INTRODUCTION

This report describes research funded in collaboration with NOAA's cooperative agreement and the CIRA Joint Institute concept for the period July 1, 2002 through June 30, 2003. In addition, we also included non-NOAA-funded research (for example, DoD-funded Geosciences, NASA-funded CloudSat and National Park Service Air Quality Research Division activities) to allow the reader a more complete understanding of CIRA's research context. These research activities are synergistic with the infrastructure and intellectual talent produced & used by both sides of the funded activities.

The research descriptions are designed to give the reader an overview of research topics with the details available in the Scientific Publication section. In the Scientific Publication section, we provide publication information from the beginning of the project which is often multi-year.

For further information on CIRA, please contact our web site:

http://www.cira.colostate.edu/

CIRA MISSION

The mission of the Institute is to conduct research in the atmospheric sciences of mutual benefit to NOAA, the University, the State and the Nation. The Institute strives to provide a center for cooperation in specified research program areas by scientists, staff and students, and to enhance the training of atmospheric scientists. Special effort is directed toward the transition of research results into practical applications in the weather and climate areas. In addition, multidisciplinary research programs are emphasized, and all university and NOAA organizational elements are invited to participate in CIRA's atmospheric research programs.

The Institute's research is concentrated in several theme areas that include global and regional climate, local and mesoscale weather forecasting and evaluation, applied cloud physics, applications of satellite observations, air quality and visibility, and societal and economic impacts, along with cross-cutting research areas of numerical modeling and education, training and outreach. In addition to CIRA's relationship with NOAA, the National Park Service also has an ongoing cooperation in air quality and visibility research that involves scientists from numerous disciplines; and the Center for Geosciences/Atmospheric Research based at CIRA is a long-term program sponsored by the Department of Defense.

CIRA VISION

CIRA's Vision is to improve interdisciplinary research in the atmospheric sciences by entraining skills beyond the meteorological disciplines, exploiting cutting-edge advances in engineering and computer science, facilitating transitional activity between pure and applied research, and assisting the Nation through the application of our research.

EMPLOYEE SUPPORT BY JOB TITLE

		FY02/03 Support							
		Bachelors		Masters		Ph.D.		Prof Cert/Other	
Job Title	Category Total	NOAA	Other	NOAA	Other	NOAA	Other	NOAA	Other
Director	1					1			
Deputy Director	1			1					
Associate Director	1					1			
Senior Manager	1			1					
Manager	1				1				
Associate Manager	1	1							
Asst. Manager for Human Resourc	1	1							
Administrative Support	7	1	2	2				1	1
Senior Research Scientists	4					3	1		
Research Scientists	20					10	10		
Research Associates	76	28	7	25	7	4	1	2	2
Coordinators	2	1	1						
Post Docs	12					12			
Student/Other Hourlies	32								32
Undergraduate Students	0								
Graduate Students	18	15	3						
Visiting Scientists	1						1		
TOTAL	179	47	13	29	8	31	13	3	35

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Thomas Vonder Haar (Chairperson)
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AWARDS

Recipient	Award
Thomas Vonder Haar	Election to the National Academy of Engineering
Stan Kidder	NOAA's Atmospheric Research and Applications Division Trainer of the Year Award
Shripad Deo	NOAA National Weather Service Certificate of Recognition for Phase II of the AHPS and IFPS WFO Web Structure
Ali Zimmerman, Maureen Murray and Lisa Gifford	NOAA's Forecast Systems Laboratory Annual Web Award - 2002
Ali Zimmerman	NOAA Forecast Systems Laboratory Employee of the Month – September 2002
Jim Frimel	NOAA's Forecast Systems Laboratory Employee of the Month – March 2003
Mark DeMaria, Debra Molenar, et al (CIRA Affiliated Scientists)	Department of Commerce Bronze Medal Award for Superior Federal Service for Implementation of a Critical Satellite Receiving Station in Central America as Part of the Hurricane Mitch Reconstruction Project
A. Scott Denning (CIRA Colleague)	Colorado State University Monfort Professor Award
Richard Johnson (CIRA Colleague)	National Science Foundation Special Creativity Award
Graeme Stephens (CIRA Colleague)	Fellow of the American Geophysical Union

Annual CIRA Research Initiative Award

This award recognizes outstanding research initiative or achievement by CIRA administrative professionals—individuals or groups. Nominations may be for single or multiple contributions/projects having taken place over the previous 3 years. Nominations may be submitted by any sponsoring agency manager or CSU/CIRA employee.

Dave Watson, Bernadette Connell and Hiro Gosden	2002 CIRA Research Initiative Award for Essential Support on the GOES Rainfall Auto Estimator. Coordination of Training, and Installation of GOES Satellite Receiving Station and Network Stations Throughout Central America As Part of the Hurricane Mitch Reconstruction Project
Gerald Browning	2002 CIRA Research Initiative Award for Inspiring Mentorship, Contributions to the NOAA Forecast Modeling Lab, Advanced Modeling Efforts and Pioneering Work in Numerical Modeling
Jim Frimel	2002 CIRA Research Initiative Award for Technical Leadership, Commitment, Productivity and Dedication Vital to the Recent Success of the FAA TMU Project
Roger Ames, Shawn McClure, Shuxin Yin and Bret Schichtel	2003 CIRA Research Initiative Award as VIEWS Team Members for Being Among CSU's Most Productive and Innovative Scientists and for Bringing Attention to the Cutting-edge Research on Which They Have Been Working
Cliff Matsumoto	2003 CIRA Research Initiative Award Acknowledging His Contributions to the Overall Research Environment at CIRA and Special Activities to Foster New Research With CIRA's Partners
Chris MacDermaid, Leslie Ewy, Paul Hamer, Bob Lipschutz, Glen Pankow, Richard Ryan and Amenda Stanley	2003 CIRA Research Initiative Award as Members of the ITS Data Systems Group for Being Among CSU's Most Productive and Innovative Scientists

CIRA HIGHLIGHTS
July 1, 2002 – June 30, 2003

Global and Regional Climate Dynamics

- Continued participation in the Global Air-ocean IN-situ System (GAINS) support included several demonstration test flights this past year. GAINS is a long-duration stratospheric platform, instrumented for environmental sensing through a combination of dropsondes, XBTs, and chemistry, particulate, in-situ, and remote sensors.

Mesoscale and Local Area Forecasting and Evaluation

- The results of the collaborative work with Canada's RPN and UCLA to ascertain the appropriate large-scale forcing that should be included in the hyperbolic system was incorporated into the Canadian operational global assimilation system and model. The reduction in the error relative to in-situ surface pressure and upper air data over North America can be seen on the Canadian website: www.msc-smc.ec.gc.ca/cmc/index_e.html

- The use of well posed and stable open boundary conditions for the multiscale system for oceanography has been demonstrated to be capable of recreating the flow in a limited area of a global basin similar to the atmospheric case. The multiscale system for the ocean appropriately reduces to the incompressible Navier-Stokes equations for smaller scales of motion and variants of the multiscale system are being used in a number of physical applications.

- Several new research collaborations on mesoscale studies were initiated this past year. One involved the analysis and modeling of bores detected during the IHOP field experiment during May – July 2003. Another effort involved the development of a new convective parameterization based on ensemble representation of convective closures combined with data assimilation techniques and climatological analysis. A third project is designed to assess how accurately the land surface schemes in atmospheric models can simulate runoffs and to identify and begin work on the research tasks necessary for operational hydrologic forecast capabilities to be fully integrated within atmospheric systems.

- A benchmark-testing package for evaluating various GPS tomography techniques was developed and distributed to various attendees at the GPS Meteorology Conference hosted by the Japan MRI this past January. Based on new results from associated 3DVAR research, a more general version of the GPS tomography software has been developed.

- The successful implementation of an integrated weather system, involving LAPS and a diabatically initialized MM5, at Vandenberg AFB (with Cape Canaveral to follow) leveraged government "off-the-shelf" technology to maintain an effective upgrade path between civilian and military weather agencies. Local data ingest (via AWIPS/LDAD), national and local data display (via AWIPS D2D), data assimilation (via LAPS), and NWP (via hot-started MM5) will provide a unique capability to enhance pre-and post-launch space vehicle launches and range safety operations.

- In support of the US Fire Consortia for Advanced Modeling of Meteorology and Smoke, CIRA researchers created one 12-km western US and two 4-km Rocky Mountain and Southwest region windows of LAPS and MM5 forecast runs on the iJet supercomputer to provide experimental real-time fields. Collaborating with the US Forest Service Rocky Mountain Research Station, the team created web displays of several fire weather indices, PBL mean wind, and an interactive point forecast.

- In perhaps the first quasi-operational implementation of the new WRF model and the first NWS-sanctioned local modeling effort, CIRA researchers participated in the Coastal Storms Initiative to perform a proof-of-concept for local data assimilation and NWP within a NWS Forecast Office (Jacksonville). With the first use of satellite and radar data for real-time WRF initialization, early results are promising.

Applications of Satellite Observations

- CIRA has installed a Data Processing and Error Analysis System (DPEAS) at NESDIS/OSDPD. This 8-node PC system is processing AMSU data and is demonstrating the use of PC to perform real-time satellite data processing for significantly lower cost than conventional methods.

- Began the analysis, using cross-sensor method of land microwave emissivity. This is the beginning of the validation of the NESDIS Microwave Land Emissivity Model (MEM).

- Developed a CD-ROM of over 60,000 IR images of Atlantic and Eastern Northern Pacific tropical storms. These data are being used for tropical storm research such as improvements in the Dvorak intensity estimation algorithm.

- Our development work on the CloudSat Data Processing Center has been recognized by NASA as an outstanding portion of the CloudSat mission. The significance of this to NOAA is that CIRA is building a prototype data system that has several unique attributes that could be incorporated in future NOAA/NESDIS mission support systems:

    - It ingests several different satellite platforms (the A-train) that includes AIRES, MODIS, Calypso, and CloudSat to build specific products.
    - It will provide not only CloudSat data to the science community, but the correlative data from these other sensor platforms, surface validation data, and analysis grids subsetted for the location and time of CloudSat overpasses.

Numerical Modeling

- In May of 2003, the CIRA RUC team participated in replacing the analysis scheme used in the operational 20km RUC (OI) at NCEP with a 3D variational method. Use of the 3DVAR package allows more efficient integration of additional observation data.

- An optimized configuration of the LAPS hot-start forecast system, coupled with the non-hydrostatic MM5 forecast model, was developed, tested and implemented operationally at Vandenberg AFB, CA. The configuration utilizes a triple-nested domain, with the domains having a grid spacing of 10 km, 3.3 km, and 1.1 km. This configuration has been installed on a Linux cluster coupled to the local data assimilation and forecast system at the western space launch facility. A similar configuration is being tested for the eastern range (Cape Canaveral).

- The WRF Standard Initialization package was significantly enhanced to better process various datasets required for the initialization of the WRF land surface packages. Additional flexibility was added to allow users to more easily use separate input datasets for the initial, lateral, and lower boundary conditions. Gridded fields that are on non-isobaric surfaces can also now be ingested. Mercator and Lambert FORTRAN map projection routines were simplified and standardized.

- Case study reruns of LAPS analyses and forecasts for the IHOP campaign have been performed for RAMS initialization. More detailed studies (high resolution of 50- or 100-m) are planned to investigate the interaction of surface heterogeneities and the LLJ.

- An experimental 10km WRF is being run over the TAQ (New England Temperature and Air Quality Program) domain and a 20km WRF is being run over the CONUS domain. The TAQ project incorporates a number of special observations, including boundary layer profilers, GPS precipitable water, radar reflectivity and Mesonet observations into a nested (10-km nest) model running out to 48 hours four times per day.

- Development of an operational ensemble forecast system, including several diverse regional forecast models such as NCEP's Eta and RSM, FSL's RUC, and NSSL's MM5, continued this past year. Each model is expected to provide five ensemble members. Thus far, an ensemble forecast system for the RUC has been developed and put into operation.

Cloud Physics

- During the past year, an algorithm for retrieving stratus cloud droplet liquid water flux due to gravitational settling using cloud radar reflectivities was developed. By computing the divergence of the flux, the cloud heating and cooling due to gravitational settling of cloud droplets can be estimated and compared with the calculated radiative cooling and heating.

Education, Training, and Outreach

- The GLOBE program initiated in 1995 continues to grow and now includes over 13,000 schools in 102 partner countries, with 23,000 teachers having attended GLOBE workshops and GLOBE students having reported data from 9.7 million measurements worldwide. Science protocols now include Atmosphere/Climate, Hydrology, Soil, Land Cover/Biology, Phenology, as well as several special observations such as hummingbird behavior, budburst, and lilac phenology.

- Our RAMM Team has conducted over 600 training sessions for over 11,000 students for the Virtual Institute for Satellite Integration Training. This program is a prototype for rapid technology transfer of University satellite research to the NWS operational field offices.

- Performance of the FX-Net system as an experimental fire weather forecaster workstation during the 2002 fire season was a resounding success. With the addition of a variety of new functionalities to the FX-Net client, including new fire weather products and new user-friendly tools, the system will support the National Interagency Fire Center and the Geographic Area Coordination Centers as an operational fire weather support platform during the 2003 fire season. FX-Net continues to support the AIRMAP Program, through the University of New Hampshire, that focuses on the long-term monitoring and forecasting of air quality parameters like nitrogen oxides, sulfur dioxide, carbon monoxide and low-level ozone.

- Conversion of the WFO-Advanced forecast system (core software for AWIPS) from Hewlett Packard Unix (HPUX) operating system to Linux has proceeded smoothly. The AWIPS radar data ingest capabilities were enhanced in anticipation of new radar volume scan strategies. Display of local lightning data was a significant addition to the workstation software in support of the space launch facilities at Vandenberg AFB and Cape Canaveral.

- Collaboration continued on the web dissemination component of LDAD known as the Internet-based Emergency Management Decision Support (EMDS) system. It is a web-based applet/application for use by a small number of state and local government users and/or a large number of public Internet users. During the past year, a surveillance capability within the EMDS was completed. The surveillance capability includes the ability to create derived grids and to monitor conditions within some distance of a point for the purpose of generating alerts if specified thresholds are exceeded.

- The PACE effort comprised of two separate investigative projects—the FX-Connect and the TMU projects—is examining innovative software and data products to help minimize adverse weather disruptions to air traffic operations over the US. Aviation data sets and forecast products specifically tailored for the ARTCC air traffic weather forecasting environment are being prototyped, along with investigation into the utilization of collaborative weather forecasting techniques. The initial phase of a four-phase project is designed to address the weather information needs of the TMU relating to the weather-related hazards of convection, icing, turbulence, and ceiling/visibility.

- The Advanced Computing group initiated an investigation into how grid technology can be utilized by the atmospheric and ocean research communities. The project's goal is to determine the feasibility of running a coupled model on the grid with one model, e.g., atmospheric, running on one machine and the other, e.g., ocean, running on a second machine at another facility.

- After successfully applying the wavelet transform data compression technique to satellite imagery, the wavelet compression technique, including a user-defined "precision control," was further modified to address 3-D gridded model fields. Early results with temperature fields indicate 2 to 6 times higher compression ratios compared to typical lossless codecs with the same precision requirements.

Societal and Economic Impacts

- Several research efforts in collaboration with the National Geophysical Data Center (NGDC) continued involving DMSP imagery, Geographical Information Systems (GIS) and other specialized remote sensing data manipulation and mapping techniques. These efforts included: 1) a project to show that coral reef bleaching can be detected with IKONOS satellite data using radiometric normalization of image pairs using difference-image processing techniques; 2) data processing of Landsat ETM imagery for use in analysis of accuracy of active fire detections in AVHRR, DMSP and MODIS in Southeast Asia, and burn scar from MODIS; 3) processing of nightly DMSP data for Madagascar for time period of August 2002 through December 2002, for mapping of fires; and 4) analysis of high-resolution aerial photography for calibration of DMSP nighttime lights data to produce images estimating percentage of impervious surfaces in the U.S as input to carbon cycling models.

- Joint collaboration with the National Renewable Energy Laboratory (NREL) is ongoing to investigate forecast methods to improve low-level wind prediction for wind energy production. The wind study uses model ensembles to estimate probability distributions of low-level wind forecasts to provide confidence levels in predicting wind-energy power generation.

Infrastructure

- CIRA's satellite earth station has successfully transitioned its real-time data collection to a DVD storage system. Designed by our in-house engineering staff, the system is collecting over 55 Gbytes of data each day. Unlike previous 8mm and digital linear tape systems we now have a verified data collection. Tapes are usually written to and the quality of the data on the tape is taken as an act of faith. Only subsequent reads of the data verify that the data actually was successfully transferred. Unfortunately each subsequent read on tape systems posses a threat to the data due to the possible scrapping of oxides from the tapes' surface. DVDs, using optical retrieval, suffer no damage from repeated reads, are random access, and during the 4 months of operation have saved CIRA over $19,000 in media costs.

- Besides the DVD systems, CIRA also converted all its critical mail, ftp, and data ingest storage systems to RAID technology. Although not a new technology, RAID systems in 2003 became available at low cost. We are now able to build redundant fault tolerant 1-terabyte storage systems for $3800 each.

RESEARCH DESCRIPTIONS
NOAA RESEARCH

JULY 2002 - JUNE 2003

CIRA's Cross-Sensor Products for Improved Weather Analysis and Forecasting

Principal Investigators: S. Kidder; A. Jones

Background:

In the forty some years since the beginning of weather satellites, satellite imagery has revolutionized weather analysis and forecasting. Satellite "pictures" and "movie loops" are routinely and extensively used to analyze the current weather and to make short-term forecasts. Yet a brief analysis of how the data are used reveals that much more could be learned about the weather from satellite data.

One of the problems is that, except in atmospheric sounding retrievals, data from separate satellite sensors is almost never combined to make an improved product. An example of this concerns precipitable water observations. While most components of the atmosphere have relatively fixed concentrations, water vapor varies from near zero percent to in excess of four percent of atmospheric molecules. Further, the spatial variation of water vapor concentration is also quite variable. Forecasters need to know where the water vapor is to make precipitation forecasts, and several satellite instruments have been flown to make these vital measurements. However, data from different satellite sensors are not combined to make a unified water vapor product. Instead, separate water vapor products are created for each sensor, and the forecaster is left to sort through them to discover the truth.

Proposed Work:

The work proposed herein has three main parts.

1. *A Combined SSM/I and AMSU Precipitable Water Product.* We will acquire SSM/I data from NESDIS to compliment the AMSU data that we already get. We will investigate biases and standard deviations between the products and develop a way to make a combined product which eliminates the "holes" that exist in a product from only a single sensor. The combined product will be made available to forecasters at CIRA and SAB in real time for testing and evaluation purposes. Feedback on the usefulness of the product will be incorporated into improved products. It is hoped to use the experience in developing a precipitable water product to make a combined SSM/I and AMSU rain rate product.

2. *Moisture Profiles Over Land and Ocean.* In related research (see publications, below) we have developed a moisture profile retrieval scheme for AMSU-B data. Currently it works only over the ocean, and it doesn't properly take clouds into account. Using AVHRR data and perhaps HIRS data—both acquired from NESDIS—we will develop techniques to retrieve moisture over land and use the IR cloud information to improve cloud correction for oceanic moisture profiles. Products such as precipitable water above 700 mb will be made available to forecasters in real time.

3. *Auxiliary Information.* As the above work progresses, we will develop and make available to forecasters, methods to supply auxiliary information about products, such as the time that a particular observation was made, which sensor made it, and what the geometry of the observation was. These data both improve the usefulness of the product itself (e.g. precipitable water), but they also make possible further processing using the data.

This project is part of the NOAA/NESDIS Product Systems Development and Implementation (PSDI) program.

Progress to date:

So far we have acquired the computers necessary for the data processing, and we have begun to ingest the SSM/I data in real time. We are currently working on the mapping and compositing software. We expect to have a preliminary version of the blended SSM/I-AMSU total precipitable water (TPW) product operating by fall 2003.

Publications: None yet.

DMSP Data Processing and Analysis

Principal Coordinator: John Dietz

In collaboration with the Solar-Terrestrial Physics Division at the National Geophysical Data Center (NGDC), several collaborative projects involving DMSP imagery, Geographical Information Systems (GIS) and other specialized remote sensing data manipulation and mapping techniques continued.

1) A project to show that coral reef bleaching can be detected with IKONOS satellite data was completed. A pair of IKONOS images was acquired for an area in the Great Barrier Reef off the northeast coast of Australia—one prior to the bleaching event and one during the bleaching event. The bleaching was primarily caused by elevated sea-surface temperatures during the 2002 El Nino phenomenon. Radiometric normalization of the image pairs allowed for difference-image processing techniques to map the extent of the bleaching. Figure 1 provides an example of the technique.

2) Data processing of Landsat ETM imagery, for use in analysis of accuracy of active fire detections in AVHRR, DMSP and MODIS in Southeast Asia, and burn scar from MODIS. Both day and nighttime Landsat ETM data were distributed to project partners to be used with data from ASTER, and ground truthing (where available). The goal is to document detection limits for various sensors, to help improve the fire detection algorithms, and to develop calibrations for more accurate input into models.

3) Processing of nightly DMSP data for Madagascar for time period of August 2002 through December 2002, for mapping of fires. This involved masking out false fire detections (primarily moonlit clouds). This is an ongoing annual project funded by and delivered to USAID/Madagascar.

4) Significant effort was made this past year on the "Sprawl" project involving collaboration using analysis of high-resolution aerial photography for calibration of DMSP nighttime lights data, resulting in images estimating percentage of impervious surfaces in the U.S. That data was subsequently used as input to carbon cycling models.
(see http://dmsp.ngdc.noaa.gov/pres/sprawl_042502/sprawl/title.html for additional information)

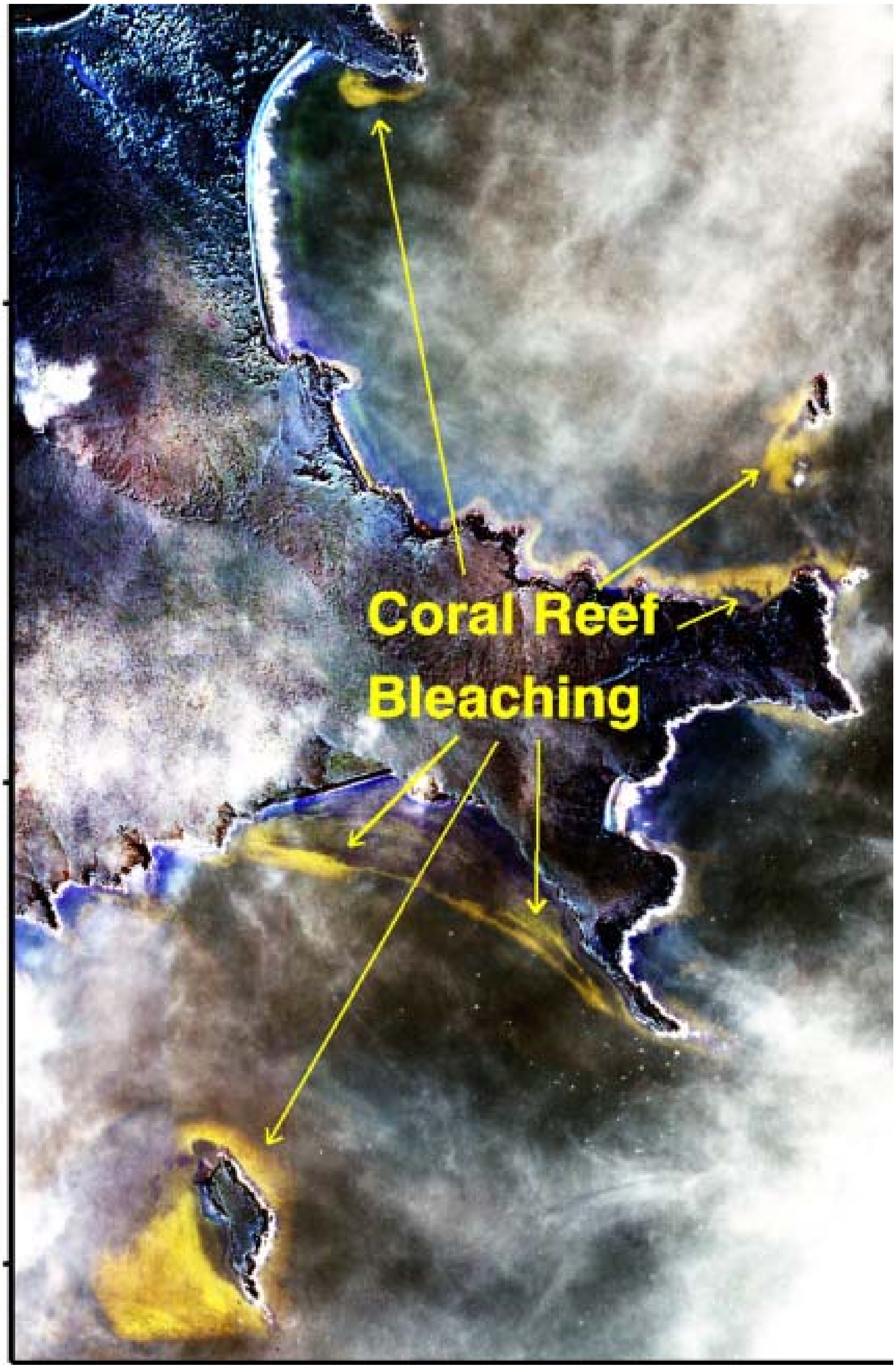

Coral Reef
Bleaching

Figure 1. Mapping of the extent of coral reef bleaching at Keppel Islands (Australian Great Barrier Reef) with a pair of IKONOS images.

Publications:

Elvidge, C.D., Hobson, V.R., Nelson, I.L., Safran, J.M., Tuttle, B.T., Dietz, J.B., Baugh, K.E., 2003, Overview of DMSP OLS and scope of applications. Chapter 13 in Mesev, V., Remotely Sensed Cities, Taylor and Francis, London, pp. 281-299.

Elvidge, C.D., V.R. Hobson, I.L. Nelson, J.M. Safran, B.T. Tuttle, K.E. Baugh, and J.B. Dietz, 2002: Global observation of urban areas based on nocturnal lighting, The Land Use and Land Cover Change Newsletter of the LUCC project of the International Geosphere Biosphere Programme and the International Human Dimensions Programme, December 2002 issue, pp. 10-12.

Elvidge, C.D., J.B. Dietz, R. Berkelmans, S. Andrefouet, W. Skirving, and A.E. Strong, 2002: Satellite observation of Keppel Islands (Great Barrier Reef) coral bleaching using IKONOS data, Coral Reefs. (submitted)

EAR—Multiscale Theory and Model Development

Principal Investigator: Gerald Browning

The collaborative work with RPN and UCLA discussed in the previous report and presented at the Canadian CMOS meeting last May (Gravel et al., 2002) was incorporated into the Canadian operational global assimilation system and model. The reduction in the error relative to in-situ surface pressure and upper air data over North America can be seen on the Canadian website mentioned in the manuscript.

The use of well posed and stable open boundary conditions for the multiscale system for oceanography have been demonstrated to be capable of recreating the flow in a limited area of a global basin similar to the atmospheric case. The multiscale system for the ocean appropriately reduces to the incompressible Navier-Stokes equations for smaller scales of motion and variants of the multiscale system are being used in a number of physical applications (e.g., see Mahadevan et al.)

Reference:
Mahadevan, A., J. Oliger, and R. Street, 1996: A nonhydrostatic mesoscale ocean model: Part I: Well posedness and scaling. Part II: Numerical Implementation. JPO, 26, 1868-1900.

EAR—GPS Tomography Analysis

Principal Researcher: Yuanfu Xie

Two promising GPS research initiatives have been completed toward practical implementation of a US GPS receiver network in the future. One involves sensitivity and accuracy of a GPS network density study and the other is the impact of multi-grid technique in GPS tomography. Based on the experiments, we found that retrieved water vapor distribution from GPS tomography losses significant accuracy if the network density is over 100km and without a multi-grid technique; the analysis not only brings in a lot of unresolvable noise but also loses useful resolvable information. Our results were well received by participants at the Japanese GPS Meteorology Conference held in Tsukuba, Japan in January, and we also received a lot of constructive comments and suggestions. During the conference, several GPS tomography participants, including UCAR, MRI (Japan), FSL and several other institutes from Japan, Europe and Taiwan, met and discussed several important issues. One of them involved having a benchmark-testing package available for everyone to test their GPS tomography techniques, as all of them have different implementations. FSL was selected to develop this package. The first version of this package has been released to these institutes.

Associated with the new results from my 3DVAR research, we are developing a more general version of GPS tomography software. It has several major features. Combined with a recursive filter, we expect it to be more efficient numerically. It also offers general coordinate systems and is compatible with the benchmark-testing package. However, the software will require more development during the coming year.

Collaborating with UCAR/GST, we have been analyzing the GPS slant path dataset from the IHOP region and produced interesting results on the weather cases in June 12-14, 2002. Our presentation on the case study has been accepted by AMS for the 31st Conference on Radar Meteorology in August 2003 in Seattle.

Formal Presentations

Xie, Y., 2003: The role of a multigrid technique in diagnosis of three-dimensional water vapor over Tsukuba GPS network. An invited presentation at the International Workshop on GPS Meteorology, Tsukaba, Japan, 16 January 2003.

MacDonald, A. E., and Y. Xie, 2003: Density impact of a ground-based GPS network on water vapor analysis. A keynote speech at the International Workshop on GPS Meteorology, Tsukaba, Japan, 15 January 2003.

Conference Paper

Braun, J. J. and Y. Xie, 2003: Observed convergence of water vapor prior to and during the June 12, 2002 northern Oklahoma storm using the Global Positioning System. AMS 31st Conference on Radar Meteorology, Seattle, WA, August 2003.

EAR—Three-Dimensional Variational Data Assimilation (3DVAR)

Principal Researcher: Yuanfu Xie

A Fourier analysis theory for 3DVAR systems was developed last year and the implementation of a new version of 3DVAR using Fortran 90 at FSL was begun this past year with many new features. To demonstrate its advantages, some preliminary comparisons with the MAPS/RUC 3DVAR system were made. These initial experiments reflect exactly what our theory concluded. The RUC 3DVAR produces a set of unresolvable motions by the observation network with roughly equal radius. However, the new 3DVAR system provides resolvable scales of motions varying with the observation network density even though a very simple diagonal covariance matrix is used. We have finished a manuscript for publication in Monthly Weather Review, and an internal FSL review is in process.

The main framework for this 3DVAR system has been developed but the detailed implementation may take a much longer time. During the setup of the main structure, we have considered how to apply our theory, which mainly focuses on wind velocity, to other 3DVAR control variables. Using a one-dimensional variational analysis structure, we are carrying a set of experiments to see how to choose control variables in 3DVAR systems except the wind velocity field, with the purpose of not only capturing the most useful information from the observations but also providing more efficient algorithms to solve the systems.

To demonstrate why RUC 3DVAR cannot provide resolvable features from observation systems, the recursive filter was also transformed into Fourier space and its property analyzed. The analysis explains why it could help RUC 3DVAR and why it cannot provide good analysis. This part of the research findings is included in the manuscript to be submitted to MWR.

Publication

Xie, Y., A. MacDonald, and S. Koch, 2003: Advantages of using vorticity and divergence as control variables for three-dimensional variational systems. (Internal review for MWR)

EAR—A New Global Forecasting Model

Principal Researcher: Yuanfu Xie

Collaborations began on a new global numerical forecast model being developed by FSL. This innovative new model will be an extremely efficient forecast model based upon finite difference schemes over a so-called "Icosahedron grid". Since this will be the first of its kind, participation in its development has begun with its basic design. Initially proposed as a simple second order scheme based upon a great circle on a sphere, with the WRF models approaching higher accuracy scheme, e.g., 5th or 6th order, consideration has been given to designing some higher order finite difference schemes over the Icosahedron grid. For the higher order schemes, the partial derivatives of the model variables at grid points must be evaluated. I proposed a direct finite difference scheme which can use 15 neighbors of a given grid point to evaluate the model variables as long as its derivatives. This scheme avoids extra interpolation computations for computing the derivatives and it could be implemented on a massively parallel processing system extremely efficiently following Dr. MacDonald's incoherent memory access expectation. This new idea is under testing now. Various global Icosahedren grids for a new observation network and the SOS projects were developed as part of this effort.

EAR—Mesoscale Modeling Research

Principal Researcher: Chungu Lu

The major task this past year has been the focus on the Short-Range Ensemble Forecast project. The goal of this project is to develop an operational ensemble forecast system, which includes several diverse regional forecast models. The resultant ensemble forecast products are expected to improve the overall model prediction. The proposed models to join this ensemble forecast system are NCEP's Eta and RSM, FSL's RUC, and NSSL's MM5. Each model will provide five forecast members. Thus far, the setup of the RUC ensemble forecast system has been completed, including an interpolation package (Hybext), a pre-processing package (Hybpre), the RUC forecast model (Hybcst), and a post-processing package (Hybpost). During the past year, the RUC Short-Range Ensemble Forecast system (RUC-SREF) was developed and placed into operation.

The RUC-SREF system includes a preprocessor for NCEP regional breeding initial (IC) and lateral-boundary conditions (BC), a scheme for NCEP SREF domain configuration using WRFSI, a RUC forecast model, and a postprocessor for RUC hybrid-grid forecast products. Five ensemble members of RUC-SREF have been running twice daily, initialized at 00Z and 12Z, respectively. Each forecast is run out to 60 hours with output every 3 hours. The horizontal resolution is 48 km with 40 levels in the vertical. The post-processing package converts the RUC hybrid-coordinate data to the pressure-level data, and writes the data back into GRIB format. The GRIB format files are transferred to NCEP via FTP on a daily basis, where these files are converted to AWIPS-212 grid data and have been displayed on NCEP’s ensemble website. Figures 1 *a-e* are the examples of five members of RUC-SREF 36-h forecasts for surface pressure on Sept. 27, 2002, and Figures 2 *a-e* are the examples for the 36-h forecasts for precipitation. Note that there is significant variability in the forecast among ensemble members.

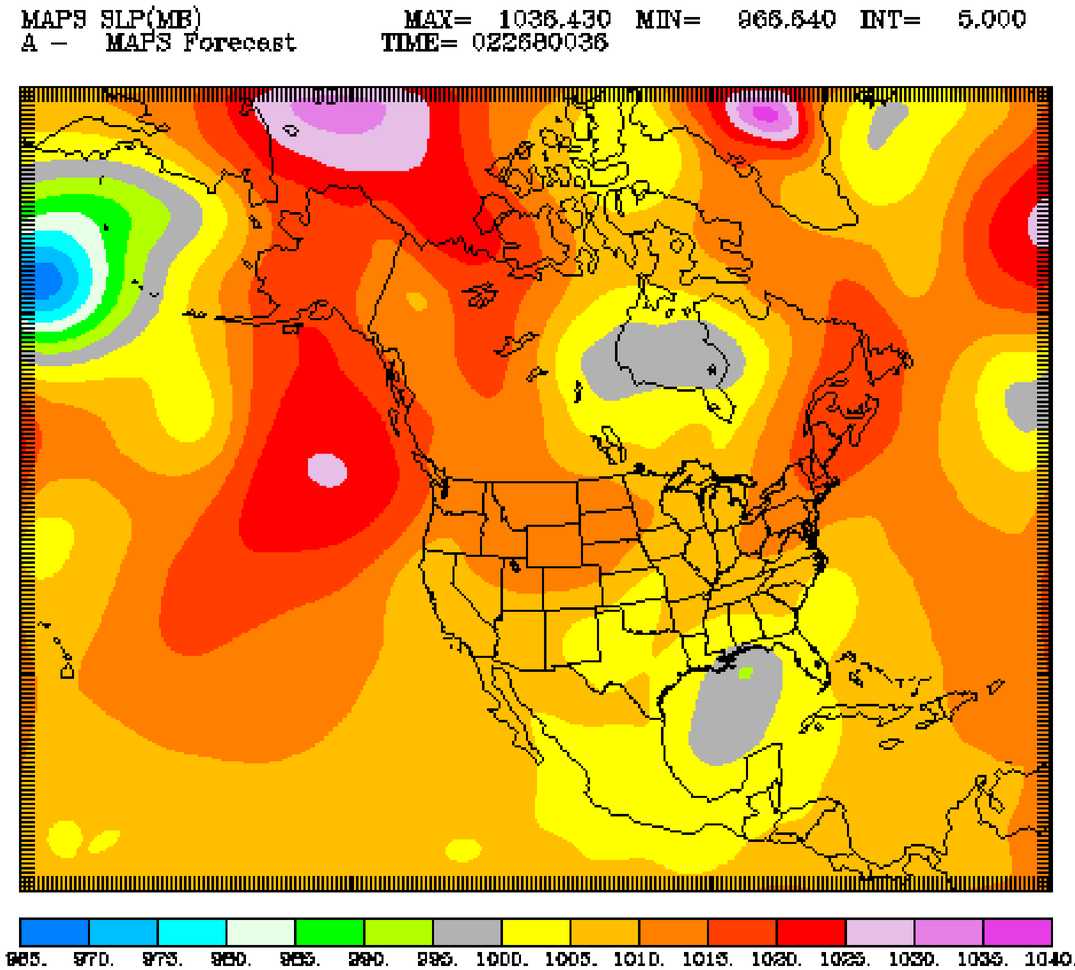


Figure 1a. RUC-SREF 36-h forecast (controlled run: ctl) of SLP, initialized at 00Z 25 Sept 2002.

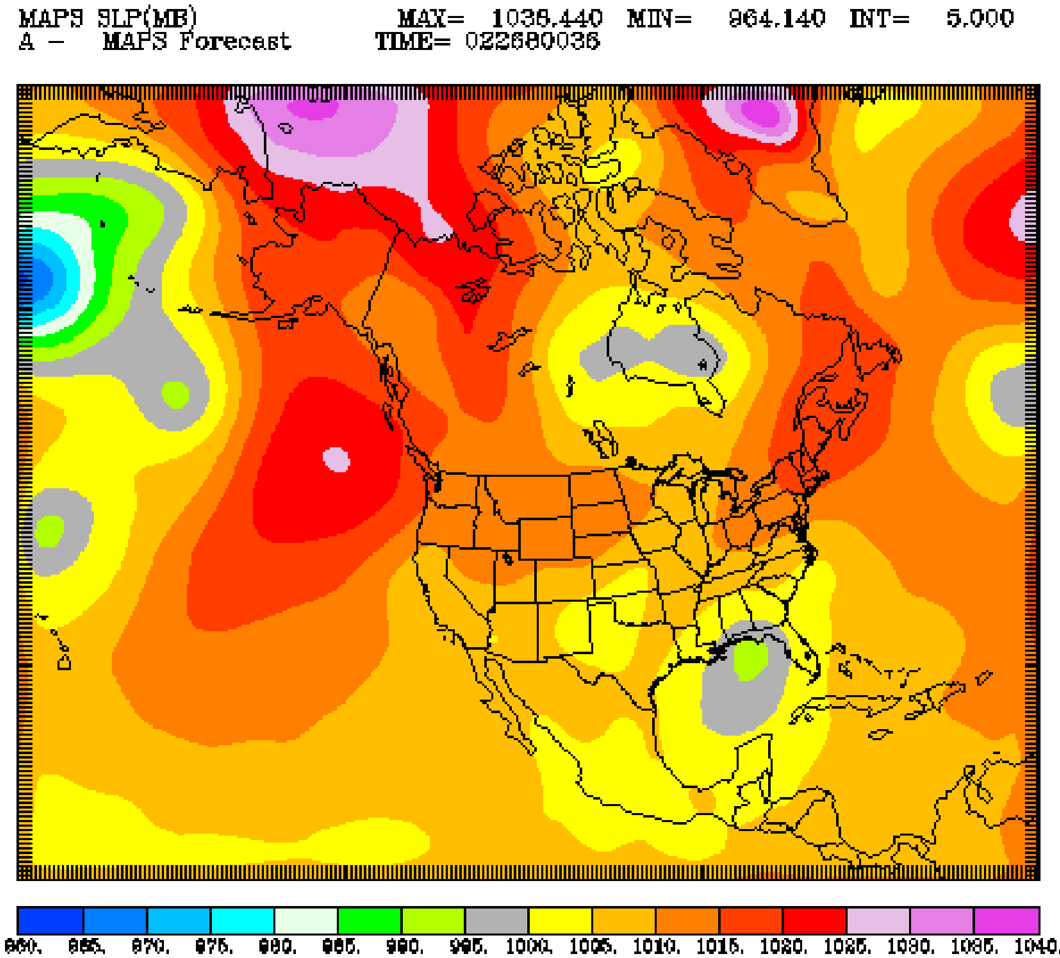


Figure 1b. RUC-SREF 36-h forecast (negatively perturbed: n1) of SLP, initialized at 00Z 25 Sept 2002.

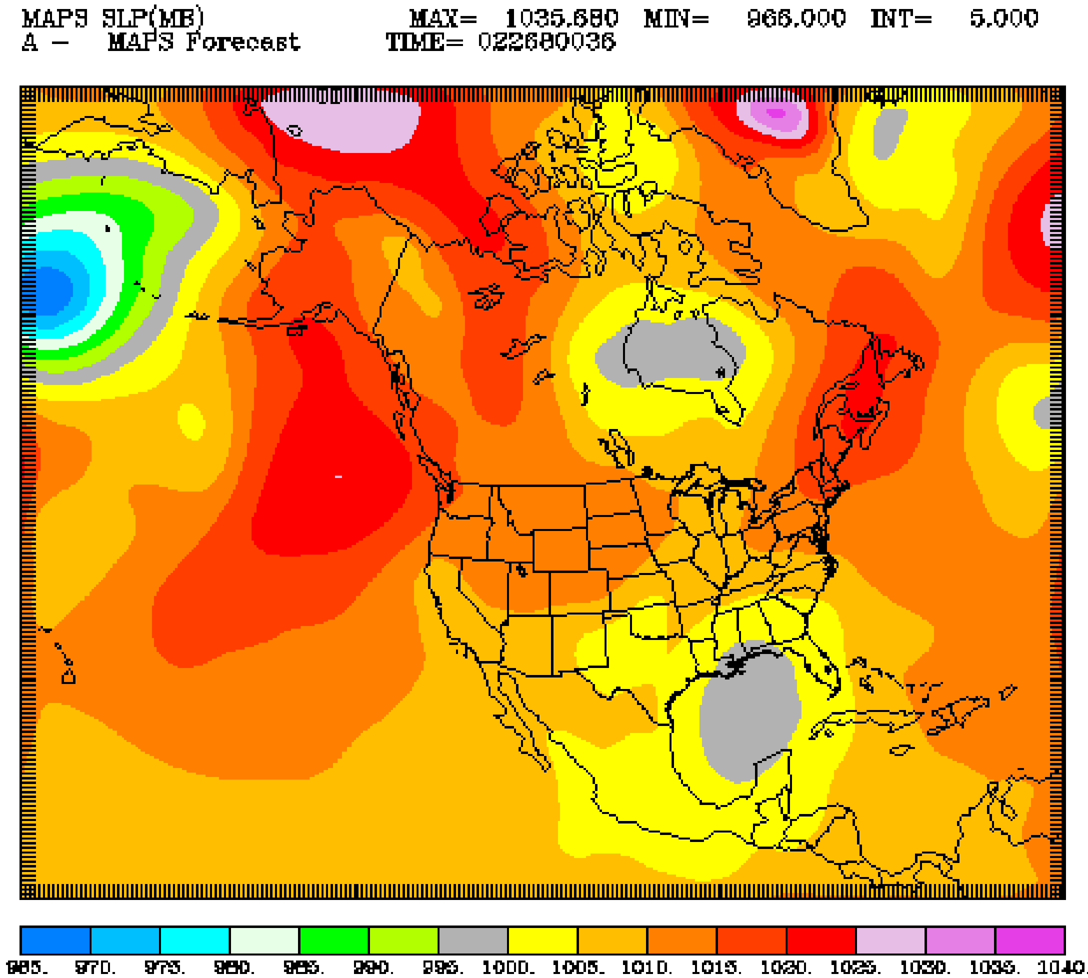


Figure 1c. RUC-SREF 36-h forecast (negatively perturbed: n2) of SLP, initialized at 00Z 25 Sept 2002.

