists were instrumental in developing a highly detailed damage survey of the 3 May 1999 F-5 tornado that struck the Oklahoma City metropolitan area. The survey maps include contours of the Fujita-scale damage intensity rating, which were developed using ground and aerial surveys. These F-scale contours were then digitized into shape files for use within ArcView GIS.

WSR-88D radar data from Twin Lakes, OK (KTLX) were also digitized as ArcView shapefiles, and overlaid with the F-scale damage contours to compare the radar observations with the actual damage path of the tornado. Furthermore, output from the NSSL Mesocyclone Detection Algorithm at the 0.5-degree elevation angle was also digitized and compared with the actual damage path location. Initial findings indicate that the WSR-88D observed vortex detections were about the same diameter as the tornado in rural Grady County (3/4 mile wide), but larger than the damage path width in Cleveland and Oklahoma Counties (radar 3/4 mile wide, tornado 1/3 mile wide). These findings indicate that the WSR-88D does not detect the actual tornadic vortex except for the most rare very large tornado cases ("wedge" tornadoes), and only close to the radar. The distance between the radar-detected vortex and the damage path was typically no more than 1/2 km.

Severe Storms Analysis Program - SSAP (Contributors: Stumpf, Cooper, Smith)

In support of ongoing CIMMS research, CIMMS scientists continued to develop, maintain and enhance their Severe Storms Analysis Package (SSAP), including the following meteorological algorithms that have been evaluated off-line and in real-time during NWS forecast office operational tests:

- Tornado Warning Applications: Mesocyclone Detection Algorithm (MDA); Tornado Detection Algorithm (TDA); Vortex Detection and Diagnosis Algorithm (VDDA); Bounded Weak Echo Region (BWER) algorithm;
- Severe Storm Warning Applications: Storm Cell Identification and Tracking (SCIT) algorithm; Hail Detection Algorithm (HDA); Damaging Downburst Prediction and Detection Algorithm (DDPDA);
- Applications related to both: Near-Storm Environmental (NSE) algorithm

All algorithms have been converted to output data in "rapid update" mode (currently only displayable in WDSS-II). On the baseline WSR-88D system, the algorithm information is processed after an entire volume scan is completed, and volume products are typically 5-6 minutes older than the lowest-altitude elevation scan in that volume. Rapid Update mode allows for algorithm information to be processed after each elevation scan, for more timely output of information to warning forecasters.

Development is nearly completed to recode the SSAP algorithms to C++ and for the future WSR-88D Open-Systems RPG. The SCIT algorithm is complete, and the recode SCIT has been established as the new WSR-88D baseline. The HDA and TDA are nearly complete and are awaiting final regression testing to determine their baseline status.

***Integration of Scale Separation/Correlation Tracker and SCIT** (**Contributors: Janish, Elmore, Lakshmanan**)*

During the past year, the latest version of the SS/CT algorithm was acquired from MIT/Lincoln Laboratory. Work has been completed to allow the SS/CT algorithm to utilize NSSL's "hires" data format for input and to allow display of forecasts from the SS/CT algorithm in NSSL's WDSS-II. Within the WDSS-II framework it is possible to display the SS/CT algorithm forecasts along with the cell identifications and tracking information from the SCIT algorithm. This project supports other ongoing CIMMS research.

***Vortex Detection and Diagnosis** (**Contributors: Stumpf, Marzban**)*

CIMMS scientists continued to test the Mesocyclone Detection Algorithm (MDA) on an ever-expanding database consisting of a variety of tornadic and non-tornadic supercell cases. The MDA allows for the detection of storm-scale vortices of various sizes and strengths, and classifies them into a number of different vortex types (including Mesocyclone, Low-Topped Mesocyclone, etc.). Trends of vortex attributes are also computed. The database now contains over 130 individual storm event days from a variety of locations across the country. The database includes over 1000 tornadoes with over 810 hours of radar data. This represents over 60 more events analyzed since FY00.

CIMMS scientists have also been developing a special web-based case study collection of a variety of storm types collected nationwide. This web page depicts a wide range of the types of tornadic storms that have been observed with the WSR-88Ds, and provides detailed discussions, images, and algorithm output evaluations.

Enhancements made to the MDA include the addition of Near-Storm Environmental (NSE) algorithm parameters (as derived from RUC mesoscale model grids). Over 100 NSE parameters have been incorporated into the MDA (and TDA). Work was completed to statistically analyze the integrated data. Although individual NSE parameters showed little skill by themselves to discriminate tornadic from non-tornadic detections, a prototype neural network trained on a small potion of the integrated data set (14 events) showed nearly a doubling in the skill (using Heidke Skill Statistic as a measure) in diagnosing the probability of a tornado for each detection (from about 35% to 60%). A more robust neural network is presently being developed that is being trained on the 83-event Tornado Warning Guidance data set.

Web-based tornado warning guidance truthing software was evaluated to aid CIMMS scientists and NWS field forecasters in the development of local MDA and TDA data sets, suitable for local adaptable parameters studies, and for the incorporation of field data into the nationwide database to be collected at NSSL. The software guides forecasters by using the same truthing, association, and scoring methods employed by the NSSL and ROC so that there is consistency in validation efforts.

***Bounded Weak Echo Region (BWER) Algorithm** (**Contributors: Lakshmanan, Stumpf**)*

A Bounded Weak Echo Region (BWER) algorithm was developed in 1998 to detect and classify (using probabilistic "confidence" factors) weak-echo vaults within severe thunderstorms using WSR-88D reflectivity data. The BWER data has been integrated with the MDA and TDA data for the entire 123-event Tornado Warning Guidance data set. An 83-event combined MDA/TDA/BWER and NSE dataset are being used to develop a new neural network, and to develop statistical analyses for the 2002 NWS Tornado Warning Guidance (TWG02) documentation.

Neural Network and Statistical Analyses (Contributors: Marzban, Stumpf)

Three neural networks for the HDA were updated, completed, and implemented into WDSS. These are: one for producing a Probability of Severe Hail (POSH); another for estimating Maximum Expected Hail Size (MEHS) in some physical unit; and a third for estimating the hail size in terms of three size classes (> .75", >1.5", >2.25"). A journal article was accepted for publication.

A number of statistical techniques were applied to an 83-event data set for the purpose of extracting Tornado Warning Guidance. Also, a preliminary MDA/TDA/BWER/NSE neural network was developed based on the 83-event data set. A journal article on a Markov chain for tornadic activity was completed and submitted as well.

Hail Detection Algorithm (HDA) - New Techniques for Severe Hail Detection and Prediction (Contributor: Marzban)

The neural networks developed for the HDA were implemented into NSSL/SWAT Severe Storm Analysis Package (SSAP). The HDA now makes predictions for the Probability of Hail (POH), POSH, MEHS, and conditional probabilities of hail occurring in one of three different size categories: "coin" size (0.75 - 1.3 in.), “golf-ball” size (1.3 - 2.3 in.), and “baseball” size (>2.3 in.). All of these predictions, except for the POH, are produced by the HDA's neural networks. An initial test of the new HDA and SSAP showed that the various hail size predictions looked reasonable. However, some anomalies were observed in the POSH output, which are currently being investigated.

Damaging Downburst Prediction and Detection Algorithm (Contributors: Smith, Myers, Elmore)

The Damaging Wind Events Database, used to build prediction equations for the DDPDA, was expanded by 48 severe downburst-producing storm cells and 1137 cells that did not produce severe winds. These storms are classified as "pulse" cells that formed in an environment of moderate-to-high convective available potential energy (CAPE) and weak vertical wind shear. This brings the total number of cells in the database to 148 severe and 2445 non-severe cells, from 76 different event days. Approximately one half of these events are from the U.S. Desert Southwest region. One quarter of the remaining events are from the Florida/Georgia region, while the remaining events are scattered across the Midwest and Central Atlantic states.

***Near-Storm Environment (NSE) Algorithm** (**Contributors: Stumpf, Spencer**)*

The goal of the NSE algorithm is to integrate Doppler radar and mesoscale model data to provide the SSAP algorithms with information about the environment of each storm cell, such as shear and stability parameters. Currently, NSE uses output from the Rapid Update Cycle-2 (RUC2) model to help determine the environment of storm cells.

During the past year, CIMMS scientists completed a statistical study of integrated MDA, TDA, and NSE data for the Tornado Warning Guidance. NSE gridded data are bilinearly interpolated to the location of the MDA and TDA centroids to determine values for each vortex detection. Initial results looked at bivariate distributions of the data, and this suggested that only a few NSE variables offer some diagnostic value for determining whether or not an algorithm-detected storm-scale vortex is tornadic or non-tornadic. Later, a neural network was developed on the data set. An early neural network using a subset of the data showed nearly a doubling in the skill (using Heidke Skill Statistic as a measure) in diagnosing the probability of a tornado for each detection (from about 32% for a neural network with no NSE data to 60% for a neural network that included NSE data). A more robust neural network using the NSE data is being developed, with results forthcoming during the next fiscal year.

NSE data are also used to improve the HDA and the DDPDA. The NSE algorithm also supplies real-time data to several of NSSL/SWAT WDSS real-time data sites.

***Storm Cell Identification and Tracking (SCIT) Algorithm: Vertical and Time Association Improvements** (**Contributor: Krause**)*

The goals of the SCIT algorithm are to accurately identify the complete depth (volume) of each storm cell and to correctly match cells between volume scans so as to provide reliable trend and forecast movement information. Numerous deficiencies in the tracking routines have been identified, and many traced back to errors in the vertical association routines. A multiple-year project with the ROC Applications Branch was started this year to identify methods to improve the vertical association within the SCIT algorithm.

***Ensemble Cloud Model Applications** (**Contributors: Elmore, Zaras, Baldwin**)*

Starting 15 July 2001, a cloud model ensemble has been run daily at NSSL with output supplied to the SPC and available on the web. Each day, the ensemble is run over a region centered on a point. The location of the point is determined based on the Day 2 convective outlook form the SPC. The cloud model ensemble consists of 39 separate cloud model runs, each initialized with a different sounding. The cloud model is the COllaboartive Model for Mesoscale Atmospheric Simulation (COMMAS) developed by Dr. Lou Wicker of NSSL. The model is initialized as a horizontally homogenous environment using a single sounding, derived from a mesoscale model. The soundings come from a 160 km by 160 km region over a period of 9 hours. Two separate ensembles are run. The first uses a mixture of the operational Eta and the Eta run at 22 km grid spacing using the Kain-Fritch convective parameterization (EtaKF). The second ensemble uses a mixture of the RUC20 and the EtaKF. The cloud model uses 1.25 km horizontal grid spacing and a stretched vertical grid with an equivalent computational spacing of 450 m. The model is run for a 2 h simulation and convection is initialized with a 3.5 K warm bubble. Because a warm bubble constitutes and unbalanced initial state, there is a "spin-up" period for the model. Hence, the first 30 minutes of simulation time are discarded. Note that this kind of initialization does not help determine if convection will occur. Insight into the initiation of convection has not been tested. The ensemble is intended to provide conditional guidance; should storms occur, the ensemble is intended to provide insight into the nature of the convection. The ensemble is run on a 40-node Beowulf cluster consisting of 40 450-MHz Intel Pentium-III processors, each with 193 MB of RAM.