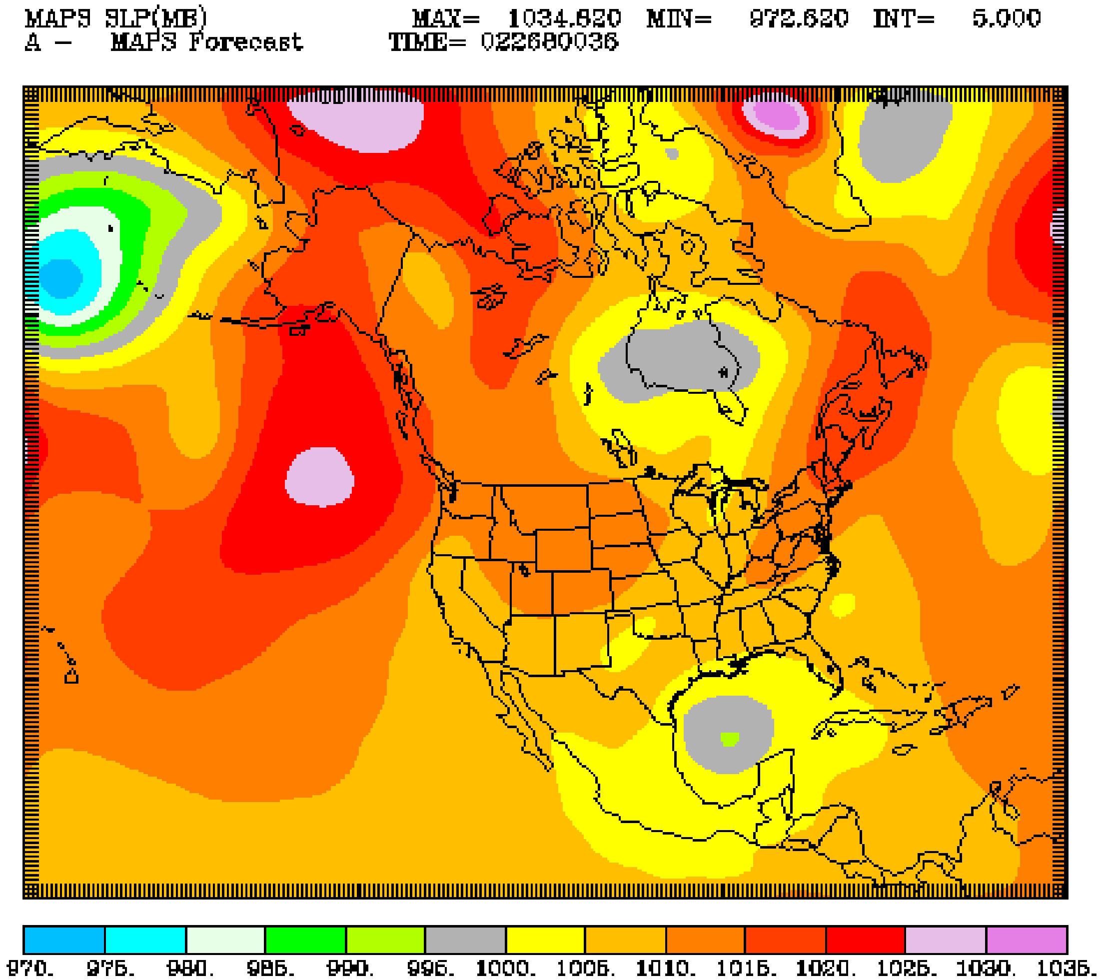


Figure 1d. RUC-SREF 36-h forecast (positively perturbed: p1) of SLP, initialized at 00Z 25 Sept 2002.

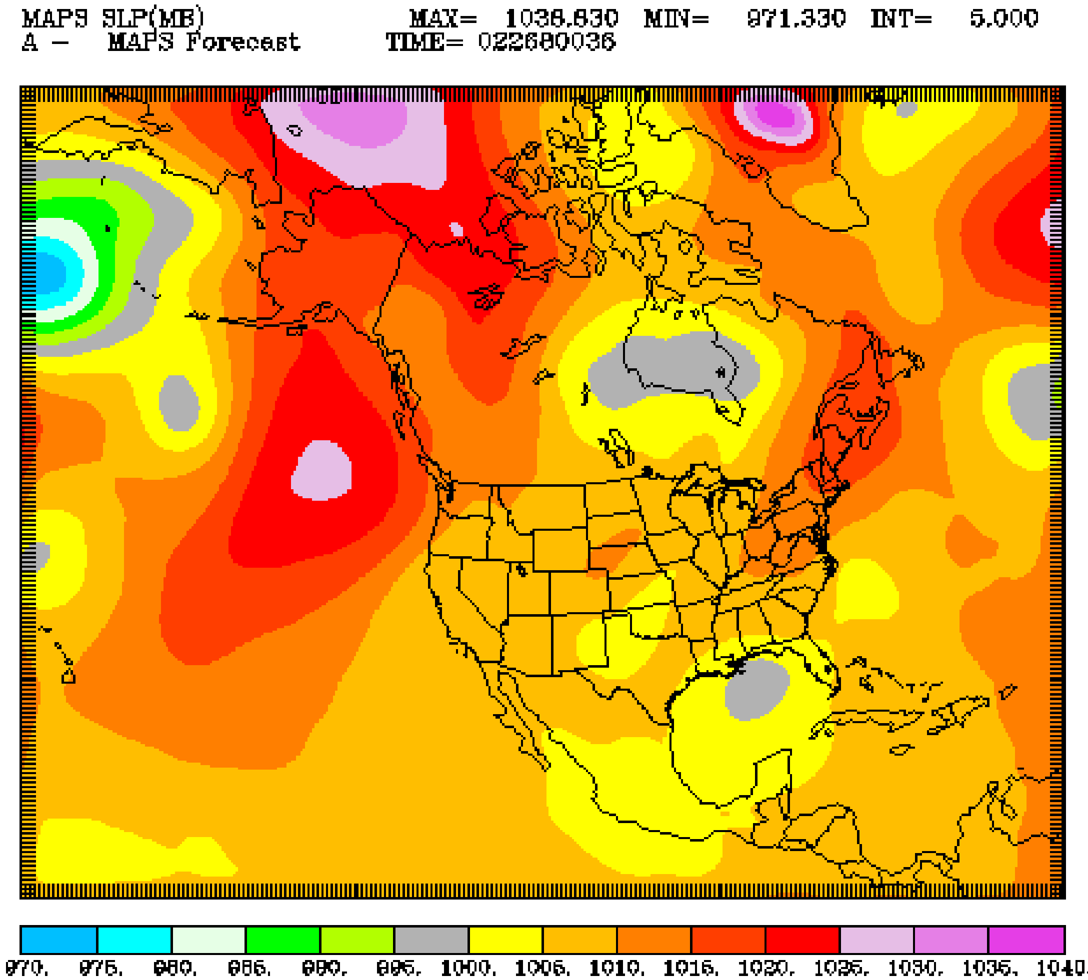


Figure 1e. RUC-SREF 36-h forecast (positively perturbed: p2) of SLP, initialized at 00Z 25 Sept 2002.

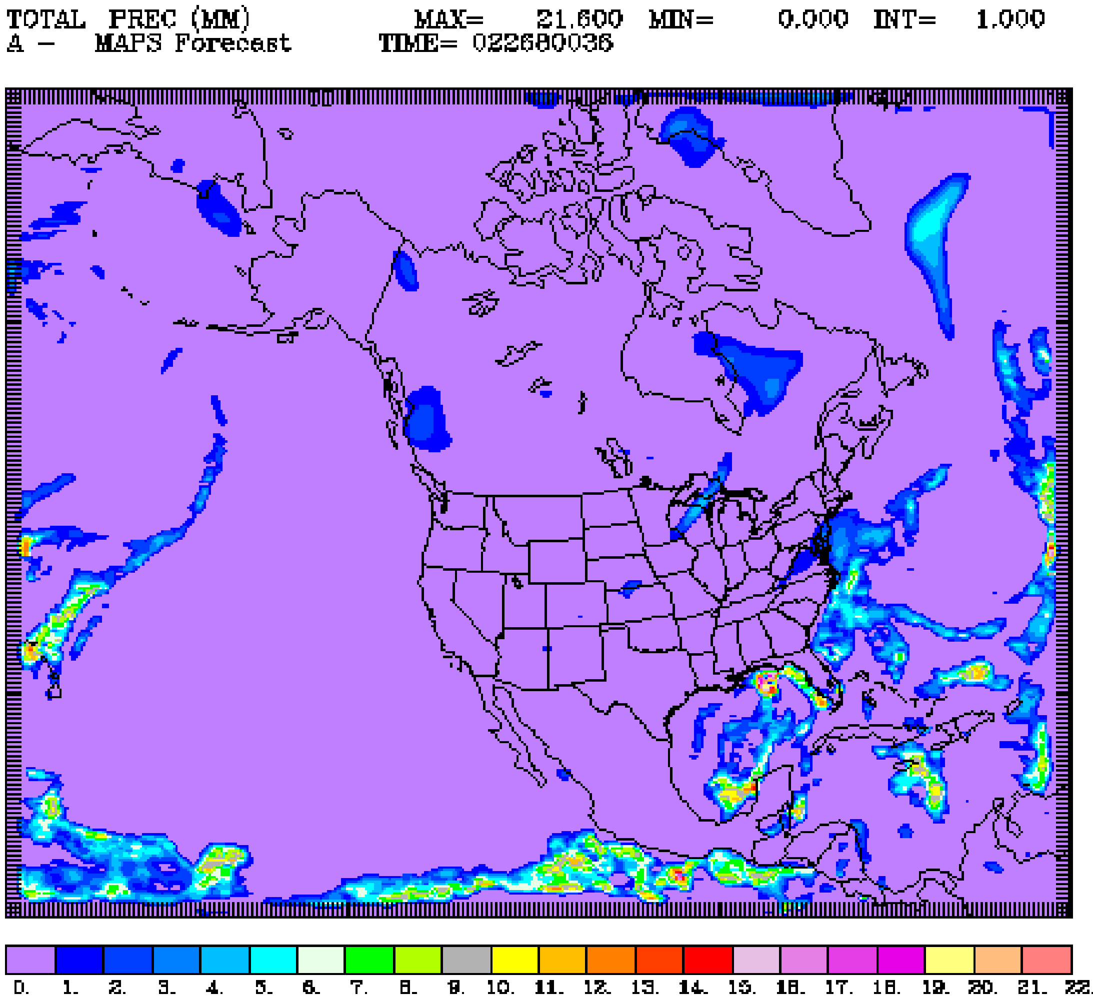


Figure 2a. RUC-SREF 36-h forecast (controlled run: ctl) of precipitation, initialized at 00Z 25 Sept 2002.

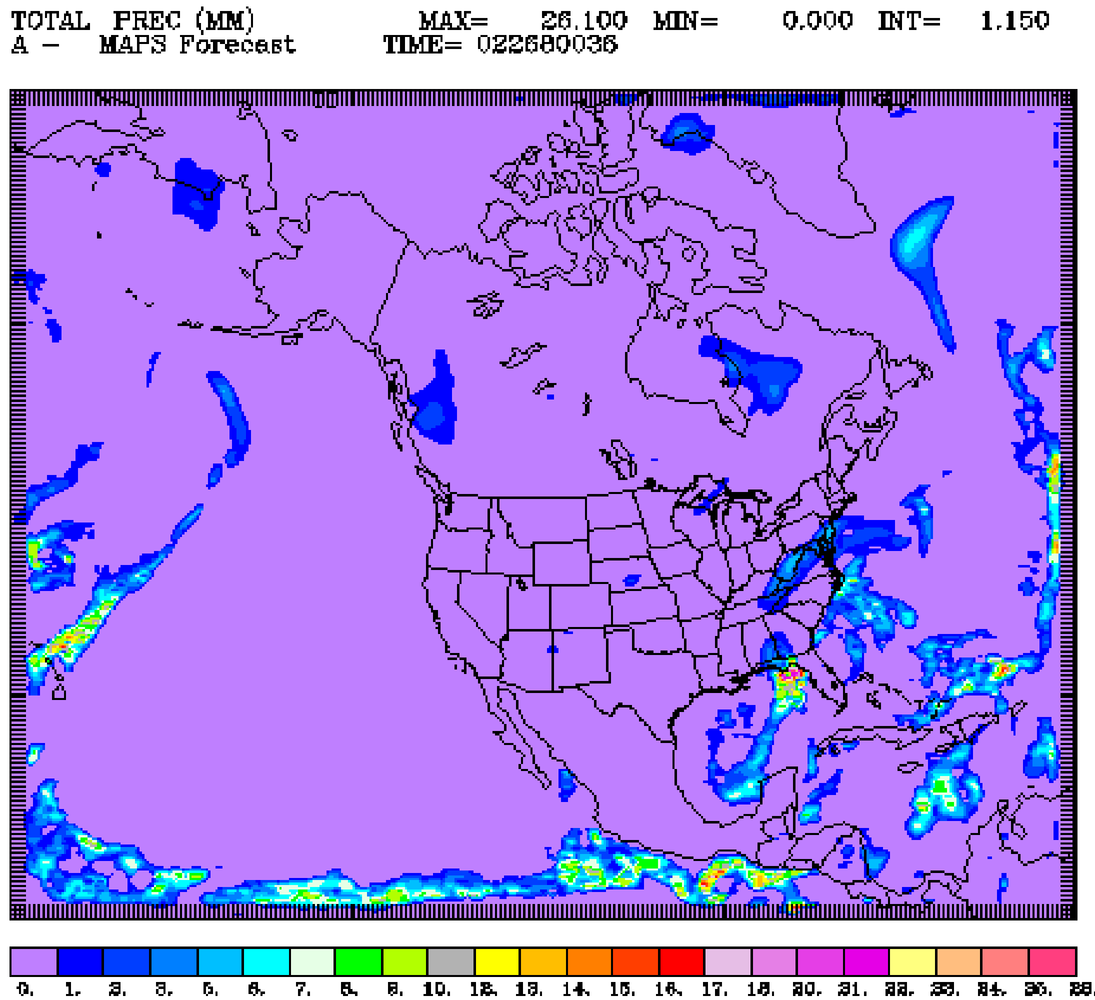


Figure 2b. RUC-SREF 36-h forecast (negatively perturbed: n1) of precipitation, initialized at 00Z 25 Sept 2002.

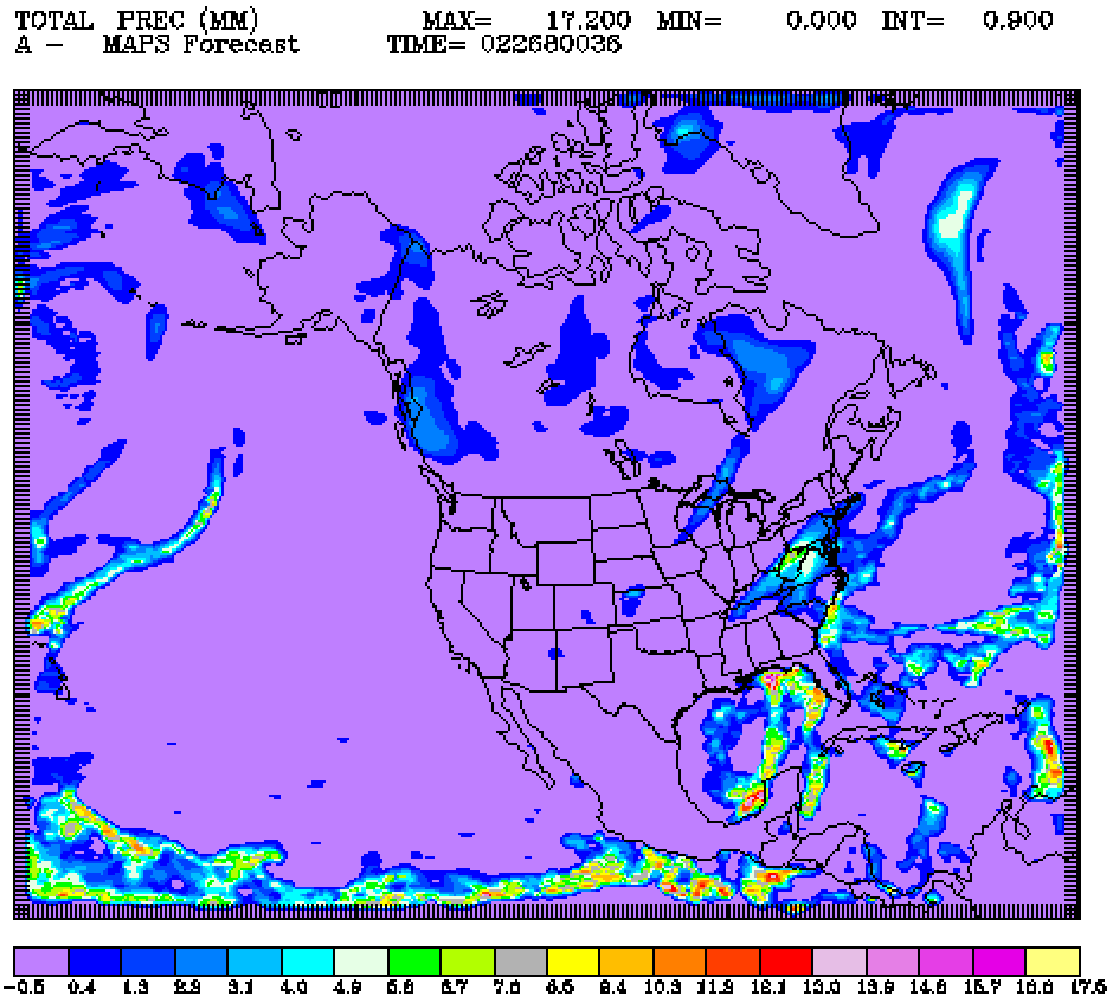


Figure 2c. RUC-SREF 36-h forecast (negatively perturbed: n2) of precipitation, initialized at 00Z 25 Sept 2002.

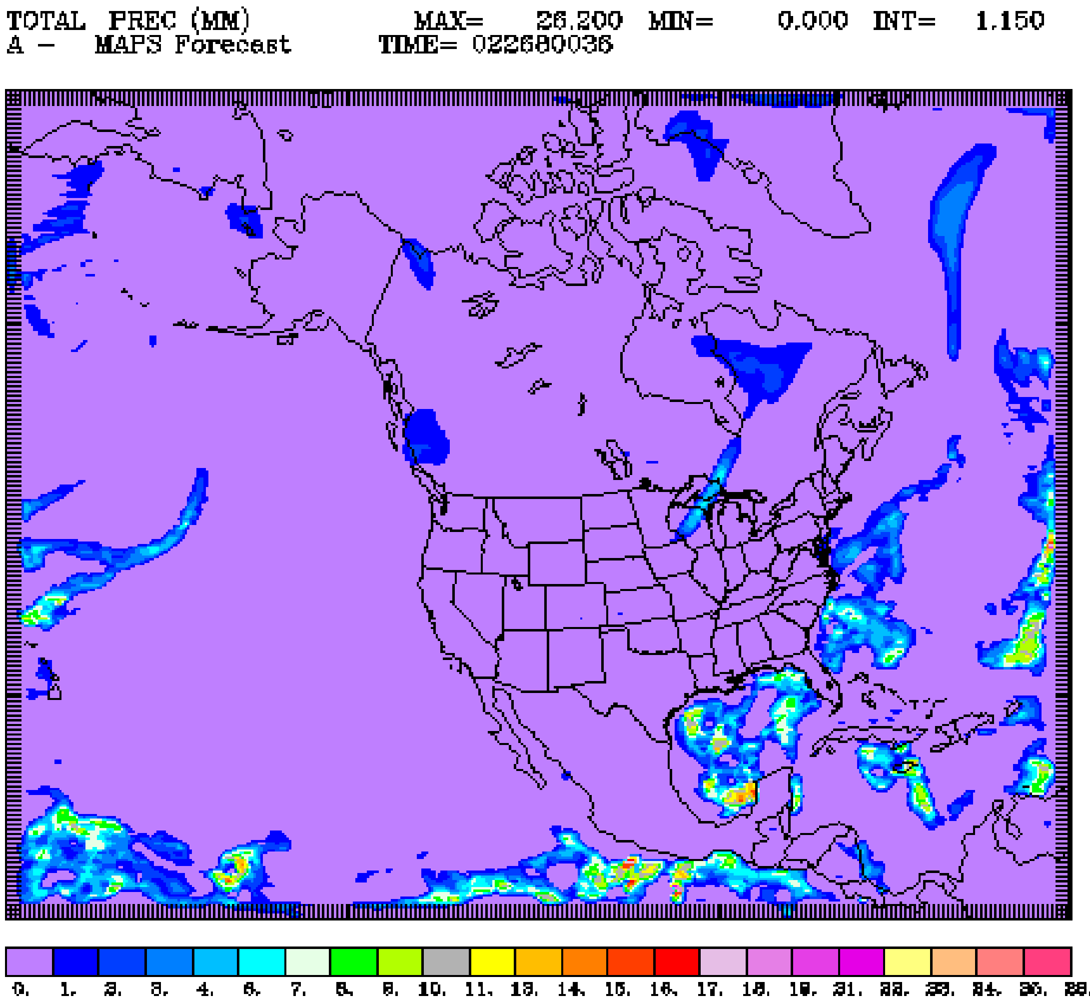


Figure 2d. RUC-SREF 36-h forecast (positively perturbed: p1) of precipitation, initialized at 00Z 25 Sept 2002.

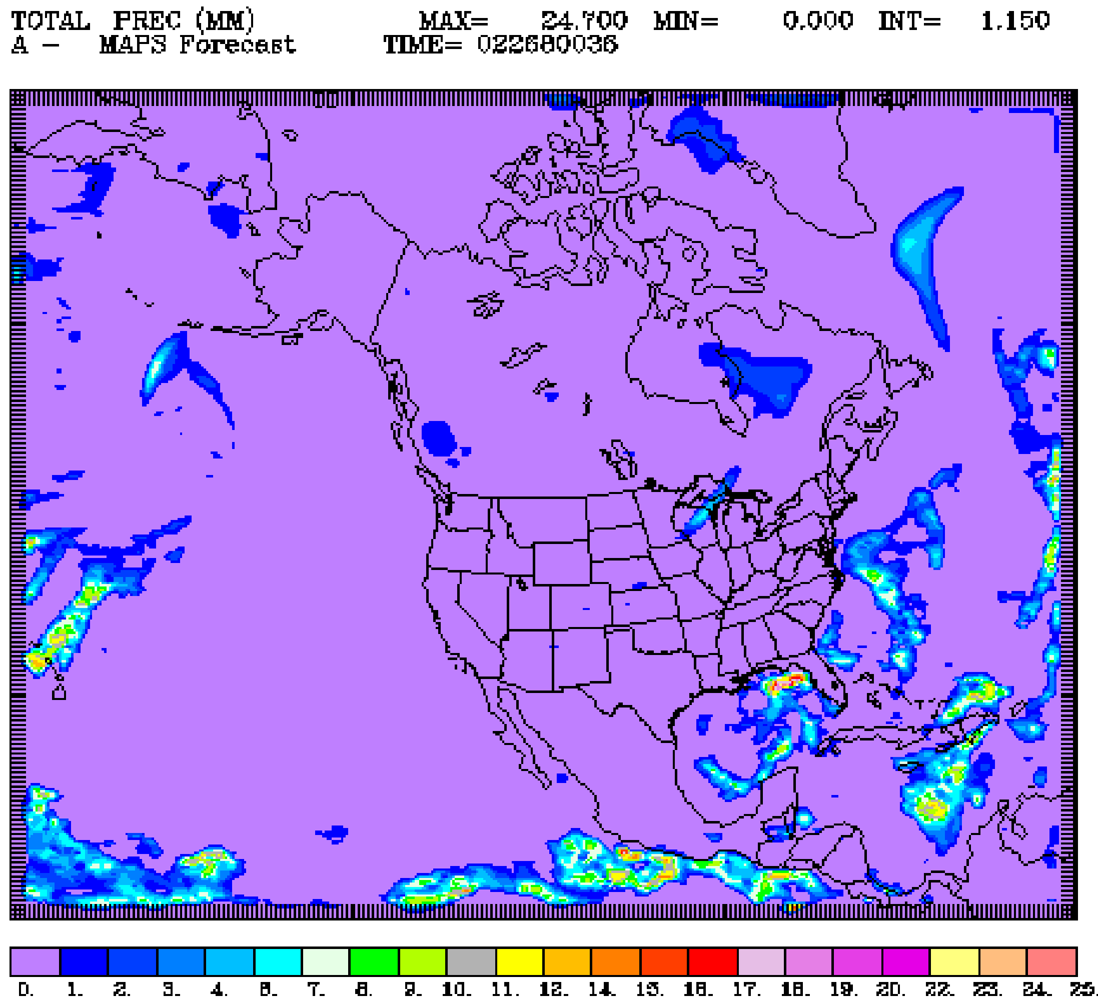


Figure 2e. RUC-SREF 36-h forecast (positively perturbed: p2) of precipitation, initialized at 00Z 25 Sept 2002.

Statistical verifications of RUC-SREF forecasts have been performed against ETA 6-hourly analysis, and comparisons of these forecasts with Eta 12-km high-resolution forecasts were also made. Tables 1-6 are examples of these verifications. Note that RUC-SREF forecasts mean errors are very small in comparison with the Eta analyses.

RMS FCST ERROR OF SLP (mb) Initiating from 12z 4/26/2003

hr	ctl	n1	p1	n2	p2	mean	med	best	worst	opl	err	std	ME
0	2.1	2.1	2.2	2.3	2.1	2.1	2.1	2.1	2.3	.0	2.2	.3	-.6
6	1.5	1.7	1.8	2.0	1.9	1.5	1.5	1.5	2.0	1.2	1.8	.8	.0
12	1.8	1.9	2.2	2.4	2.1	1.9	1.8	1.8	2.4	1.3	2.1	.8	.4
18	2.0	1.9	2.7	2.5	2.4	2.0	2.0	1.9	2.7	1.5	2.3	1.1	-.1
24	2.5	2.2	3.1	2.8	2.7	2.4	2.4	2.2	3.1	1.6	2.7	1.0	-.1
30	2.5	2.3	3.2	2.9	2.8	2.4	2.4	2.3	3.2	1.9	2.7	1.2	-.3
36	2.7	2.8	3.2	3.2	3.1	2.6	2.6	2.7	3.2	2.0	3.0	1.2	.5
42	2.8	2.8	3.6	3.5	3.6	2.8	2.8	2.8	3.6	2.2	3.3	1.4	.1
48	3.1	3.4	3.7	3.7	4.1	3.0	3.0	3.1	4.1	2.4	3.6	1.6	.0
54	2.6	3.8	3.4	3.7	4.0	2.8	2.8	2.6	4.0	2.4	3.5	1.7	.4
60	3.0	4.2	3.7	4.4	4.3	3.3	3.2	3.0	4.4	2.4	3.9	1.7	1.0

Table 1: Statistical verification of RUC-SREF members (ctl, n1, n2, p1, p2) against Eta analysis every 6 hours for SLP.

RMS FCST ERROR OF 500 H (m) Initiating from 12z 4/26/2003

hr	ctl	n1	p1	n2	p2	mean	med	best	worst	opl	err	std	ME
0	14.8	17.8	16.3	17.0	17.6	14.9	14.8	14.8	17.8	.0	16.7	6.3	-2.6
6	13.7	16.2	17.3	16.9	21.4	13.6	13.7	13.7	21.4	10.8	17.1	9.4	-7.2
12	16.7	21.7	19.7	21.0	25.2	16.8	16.7	16.7	25.2	11.6	20.9	10.5	-9.8
18	19.0	21.2	25.7	23.0	30.3	18.3	18.9	19.0	30.3	14.3	23.8	13.1	-8.2
24	21.6	23.6	27.7	23.6	32.7	20.7	21.0	21.6	32.7	13.4	25.8	13.1	-8.6
30	28.5	28.7	33.7	29.4	38.0	26.9	27.6	28.5	38.0	18.3	31.7	14.1	-17.4
36	31.9	31.6	36.3	31.4	42.9	29.5	30.7	31.4	42.9	18.1	34.8	15.2	-17.8
42	32.1	32.8	37.6	33.0	47.7	29.9	31.2	32.1	47.7	18.2	36.6	17.2	-16.2
48	29.7	37.1	34.4	34.3	48.6	28.2	29.2	29.7	48.6	18.0	36.8	19.0	-12.3
54	39.8	45.5	43.4	42.2	57.0	37.6	38.9	39.8	57.0	24.3	45.6	20.3	-19.9
60	41.7	47.5	43.2	43.2	61.1	39.4	40.5	41.7	61.1	22.1	47.3	20.5	-19.0

Table 2: Statistical verification of RUC-SREF members (ctl, n1, n2, p1, p2) against Eta analysis every 6 hours for 500-mb Height.

RMS FCST ERROR OF 850 T (C) Initiating from 12z 4/26/2003

hr	ctl	n1	p1	n2	p2	mean	med	best	worst	opl	err	std	ME
0	.5	.7	.9	.9	.7	.5	.5	.5	.9	.0	.8	.4	.1
6	1.2	1.5	1.3	1.4	1.5	1.2	1.2	1.2	1.5	.8	1.4	.5	-.4
12	1.8	2.1	1.8	1.9	2.2	1.8	1.8	1.8	2.2	1.2	1.9	.5	-.8
18	1.6	1.8	1.8	1.7	2.0	1.6	1.6	1.6	2.0	1.4	1.8	.6	-.4
24	1.7	1.8	1.8	1.9	1.9	1.6	1.6	1.7	1.9	1.4	1.8	.7	-.4
30	2.1	2.2	2.3	2.4	2.3	2.1	2.1	2.1	2.4	1.6	2.3	.7	-.8
36	2.6	2.6	2.8	2.7	2.8	2.6	2.6	2.6	2.8	1.6	2.7	.7	-1.3
42	2.4	2.4	2.7	2.5	2.6	2.4	2.4	2.4	2.7	2.0	2.5	.8	-1.0
48	2.3	2.3	2.7	2.6	2.6	2.3	2.3	2.3	2.7	1.9	2.5	.9	-.9
54	2.9	2.8	3.2	3.0	3.2	2.8	2.8	2.8	3.2	2.0	3.0	.9	-1.5
60	3.5	3.3	3.8	3.6	3.7	3.4	3.4	3.3	3.8	2.1	3.6	1.0	-1.9

Table 3: Statistical verification of RUC-SREF members (ctl, n1, n2, p1, p2) against Eta analysis every 6 hours for 850-mb Temperature.

RMS FCST ERROR OF 850 U (m/s) Initiating from 12z 4/26/2003

hr	ctl	n1	p1	n2	p2	mean	med	best	worst	opl	err	std	ME
0	1.5	1.8	1.8	2.0	2.0	1.5	1.5	1.5	2.0	.0	1.8	.8	-.2
6	2.2	2.4	2.4	2.7	2.7	2.2	2.2	2.2	2.7	1.6	2.5	1.0	.1
12	2.9	2.9	3.3	3.5	3.1	2.8	2.8	2.9	3.5	2.3	3.1	1.1	-.2
18	3.4	3.4	4.0	4.0	3.9	3.3	3.4	3.4	4.0	2.7	3.7	1.3	-.1
24	3.3	3.6	4.1	4.1	4.1	3.3	3.2	3.3	4.1	2.6	3.8	1.6	-.3
30	3.6	3.5	4.5	4.3	4.1	3.4	3.5	3.5	4.5	2.7	4.0	1.7	-.7
36	4.0	3.9	4.7	4.5	4.4	3.7	3.9	3.9	4.7	3.1	4.3	1.8	-.3
42	4.2	4.3	4.7	4.4	4.7	3.8	4.0	4.2	4.7	3.4	4.5	1.9	-.3
48	4.2	4.5	4.5	4.5	4.5	3.7	3.9	4.2	4.5	3.4	4.4	2.0	.2
54	4.1	4.7	4.4	4.3	4.8	3.8	3.8	4.1	4.8	3.3	4.5	2.0	-.1
60	4.0	4.8	4.5	4.7	4.7	3.9	3.9	4.0	4.8	3.4	4.6	2.0	-.3

Table 4: Statistical verification of RUC-SREF members (ctl, n1, n2, p1, p2) against Eta analysis every 6 hours for 850-mb U wind.

RMS FCST ERROR OF 850 V (m/s) Initiating from 12z 4/26/2003

hr	ctl	n1	p1	n2	p2	mean	med	best	worst	opl	err	std	ME
0	1.3	1.7	1.8	1.8	1.8	1.3	1.3	1.3	1.8	.0	1.7	.8	-.1
6	2.3	2.7	2.5	2.5	2.9	2.3	2.3	2.3	2.9	1.9	2.6	.9	-.3
12	2.7	3.0	3.0	3.2	3.2	2.6	2.6	2.7	3.2	2.5	3.0	1.2	.0
18	3.3	3.7	3.7	3.9	3.9	3.2	3.2	3.3	3.9	2.5	3.7	1.4	-.5
24	3.4	3.5	3.9	4.0	3.8	3.2	3.3	3.4	4.0	2.7	3.7	1.5	-.4
30	3.3	3.4	3.9	4.2	3.5	3.1	3.3	3.3	4.2	2.7	3.7	1.6	.1
36	3.7	3.7	4.3	4.4	4.1	3.5	3.6	3.7	4.4	3.0	4.0	1.7	.3
42	3.8	4.0	4.3	4.3	4.4	3.5	3.6	3.8	4.4	3.1	4.2	1.9	.1
48	3.9	4.0	4.5	4.3	4.4	3.5	3.7	3.9	4.5	3.2	4.2	1.9	.5
54	3.8	4.0	4.5	4.7	4.4	3.6	3.7	3.8	4.7	3.4	4.3	2.0	-.2
60	3.8	4.1	4.4	4.3	4.8	3.6	3.6	3.8	4.8	3.3	4.3	1.9	.1

Table 5: Statistical verification of RUC-SREF members (ctl, n1, n2, p1, p2) against Eta analysis every 6 hours for 850-mb V wind.

RMS FCST ERROR OF 850 RH (%) Initiating from 12z 4/26/2003

hr	ctl	n1	p1	n2	p2	mean	med	best	worst	opl	err	std	ME
0	3.0	6.9	6.8	7.0	7.0	3.1	3.0	3.0	7.0	.0	6.2	4.1	-.1
6	10.0	11.9	12.1	12.2	12.5	9.8	10.0	10.0	12.5	6.4	11.8	4.9	1.0
12	15.2	16.2	17.3	17.6	17.4	14.9	15.1	15.2	17.6	10.6	16.7	5.8	4.1
18	18.2	19.6	19.4	20.1	21.3	17.8	18.0	18.2	21.3	12.9	19.7	6.6	3.0
24	20.5	21.5	22.1	22.3	23.4	20.0	20.4	20.5	23.4	14.1	22.0	7.3	3.2
30	18.9	19.1	20.8	21.3	21.7	18.0	18.4	18.9	21.7	14.2	20.4	7.7	1.9
36	21.9	21.9	23.6	23.7	24.0	20.7	21.2	21.9	24.0	14.8	23.0	8.1	4.5
42	22.5	23.3	23.8	23.5	24.9	21.0	21.6	22.5	24.9	16.1	23.6	8.6	3.7
48	23.1	24.0	24.5	24.2	25.9	21.4	22.1	23.1	25.9	16.8	24.3	9.2	4.7
54	21.5	23.1	22.9	22.9	24.0	19.5	20.3	21.5	24.0	16.2	22.9	9.8	4.5
60	24.3	24.7	26.1	25.7	25.0	22.1	23.1	24.3	26.1	17.1	25.1	9.9	6.3

Table 6: Statistical verification of RUC-SREF members (ctl, n1, n2, p1, p2) against Eta analysis every 6 hours for 850-mb RH.

With the final stage of this project approaching, collaborations with NCEP researchers have begun to prepare several publications based on this ensemble forecast system. A potential proposal using this system is also being planned for submission to the NOAA-NASA/GAPP program.

A second task involves activities on a Clear Air Turbulence project, including the analysis of a set of high-resolution-model output data to identify the characteristics of gravity waves and turbulence.

Accomplishment for the FAA's clear-air turbulence project involved the development of a wavelet diagnostic tool using Dr. Ning Wang's wavelet transform data compression package. Using this wavelet diagnostic tool, SCATCAT aircraft in-situ observational data were analyzed. The combined frequency-time domain analysis has generated some striking results of how gravity-wave activities interact with turbulence at upper-level atmosphere. Figures 3-4 show examples of these results.

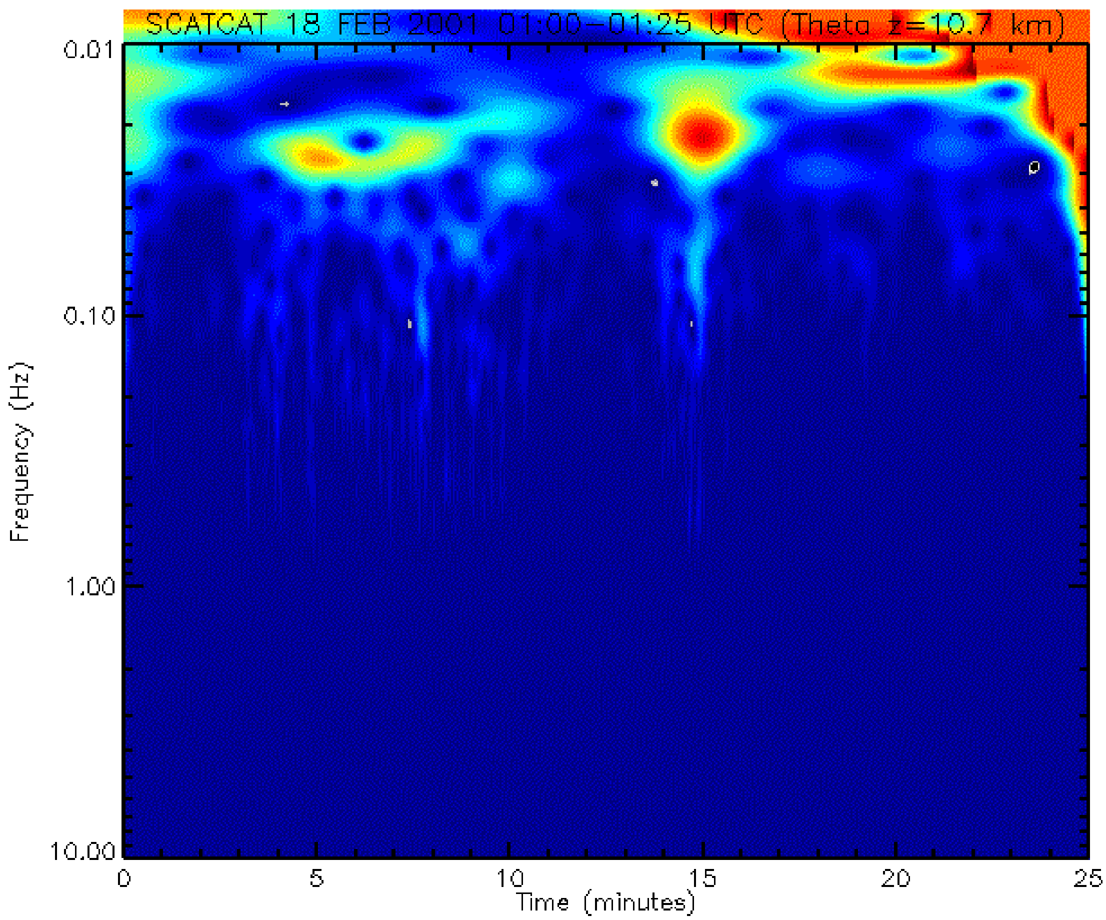


Figure 3. Power density from the wavelet analysis of SCATCAT G-IV in-situ observational data. Figure shows that the turbulence (~0.3 Hz) burst is closely related to the internal gravity-wave activities (~0.02 Hz) at 10.7 km altitude.

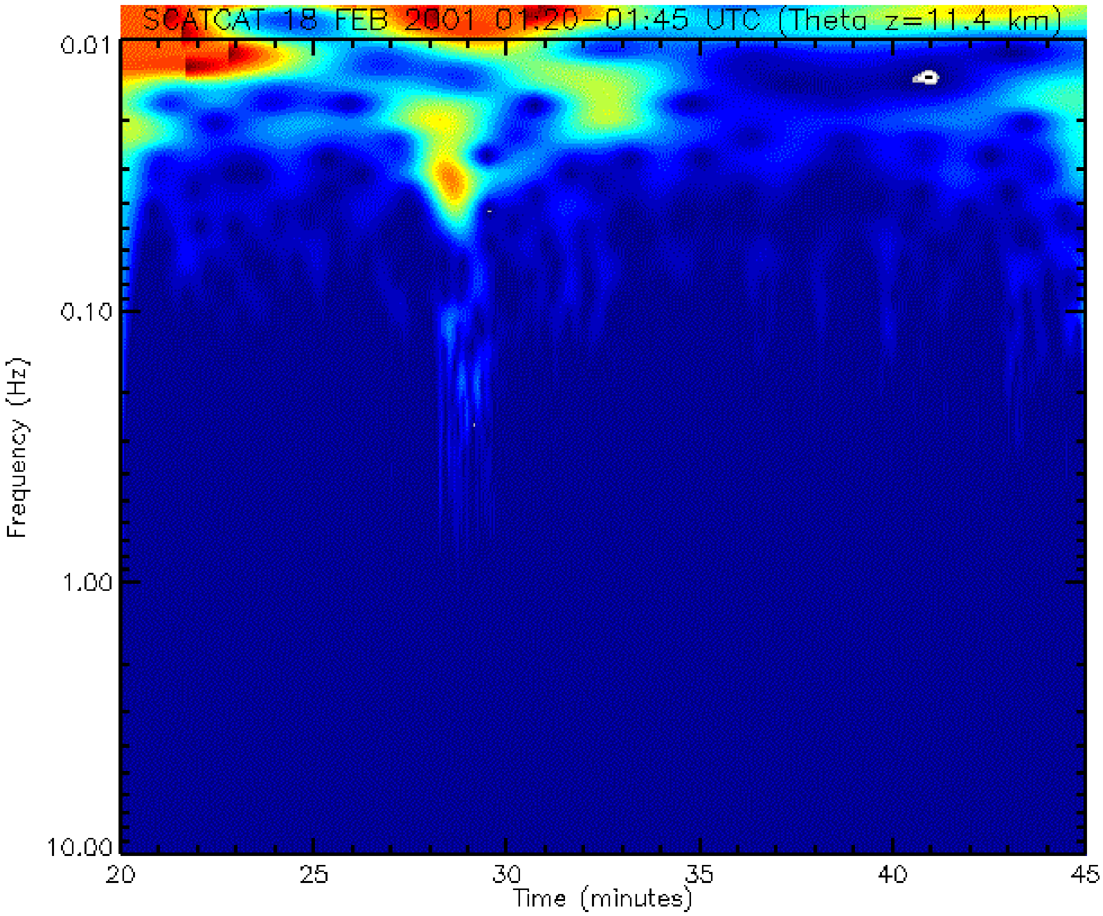


Figure 4. Same as Figure 3, except at 11.4-km altitude.

One paper has been written and presented (by Dr. Steven Koch) at the AMS 10th Conference on Mesoscale Meteorology (Portland, OR), and two journal papers are in preparation. They are:

Lu, C., S. Koch, and N. Wang, 2003: Gravity wave activities and clear-air turbulence in the atmosphere. *Science*, in preparation.

Koch, S., B. Jamison, T, Smith, E. Tollerud, C. Lu, N. Wang, M. Shapiro, D. Parrish, and O. Cooper, 2003: Field observations of turbulence and gravity waves. *JAS*, in preparation.

Most recently, a new task involves the integration of the WRFRUC forecast system for the TAQ project. The WRFRUC forecast system is comprised of a WRFRUC pre-processing package that is a modified version of the WRFSI, the WRF forecast model, and a WRFRUC post-processing package. The project has progressed well and the system is running operationally to support the TAQ project.