The maximum vertical velocity anywhere in the grid domain is retained from each run. A storm is defined to exist when the maximum vertical velocity exceeds 8 m/s. A time series of the maximum vertical velocity is analyzed to yield likely modes for the convection. For example, there may be a strong, long-lived mode, a medium length, medium strength mode, and finally a short, weak "pulse-type" mode.

In addition, a supercell criterion is applied, and simulated storms that meet the supercell criteria are highlighted. Supercell criteria are met for any storm that lasts longer than 40 minutes and maintains a correlation between mid-level vertical vorticity and mid-level vertical velocity greater than 1 m/s of at least 0.5 for at least 20 minutes. A height of 5 km is used as mid-level for this purpose. Thus, if the correlation between those vertical velocities greater than 1 m/s at 5 km and the vertical vorticity field at 5 km is at least 0.5, and is maintained for at least 20 minutes for a storm that lasts at least 40 minutes, the supercell criteria are met.

The project continues through 30 September 2001. No formal analysis is yet available, but informal discussions with SPC forecasters indicate that the ensemble provides useful information. Also, there is some indication that simulated storms that are short-lived but that contain large vertical velocities tend to be strongly correlated with severe wind reports in and around the ensemble region, but this indicator has not yet undergone formal analysis. Formal analysis will begin in September 2001.

Weather and Radar Processor (WARP) Base Reflectivity Radar Mosaic (BRRM) Algorithms (Contributor: Porter)

Work to date has centered on generating a white paper that describes the various current methods for removing anomalous propagation and ground clutter (AP and GC) in the Weather and Radar Processor (WARP). The primary WARP contractor is currently behind schedule, so the data collection and analysis phase has yet to begin. As soon as data are available, the current WARP AP and GC algorithms will undergo a rigorous statistical evaluation to determine optimal parameter settings and overall performance. Based on these results, CIMMS scientists will collaborate with those at NSSL to make recommendations regarding the next level of improvements to be made.

Evaluation of ARPS and GDST 1-6 Hour Forecasts (Contributors: Porter, Janish)

Six-hour forecasts of position, coverage, and strength for five strongly-forced convective events from the Advanced Regional Prediction System (ARPS) and MIT/Lincoln Lab's Growth and

Decay Tracker (GDST) were compared using statistical indices such as Probability of Detection (POD), False Alarm Rate (FAR), and Critical Success Index (CSI). Subjective parameters are also used to evaluate forecasts (e.g., storm intensity, initiation location, movement, growth and decay) including a synopsis of the storm-scale/mesoscale environment. Test cases are selected from the Spring Operations Period 1999 (SOP99) - a real-time forecast testing period that demonstrated the value of initializing the model with Level-III (NIDS) WSR-88D radar data. ARPS forecasts always contain the proper mode and orientation of convective systems providing potential for accurate forecasts. However, ARPS did suffer from some consistent forecast problems associated primarily with spurious convection, areal coverage of higher reflectivities, and intensity of convection. In general, the GDST is able to discern the magnitude of propagation for convective systems as a whole, although it fails to simulate the initiation of new convection. It is able to produce a more accurate forecast over the initial 2-hour forecast period while ARPS forecasts produce more skillful forecasts in the 2-6 hour forecast period. POD and CSI values for the GDST are very near zero by the second hour of the forecast, but higher than the averaged ARPS values through the first forecast hour. Beyond the second hour, the ARPS POD and CSI values rise with POD averaged values near 0.35 and CSI averaged values near 0.13.

Plans - FY02

Implementation of CIMMS Stratiform Cloud Parameterization into a NWP Regional Model (Contributors: CIMMS Cloud Physics Group, led by Y. Kogan)

In the coming year the 6-year project supported by the Department of Defense Grant to OU under the Multidisciplinary University Research Initiative Program will be completed. A presentation of the research findings at scientific conferences and in journal publications will be an important part of this year's effort.

Quantitative Precipitation Estimation Using Multiple Sensors - QPE SUMS (Contributors: Gourley, Maddox, Arthur, Zhang)

Improvement of the QPE SUMS algorithm will continue. Specifically, efforts are underway to integrate RUC-2 model data in the QPE scheme. Also, a radar notification product will be generated that describes how frequently the radar data from a given NEXRAD site is transmitting data to the machine where the software is running. Lastly, more robust logic is being developed for the utilization of high-density rain gauge networks.

Supercell Identification Algorithm (Contributor: Lynn)

The Supercell Identification Algorithm will be optimized using a test data set. The algorithm will then be evaluated on other data sets and tested in real-time using the WDSS-II testbed.

Storm Cell Identification Through K-Means Clustering of Base Radar Data (Contributor: Lakshmanan)

Future plans for this project include adding a hierarchical overlap segmentation for use in storm cell tracking.

Three-dimensional Multiple Radar Reflectivity Mosaic (Contributors: Zhang, Gourley)

Will continue to improve the mosaic algorithm and begin to develop new products from the reflectivity mosaic grid. We will also develop a multi-resolution, nested grid of multiple radar reflectivity mosaic for the FAA's northeast U.S. corridor.

Warning Decision Making Analysis (Contributors: Magsig, Wood, Yu, Hoggard, Tan)

Warning decision-making analysis is planned to continue in the next plan year. One of the areas of analysis will focus on WDTB workshops dealing with warning methodologies. While workshops have primarily been focused on severe weather associated with deep convection, they are growing to include severe winter weather forecasting. From the collaboration in these workshops, refinement of multi-sensor warning methodologies are planned as they relate to tornadoes, hail, wind, flash flooding, and winter weather. More focus will be given to developing meaningful graphical and text products that concisely convey information and uncertainty. How to best utilize ensembles of numerical model guidance in the warning decision-making process will also be a new component of warning decision making analysis.

Warning-Related Forecast Improvements (Contributors: Magsig, Wood, Yu, Hoggard, Tan)

Ongoing warning-related forecast improvements are planned to continue at WDTB in the next year. More time will be spent using high-resolution radar data (such as the Doppler On Wheels) to evaluate sampling limitations of the operational WSR-88D radar. Multi-sensor integration into warning decision-making will continue to be an area of active research. Determining optimal ways to ensemble numerical model guidance into warning decision making for severe deep convection and winter weather are also planned. Exploring new ways to verify warnings and severe weather will occur in the next year.

Warning Simulation (Contributors: Magsig, Wood, Yu, Hoggard, Tan)

Enhancements are planned for the current CIMMS warning simulation capabilities. More decision support tools, such as the System for Convection Analysis and Nowcasting (SCAN) and version 2 of the Flash Flood Monitoring and Prediction System (FFMP 2.0), are going to be added to the Warning Event Simulator to evaluate methodologies in warning decision making. An automated warning analysis component is also planned to verify the accuracy and content of generated warnings for research into new warning verification techniques. More research into warning decision-making using the Warning Event Simulator is planned on past events and any new events occurring during the next year.

National Basin Delineation (Contributors: Cox, Arthur, Kuhnert, Slayter)

The current national basin delineation project will conclude during October 2001. However, many issues such as maintenance of the basin data set, updates to incorporate improved terrain data, and training for NWS forecast office staff on how to use and/or edit the files will remain. The NSSL basin delineation group hopes to continue to provide support for this data set and its users.

Taiwan Basin Delineation (Contributors: Cox, Arthur)

To support the implementation of the QPE-SUMS precipitation algorithm and a distributed hydrologic model, basins will be delineated for Taiwan. The delineation will be based on 40-meter resolution digital terrain data using ArcView GIS with the Spatial Analyst Extension.

FFMP Implementation and Improvements in AWIPS (Contributor: Xin)

We will pursue enhancements and improvements for FFMP and add more flexibility for users to utilize the system. We may also perform alpha tests at weather forecast offices and river forecast centers to get valuable feedback on the release of the product.

RIDDS Support, Maintenance, and Installation (Contributors: Benner, Cooper)

The RIDDS project will undergo major changes during the upcoming year because of the installation of the Open RPG at all WSR-88D sites. ORPG will bring with it a new Base Data Distribution System (BDDS). BDDS will change the connection architecture at all WSSR-88D sites. The year will be spent in switching to the new BDDS at all WSR-88D sites. In addition, at many sites, the architecture will be further changed to combine with the Collaborative Radar Acquisition Field Test (CRAFT) to provide compression (lower bandwidth) of the transmitted data.

Improving Numerical Guidance for Mesoscale Forecasting (Contributors: Kain, Baldwin)

We will continue to produce semi-operational (twice daily) forecasts with our experimental version of the Eta model. We will continue to use verification statistics to compare the two versions of the model and look for ways to improve the Kain-Fritsch convective parameterization scheme. This work will be done in close collaboration with SPC forecasters.

A semi-operational procedure for running and evaluating the WRF model will be developed. In particular, the computational performance of the model will be optimized and forecasts will be generated at least once daily. Forecast output will be disseminated to SPC forecast workstations in a format similar to Eta model output. This will facilitate comparison with other operational and experimental models at NSSL/SPC. Model output will be evaluated subjectively in collaboration with SPC forecasters, in addition to objectively, using both traditional verification metrics and new techniques that are currently under development.

Collaborations with the Operational Forecasting Community (Contributors: Kain, Baldwin)

Another forecast and research program will be designed this year and executed in the spring of 2002. This study will likely have a component of interaction with two major field programs, but will focus on the combined interests of NSSL and SPC. Additional student mentorships are likely and involvement with COMET will continue.

Verification Issues in Forecasting (Contributors: Kain, Baldwin)

Computation of the ET and bias scores for various operational and experimental prediction models (including Eta and WRF) will continue. These scores will be computed in an automated fashion for the verification of quantitative precipitation amounts, and will also be utilized for comparison with the subjective verification dataset collected during the NSSL-SPC spring program. The long-term archive of Eta model forecasts will be statistically analyzed to determine significant systematic errors, broken down as a function of season or predominant flow pattern. New verification techniques will be developed and compared with traditional accuracy measures. Our strategy in developing these new techniques is to decompose forecast and observed fields into sets of meteorological events or phenomena that can be objectively classified. Once identified within the fields, the joint probability of the observed and predicted events will be analyzed. To ensure that the information obtained by these new verification methods are of value to operational forecasters, this work will proceed as a collaborative effort between the NWS (including the SPC, EMC, and HPC), OU, and the NSSL.

WSR-88D Algorithm Testing And Display System (Contributor: Cooper)

WATADS support will continue as in the past reporting year. If the National Climatic Data Center (NCDC) changes the format of the Level II (high-resolution) WSR-88D data they now distribute, WATADS will be modified to accept the new NCDC formats, possibly including files transferred via FTP.

The Risks and Rewards of High-Resolution Mesoscale Modeling (Contributor: Schultz)

Due to the increase in computer speed and the power of numerical weather prediction models, numerical modeling is the on the verge of providing high-resolution (1-2 km horizontal grid spacing) model output in an operational forecast environment. The potential benefits of such resolution are tremendous. The potential for misuse, misinterpretation, and mistakes is also high, however. Combining research results from several groups who are actively pursuing the future of operational numerical modeling, this research aims to address what the risks and rewards of high-resolution numerical modeling are. The goal is to write a *Bulletin of the AMS* article that will address these topics.

Hazardous Winter Weather Climatologies (Contributor: Cortinas)

Using available surface observations from 1976 to 1990, this project will continue to analyze the distribution of freezing rain, freezing drizzle, and ice pellets across North America. This analysis will be published and distributed to NWS weather forecasters for use in winter weather forecasting.

Creation, Evaluation, and Implementation of a Precipitation-Type Forecasting System (Contributor: Cortinas)

During the next year, algorithm output will be collected and provided to NWS forecasters from November 2001 through March 2002. Verification studies will be performed using the algorithm output that was created during the winters of 2000-2001 and 2001-2002. This verification study will determine the quality of the forecast system and determine if a combination of the algorithm output provides forecasters with additional information about the accuracy of the forecast.

NSSL/ROC Level II Database (Contributors: Smith, Palmer)

NSSL/SWAT, with support from the ROC Applications Branch, will continue to acquire additional radar and environmental data. The database and web site will also be redesigned to better serve our customers. NSSL/SWAT will develop an on-line specialized Level II database and digitally store compressed Level-II data on a terabyte RAID system that will allow for easier access and FTP downloads of our datasets.

NWS Tornado Warning Guidance (Contributors: Stumpf, Marzban, Burke, Cheresnick, Hannon, McCoy)

The 2002 Tornado Warning Guidance document will expand upon the 1999 edition. It will include an updated qualitative general guidance section based on leading-edge research results, including information on integrating knowledge of the near-storm environment into tornado warning decision making. It will also include results from the new statistical analysis of MDA, TDA, and BWER data that:

- Will include integrated NSE algorithm data from the RUC1 and RUC2 mesoscale models
- Division of data into subsets representing various storm types as dictated by the NSE (e.g., mini-supercell, squall line tornadoes, tropical-cyclone tornadoes, HP, LP, or CL supercells, etc.)
- Division of data by range (km) from the radar
- A greatly expanded data set (83 cases with integrated data from all 4 algorithms)

The 2002 document will be released to NWS forecast offices sites prior to the 2002 convective season.

Climatology of Radar Signatures Using the WSR-88D (Contributors: Stumpf, Marzban, Cheresnick, Hannon, Palmer)

With these nearly complete multi-year data sets from the two radars, CIMMS employees plan to determine the kinds of statistics that can be generated for all the WSR-88D sites nationwide. The vision is to develop web resources that will automatically tally and update, in real-time, statistics for all the WSR-88D radars in order to develop a national climatological database. The

Mesocyclone Project at the OU School of Meteorology has been set up to develop the real-time climatology system, and CIMMS scientists are working in concert with them.

The above problem is one-dimensional, resulting in a single number of tornadoes synthesized for a given area and period of time. During the next year, CIMMS scientists plan to develop a two-dimensional spatial synthetic climatology for the same dataset, and compare the results to the spatial distribution of tornadoes for the same period. A temporal analysis will also be conducted to synthesize the spatial tornado distribution by season.

New Volume Coverage Pattern (VCP) Development and Testing (Contributor: Janish)

CIMMS will work with NSSL scientists to subjectively evaluate the system impacts of the two newly optimized MPDA-VCPs that take advantage of the greater temporal and vertical resolution of the experimental VCPs and the velocity dealiasing capability of MPDA scans. Also, CIMMS will study the algorithm's performance using the Fast-VCPs that updates in about half the time (2.3 minutes) of the present VCPs. CIMMS will also collaborate with the ROC Applications Branch to perform a cost-benefit analysis of the effect of the new VCPs on the system, figuring in benefits to warning improvement. CIMMS will also continue working with NSSL and ROC to study mountaintop VCPs.

Comparison of WSR-88D data to the 3 May 1999 Oklahoma City Tornado Damage Path (Contributors: Stumpf, McCoy)

CIMMS scientists plan to continue the analysis comparing the damage path to radar data from higher elevations. This could be helpful in determining the tilt of typical radar-detected tornadic vortices, and to aid in the location of tornadoes on the ground given the combination of the height of the radar beam and other parameters such as shear that may affect the tilt of a vortex within a thunderstorm. This will provide additional spatial information for operational tornado warning decision-making.

Severe Storms Analysis Program - SSAP (Contributors: Stumpf, Cooper, Smith)

In support of the integration of Terminal Doppler Weather Radar (TDWR) and the future Phased Array Radar (PAR), CIMMS employees plan to migrate the SSAP to a multiple-radar platform, combining data from multiple radars at rapidly-updating regular intervals (30-60 seconds) using virtual multiple-radar volume scans (which are VCP independent) and 3D mosaic radar products (reflectivity, azimuthal and radial shear).

Future algorithm development will support ongoing CIMMS research and will be facilitated by the WDSS-II, its display system, and its set of common Application Program Interfaces (APIs).

Integration of Scale Separation/Correlation Tracker and SCIT (Contributors: Janish, Elmore, Lakshmanan)

Future work will focus on software changes that will allow the SS/CT algorithm to run in real time within the WDSSII framework, alongside NSSL's other experimental algorithms.

***Vortex Detection and Diagnosis** (**Contributors: Stumpf, Marzban**)*

CIMMS scientists plan to develop and examine multiple-radar versions of MDA and TDA that will run on virtual blended volume scans in rapid update mode. CIMMS will also complete the development of an MDA/TDA/BWER/NSE neural network.

As the first versions of the WDSSII are released, initial source code testing for the Vortex Detection and Diagnosis Algorithm (VDDA), an algorithm that combines ideas from the MDA and TDA but with improved vortex detection and diagnosis techniques, will commence.

Bounded Weak Echo Region (BWER) Algorithm** (**Contributors: Lakshmanan, Stumpf)

Work will continue to evaluate the BWER algorithm, including integrating the information with other data sources.

***Neural Network and Statistical Analyses** (**Contributors: Marzban, Stumpf, Spencer**)*

CIMMS scientists plan to finalize the testing of the HDA neural network. We also plan to finalize the development of the MDA/TDA/BWER/NSE neural network for the 83-event Tornado Warning Guidance data set.

***Hail Detection Algorithm (HDA) - New Techniques for Severe Hail Detection/Prediction** (**Contributor: Marzban**)*

The new HDA neural networks will be evaluated during real-time testing of the WDSSII system.

***Damaging Downburst Prediction and Detection Algorithm** (**Contributors: Smith, Myers, Elmore**)*

Plans for 2002 include the development of a new version of the DDPDA prediction equations based on the expanded data set. A formal DDPDA journal publication is in development as well.

***Near-Storm Environment (NSE) Algorithm** (**Contributors: Stumpf, Spencer**)*

To assist with ongoing CIMMS research, CIMMS scientists plan to modernize the NSE algorithm. The plans include porting the algorithm to Linux, adapting it to run with the latest version of the Rapid Update Cycle model (RUC20), making the algorithm more flexible in its input grid architecture (to run on any mesoscale model, e.g., ARPS, LAPS, MM5), and recoding it in an object-oriented language (C++) and optimizing the code.

***Storm Cell Identification and Tracking (SCIT) Algorithm: Vertical and Time Association Improvements** (**Contributor: Krause**)*

In order to improve the accuracy of the SCIT algorithm, changes will be made to the algorithm's vertical association process to reduce the frequency of storm "fragmentation" (i.e., the tendency of the algorithm to produce multiple cell detections within an individual storm). The criteria for merging SCIT detections in close proximity to one another will be modified so as to minimize storm fragmentation. Also, an alternate vertical association procedure involving the areal overlap of 2D storm components will be compared to the current method (which simply checks the proximity of centroids locations). Other methods to improve the vertical and time association will also be tested during the year.

Ensemble Cloud Model Applications (Contributors: Elmore, Zaras, Baldwin)

The overall ensemble will be revamped to make three separate runs based on mesoscale output form three different models. This way, should forecasters determine that a systematic error in one model leads to unreasonable or unrealistic initial conditions, ensemble members from that model could be excised. Verification will be a focal point. We can easily verify the following:

- Storm occurrence in and near the ensemble region (binary yes/no)
- Damage occurrence (binary yes/no)
- Damage type (categorical TOR, HAIL, WIND)
- Supercell occurrence (binary yes/no, requires daily verification analysis by hand)
- Storm lifetime (continuous, requires WSR-88D level II data from ensemble region)
- Do certain mesoscale models work better in different scenarios?

Weather and Radar Processor (WARP) Base Reflectivity Radar Mosaic (BRRM) Algorithms (Contributor: Porter)

The Unisys/WARP anomalous propagation and ground clutter algorithms will be evaluated to determine the optimal setting of the techniques' adaptable parameters. The optimal setting of the parameters may be a function of weather regime and geographical location.

Physical Process Studies in Support of SPC Forecast Tool Development (Contributors: CIMMS Scientists at SPC)

Studies involving CIMMS scientists will focus on mesoscale and synoptic scale systems that cause "extreme" events involving severe weather, heavy rains or flash floods, heavy freezing rain, heavy snow, or the rapid spread of wildfires. Studies will also be undertaken relative to weather events in which one type of hazardous weather evolves into another type (e.g., severe weather evolving into heavy rains or flash floods) and in which systems involve multiple hazardous weather elements simultaneously.

Specific research efforts anticipated include investigations of cloud-to-ground and total lightning climatologies and the development of techniques to refine their prediction. Additional efforts are needed to improve understanding of convective initiation (both timing and location) to aid forecasts of severe convection and produce improved tornado and severe thunderstorm lead times. Better understanding of the physical processing governing the initial mode of deep convection and the processes governing the temporal evolution of convection are also essential to improved forecasts. Finally, all investigations will include efforts to create and exploit synergies between the forecast and research communities. Advances made in the fundamental understanding of the processes governing mesoscale weather systems obtained through the research described above will then allow SPC scientists to effectively develop tools and techniques to help forecasters make needed decisions.

3. Climatic Effects of/Controls on Mesoscale Processes

Progress – FY01

Atmospheric Radiation Measurement (ARM) Program of the U.S. Department of Energy (Contributors: Lamb, Peppler, Bahrmann, Sonntag, Dean, Kogan, Richardson)

For almost 10 years, CIMMS has played a pivotal role in the Atmospheric Radiation Measurement (ARM) Program of the U.S. Department of Energy. The ARM Program is part of the U.S. effort concerning "global warming" -- it has the "ultimate goal of improving the parameterizations of clouds and radiation used in climate models" that are being employed to anticipate global and regional climate for the coming decades. This climate model improvement is heavily dependent on measurements of the atmosphere and earth's surface being made across three large regions -- the Southern Great Plains, the Tropical Western Pacific Ocean, and the North Slope of Alaska and adjacent Artic Ocean.

Since April 1992, CIMMS has played the role of "Site Scientist" for the Southern Great Plains ARM Site. This involves (1) provision of scientific guidance for site operations, (2) conducting a substantial research program that uses observations from the site and feeds back to enhance the effectiveness of the site, and (3) providing educational outreach across the K-12 levels to approximately 200 schools in Oklahoma and south-central Kansas. The educational outreach component is performed by the Oklahoma Climatological Survey. Because of CIMMS' superior performance in this Site Scientist role, it was chosen in 2000 to also house the new Data Quality Office for the entire ARM effort, involving the data from all three ARM sites. Two CIMMS scientists also act as "Instrument Mentors" for particular suites of instruments at the ARM sites.