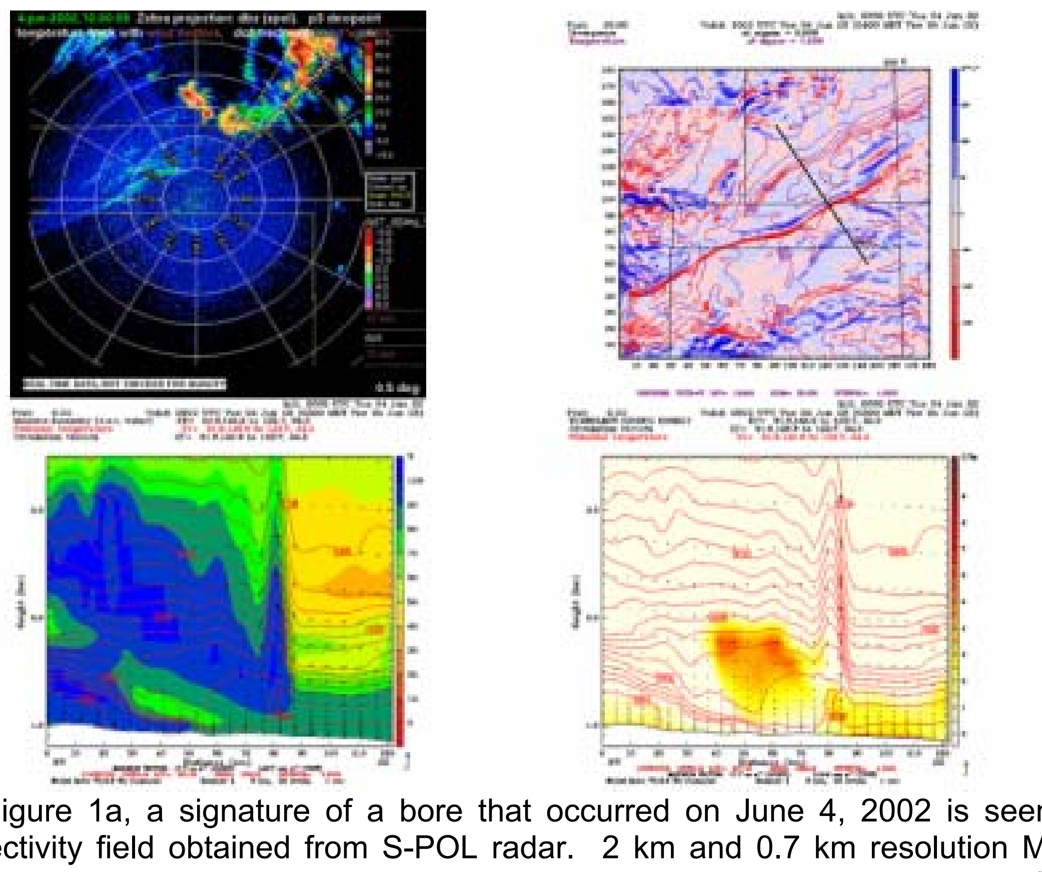
EAR—Mesoscale Studies and Model Research and Development

Principal Researchers: Mariusz Pagowski and Ming Ge

Several mesoscale research studies were conducted during the past year:

1. Analysis and Modeling of Bores during IHOP

IHOP (International H_2O Project) was an extensive field experiment carried out in May, June and July 2003 over the southern Great Plains for the purpose of obtaining an improved characterization of the time-varying, three-dimensional water vapor field and to determine its importance in understanding and predicting convective processes. The role of bores, which are gravity waves propagating above a nocturnal inversion ahead of a gravity current intruding on a stable boundary layer, in enhancing nocturnal convection was also one of the objectives. Data collected by FM-CW radar, band radar, interferometer, Raman lidar, Doppler radar, aerosol backscatter radar and surface mesonet network provide a unique opportunity for an analysis of the structure and dynamics of bores. In collaboration with Steve Koch, numerical modeling is also now used to improve our understanding of the physics of bores.



In Figure 1a, a signature of a bore that occurred on June 4, 2002 is seen in reflectivity field obtained from S-POL radar. 2 km and 0.7 km resolution MM5 simulations captured the event with a surprising accuracy as seen in the surface convergence/divergence pattern (Fig. 1b). Model results suggest (Fig. 1c) that the gravity current, which originated as an outflow from a cold front, entered a stably stratified boundary layer and induced a bore, which propagated ahead of the front. Based on the results, we believe that waves seen in the wake of the bore are a result of wave trapping rather than dispersion as previously suggested by some authors. Boundary layer growth and generation of turbulence (Fig. 1d) will be further studied with explicitly resolved turbulence (LES) using WRF/Clark model.

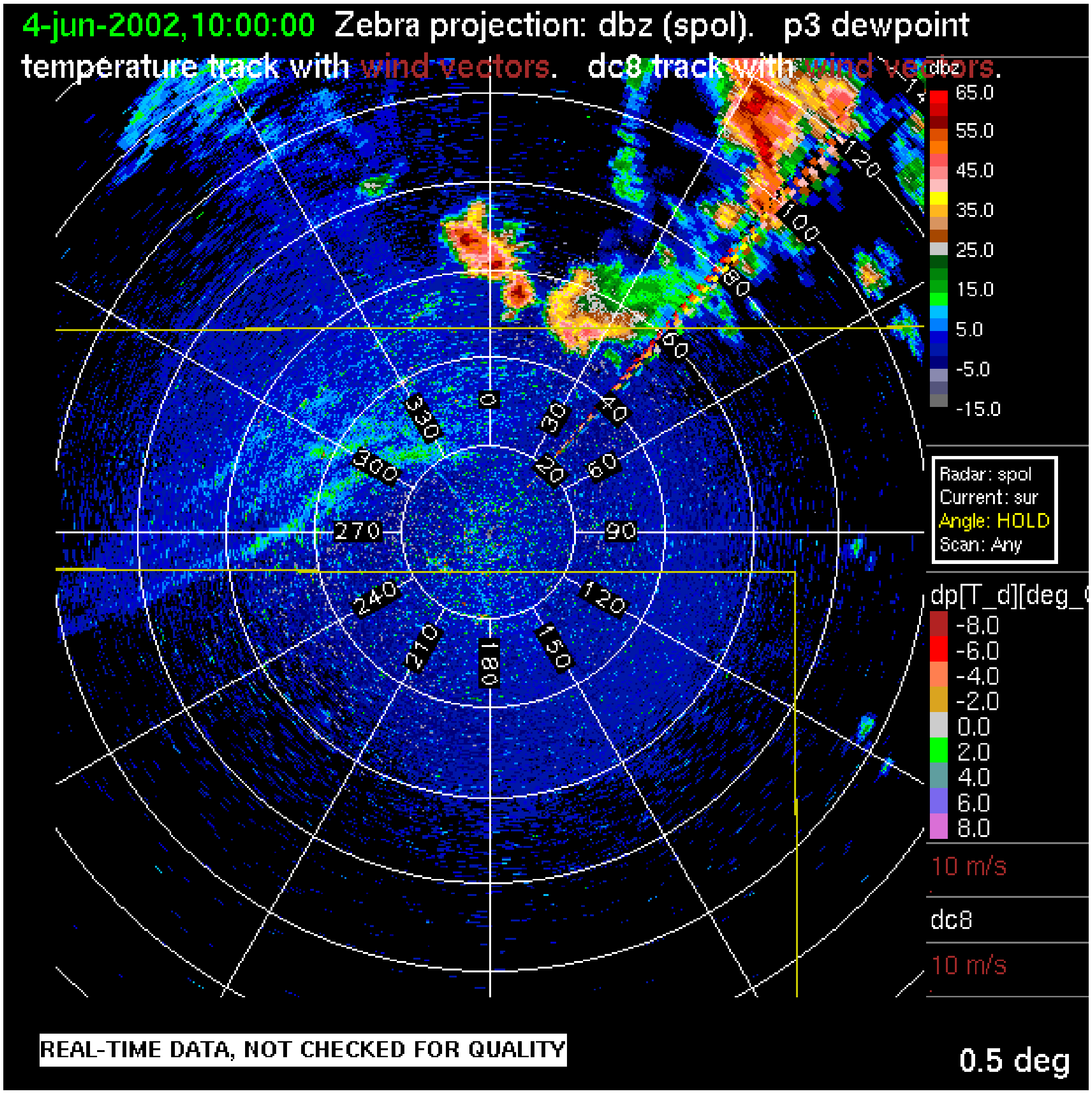


Figure 1a.

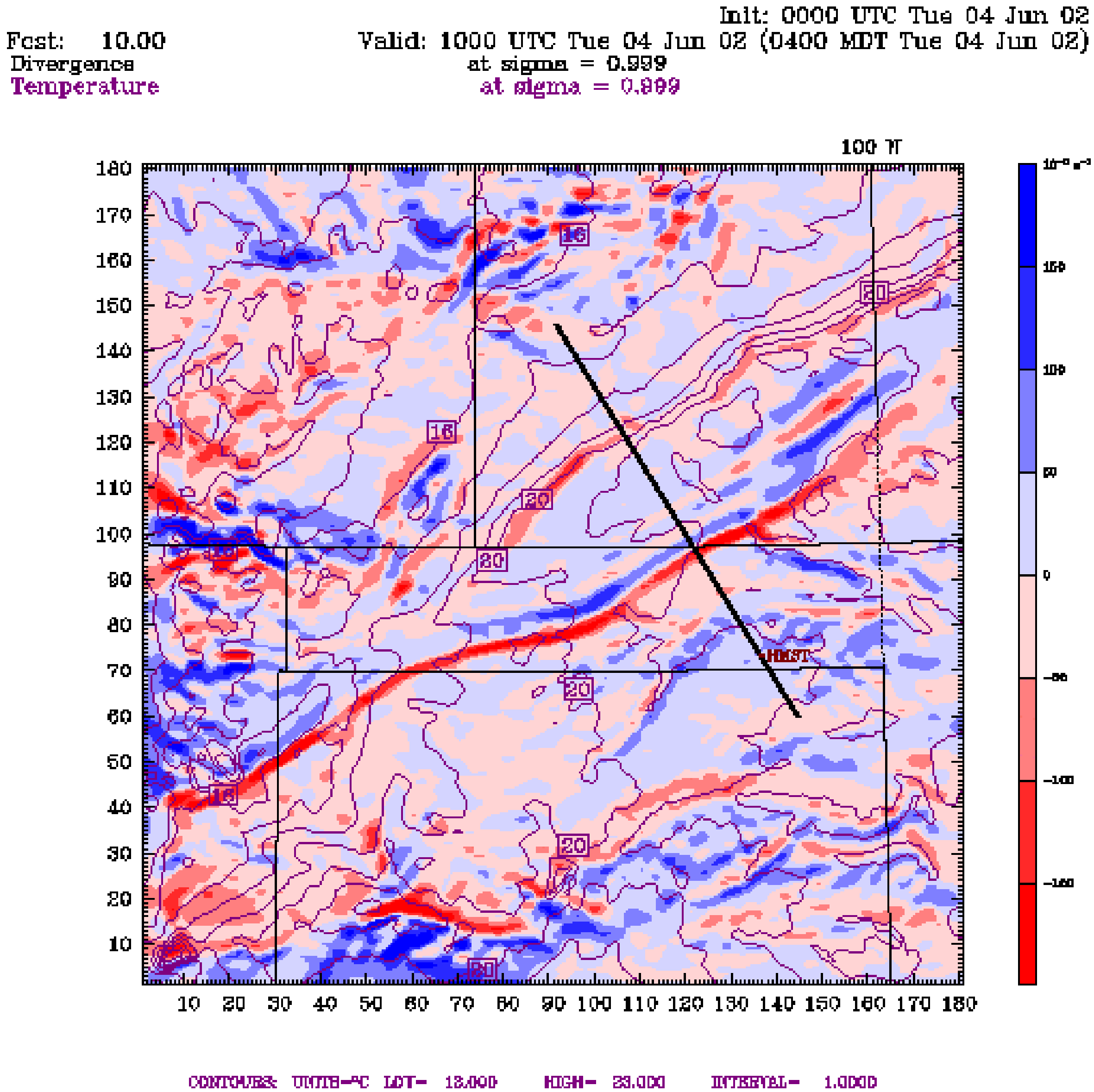

Init: 0000 UTC Tue 04 Jun 02
Fcst: 10.00
Valid: 1000 UTC Tue 04 Jun 02 (0400 MDT Tue 04 Jun 02)
Divergence
at sigma = 0.999
Temperature
at sigma = 0.999
100 W
CONTOURS: UNITS=°C LOW= 12.000 HIGH= 23.000 INTERVAL= 1.0000

Figure 1b.

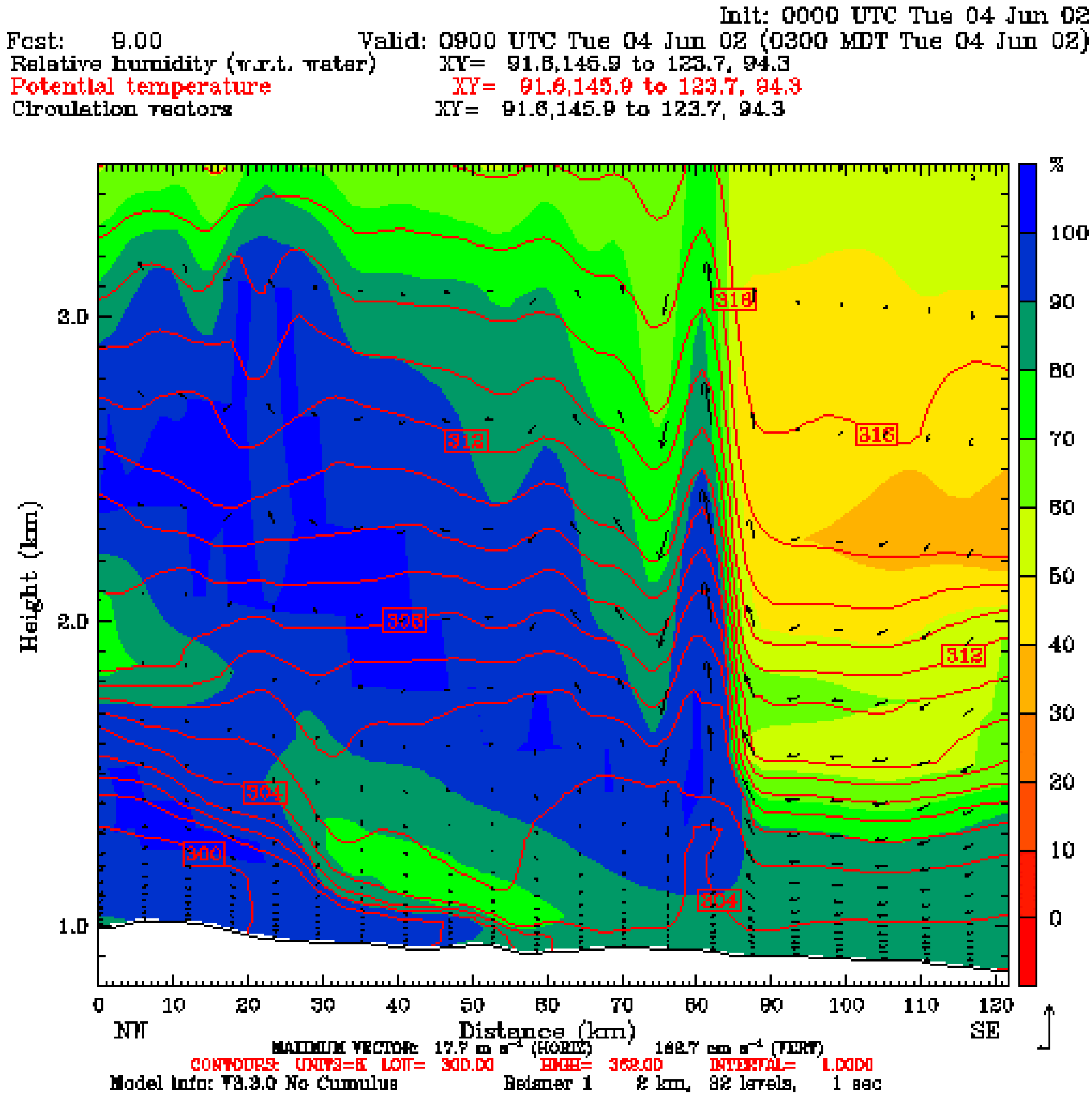

Init: 0000 UTC Tue 04 Jun 02
Fcst: 9.00
Valid: 0900 UTC Tue 04 Jun 02 (0300 MDT Tue 04 Jun 02)
Relative humidity (w.r.t. water)
XY= 91.6,145.9 to 123.7, 94.3
Potential temperature
XY= 91.6,145.9 to 123.7, 94.3
Circulation vectors
XY= 91.6,145.9 to 123.7, 94.3
Height (km)
Distance (km)
NW
SE
%
MAXIMUM VECTOR: 17.7 m s⁻¹ (HORIZ) 162.7 cm s⁻¹ (VERT)
CONTOURS: UNITS=K LOW= 300.00 HIGH= 369.00 INTERVAL= 1.0000
Model Info: V3.3.0 No Cumulus Reisner 1 2 km, 32 levels, 1 sec

Figure 1c.

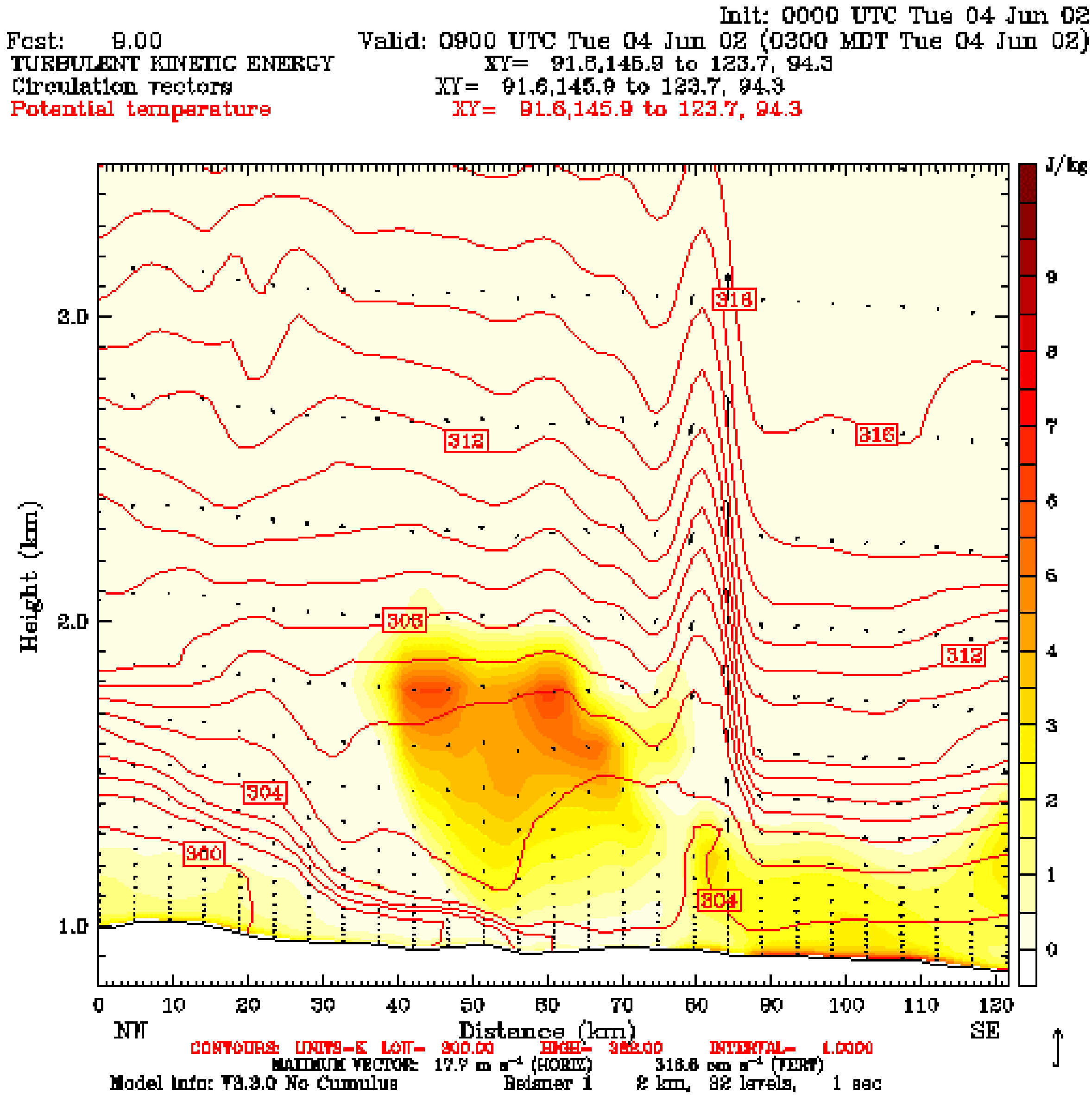


Figure 1d.

Further details are given in Koch, et al (2003), Koch, et al (2003), and Flamant, et al (2003).

References:

Flamant, et al., 2003: "The life cycle of a bore event over the Southern Great Planes during IHOP 2002. 6th Conference on Mesoscale Processes, Portland, OR.

Koch, et al., 2003: Multisensor study of a dual bore event observed during IHOP. 6th Conference on Mesoscale Processes, Portland, OR.

Koch, et al., 2003: Structure and dynamics of a dual bore event during IHOP, as revealed by remote sensing and numerical simulation. ISTP Symposium, Leipzig, Germany.

2. Development of a Convective Parameterization

In collaboration with Georg Grell and Dezso Devenyi, a new convective parameterization is being developed based on ensemble representation of convective closures combined with data assimilation techniques and climatological analysis. Details are given in Grell and Devenyi (2002), Grell, et al (2003), and Grell, et al (2003).

References:

Grell, G.A. and D. Devenyi, 2002: A generalized approach to parameterizing convection combining ensemble data and data assimilation techniques. Geophys. Res. Letters, Vol. 29, No. 14.

Grell, G., D., Devenyi, S. Weygandt, and M. Pagowski, 2003: Applying data assimilation to a new convective parameterization, EGS, Nice, France.

Grell, G., D. Devenyi, M. Pagowski, and S. Weygandt, 2003: Using uncertainty for the development of a new convective parameterization, EGS, Nice, France.

3. One- and Two-Way Coupling of Atmospheric and Hydrologic Models

This is a project in collaboration with G. Grell, M. Clark (CIRES), L. Hay (USGS), and W. Gutowski (ISU). The project is designed to assess how accurately the land surfaces schemes in atmospheric models can simulate run-off, and to identify and begin work on the research tasks necessary for operational hydrologic forecast capabilities to be fully integrated within atmospheric systems. The focus is on two river basins: a mountainous, snowmelt-dominated river basin in northwestern Colorado (Yampa River) and a flat, rainfall-dominated river basin in Kansas (Walnut River).

To achieve this objective, MM5 with Smirnova land-surface model is used to conduct 5-year climate simulations (October 1994 to September 1999) at 5 km and 1.7 km horizontal resolution for domains spanning Yampa and Walnut River basins. The strength of the current study, compared to the previous high-resolution mesoscale modeling efforts, is the long period of the simulations. This allows us to summarize the advantages and limitations of high-resolution climate modeling with more confidence. In addition, the use of an identical modeling strategy in two markedly different river basins will provide an improved understanding of possible problems and possibilities when integrating hydrologic forecast capabilities within atmospheric modeling systems and will lead to improved management of water resources. Further details are given in Clark, et al (2003).

References:

Clark, M., L. Hay, M. Pagowski, and G. Grell, 2003: One-way and two-way coupling of atmospheric and hydrologic models, GAPP PIs meeting, Seattle, WA.

4. A number of forecast experiments were performed with varying WRF model grid sizes. The initial results suggest that the forecast is very sensitive to small grid size. Experimental tests were also conducted using WRF-Mass and WRF-Height coordinate versions of the model, together with some sensitivity experiments on various microphysical packages. Idealized tests were also made. WRF initialization tests are still continuing with the use of MM5 output to initialize 2-km WRF.

EAR—The PACE Project

Principal Researchers: Jim Frimel, Young Chun, and Lisa Gifford

<u>The Center Weather Service Unit (CWSU) Prototyping and Aviation Collaboration Effort (PACE)</u>

PACE is an operational test area located within the Fort Worth Air Route Traffic Control Center's CWSU for developing innovative science and software technology used to directly provide weather support for the ARTCC Traffic Management Unit (TMU). A major goal of PACE is to investigate aviation data sets and forecast products specifically tailored for the ARTCC air traffic weather forecasting environment among operational weather forecasting facilities, and to investigate the utilization of collaborative weather forecasting.

The FAA PACE effort as it relates to CIRA research at NOAA's Forecast Systems Lab is currently comprised of two separate investigative projects: the FAA FX-Connect project and the TMU project. The PACE effort was born from the necessity to research and investigate innovative software tools, data products, and for minimizing adverse weather disruptions in air traffic operations within the National Airspace System (NAS). Requirements and needs can be found in the study performed by FAA ARS-100 on "Decision-Based Weather Needs for the Air Route Traffic Control Center (ARTCC) Traffic Management Unit."

The FAA FX-Connect project is the research and development of software utilized in the PACE facility for investigating and demonstrating collaboration and prototyping of aviation-specific data products. The TMU project is the web-based research and development of products available directly to the Air Traffic Controllers for their evaluation via the Internet. The Aviation Weather Center in Kansas City and the Fort Worth CWSU are the facilities participating in this exercise.

The FX-Connect software (FXC), developed by FSL's Systems Development Division, is a major component of the FAA FXC project. FXC is a software application tailored and utilized in the PACE facility. The major system used to acquire, distribute, create and provide the required data sets for the FAA FXC and TMU projects is the AWIPS Linux data ingest system. The FXC system allows for the remote access and display of AWIPS data sets over the Internet, a collaboration capability among participants at physically different locations, and the ability to utilize tools to aid in discussing forecasts. The TMU project is comprised of an AWIPS Linux data ingest system and web servers specifically developed for the creation of web-based products.

The TMU project is currently in the initial phase of a four-phase project designed to address the weather information needs of the TMU relating to the weather-related hazards consisting of convection, icing, turbulence, and ceiling/visibility. Each phase will address the tactical (0-1 hour) and the strategic (2-6 hour) application of the above products to help the TMU decision maker in directing air traffic into and out of the ARTCC airspace. All phases will be subjected to the iterative process of defining, developing, demonstrating, and evaluating the weather-related hazard graphic and its presentation to Traffic Manager users.

For phase one—advanced product displays, visualization and the WWW—CIRA researchers have developed and are evaluating the prototype Tactical Convective Hazards Product (TCHP) on the Traffic Management Unit (TMU) restricted web site (http://tmu.fsl.noaa.gov). The web site was enhanced based on feedback from the Traffic Managers from static displays of the TCHP to allow the Traffic Manager user to toggle capabilities of map backgrounds and convective products that comprise the TCHP. The convective SIGMET portion of the TCHP was enhanced to include convective SIGMET nowcast, convective SIGMET forecast, and convective SIGMET text. The convective SIGMET forecast is created by advecting the convective SIGMET nowcast using the motion information so that it is time matched with the National Convective Weather Forecast. A new impacted jet route map background was created using the convective products that comprise the TCHP for color-coding jet route segments. Testing, training, and evaluation plans have been created and added to the web site. The TCHP Viewer has also been enhanced to allow for looping.

The goal of the TCHP is to consolidate all tactical thunderstorm information into a single graphical product or limited suite of products for presentation to TMU decision-makers in an easily understood format. The TMU project will capitalize on development of advanced products from the AWRP and optimize the use of conventional advisories. Feedback from the ZFW Traffic Management Unit and Center Weather Service Unit participants will help refine the content and presentation. The Demonstration and Evaluation (D&E) will expedite fielding of advanced products by obtaining operational input early in the process. When there is agreement between the participants that a satisfactory product has been created, specific recommendations will be made for national implementation on FAA operational systems such as the Volpe National Transportation Systems Center Enhanced Traffic Management System.

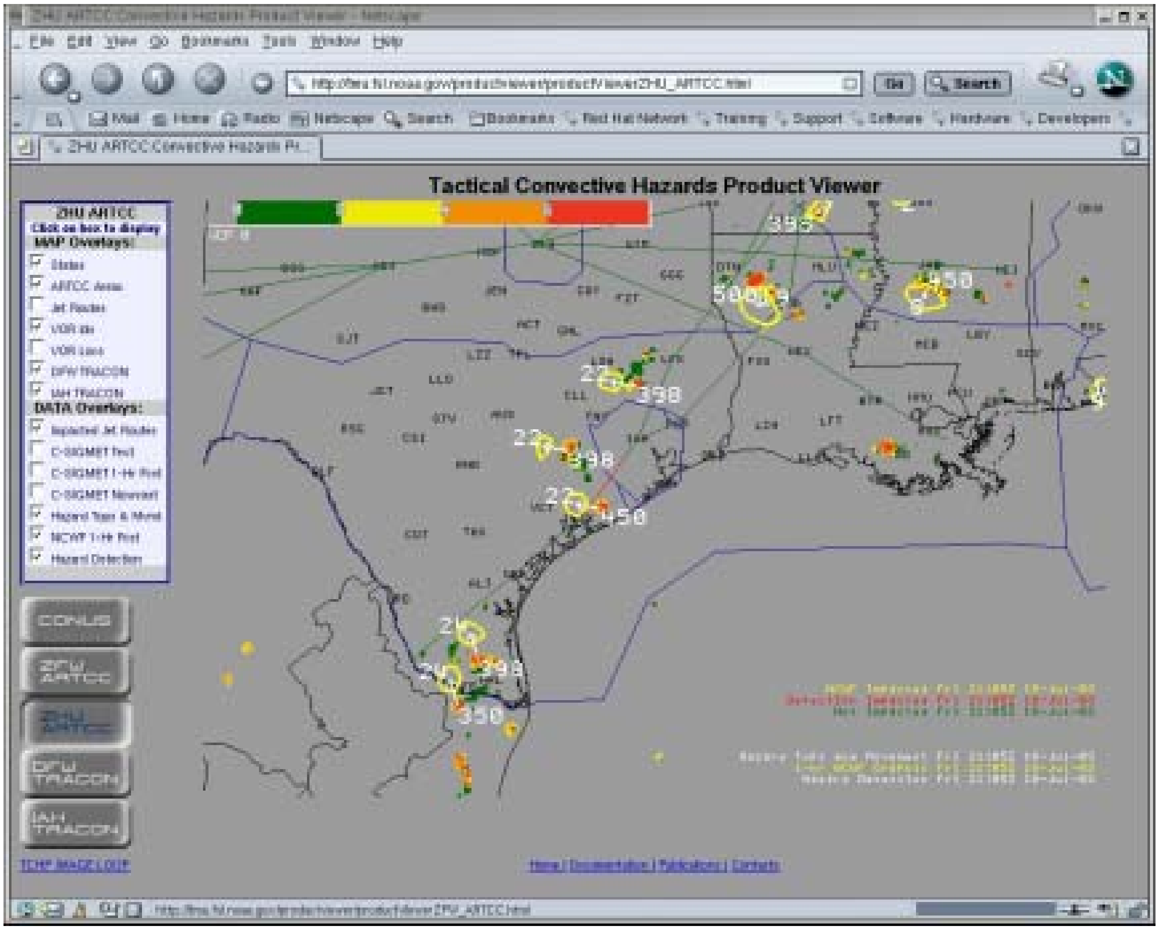


Figure 1 provides a view of the TMU website TCHP showing the default ZHU ARTCC Scale with Impacted Jet Routes.

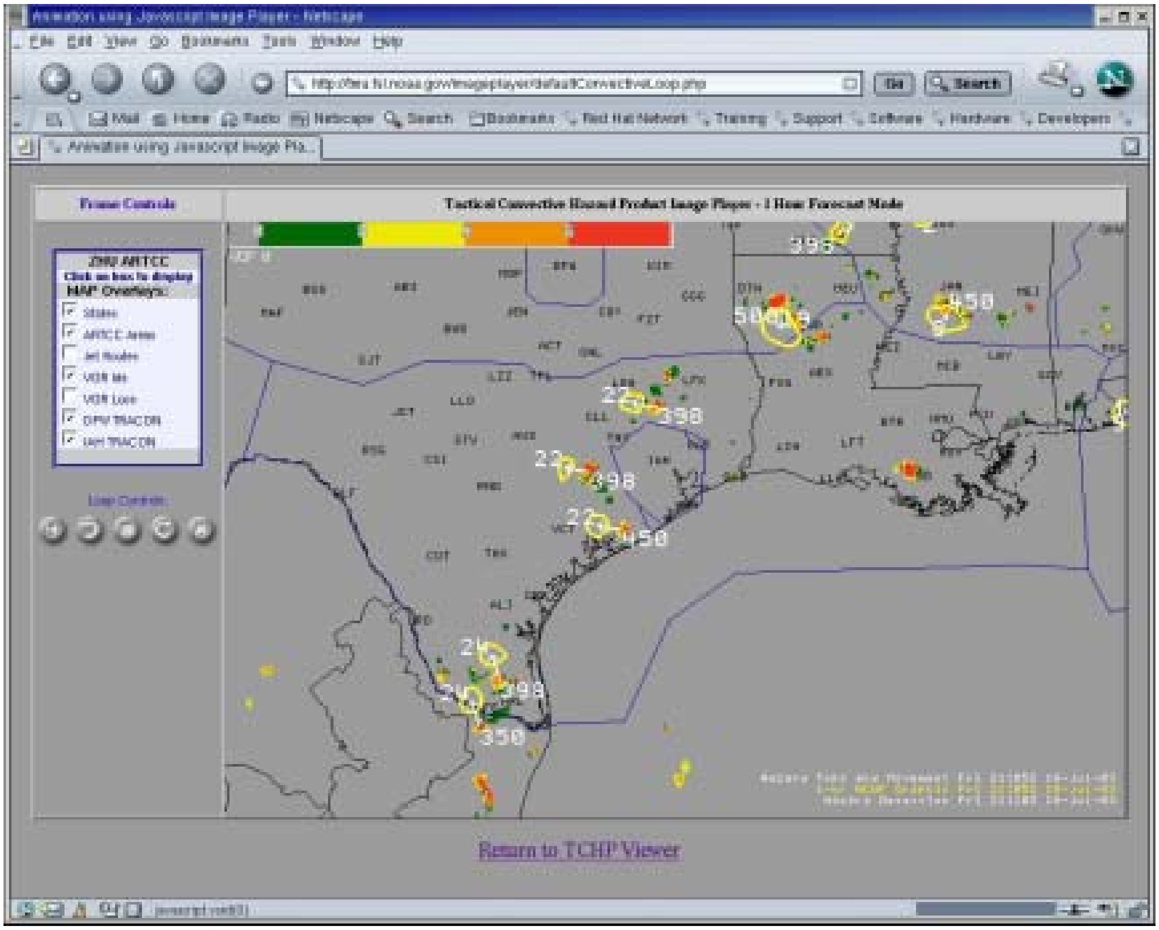


Figure 2 provides a view of the TMU website TCHP Image Loop with default Convective Hazards.

EAR—High Performance Computing

Principal Researchers: Dan Schaffer and Jacques Middlecoff

The Scalable Modeling System (SMS)
Development has continued on a directive-based model parallelization tool called SMS that is used in the parallelization of weather and ocean models. The approach is to provide the modeler with a set of simple, general directives that can be added to the code. These directives (FORTRAN comments) are then translated by SMS, generating new or modified code which allows the model to run correctly on an arbitrary number of processors. This code includes calls to SMS library routines that implement the communication necessary to run the model on parallel machines.

This year, a paper has been submitted to the Tenth ECMWF Workshop on the Use of High Performance Computing in Meteorology analyzing the performance of SMS. The paper is entitled "Performance Analysis of the Scalable Modeling System." The paper is located on the web at http://www-ad.fsl.noaa.gov/ac/sms.html (click on "papers"). The article demonstrates that SMS adds insignificant overhead to equivalent hand-coded MPI parallelizations of the NCEP Eta model and the Rutgers/UCLA Regional Ocean Modeling System (ROMS).

Grid Technology
An investigation has been initiated on how grid technology can be utilized by the atmospheric and ocean research communities. Grid software provides a means to simply, securely, and efficiently access multiple geographically separated computing resources. Ideally, a user can submit an atmospheric or oceanic model to "the grid" and have it run on whatever computer resources are currently available, regardless of their location. The project’s specific goal is to investigate the possibility of running a coupled model on the grid where one model runs on one machine; the other on a second machine. This year, a dummy coupled "ocean" and "atmosphere" model was constructed that runs on the grid. Early in the coming year, an analysis of the feasibility of running coupled models in this fashion will be conducted.

Weather Research and Forecasting (WRF) Model
A project to develop coupled model infrastructure has been undertaken. This effort is funded by the Department of Defense through NCAR. The specific goal is to develop a coupling implementation of the WRF I/O Application Program Interface (API). The fundamental idea is that an application can call the same API for I/O or coupling. So, for example, the WRITE_FIELD subroutine in the API will send data to disk when an I/O implementation is used and send data to another model component when a coupling implementation is used. This year, the coupling implementation of the API was developed using the Model Coupling Toolkit; lower-level coupling software developed by the Argonne National

Laboratories. Early in the coming year, the coupling implementation of the API will be used to couple the WRF and ROMS models.

The NCEP Post Processor and the NCEP Verification package have been ported to ijet in preparation for the implementation of the WRF Test Plan. The WRF Test Plan will evaluate ensemble forecasting, using the WRF Mass Coordinate core and the WRF NMM core, as a candidate for replacing Eta as the NCEP operational code for weather prediction.

The Standard Initialization was modified to provide the capacity of doing output in the WRF I/O API. The WRF regression test was ported to and optimized for jet and ijet.

Taiwan Central Weather Bureau (CWB)
A project is underway to provide support to the CWB for their upcoming procurement of a new high performance computer. The specific goal this year is to port their main forecast model to the FSL supercomputer and analyze its readiness for the procurement.

Rapid Update Cycle (RUC) Model
Support for the RUC team continues. The RUC code was optimized for the new IBM Power 4 at NCEP. A 13% speedup was achieved. Realistic timing runs were made so the RUC time allotment on the IBM Power 4 can be best utilized.

EAR—Real-Time Verification System Project

Principal Researcher: Christopher E. Steffen

The Real Time Verification System (RTVS) collects forecasts and observations. It then compares the forecasted values at a geographical location to the observed values at a particular time to generate statistics concerning the accuracy of the forecast. These statistics are then disseminated via a website. The overall RTVS architecture was evaluated. Several improvements to the architecture were suggested to improve the modularity, reliability, and maintainability of the RTVS system. Performance improvements were also made. A test harness framework for IDL was written for use with the RTVS code base. One product, "Gtg', is currently in the process of being implemented according to the new architecture. Partial documentation for the existing architecture was also generated.

EAR-Outreach and Science/Technology Transfer

Principal Coordinator: Sher Wagoner

In keeping with NOAA/FSL's Technology Transfer mission, this program aims to develop relationships with scientists who seek to solve the DoD's operational weather problems, and to create programs that can apply the solutions. In pursuit of this goal, the Technology Transfer program has created an agreement between CIRA and FSL to allow CIRA programs to support FSL technology insertion tasks.

Partnership Coordination

This aspect of the Science and Technology Transfer program works to encourage industrial and federal agency partnerships. In support of this program a number of projects were initiated, as follows:

Organization and Coordination of the First Technology Day at FSL

The day was organized to present scientific algorithms, atmospheric observing systems, and weather data display and data base systems that are in various stages of research and development. They were presented to potential industry and federal agency partners to foster collaborative programs that would mature the research and development into viable operational systems. Twelve systems and algorithms were demonstrated or presented to a group of 70 industrial, DOC, DOD, FAA, state government and university visitors. The format of the Day consisted of a room full of systems and posters that could be demonstrated on a half-hourly or hourly basis, and a separate conference room for oral presentations. Comments from attendees were very positive regarding the format and content of the Technology Day. Consensus from the FSL participants was also very positive. Another Technology Day is planned for summer or fall in FY04.

Research Coordination

Development of a partnership with the NPOESS IPO and FSL was pursued to compare several compression technologies. The controlled-precision wavelet compression developed by CIRA at FSL will be compared to other compression algorithms for its use in the NPOESS data transmission and storage program. This project is ongoing.

Partnership with the Air Force Weather Agency (AFWA) was fostered to use the wavelet algorithms to compress 3D model grids. The GFS (Global Forecasting System) grids have been compressed and will be sent back to AFWA for testing as a part of their MM5 GTWAPS system. This project is ongoing.

Partnership Coordination for the Global Unified Profiling System (GUPS)

Teleconferences and planning meetings with potential industrial and government partners were coordinated to develop support and advocacy for the GUPS initiative. A preliminary proof of concept plan (PAC Plus) was developed with the GUPS team and laboratory partners. An initiative has been written for FY05. Alternative observing system platforms for the GUPS concept were also researched and presented.

Partnership Coordination for the GPS-IPW Program

- Identified new sites for dual-frequency antennas to provide additional coverage for National Weather Service WFO's, including the WFO at Salt Lake City, Utah and C-MAN Station in Dry Tortugas.
- Presented a GPS Meteorology seminar on 'Forecasting the Weather with GPS -IPW' to the Houston Chapter of the AMS in October 2002.
- Presented a GPS Meteorology talk to Eastern Region forecasters.
- Provided 'GPS-IPW and Surface Transportation', exhibit demonstrations at the Transportation Research Board Annual Meeting and Exhibit, January 2003.
- Presented "Technology Transfer Challenges" as part of the Space Environment Center monthly 'Science Seminars' series at the David Skaggs Research Center in August 2002.
- Developed new graphic materials for outreach displays and informational handouts.
- Developed formal publication information about the program for NWS Science Operation Officers and observation managers at NWS headquarters.
- Provided user requirements and design support to the developers of the GPS-IPW website. Evaluated operational NWS activities to which the GPS-IPW data would add value.
- Identified student research opportunities between the CSU Atmospheric Sciences Department and the GPS-IPW program.
- Identified a new Aerospace program opportunity to get NOAA involved in GPS Radio Occultation (RO) meteorology.
- Met with Aerospace engineers regarding the SBIRS-Low (RO) receiving system. The program has been renamed (STSS) and will not have an RO sensor for 6 or 7 years.
- Co-authored three papers on GPS Meteorology as follows:

Publications:

Gutman, S.I., R. Pursaud, and S.M. Wagoner, 2003. Use of federal and state departments of transportation continuously operating GPS reference stations for NOAA weather forecasting, *AMS 19th Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, P1.39, Long Beach, CA, p. 139.

Gutman, S.I., S.M. Wagoner, M. Codrescu, and T.F-Rowell, 2002. The use of atmospheric models to improve differential GPS positioning accuracy, Session on GPS User Accuracy Models, 2002 Core Technologies for Space Systems, Colorado Springs, CO, 19-21 November 2002.

Gutman, S.I., and S.M. Wagoner, 2002. Impact of geomagnetic storms on GPS tropospheric delay estimates, NOAA Space Environment Laboratory Science Seminar, David Scaggs Research Center, Boulder, CO, 8 August 2002.

Other Papers and Articles:
'GPS-IPW for Satellite Cal-Val', White Paper for NPOESS IPO

FSL Forum; "Collaborating to Improve GPS Accuracy and NOAA Weather Forecasting"

EAR—Regional Analysis and Prediction (RAP)

Principal Researchers: Kevin Brundage and Tracy Smith

The primary focus of the RAP group is research and development of the Rapid Update Cycle (RUC), an hourly 4-dimensional data assimilation and numerical forecast model system. The RUC runs operationally at the National Center for Environmental Prediction (NCEP) as the RUC20. CIRA researchers at FSL play a key role in this development.

In May of 2003, the analysis scheme used in the 20km RUC was replaced with a 3D variational method, developed in the RAP group. Extensive testing of the 3DVAR package was performed to ensure that the resulting analysis and forecasts were as good or better than those produced using the OI scheme used previously. Use of the 3DVAR package allows us to integrate additional observation data more effectively.

The RUC team is integrally involved in the development of the WRF package. Currently, we run an experimental 10km WRF run over the TAQ domain, and a 20km WRF run on the CONUS domain. CIRA scientists serve on several of the WRF working groups, including post-processing and operations.

CIRA scientists are currently principal investigators for the RAP team's participation in the New England Forecasting Pilot Program known as the Temperature and Air Quality (TAQ) Program, and a joint collaboration with the National Renewable Energy Laboratory (NREL) studying forecast methods to improve low-level wind prediction for wind energy production and a study of benefits of additional GPS precipitable water observations in NWM (GPS-PW). The TAQ project incorporates a number of special observations, including boundary-layer profilers, GPS precipitable water, radar reflectivity and Mesonet observations into a nested (10-km nest) model running out to 48 hours 4 times per day. The NREL wind study uses model ensembles to estimate the probability distributions of low-level wind forecasts to provide confidence levels in predicting wind-energy power generation.

The Internet continues to be an important mechanism in MAPS/RUC development. The MAPS/RUC web pages now include a variety of plots derived from RUC20, development RUC, and experimental 10km RUC-TAQ.

For further information regarding MAPS and RUC-2, as well as a variety of real-time weather graphics and publications, see http://ruc.fsl.noaa.gov

EAR—Local Analysis and Prediction (LAP)

Range Standardization and Augmentation (RSA) Project

Participating CIRA Researchers: **Brent Shaw, Steve Albers, and Ed Szoke**

Along with maintaining the three LAPS analysis windows running within the FSL testbed, the LAPS ingest was also enhanced so that it can read several types of local range data, such as profilers and ASOS soundings; SODAR, and towers are soon to be added. This includes a tie-in between the RSA QC system and LAPS to provide better quality profiler and RASS data. At this time, real-time data from the 915 MHz and 50 MHz profilers are ingested. New methodologies in how surface observations influence land and water points in the LAPS domain were refined to more realistically depict the gradients of surface temperature and moisture in coastal areas (Figure 1).

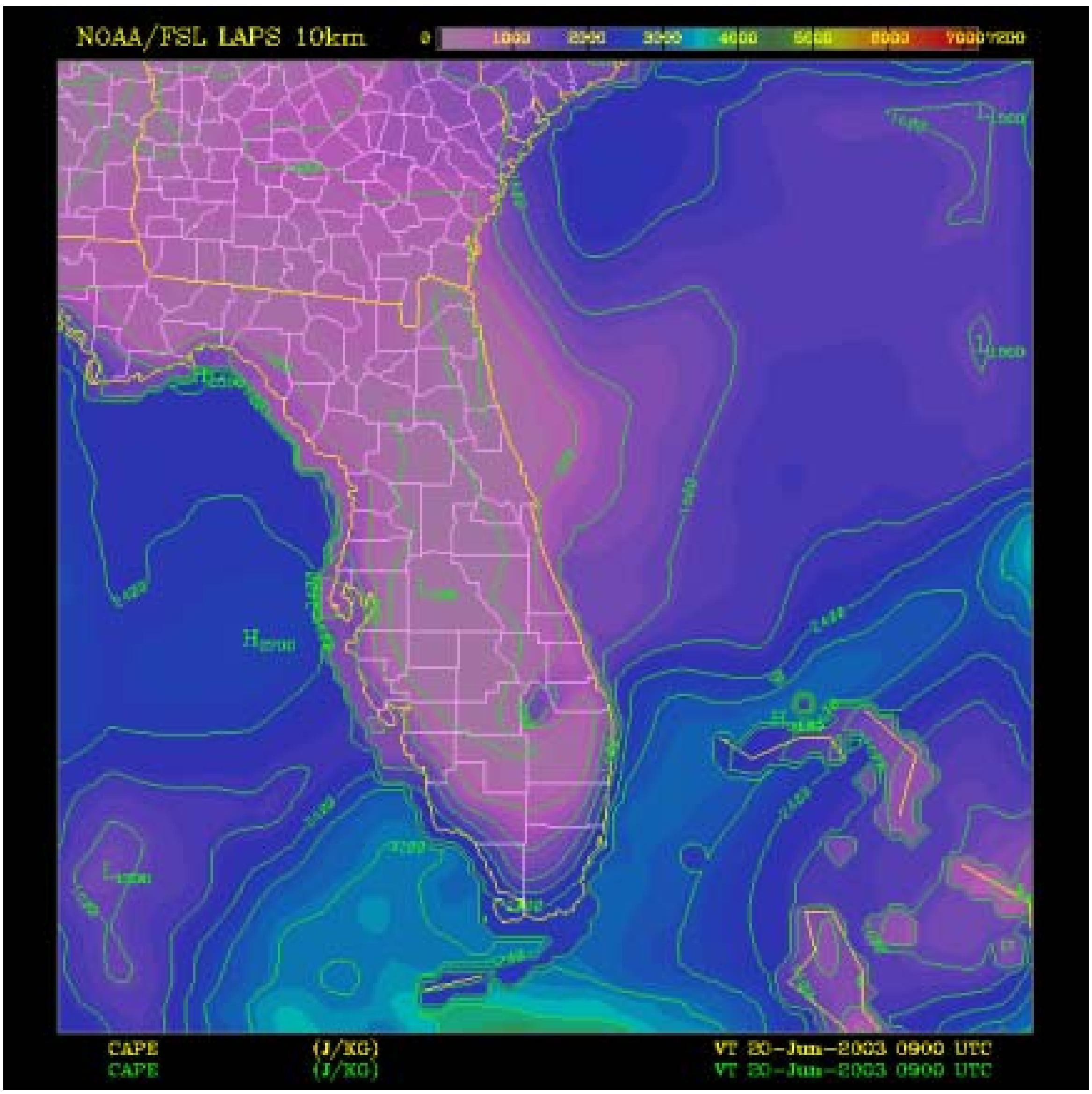


Figure 1. Analyzed CAPE field for RSA 10km domain centered at the Kennedy Space Center. Note the depiction of the coastline gradient showing nocturnal stable air over the land.

At the ranges, narrowband data from all WSR-88D sites in the region are available. Finishing touches were accomplished on software modifications for mosaicing multiple narrowband sites together to improve coverage in the LAPS/MM5 domains. The capability to merge the wideband data with the narrowband data has been further refined and is currently running at both ranges.

In addition to the LAPS analysis improvements, several changes to the MM5 forecast model configuration were made. First, various planetary boundary layer (PBL) schemes were tested. In order for the MM5 output to be coupled with the HYPACT dispersion model at the ranges, a PBL scheme that produces forecasts of turbulent kinetic energy (TKE) was required. After our testing and evaluation, the ranges are now employing the Burk-Thompson scheme. Second, a cumulus parameterization on the 10km grid was reinstated. After deactivating the parameterization over the winter months, the MM5 was found to have a high QPF bias during fair weather cumulus conditions. The use of the Kain-Fritsch parameterization, which accounts for shallow cumulus effects, has reduced this bias. Furthermore, the Kain-Fritsch scheme was modified and tested to make use of a mechanism that allows parameterized condensate to be fed back to the resolved condensate grids. This eliminates inconsistencies between simulated radar reflectivity and accumulated precipitation that often occurs when employing convective parameterization schemes.

Finally, CIRA researchers developed and presented training materials for use by the forecasters at the ranges. This training will allow the forecasters to optimize their use of the LAPS/MM5 system in daily operations.

<u>USAF (AFWA) Project</u>

Participating CIRA Researcher: Brent Shaw

CIRA staff responded to several Weather Research and Forecast (WRF) Standard Initialization (SI) tasks to support AFWA. These tasks consisted of various enhancements to the SI package to better accommodate the land surface modeling (LSM) component of the new WRF model which will become the operational model at NCEP and AFWA within the next 2 years. These enhancements include improved interpolation of the various land surface parameters (soil moisture, soil temperature), the ability to use land and soil categories from the background model being ingested, and the integration of the AFWA agricultural meteorological model (AGRMET). These improvements will allow the WRF model to be readily coupled to at least two state-of-the-art LSMs: the new unified Noah model, developed jointly by the Air Force, NCEP, Oregon State University, and the Hydrometeorological Center; and the Rapid Update Cycle (RUC) LSM, developed at the Forecast Systems Laboratory.

AWIPS Support to the NWS

Participating CIRA Scientists: Ed Szoke, Steve Albers, and Brent Shaw

AWIPS/LAPS

The storm relative helicity calculation now uses the Bunkers method to calculate the assumed storm motion. This makes the helicity field more in line with the current National Weather Service convention and thus better suited for forecaster interpretation in the local weather office (Figure 2).

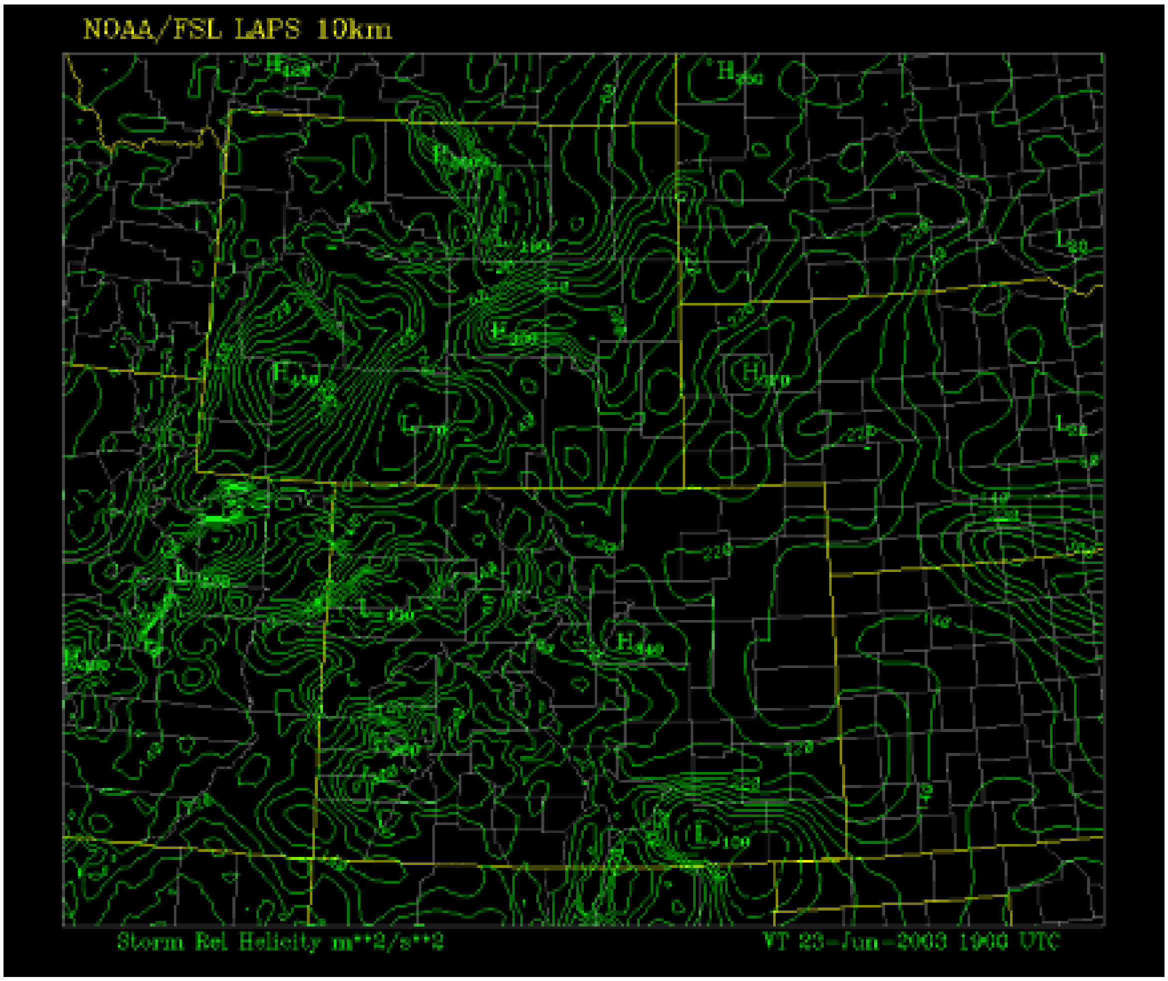


Figure 2. Analyzed helicity field for the 10km domain centered over Colorado.

D3D Activities

As a participating meteorologist working with the D3D development group, meteorological input to the potential incorporation of 3D in AWIPS was provided. Although D3D is still considered an experimental potential application to AWIPS at this time, an agreement was reached with the NWS Office of Science and Technology that will allow for formal tracking of D3D developments. Our main efforts continue to be to distribute D3D to WFOs (Weather Forecast Offices) that are interested in testing it and record feedback from these offices, and spread the word on D3D through conference presentations. In addition, we interacted with UCAR/COMET which resulted in D3D being used during their most recent NWS SOO (Science Operation Officer) training course. A D3D presentation was made at the 19th IIPS Conference, held with the 83rd AMS Annual Meeting in February 2003 (Long Beach, California). A presentation was also made at the 2003 Mountain Weather Workshop (March) held in Cheyenne, Wyoming and organized by the Cheyenne NWS WFO.

EFF Activities

Interaction with the local NWS/Boulder WFO, located in the Skaggs Building, continued through workshops and providing real-time runs of the MM5-hotstart for their forecast area. Operational forecast shifts, averaging 2-4 shifts per month, also occur which allows forecasters more time to pursue interactive projects, as well as fostering other cooperative projects. In addition, this activity allows for familiarity with operational forecast issues and is invaluable in our training activities.

<u>LAPS Improvements</u>

Participating CIRA Researchers: Steve Albers and Brent Shaw

Improvements were made in LAPS to analyze observations from new types of instruments and new data formats - thus expanding the envelope of meteorological data environments that we can operate in with our ever growing set of users. Following are some details.

LAPS Observational Data Sets

Improvements were made in LAPS to analyze observations from new types of instruments and new data formats - thus expanding the envelope of meteorological data environments that we can operate in with our ever growing set of users. This is outlined below for surface and upper air observations.

Wind QC checks now work more robustly for surface METAR and mesonet data. Scripts were improved for reporting the types of surface observations making it into a given LAPS run. Collaboration within the Lab was pursued to allow our ACARS and RAOB ingest to function in the AWIPS environment, including better QC checks. Several stations were added to our QC blacklist for dewpoint, humidity, and altimeter setting.

The sounding ingest now has expanded capability, especially with the incorporation of dropsondes. Rawinsonde ingest was improved so that it properly sorts and otherwise uses the significant temperature level data. The QC and software organization (e.g. for sounding output) was improved for rawinsonde ingest. Sounding ingest is also being transitioned to allow latitude, longitude, and time information to be specified at every level instead of just for the sounding as a whole.

Wind and RASS profiler ingest (50 MHz and 915 MHz) was expanded (including QC checks) to accept RSA/LDAD input formats. Data ingest for several data sources was modified to prevent empty intermediate files thus helping with product tracking.

Surface Analyses

A new version of the land/sea weighting was set up and enhanced in collaboration with Tim Hume from New Zealand. This uses a .01 land fraction threshold and is being implemented for most state variables except pressure. The consistency check between surface and upper level temperature fields is now adjusted automatically according to the local terrain.

Improvements in the use of the reduced pressure background were made to give the resulting analysis better terrain related characteristics. Observations are now more accurately being placed onto the nearest LAPS grid point for subsequent analysis steps. Dewpoint observations are now being checked against the model background while QC parameters were tightened for dewpoint and reduced pressure to help prevent bull's-eyes in the analyses. Default parameters were adjusted to allow for a large increase in the number of available observations. Level information was clarified in the output (e.g. temperatures are at 2M AGL, winds are at 10m AGL, etc.). Other changes were made to make the surface analysis more robust in the presence of few observations. This includes specifying whether any surface observations are required for running the analysis.

Radar Processing

Strides were made towards more efficiency and other functional improvements for radar remapping and mosaicing. For example, remapping and mosaicing were reworked, as well as other radar processing software, to allow simplification and flexibility of namelist and other parameters. Resolution dependent parameter inputs for remapping were made more versatile and user friendly. The radar remapper now has a data structure to facilitate the input of new run-time parameters. Wideband remapping was made more robust for different combinations of reflectivity and velocity data in the tilts. The memory use and software organization was streamlined within the remapping, as well. Efficiency has been improved for the remapper in its directory searches while in both real-time and archive modes. The remapping program can now process more radar scans with each run.

The remapping software was made more versatile for timing in a stand alone mode, and can now process raw data with AWIPS or NIMBUS filename conventions. Separate coverage QC thresholds are now allowed for reflectivity and velocity during the wideband remapping. Reflectivity QC flags are now being better accounted for during the horizontal remapping fill step. Some design work for additional clutter screening of narrowband data was done based on reflectivity and distance. A strategy for compressing intermediate full volume (wide-band) Doppler radar files using run-length encoding is being developed and tested.

Wideband and/or narrowband radar data can now be mosaiced simultaneously. In a related note, the merging of full-volume reflectivities with various kinds of low-level radar data is now more flexible. Mosaics have been configured so they can be generated for multiple times within the main LAPS cycle time. We improved the handling of missing radar areas in the column maximum reflectivity field. Intermediate radar files are synchronized better with the raw radar files while radar purging was improved.

Wind Analysis

A significant overhaul of the wind analysis was begun to handle observations using data structures instead of 3-D arrays. This will help to individually utilize high resolution observations that might otherwise get thrown out when they overlap within the same 3-D gridpoint. This also allows more efficient memory usage.

The weight of Doppler radial velocity data was increased (assumed error reduced) to allow the radar data to have a better impact on the analyzed winds. The vertical velocity calculation has been reworked with a more accurate lower boundary terrain specification. Further improvements were made to the SMS version of the wind analysis for parallel processing platforms. Additional verification statistics were implemented. The tracking of which individual radars are processed in the wind analysis was improved. Doppler velocity dealiasing was simplified so users can better understand it. Sounding data processing was improved to better handle missing heights with pressures.

Stability Indices

Stability calculations are now more robust with memory allocation bugs fixed.

General Software Improvements & Portability

LAPS software was made more dynamic while error checking, logging, CDL descriptions, and documentation were improved. Logging information concerning QC, verification, and what data made it into the analyses was also improved. Analysis software (including I/O routines) is now better organized as well as more robust in its working on various platforms. More constants were added to a centralized ‘include file’ to help ensure consistency throughout LAPS. String parsing routines are now more versatile.

Software configuration and build scripts were made more reliable so that LAPS compiles and runs better on various platforms. Other scripts were maintained and improved for running in the JET computing environment. Improvements were made in scripts that report what data get into the analyses and that monitor LAPS output. In particular, data reporting scripting/logfiles now work better with the AWIPS/LAPS implementation. Various improvements were made to Makefiles, as well.

WWW LAPS Interface

Plotting software was made more robust for radar and cloud observations, as well as high density coastline and land fraction information. 3.9 micron satellite and other cloud plots were improved. Observation plots were improved for fields such as upper-level temperature and wind, and precip-only surface stations are now excluded from state-variable plots. Other bug fixes now make the plotting more robust for relative humidity, various cross-sections, and derived radar winds. Plots were improved for a variety of divergence, omega, and vorticity fields. Other fields were added, such as total precipitable water and 3-D precipitation type forecasts. Image capability was added for a number of horizontal and vertical section plots. Image color tables and color bars were expanded and improved while labels are now more descriptive for a variety of fields.

Some of our web pages and related scripts are now in the LAPS software distribution to help with on-site implementation of LAPS displays by some of our collaborators. We made corresponding improvements to the organization and content of the web processing scripts. This includes enhancements so that they can be initiated from remote platforms. With our "on-the-fly" page, a contour density widget was added and more automation was added in specifying model forecast times. Difference fields are now displayable with cross-sections. Memory allocation was made more efficient, including for cross-sections. More runtime parameters were added for flexible user control while a data structure was added to help input these parameters, such as time-zone handling.

In addition to the "on-the-fly" page, many of our NWP forecast model runs initialized with LAPS are now on the Internet using an improved interface. These can now be viewed at http://laps.fsl.noaa.gov/forecasts.

Mesoscale NWP Model Initialization and Evaluation

Additional research and development was performed to improve the LAPS diabatic initialization of mesoscale NWP models. Sensitivity experiments were performed to determine the relative importance of the balanced wind field versus the need for saturation/supersaturation for "cloudy" grid columns. Fine tuning of the initialization step included adding horizontal scale dependencies to the hydrometeor concentrations and the vertical velocity profiles. These improvements will be subjectively and objectively evaluated using data collected during the International H_2O Project (IHOP_2002).

Water in All Phases (WIAP)

Participating CIRA Researcher: Steve Albers

Clouds & Precipitation Analyses

To improve the Water In All Phases analysis effort, the cloud analysis was set so that it requires IR satellite data before generating output. The satellite time window was increased to further help the cloud analysis. The cloud analysis was improved to better log the use of satellite data and its interaction with non-satellite observations of cloud layers. The edge extrapolation check for the cloud analysis was improved and the humidity/cloud ramp start point was modified from 60% to 70% to improve the use of the model first guess. Internal QC checks were refined to make the software more reliable while logging information was improved to help track down anomalous holes in the analyzed cloud field.

The 3.9 micron satellite data usage was adjusted to use it for cloud building only (turning it off for cloud clearing). Land fraction is now considered with improved 3.9 micron satellite brightness temperature criteria. Further work may be needed on this since there is quite a bit of small-scale structure in the 3.9 micron data that may or may not be real.

A new algorithm that uses visible satellite data in the cloud analysis to build clouds (e.g. daytime marine stratus) has been put into place and is now active in a wide variety of situations. This complements the pre-existing cloud clearing step. Within this algorithm, a routine determines the cloud top level with simultaneous consideration of 11u brightness temperature, visible cloud cover, and ground temperature. A land fraction test was recently added as part of the cloud building logic. The use of static albedo data was generally improved when visible satellite is used in the cloud analysis. Logging information was improved to characterize and compare the albedo from the visible satellite and from the terrain. One aspect of this is construction of histograms of the satellite albedo vs. the static albedo. A parameter was added to allow the option of using visible only if it has complete coverage.

Software for insertion of radar data into the cloud field was streamlined. The cloud and radar analyses now accept more information about the quality of input narrowband (two-dimensional) reflectivity data. This allows the assignment of a more accurate reliability to the radar data within the cloud analysis to help prevent false echoes from showing up in the final cloud and reflectivity fields. The requirements for (wideband) echo top to be >1000m AGL were increased when ground clutter is suspected. This is another step that may help in quality control for various situations such as nighttime clouds.

Weather Research and Forecast Model (WRF)

Participating CIRA Researchers: Brent Shaw and Steve Albers

Numerous improvements to the WRF Standard Initialization were made. In addition to several new data sets being added to support the Land Surface Model (LSM) component (see the AFWA task), additional flexibility was added to allow users to more easily use separate input data sets for the initial, lateral, and lower boundary conditions. Additionally, the WRF SI can now ingest gridded fields that are on non-isobaric surface (e.g., the RUC model on its native vertical coordinate). The various scripts used to install and run the SI package were made more user-friendly, based on feedback from last year's WRF User's Workshop. Scripts were added to provide better coupling between the SI and the WRF model, and now allows users to run the SI and WRF model together with a single command. The Mercator and Lambert FORTRAN map projection routines were simplified and standardized to work better in a wider variety of situations. This was done in support of the WRF GUI being worked on by several FSL and CIRA scientists. CIRA researchers continue to provide training and consulting to the community via NCAR on the setup and use of the WRF SI. Internally at

FSL, we have become the de facto WRF "experts" as more FSL and CIRA staffs begin to use the system.

US Forest Service (USFS) Project

Participating CIRA Researchers: Steve Albers and Brent Shaw

CIRA researchers set up and maintained three windows of LAPS analysis and MM5 forecast runs on the JET supercomputer, providing experimental real-time fields in support of the US Forest Service (USFS) Rocky Mountain Research Station (RMRS). In particular, calculations, output fields, and analysis/forecast web displays of several fire weather indices were created. These include the Haines Index (mid/high level), Fosberg Fireweather, and Ventilation Index. Also, collaboration with Dan Birkenheuer of FSL on the PBL top & depth occurred. Much of the software for this was obtained from the Fire Weather Consortium in Seattle, though it had to be modified and redeveloped to work with the LAPS analysis pressure grid in addition to the MM5 sigma grid. Consultation with the USFS in web page design and continual improvement of fire weather product displays based on feedback from fire weather forecasters occurred (viewable in real-time at http://www.fs.fed.us/rmc/). The displays include plan views of analyses and forecasts for various fields, as well as time series representing point forecasts.

The LAPS Fire Weather index, similar to yet having advantages over the Fosberg index, is also being shown to the fire weather community (Figure 3).

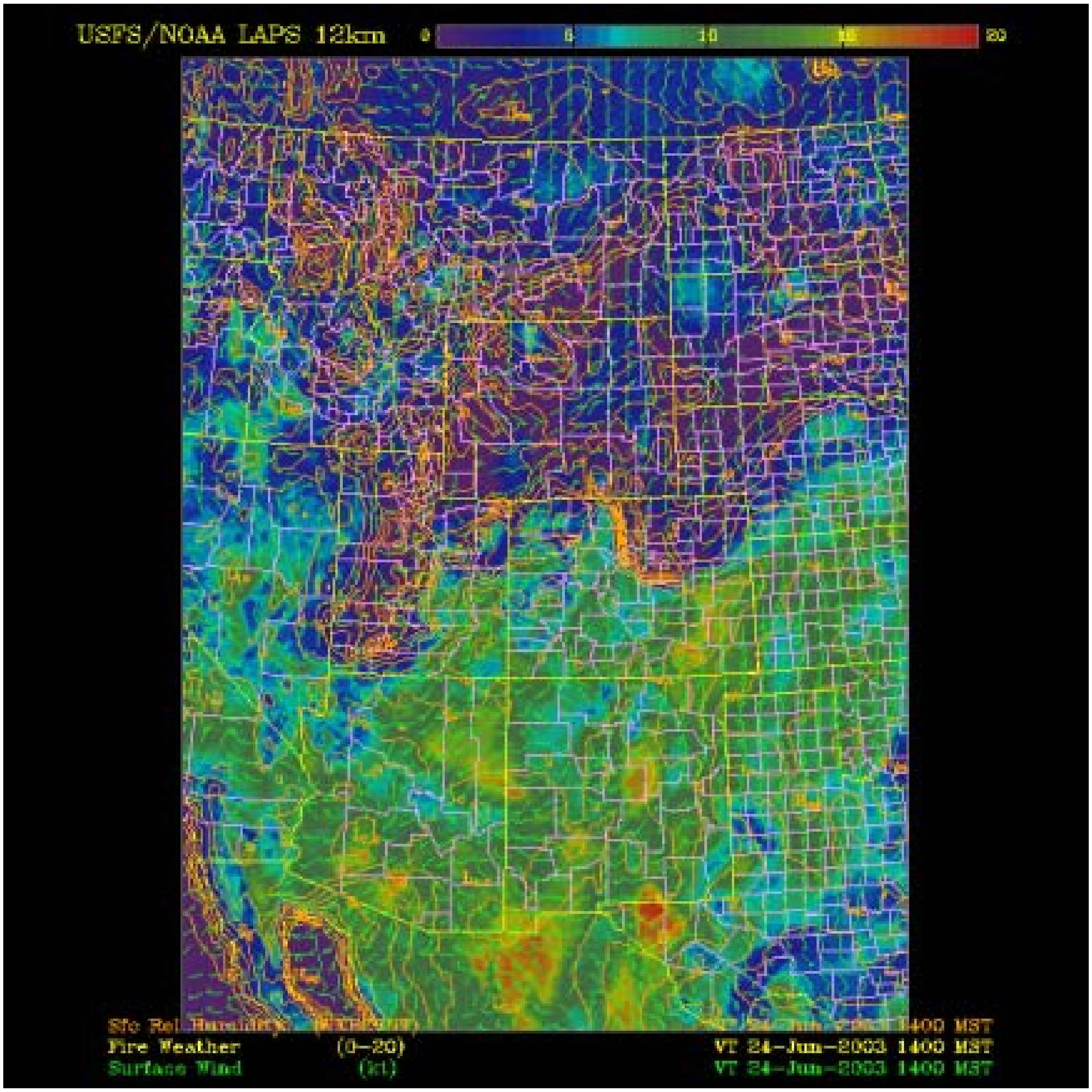


Figure 3. Analyzed fire weather summarizes the fire threat as a function of surface humidity, wind, and temperature. The red areas in westernmost Texas represent high fire danger.

A strategy for calculating and displaying the mean wind in the boundary layer for use in the ventilation index was implemented. An option for possible future use is in place to set the Haines Index to missing if part of the forecast layer extends below the ground.

As mentioned earlier, there is an ongoing improvement of our web pages to support our collaboration with the US Forest Service. This now allows a more complete set of analysis and forecast fire weather products to be plotted, including more user friendly color tables and labeling. Jared Seehafer of FSL helped out with various aspects of the forecast web pages.

We continued to enhance and expand the point forecast component of our NWP model post-processing. The ability to change the units of various parameters and customize the time zone displayed for the time column was added to better accommodate the fire weather community. Additional parameters, such as the Fosberg, ventilation, and Haines indices were added to the point forecasts. Improved web interfaces to create, edit, delete, and view point forecasts were developed.

CIRA researchers worked closely with the staff at the USFS Rocky Mountain Research Station to specify the requirements for a Linux cluster that was purchased for the purpose of eventually hosting a locally run LAPS-based operational service. Additionally, CIRA has been training the USFS staff on how to set up the system for real-time use.

International Projects

Participating CIRA Researchers: Steve Albers and Ed Szoke

Taiwan Central Weather Bureau (CWB)

CIRA researchers continued to run LAPS analyses for a 5km domain over Taiwan on machines at the CWB and at FSL (shadow run). A 9km window over Taiwan is now running at both locations as part of a transition process to Linux machines. Collaborations with the CWB were required to expand the LAPS sounding ingest to include CWB dropsonde data and to improve the surface observation ingest software so that it utilizes a much greater fraction of the available surface observations in Taiwan. This includes better reporting of observation type so we can keep track of the diverse sources of their surface data. SYNOP observations are also being processed to utilize the cloud layer information more fully. We collaborated with Yi-Chih Huang and Guo-Ji Jian from the CWB to further improve the SYNOP, mesonet (several sources), and model background data ingest.

We worked on visible satellite albedo calibration so we can make better use of the GMS satellite data in the cloud analysis. As the GMS satellite is being supplanted by GOES-9, we are working with John Smart and CWB personnel to manage the changing of satellites going into LAPS.

We collaborated with visiting scientists Dr. Adan Teng and Dr. Shiow-Ming Deng from the CWB by exchanging information on their radar processing and our LAPS analyses. This includes topics such as radar quality control and velocity de-aliasing.

Visits to the CWB in Taiwan included discussions on the LAPS implementation at CWB and presentations on the use of LAPS analyses for nowcasting in Taiwan. Extensive discussions were also engaged in with a number of CWB people and good progress was made in helping to set the future direction of our collaboration.

Korean Meteorological Agency (KMA)
We gave talks about LAPS for several Korean Meteorological Agency visitors. Other interaction included radar discussions with visitors from Korea.

Hong Kong Observatory (HKO)
We collaborated with visiting scientist P.W. Li from HKO to discuss aspects of the LAPS analyses and their implementation. This includes the optimal utilization of Doppler radar data in the wind analysis for tropical cyclone cases.

Federal Highways Road Weather Modeling

Participating CIRA Scientists: Brent Shaw and Adrian Marroquin

During the winter of 2002-2003, FSL ran a six-member mesoscale NWP ensemble and provided the output grids to NCAR for use in the Federal Highways Maintenance Decisions Support System. CIRA scientists configured and managed the real-time runs of WRF, MM5, and RAMS. Each model was run 4 times per day with two sets of lateral boundary conditions (national Eta and AVN grids). All were initialized with a LAPS analysis, also configured and managed by the CIRA staff that made use of satellite imagery, radar data, as well as conventional surface observations and aircraft reports. These forecasts were part of a larger data set used to produce decision products used by the Iowa Department of Transportation in their winter weather road maintenance efforts. Future efforts will consist of probabilistic forecasting products and techniques from mesoscale ensembles.

Coastal Storms Initiative

Participating CIRA Researcher: Brent Shaw

The Coastal Storms Initiative (CSI) is a project sponsored by the National Ocean Service and managed by the NWS Office of Science and Technology to perform a proof-of-concept for local data assimilation and NWP within a NWS Forecast Office. CIRA researchers set up, configured, and tested the new Weather Research and Forecast (WRF) model on a Linux cluster installed at the Jacksonville, FL, forecast office. The WRF is running at very high resolution (5 km grid spacing) and is using a matching LAPS analysis in a diabatic initialization mode. Forecasters at Jacksonville access the forecast grids directly on their operational AWIPS workstations and have the ability to import the grids into the Graphical Forecast Editor. Currently, 4 runs per day are performed and are being subjectively evaluated as well as being verified objectively at FSL via the Real Time Verification System (RTVS). Figure 4a shows a radar image from Jacksonville on 24 May, and Figure 4b shows the corresponding precipitation forecast from WRF. While not exact in location, the WRF clearly was able to forecast the mode of small scale storms along the sea breeze front that the national models missed on this day.

To our knowledge, this is the first quasi-operational implementation of the new WRF model, and the first time satellite and radar data have been used to initialize real-time runs of the WRF.

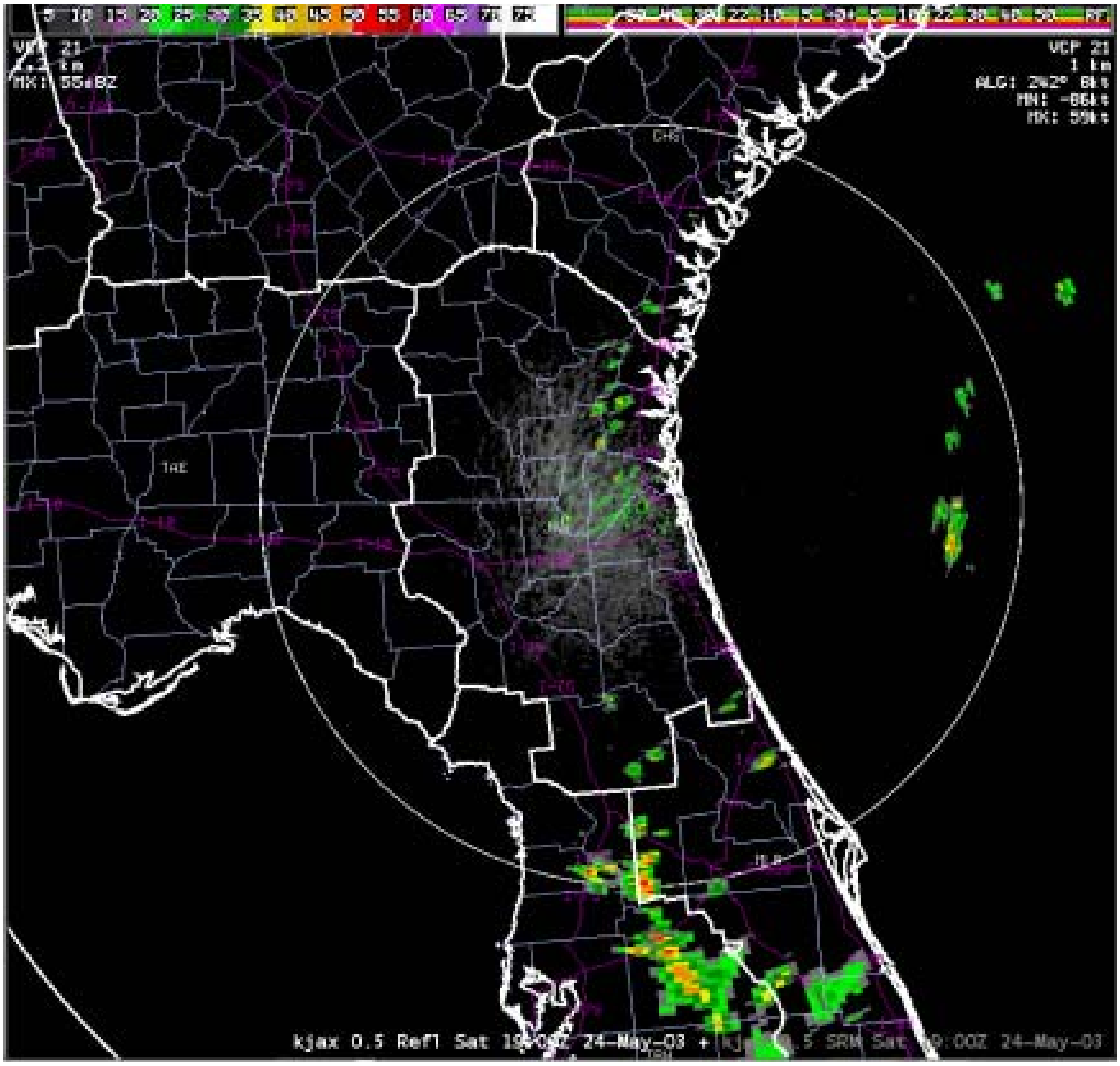


Figure 4a.

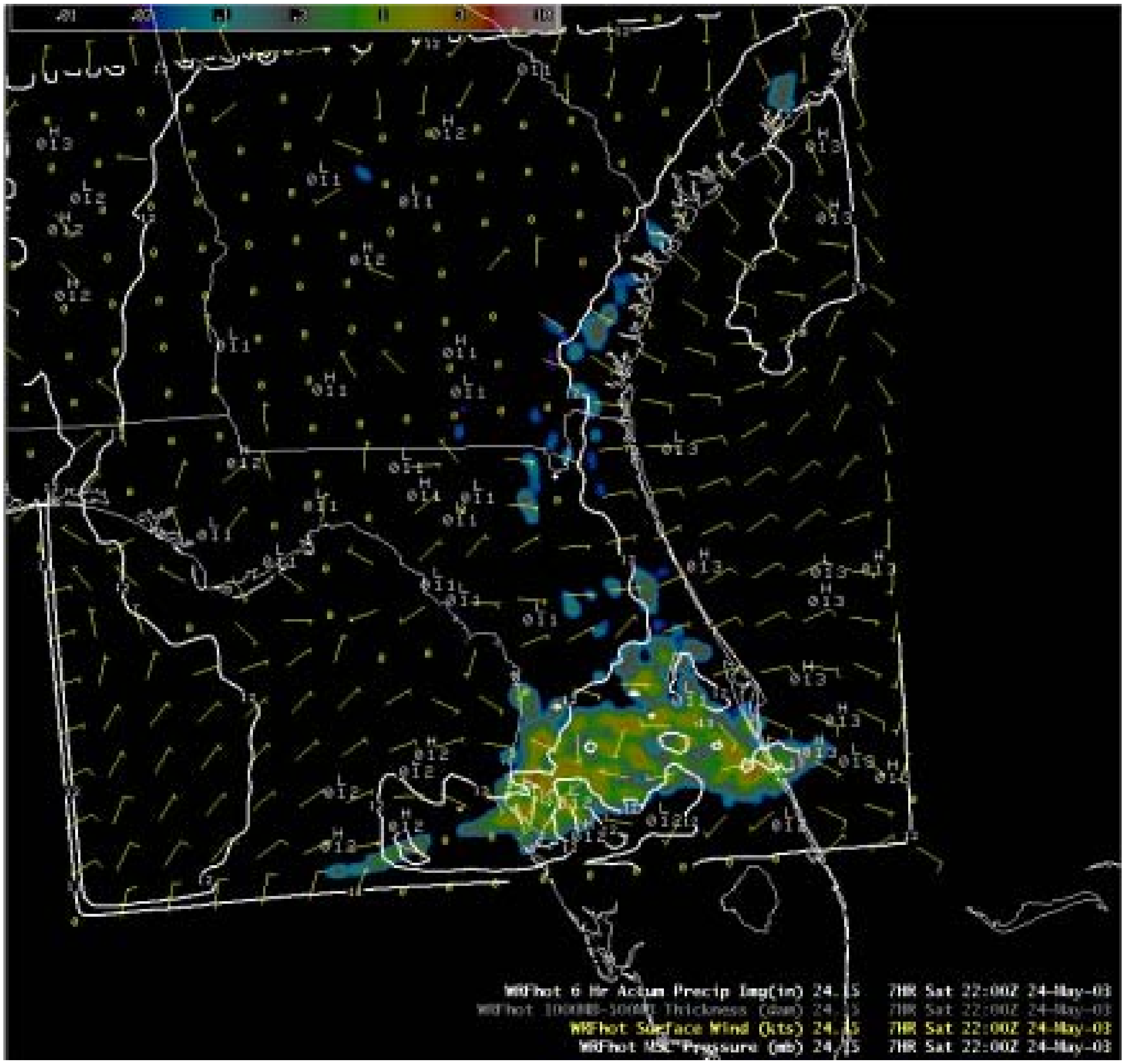


Figure 4b.

<u>International H_2O Project (IHOP)</u>

Participating CIRA Scientists: Ed Szoke, Brent Shaw, Adrian Marroquin, and Steve Albers

CIRA scientists are working in the area of IHOP case study reruns of LAPS analyses and forecasts. For the analyses some limited runs have been performed for RAMS initialization. The RAMS model has been tested with LAPS initial fields and boundary conditions from RUC-20km valid at 1500 UTC 3 June 2002, corresponding to one of the low-level jet (LLJ) cases observed during IHOP. The model was run using a two-nested grid (12 - 4 km) configuration centered over the IHOP area. The verification of the results (4 km grid) shows that RAMS is able to describe the LLJ and its interaction with convective activity over Kansas at 1800 UTC. More detailed studies (high resolution of 50- or 100-m) are planned to investigate the interaction of surface heterogeneities and the

LLJ. Most importantly, the modulation of the vertical and horizontal transport of heat and moisture by these heterogeneities is the target of these studies.

A more general design for running LAPS from archived data is currently underway. The design includes appropriate script and software changes, methods of gathering raw archived data, converting stored radar and model background files to NetCDF, and running the analyses. Also with IHOP reruns in mind, improvements to the LAPS rawinsonde ingest have been made that now allow proper inclusion of significant temperature sounding levels. Modules are currently being developed to ingest the AVAPS IHOP/CLASS soundings along with the more standard soundings into the LAPS analyses.

A presentation on some preliminary analyses of IHOP model forecasts was made at the AMS 21st Conference on Severe Local Storms, held in San Antonio in August. We also participated and made a presentation at the IHOP workshop organized by NCAR, and held in Boulder in March.

An NSF/IHOP proposal entitled "Surface Inhomogeneities and their impact on fluxes and Low Level Jet dynamics during IHOP: Diagnostic and Numerical Modeling Studies" has been submitted. A summary of the proposal follows:

Through a comprehensive variety of observations, the IHOP field campaign sought to address questions under four main scientific goals and hypotheses components: a) the qualitative precipitation forecast component, b) the convective initiation component, c) the atmospheric boundary layer processes component, and d) the instrumentation component. The main objectives of the present proposal are to investigate some of the issues addressed in the atmospheric boundary layer processes component. More specifically, by means of diagnostic and numerical modeling studies, the interactions between the LLJ and surface heterogeneities will be investigated. One of the aims of these studies will be to understand the influences of scale-dependent structures of the LLJ on the heat and moisture transport within the atmospheric boundary layer. To do so, we will incorporate IHOP observations into analyses, diagnoses, and simulations of preselected LLJ cases. The analyses and diagnostics activities, representing the basic framework of the proposal, will allow us to cast the heterogeneous IHOP observations into three-dimensional atmospheric fields, which can then be used to address issues (using diagnostic studies) of the atmospheric boundary layer processes component as well as providing the fields for model initialization and verification. The main objectives of the numerical simulations are: a) to investigate the adequacy of observational data to initialize models, b) to investigate the evolution and dynamics of the small- scale structures of the LLJ that impact the weather locally, c) to understand how the local surface conditions modulate the heat and moisture fluxes by the LLJ, and d) to investigate the adequacy of numerical weather prediction models for LLJ prediction. Furthermore, through sensitivity experiments, the use of high-resolution terrain, soil type, vegetation, soil moisture, urban area characteristics in the high resolution simulations will help us assess the impact of human activities such as urban development, crop practices, and deforestation on the development and evolution of LLJs.