ARM SGP Site Scientist Team activity also includes participation in Intensive Observational Periods (IOPs) conducted at or near the Central Facility site. During the past year CIMMS participated in many of these multi agency IOPs, including the ARM-FIRE Water Vapor Experiment in November-December 2000 and the EOS MOPITT Validation Exercise (MOVE) Campaign. In addition, a CIMMS Scientist spent significant time at the Central Facility providing SGP Site Operations personnel with scientific support for the operation of the site. This scientist also participated in field site inspection visits as part of the Continuous Quality Improvement Program (CQIP). The CQIP is a field inspection program designed to routinely evaluate collection sites from the scientific, engineering, operational, and safety perspectives.

CIMMS involvement in the international ARM Program has produced many scientific journal papers, a number of M.Sc. Theses and Ph.D. Dissertations, national and international recognition for a growing number of faculty, scientists, and graduate students, and exposure of K-12 students to data and results from a cutting edge global warming project. Funding from the U.S. Department of Energy for 1992-2004 will approach $7.5 million. This ARM effort has been an important contributor to the impressive strengthening of the total OU Meteorology Program.

ARM Program Data Quality Office (Contributors: Peppler, Sonntag, Dean, Bahrmann)

The ARM Data Quality Office was established at CIMMS in July 2000 with staff hired in July 2000 and January 2001, respectively. The office has the responsibility to:

- Develop and implement a process to systematically inspect and assess all ARM datastreams, including those from the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska sites;
- Comprehensively inspect and assess ARM datastreams for quality (this activity is done in coordination with ARM Program instrument mentors and site scientists);
- Transmit quality assessment results to site operators in a timely manner so that corrective maintenance and troubleshooting can be accomplished quickly, reducing the amount of unacceptable data collected (done in coordination with instrument mentors and site scientists);
- Transmit quality assessment results to data users in a reasonable fashion so that they may make informed decisions when using ARM data in their research;
- Ensure that documentation (now web-based) about ARM data quality is available and useful to all; and
- Participate in discussions relevant to furthering the ARM data quality program.

Activity has occurred to date in all six categories, though the prime thrust of the past year has come within the first responsibility, and has involved creation of the process (system) with which to inspect and assess ARM datastreams. It is web-based and can be seen for the Southern Great Plains site at http://r1.sgp.arm.gov/~sgpdq/QCNEW/home.html.

North Atlantic Climate Variability on Different Timescales (Contributors: Portis, El Hamly, Lamb)

The North Atlantic Oscillation (NAO) is a robust regional circulation pattern with a very important location in the climate system. It occurs over major oceanic gyres that are linked to the thermohaline circulation that affects global climate. There is evidence that the NAO plays a significant role in capping or intensifying the convection within these gyres through advection of Arctic sea ice, the advection of waters into the gyres of different salinity and temperature, or in-situ precipitation. The NAO also has a significant impact on regional precipitation patterns over northern Europe and northwest Africa. Since 1994, our research group has investigated in depth the NAO control on Moroccan precipitation that maximizes over the northwest and southwest regions of the country during winter. One of our primary objectives was to generate seasonal precipitation forecasts for Moroccan officials so that they could make better socio-economic decisions.

Understanding the temporal and timescale behavior of the NAO signal is essential for developing its predictive capability. We have investigated the NAO signal over seasonal, intraseasonal, decadal and century timescales. Since there is a seasonal migration of the centers of actions of the NAO, we developed a "mobile" index. As measured by the new "mobile" index (NAOm), the NAO maintains its intensity from winter-to-summer to a greater degree than has been indicated by traditional NAO indices based on fixed stations in the eastern North Atlantic.

Monthly hemispheric teleconnection maps show that the broader associations of the NAO, particularly over the western North Atlantic and eastern North America, are more apparent during spring-summer-autumn when the new NAOm index is used. This NAOm has enabled us to study the coupling between the seasons in the evolution of the NAO on intraseasonal and decadal timescales. We believe that this is an important key to understanding the climatic forces behind the NAO on different timescales and to developing predictive capability.

Over the past year, our work on the behavior of the NAO signal on different timescales has had international exposure. We have had one paper published, another one submitted, and have made three poster presentations at the Chapman Conference on the NAO that was held in Spain. Currently, we are working on a comprehensive paper detailing all of our work in this area.

North Atlantic Storm Track Variability and Associations with Monthly Regional Climate Variations (Contributors: Portis, El Hamly, Lamb)

Fifty-two years (1948-99) of reanalysis products and other data (e.g., NAO) was used to document North Atlantic winter storm track variability (October-March) and its associations with monthly regional climate variations. Cyclone counts were estimated by Serreze's cyclone detection and tracking algorithm using 6-hourly NCEP/NCAR reanalysis sea level pressure (SLP) fields. The study domain extended over the Atlantic basin from 20°N to 72°N, and from 80°W to 0°. The first step in our analysis was the construction of a cyclone track density field (CDF) for the study domain. The CDF field was designed to provide a description of the storm tracks on time scales of two weeks and longer, rather than to describe the movement of individual cyclones

The principal modes of North Atlantic winter storm track variability were identified from a rotated principal component analysis of the CDF field. The cyclone behavior over the North Atlantic can be classified into six major regime patterns; corresponding to the positive and negative amplitude excursions of each of the first three rotated principal components. These patterns were found to be dynamically consistent with the anomaly fields of SLP and 500hPa height. The centers of action for the first rotated principal component (RPC1) have the closest location to the Icelandic low and the Azores high. RPC1-based composite differences of SLPA and CDFA resemble a strong positive NAO. RPC2-based composite differences of SLPA and CDFA resemble a negative phase of the NAO with the southward migration of the NAO centers. It is the positive pattern of this regime that brings the most cyclones into the Iberian Peninsula and Morocco. RPC3-based composite differences of SLPA and CDFA show that this is a very dry pattern for Europe. The linkage between the NAO and these CDF patterns was further investigated by spatial correlation of these patterns with the NAO index and composites of the CDF patterns during extreme phases of the NAO.

Investigation of Temporal and Spatial Variations of Broadband Surface Albedo across the ARM Southern Great Plains Area (Contributors: Duchon and Hamm)

Surface albedos have been calculated for days of little or no detectable cloud cover using data obtained from six ARM Program SGP extended facilities (EFs). [The six locations were previously selected from all radiometer-equipped EFs to be the most representative of their surroundings.] Plots have been prepared showing the diurnal variations of clear-sky albedo for the six sites over the 2-year period of study. Additional plots have been prepared showing seasonal variations of clear-sky albedo. Dependence of clear-sky albedo on antecedent rainfall has also been studied. Current work includes a climatological study of daily surface albedo for all radiometer-equipped EFs. Software is currently being developed to facilitate this study.

Soil Moisture from the Oklahoma 'Moistnet' (Contributors: Bahrmann, Lamb, Crawford, Starks)

Coordination continued at OU and the University of Idaho between the ARM, USDA/ARS, and Oklahoma Mesonet soil moisture measurement networks regarding calibration and validation efforts. The development of a second-generation calibration technique to address sensor limitations under wet conditions led to a major reprocessing effort on the archived ARM soil moisture data.

A manuscript entitled “Spatiotemporal Variations in Soil Water: First Results from the ARM SGP CART Network” is being composed. This manuscript provides a description of the ARM soil moisture (“SWATS”) sensors and network, outlines calibration issues, and discusses representative time series from the first three years of operation. Of special interest are periods of drying in spring and summer and subsequent cool season recharge of soil water.

Characteristics of the Kiremt (June-September) Rainy Season in Ethiopia (Tessema and Lamb)

One of the most important steps in investigating the characteristics of the main rainy season of Ethiopia is developing a unique research-quality database. Starting with a trip to Ethiopia in June 2000, we have collected and computerized daily rainfall data for 120 stations that have 13 to 50 years of observations, and 25 years of daily upper-air soundings for Addis Ababa. This database, the first of its kind for Ethiopia, was extensively quality controlled through visual inspections and computerized program checks.

The next major accomplishment was the objective determination of the start and end times of the rainy season of Ethiopia based on daily rainfall of 120 stations. In addition, we have objectively determined the 'breaks' of the summer rains. These objective analyses have provided not only the climatology of onset, cessation and breaks, but also enabled us to investigate the interannual variability of rainfall, and specifically the characteristics and causes of droughts in Ethiopia. In this regard we have made a preliminary investigation to understand the causes of the extreme drought of 1984, one of the most severe droughts of Ethiopia.

SuomiNet Efforts in the U.S. Southern Great Plains (Contributors: Peppler, Ahern, Carr, Droegemeier)

SuomiNet is a university-based, real-time, national network of Global Positioning System (GPS) installations established in 2000 for geosciences research and education, with funding from the National Science Foundation and cost sharing from collaborating universities. The network exploits the ability of ground-based GPS receivers to make atmospheric measurements, including integrated water vapor. OU, in partnership with the U.S. DOE ARM Program, has participated during the past year in the establishment of geodetic quality SuomiNet receivers at 15 ARM Southern Great Plains extended facilities located throughout Oklahoma and Kansas and at the Norman Oklahoma Mesonet weather station in central Oklahoma. Data collection has begun at some locations.

Plans – FY02

Use of the ECHAM5 GCM for Regional Climate Modeling (Contributor: Lamb)

CIMMS wishes to pursue additional climate research and applications over the next several years that will in particular involve work with the imminent ECHAM5 GCM from the Max-Planck Institut für Meteorologie (MPIM), including nesting the CAPS regional scale model (ARPS) within ECHAM5 to address regional climate issues. The ECHAM5 GCM would be ported to and operate on an OU supercomputing system. On the basis of preliminary discussions with MPIM, we expect this will be collaborative between our institutes. This collaboration will likely include MPIM sending a sequence of Visiting Scientists to CIMMS for periods of 1-2 years per person. The collaboration has also been extended to involve a large multinational company (Williams, Inc.) that is interested in using ECHAM5 to guide its season-to-season planning and operations.

Role of Tropical Atlantic Ocean in West African and North Atlantic Climate Variability (Contributor: Lamb)

The response of the Atlantic Ocean to ENSO (El Niño/Southern Oscillation) is currently an important theme for the developing international Climate Variability and Predictability (CLIVAR) Program. The subsequent response of the Atlantic-North Africa climate system, especially in terms of the finer fabric of climate, such as changes in weather events, is a further important theme, establishing the science that will lead to societal applications of the CLIVAR program. This project will deal with both of these themes following on from previous findings by CIMMS and other researchers that suggest the problems posed here are tractable. The focus is on a particular period in the annual cycle and for two particular regions – subtropical Northwest Africa in March-April and West Africa in May-October. The research will be conducted through analysis of a range of data sets and model simulations. Daily rainfall data sets for West Africa and Morocco will be used in conjunction with the reanalysis data sets, outgoing longwave radiation, global sea-surface temperature (SST), and the PIRATA moored array in the tropical Atlantic. Diagnostic findings will be supported and further investigated through a set of targeted modeling experiments. The ECHAM5 GCM will be used to study the large-scale response of the atmosphere to SST in selected years, while the ARPS Limited Area Model (LAM) will be nested within the ECHAM5 to investigate the extent to which the finer fabric of the climate anomalies (e.g. changes in weather system frequency) can be simulated by the models, and to investigate details such as how SST modifies the moisture fluxes feeding to individual weather systems. The ARPS model has already been successfully nested in the ECHAM4 GCM in house at CIMMS.