Scientifically, the proposed work addresses several areas of high interest and importance. First, it will be possible to derive a better understanding of small-scale structure in both the cross-flow and along-flow components (and their relation to surface inhomogeneities) of the daytime LLJ and their impact on the boundary layer circulations. Second, it will provide diagnostics relevant to the influence of the LLJ on mesoscale circulations (such as storm triggering) to be contrasted with the coarse description of the LLJ used until now to forecast MCSs. Finally, results from this work will provide guidelines for future work on the adequacy of fine-resolution simulations, planning of field experiments similar to IHOP, and other LLJ forecasting issues.

From the perspective of the National Weather Service and other operational forecasting communities, two principal impacts of this research can be expected. First, it will provide confirmation and further elucidation of "common knowledge" forecasting techniques that exist for the LLJ. For instance, the forecasting rule of thumb that the intersections of the LLJ and frontal or other boundaries are locations prone to convective development may be quantitatively evaluated and assessed. Second, it is our presumption that the dense IHOP observations both on the ground and within the boundary layer will provide analyses of the LLJ and the moisture it transports that are unprecedented in detail and in temporal continuity. However, it must still be shown that these observations assimilated into numerical models do in fact improve forecasts. These model results in particular have obvious implications for predictability of the water cycle over the central U.S.

<u>JCSDA (Joint Center for Satellite Data Assimilation)</u>

Participating CIRA Researcher: Steve Albers

CIRA researchers provided presentations as part of the discussions involving the use of satellite data in LAPS and RUC for JCSDA participation. One outcome of this may be to apply these methodologies in a WRF and 3DVAR context.

An IDL procedure that compares GOES-8 and GOES-12 visible calibration to arrive at a stretch correction was developed that can be applied to the new GOES-12 data.

WINDPADS Dropsonde Assimilation and Turbulence Assessment

Participating CIRA Scientists: Adrian Marroquin and Steve Albers

Since 1996, FSL has participated in the development of diagnostic algorithms to forecast turbulence using numerical model output for the Federal Aviation Administration (FAA). Taking advantage of these algorithms and in a joint effort with FSL scientists, a modified turbulence algorithm was used to provide variance and mean of the winds along dropsonde trajectories to estimate a probabilistic envelope within which the dropsonde would hit the target. This algorithm is now implemented in a program for the military to estimate the proper location of cargo dropping from aircraft in the battle field.

In support of this dropsonde effort, an overhaul of the wind analysis is being embarked upon so that we can fully utilize dropsonde data with high vertical resolution. If the data has more than one observation in a given LAPS vertical level, then only one of the observations is currently being utilized. A further phase-in of data structures for storing observations will help us to improve our handling of increased observation density.

Regional Radar Volume Project (RRV)

Participating CIRA Researcher: Steve Albers

Progress was made with the RRV project. This involves using LAPS software to remap Doppler reflectivity and velocity data from polar to cartesian coordinates and then produce high-resolution mosaics. Parameters have been adjusted in our testbed, now running regularly in FSL's Modernization Division, where KFTG radar is being processed into a 2-km mosaic (Figures 5a, 5b).

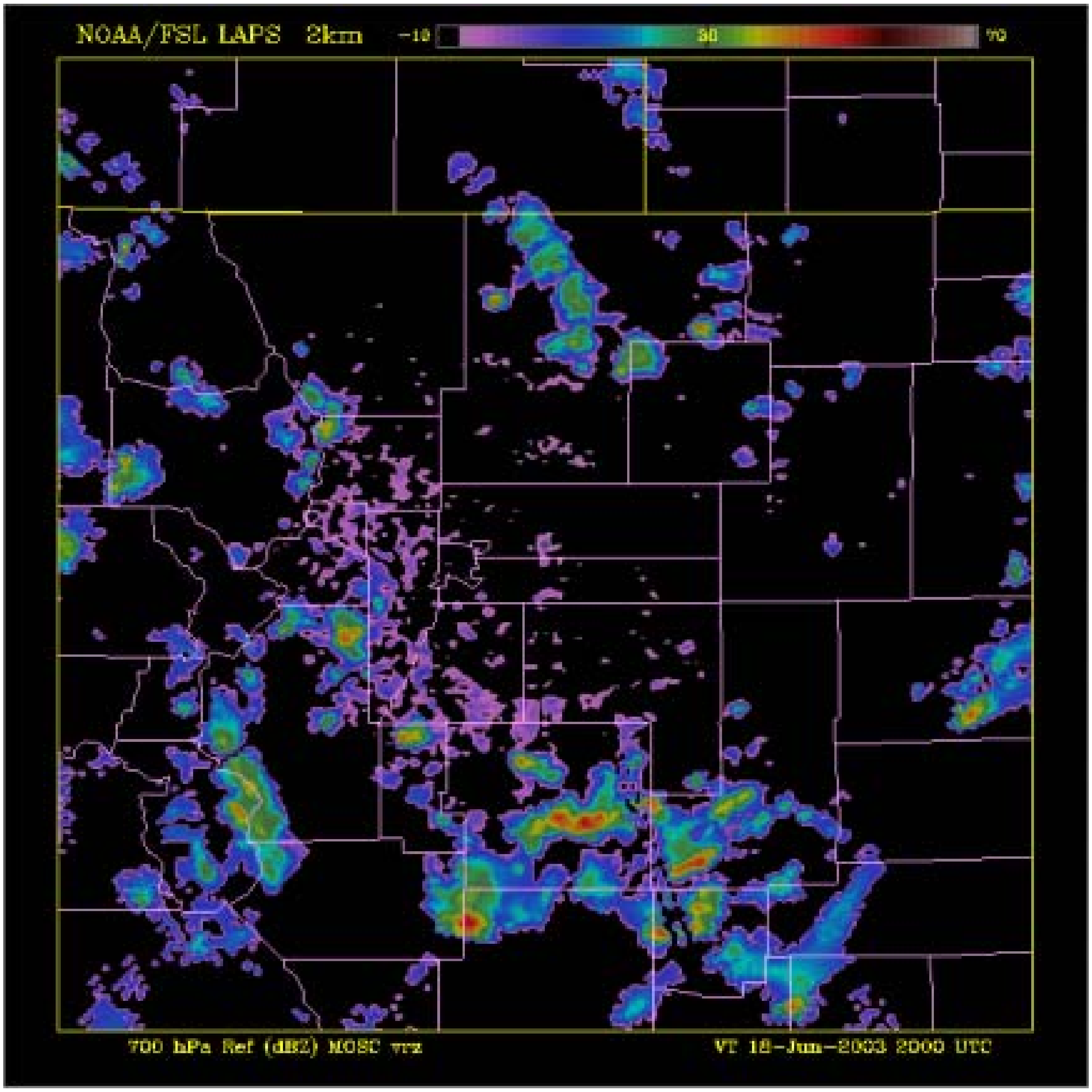


Figure 5a. 700 hPa reflectivity from KFTG radar as mapped onto a 2km grid for the RRV project.

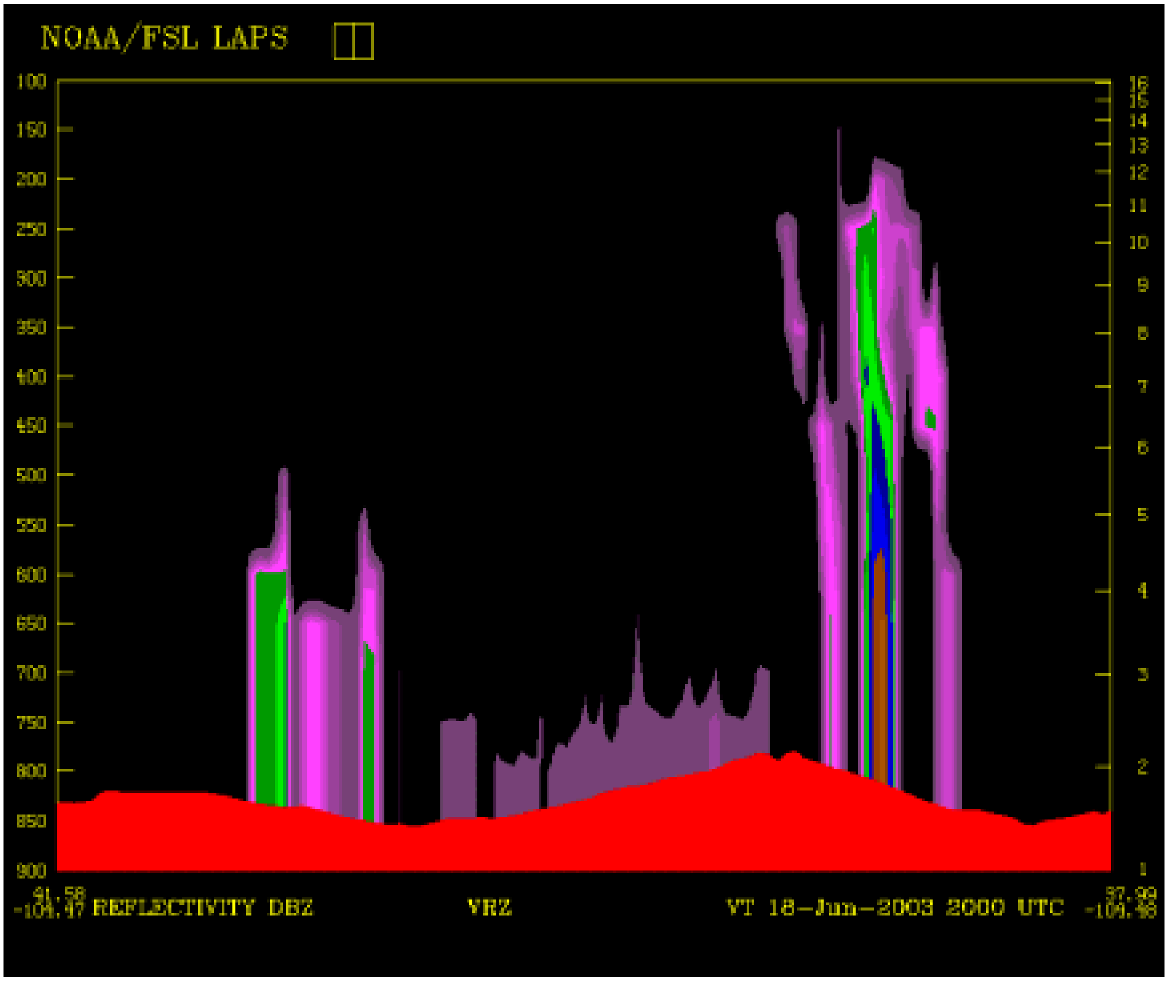


Figure 5b. Reflectivity (N-S cross-section) from KFTG radar as mapped onto a 2km grid for the RRV project.

In addition, LAPS scheduling scripts were enhanced such that they can run just the radar related processes in the context of the Regional Radar Volume project.

Publications (Conference)

Janish, P.R., S.J. Weiss, R. Schneider, J.P. Cupo, E. Szoke, J.M. Brown, and C. Ziegler, 2002: Probabilistic convection initiation forecasts in support of IHOP during the 2002 SPC/NSSL Spring Program. *21st Conference on Severe Local Storms***,** San Antonio, TX. Amer. Meteor. Soc., 283-286. Available from the AMS at (pdf).

Shaw, B.L., D. Birkenheuer, S. Albers, J. McGinley, E. Szoke, and P. Schultz, 2003: LAPS diabatically initialized MM5 for the IHOP_2002 campaign. *13th PSU/NCAR Mesoscale Model User's Workshop*. Boulder, CO, National Center for Atmospheric Research, 113-115.

Szoke, E.J., U.H. Grote, P.T. McCaslin, and P.A. McDonald, 2003: D3D update: Is it being used? *19th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Antonio, CA. Amer. Meteor. Soc., P1.10.

Szoke, E.J., B. Shaw, M. Kay, J.M. Brown, P. Janish, and R. Schneider, 2003: A preliminary examination of the performance of several mesoscale models for convective forecasting during IHOP. *21st Conference on Severe Local Storms*, San Antonio, TX. Amer. Meteor. Soc., J37-J40.

Publications (Other)

Albers S., 2002: Using LAPS as a CWB nowcasting tool (presented in Taiwan to CWB staff)

Albers S., 2002: The fusion of radar data and satellite imagery with other information in the LAPS analyses. (Forecast Research Division Science Seminar)

Szoke E., 2002: Nowcasting: Ideas and use of LAPS (presented in Taiwan to CWB staff)

Szoke E., 2003: D3D update. (presented at the 2003 Cheyenne WFO Mountain Weather Workshop)

EAR—Meteorological Applications

Principal Coordinators: Randy Collander and Brian Jamison

Global Air-ocean IN-situ System (GAINS)

The GAINS project involves testing of a prototype weather balloon that differs from the "traditional" weather balloon in that it can ascend or descend on command. The "cannibal-loon" as it is sometimes called, consists of a helium-filled balloon within an air-filled balloon within a non-expanding fabric shell. Using radio control and on-board pumps, the amount of air within the balloon can be controlled, and since the fabric shell holds the volume constant, the density of the air can be increased substantially. This makes it possible for the balloon to have super pressure which can overcome the buoyant effects of the helium, and allow the balloon to descend.

GAINS is a major change in system concept from earlier efforts in developing a Shear-Directed Balloon System (SDBS). The SDBS program represented development toward a recoverable, reusable global sounding system to be operated in the troposphere. GAINS, in contrast, is a long-duration stratospheric platform, instrumented for environmental sensing through a combination of dropsondes, XBTs, and chemistry, particulate, in-situ, and remote sensors. Designed as a 120-ft diameter superpressure vehicle carrying a payload of 780 pounds for year-long flights up to 75,000 ft, GAINS is targeted to meet NOAA's observing and monitoring mission in the next century.

GAINS uses rechargeable batteries to power nearly all balloon functions, and has external solar panels for recharging. Communications to and from the balloon are currently done by high frequency radio, which will eventually be replaced by employing Low Earth Orbiting (LEO) satellite communications provided by Globalstar, ORBCOMM, and/or ARGOS. The balloon's position is provided by on-board Global Positioning System (GPS) instruments and ARGOS satellites.

Tasks in support of the GAINS project include: preparing for and participating in field tests, writing test plans and results, obtaining, constructing, and repairing equipment and components as necessary, and maintaining an inventory of equipment and consumables. Software related to the GAINS project have been written and updated, including software to decode and quality control raw data transmissions from the balloon, display web pages and forecast trajectory.

Balloon Flight Tests

- Participated in an anchor balloon flight test to prove the ability of the recently developed turbine pump to provide 15% superpressure at altitude. The turbine was connected to an anchor balloon (i.e. a 500g latex balloon housed within a fabric shell) which was carried by a 19000 cu ft zero- pressure balloon. At specific altitudes, on-board software operates the pump which fills the latex anchor balloon with air, and pressure sensors provide superpressure information. This test was launched from Meadow Lake Airport in Colorado Springs, CO on August 17, 2002. A front came through during the evening prior to the launch and winds were very strong. The strong wind continued through the morning and caused problems with the launch. The direction of the balloon train was changed twice due to the changing direction of the wind. The lift balloon was unmanageable once it was filled with helium, and periodic contact with the ground produced a number of small holes of which only some were noticed and repaired by tying knots at those locations. Problems were also encountered with the top grommet of the anchor balloon and the release block in the launch arm. The launch was problematic, but systems had survived. The balloon only reached about 210 mb altitude before it began descending, due to the holes in the lift balloon. Thus, none of the tests of the turbine pump were carried out since the first test altitude was 100 mb. The balloon payload, anchor balloon, and lift balloon were all successfully recovered. Though no turbine tests were performed, many valuable lessons were learned on this flight that would be corrected for the March 30 flight.

- Participated in a re-test of the anchor balloon flight on March 30, 2002. There was a mix of successes and failures, but was generally considered to be a positive advancement of the project. Problems that were encountered during the August flight were remedied for this flight, and better wind conditions yielded a perfect launch. Filling of the anchor balloon occurred as planned at the first test level of 50,000 ft, but the superpressure in the anchor balloon did not reach the desired level, and the pump spool-ups planned for 60,000 and 70,000 ft did not occur. Graphs of flight telemetry data indicated loss of battery voltage coincident with superpressurization, and a return to nominal volatge at the end of the pump test period. The investigation focused on the batteries and the circuitry which feeds power to the motor, including the voltage regulators. The cause was ultimately determined to be a failure of the voltage regulators due to excessive heating.

Statistical Analysis

- Retrieved MAPS/RUC initializations (40km isobaric coordinates) for calendar year 2001 in preparation for a presentation at COSPAR 2002 in Houston, Texas. Baseline trajectories computed from these initializations were compared to trajectories predicted from rawinsonde and AVN model output. The comparisons were on a month-by-month basis for the period March through August, as well as by season (spring and summer only).

Balloon Flight Prep

- Weighed individual balloon and payload instrument components and compiled weight budget for GAINS Anchor Balloon Field Test.
- Gathered equipment and supplies needed by balloon launch and recovery personnel for completion of flight activities for the August 17, 2002 and March 30, 2003 experimental balloon flights.

- Reinforced lower line tabs on the anchor balloon shell using more layers of material and larger grommets.
- Sewed all the gores of the 8 ft. diameter anchor balloon shell and conditioned the balloon with 30 mb of pressure for 12 hours for the August 17 test.
- Performed routine backup and maintenance of desktop and laptop computers used for the GAINS project.
- Assisted with flight preparations for August 17, 2002 GAINS pump test flight, including review of final flight prep checklists, verification of instrument readiness and prediction of expected trajectory based on most current wind data and numerical model wind predictions.
- Repaired damage incurred by the balloon shell during the August test, and reinforced the top endcap and load tab using Kevlar material. The repaired shell was re-conditioned as was done prior to the August test.
- Assumed the role of lead meteorologist (Randy) for the project (after retirement of project leader Cecilia Girz), assisting Russ Chadwick with flight planning, performed weather forecasting in the days and hours preceeding the launch, and gave "go" or "no-go" decision on flight day.
- Discussed flight plans with EOSS (Edge Of Space Sciences) volunteers who assisted with flight logistics.
- Assisted Tom Shilling (Advanced Engineering) in documenting the rebuild of the instrument lander and instrumentation damaged during the August 17, 2002 pump test flight in August.
- Conducted weekly telephone conferences with FSL and all collaborators to discuss flight issues.

GAINS Flight Base Operations

- Traveled to Meadow Lake Airport on Saturday, March 29, 2003 to monitor weather conditions and forecast conditions for expected launch at dawn on March 30. Assisted with payload preparation during Saturday evening, then arose at 2:30 am Sunday morning to resume pre-flight forecasting duties. With all indications that winds would become acceptable in the dawn and post-dawn hours, the launch crews were instructed to begin their preparation. As predicted, winds were marginally acceptable (mostly under 5 kt with some gusts above 5 kt). Problems with payload instrumentation delayed the launch by over an hour, and a successful launch occurred at 7:18 am MST. Track and recovery crews successfully located the balloon and payload after landing east of Pueblo Colorado.

Field/Lab Experiments

- Assisted with field test of balloon launch arm mechanism developed and constructed by Tom Shilling. The arm is designed to hold the balloon and payload in place prior to launch until favorable wind conditions permit a nearly vertical ascent angle and allow for a shock-free launch.
- Performed GAINS instrument testing in Climate Modeling and Diagnostic Laboratory (CMDL) environmental chamber. Use of the 27 cubic ft chamber allows for testing of instrumentation and balloon structural elements in an

environment which simulates the pressure and temperature conditions expected during experimental flights. For the anchor balloon test flights, specific changes were made to the Basic Stamp software to maintain turbine RPM during fill and pressurization, which is essential to define turbine characteristics and flow rates at altitude.

Post-Flight Analysis

- Performed post-flight trajectory analysis of the June 21, 2002 GAINS Prototype-III balloon flight launched from Tillamook, Oregon. Examined numerical model output of surface and upper level winds and rawinsonde stability parameters. Ascent was not constant due to a marine inversion which caused the balloon to oscillate up and down in a narrow layer for over 30 minutes.
- Participated in post-flight debriefing of the August 17, 2002 anchor balloon experimental test flight.
- Participated in post-flight debriefing of the March 30, 2003 anchor balloon experimental test flight.
- Made adjustments to parsing software to accomodate changes in the raw data messages, and parsed the data from both test flights for analysis.

GAINS Web Pages

- Developed a web page for access to text and graphic images (maps) of trajectories predicted by Version 8 trajectory computation software, which uses climatological wind averages from 1946-1999. This page lists, in reverse chronological order, all trajectory predictions requested by users, aging these data off after 45 days.
- Created duplicate of GAINS briefing webpage for use by Mark Conner of the NSTAR balloon group. Also modified upper-air charting software to produce 20-mb and 10-mb charts (Mark's balloons reach altitudes above 90,000 ft).
- Created Meadow Lake Observation webpage (http://www-frd.fsl.noaa.gov/mab/ sdb/briefing2.htm) for use in monitoring and forecasting weather conditions at Meadow Lake. This page contains the date and time of the latest page update (the page is set to refresh every 5 minutes), as well as the prognosis for launch (favorable, marginal, unfavorable) and a link to the latest forecast discussion. Current surface observations from Russ Chadwick's weather station at Meadow Lake, as well as from nearby NWS sites, are decoded and placed here, along with the upper-level wind observations from the NWS rawinsonde network, and the pseudo-sounding for the nearest grid point in the MAPS model. There are links to charts of these data, as well as radar and satellite observations. Brent Shaw (LAPS) set up a version of LAPS/MM5 to produce text and graphical forecasts specific to Meadow Lake Airport. These forecasts are produced every 6 hours and forecast conditions at 1-h intervals out to 24 hours. Data from Russ' weather station are integrated into these forecasts. Comparisons of forecast vs actual conditions are made and appear as direct comparisons and statistical analyses on this webpage. Observation statistics from Russ'

weather station for the past 7 days are listed at the bottom of the web page. These are used to infer the typical wind (and other) conditions at each hour of the day and will aid in determining the best launch times.

- Updated the Meadow Lake Observation webpage. Due to various issues with relaying of observations at Meadow Lake Airport to the Internet, cosmetic changes were made to reflect the amount of data available (and thus, the statistical significance of the means and median values) in the 7-day statistical evaluation. The temporal resolution of the observations is 5 minutes, yielding a maximum number of 84 observations for each hour of the day. Using a significance of 2/3, statistics for hours having at least 56 observations (2/3 of possible) are considered to be the best and are demarked in the table by showing the hour number in bold typeface (light gray otherwise). Hours with between 28 (1/3) and 56 (2/3) observations yield useful values, but for less than 28 (1/3) observations, the computed statistics cannot be trusted to reflect the typical conditions for that hour, and are demarked in the table by striking out (placing a horizontal line through the number) the hour in the first hour column, as well as the median wind speed value.
- Posted to GAINS restricted website all GAINS instrument electronics schematics and other drawings for access by project personnel and collaborators.

Station-Keeping Balloon

- Assisted with the covering, motor-mounting and transporting of a model of a Station-Keeping Balloon. The model consisted of a “canopy”, which was a triangular shaped housing for three sounding balloons, and a “gondola”, which was a smaller craft that hung below the canopy which theoretically would carry dropsondes and communications equipment. The Station-Keeping Balloon was a scale model of a balloon vehicle that would be able to maintain a constant position at high altitude, and drop dropsondes at regular intervals. The resulting data would then be used in numerical models. The canopy and gondola were brought into the DSRC lobby, tied together, and brought to a floating equillibrium using helium-filled sounding balloons. A flight demonstration was performed in the lobby for approximately two hours using radio-controlled ducted fans for control. After the demo, the model was put on temporary display in the DSRC lobby.

Publications/Presentations

- Prepared materials and presented at the GAINS FSL Technical Review.
- Wrote paper, "Evaluation of Balloon Trajectory Forecast Routines for GAINS," as lead author with Cecilia Girz for 2002 COSPAR meeting in Houston, Texas.
- Collaborated with GAINS personnel and collaborators, with Cecilia Girz as lead author, on COSPAR paper, "Results of the Recent GAINS Flight Test."
- "GAINS-A Global Observing System" published in Advances in Space Research, Volume 30 Number 5.

International H_2O Project (IHOP)

Principal Coordinator: Brian Jamison

Although IHOP is a project comprised of a number of diverse missions, the focus of the MAB participation was to undertake two low-level jet observation missions. These missions employed four aircraft, two of which flew opposite each other on a path defined by a rectangular "box" over northwestern Oklahoma, southwestern Kansas, southeastern Colorado and the eastern Texas panhandle regions. These aircraft dropped high-resolution dropsondes at pre- defined intervals for later analysis of moisture transport within the low- level jet.

- Created cross sections of relative humidity, wind magnitude, and the product of relative humidity with the normal component of the wind from dropsonde data taken during the 9 June 2002 mission, and provided these images to Ed Tollerud, who used them in a poster for an IHOP workshop held at the NCAR Foothills Lab.
- Presented the poster outlining the two low level jet missions, and answered questions from workshop attendees.

SCATCAT01 Project

Principal Coordinator: Brian Jamison

Involvement in the SCATCAT (Severe Clear Air Turbulence Colliding with Air Traffic) project continued this past year. This project, headed by Mel Shapiro of NCAR and Steve Koch of FSL/FRD, is a collaborative effort to measure in-situ turbulence at jet stream levels near Hawaii. A GulfStream IV aircraft was flown to regions of predicted turbulence and dropped high- resolution dropsondes in short time intervals. The aircraft then flew back along the same route, but at lower levels and in a specific "stacking" type pattern to capture in-situ turbulence. CIRA collaboration involved analysis of the resultant data, and evaluation of numerical model simulations.

- Created graphical plots of numerical values of potential temperature and wind speed and direction as a cross section plot for hand analysis by Mel Shapiro.
- Used NCPLOT software to analyze turbulent regions and discovered an inverse relationship between potential temperature and wind speed.
- Wrote software to merge ozone and flight data and prepare the data in Excel format.
- Worked with Steve Koch in preparing spectral analyses of data.
- Created time series plots of potential temperature, wind speed, and vertical velocity for analysis.
- Created cross sections of data from a second turbulence flight performed in February 2002.

Turbulence Project

Principal Coordinator: Brian Jamison

MAB, under support from the FAA Aviation Weather Research Program, conducts research to improve forecasts of clear air turbulence (CAT) by developing diagnostic algorithms and conducting field programs. Tasks related to this project include: design and development of web pages to graphically display diagnostic algorithms for analysis, developing software to automate the process of data ingest and model output, and developing software scripts to keep webpage displays updated.

- Wrote software to read Rapid Update Cycle (RUC) 20-km model data, allow input of the latitude and longitude of two end points, and compute the latitudes and longitudes of a variable number of points in between. Using output generated from this routine, vertical cross sections of data were created from the RUC for analysis.
- Wrote NCAR Command Language (NCL) scripts to analyze horizontal cross sections of data from the RUC model at constant pressure flight levels.
- Updated webpages of unbalanced flow turbulence prediction products.

Air Quality Web Page

Principal Coordinator: Randy Collander

NOAA is launching a major new initiative related to chemical weather forecasting. This research program, leading ultimately to an operational national air quality forecasting system, will be a collaborative effort that is built on past work and will involve other federal agencies (most notably the EPA) and the private sector. At FSL, a multiscale air pollution prediction system based on the fifth generation Penn State/NCAR nonhydrostatic meteorological model (MM5V3), coupled with the RADM2 chemical mechanism, is used. In addition, biogenic emissions, deposition, tracer transport by convection and turbulence, photolysis, and transport by advection are all treated simultaneously with the meteorology ("online"). (See Grell et al., 2000).

- Developed procedures for retrieval of model output images and generation of GIF animation of these images for 13 output products, analysis through 36 hour forecast.
- Linked static images and animations to webpage, http://www-frd.fsl.noaa.gov/aq, created by Denice Walker (FSL).
- Assumed maintenance and update role for webpage, working with Bill Moninger (FSL) on enhancements and aesthetic improvements.

NCAR Driftsonde

Principal Coordinator: Randy Collander

The Inter-Continental Radiosonde Sounding System (ICARUSS), also called Driftsonde, is a proposed new atmospheric sounding system for use during the upcoming THORPEX experiment in 2003 or 2004.

The ICARUSS concept uses a thin polyethylene balloon (0.35 mil) with a volume of 268 cubic meters to lift a payload (< or =40 kilograms) of 24 dropsondes or modified radiosondes to an altitude of about 100 to 75 mb (53,000 - 60,000 feet) and maintain that altitude for 5-6 days. The altitude of the balloon can be adjusted over a limited range to take advantage of the most favorable upper-level westerly wind flow.

Simulations using 1999 wind data over the Atlantic and Pacific oceans show that balloons launched from coastal radiosonde sites (eastern U.S. or Asia) will travel across the oceans in approximately 5-6 days. The dropsonde would telemeter the measured profile data back to the balloon where it would be received, processed, and stored. A compressed data set (e.g. WMO message or 10 second data) would be sent through a Low Earth Orbiting satellite (e.g. ORBCOMM) to a ground station and on to the THORPEX control center for further processing and/or input into the Global Telecommunications System (GTS).

The balloon gondola would house 24 dropsondes, a telemetry receiver card, PTH and GPS wind processing cards, a single board computer card for data processing and ballast control, a satellite transceiver card, a lithium battery power supply and a passive thermal control system to maintain the electronics above -10 deg C. During the nighttime transition period when the balloon volume decreases due to radiational cooling of the helium, ballast would be dropped to maintain altitude. An additional natural rubber balloon may be required during rain, wind and snow conditions to tow the ICARUSS balloon and payload through the severe weather. The rubber balloon would be jettisoned above the severe weather.

- Created webpage with links to trajectories predicted for NCAR Driftsonde experiment and upper-air charts (http://www-frd.fsl.noaa.gov/mab/sdb/tech_doc/driftsonde.htm).
- Modified Global Aviation (AVN) model version of trajectory prediction software in order to compute trajectories for touch-and-go ascent to 60,167 ft MSL (approximately 75mb).
- Modified webpage generation script to automatically update and generate separate webpage for use by NCAR project personnel and updated PC scripts to plot trajectories from special NCAR predictions onto map backgrounds.

Maintenance Decision Support System

Principal Coordinators: Randy Collander and Brian Jamison

The Maintenance Decision Support System (MDSS) is a project sponsored by the Federal Highways Administration. The goal of this project is to create a decision support software package to help winter road maintenance personnel decide how to best respond to weather problems on highways. MDSS takes automated weather observations and forecasts and runs pavement conditions models to suggest an optimum combination of plowing and chemical applications, and recommends the time to make these treatments.

FSL will provides web resources for display of output from the MM5, RAMS, and WRF numerical models (initialized by two different models, NCEP's AVN and Eta) for a total of six model runs, each run four times per day out to 36 or 48 hours.

- Defined product types to be presented on the MDSS webpage (http://www-frd.fsl.noaa.gov/mdss/).
- Developed NCAR Command Language (NCL) scripts and Perl code to automatically produce timely model images of temperature, relative humidity, wind, precipitation amount and type, and snow depth.
- Incorporated changes to image products suggested by the LAPS branch.
- Determined the logistics of providing images to the webpage, producing loops of the images, and having the webpage automatically update as new model runs completed.
- Worked with Bill Moninger on modifications to the cgi script which allows users to select model run and products for display. Links are only active for product images that actually exist.
- Completed preliminary MDSS website for a domain centered on Iowa, and maintained the site through the winter season. Plans include adding another domain for image display, the addition of more products and multi-frame displays, contingent upon additional funding.

National Wind Profiler Network Resource Webpage

Principal Coordinators: Randy Collander and Brian Jamison

Wind Profilers operate at a frequency of 404 MHz, too close to the frequency used for satellite-based Search and Rescue operations, resulting in the need to shut down profilers whenever a satellite passes overhead. This situation will worsen in 2006, when the European Community plans to launch a constellation of satellites. Several options exist for retrofitting the wind profiler sites to use an alternative frequency, but the cost of doing this is high.

In order to demonstrate the usefulness and need for continuing the operation of wind profilers, and to provide materials in support of this position to all interested parties, the construction of a website which includes case studies, testimonials and other materials was initiated.

- Designed framework for initial layout of profiler information website. Given the diverse audience for this site, design is basically a pyramid in shape: strongest point made at the top level, expanding with each layer providing more detail as users move through the site.
- Produced scripts to run Stan Benjamin's plotfield software and generate multiple numbers of images without need for interactive input. More than 26,000 images were created for the webpage.
- May 3, 1999 Oklahoma City tornado outbreak and winter storm of February 9, 2001 were chosen for case study section. Three images for each meteorological product selected can be displayed: images from the control and no-profiler model runs, and the difference field. A fourth image will be the analysis valid at the selected time.
- Developed and tested cgi script which allows users to access output products from the case studies. Added selections for domain (profiler or downstream), display type (4-panel or 4-window) and case (3 May 1999 or 9 February 2001).
- Used ImageMagick image manipulation software to resize product images. All images were modified and stored for access via cgi script.

WRF Model Air Chemistry Website

Principal Coordinator: Randy Collander

The mission of the WRF atmospheric chemistry working group (WG11) is to allow the option of simulating online chemistry and aerosols within the WRF model. The resulting WRF-chem model will have the capability to simulate the coupling between dynamics, radiation and chemistry. Uses include forecasting chemical- weather, testing air pollution abatement strategies, planning and forecasting for field campaigns, analyzing measurements from field campaigns and the assimilation of satellite and in-situ chemical measurements.

Updates to the website are needed to maintain current information and provide access to real-time model output.

- Updated WRF working group 11's (WG11) webpage (http://www.wrf-model.org/ WG11/wg11_new.html). This page will ultimately replace the current WG11 main page, after changes to team members and some cosmetic changes are completed.

- Modified product table generator used for FSL Air Quality real-time forecasts to access and display WRF model forecasts. See http://www-frd.fsl.noaa.gov/aq/wrf/ for examples (note that many products are not currently available).

Science Quality Datasets—Radiosonde Data Webpage and Archive

Principal Coordinator: Brian Jamison

A science quality archive of radiosonde data for North America began as a collaborative effort between FSL and NCDC in 1992, and continues to be a widely used baseline data set for weather researchers and climatologists nationwide. The archive exists as a CD-ROM set available from NCDC, and is complemented by a web page of global radiosonde data updated regularly by MAB. Periodic CD-ROM updates to the archive are also created.

- Wrote software to read the National Climatic Data Center's CARDS radiosonde format, and placed it into a preliminary format for inlcusion into the FSL archive.
- Managed radiosonde station history lists, and provide corrections when necessary to the ITS branch master station list.
- Responded to users' questions and requests
- Made corrections to problems found in the archive and webpage.
- Attended the "Workshop to Improve the Usefulness of Operational Radiosonde Data" in Asheville, NC and made a presentation regarding the FSL radiosonde webpage and archive.

Hourly Precipitation Data Quality Control

Principal Coordinator: Randy Collander

Precipitation observations from several thousand sites in the United States, in hourly and/or daily resolution, are received by the National Centers for Environmental Prediction (NCEP) in Washington, D.C. on a daily basis. Much of this data is manually inspected and quality controlled at the River Forecast Centers (RFC) and other locations before being disseminated to the National Weather Service (NWS) offices and other users. Goal is to have an automated, objective system for performing a more consistent quality control on these data, with the expectation that a cleaner data set would be of great value as input to current numerical weather prediction models.

- Consulted with Ed Tollerud (FSL) on project goals and tasks needed to achieve these goals, and the timetable for this work. Brainstormed on various measures of data validity and set some preliminary criteria for the valid and invalid determination. Some of the parameters to be examined will be (given

30 days of data): count or mean number of hours per day with non-zero precipitation, number of days with non-zero precipitation, total number of observations, distribution of values, and location of precipitation report patterns (e.g., report every other hour for 2 days, etc). Once individual statistics are completed, consideration will then be given to areal coverage of precipitation. That is, observations from each station will be compared to the observations at neighboring stations to aid in determining validity of observations.

- Wrote Perl code to compare station locations listed in the daily and hourly master lists and output any discrepancies.
- Wrote Perl code to compute 30 day data distributions for each station, counting the number of days data was reported, number of days with non-zero precipitation, number of hours of non-zero precipitation, maximum hourly value and monthly precipitation total. This routine also ferrets out potentially anomalous values, looking for stations which reported precip but are not found in our master station list, stations in the list which did not report at all, stations which only reported a header, stations with hourly values which exceeded a threshold value, stations with daily totals above threshold, stations whose hourly precipitation has a pattern indicative of a stuck gage, and stations for which more than one observation was reported for 1 or more hours (the result being an incorrect daily sum).

LAPS WRF Standard Initialization (WRFSI) Project

Principal Coordinator: Brian Jamison

The Local Analysis and Prediction System (LAPS) branch of FSL is developing a graphical user interface (GUI) to allow a user to define a particular domain and resolution to run the Weather Research and Forecasting (WRF) model using LAPS model initialization data.

- Instructed Thomas Helman in using NCL for model graphics display.
- Installed files to allow high-resolution map display in NCL.
- Prepared NCL scripts to display standard initialization fields. The NCL scripts are dynamic, and conform to any defined domain by recognizing and setting the map projection used, scaling colormaps and contour intervals, and automatically adjusting the viewport to handle domains with different aspect ratios.

EAR—CIRA Research Projects in the International Division

Principal Researcher: **Renate Brummer**

The GLOBE Program

Established in 1994, GLOBE is implemented through bilateral agreements between the U.S. Government and governments of partner nations. The goals of this education and research program are to increase environmental awareness of people throughout the world, contribute to a better understanding of the earth, and help all students reach higher levels of achievement in science and mathematics. Under the guidance of their teachers, students worldwide collect environmental data around their schools and post these findings on the Internet. GLOBE scientists design protocols for measurements that are simple enough for K-12 students to perform, and are also useful in scientific research. As scientists respond to the major environmental issues of today, laboratory and classroom collaboration will help unravel how complex interconnected processes affect the global environment. Years of student data collection have resulted in a significant contribution to science. GLOBE's unique global database holds more than 9 million student measurements of atmospheric, soil, land cover, hydrological, and phenological data, all of which are universally accessible on the Web for research. Since it was initiated, the GLOBE Program has grown from 500 U.S. schools in 1995 to more than 12,000 GLOBE schools located in 102 partner countries.

Figure 1: International Training Workshop in El Quisco, a small coastal town in the Valparaiso region of Chile

The CIRA GLOBE Team is responsible for the development and maintenance of the main GLOBE Website (excludes data visualizations), real-time GLOBE data acquisition tools, the central GLOBE database, and the mirrored GLOBE Web and database systems.

The GLOBE Website is used by more and more people and by different groups of people. It is primarily a place where students come to send their data and to collaborate with one another. Yet, it is also the front-end to the public who wish to learn more about the program, and the gateway into the GLOBE database. Keeping our users' interests in mind, the Website was redesigned this past year to make the homepage much cleaner. It is still intuitive how schools are to participate by following the "GLOBE Schools Log-in" link. For those who are being introduced to the concepts of GLOBE with fresh minds, they can easily obtain more information quickly via the "Learn About GLOBE" link. The returning visitors such as scientists and others in the general community simply "Enter the site." In addition to the homepage improvement, the overall appearance (e.g. color schemes) of the site was changed to give it a new look consistent with the homepage.

In looking at ways to improve site performance and to keep pace with recent technology advances, we explored implementation of J2EE components (Java Servlets and Java Server Pages) into the site. As a case study, we imported all of the content-rich pages of the site into the database and then developed code that dynamically requested content and built the Web page through the Tomcat servlet container. We also explored Oracle large object support (e.g. LOB's) to see how we can start adding more content into the central database. We are now storing the GLOBE Student Investigation reports in CLOB columns (character large objects – ideal for large text strings) in the database.

In order to accommodate schools' and science principal investigators' desires to continue to collect new datasets, our data acquisition code base is constantly growing. GLOBE schools can send their data via Web forms on the site (very interactive) or via an email message (typically used by schools wishing to report a lot of data at once). This year, we developed code for acquisition, processing, and storage of data from a digital multi-day or single-day max/min thermometer, hummingbird observations (the first protocol to study animals), and phenological gardens.

Due to GLOBE's strong international roots, we are committed to having the Website translated into the 6 UN languages. There has been expressed interest in non-UN languages, so we accommodate this as well. In addition to Dutch and German, a Japanese coordinator has begun translating the site into Japanese. This is significant as it represents our first Asian language. We are looking forward to having our first data entry pages displayed in Japanese for this coming year.

There is a separate, non-public Website which allows for GLOBE HQ staff in Washington D.C. and for GLOBE partner groups and country coordinators to track such things as GLOBE workshop participation, school contact information, and school reporting rates. We designed new interfaces so that GLOBE partners can select and specify trainers for their own workshops based on how experienced the trainer is, availability, location, and which protocols that trainer is qualified to train. The staff at HQ maintains this information on the trainers with another set of interfaces. Further, we polished and released a Web-enabled database query tool whereby HQ can look at any and all of the data we store in the central database without needing to know any database query language such as SQL.

When running an operational system, the back-end systems require constant maintenance and upgrades to help ensure they stay highly available and to keep them current with the latest software technologies. We have now migrated a significant fraction of our software and database files over to a NetApp filer to centralize data storage and to improve I/O performance. To increase uptime of our database for backups, we took advantage of the 'snapshotting' capability of our filer and shifted from cold to hot backups so that the database doesn't need to be shut down as often as it had in the past. Late in the year, we upgraded our Oracle database from version 8i to 9i. This new version in turn will help add new features to the Website.

The FX-Net Project

The FX-Net project was established to develop a network-based meteorological workstation that provides access to the basic display capability of an AWIPS workstation via the Internet. The design goal was to offer an inexpensive PC workstation system for use in a variety of forecast, training, education, and research applications not requiring the full capabilities of a WFO-Advanced type system. Although designed primarily for Internet use, FX-Net will also accommodate local network, dial-up, and dedicated line use. The system consists of an AWIPS data server, an FX-Net server, and a PC client. The FX-Net server is a modified AWIPS workstation. The server is locally mounted next to the AWIPS data server via a high-speed link. The FX-Net client sends requests for small-sized product requests via the Internet to the FX-Net server, which responds by sending the products to the client. The user interface of the FX-Net client closely resembles the AWIPS workstation user interface, except for reduced resolution and complexity to allow for rapid Internet response. Some of the FX-Net client functionality features include load, animation, overlay, toggle, zoom, and swap. Although the client Java application can be run on a number of standard PC platforms, the system performs best under Windows NT, Windows 2000, or Windows XP. The minimum client hardware configuration consists of a 500-MHz Processor with 256-MB memory. Internet bandwidth down to 56 kbps is considered sufficient to transmit FX-Net products.

The available FX-Net products are categorized into four groups: satellite data, model graphics and observations, radar imagery, and model imagery. Wavelet transform is used to compress model and satellite imagery. The application of this relatively new compression technique is critical to the success of delivering very large-size imagery via the Internet in a reasonable amount of time. The small loss of fidelity in the imagery is acceptable in exchange for very high compression ratios. Processing time can be further minimized by pre-generating and compressing all satellite data on the FX-Net server side. In contrast to the satellite imagery, the radar imagery is encoded in a standard lossless image compression format (GIF) and the small-sized model graphics are represented in a standard vector graphics format.

For the last few years, FX-Net had been supporting the AIRMAP Program, a University of New Hampshire (UNH) based NOAA-funded program, which focuses on the long-term monitoring and forecasting of air quality parameters like nitrogen oxides, sulfur dioxide, carbon monoxide and low-level ozone. These pollutants can be hazardous to human health and other organisms when present in the lower atmosphere. Many of these chemicals are the result of burning fossil fuels, and are responsible for New Hampshire's high levels of acid rain. The primary mission of AIRMAP is to develop a detailed understanding of climate variability and the source of persistent air pollutants in New England. The availability of a real-time display station like FX-Net became very important to the program's success. The FX-Net team modified the existing real-time meteorological workstation by adding air quality-related datasets to the ingest and display system. A new FX-Net/AQ client was successfully released in July 2002, just in time to support the real-time forecasters who participated in a "High-Resolution Temperature and Air Quality" (TAQ) field experiment during the summer of 2002. AIRMAP was part of the TAQ field project. The new FX-Net/AQ datasets include six parameters (O_3, CO, NO, NO_y, SO_2, Condensation Particles), which are continuously measured at three UNH sites (Mount Washington, Castle in the Clouds and Thompson Farm) located in the state of New Hampshire (see Figure 1). The FX-Net/AQ user also has access to the data from 13 wind profilers recently installed across the New England states. In addition, hundreds of new meteorological surface observation data, fixed buoy records and ship measurements are available on the latest FX-Net menu. On the continental US scale (CONUS), FX-Net displays the hourly average of the national EPA low-level ozone data. The FX-Net team is still working on the ingest and display of the MM5 air quality model. Once this task is completed, FX-Net can truly be called a "real-time air quality workstation."

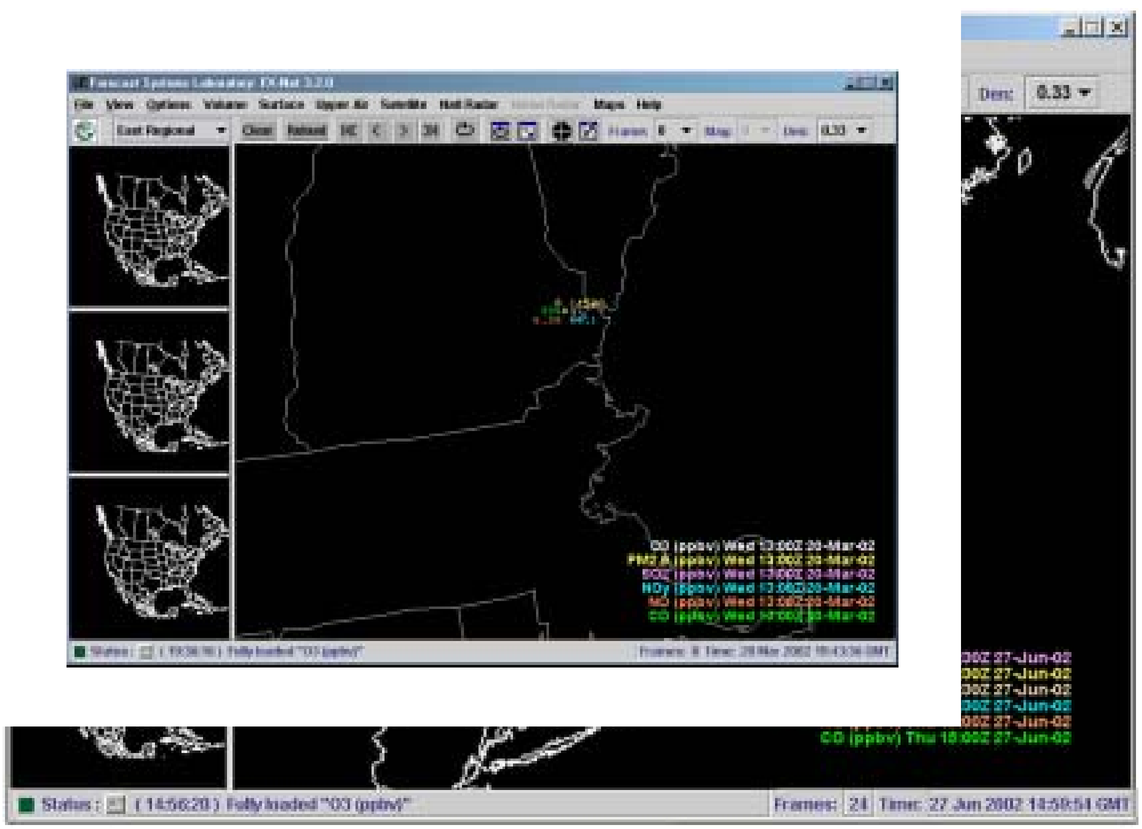


Figure 2: UNH Air Quality Measurements

During the summer of 2001, the National Interagency Fire Center (NIFC) requested that FX-Net be modified to permit its use as the primary real-time meteorological workstation by fire weather forecasters at NIFC and at the Geographic Area Coordination Centers (GACC). The plan called for the FX-Net workstation to be used during the 2002 fire season on an experimental basis, with the FX-Net server located at NOAA's Forecast Systems Laboratory in Boulder. If the workstation was accepted by the fire weather forecast community at NIFC and GACC Offices, the agreement called for the introduction of an operational solution for the 2003 fire season.

The FX-Net team added a variety of new functionalities to the FX-Net client with the goals of making additional products available to the fire weather community and adding new user-friendly tools to the client. One of the more outstanding new datasets is a complete text browser, which allows for the display of a large number of National Weather Service forecast and discussion products. Additional new tools allow for the export of products displayed in the primary window, preference client settings rather than former changes to the configuration file, and the change of contour intervals for displayed model products. FX-Net also added two special display scales, called Northern Rocky Mountains and Southern Rocky Mountains, for the viewing of high-resolution satellite imagery in areas with high potential for wild fires.

As is now well documented, the 2002 fire season turned out to be one of the worst fire season ever recorded for many states. The operational demand by NIFC and GACC forecasters for complete sets of meteorological products became paramount to support the issuance of the best possible daily forecasts. In response to the high operational tempo and requirements, the FX-Net team pursued every possibility to improve the reliability of all components of the system involved in the FX-Net data stream. Hardware was exchanged with newer systems, data streams re-routed, and multiple back-up systems were installed. By the second half of July, a significant improvement in reliability of the FX-Net related systems was successfully achieved, with reliability exceeding 98%.

The new list of fire weather products, the new functionalities added to the client, and the significant increase in reliability made FX-Net a truly operational fire weather forecaster workstation. It also resulted in very positive feedback from the NIFC management as well as from the GACC forecaster community.

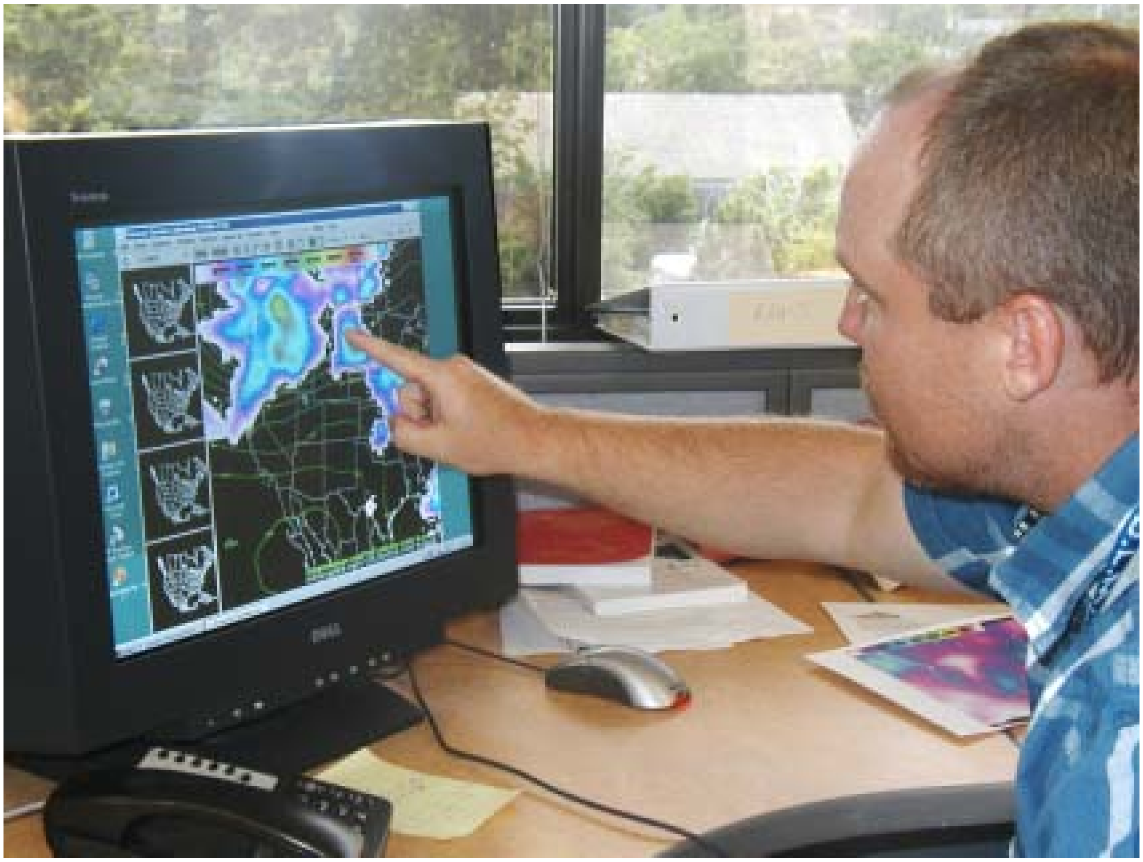


Figure 3: Fire weather forecaster using FX-Net at the Lakewood, Colorado GACC Office

The Wavelet Data Compression Research

After successfully applying the wavelet data compression technique to satellite imagery, the Wavelet Data Compression initiative was established to further investigate the possibility of using the technology for other meteorological datasets. Compared to imagery datasets, model data usually have higher numbers of dimensions, but each dimension is of much smaller size. Therefore, special treatments are needed to exploit the correlation among all dimensions. A multidimensional data arrangement and transform scheme has been developed to accommodate the special features of the model dataset. An experimental encoder and decoder package has been implemented to test various datasets with different standard waves and different post-transform compression algorithms.

During 2002 much effort was put into improving the existing wavelet compression code with the goal to achieve even higher compression ratios. The routine was also rewritten in order to improve its run time, which is an important aspect for all operational applications. A new major milestone was achieved with the introduction of the so-called “precision-control”. The precision control allows the user to define what the acceptable maximum or average error for the compressed and reconstructed data set should be. Extensive studies were conducted using the original Eta 12 forecast model (14 May 2002 12Z run). For a predefined maximum temperature error of less than 0.125 degree Kelvin our compression scheme achieved compression ratios from 17:1 (for the 1000mb) level up to 80:1 (for the 100 mb level). The average compression ratio for this data set was 50:1 (see Figure 4).

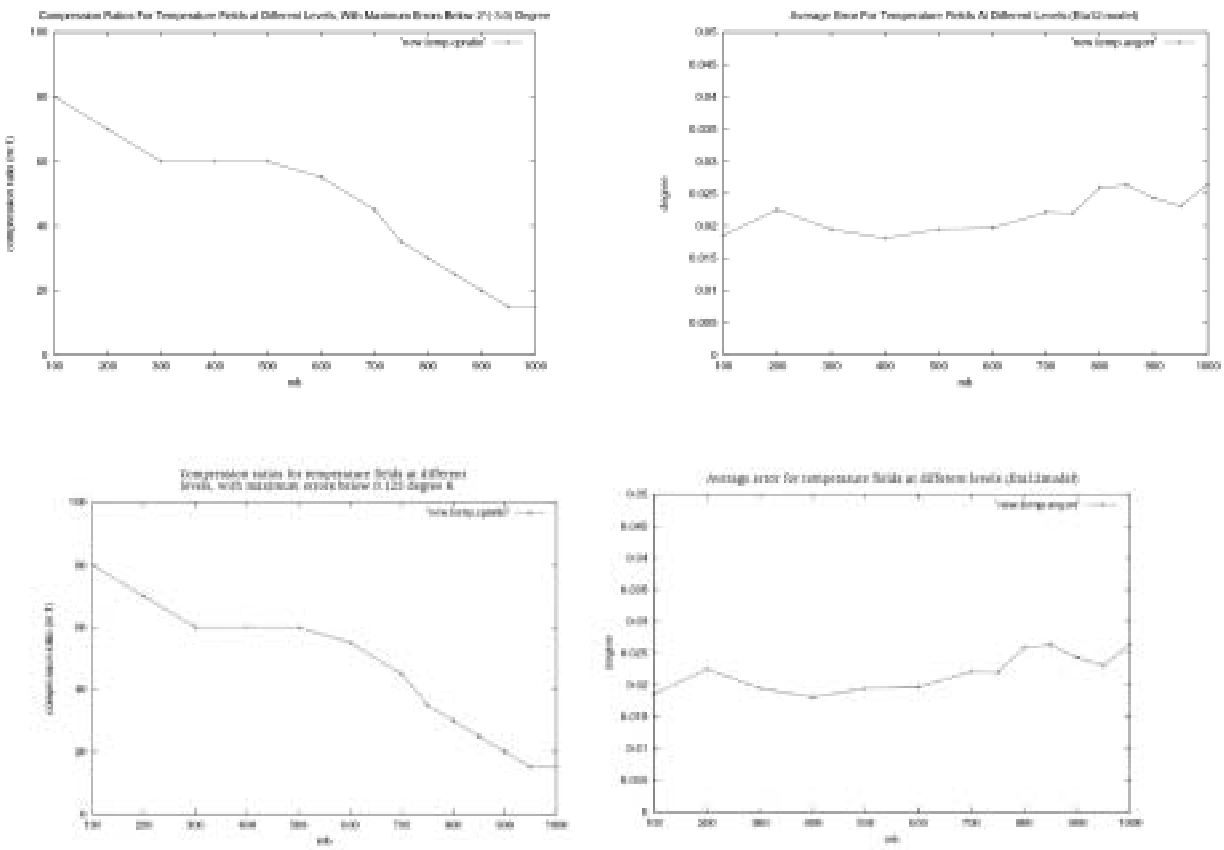


Figure 4: Left side: The compression ratios for the Eta 12 temperature field at different pressure levels with controlled precision (max error < 0.125 K). Right side: Average errors for the temperature field at different pressure levels for the same compression ratios.

The average error reflects the overall quality of the reconstructed data. In our example, the average error turned out to be nearly an order of magnitude smaller than the predefined maximum error. This large difference between the maximum and the average error reflects that the vast majority of grid points in the reconstructed field show an error much smaller than the defined maximum error.

The compression test was done on an 850-MHz Pentium III desktop computer. The average compression time to encode each field (2.5 MB) is about 2-3 seconds.

Compared to typical lossless codecs, with the same precision requirements, our codec achieves 2 to 6 times higher compression ratios. It implies that for a typical model output sized at 1 GB, if transmitted over a 1 Megabit per second communication channel, the transmission time can be reduced from about 2.8 hours to about half an hour.

The presented data compression scheme is asymmetric by nature. It takes more time to encode the data than to decode it. This asymmetry is beneficial to our practical implementation, since we usually have more computing power in the encoding machine than in the decoding machine.

EAR—Data Acquisition, Editing and Display Functionalities of Advanced Forecaster Workstations

<u>WFO-Advanced Data Acquisition System</u>

Principal Researcher: **MarySue Schultz**

The AWIPS project, sponsored by the National Weather Service (NWS), has the objective of modernizing the technology used in Weather Forecast Offices (WFOs) in the United States. As part of this effort, the Forecast Systems Laboratory (FSL) developed a data acquisition and display system which enables weather forecasters to receive and display the large amounts of data needed to produce accurate forecasts, watches and warnings. Over the course of the project, CIRA personnel in the Modernization Division have made significant contributions to the data acquisition component of the AWIPS forecast system.

The AWIPS forecast system has been installed at all of the WFOs in the United States, including sites in Alaska, Hawaii, Guam and Puerto Rico. To produce accurate forecasts, each site needs to have access to a large variety of data. The datasets that were first made available to the AWIPS system covered primarily the contiguous United States. During the past year, the AWIPS project focused more on providing data that is important to the off-continent sites. CIRA staff members were responsible for designing, writing and testing software that acquires the new datasets from the AWIPS broadcast system, decodes them from their transmission format, and makes them accessible to the AWIPS D-2D display. Data ingest software has to be particularly efficient, so that data aren't lost, and so that forecasters can view the data while it's still useful. Data ingest software also has to be flexible, so that when additional datasets become available, they can be easily incorporated into the AWIPS systems. CIRA personnel were responsible for experimenting with different software design and implementation techniques to accomplish these goals. One technique that has been particularly successful is to store data identification information in disk files that the ingest software reads at startup. New datasets can be added and changes can be made to existing datasets simply by changing the information in the file. No modifications need to be made to the software. This type of flexibility has greatly reduced the cost and the amount of time it takes to incorporate new data into the AWIPS systems.

The technology used to collect and disseminate radar data has changed over the past several years, and with the changes have come some opportunities to redesign parts of the radar ingest software. The changes have resulted in increased reliability and in the reduction of maintenance costs to the Weather Service. The AWIPS program has taken advantage of the fact that a WFO can now request data from a neighboring radar via the Wide Area Network (WAN) that connects the WFOs to each other. This is particularly important to the Weather Service, because it will allow them to remove the phone lines that were needed to support the previous implementation of the request capability. CIRA staff members were responsible for designing, writing and testing the AWIPS software that sends data requests to the radars via the WAN, and receives the data that is sent back in reply. This software will first be used as a proof of concept, since this method of requesting radar data is unproven. If it's successful, the software will be distributed to the WFOs.

Another change to the radar technology involves the Volume Coverage Patterns (VCP) used by the radars to collect data during different atmospheric conditions. There are currently four different VCPs available: two that are used during clear-air conditions, and two that are used during storm conditions. In the next year, two more storm VCPs will be added, and several more will follow in subsequent years. During real-time operations, when a radar's VCP changes, the AWIPS software needs to respond by sending an appropriate set of product requests to the radar, based on the VCP. CIRA staff members were responsible for redesigning the sections of the software that are responsible for this interaction, to accommodate the new VCPs. Since there will be more VCPs coming on line in the future, a flexible design was used, to allow the new VCPs to be accommodated without having to modify the software. CIRA staff members also implemented and tested this new capability, which will be distributed to the WFOs during the next year.

Range Standardization and Automation (RSA) Project

Principal Researcher: MarySue Schultz

The RSA project is a collaboration between the Air Force, the Missile Systems Division of Lockheed Martin and FSL. The purpose of the project is to provide Air Force launch sites with weather forecasting technology based on the AWIPS system, to aid in weather forecasting responsibilities at the sites.

There are several datasets local to the launch sites that need to be displayed by the RSA systems. Lightning data, in particular, is important, since lightning affects not only launch schedules but also daily operations. It is important to protect missiles that are on the launch pad and personnel working on the scaffolding from lightning. There are three different types of lightning detection systems that provide data to the launch pads: 1) the Cloud-to-Ground Lightning Surveillance System (CGLSS), which has very good detection efficiency and excellent ground strike accuracy; 2) the Launch Pad Lightning Warning System (LPLWS), which assesses triggered lightning potential, and gives early identification of cloud electrification; 3) the Lightning Detection and Ranging (LDAR) system, which provides 3-dimensional locations of in-cloud and cloud-to-ground lightning. CIRA personnel in the Modernization Division designed and implemented software that receives all three types of lightning data and processes it for the RSA displays. CGLSS and LPLWS data will be displayed on

D-2D; a new 3-D display capability is being developed by CIRA staff members in the Systems Development Division to display LDAR data.

CIRA personnel experimented with new data ingest techniques for lightning data, since these data types are available only at the launch sites, and will not be delivered by the AWIPS broadcast system. The new ingest design is currently being implemented and tested, and will be delivered to the RSA sites in the fall of 2003.

<u>WFO-Advanced Graphical Forecast Editor Suite (GFESuite)</u>

Principal Researchers**: Deborah Miller and David Howard**

The GFESuite is a series of programs that provide an end-to-end interactive forecast preparation capability. The GFESuite components derive surface sensible weather elements from model data, manage the forecast data and metadata in a database, provide viewing and editing capability of the forecast data, and generate output products in a variety of formats.

The GFESuite has been designed for forecast situations where more than one forecaster will be simultaneously editing grids, which is usually the case at most forecast offices. The database server prevents simultaneous editing of the same forecast grids and lockout of grids while editing. It also provides notification of data changes, and when forecasters save their edited gridded forecast, all other GFEs connected to the same database server will see the changes immediately.

CIRA staff members at FSL responsible for the GFESuite, have aided in the research to carefully investigate and incorporate cutting-edge software design and development techniques. Those decisions include Object-Oriented design, Extreme Programming concepts and the use of Python, an interpreted programming language as an adjunct to C++. CIRA researchers have designed and developed core software, enhancements and procedures to test the entire GFESuite. The efforts of the CIRA staff have directly contributed to the quality of the product and overwhelming acceptance by its users.

EAR—WFO-Advanced Workstation

Principal Researcher: Mike Biere

Workstation Development Activities

The WFO-Advanced workstation software is the core of AWIPS display capabilities, as well as the display generating engine behind the FX-Net and FX-Connect workstations. CIRA researchers continued to extend and maintain the WFO-Advanced workstation capabilities, mainly in conjunction with AWIPS and RSA projects.

CIRA researchers managed the configuration management of FSL software trees for four operational AWIPS builds during the year: patches for AWIPS 5.2.2 through initial development for OB3 (AWIPS Operational Build 3). The AWIPS Linux operating system was upgraded to Red Hat 7.2 in November 2002. OB3 included upgrading to gcc3.2.3 which required the C++ software base to be ANSI C++ compliant.

The automated warning generation program for AWIPS (Warngen) was the focus of numerous bug-fixes and enhancements, including adding a follow-up capability, and issuing corrections in a formalized manner.

The AWIPS radar capabilities were enhanced in anticipation of new radar scan strategies. This required changes in AWIPS to both data management and display capabilities.

Display of local lightning data was a significant addition to the workstation software in support of RSA use of the AWIPS software. Numerous other minor bug-fixes and enhancements were made to address RSA-specific requirements.

Some enhancements to the AWIPS user interface software were also made, including the implementation of some simple internationalization capabilities which allowed the Korean Meteorological Administration to specify menus in a Korean font. (See publication reference below)

Multicast Data Distribution

A project to investigate multicasting to distribute data from a central server to individual workstations on a local area network was completed. The multicast transmission was successful in transferring data, but there were significant ramifications to the existing AWIPS system and software design before such a mechanism could be implemented routinely in AWIPS. After testing the multicast approach, it appears that the performance improvements and extensibility of the approach are insufficient, given the considerable complexity that would be added to the AWIPS site architecture. The conclusions of this research were presented at the 2003 AMS IIPS conference. (See publication reference below)

Science-On-A-Sphere

NOAA's Science-On-A-Sphere project (SOS) displays and animates global datasets on a large sphere. CIRA researchers added a number of system capabilities to the SOS project, including the display of AWIPS global data sets, a polar-orbiting satellite simulation. Software for easily preparing data sets for SOS and a graphical user interface to allow easy control of the system were developed.

Publications

Biere, M. and D.L. Davis, 2003: Multicast data distribution on the AWIPS Local Area Network. *AMS 19th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Long Beach, CA, CD-ROM, 4.7.

Jung, Y.-S., F. Moeng, B.H. Lim, M. Biere, H. Lee, and S.K. Chung, 2003: FAS: An international version of AWIPS. AMS 19th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, Long Beach, CA, CD-ROM, 4.6.

Three -Dimensional Display Development

Principal Researcher: Phil McDonald

The Display-3D (D3D) workstation has the goal of providing an advanced meteorological workstation for operational forecasters with interactive three-dimensional visualization of atmospheric data. In October 2002, further development of D3D was terminated due to lack of funding.

As part of the Range Standardization and Automation project, an operational user interface and data visualization display application for high-volume three-dimensional LDAR (Lightning Detection and Ranging) data began development. Figure 1 provides an example of the 4-panel display and its customized Tcl/Tk GUI. The visualization layout is similar to the LDAR data display currently in use at Cape Canaveral. It includes a plan-view in the lower left panel, a view from the south in the upper left panel, and a view from the west in the lower right panel. To aid volume visualization, the upper right panel contains a three-dimensional rendering with a point of view that can be interactively manipulated by the user. To ensure optimum functionality, users of this application have been consulted on a number of occasions. Delivery of the application is scheduled for

September 2003.

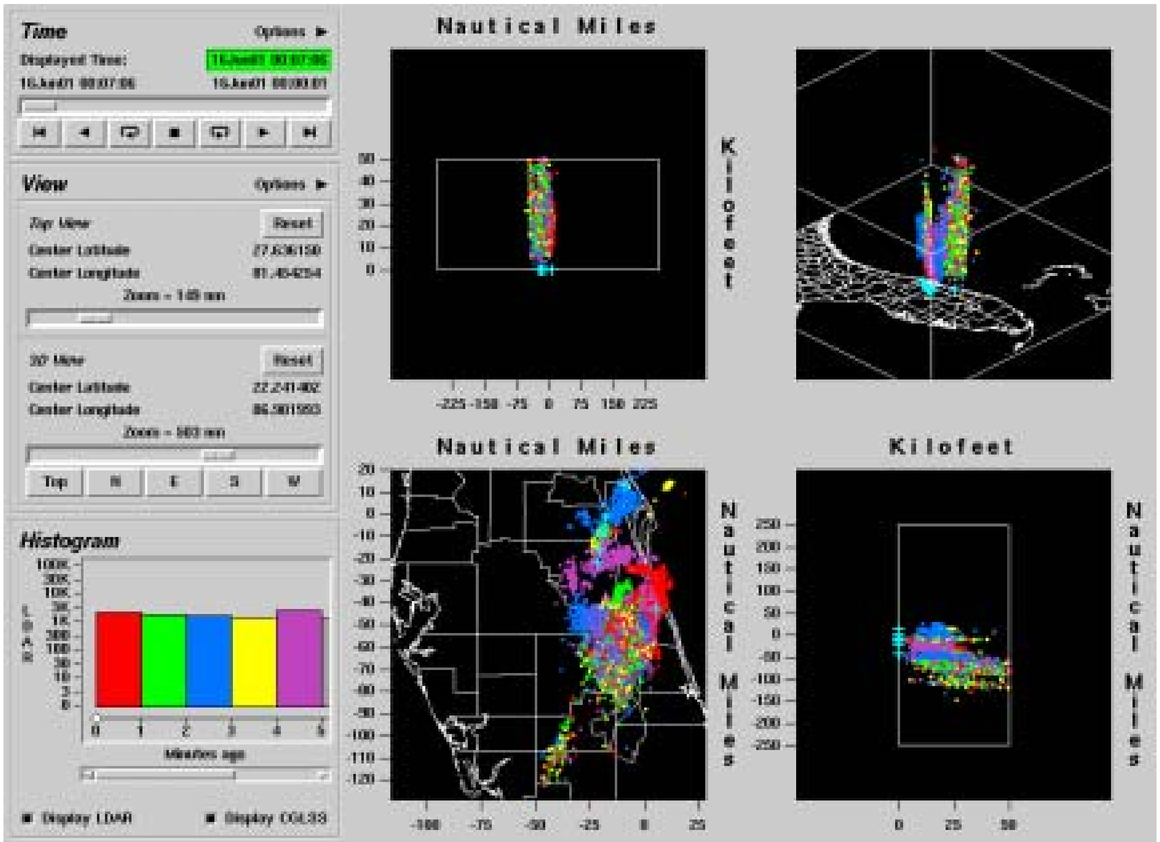


Figure 1. Actual 3D and 2D data from sensors at the Kennedy Space Center from 16 Jun 2001. Small dots are plotted at each of the lightning step leader nodes and are colored according to their age: red 0-1 minute; green 1-2 minutes; blue 2-3 minutes; yellow 3-4 minutes; purple 4-5 minutes; gray more than 5 minutes. The histogram at the bottom left indicates the frequencies of each of these age categories. Small cyan pluses ("+") are plotted at the locations of cloud-to-ground lightning strikes.

Publications:

Szoke, E.J., U.H. Grote, P.T. McCaslin, and P.A. McDonald, 2003: D3D update: Is it being used? *AMS 19th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Antonio, CA., P1.10.

<u>Local Data Acquisition and Dissemination (LDAD) Project—EMDS Component</u>

Principal Researcher: Christopher E. Steffen

FSL and CIRA research collaboration continued on the web dissemination component of LDAD known as the Internet-based Emergency Management Decision Support (EMDS) system. It is a web-based applet/application for use by a small number of state and local government users and/or a large number of public Internet users. The EMDS disseminates all types of weather data, including high-resolution weather analysis/forecast/model grids, radial radar grids, observations, quality control information and textual forecasts in a multi-modal GUI to a variety of users. It also allows the local and state government agencies to integrate weather information from the National Weather Service with their GIS data sets to create a personalized Decision Support System. The EMDS should now be installed at all Weather Forecast Offices in the US.

The HPCC proposal to implement a surveillance capability within the EMDS was completed. The use of the EMDS over a cell phone link was demonstrated. The surveillance capability includes the ability to create derived grids using python scripts and to monitor conditions within some distance of a point for the purpose of generating alerts if specified thresholds are exceeded.

Weather Data Compression Project

Last year's results from researching the feasibility of using rounding, differencing, and either bzip2 or gzip to compress model grids before transmission over the satellite broadcasting network were summarized in an AMS conference paper. Rounding, differencing, and bzip2 compressed floats by about 10:1 which was about 3 times better than GRIB1 is currently doing. While more research could be done to improve the compression ratio, the wavelet compression method Ning Wang investigated appears to be the best approach. Compression of 50 to 1 was achieved for some model data, which is about 16 times better than GRIB1 is currently doing.

AWIPS Usage Log Collection and Analysis Project

Python scripts that collect and analyze the AWIPS usage logs were completed.

EAR—Profiler Software Enhancements

Principal Researcher: Robert Prentice

CIRA researchers are improving the efficiency and reliability of the software development process associated with atmospheric profiler data acquisition and quality assurance. This software is critical to supporting the wide distribution of profiler data to many government agencies. Data is received and distributed in numerous formats and through a variety of communications technologies. Reliability and timeliness of data delivery are of utmost importance, as is applying quality control to the data to screen out anomalies caused by aircraft, ground clutter, and other irregularities.

Careful configuration of tools such as CVS, Ant, and Eclipse has made it possible to automate software builds and to bring new levels of consistency and efficiency to the software development process. The majority of this work was completed during this year. Continuing activity will be required to support the group's first use of branching to more efficiently support simultaneous development on multiple versions of software.

Work is now underway to extend this new level of efficiency to the process of software installation and testing with two planned capabilities. The first is to extend the automated build process to the point where software can be packaged into Linux RPM modules for software installation. This technology simplifies the otherwise complex process of maintaining numerous software components on multiple machines at known, compatible version levels.

The second planned capability is to provide system administrators with a tool that tests newly configured systems to ensure that they are configured to provide a fully functional runtime environment for profiler software. This tool will run through a configurable series of tests, and issue messages as needed to make administrators aware of necessary changes.

Most of these completed and planned capabilities, and the tools that support them, are new to the profiler project, and to the division within which it resides. Bringing these capabilities online required investigating how to effectively utilize new tools in the target development environment, and carefully reconfiguring the development process and the organization of software components to allow these tools to be utilized. Documentation of the new environment and working with developers to help them understand it helped to make the transition successful.

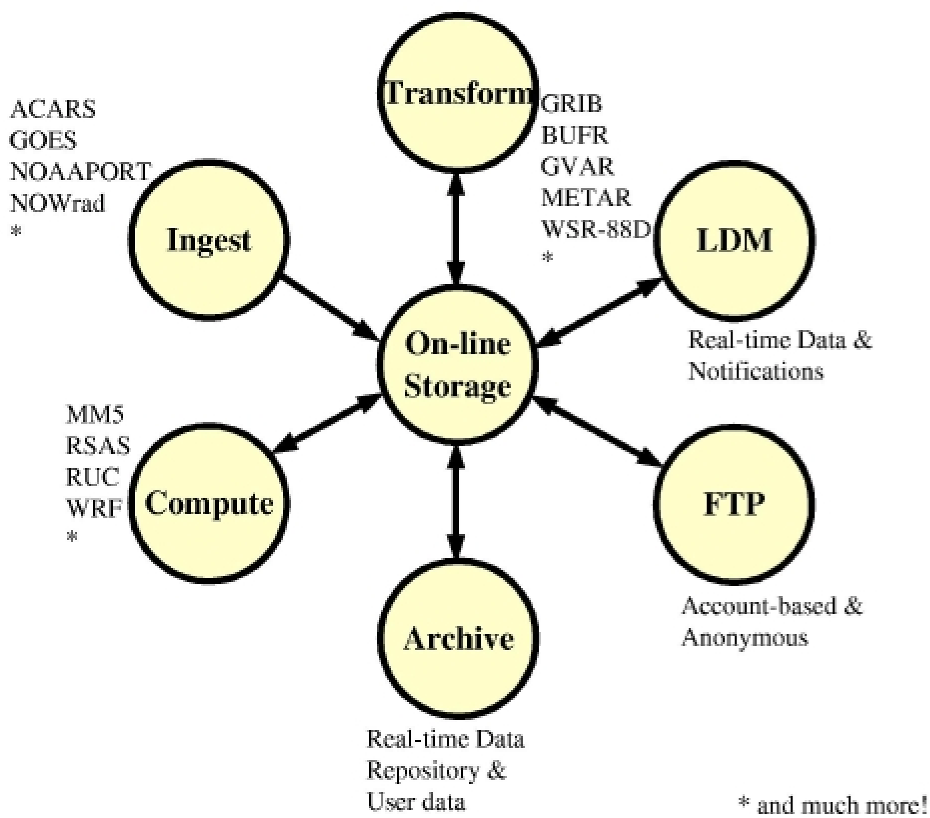
New levels of organization and documentation are being applied to the software supporting the CAP (Cooperative Agency Profiler) program. This program collects data from numerous profilers where each has numerous unique aspects to the way data is generated and collected. As the program looks to expand in size and perhaps become part of a national network, it becomes increasingly important for the software governing the acquisition, quality control, and dissemination of software to be well understood, readily maintainable, and flexible with regard to future expansion. Software documentation is being generated in HTML with PNG images, so that it is readily viewable by web browsers. Images are generated using Adobe Illustrator.

Gaining the knowledge to make organization and documentation of this software possible has required becoming directly involved in the software development process. The on-going maintenance of the profiler network requires constant activity to keep pace with numerous external changes and requirements, and to migrate software off of aging equipment. This development has involved both Java and Perl on Linux and Windows platforms.

EAR—Data Systems Group

Principal Researcher: Christopher MacDermaid

CIRA researchers in the Data Systems Group (DSG) collaborate with Forecast Systems Lab (FSL) and Cooperative Institute for Research in Environmental Sciences (CIRES) scientists, researchers and developers on research into how to assemble and maintain a state of the art meteorological data center. The results of this work facilitate the ability of fellow scientists to perform advanced research in the areas of modeling, application, and meteorological analysis/forecast workstation research and development. Multiple computers operate in a distributed, event-driven environment known as the Object Data System (ODS) to acquire, process, store, and distribute conventional and advanced meteorological data. The following figure illustrates schematically the Central Facility (CF) Services developed by DSG.



Data are received from a variety of operational and experimental sources that include:
* The National Weather Service (NWS)
* NOAAPORT
* The National Centers for Environmental Prediction (NCEP)

* WSR-88D Doppler radar
* Aeronautical Radio Inc. (ARINC)
* Weather Services International Corporation (WSI)
* The Forecast Systems Lab (FSL) Demonstration Division
* The Geostationary Operational Environmental Satellite (GOES)-10 and GOES-12
* The National Center for Atmospheric Research (NCAR)
* Meteorological Assimilation Data Ingest System (MADIS) data providers
* Fleet Numerical Meteorology and Oceanography Center (FNMOC)

Real-time data are also distributed to many external organizations using the Unidata Local Data Manager (LDM) protocol. Distributed data sets include:
* GOES imagery to the NOAA Environmental Technology Laboratory (ETL)
* Wind profiler data to University Corporation for Atmospheric Research (UCAR) Unidata program
* Quality controlled Aircraft Communications Addressing and Reporting System (ACARS) data to NCAR and a number of government agencies as well as universities
* WSR-88D Level-II data to the Collaborative Radar Acquisition Field Test (CRAFT)

Data Acquisition Systems

Design and development of subsystems for the ingest and processing of radar and GOES GVAR data were completed, and these systems are now running in production. These data are used by various meteorological analysis and modeling applications, both internally and by external university and private organizations. Additionally, the GOES subsystem was configured to acquire data from GOES-12, which became operational April 1, 2003.

ACARS ingest hardware and software were upgraded. The legacy X.25 connection with ARINC was replaced with a TCP/IP feed running on a Linux system using IBM's MQ software. ACARS processing was also updated to handle several additional formats.

Data Processing Systems

Software was designed and developed to streamline the acquisition and processing of point, radar, and satellite data. This new software was created using Object Oriented (OO) methods to reduce maintenance and to allow for the generic handling of data types. Acquisition and processing was added for Center Weather Advisory (CWA), Terminal Aerodrome Forecast (TAF), National Convective Weather Forecast (NCWF), Lightning Detection Network (NLDN), and Sferic Lightning data. Updates were completed to handle Grid in Binary 2 (GRIB) format and the WSI ingest within the ODS scheme.

A complete rebuild of ODS was finished using the GNU Compiler Collection (GCC) version 3.

Investigation began toward installation of an Open Radar Product Generator (OpenRPG) system for the CF. This will be used to generate WSR-88D Level-III products for users of the CF Advanced Weather Interactive Processing System (AWIPS) and for storage on the Mass Store System (MSS).

Research and development of an OPeNDAP (Open-source Project for a Network Data Access Protocol) server began. OPeNDAP provides a discipline-neutral means of requesting and providing data across the World Wide Web. The goal is to allow end users, whoever they may be, to access immediately whatever data they require in a form they can use, using widely available applications.

Development of Concurrent Versions System (CVS) methods continued, focusing on efficiently maintaining real-time software configurations for over 30 CF servers.

Software and procedures were developed to backup NCEP with the Rapid Update Cycle (RUC) model and the Rapid Update Cycle Surface Assimilation System (RSAS).

Facility Information and Control System (FICS)

FICS Monitor changes were implemented to account for the arrival of a variety of new data sets. Several new monitoring components were implemented. An FX-Net Monitor was developed for FICS in collaboration with the FX-Net team to report system status to the FICS server and a monitor was developed for Jet, the FSL High Performance Computing System (HPCS). In addition, a System Load Monitor was developed to alert Operations staff to potential problems on over 30 operational real-time systems.

Porting of FICS to a Linux high-availability server pair was begun. This will provide increased reliability and automated fail over for the FICS servers.

Real-Time Advanced Weather Interactive Processing System Data Processing

In collaboration with the FX-Net project, several data severs were customized for the display of data for the NOAA New England High Resolution Temperature and Air Quality Forecasting Pilot Program (TAQ), Fire Weather, and FX-Net NWS regional headquarters projects. Associated FICS monitoring and troubleshooting procedures were developed to monitor these systems.

AWS Convergence Technologies, Inc. (AWS) WeatherNet network data are being acquired as part of NWS and AWS's new public-private partnership to bolster the government's ability to respond to a homeland security event and protect lives and property. The AWS WeatherNet network is a dense, nationwide commercial network that includes more than 6,000 automated weather station locations based primarily at schools. AWS data is being sent every 15 minutes for ingest into MADIS. This data is then made available to NWS.

Research into replacing the aging NOAAPORT ingest system with a Linux-based system was completed. Systems were evaluated for optimum performance and reliability. A Linux system from Planetary Data, Inc. (PDI) was selected and put into production.

Data Storage and User Access

The FSL Data Repository (FDR) and the Real-Time Data Saving system (RTNDS) were merged. Using ODS software to create a configurable and scalable system, the new FDR method reduces both the number of files (using Unix tar - tape archive) and the volume of data (using gzip compression) that is being stored using the MSS. Improvements to this system will continue.

A new FSL Data Repository (FDR) Report script was developed to provide daily statistics on the storage to the MSS of CF data sets. Other FDR scripts were updated to improve reliability.

Data Storage and Retrieval System Support (DSRS)

Research into replacing the legacy FileServ/VolServ-based MSS with a StorNext-based MSS was completed and an acceptance plan was created. Acceptance testing was accomplished and the StorNext-based MSS installation was completed. A number of user utilities were converted to use the StorNext-based MSS including some FDR scripts.

Technology Transfer

ODS software to acquire GOES GVAR data was packaged and delivered to the Central Weather Bureau of Taiwan. This system replaces the operational satellite data acquisition and processing that had been used for the now decommissioned Geostationary Meteorological Satellite (GMS). ODS software to acquire GOES GVAR was also delivered to the Marshall Space Flight Center. ODS software for converting GRIB to NetCDF was delivered to the NWS and the Aviation Weather Center (AWC). ODS software for converting NEXRAD to NetCDF was delivered to Goddard Space Flight Center, the Marshall Space Flight Center, and the NWS.

DSG members participated in the FSL Technology Day 2002, preparing a poster and white papers describing the work of the group.

A Look Ahead

Design and development for new and modified data sets will be an on-going activity. Use of ODS applications and methods will expand as legacy translators and product generation methods are replaced by new, more flexible techniques. OO software development for point data types will continue.

Design and development will continue toward creating an automated "archive search" system. This will facilitate the retrieval of data sets for use by researchers studying interesting weather events.

Development of new metadata handling techniques are planned that will facilitate the use of real-time and archived data sets. An automated system for acquiring and incorporating metadata is part of this plan. Further research will be conducted on the interactive interface that allows for easy query and management of the metadata content. Program interfaces will be added to allow for secure controlled data access. Retrospective data processing and metadata management are slated for incorporation.

Refer to http://www-fd.fsl.noaa.gov/dsg/ for additional information on DSG.

Harnessing the Spare Computing Power of Desktop PCs for Improved Satellite Data Processing and Technology Transition

Principal Investigators: A. Jones/T. Vonder Haar

This is a collaborative project with NESDIS/OSDPD (lead: Ms. Ingrid Guch) to harness the idle computing cycles of desktop PCs for satellite data processing. The work is funded by the NOAA High Performance Computing and Communications (HPCC) Program. A typical office PC can be idle more than 80% of the time. This work uses an innovative PC-based grid computing system developed at CIRA called the Data Processing and Error Analysis System (DPEAS). The new system enables the previously wasted computing cycles to be used for NOAA data processing efforts in a secure and efficient manner.

Because the hardware, operating system and maintenance of NOAA office PCs are already paid, the cost-savings are significant both in terms of short term (hardware purchases) and long term (staff hours for maintenance and upgrades) costs when compared to an equivalent Linux-cluster of machines. A preliminary cost-benefit analysis compared a cluster of 100 office PCs to a cluster of 40 dedicated dual-processor Linux machines and found the office PCs provided a savings of over $1,000,000 during a 5 year period ($2,214 per office PC per year)

The technology transition process is also now simplified. NOAA and CIRA have had a long-standing cooperative agreement for research in the atmosphere. However, until now, it has been significantly difficult to transfer research at CIRA (and other research institutions) to operations in NOAA. Now, both groups have access to Windows-based office machines that can process satellite data. A single executable from CIRA can be transferred to NOAA in a matter of hours rather than having to rewrite and recompile over a period of weeks or even months, leaving more time for NOAA to understand, optimize and document the code for operations.

Accomplishments This Year:

1. Installation of a DPEAS grid-computing cluster at NESDIS/OSDPD at Suitland, MD on 2 test systems, using “test” OSDPD office PCs.
2. Creation of a Windows domain at OSDPD (similar to CIRA’s Windows domain) hosting an 8-node grid computing system using a subgroup of working OSDPD office PCs. The system is currently processing selected Advanced Microwave Sounding Unit (AMSU) data flows in near real time using the new grid computing system at OSDPD. This work was presented at the AMS conference (Guch et al., 2003).
3. A Total Cost of Ownership (TCO) analysis using the OSDPD office environment shows savings exceeded $2000 per PC.

4. A final report was created detailing the TCO analysis results, and suggestions for next steps (Guch et al., 2003).

Publications This Year:

Guch, I. C., A. S. Jones, R. Ferraro, M. Kane, and C. Karlburg, S. Q. Kidder, 2003: Harnessing the spare computing power of desktop PCs for improved satellite data processing and technology transition, Preprints, *19th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology,* February 10-13, Long Beach, CA, Amer. Meteor. Soc., paper 11.9.

Guch, I. C., A. S. Jones, I. Tcherednitchenko, M. Kane, R. Ferraro, and C. Karlburg, S. Q. Kidder, 2003: NOAA HPCC Final Report: Harnessing the Spare Computing Power of Desktop PCs for Improved Satellite Data Processing and Technology Transition, 13 pp.