Atmospheric Radiation Measurement (ARM) Program of the U.S. Department of Energy (Contributors: Lamb, Bahrmann, Richardson)

Funding from the ARM Program has been received for three more years, taking us out to our 12th year of involvement in the program. Immediate plans call for the hiring of an additional site scientist to perform scientific support for site operations at our Lamont, OK, central facility and research on instrument-specific issues.

Instrument mentoring activities within the Site Scientist Team at CIMMS will also continue for chilled mirror hygrometers and the soil water and temperature system. Mentors are charged with deploying, maintaining, and improving instrument systems, and assuring the quality of the data from them.

The absolute accuracy of Vaisala radiosondes used in the ARM Program is being examined by CIMMS and Argonne National Laboratory to ensure that accurate estimates of column water vapor can be obtained. A more detailed analysis of radiosonde accuracy is needed and will be conducted during the next two years. This analysis will include the dual sonde launches that have occurred at the ARM Central Facility during intensive observation periods, and comparison of surface sonde measurements with highly accurate surface measurements of temperature and relative humidity. This research may result in a procedure that can be used to scale the sonde relative humidity over the entire vertical profile based on a surface reference point (the temperature measurements from the sondes have proven very accurate, so a temperature scaling will not be necessary).

The SGP site scientist team at CIMMS will also continue to provide support for quicklook (visual aid) development on SGP data streams as part of its routine duties. Scientists from Argonne National Laboratory, the University of Utah, Eastern Illinois University, and OU have received NSF funding related to ARM quicklooks. The goal of the project is to use near-real time visualization of atmospheric data and the associated visualization code as a collection for the National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL)-Atmospheric Visualization Collection, and as a research training ground for students. CIMMS is involved in this project as a programming and scientific consultant on ARM instrumentation and associated data streams. The initial funding is for two years and began in late 2000. This project will represent a new aspect for ARM quicklooks and educational outreach, and help ARM meet its needs for providing real time quicklooks. A highly popular web site has been developed and is continually being augmented with new visuals.

ARM Program Data Quality Office (Contributors: Peppler, Sonntag, Dean, Bahrmann)

Work in the next year will focus on extending the newly developed system for comprehensively inspecting and assessing Southern Great Plains datastreams to the Tropical Western Pacific and North Slope of Alaska data collection sites. Once completed, we will take a new look at how data values are flagged in present automated algorithms with the goal of improving them. Methods of looking at longer time series of data will also be explored, with the goal of automatically detecting instrument degradation and calibration drift. The improvement of documentation will be a prime focus of the next year as well.

North Atlantic Climate Variability on Different Timescales (Contributors: Portis, El Hamly, Lamb)

Submission of the comprehensive NAO paper summarizing all of our NAO work on different timescales is forthcoming. This paper will explore the NAO signal in the context of the entire calendar year to see if there is a cohesive signal among the months on different timescales. In the case of decadal variability, this paper hopes to shed some light on a recent debate surrounding the NAO - is its decadal variability just an integration of the stochastic variability of the atmosphere, or are other climatic factors involved (e.g., the ocean and the cryosphere)?

North Atlantic Storm Track Variability and Associations with Monthly Regional Climate Variations (Contributors: Portis, El Hamly, Lamb)

We plan to participate in the Arctic Oscillation (AO)/NAO session at the American Geophysical Union fall meeting 10-14 December 2001 in San Francisco, California. For this meeting, Mr. El Hamly will build on his past research by investigating the linkage of the AO to the storm track variability of the Atlantic Basin. He will also use this research on the winter storm track variability over the North Atlantic for his doctoral thesis.

Investigation of Temporal and Spatial Variations of Broadband Surface Albedo across the ARM Southern Great Plains Area (Contributors: Duchon and Hamm)

Future work includes continuing analysis of the spatial and temporal gradients of clear-sky albedo to better determine their dependence on precipitation, soil moisture, and vegetation cover. In addition, the climatological study of daily surface albedo for our six primary sites will be used to verify satellite estimates of broadband surface albedo using the AVHRR radiometer. Completion of this work will result in a M.Sc. thesis in meteorology and serve as the basis for a journal manuscript.

Characteristics of the Kiremt (June-September) Rainy Season in Ethiopia (Tessema and Lamb)

This research will be finalized with a comprehensive investigation of the interannual variability of the onset, cessation, and breaks of the principal Ethiopian rainfall season in association with local upper air soundings and global atmospheric and oceanic circulation patterns. The results of the study are expected to be published in a major journal.

Accuracy of Atoll Rainfall Measurements (Contributor: Morrissey)

Rainfall and its associated processes are important for the balances involved in the global climate system. In situ measurements of rainfall in the tropical Pacific are almost exclusively made from islands. It is clear that islands with imposing terrain strongly affect local meteorological conditions, and that the rainfall amounts measured on those islands are not representative of open ocean conditions. Less clear is the representativeness of rainfall measurements taken on atolls or islands with minimal terrain, where orographic lifting likely does not influence weather conditions. However, heating of shallow water in the lagoons encircling these islands and the resulting increased ocean-atmosphere heat flux (relative to the open ocean), plus the greater roughness of the island surface itself, may have an impact on the initiation of convection. If so, conditions over on the leeward side of the atoll may not be representative of conditions over the open ocean.

A combined rain gauge and radar study conducted by CIMMS is proposed to reveal whether there are variations in the weather and climate across atolls or islands and also to the leeward side of atolls. The Doppler-on-Wheels (DOW) radars would be transported by ship to an atoll such as Majuro (which has paved road around 180 degrees of the atoll ring), or other atolls in the tropical Pacific region of interest, to study precipitation systems and investigate if rain preferentially initiates on or near the atolls. In addition, a network of automatically recording rain gauges would be placed at roughly 30-degree intervals around the Majuro atoll (i.e., a total of approximately 12) to study whether, in a climatological sense, there is an enhancement of precipitation on different sides of the atoll having different wind regimes. The surface-based rain data and the radar data would also be compared with TRMM rainfall measurements.

SuomiNet Efforts in the U.S. Southern Great Plains (Contributors: Peppler, Ahern, Carr, Droegemeier)

The scientific applicability of the SuomiNet sites recent established within Oklahoma and Kansas will have several unique aspects. SuomiNet water vapor data will augment ARM's suite of water vapor measurements, which includes a GPS micronet centered on the site's central facility in northern Oklahoma, a number of microwave radiometers, a microwave profiler, a Raman lidar, an atmospheric emitted radiance interferometer, radiosondes, and various standard relative humidity devices located at ground level and on a 60-m tower. The ability to perform water vapor measurement intercomparison studies, conduct instrument development, and operate enhanced, short-term water vapor experiments over the region will be greatly enhanced by SuomiNet's dual-frequency GPS receivers. These high quality receivers, along with co-located surface meteorological data, will allow direct measurement of wet delay and, therefore, total slant-path water vapor between the surface and the satellites overhead. The average station spacing is 50-60 km, thus providing a meso-beta scale horizontal distribution of integrated precipitable water. One unique aspect of the ARM deployment will be the use of ruggedized laptop computers to collect the GPS data and push them to SuomiNet computers every 30 minutes using local Internet Service Providers (ISPs). The OU School of Meteorology and Center for the Analysis and Prediction of Storms (CAPS) will evaluate the potential of using the suite of water vapor measurements to improve the skill of numerical weather forecast models such as ARPS. Because these receivers were placed on geodetic-quality monuments drilled into bedrock, OU scientists in the School of Geology and Geophysics will use the position information provided by the GPS receivers to conduct plate tectonics studies.

4. Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

Progress – FY01

Mitigating Severe Weather Impacts on Society and the Civil Infrastructure (Contributor: Vieux)

Over the last 35 years, the costs of weather-related disasters have doubled or tripled each decade. Weather-related natural disasters alone have taken lives, damaged property, and produced other costs averaging at least $50 billion per year. The mid-continental U.S. from the Gulf coastal plains to Canada experience natural hazards related to severe storms every year. The May 3, 1999 tornado outbreaks in Oklahoma and Kansas, and numerous flood events, are potent examples of the hazards that severe storms pose to communities. The reported costs of such disasters are just a fraction of the actual costs, which include damages to natural resources, loss of landfill capacity, loss of wages, productivity, and threats to public health. The costs of natural hazards are projected to increase if steps are not taken to help communities reduce their vulnerability and prevent natural hazards from becoming natural disasters. These increasing costs are of great concern to government agencies, the private sector, and the public.

In response to a multitude of natural hazards and disasters, national focus is changing from reactive to proactive efforts to reduce impacts to society. For efforts ranging from learning the best methods of response to developing of mitigation measures, a venue was needed to bring together the diversity of stakeholder organizations, both public and private, to formulate strategies for improving the safety and well being of society so that a natural hazard does not become a disaster. Mitigation planning is an emerging industry requiring expertise ranging across scientific and engineering disciplines. As a start to research on these subjects, a symposium was held in spring 2001 in Tulsa, Oklahoma. It focused on weather-related disasters, bridging engineering and meteorological disciplines, to reduce societal impacts, loss of life, and property loss. This symposium addressed the issues of severe weather impacts on the civil infrastructure, best methods to mitigate disasters, and new technologies for prediction and dissemination of information and warnings. The ultimate goals of this symposium were to develop intervention strategies, identify challenges for the future, and determine how to proceed. Topics included floods, wind, drought and other severe impacts of weather and storms. Groups who planned this event include the Oklahoma Weather Center (of which CIMMS is part), the OU International Center for Natural Hazards and Disaster Research, and the OU School of Civil Engineering and Environmental Sciences, in collaboration with FEMA Project Impact, Tulsa Project Impact, the Oklahoma Department of Civil Emergency Management, the NWS, NSSL, and other local, state and federal agencies.

Plans – FY02

Regional Climate Impact Studies (Contributor: Lamb)

Recent years have dramatically reinforced that seasonal climate extremes can have profound societal and economic impacts, and, conversely, that climate information and predictions can be used for public good and economic advantage. Fortunately, 35 years of scientific discovery have provided understanding and methods needed to predict – several months in advance and with considerable confidence and accuracy – seasonal precipitation and temperature anomalies for some regions in some years. Further progress must and will occur as world demand for climate information and predictions increases.

During the next year and continuing throughout the period of the new cooperative agreement, CIMMS proposes to undertake focused research and development to underpin regional climate impact prediction capabilities for areas of 10^3 to 10^6 sq km. The goal of this effort will be the development and demonstration of complete, rigorously scientific technologies that connect regional climate predictions with socioeconomic impacts to facilitate formation of societal response strategies. It will draw on, integrate, and enhance expertise at three locations – OU (weather system observation and simulation; regional climate diagnostic and impact analysis and prediction; energy economics and policy; science and public policy); Texas A&M University (economic, environmental and natural resource, public health, hydrologic, and biophysical analysis and simulation; communications and public policy); and Scripps Institute of Oceanography (regional and global climate simulation, ocean-atmosphere interaction analysis and simulation; hydrologic impacts).

CIMMS will develop prediction capabilities for spatial extent, timing, and magnitude of regional climate impacts, to capitalize on improving capability to simulate and predict large-scale global climate system behavior. Its uniqueness will result from targeting specific demonstration regions to quantify crucial climate-environment-society linkages. These linkages extend from the global climate system through weather patterns to regional-scale climate anomalies, and on to environmental and biophysical impacts with societal consequences. We will establish these linkages through combined use of environmental, economic, and behavioral data, statistical techniques, and a suite of models. This will complement and assist operational climate prediction units emerging worldwide.

This focus is at the forefront of the U.S. Global Change Research Program (USGCRP). A U.S. National Assessment of the potential consequences of climate variability, mandated under the USGCRP, is now under review. CIMMS will develop the capability to routinely perform such a function in the future through interactions with public and private sector decision-makers, and so could act as a prime facilitator and coordinator of subsequent Assessments.

Elements of this project will start soon, as OU President David Boren has agreed to provide $1 million over the next five years to expand the Climate Research and Development done within CIMMS. This new money will support three positions -- a Climate Outreach Coordinator, who will be shared with the OU Institute for Energy Economics and Policy (IEEP); a post-doctoral scientist to statistically investigate the linkages between regional climate variability and energy demand/prices (also to be shared with IEEP); and another post-doctoral scientist to conduct experiments with the ECHAM 5 GCM (solely within CIMMS; as indicated above, probably with a person on loan from Max-Planck Institute). The initial effort will emphasize interactions between regional weather/climate and energy demand, availability and price. There will likely be significant involvement of the private sector. A major national workshop on this topic is being planned.

Societal Impacts and Interdisciplinary Research (Contributors: Doswell and Greene)

In collaboration with Prof. Scott Greene (OU Department of Geography), a project is being considered that will undertake one of several candidate projects aimed at assessing the societal impact of weather information. A graduate student has been identified and once the project is determined, a proposal will be written to seek funding support for this work.

5. Doppler Weather Radar Research and Development

Progress - FY01

C-Band (5.5 cm) Dual Linear Polarimetric/Doppler Radars for Weather and Weather Engineering Research (Contributors: Straka, Wicker, Ziegler)

During the past year most of the fabrication of the Shared Mobile Atmospheric Research and Teaching (SMART) radars was completed. Parts were obtained to construct the radar systems and the truck assemblies. A design upgrade replaced the older combination of high voltage power supply, pulse forming network, and vacuum relay with the newer integrated solid state modulator assembly, which will be required to ultimately add polarization. The radar parts included stabilized local oscillators (STALO), the SIGMET digital antenna controllers, and solid-state modulator assemblies for two radars. As of 30 June 2001, we and the other collaborating institutions completed two radar systems and two truck assemblies. Pedestals, transmitter cabinets, and generators were integrated to both trucks, and one of the radar systems was fully integrated to one of the truck assemblies.

Digital Ingest and Archive of WSR-88D Base Data as a Prototype for a National System and CRAFT: A Prototype for Accessing and Distributing WSR-88D Base Data (Contributors: Droegemeier et al.)

The CRAFT (OU CAPS collaboration with the NOAA Weather Partners) network of WSR-88D radars that deliver compressed Level II data via the Internet in real time has been expanded from 6 (i.e., the original radars located in and around Oklahoma) to 21, with 18 more radars to be added by the end of calendar year 2001. The National Climatic Data Center now is receiving and directly archiving, on its HDSS system, Level II data from these 21 radars, thus completely bypassing the legacy 8mm tape recording methodology. Indeed, CRAFT has been so successful as a prototype that 8 mm recording has been discontinued at 13 sites. The data archival rate at NCDC, which was approximately 65% based upon the 8 mm recording technology, is well above 95% under Project CRAFT.

Whereas efforts to date in Project CRAFT have focused mostly on the acquisition of data from the radars, attention now is being given to data dissemination via collaborative research partnerships with universities (UCLA, Washington, Penn State, Illinois), NOAA laboratories/operational centers (FSL, NCEP), and private companies (WeatherData, Baron Services). Initial work in data mining also has begun, with emphasis on establishing climatologies of and interrelationships among convective storm attributes (e.g., VIL, echo top, echo mass and area, motion). These early results are being used as a foundation for follow-on proposals to the National Science Foundation.

Meteorological Algorithm Recode (Contributor: Krause)

The Recode project has completed major deliverables this past year and worked on improvements to last year's deliverables. Last year, the Recode project provided the SCIT algorithms to the ROC Applications Branch. This year, working with NSSL on the vertical association task, we were able to improve and stabilize the algorithm, and it is now ready for additional testing and validation. The Recode project also coded, tested, and delivered the Tornado Detection Algorithm this year and is in the process of testing the Hail Detection Algorithm.

Open Systems Radar Product Generator - ORPG (Contributors: Adams, Burcham, Forren, Priegnitz, Thompson, Suppes, Jing, Ray)

The ORPG Project is a cooperative project between the NSSL and the Tri-Agency NEXRAD Program. We continued to support the implementation and testing of the ORPG software. Work over the past year focused on the communication area, supporting development and system testing, and documenting the ORPG software. Early in 2000, the manufacturer of the communication server for the ORPG went out of business. A replacement server was identified and software adjustments and extensive testing were required to incorporate the new hardware into the ORPG. Working closely with the NWS, extensive testing (integration and system level) was conducted. Software defects detected during testing and selected enhancements requested by the NWS were addressed during this period. Documentation of the software design and implementation went into full swing later in the period. Advanced technical training in operating systems, interconnectivity, and related areas required for ORPG deployment support readiness was completed as well. Development and implementation was completed of a unique training program that systematically prepares ROC hotline operations personnel to support worldwide fielding of the advanced open architecture radar product generator ORPG throughout the NEXRAD network.

NEXRAD Open Principal User Processor - OPUP (Contributors: Ciardi, Lakshmanan, Brogden, Kerr)

The OPUP team has developed additional capabilities for managing the interface with the WSR-88D Radar Product Generator (RPG) and displaying data. Several of the early display prototypes were redesigned to provide more functionality and ease of use.

Re-engineering has included the formation of regional weather hubs that took over responsibility for issuing weather warnings and terminal forecasts from the base weather units so that the base weather units could concentrate on providing mission-unique weather support. The OPUP will replace some of the PUPs currently in use throughout the Air Force Weather Agency (AFWA). While the old PUP could have only one dedicated telecom connection to a NEXRAD radar and had only one workstation, the OPUP can have dedicated connections to up to 20 radars and products can be displayed on multiple workstations over a local area network. The project began in late 1997 and is scheduled to finish in October 2003. In January 2000, the project shifted from a "waterfall" to a "spiral" development model to satisfy AFWA's requirement for earlier deployment.

The OPUP will be deployed in two phases, called Spiral I and Spiral II. Spiral I includes the deployment of four Large OPUP systems to AFWA's four regional weather hubs at Scott AFB, IL, Barksdale AFB, LA, Davis-Monthan AFB, AZ, and Shaw AFB, SC. Spiral I was completed 31 July 2000, on schedule. From July through March 2001, the OPUP project developed and then deployed an interim software release that added critical functionality to the OPUP system. The additional functionality included the ability to display radar cross-section products, improvements to alert processing, and the ability to dial multiple radars simultaneously. In January 2001, AFWA requested an additional Spiral I deployment to Yokota AB, Japan, by 31 August 2001. Deployment preparations were on schedule at the end of the reporting period.

Warning Decision Support System (WDSS) Integrated Information - WDSSII (Contributors: Lakshmanan, Cooper, Song, Bailor, Lynn, Vaughan)

CIMMS employees designed a visualization system that can interactively process, in real-time, 3D radar data from multiple sources, and integrate them together. It is known as the Warning Decision Support System (WDSS). The WDSS display software was modified from its early prototype and has been used to display reflectivity data mosaics from multiple radars, lightning data, and new algorithm outputs (including the Hail Detection Algorithm implementation with neural network output and the dual polarization Hydrometeor Classification Algorithm from the Cimarron radar). The display uses an earth-centric coordinate system and an automatically updating simulation time to manage the display. The 3-dimensional displays allow the user to interact with the radar data to display cross sections or CAPPIs from a volume of radar data. The ability to rapidly update the algorithm displays (after each elevation angle) was designed and developed. The algorithm outputs from each radar volume were also ingested and organized into a table that may be used to generate trends of each detection characteristic. These tables allow the user or algorithm developer to access to the time-varying characteristics for use in other applications. The WDSS visualization system also integrates maps and other Geographical Information Systems information such as Digital Elevation Maps (DEMs). We tested this system at the National Weather Service Forecast Office in Norman.

Compression of Radar Reflectivity Data (Contributor: Lakshmanan)

We designed a linear prediction algorithm along with a Huffman encoder to efficiently compress ('lossless' compression) radar reflectivity data.

Joint Polarization Experiment - JPOLE (Contributors: Schuur, Ryzhkov, Krause, Shen)

In the past year, work has progressed on planning for the Joint Polarization Experiment (JPOLE), which will serve as the first operational test of weather radar polarimetry. In preparation for the operational demonstration, which will be conducted as a multi-seasonal test and evaluation period (to begin in the spring of 2002) and an intensive observational period that will utilize the addition of numerous field facilities for the collection of verification data sets (to begin in the spring of 2003), prototype real-time polarimetric algorithms have been developed and supplied to operational forecasters at the Norman, OK NWS forecast office since the spring of 2001.

In addition to the operational demonstration, JPOLE will provide an opportunity to investigate many complementary hydrological and meteorological scientific objectives. As such, input on science objectives has been gathered from potential project PIs and work has begun on initial drafts of project operational and science overview documents.

Hydrometeor Classification Using Polarimetric Radar (Contributors: Ryzhkov, Schuur, Krause, Shen, Liu)

A real-time version of the hydrometeor classification algorithm based on polarimetric radar data was developed and tested during the spring/summer convective season of 2001. The current version of the real-time algorithm allows us to distinguish between different types of rain, rain/hail mixture, biological scatterers (insects and birds), and ground clutter (including anomalous propagation echoes). The output products (fields of different polarimetric variables and results of classification) are delivered on the regular basis to the Norman NWS forecast office.

Polarimetric Radar Developments (Contributors: Ryzhkov, Schuur, Melnikov, Giangrande, Godfrey, Krause, Shen)

Regular observations of rain with the Cimarron polarimetric radar combined with observations from conventional KTLX (central Oklahoma) NEXRAD radar, 2D-video-disdrometer, the ARS raingage micronetwork, and the Oklahoma Mesonet continued through the year. Analysis of simultaneous data showed that polarimetric rainfall algorithm gives about 1.5 to 2 times the reduction in the standard deviation of the estimate of the one-hour areal rain accumulation for the micronetwork region (40 by 30 km area). As documented by the 2D-video disdrometer, polarimetric rainfall estimation algorithm clearly outperforms the conventional method in the cases of hail contamination. Polarimetric data from the testbed WSR-88D radar have been collected for the first time. Some engineering and performance characteristics of the polarimetrically upgraded WSR-88D were evaluated using observational data.