Impact of Surface Inhomogeneities on Weather

Participating Investigators: Roger Pielke Sr. and Adrian Marroquin

The improved new CIRA computer cluster has facilitated very high-resolution simulations to investigate the impact of surface heterogeneities on boundary layer circulations. For this work, cases were chosen from the Vertical Mixing and Transport Experiment (VTMX-2000) over the Salt Lake City Area for which we have several observational datasets such as lidar, class soundings, profilers, and surface observations. Preliminary results from the 15 October 2000 case were presented at the annual review meeting of the Center for Geosciences/Atmospheric Research (CGAR) that took place at Adelphi, Maryland on January 6-10, 2003. Preliminary results for the 15 October 2000 are posted on the CSU webpage http://blue.atmos.colostate.edu/imagegallery. Simulations at 50-m grid spacing (three- nested grid system) for the innermost grid show that RAMS, initialized with RUC20 output, is able to generate the observed drainage flow observed during the night of 14-15 October to the east of Salt Lake City along the canyons. The drainage flow begins to appear at about 30 minutes into the simulations which means that the spin-up time has been reduced considerably. Also, the model was able to describe a system of horizontal eddies (1-km or less in diameter) along the foothills, east of Salt Lake City. The existence of these eddies has been reported from observations and other numerical simulations. The results suggest that the model with coarse grid spacings (e.g., 250-m to 1-km) would not be able to forecast the existence of these eddies effectively. Since these eddies appear at the interface (east of Salt Lake City) of flow along the valley and the flow from the mountains, a recycling of pollutants could result.

Infrastructure Group

Group Manager: Michael Hiatt

Members: Michael Hiatt – Group Manager/Engineer
Karll Renken – PC Technician

The Infrastructure Group provides all planning, development, deployment, maintenance, and support for CIRA's computer infrastructure, local and wide area network, and satellite earthstation**.**

Infrastructure

The CIRA Infrastructure currently has 145 PC systems that represent CIRA's core computer base. These systems are custom designed, assembled, and maintained by the group. The following list gives an overview of the infrastructure services managed by this group:

- Complete system management: Pentium-4 servers/workstations using the Microsoft Windows 2000/2003 operating system. Software acquisition, installation, and support. System upgrades, software patches and service packs
- E-mail, CIRA website, accounts, accounting, FTP, DHCP, DNS, printing, dialup, security, antivirus, antispam, and property accounting
- LAN/WAN and CIRA subnet
- Infrastructure budget and expenditures
- Technical consulting for: RAMM, NPS, Bacimo, AMSU, Geosciences, CHANCES, CloudSat, Students, Visiting Scientists

A notable change this year was the addition of RAID (Redundant Array of Inexpensive Disks) systems to several key servers. These RAID systems provide total uninterruptible hard drive redundancy further minimizing server downtime.

Earthstation

The satellite earthstation provides key metrological data for CIRA research. The earthstation collects, processes, distributes, and archives:

- GOES-8
- GOES-9
- GOES-10
- GOES-11
- GOES-12
- NOAA-16/17
- Meteosat-5

- Meteosat-7
- GMS-5

All products are collected at full resolution and processed into McIDAS formatted files. These files are distributed to researchers on high speed servers and archived for future use.

An important addition to the earthstation this year was the development and deployment of a DVD archive system. This innovative system realized the goal of having a more reliable medium than tape. Key enhancements include:

- Lower Cost: At today's prices, DVD storage is 1/3 the price of tape storage.
- Data verification: Verification on tape is not practical since there is physical contact between the tape and tape drive.
- Longer Life: DVD's are rated at least 30 years and less affected by environmental issues. Tapes are easily damaged by temperature, humidity, age, and magnetic fields.
- Random access: Data retrieval from DVD is significantly faster since the DVD's are random access.
- Distribution: Large data requests can be handled faster since the DVD's can be quickly duplicated.
- Retrieval: Web based HTML log files allow quick and easy searching from any Internet computer. Library style indexing and storage make it easy for student help to locate the correct DVD's.

Future work includes development and installation of a Meteosat Second Generation (MSG) earthstation.

Radar Remote Sensing of Marine and Continental Stratus Clouds

Principal Investigator: Shelby Frisch

Objectives

The quantities that are needed for instantaneous atmospheric radiative flux calculations with clouds present are the cloud boundaries, liquid water profiles, liquid water fluxes and the effective radius of the cloud droplets. In addition, we are looking at the cloud variability and seeing how this variability may cause problems in models. The objectives of these studies were to supply radar derived estimates of these quantities from available data sets such as data taken at the CART site at the North Slope of Alaska, SHEBA, and the cloud radar on the NOAA research ship Ron Brown.

Approach

During this last year, we developed an algorithm for retrieving stratus cloud droplet liquid water flux due to gravitational settling using cloud radar reflectivities. This is done in the non-drizzling part of the cloud. By computing the divergence of the flux, we can estimate the cloud heating and cooling due to the gravitational settling of cloud droplets and compare it with the calculated radiative cooling and heating. In addition, we are using the cloud radar reflectivity calculation to estimate the stratus cloud optical depth for liquid water.

Results

Publications

Frisch, S. and P. Zuidema, 2003: On the vertical profile of stratus liquid water flux using a millimeter cloud radar. Proceedings from the *AMS 31st Conference on Radar Meteorology*, Seattle, WA, 6-12 August 2003, P2A.4.

Reinking, R., D. Korn, A.S. Frisch, B.W. Orr, L.R. Bissonnette, and G. Roy, 2002: Observations of effects of mountain blocking on traveling gravity-shear waves and associated clouds. *Weather and Forecasting (accepted)*

Studies of the Stable Boundary Layer during the Cooperative Atmosphere/Surface Exchange Study - 1999 (CG/AR)

Principal Investigator: Rob Newsom

The overall goal of this project is to increase our understanding of the nighttime stable boundary layer (SBL) through analysis of field data obtained during the CASES-99 experiment. The Center for Geosciences/Atmospheric Research (CG/AR) in cooperation with the NOAA Environmental Technology Laboratory (NOAA/ETL) deployed ETL's High Resolution Doppler Lidar (HRDL) to the CASES-99 field site near Wichita, Kansas. After participating in planning and preparation, a highly successful field project was completed in October 1999. An extensive dataset was acquired containing measurements of radial velocity and aerosol backscatter showing excellent examples of nocturnal low-level jet (LLJ) behavior, gravity waves, shear instabilities, density currents, drainage flows and turbulent eddy formation. The research described here is focused primarily on the analysis of HRDL data, and is being conducted in close collaboration with other CASES-99 researchers.

Combined analyses of in-situ and HRDL data indicate that turbulent mixing in the stable nocturnal boundary layer is controlled in large part by the vertical wind shear that initially develops during the evening transition period as the flow aloft decouples from the surface layer due to reduced stress. Decoupling allows the winds aloft to accelerate to super-geostrophic speeds, depending on the degree of ageostrophic departure prior to sunset. This results in the formation of the LLJ. The strength and height of the LLJ controls the vertical shear and thus the turbulence within the stable boundary layer. In addition to the more conventional methods of analysis, we have been using four-dimensional variational data assimilation (4DVAR) to aid in the interpretation of the lidar data collected during CASES-99. 4DVAR is being used to the retrieve microscale flow structures from the single-Doppler lidar data. The retrieval algorithm uses the adjoint of a large eddy simulation to retrieve three-dimensional, time varying wind and temperature fields from spatially and temporally resolved radial velocity measurements.

Technological Transfer and Validation of the CIRA Scheme for the Tropical Rainfall Potential (TRaP) Technique

Principal Investigator: S. Q. Kidder

Background:

Heavy rainfall from landfalling tropical cyclones is a major threat to life and property. Rappaport (2000), for example, found that in the contiguous United States during the period 1970–1999, freshwater floods accounted for more than half of the 600 deaths directly associated with tropical cyclones. Forecasting rainfall from tropical cyclones is, thus, an important task, but a quite difficult one. While the storm is offshore, few rainfall observations are possible, and initializing numerical weather prediction models with sufficient details of the storm so that accurate rainfall forecasts can be made is beyond the state of the art. Radar observations of storm rain rate and rain area are valuable, but only when the storm is within radar range of the coast. The best hope for tropical cyclone rainfall forecasts, therefore, lies with satellite observations.

Since 1992, the Satellite Services Division (SSD) of the National Environmental Satellite, Data and Information Service (NESDIS) has experimentally used the operational Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) rain rate product to produce a rainfall potential for tropical disturbances expected to make landfall within 24 hours. The launch in 1998 of the first Advanced Microwave Sounding Unit (AMSU) on the NOAA 15 satellite provided an additional rainfall data source.

The original NESDIS/SSD Tropical Rainfall Potential (TRaP) technique was performed manually by an analyst and resulted in a single number defined as

$$\mathbf{TRaP} \equiv \boldsymbol{R_{av}DV^{-1}},$$

where R_{av} is the average rainfall rate of the storm, D is the diameter of the raining area of the storm, and V is the speed of the storm. The logic of this equation is that the duration of rain expected at a station is approximately DV^{-1}, and the total rainfall (TRaP) is approximately R_{av} times the duration. The analyst typically chose the maximum diameter or the line (parallel to the storm's motion) with the maximum average rain rate to maximize the rainfall potential and thus determine the maximum threat.

At CIRA, under a previous grant, the TRaP technique was improved by automating it and by calculating the rainfall at every point in an image, so that the location as well as the amount of the precipitation could be estimated. NOAA 15 AMSU-A rain rate data were first used. The TRaP technique was further improved in 2001 by (1) adding a second satellite (NOAA 16), (2) using higher-resolution AMSU-B rain rate images, and (3) acquiring more track forecasts to be able to use the technique over a larger fraction of the globe.

A similar but not identical TRaP method was developed by NESDIS/SSD and is now used operationally by analysts to calculate TRaP images. This technique has been quite useful in the preparation of heavy rain forecasts, associated with tropical cyclones, for their users.

The purpose of this project was to compare the CIRA TRaP technique with the NESDIS/SSD TRaP technique so that the best of both techniques can be combined in an improved technique.

Tasks:

1. Advise NOAA/NESDIS about the capabilities of the TRaP code which runs at CIRA.
2. Run the CIRA TRaP code for the 2002 tropical season and validate NESDIS/SSD TRaP fields by comparing them with those produced at CIRA.
3. Devise a conceptual model for a Web-based system in which an analyst could select a storm, a track forecast, a forecast period, and a source of satellite rain rate imagery to product a TRaP.

All tasks were completed and a final technical report was submitted in March 2003.

Major findings:

1. The automated CIRA technique produces many more TRaPs than appear on the SSD Web page
2. The automated CIRA technique occasionally fails due to lack of timely data
3. SSD TRaPs are quite similar to CIRA TRaPs, especially when both are produced from AMSU data
4. Time is important in the construction of the TRaP product
5. Information about the storm track used in the TRaP needs to be available
6. Only the precipitation which moves with the storm should be part of TRaP
7. There is a problem with AMSU TRaPs at coastlines

Recommendations:

1. TRaP calculations should be based on the exact time of satellite observation of the storm. This will improve the precision of the TRaP product.
2. The start and end time of the TRaP need to be precisely specified. This will help both forecasters and those attempting to do verification.
3. Each TRaP image should be accompanied by the storm track as well as the original rain rate image. This will help TRaP users evaluate the quality of the TRaP.
4. A screen to eliminate precipitation not related to the storm should be used. This will lessen “clutter” in the TRaP images.

5. The coastal problem with AMSU-B rain rate data needs to be fixed. This will improve the accuracy of the TRaP.
6. The TRaP technique needs to have an automatic component, initiated by the receipt of either a new track forecast or new satellite data.
7. For the foreseeable future, quality control by an analyst and the manual posting of the TRaP product to the SSD Web page are essential in distributing a reliable product.

Publications:

Ferraro, R., P. Pellegrino, S. Kusselson, M. Turk, and S. Kidder, 2002: *Validation of SSM/I and AMSU Derived Tropical Rainfall Potential (TRaP) During the 2001 Atlantic Hurricane Season.* NOAA Tech. Rep. NESDIS 105, Washington, DC, 43 pp.

Kidder, S. Q., S. J. Kusselson, J. A. Knaff, R. R. Ferraro, R. J. Kuligowski, and M.

Turk, 2003: The Tropical Rainfall Potential (TRaP) Technique. Part 1: Description and Examples. In preparation.

Ferraro, R. R., P. Pellegrino, S. J. Kusselson, R. J. Kuligowski, M. Turk, S. Q. Kidder, and J. A. Knaff, 2003: The Tropical Rainfall Potential (TRaP) Technique. Part 2: Validation. In preparation.

Validation of NESDIS Microwave Land Emissivity Model

Principal Investigators: J. Forsythe/D. McKague

The NESDIS Microwave Land Emissivity Model (MEM) is used as an important radiative boundary condition for 3D satellite data assimilation within the NCEP Global Data Assimilation System (GDAS). The purpose of this project is to develop advanced techniques to validate the MEM using satellite data sources and other ancillary data sets such as water vapor profiles and land surface temperature fields.

Accomplishments This Year:

1. Development and application of a 1D variational optimal-estimation algorithm suitable for near real-time atmospheric profiling and surface emissivity retrieval at microwave frequencies. This method was successfully applied to ocean areas (McKague et al., 2003).

2. Analysis of the land surface temperature fields in conjunction with “stand-alone” cross-sensor microwave surface emissivity retrievals (using IR and microwave satellite data sets) for use to derive the microwave land emissivity over complex terrain for validation purposes (Ruston et al., 2003).

3. Incorporation of the 1DVAR algorithm (item 1) into the CIRA Data Processing Error Analysis System (DPEAS) for use and extension over land surfaces and intercomparison with the MEM model output. Testing and validation is continuing (Jones et al., 2003).

Publications This Year:

Jones, A. S., J. M. Forsythe, S. Q. Kidder, T. H. Vonder Haar, 2003: Extension of a 1DVAR passive microwave algorithm for near-real time atmospheric profiles and emissivity over land, *BACIMO 2003,* September 9-11, Monterey, CA, paper 6.04. In preparation.

McKague, D. S., J. M. Forsythe, A. S. Jones, S. Q. Kidder, T. H. Vonder Haar, 2003: A passive microwave optimal-estimation algorithm for near real-time atmospheric profiling, Preprints, *12th Conference on Satellite Meteorology and Oceanography*, February 10-13, Long Beach, CA, Amer. Meteor. Soc., P4.14.

Ruston, B., T. H. Vonder Haar, and A. S. Jones, Microwave land emissivity over complex terrain, *BACIMO 2003,* September 9-11, Monterey, CA, P1.22. In preparation.

DOD CENTER FOR GEOSCIENCES/ATMOSPHERIC RESEARCH

CG/AR has completed its Phase IVb funding period and continues to focus on research associated with the following research themes:

- Hydrometeorology
- Cloud Structure, Dynamics and Climatology
- Data Assimilation and Data Fusion
- Chemistry, Aerosols, and Visibility
- Remote Sensing of the Battlespace

Please note that these are congruent with the following NOAA research themes:

- Global climate dynamics
- Cloud physics
- Local-area weather forecasting
- Application of satellite observations to climate studies
- Regional and local numerical modeling of weather features

These themes are cross-tied and focused, as illustrated in Figure 1. Work in one task can contribute to the progress of another task. For example, field measurements of mid-level clouds can be developed into improved model parameterizations, which affect how satellite radiances are utilized in a forecast model. Here we present highlights ordered by research theme, but the overlap between tasks should be apparent. More extensive detail on the research tasks is available in the quarterly reports, which have been provided to the Cooperative Agreement Manager and are available at http:/www.cira.colostate.edu/GeoSci/overview.htm.

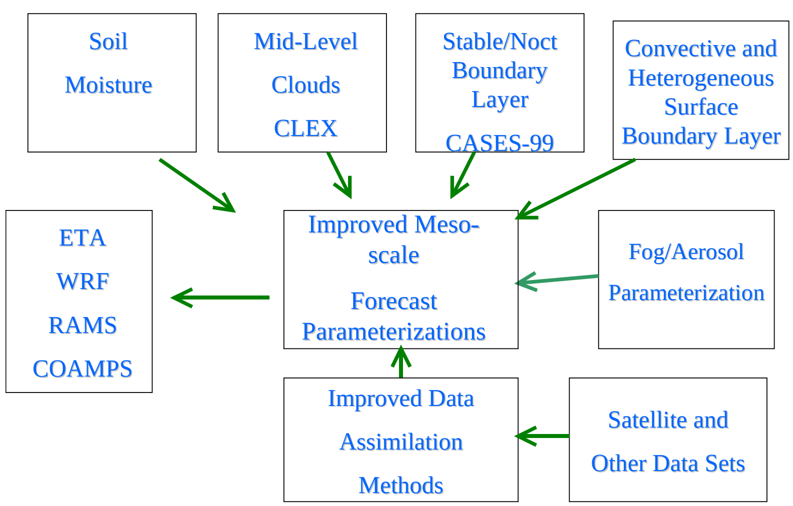


Figure 1. CG/AR research themes are cross-tied and focused

Hydrometeorology

The Hydrometeorology research theme supports DoD interests related to trafficability and infiltration of water and hazardous materials into the land surface. Traditional hydrologic topics of subsurface and overland flow and sediment transport are addressed as well. Remote sensing of surface moisture and its feedback to short-term weather prediction is addressed. This work crosses the boundaries of hydrology and atmospheric science.

The CASC2D model, which carries sediment as well as water, has been tested on several instrumented watersheds (Figure 2). The model has now been run at 30 m resolution for the first time. The lead time for peak discharge prediction was increased by 5 hours in one case. A new mechanistic hillslope hydrology model has made possible studies of the effects of real world variation of surface properties on rainfall-runoff characteristics. An application of use to DoD is to show how ruts left by heavy vehicles will change the water and sediment flow evolution of a hillslope.

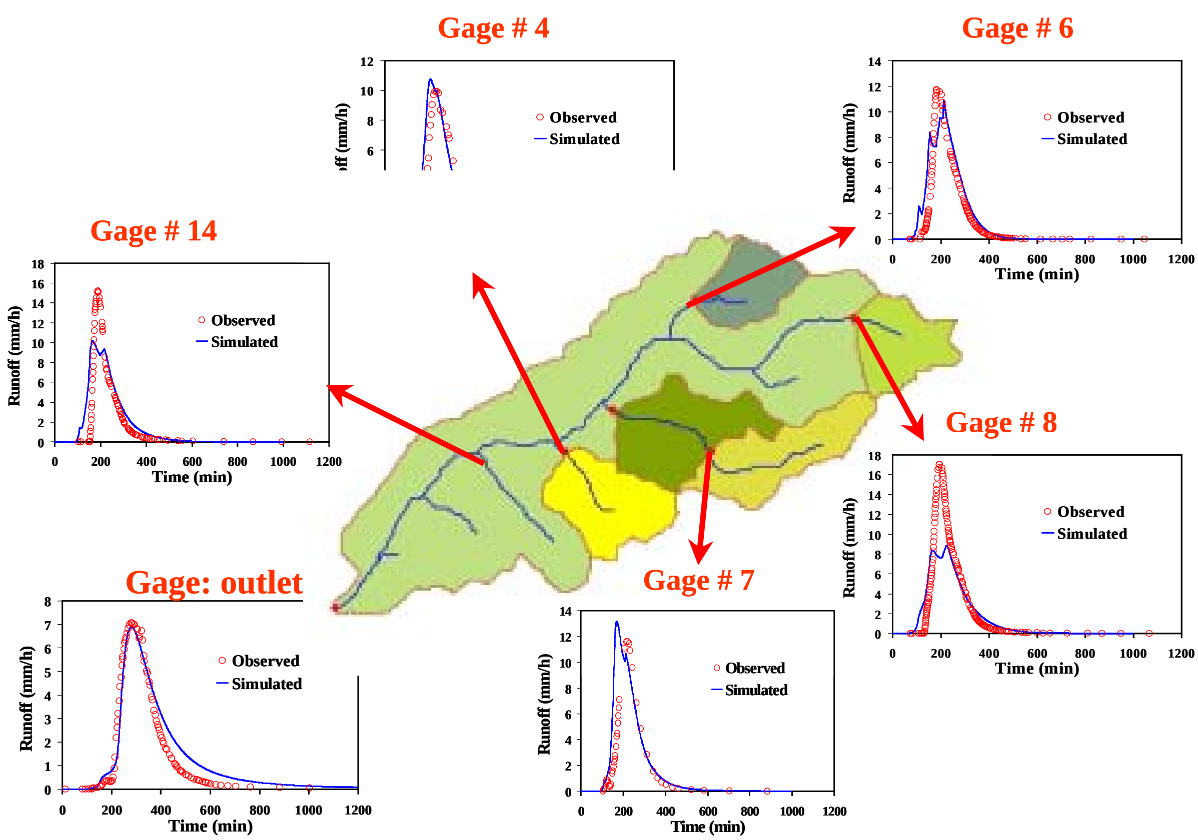


Figure 2. Comparison of CASC-2D hydrographs with measurements.

CG/AR research has begun to bring the power of remotely sensed data into hydrological applications via weather forecast models. This work is closely coupled with the N-Dimensional Data Assimilation research theme. Such models may have a "memory," allowing soil moisture to be routed through the model through time. This approach will provide an avenue to attack the difficult deep (greater than 10 cm) soil moisture problem, which is intractable using only conventional weather satellite measurements and retrievals.

Cloud Structure, Dynamics and Climatology

This task addresses global occurrence of clouds with a special focus on mid-level, mixed-phase clouds. These clouds are important to the DoD because they occur in the critical altitude range of 10 – 20,000 feet, below which aircraft can be vulnerable to ground fire. They impact battlefield surveillance and battle damage assessment efforts as well, so improved forecasts of mid-level clouds will translate into better utilization of reconnaissance resources. The importance of mid-level clouds in operations is expressed by the UAV operator's quote.

A major accomplishment of the Cloud Structure, Dynamics, and Climatology task was the successful completion of several field experiments to gather data on mid-level, mixed-phase clouds. These clouds have been largely ignored by the civilian meteorological community. A series of field experiments called the Cloud Layer Experiment (CLEX) began in 1996 with CG/AR support and continued under this Cooperative Agreement. Major field campaigns occurred in November -December 1999 and October - November 2001. Details of the CLEX campaigns are available at **http://www.cira.colostate.edu/GeoSci/CLEX/clex_main/clex_home.htm**.

We have two principal findings from our analysis of the CLEX data:

1. Mid-level, mixed-phase clouds have a strong tendency to dissipate around sunrise (Figure 3).

2. These clouds have abundant supercooled liquid water, and are "upside down" with respect to current model microphysical parameterizations (i.e., the clouds have more liquid water at cloud top than at cloud base). Figure 4 shows some CLEX *in situ* ice and liquid water measurements.

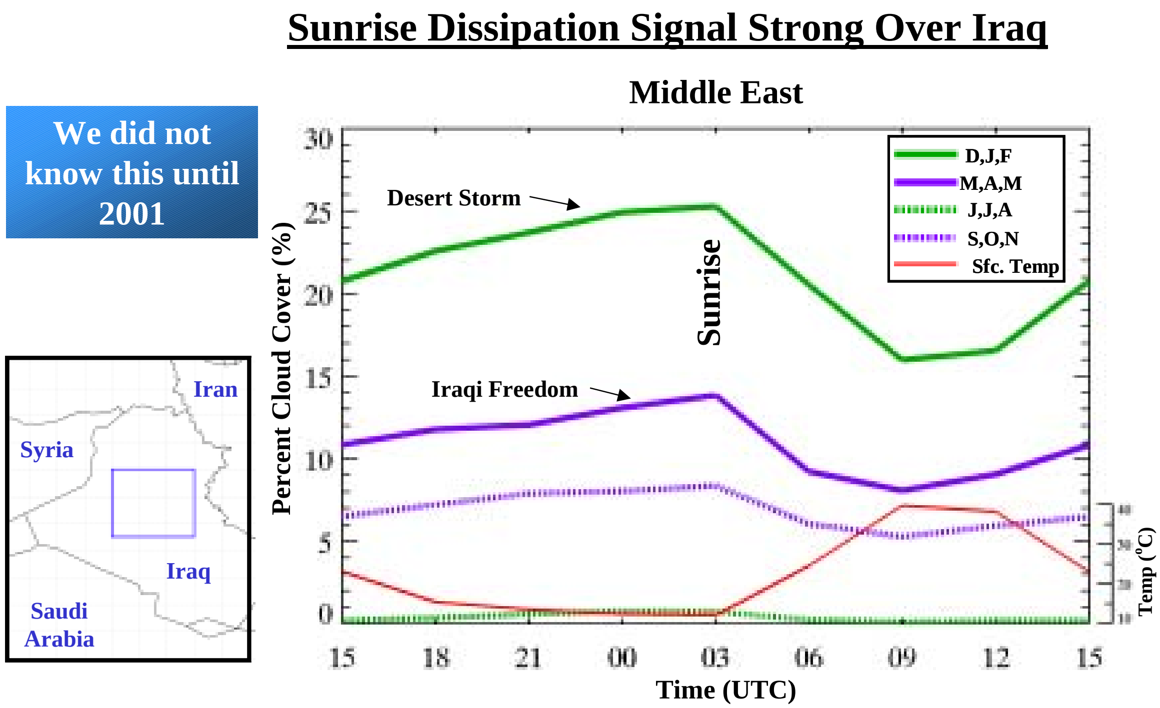


Figure 3. Cloud cover frequency as a function of time of day over a region in Iraq from 20 years of ISCCP data. Note the strong tendency for dissipation near sunrise in the winter and spring.

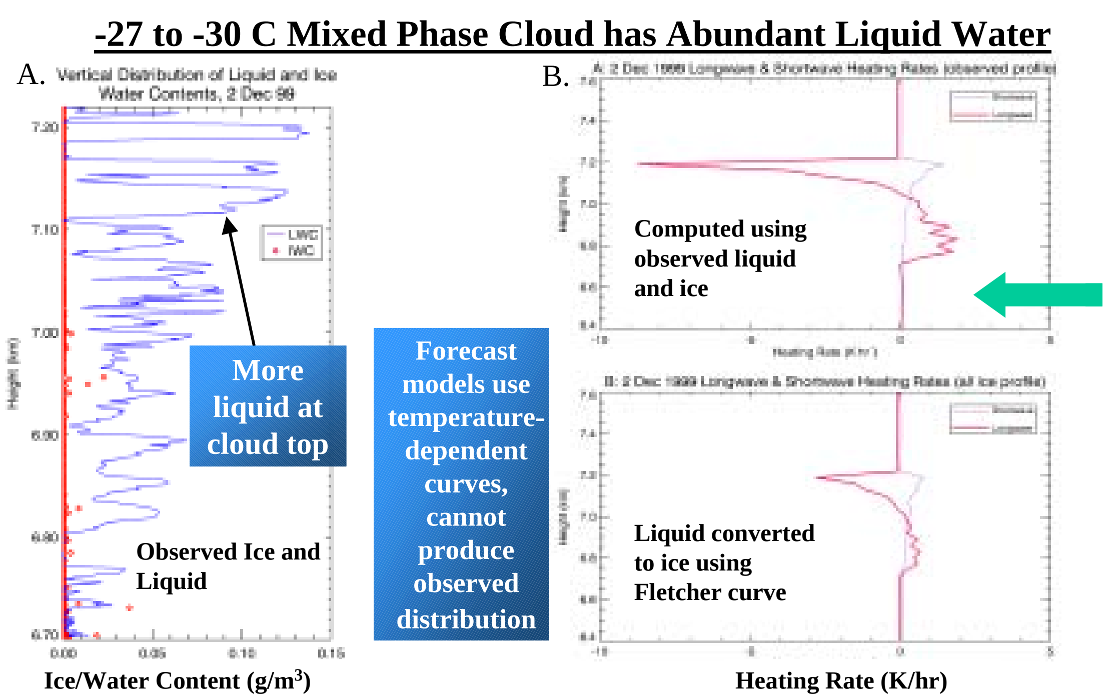


Figure 4. A) Mid-level liquid and ice measurements during CLEX-9. Note the large amount of super cooled liquid water at colder temperatures, in contrast to typical model microphysics. This has a large impact on heating rate calculations (B).

Our knowledge of the global and regional occurrence of clouds was enhanced during this period by the creation of two more years of CHANCES data spanning July 1997 - July 1998 and July 1999 - July 2000. These two years cover El Nino and La Nina conditions, respectively. In quick response to the events of September 11, 2001, CG/AR created some special regional cloud products of DoD interest over the Middle East. An example of cloud occurrence over Afghanistan is shown in Figure 5.

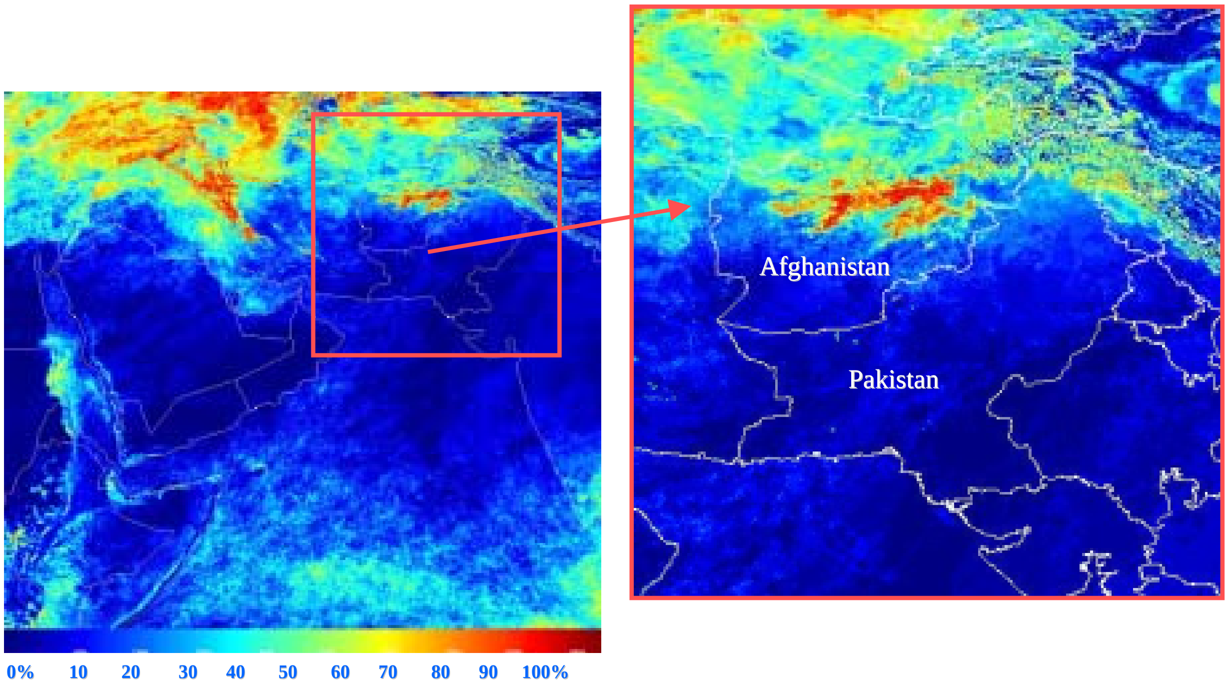


Figure 5. Frequency of Occurrence of Cloud from CHANCES database full-resolution sector at January 2001 0900 UTC (visible only).

A cloud classification scheme with temporal updating was created. A technique to use a cloud classification to spread cloud base measurements into data-denied regions was developed. This work is relevant to interpretation of data from CloudSat, a NASA ESSP mission scheduled for launch in late 2004 (CIRA is the data processing center for CloudSat).

Remote Sensing of Battlespace Parameters

A wide range of DoD-relevant research was conducted under the umbrella of this research theme. Detection of thin cirrus, dynamic properties of the nocturnal stable boundary layer, and satellite microwave retrievals were among the major areas investigated. CG/AR performed research into the stable boundary layer, which is important for modeling dispersion of contaminants and acoustic propagation. A highlight of this work was participation in the Cooperative Atmosphere-Surface Exchange Study 1999 (CASES-99) field experiment in Kansas. CG/AR used a High-Resolution Doppler Lidar (HRDL) to probe the turbulence structure of the nighttime stable boundary layer. Figure 6 shows an example of HRDL measurements which detected a low level jet. CASES collected basic science measurements that can be developed into improved boundary layer parameterizations for forecast models. Additional research with the RAMS model was conducted during the Lake-ICE field experiment in 1998. RAMS did a good job of describing the flow direction, temperature structure and occurrence of clouds.

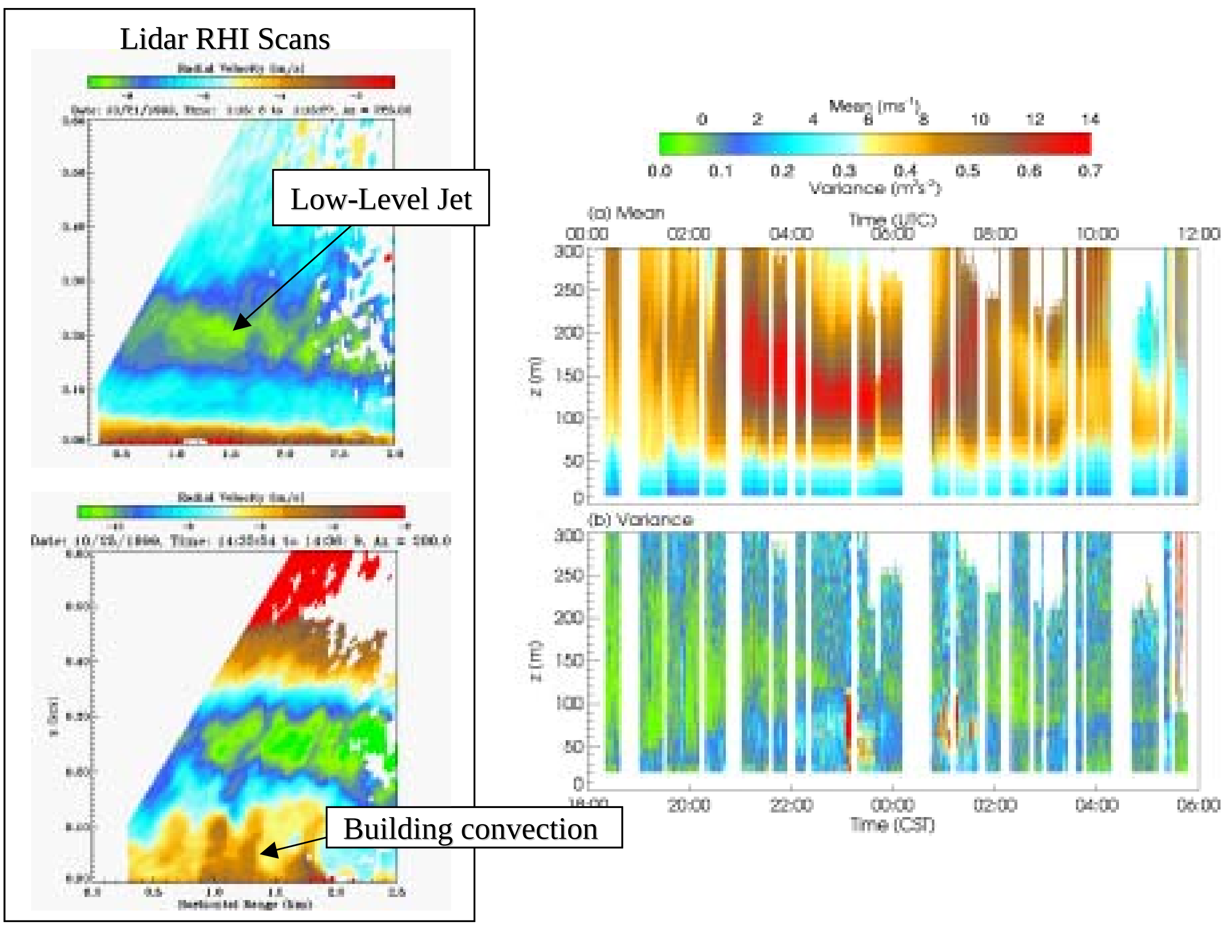


Figure 6. High-resolution Doppler lidar scans taken during CASES-99, showing a low-level jet and developing convection.

A new approach to detecting thin cirrus from geostationary satellite measurements was developed. Thin cirrus are a bane to overhead reconnaissance and missile launch detection. 3.7 □ radiances are used to determine the transmittance of cirrus. This work will benefit DoD in many ways. An example is to allow for a correction due to thin clouds in the scene to remote measurements of the temperature of a ground target.

Two research efforts to realize the potential of satellite microwave observations were initiated. Profiles of temperature, water vapor, and clouds can be obtained from this data over data-denied regions, which are essential inputs for many tactical decision aids. This work has future application to upcoming DoD sensors such as SSMIS on DMSP (launch scheduled late 2003) and instruments aboard NPOESS. Model moisture fields such as from NOGAPS can be compared to the profiling results, allowing forecasters to assess the performance and reliability of the forecast (Figure 7). Additional work on microwave land surface emissivity is underway, allowing extension of the retrievals to land, which has long been a barrier problem in microwave remote sensing.

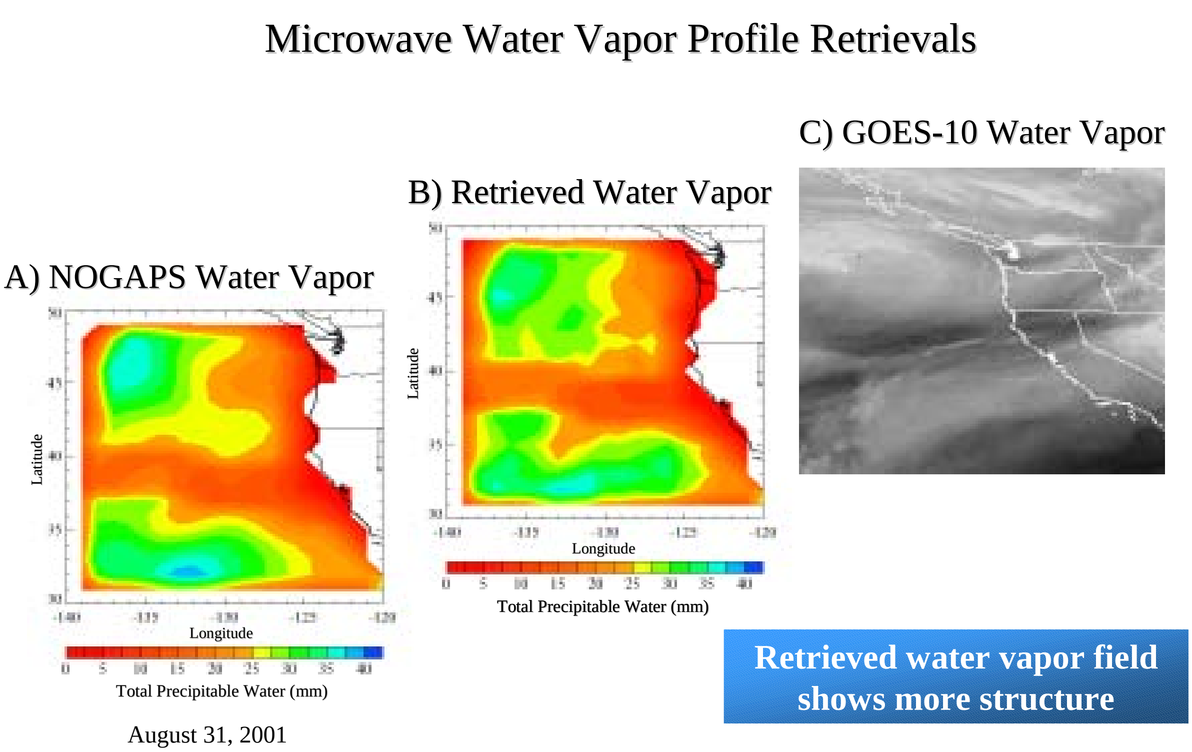


Figure 7. Comparison of NOGAPS and (B) AMSU retrieved total precipitable water off the West coast of the U.S. GOES-10 6.7 micron image shown in (C)

A novel temporal updating technique was developed for cloud classification using a neural network. This insures consistency through time between cloud classifications of images with differing scene properties. An example is the change in solar zenith angle affecting visible data and diurnal changes in land surface temperature which affect infrared classifications. Figure 8 shows an example of the classification using temporal adaptation.

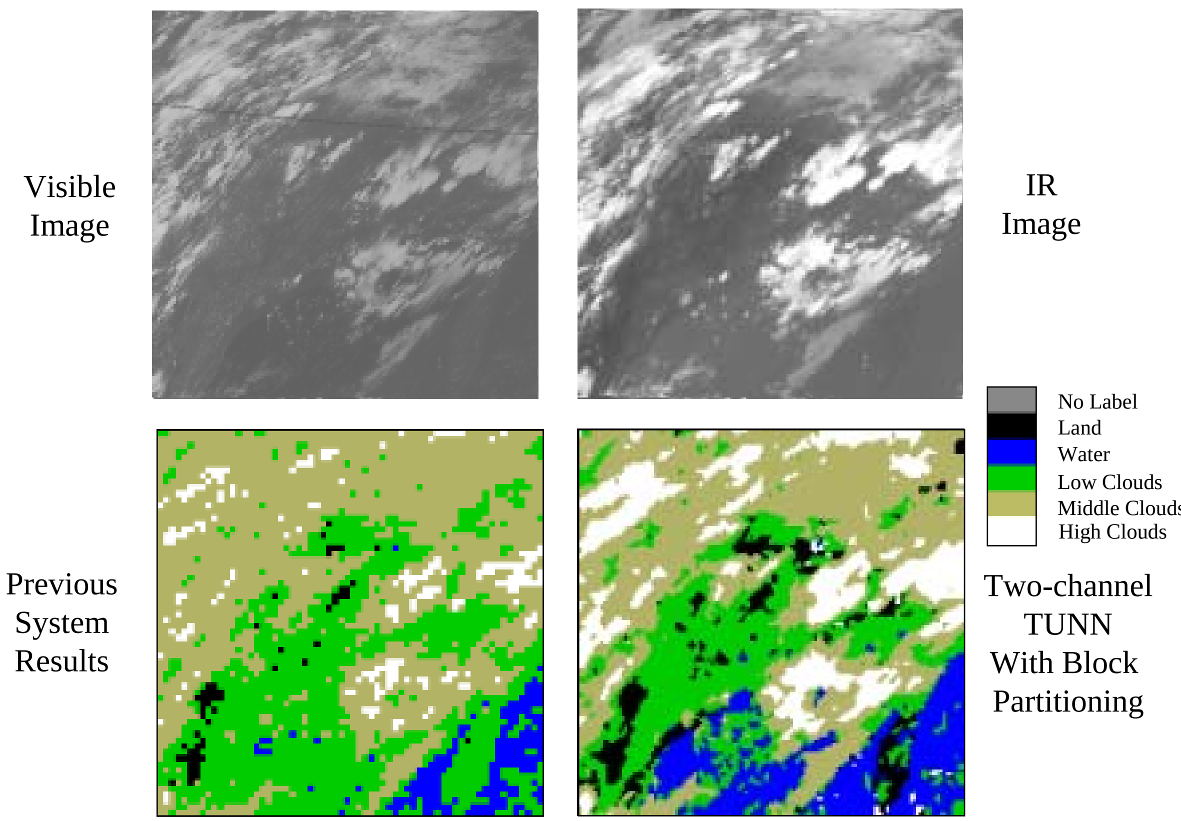


Figure 8. GOES visible (A) and infrared (B) images and their neural net cloud classifications. The method without temporal updating is shown in (C) while (D) uses the temporal updating method developed at CG/AR.

N-Dimensional Data Assimilation and Fusion

This task seeks to exploit the powerful information contained in a variety of remote sensing measurements to improve weather forecasts. This is a cross-cutting task, in that better physics and remote sensing advances from other research themes can be incorporated into the model system. The research at CG/AR focuses on mesoscale data assimilation in a cloudy atmosphere, a challenging problem that has been bypassed by much of the previous work in the field due to its difficulty. Short-term (0-12 hour) cloud forecasts are of critical importance to DoD for surveillance and strike planning.