Multiple PRF Dealiasing Algorithm – MPDA (Contributor: May)

The MPDA algorithm attempts to reduce range folding in velocity data by combining data from two or three PRFs for each elevation slice. The technique thus far has proven very useful, as it increases the amount of useful velocity data while decreasing dealiasing errors. The increase in useful data should improve the performance of other algorithms, such as the Tornado Detection Algorithm (TDA) and Mesocyclone Detection Algorithm (MDA). We have been to calculate range unfolding and dealiasing statistics for data collected using VCP44. VCP44 is a volume coverage pattern that uses 3 different PRFs to collect velocity data. The study has used different pairs of these 3 PRFs, as well as each PRF individually, to compare against the performance of the 3 PRFs together. Range unfolding statistics are based upon algorithm output of the number of range folded bins in the data. Dealiasing statistics were calculated for data gathered by scoring 3115 velocity images for dealiasing errors.

Plans - FY02

Phased Array Radar (Contributors: Many scientists and engineers at CIMMS and NSSL)

SPY-1 technology (U.S. Navy) will be tested and enhanced at NSSL with the vision of using this technology to potentially upgrade the WSR-88D radars. The Department of Defense has allocated $10 million for the project, which will create a testbed facility in Norman during its initial stage. SPY-1, a phased array radar, uses multiple beams and frequencies, controlled electronically, which allow it to scan the atmosphere six times faster than the WSR-88D. Phased array radar uses electronic scanning to quickly provide a full three-dimensional picture of the atmosphere, and it could ultimately allow weather forecasters to increase the average tornado warning lead time from the current 12 minutes to as much as 22 minutes. SPY-1 was originally developed by Lockheed Martin to support tactical operations aboard U.S. Navy ships.

C-Band (5.5 cm) Dual Linear Polarimetric/Doppler Radars for Weather and Weather Engineering Research (Contributors: Straka, Wicker, Ziegler)

The overall plans for the next year are to complete the Doppler radar fabrication process and support the initial field deployments of the SMART radars. A fire at the NSSL "balloon barn" on 3 July 2001 destroyed one of the SMART radar trucks. Through the use of NOAA and OU fire recovery funds, we are proceeding to replace the destroyed truck along with the radar pedestal, bed modifications, hydraulic leveling system, generator, and interior cab modifications including computers, computer racks, wiring, and communications. Fortunately, most of the other radar components were not yet installed on the destroyed truck and were also located off-site at Texas A&M University. These components will be integrated to the rebuilt truck when it is ready for final assembly. Simultaneously with fire recovery, the other SMART radar was completed and sent on its initial field deployment to Key West, Florida for CAMEX and KAMP, under the supervision of Professor Mike Biggerstaff of Texas A&M. Following from a pending NSF proposal led by Conrad Ziegler, the goal is to have both SMART radars ready to participate in the IHOP experiment planned for 13 May - 30 June 2002.

Digital Ingest and Archive of WSR-88D Base Data as a Prototype for a National System and CRAFT: A Prototype for Accessing and Distributing WSR-88D Base Data (Contributors: Droegemeier et al.)

The move toward full operational implementation of the CRAFT concept, using the national Abilene network as a foundation, was studied at a National Stakeholder's Workshop held in Boulder in February 2001 and organized jointly by CAPS and the UCAR Unidata Program. Recommendations from that workshop have been presented to the NWS Office of Science and Technology, and work continues in evaluating a variety of technical issues including the collection of networking latency statistics and plans for phased implementation with the ORPG. Further, alternative strategies to the use of Abilene are being explored, and cost-benefit analyses are underway.

***Meteorological Algorithm Recode** (Contributor: Krause)*

Testing of Hail Detection Algorithm recode will continue, with completion and delivery expected by 31 September 2001. This will conclude work on the project.

***Open Systems Radar Product Generator - ORPG** (Contributors: Adams, Burcham, Forren, Priegnitz, Thompson, Suppes, Jing, Ray)*

Support for the system and beta testing of the ORPG project being conducted at the ROC will continue through October. Completion of the administration of new technology training for NEXRAD hotline operations staff will occur. Completion of the software documentation will also take place over the same time period, completing this long-term project.

Critical communications and configuration databases will be updated and cross-checked as legacy display and analysis equipment is deactivated at NEXRAD field sites throughout the radar network. Expertise on optimum use of new system capabilities will be developed and shared for filtering non-precipitation returns with field sites throughout the radar network. Assistance will be given to field sites regarding both the legacy and newly installed computing architectures and radar systems.

***NEXRAD Open System Principal User Processor - OPUP** (Contributors: Ciardi, Lakshmanan, Brogden, Kerr)*

The remaining Graphical User Interface (GUI) screens will be developed and tested prior to transfer of the code to the Radar Operations Center.

As previously stated, the OPUP will be deployed in two phases, called Spiral I and Spiral II. Spiral I was completed on 31 July 2000. During the upcoming period, the ROC and NSSL will continue development of Spiral II software functionality and hardware integration. The major challenge facing the project is to integrate OPUP with the AFWA's Operational Weather Squadron (OWS) Production System (OPS). Spiral II software coding is expected to be completed in May 2002. At the end of the next reporting period, the OPUP should be undergoing rigorous system testing.

Warning Decision Support System (WDSS) Integrated Information - WDSSII (Contributors: Lakshmanan, Cooper, Song, Bailor, Lynn, Vaughan)

Several additional display capabilities will be developed to extend the algorithm development and evaluation capabilities. The ability to visualize the radar volume will be improved and will provide the user/developer with a friendlier interface. The 3-dimensional display interface will also be improved to provide a more friendly display system. The team will also develop the capability to display other data sources (surface observations, satellite data, and model data) and integrate these with the radar and GIS information already being visualized.

Joint Polarization Experiment - JPOLE (Contributors: Schuur, Ryzhkov, Krause, Shen)

A second JPOLE planning meeting is scheduled for October 2001. After the meeting, operational and science overview documents will be completed. Work will also begin to secure funding for the field phase of the JPOLE project, plan logistics of instrument deployment, and develop web-based capabilities for sharing real-time polarimetric products.

Hydrometeor Classification Using Polarimetric Radar (Contributors: Ryzhkov, Schuur, Krause, Shen, Liu)

Fine-tuning of the real-time classification algorithm will be performed on the basis of regular polarimetric radar observations. Winter precipitation (dry/wet snow) will be added to the list of classes for real-time discrimination.

Polarimetric Radar Developments (Contributors: Ryzhkov, Schuur, Melnikov, Giangrande, Godfrey, Krause, Shen)

We will continue to collect regular observations of rainfall with polarimetric and conventional radar and make comparisons with different sources of ground-truth information. We will also continue to develop real-time versions of the polarimetric rainfall estimation algorithm and display. Work will include an examination of the range effects on the performance of the rainfall polarimetric algorithm. We also plan to complete polarimetric upgrade of the testbed WSR-88D radar and evaluate the quality of polarimetric measurements with the data processor in a full-fledged mode of operation.

Multiple PRF Dealiasing Algorithm – MPDA (Contributor: May)

We plan to continue work with MPDA, analyzing the performance of kinematic algorithms with MDPA data. Data for this portion of the project will come from a comparison of TDA performance using MPDA data to TDA performance using standard data from the KTLX radar in central Oklahoma, both for 3 May 1999. We are also in the process of gathering more MPDA data using the KCRI radar, and when such data become available, more analysis will be done.

Snow Accumulation Algorithm – SAA (Contributor: May)

Work is planned for the Snow Accumulation Algorithm (SAA). A new set of adaptable parameters has been calculated for the Reno, NV radar, KRGX. We will be comparing accumulation totals for the 1-hour, 3-hour, and storm total products against gage measurements for several sites around the radar. It is anticipated that these new parameters will improve the performance of the SAA.

6. Climate Change Monitoring and Detection

Progress – FY01

Implementation of the U.S. Climate Reference Network - CRN (Contributor: Duchon)

The purpose of this project was to advise Climate Reference Network (CRN) management on station design and development. In addition, advice was provided to NCAR on the design, execution, and analysis of data collected in the Snow Gauge and Wind Shield Evaluation Studies conducted during winter 2000-2001 at NCAR's Marshall field site south of Boulder, CO. Data were collected from 10 all-snow events and 3 rain-snow events. The final report provided a comparison of snow accumulations from each event for 6 different wind shields that included use of heated gauges and an analysis of gauge performance. The report was submitted to project management on 17 July 2001.

Other Contributions to the U.S. Climate Reference Network (Contributor: Duchon)

The purpose of this work is to provide continuing advice to the CRN management on station development, particularly with issues associated with the measurement of precipitation. Included in this contribution is input relevant to (a) final selection of wind shield types for snow and rain, (b) determination of which stations should have only a snow shield and which should have only a rain shield, (c) selection of a backup precipitation gauge and which stations should have a backup gauge, and (d) the selection of locations for paired CRN stations. This work is coordinated with NOAA/NESDIS/NCDC and the NOAA Atmospheric Turbulence and Diffusion Division (ATDD), Oak Ridge, TN.

Plans – FY02

Research Collaborations with the National Climatic Data Center – NCDC (Contributors: Lamb and NCDC)

The goal of this new CIMMS 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 climate change questions, including those stemming from the Intergovernmental Panel on Climate Change (IPCC) process. This work will be done in collaboration with NESDIS and its National Climatic Data Center (NCDC) in Asheville, North Carolina. Specific projects will include:

- <u>Radar Precipitation Detection</u>. Work will be done on radar climate precipitation that puts radar-derived precipitation into historical perspective, thereby making it possible to use this information for real-time climate monitoring.
- <u>Improved Monitoring</u>. Improved quality control procedures will be developed that merge satellite, radar, and in situ information to improve final climate monitoring capabilities over what might be derived from each of these data sources alone.
- <u>Wind Climatology</u>. A wind climatology will be developed suitable for putting real-time ASOS winds into historical perspective, thereby making ASOS data useful for climate monitoring.

- Lightning Climatology. A lightning climatology will be developed to help make lightning network data useful for climate monitoring and to set individual events into historical perspective.
- Quality Control Using Climate Reference Stations. An improved quality control approach will be developed that properly utilizes the highly reliable Climate Reference Station data in the quality control of nearby cooperative stations.
- Storm Climatology. Storm climatologies and climate monitoring capabilities will be developed that will help answer a key set of lingering questions – for example, has there been a change in number, climatology, or intensity of nor-easters or Arctic clippers?
- Quality Control of Historical Climate Data. Systems will be developed for performing a high level of quality control (including temporal, spatial, and complex elemental relationships) for data that have been recovered via the NOAA Data Rescue Program and the Climate Database Modernization Program.

Verification of Satellite-Based Rainfall Algorithms for the Global Precipitation Climatology Project: The Surface Reference Data Center (Contributor: Morrissey)

The Surface Reference Data Center (SRDC) is expected to continue operation over the next several years. The SRDC is a raingauge database that is expanding throughout the tropical Pacific. It is used as ground truth for satellite-based rainfall algorithms and constitutes a long-term climate-observing network in the Pacific.

As the SRDC begins to use data from a wider range of sources, it is becoming more difficult to work with the various formats. Goals for the next few years include the design of data ingest and analysis procedures that are modular. This will ensure that individual components can be changed easily without impacting other procedures. This will also allow new data sets and analysis procedures to be integrated in a "plug-and-play" fashion. Sustainability is another goal; the system should be robust and simple enough that anyone can maintain it with a minimal amount of instruction. Data integrity and security are also important concerns. These goals will be accomplished with the implementation of a new database management system.

III. PUBLIC AFFAIRS AND OUTREACH

ARM Program Educational Outreach (Contributors: Melvin, Kloessel, Bahrmann)

During the past eight years, the Oklahoma Climatological Survey (OCS) has established a solid infrastructure for atmospheric science education, primarily at the pre-college (K-12) level, with the support of the U.S. DOE ARM Program. Environmental data, including those from the ARM Southern Great Plains site in Oklahoma and Kansas and the Oklahoma Mesonet, are available to educators who have web access (http://outreach.ocs.ou.edu/arm/). Unique display software has been developed to provide student interactivity with the data. Reference materials and lessons are online and in printed form to aid the educator in the application of the data in the classroom. And, most importantly, master teachers have been educated to understand and use the data in their activities. These master teachers represent a significant resource to provide workshop instruction to additional K-12 teachers.

As the OCS continues to upgrade this infrastructure, the primary goal of the next several years of the ARM SGP outreach program will be to expand the awareness and use of this infrastructure across not only Oklahoma and Kansas, but also across the entire nation. To this end, we will enhance our Web pages by including more data types, display types, and with help from the ARM Program, data from the ARM Tropical Western Pacific and North Slope of Alaska locales. We will conduct workshops at local schools in Oklahoma and Kansas and at appropriate educational conventions, using several of our current master teachers as instructors. In concert with the Oklahoma EPSCoR program, we will offer instruction to faculty at Oklahoma's two- and four-year colleges so that they can include ARM/OCS materials in the courses they offer to pre-service teachers. We will produce newsletters, conduct science fairs, and give conference presentations that help publicize the availability of the data and materials to educators.

In addition, we will continue to develop scientifically accurate reference materials and pedagogically sound teaching lessons, placing them online and producing them in print. We will enhance our software to allow the overlay of data from different networks, such as ARM's extended facility stations, Oklahoma Mesonet sites, and National Weather Service ASOS, satellite, and NIDS networks.

Workshops on Regional Climate Prediction and Applications (Contributor: Lamb)

This workshop series was initiated by CIMMS in 1999-2000 and will continue through the next several years. The workshops are intended to improve the capabilities of national meteorological services (NMSs) in developing nations in the following respects – to understand the behavior of the global climate system; to use such understanding to develop or adapt seasonal climate (especially rainfall) prediction schemes for their countries; and to work with other professionals in their countries to apply the prediction schemes in the management of agricultural production, water resources, energy generation and consumption, and public health. The need for these Workshops emerged from NMS leaders of many developing nations recognizing that their organizations did not possess the expertise to capitalize on the seasonal prediction and application opportunities offered by the 1997-98 El Niño.

Workshops are held at the OU College of Continuing Education, with the primary financial sponsorship of the International Activities Office of the U.S. National Weather Service, and additional support from NOAA’s Office of Global Programs, the World Meteorological Organization, and other U.S. and international agencies. Each Workshop extends, on a full-time basis, for 6 weeks and has 12-20 participants. Lectures are given by the CIMMS Director, one or two additional Course Lecturers, and several Guest Lecturers. The participants develop small research projects using data from their country. The series is intended primarily for young NMS personnel who have received excellent training in basic meteorology at a University (B.Sc. level) or World Meteorological Organization Training School (Class II level), but who have limited exposure to the fundamental principles of modern climate dynamics and their application to economic management and other environmental and societal issues. Meteorologists who work outside their NMS (e.g., in regional meteorological centers like ACMAD and the DMCs, universities, other government agencies, or NGO's), but who have strong working relationships with the NMS, may also be accepted. Applications are particularly encouraged from meteorologists who have attended preliminary training workshops in climate prediction (e.g., the African Centre of Meteorological Applications for Development, ACMAD) or had other opportunities to acquire some basic knowledge of climate dynamics and its applications. These Workshops further develop the skills of such individuals, especially since substantial material is presented from the University of Oklahoma M.Sc. module in Climate Dynamics.

The First Workshop (late 1999) and Second Workshop (mid-2000) both focused on the Tropical Atlantic Basin and trained 25 meteorologists from the following nations in Africa, Central and South America, and the Caribbean – Mexico, El Salvador, Costa Rica (2), Barbados, Netherlands Antilles, Venezuela, Brazil (4), Paraguay, Argentina, Algeria, Morocco, Senegal, Ghana, Burkina Faso, Niger, Bénin, Nigeria, Chad, Cameroon, Congo, and Tanzania. The Third Workshop in mid-2001 dealt with the Tropical Pacific Islands and Rim, and had approximately 20 participants from Malaysia and Vietnam in the west, across the Pacific Islands to Ecuador and Chile in the east. Subsequent workshops in 2002 and later years will deal with the Circum-Indian Ocean Region and then return to the Tropical Atlantic Basin.

NOAA Weather Partners Educational Outreach (Contributors: Zaras, Tarp)

Throughout the year, outreach staff were involved with numerous activities related to making the public aware of the research and forecasting/warning activities of CIMMS and its NOAA Weather Partners:

- Gave tours to 1439 people. An additional 800+ attended the NOAA Weather Partners Open House
- Answered 550 email letters to the NSSL web site
- Answered 287 phone calls ranging from tour inquiries to questions about the weather to media interviews
- Assisted with NSSL/CIMMS exhibit at the American Meteorological Society's annual meeting in Albuquerque, NM in January 2001
- Assisted with Operation Warn at the Sooner Mall 14 April 2001
- Hosted six teachers from the Oklahoma City Schools for several days as part of an enrichment program.
- Mentored several high school and college students through a NOAA program called Practical Hands-On Applications to Science Education. The students transcribed all STEPS audio files from the mobile mesonet vehicles
- Updated the Resources for Weather and Climate Instruction document and copied onto disks for the National Science Teacher's Association Annual Meeting in St. Louis in March 2001. NSSL Director Jeff Kimpel spoke at the meeting
- Began (and spent considerable time on) the self-guided tour project for NSSL facility, where many CIMMS employees work. This involves communicating the breadth of NSSL's research, including joint CIMMS research projects, in pictures, text, and a narrated audio CD. Completion is expected in FY02.

'NSSL BRIEFINGS' Newsletter (Contributor: Cobb)

We continued our efforts to collect stories on CIMMS and NSSL research activities and publish this information in a periodic newsletter. This newsletter is sent to collaborators, funding agencies, managers in NOAA, and other relevant agencies.

NSF Research Experiences for Undergraduates (Contributor: Zaras, Schultz, Kay, Peppler)

A new proposal, with funding through 2003, was awarded to OU for the Research Experiences for Undergraduates (REU) program, funded by the National Science Foundation. A successful 10-week REU program was conducted during the summer of 2001 involving ten undergraduate students from across the U.S. Each student worked on a research project with an OU or NOAA investigator, wrote a substantial final paper, and made a conference-style presentation on his/her findings in early August. Recruitment for the summer 2002 REU Program will begin in early 2002. The search committee includes several CIMMS scientists. A large number of our REU alumni have received American Meteorological Society awards and fellowships.

IV. COMPUTER SUPPORT

Computer Support Activities Related to CIMMS at the NSSL (Contributor: Skaggs)

Computer support for CIMMS scientists at NSSL was reorganized during the past year. The various support functions were centralized into one group known as "Information and Technology Services" (ITS). This group is responsible for the management and administration of the computer network used by CIMMS scientists. This network consists of Linux-based systems, a significant number of Windows-based and Macintosh clients, and various networking systems.

CIMMS scientists worked with data users from Australia to help them solve problems converting Australian Doppler radar data to WSR-88D format and to coordinate NSSL algorithm installation for use during the 2000 Summer Olympics in Sidney. This also allowed CIMMS scientists to study convective weather systems outside of the U.S.

CIMMS and NSSL scientists have started development of an advanced data compression algorithm that will be used to compress data for transport on a developing testbed network of WSR-88D radar systems. This testbed has attracted the attention of the NWS as a potential avenue for reliably archiving WSR-88D data nationwide.

CIMMS computer support scientists also spent much time on "worm" and "virus" problems, and computer security in general. Time was spent not only on monitoring for these intrusions and securing computer systems against them, but also in rectifying actual problems and assessing potential data damage.

CIMMS scientists are also responsible for the maintenance and development of the NSSL website. This website is used to highlight research collaborations with CIMMS scientists as well as internal information relevant to all NOAA collaborators working at the NSSL facility.

Computer Support Activities Related to CIMMS at the SPC (Contributor: Liang)

We have improved the performance of the SPC operational NAWIPS workstation to better handle the larger, more fine grain data sets in a time critical operational environment.

With the new NFS server (NetApp F720) we were able to de-couple the compute server and the file/data server. This configuration allows SPC to upgrade the compute server with minimal impact to SPC data flow and research efforts.

Continual efforts were made to better monitor data flow and system status. The goal is to proactively maintain and repair any problems before they became obvious to the forecast staff and researchers.

With the rapid improvement and adaptation of the Linux distributions, we experimented Linux on several hardware platforms ranging from the entry level Pentiums to Pentium IVs with large memory space to evaluate the fitness of Linux systems in the SPC operations. We found some interesting results with which we are cooperating with hardware vendors to seek improvements/resolutions.

Plans include continual improvement of SPC data storage. We would like to improve robustness in data availability, file-serving speed in preparation for ever-increasing data size and higher network bandwidth.

Evaluation of the SPC data storage paradigm will continue. Since we started the new de-coupled data/compute paradigm last year, we like to find out how well it really worked and any further improvement we may make.

We like to design and implement a monitoring system to display, in near real time, the progress of the SPC products distribution. Currently, when a SPC product is sent, the progress of its distribution is not immediately known. With the progress monitor, we will be able to better pinpoint the cause of an unsuccessful product distribution. With such information, we may be able to correct the problem quicker or even prevent the problem to occur beforehand.

Computer Support Activities Related to CIMMS at the ROC (Contributor: Covey)

Efforts in licensing, property management, documentation, updating computers, installing servers, and computer networking have been undertaken. Documentation mainly involves the writing of procedures to perform a particular task correctly. Procedures include specific software installation processes, loading machines, preparing computers from scratch, using computer imaging software, and installing print drivers. Solution procedures are also documented.

Computer Support Activities Related to CIMMS at the NWS Southern Region Headquarters (Contributor: Grice)

A CIMMS scientist at NWS SRH is researching better ways to serve meteorological data and information to the public through the Internet. This research includes design of structured query language (SQL) databases and web-based interfaces to those databases.

V. PUBLICATIONS

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