The 4-dimensional data assimilation system developed at CIRA is called RAMDAS. It uses the CSU-RAMS model as its dynamical core. Mesoscale data assimilation promises to improve cloud forecasts, not to mention the forecast improvement in non-cloud variables such as land surface temperature which are functions of the cloud field. The power of 4DDA lies in the fact that the model uses the input data to produce a dynamically consistent solution in a way which is unavailable to strictly remote sensing approaches. The impact of the satellite data on the forecast is enhanced. For instance, the presence of clouds in satellite imagery will force the model to adjust its moisture and vertical motion fields, which will then feed back into other model state variables such as wind and pressure.

Data assimilation is a modular endeavor which uses a combination of observations, a forecast model, physics and radiative transfer packages, and assimilation methods to solve the problem of interest. Separation of the variables makes the problem tractable. Much of the work is in choosing the "right tool for the job." Figure 9 schematically shows the system challenge of data assimilation.

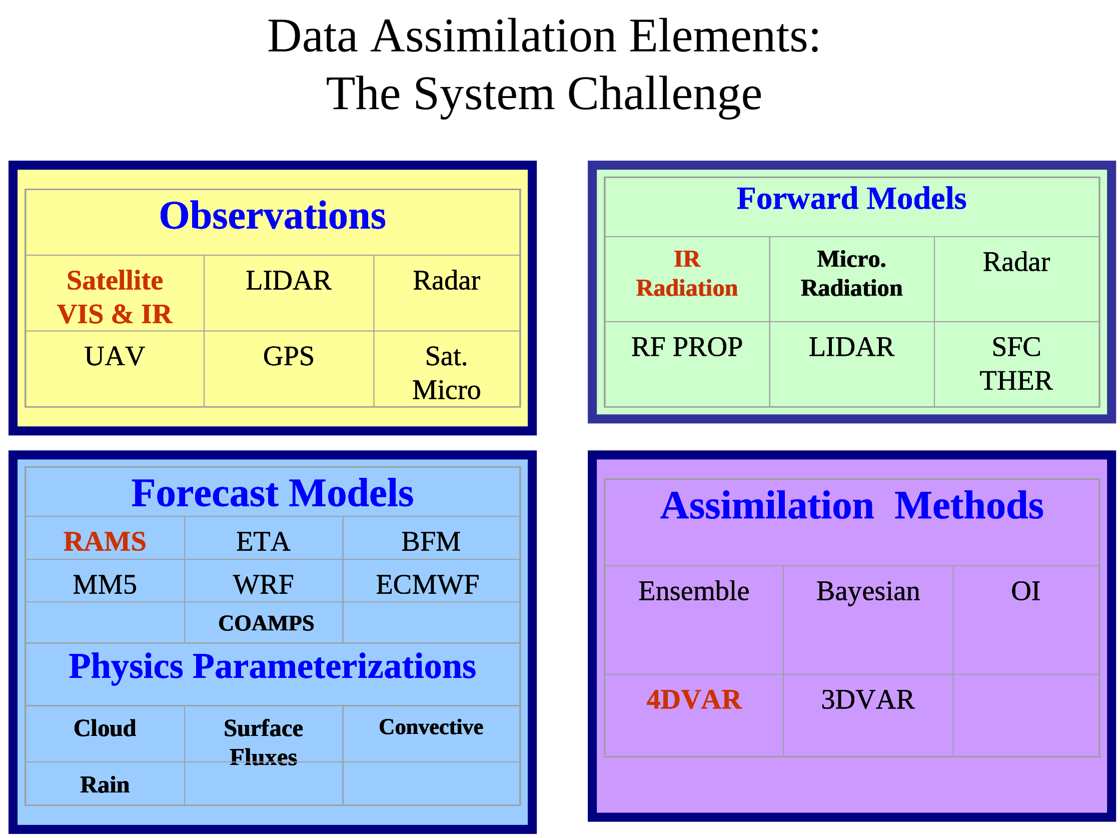


Figure 9. Notional diagram of the system variables to be chosen in data assimilation. Choices must be made among observations, forward models, forecast models, and assimilation methods. A modular approach ensures the particular problem of interest can be investigated.

Developing observational operators and their adjoints is a major part of the effort in the data assimilation task. Many of these were developed during the past few years. An ensemble Kalman filter method was developed to better determine the error covariance matrix, which allows more optimal use of the satellite radiances.

In the first test of the RAMDAS system, GOES infrared and visible data has been successfully assimilated. Figure 10 shows the RAMDAS simulation of the five GOES imager channels for the May 2, 1996 case over Texas.

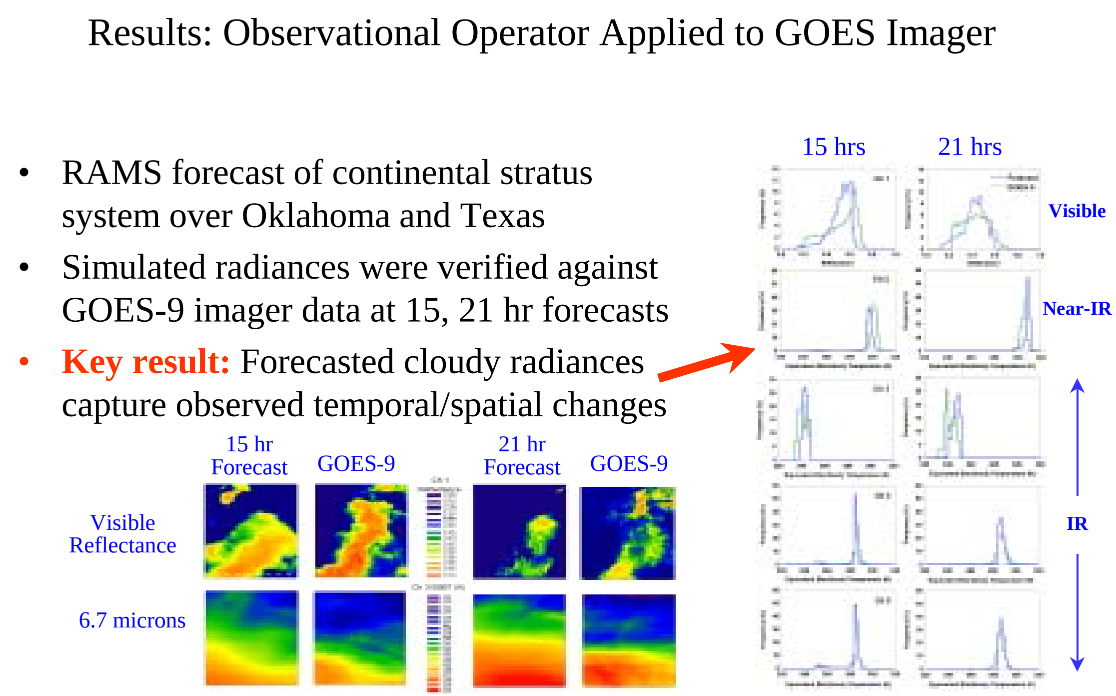


Figure 10. Initial results from assimilation of GOES visible and infrared data look promising.

A Backus-Gilbert filter and new observational operators have been designed. These allow retrieval of land surface characteristics from microwave observations and better assimilation of these characteristics into weather models. Spatial resolution can be traded for noise reduction if necessary, or vice versa. This work has future application to NPOESS, i.e., in dealing with RFI-contaminated scenes and in multi-sensor data fusion.

Chemistry, Aerosols & Visibility

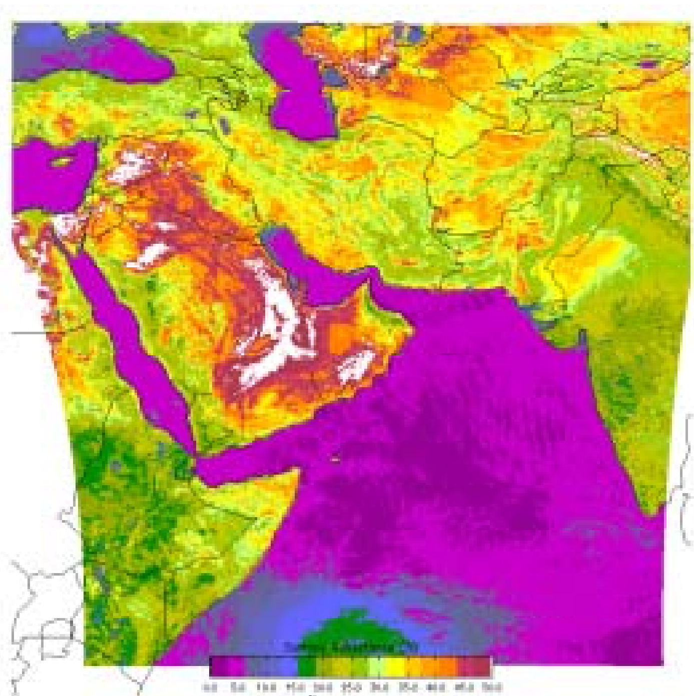
Accurate estimates and forecasts of visibility are vital to tactical decision aids. Measurements and Signals Intelligence (MASINT) results are affected by the intervening aerosol burden. This research theme has investigated satellite remote sensing of aerosol optical depth over land as well as measurements of aerosols from existing ground sites.

The surface reflectance and aerosol detectability was characterized over the Middle East from Meteosat data (Figure 11). This was developed from CG/AR-sponsored research which showed that aerosol optical depth retrievals over land from geostationary satellites were feasible.

Surface Reflectance

Red/white areas correspond with high albedo areas

This map also corrected for solar phase function



Reflectance (%)

Figure 11. Clear-sky surface reflectance over Middle East. This is used as a background for satellite aerosol retrievals.

CG/AR scientists provided an independent review and white paper to ARL of the value of a polarimeter on board the NPOESS platform for aerosol remote sensing.

CLOUDSAT DATA PROCESSING CENTER (DPC)

CloudSat is a satellite experiment designed to measure the vertical structure of clouds from space and, for the first time, will simultaneously observe cloud and precipitation. The primary CloudSat instrument is a 94-GHz, nadir-pointing, Cloud Profiling Radar (CPR). The current launch date for CloudSat is December of 2004 (The launch date has been delayed to accommodate a delay in the CALIPSO program. CALIPSO is CloudSat launch partner).

A unique aspect of this mission is the fact that CloudSat will be flying in formation with other Earth Sciences missions. CloudSat will be part of a constellation of satellites that currently include NASA's EOS Aqua and Aura satellites as well as a NASA-CNES lidar satellite (CALIPSO), and a CNES satellite carrying a polarimeter (PARASOL). A unique feature that CloudSat brings to the constellation is the ability to fly a precise orbit enabling the fields of view of the CloudSat radar to be overlapped with the lidar footprint and the other measurements of the constellation. The precision of this overlap creates a unique multi-satellite observing system for studying the atmospheric processes of the hydrological cycle. Additional information about the CloudSat mission may be found at http://cloudsat.atmos.colostate.edu

CIRA will provide all of the science data processing support for the mission. All of the CloudSat standard data products will be produced at the CloudSat Data Processing Center in the new ATS-CIRA Research Center (completed in June, 2002, and located adjacent to CIRA and the Atmospheric Science Department). CloudSat data will be downlinked to the U.S. Air Force Satellite Control Network and transferred via the RTD&E Support Center (RSC), in Albuquerque, NM, to the CIRA DPC (see figure 1). CIRA is responsible for the implementation of the hardware and software infrastructure that is necessary to produce the nine standard data products. Members of the CloudSat Science Team will develop the science algorithms and software for each of these products (Table 1). Four universities and the NASA Jet Propulsion Lab (JPL) are participants on the CloudSat algorithm development team.

Standard Data Product	Description	Algorithm Dev.
1B-CPR	Level 1b CPR	JPL
2B-GEOPROF	CPR Geometrical Profile	U. Utah
2B-CLDCLASS	Cloud Classification	U. Maryland
2B-TAU	Cloud Optical Depth	CSU/Atmos
2B-LWC	Cloud Liquid Water Content	CSU/Atmos
2B-IWC	Cloud Ice Water Content	U. Utah
2B-FLXHR	Atmospheric Radiative Fluxes and Heating Rates	CSU/Atmos
2B-GEOPROF-LIDAR	CPR Geometrical Profile (CPR + Lidar)	U. Utah
2B-CLDCLASS-LIDAR	Cloud Classification (CPR + Lidar)	U. Alaska

Table 1. CloudSat Standard Data Products and responsible Algorithm Development Group

During the Operational (on-orbit) Phase, the DPC will be staffed by CIRA employees, Science and Technology Corporation personnel (under a sub-contract to CIRA), and part-time CSU students. More information about the DPC can be found at http://cloudsat.cira.colostate.edu

During the past year, CIRA has made significant progress in the development and implementation of the eight subsystems identified in Table 2. The first operational version of the CloudSat Data Processing System will be delivered in October of 2003.

Subsystem Name / Function	Description
Algorithm Interface Management System (AIMS)	A database server that allows algorithm developers to specify both external and internal file and data specifications. It provides a single source for documentation and interface specifications for all Standard Data Products.
CloudSat Operational and Research Environment (CORE)	The system software shell that will manage input into, execution of, and output from each of the standard data product applications. The system will also be used to generate experimental products during the on-orbit phase.
Process Log and Data Status (PLaDS)	A comprehensive database that contains the status of all applications as well as serving as the central database for metadata from individual products.
Data Management System (DataMan)	Components include: Data Transfer (transfer of data between PC systems), Data Storage (tape / CD / DVD write and read), and Database (PLaDS) Query and Update.
Product Display and Quality Control (PDQC)	This system will provide a user interface for the operator to display and manually quality control CloudSat input and output data products.
Data Distribution and Query (DDaQ)	Manages the internet distribution of CloudSat data to CloudSat Science Team and other worldwide requestors of CloudSat Standard Data Products. The primary function of this subsystem is to control the flow of the large volume of CloudSat data products through an internet distribution network.
Operator Control System (OpCon)	Operator interface to the scripts that will control the execution of CORE and other applications, plus an interface into the PLaDS database to monitor the status of the individual applications.
Web Interface (WebI)	External interface to all subsystems

Table 2. CloudSat Data Processing Center Subsystems.

To date, CIRA has received, implemented, and tested, the Algorithm Team software as shown in Table 3. Version 2 (V2) is considered an operational version.

Standard Data Product	Current Version Implemented at DPC
1B-CPR	V2
2B-GEOPROF	V2
2B-CLDCLASS	V2
2B-TAU	V2
2B-LWC	V2
2B-IWC	V2
2B-FLXHR	V2 due 9/1/2003
2B-GEOPROF-LIDAR	V0 due 9/1/2003
2B-CLDCLASS-LIDAR	V0

Table 3. Standard Data Product software implementation status

The following graphic shows the overall flow of data through the CloudSat system when the Data Processing Center system becomes operational.

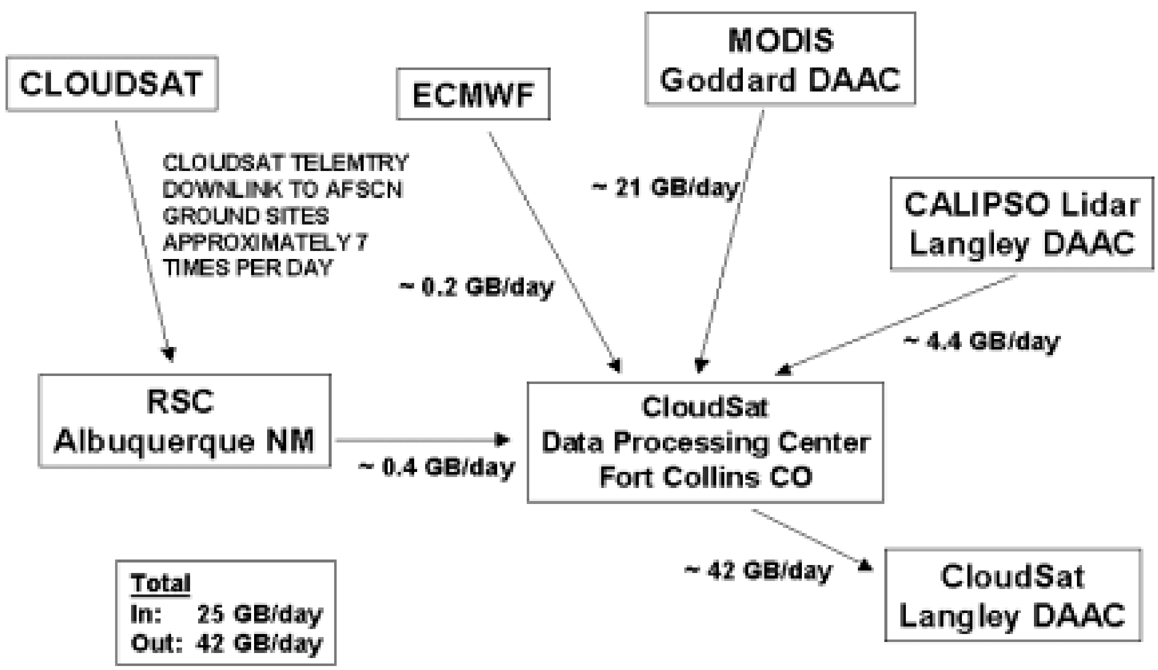


Figure 1. CloudSat System Data Flow and Data Rates

NATIONAL PARK SERVICE (AIR QUALITY DIVISION)
FORT COLLINS

Principal Scientists: W. Malm / B. Schichtel / D. Fox

Introduction & Background

Since the early 1980s CIRA has supported the National Park Service visibility research program directed by Dr. Bill Malm. Through these years, this group has been responsible for formulating and implementing the Clean Air Act mandate to land managers to protect the visual resources of such special federal areas as National Parks and Wilderness, so called class 1 areas. The Clean Air Act, in 1977, set as "…a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Federal class 1 areas which impairment results from manmade air pollution."

Since the Act passed, the EPA has issued regulations to accomplish this goal, first, in 1980 addressing pollution that was "reasonably attributable" to a specific source, and most recently, in April 1999 addressing "regional haze." The regional haze regulations require States to plan to achieve "natural" visibility conditions within the next 60 years.

The NPS/CIRA research group under Malm's leadership has been instrumental in advancing the science and developing the methodologies that have enabled these regulations. Included in past accomplishments is development of the appropriate metrics to use for characterizing visibility, determination of the most appropriate instruments to measure visibility for this application and designing and implementing the national monitoring network for visibility. It is the national monitoring network, the IMPROVE network, that represents the group's most important contribution. IMPROVE is supported by the EPA, federal land managers and States, and implemented through contracts with the University of California, Davis and Air Resources Specialists, Inc. as well as others. This network has developed from its initial form as primarily a research tool to its current existence supporting the EPA and the States in developing and tracking accomplishments under the regional haze regulations. In addition to the IMPROVE network based aerosol research, the group conducts special studies associated with specific National Parks often, attempting to improve the understanding of relative contributions of individual pollution sources to visibility. Recently the group has developed the capability of simulating regional air quality using the REMSAD model.

Current Results from the IMPROVE Network

IMPROVE is a network of 163 sites located to represent the class 1 areas, National Parks and Wilderness identified in the Clean Air Act. It has been expanded over the past year from about 70 sites which are used for the analysis reported in the latest IMPROVE report (Malm, 2000a). The basic measurements at each site are particles that are smaller than 2.5 micrometer in diameter. These particles are collected on Teflon, nylon and quartz filter substrates so that they can be subjected to a variety of chemical analyses that yield data allowing an approximation of the chemical nature of these particles to be determined. This chemical speciation has been essential in establishing the relationship between pollution sources and their final impact on visibility even after hundreds to thousands of kilometers of transport and both photochemical and aqueous phase transformations.

The EPA regional haze regulatory program requires a determination of what levels of visibility impairment are 'natural.' This is difficult to determine because there are a number of natural activities that contribute particles to the atmosphere (forest fires, volcanoes, dust.) However, it is helpful to look at the chemical species that contribute to visibility degradation in order to identify linkage between these concentrations and sources of pollution.

Special Studies Results

Periodically, the group participates in special intensive monitoring studies, such as the current Big Bend Regional Aerosol and Visibility Observational Study (BRAVO) study. Recent work to characterize Grand Canyon visibility is also included here. These studies are designed to more fully characterize atmospheric aerosols and their optical properties, as well as to identify the major contributing sources to a particular class I area's haze. In addition, special research activities are pursued which currently include characterizing species dependent aerosol hygroscopicity; identifying the contribution of smoke to organic and sulfur aerosols; and characterization of coarse particle optical properties. This past year has seen a significant effort to characterize the sources of visibility impairment at Big Bend. This has involved conducting regional air quality simulation modeling using REMSAD, the CAPITA MontiCarlo model and CMAQ, as well as analyzing trajectories. These studies have led to quantified source-receptor relationships.

Website Development

The NPS research group at CIRA initiated development and presentation of research results including the monitoring data and information from the IMPROVE network in two newly developed, state of the science web sites. For more information about the IMPROVE website see: http://vista.cira.colostate.edu/improve/.

For the Western Regional Air Partnership, the group developed a website capable of delivering all of the IMPROVE data as well as a presenting a catalogue of air quality and meteorological data in the western United States. This site was so successful that it was implemented nationally for all of the Regional Plannig Organizations (RPOs). This site, the Visibility Information

Exchange Web Service (VIEWS), can be found at the following: http://vista.cira.colostate.edu/views/.

Future Directions for the Research

There are a number of sources of the organic carbon aerosol measured by IMPROVE. Transportation sources, other sources of volatile organic compounds, VOC's, indeed all combustion of carbon containing fuels are included. Important to the National Parks and Wilderness, however, are vegetation fires. Forest, grassland and agriculture burning, either as wildfire or within a management program, represents a source of carbon particulate that must be better understood.

Effects of Forest Fires on Visibility

We recently (Fox, et. al. 1999) suggested a list of research needs associated with smoke and visibility, largely repeated below:

--The attribution of smoke to PM2.5 and visibility degradation at points that are 100 km or more distant from a fire. While newly developed measurements of "markers" which allow attribution of elemental and organic carbon to wood smoke exist, they need to be tested in realistic field experiments.

--Instrumentation that has the capability to measure the mass of smoke emitted from various kinds of fire should be developed and tested in realistic field experiments.

--Assessing visibility impacts of smoke emission requires knowledge of the optical characteristics of smoke. The ability to accurately measure atmospheric absorption is essential for estimating the visibility effects of smoke. Smoke particle scattering albedos, extinction properties, particle size distributions, and microstructure (internal mixing characteristics) are all important for the accurate modeling of smoke optical properties. Instrumentation to estimate atmospheric absorption to an accuracy of 10% is needed.

--It is necessary to improve the capacity to simulate fire emissions and their effects on ambient aerosol concentrations. New measurement technologies combined with their use in field experiments will collect new data that can improve understanding of generation, transformation and removal processes for fine particulate. However, to determine historical levels of smoke and to evaluate the effectiveness of air quality management programs, these new data will need to be incorporated into the next generation of air quality models.

NOAA/NESDIS RAMM TEAM

RAMM Team research is focused on applications of satellite observations to problems in regional-scale meteorology, including tropical cyclones, severe weather and mesoscale aspects of mid-latitude cyclones. Highlights of RAMM Team activities for the past year are divided into the following four areas.

Tropical Cyclone Research

To improve tropical cyclone diagnostic and forecast algorithms, an archive of storm-centered IR imagery for Atlantic and Eastern North Pacific storms from 1995-2002 is available on CD-ROMs. This data set, which contains more than 60,000 images, is currently being used to improve the Dvorak intensity estimation technique, to develop storm-relative averaging algorithms, to better understand the storm response to environmental vertical wind shear, and to improve intensity forecasting methods. This data set is also revealing new insights into semi-diurnal and shorter period oscillations in tropical cyclone convection. To compliment the IR data, other tropical cyclone datasets are routinely archived including high-density winds, QuikSCAT winds, model analysis fields, aircraft reconnaissance data, and conventional (surface and upper air) observations.

Development has continued on algorithms to determine tropical cyclone wind fields from the Advanced Microwave Sounder Unit (AMSU) on the NOAA polar orbiting satellites. The algorithm is now being run using observations from NOAA-15, -16 and –17. Although the inner core of an intense tropical cyclone cannot be fully resolved, information on the vertical structure of the warm core can be obtained. Using hydrostatic and nonlinear balance constraints, the tropical cyclone wind field can be determined from the AMSU temperature soundings. Real-time analyses of the AMSU data for Atlantic and east Pacific tropical cyclones can be seen at www.cira.colostate.edu/ramm/tropic/amsustrm.asp. Statistical algorithms are also applied to the retrieved fields to estimate the maximum wind, minimum surface pressure and the radii of 34, 50 and 64 kt winds. These estimates from Atlantic and east Pacific tropical cyclones are being sent in real-time to the National Hurricane Center (NHC) in Miami, as part of a project funded by the Joint Hurricane Testbed (JHT) of the U.S. Weather Research Program (USWRP). In addition, this algorithm is being generalized to run in all tropical cyclone basins throughout the world so that it can be transitioned to operational computing systems of the NESDIS Satellite Analysis Branch (SAB) and NHC.

The operational Statistical Hurricane Intensity Prediction Scheme (SHIPS) for the Atlantic and east Pacific tropical cyclone basins is being improved through the incorporation of satellite data. The operational version of SHIPS includes predictors from climatology, persistence, the storm environment (vertical shear, etc) and sea surface temperature. An experimental version of SHIPS that also includes predictors from GOES infrared (Channel 4) imagery, and ocean heat content determined from TOPEX/Poseidon and ERS-2 satellite altimetry data was implemented at the National Hurricane Center during the 2002 hurricane season, and is being tested again during the 2003 season. Results from the 2002 season indicate that the satellite data can improve the intensity forecasts by about 5% in the Atlantic and 8% in the east Pacific tropical cyclone basins. If these results are confirmed during the 2003 hurricane season, these new capabilities will be implemented as part of the NHC operational forecasting process. This work is also a JHT project. A similar intensity forecast model for the west Pacific basin has been developed at CIRA and implemented at the Joint Typhoon Warning Center in Honolulu, and has been updated for the 2003 typhoon season.

The NOAA hurricane research aircraft (two WP-3Ds) do not currently have the capability to display real-time satellite imagery to assist with reconnaissance and research missions due to the limited bandwidth of the aircraft communication systems. In collaboration with the Forecast Systems Laboratory in Boulder, advanced data compression techniques are being developed to make GOES visible and infrared imagery available on the P-3 aircraft during hurricane flights. A limited version of this capability was tested during one flight into Tropical Storm Hanna during the 2002 hurricane season. A more advanced version of the data compression/decompression software will be installed on both aircraft, and a thorough test will be performed during the 2003 season.

Severe Weather Research

Methods are being developed to couple “forward” radiative transfer models with the Colorado State University (CSU) Regional Atmospheric Modeling System (RAMS) to create simulated data sets for current and future satellite product development. The visible, infrared and microwave frequencies are being considered. This system provides simulated satellite observations where all of the atmospheric properties are known from the model. A current application of this system is to develop improvements to the operational hydro-estimator algorithm for predicting convective rainfall rates from GOES Channel 4 imagery. The model is being used to determine factors that affect the simulated rainfall rate and the corresponding imagery. The coupled numerical/radiative transfer modeling capabilities are also being used for advanced tropical cyclone and severe storm product development for the next generation NOAA polar (NPOESS) and geostationary (GOES-R) satellites.

Research was conducted to better understand the “storm-splitting” process. A case study was performed for 25 May 1999 where both the left- and right-moving storms in northern Texas were long-lived and produced severe weather. Normally, following the split of a convective storm, the right-moving component tends to last longer and become more severe. Based upon an analysis of satellite, radar, and conventional observations, it was discovered that the dynamical factors that normally contribute to the decay of the left-moving storm in an environment with typical types of vertical wind shear can be counteracted by interaction with low-level outflow boundaries. This study provides useful guidance to operational forecasters, where the low-level outflows can be identified using satellite observations, and can help identify both left- and right-moving storms that have the potential to produce severe weather. A publication describing this project is nearing completion, in collaboration with the Lubbock, Texas NWS forecast office.

GOES Product Development and Technology Transfer

In a recently completed project, RAMM Team participated in the Hurricane Mitch reconstruction effort in Central America. Arrangements were made to have a GOES satellite ingest system installed in Costa Rica by a private contractor. This data is being accessed by RAMSDIS workstations installed in Costa Rica and six additional countries in Central America. This project has improved the utilization of GOES satellite data and products at the National Weather Service offices in Central America. In the past fiscal year, RAMM Team again worked with all of the countries involved in this project to help them convert their systems when GOES-8 was replaced by GOES-12 in April of 2003.

As described above, GOES-8 was recently replaced by GOES-12 as the operational “east” geostationary satellite. One of the major impacts of this change was the replacement of the channel 5 imager band (12.0 μm) with the channel 6 imager band (13.3 μm). RAMM Team interacted with the NESDIS SAB to assist with the development of new products for fire, smoke and volcanic ash detection, which were affected by this change. Data from a GOES-12 science test during 2001, and simulated GOES-12 imagery from MODIS were used to investigate the effect of this channel change, well before GOES-12 was made operational.

Work continued on developing GOES cloud climatologies to gain insight into the effect of local geographic features on cloud frequency and evolution. Monthly climatologies of GOES-east and –west data have been created, and can be stratified by the low-level wind regime to better understand the influence of synoptic forcing. Collaborative research continues with the NWS forecast offices in Tallahassee, FL, Wakefield, VA and Cheyenne, WY. The emphasis of the studies with Tallahassee and Wakefield is on convective initiation, and the study with Cheyenne is focused on using satellite imagery to help identify high wind events.

Training

The Virtual Institute for Satellite Integration Training (VISIT) program is designed to accelerate the transfer of research results based on atmospheric remote sensing data into National Weather Service operations using distance education techniques. During the past year, RAMM Team contributed to the creation of ten new training sessions, which have been completed or are under development.

Since 1999, more than 600 sessions have been offered to over 11,000 participants.

RAMM Team contributed to a project to improve the worldwide use of satellite data through the establishment of an "International Virtual Laboratory". The purpose of the virtual laboratory is to foster the exchange of satellite data and training material via the Internet. A network of web pages was established at EUMETSAT in Darmstadt, Germany, the Bureau of Meteorology in Melbourne, Australia, and at CIRA. The CIRA page can be seen at http://www.cira.colostate.edu/ramm/wmovl/main.html.

FELLOWSHIP PROGRAM

CIRA accepts applications each year for its Fellowship Postdoctoral Program. This program is designed to support one, two or more scientists wishing to do research at the Institute. The program is designed to be attractive to both senior scientists on leave from their permanent positions and recent Ph.D. recipients. The Fellowship announcement is disseminated both nationally and internationally to over 600 hundred academic, government and private institutions and is also available on the Internet under the CIRA Web Page.

The following are the CIRA Senior and Postdoctoral Fellows with a short description of their research at CIRA:

Barbara Ervens
Barbara received her Ph.D. in Chemistry from University Leipzig, Germany. Her work involves the development and application of heterogeneous and multiphase chemistry models in support of NOAA's Intercontinental Transport and Chemical Transformation of Anthropogenic Pollution (ITCT) field experiment.

Zhengzhao Luo (Johnny)
Johnny received his Ph.D. in Atmospheric Science from Columbia University. His work centers on the developing a Mesoscale model by constructing a new cloud-cover parameterization and implementing it into the model. He will also test the parameterization using satellite data.

CIRA/ORA Collaborations

CIRA and the NOAA/NESDIS Office of Research and Applications (ORA) have established a Working Agreement setting forth the provision for as many as 10-15 research scientists to be appointed through CIRA as Postdoctoral Fellows, with those positions being located at ORA in Camp Springs, Maryland. The appointments are supported by NOAA/NESDIS via (a) ORA central funding or (b) ORA science projects.

The Postdoctoral appointments are generally for recent graduates, although some senior scientists may be appointed for a term. The appointments also carry the title of CIRA Associate Fellow as an honor of scientific distinction. Fellows are to be actively involved in CIRA/ORA related research. Initial appointments are for one calendar year, renewable by mutual agreement.

Professional interactions are fostered among the CIRA/ORA post docs and resident scientists in both groups by scientific collaborations, working visits, workshops and seminars, sharing of facilities, software and data sets, and by other means.

Our appointments under this collaborative agreement are as follows:

Jimmy O. Adegoke

Ph.D. 2000	The Pennsylvania State University, University Park
Specialty Area:	Remote Sensing of Land Surface Properties and Processes
ORA Mentor:	Dr. Kevin Gallo

Aleksandr M. Ignatov

Ph.D. 1989	Marine Hydrophysics Institute, Sevastopol, USSR
Specialty Area:	Remote Sensing of Aerosol Parameters from Satellite (NOAA/AVHRR and TRMM/VIRS)
ORA Mentor:	Dr. Larry L. Stowe

Kinkade, Christopher

Ph.D. 2000	Columbia University, New York
Specialty Area:	Validating bio-optical products derived from visible region remote sensors and assessing the uncertainties with regard to the atmospheric correction procedures. Also performing analysis of pigment concentration variability with regard to atmospheric and tidal forcing.
ORA Mentor:	Dr. Dennis Clark

Kenneth R. Knapp

Ph.D. 2000	Atmospheric Science, Colorado State University, Fort Collins
Specialty Area:	Aerosol Remote Sensing Algorithms
ORA Mentor:	Dr. Larry L. Stowe

Liu, Quanhua

Ph.D. 1991	University of Kiel, Germany
Specialty Area:	Microwave Remote Sensing of Atmospheric and Surface Parameters and Their Applications in Numerical Weather Prediction Models
ORA Mentor:	Dr. Fuzhong Weng

Rama Varma Raja Mundakkara Kouilakom

Ph.D. 1999	Indian Institute of Tropical Meteorology, Pune, India
Specialty Area:	Doppler Wind Lidar
ORA Mentor:	Dr. James Yoe

Nicholas Nalli

Ph.D. 1999 University of Wisconsin, Madison
Specialty Area: Infrared Remote Sensing of Ocean Temperature
ORA Mentor: Dr. Larry L. Stowe

Peter Romanov

Ph.D. 1990 Central Aerological Observatory, Moscow, Russia
Specialty Area: Land Remote Sensing from Operational Environmental Satellites
ORA Mentor: Dr. Dan Tarpley

Skirving, William

Ph.D. James Cook University, Australia
Specialty Area: Development of tools and the use of those tools to study the various environmental stresses that cause corals to bleach. The main tools for this work are algorithms that are used to derive environmental variables from satellite data.
ORA Mentor: Dr. Alan Strong

Xuepeng Zhao

Ph.D. 1995 University of California, Los Angeles
Specialty Area: Radiation Transfer Calculations and Remote Sensing of Aerosol Particles Over Ocean and Land Surface
ORA Mentor: Dr. Larry L. Stowe

SEMINARS, MEETINGS, WORKSHOPS, COURSES

DATE	PRESENTER(S)	TITLE
July 1, 2002 - June 30, 2003	D. Bikos, D. Lindsey, J. Weaver, R. Zehr	3446 students participated in 183 VISIT teletraining sessions delivered to NWS offices, et al
July 9, 2002	M. DeMaria	Forty Years of Progress in Atlantic Hurricane Forecasting: 1962-2002
July 16, 2002	S. Gravel (RPN, Canada)	The Relative Contribution of Forcing Components and Data Sources to the Large-Scale Forecast Accuracy of an Operational Model
July 24, 2002	N. Nichols (Met Office, UK)	Assimilation of Data Into an Ocean Model with Systematic Errors Near The Equator
August 8, 12-16, 2002	D. Lindsey	Lightning Meteorology II: An Advanced Course on Forecasting With Lightning Data
August 14-16, 2002	M. DeMaria, J. Knaff, D. Hillger	RAMM Team Research Plans, Pingree Retreat
August 23, 2002	T. Dunkerton (Northwest Research Associates)	Monsoon and Hurricane Regimes in Angular Momentum-Conserving Circulations
September 5, 2002	R. Pielke	Climate as an Integrated Earth System Research Issue - Challenges and Opportunities
September 12, 2002	B. Mapes (NOAA/CIRES)	Strides, Steps and Stumbles in the Annual March
September 19, 2002	S. Matrosov (NOAA/ETL)	Quantitative Measurements of Rain With X-Band Radars

DATE	PRESENTER(S)	TITLE
September 26, 2002	B. Randel (NCAR)	Variability of the Tropical Tropopause Region
September 27, 2002	M. McIntyre (Cambridge University, UK)	Local Mass Conservation and Velocity Splitting in PV-Conserving Balanced Models
October 3, 2002	D. Stevens (Lawrence Livermore Laboratory)	An Analysis of Some Very Computationally Intensive Simulations: Effects of Domain Size and Numerical Resolution on the Simulation of Shallow Cumulus Clouds
October 7, 2002	E. Zipser (Univ. of Utah)	Global Distribution of Intense Convection
October 10, 2002	M. Zupanski	Challenge of Mesoscale Data Assimilation: Four-Dimensional Variational Data Assimilation and Beyond
October 15, 2002	P. Rayner (CSIRO Atmospheric Research, Australia)	Inferring Carbon Sources Using Passive NIR Satellite Measurements
October 17, 2002	J. Hurrell (NCAR)	On the Limitations of Prescribing Sea Surface Temperatures in Atmospheric General Circulation Model Experiments
October 17, 2002	J. Knaff	Current and Future Tropical Cyclone Projects at CIRA/NESDIS: An Update and Outlook
October 23, 2002	M. DeMaria, J. Knaff, D. Bikos, D. Lindsey, J. Demuth, J. Weaver	Overview of RAMM Team Research and Training to the U.S. Air Force Academy Senior Cadets
October 24, 2002	N. Doesken	The Drought of 2002 in Colorado
October 28, 2002	H. Barker (Meteorological Service of Canada)	Purification of Radiative Transfer Calculations in GCMs

DATE	PRESENTER(S)	TITLE
October 31, 2002	P. Arkin (Univ. of Maryland)	Analyses of Large-Scale Precipitation: Methods and Applications
November 5, 2002	C. Combs, M. DeMaria	Overview of RAMM Team Research and Cloud Climatologies Produced at CIRA
November 7, 2002	S. Mikaloff (NOAA)	Constraining Methane Flux Estimates Using Atmospheric Observations of Methane and 13C/12C in Methane
November 13, 2002	L. Polvani (Columbia Univ.)	An "Exact" Solution of the Primitive Equations for Testing the Dynamical Cores of Atmospheric GCMs
November 13, 2002	M. DeMaria	Tropical Cyclones
November 14, 2002	B. Connell	Use of Operational Satellite Data in Central America to Support Disaster Management
November 21, 2002	RAMM Team Staff	Project Overviews presented to Fran Holt, Director of NESDIS/ORA/CoRP
November 22, 2002	L. Cucurull (National Center for Atmospheric Research)	The Use of the Global Positioning System in Numerical Weather Prediction Models
November 29 - December 13, 2002	J. Knaff	AMSU-Based Tropical Cyclone Intensity and Structure Estimates From CIRA/NESDIS
January 10, 2003	J. Weaver	VISIT Satellite Training for NWS Forecasters, Part I - Distant Learning Operations Course (DLOC)
January 14, 2003	H. Dijkstra (Utrecht Univ.)	Stability of the Global Ocean Circulation

DATE	PRESENTER(S)	TITLE
January 31, 2003	J. Weaver	VISIT Satellite Training for NWS Forecasters, Part II - Distant Learning Operations Course (DLOC)
February 6, 2003	R. Meroney (Civil Engr.)	Fire Whirls, Fire Tornadoes and Fire Storms: History, Physics, Fluid Modeling and CFD
February 7, 2003	J. Weaver	VISIT Satellite Training for NWS Forecasters, Part III - Distant Learning Operations Course (DLOC)
February 9-13, 2003	M. DeMaria	50 Years of Progress in Operational Forecasting of Atlantic Tropical Cyclones
February 9-13, 2003	M. DeMaria, J. Knaff	Improvements in Real-Time Statistical Tropical Cyclone Intensity Forecasts Using Satellite Data
February 9-13, 2003	D. Hillger	A Simple GOES Skim Temperature Product
February 9-13, 2003	C. Combs. M. DeMaria	Examining High Wind Events Using Satellite Cloud Cover Composites Over the Cheyenne, WY Region
February 9-13, 2003	J. Knaff, R. Zehr, M. DeMaria	A Demonstration of Real-Time Transmission and Display of GOES Imagery Aboard the NOAA P-3 Aircraft During the 2002 Hurricane Season
February 9-13, 2003	D. Lindsey, J. Weaver, M. DeMaria	VISITview - Connecting Instructors With Operational Forecasters
February 18, 2003	Y. Rudich (Weizmann Inst. Of Science, Israel)	The Multifaceted Role of Dust in Affecting Cloud Properties and Rain Formation
February 20, 2003	M. Nicholls	Why Should You Care About Compression Waves?

DATE	PRESENTER(S)	TITLE
February 26, 2003	T. Hamil (NOAA-CIRES)	Generating Initial Conditions for Ensemble Forecasts with Analysis-Error Covariance Singular Vectors
February 26, 2003	D. Hillger	Volunteer Role as Webmaster for the USMA Website Hosted by CSU
February 27, 2003	G. Browning (NOAA/FSL/CIRA)	The Bounded Derivative Theory: Recent Discoveries and Developments in the Geosciences
February 28, 2003	J. Weaver	VISIT Satellite Training for NWS Forecasters, Part IV, Distance Learning Operations Course (DLOC)
March 4, 2003	J. Weaver	Missionary Ridge Fire-Spawned Tornadoes
March 6, 2003	S. Denning	Carbon-Climate Interaction as a First-Order Source of Uncertainty in Future Climate
March 10-15, 2003	M. DeMaria	A Monte Carlo Method for Estimating Surface Wind Speed Probabilities
March 10-15, 2003	R. Zehr, M. DeMaria, J. Knaff, K. Bessho	Tropical Cyclone Surface Wind Analysis Using Satellite Data - Dvorak, Microwave, Scatterometer and Cloud Motion Winds
March 10-15, 2003	M. DeMaria, J. Demuth, J. Knaff	Recently Developed Operational and Experimental Tropical Cyclone Intensity and Structure Guidance for the Western North Pacific
March 18, 2003	N. Wang, R. Brummer (CIRA/NOAA)	Wavelet Transform-Based Data Compression and Its Application to Multi-Dimensional Gridded Data Sets

DATE	PRESENTER(S)	TITLE
March 20, 2003	D. Vimont (Univ. of WA)	Is the El Nino/Southern Oscillation Initiated by the Mid-latitude Atmosphere?
March 27, 2003	B. Collins (NCAR)	Atmospheric Response to Natural and Anthropogenic Aerosols
April 3, 2003	M. Zupanski	What is Probabilistic Data Assimilation, and Why Do We Care?
April 8, 2003	N. Wang, R. Brummer (CIRA/NOAA)	Wavelet Transform-Based Data Compression and Its Application to Multi-Dimensional Gridded Data Sets
April 8, 2003	M. DeMaria	Use of Satellite Observations in Tropical Cyclone Forecasting
April 9, 2003	J. Weaver, D. Bikos	Mesoanalysis Using GOES SO Imagery - VISIT Session
April 10, 2003	M. Alexander (NOAA)	The Atmospheric Response to Arctic Sea and Ice Anomalies
April 17, 2003	S. Rafkin (SRI, Boulder)	Mesoscale Modeling of Mars' Atmosphere
April 17, 2003	B. Connell	GOES and the Characteristics of its Channels
April 21, 2003	K. Troy (Australian Bureau of Meteorology, Melbourne)	The Influence of Sheer on Tropical Cyclone Genesis in the Australian Bureau of Meteorology's Limited Area Predication System (LAPS)
April 22, 2003	M. DeMaria	Estimating Tropical Cyclone Wind Probabilities
April 24, 2003	T. Lang	Understanding the Spatial and Temporal Variability of Precipitation in the Central Himalayas

DATE	PRESENTER(S)	TITLE
April 29, 2003	P. Sellers (NASA)	STS-112, Building the International Space Station: A Global Perspective
May 8, 2003	C. Deser (NCAR/CGD)	Decadal Climate Variability Over the Pacific: What the Instrumental Records Tell Us
May 19-21, 2003	M. DeMaria	Tropical Cyclone Applications of Hyperspectral Data
May 30, 2003	J. Kossin (Univ. of WI - Madison)	Recent Advances in Tropical Cyclone Intensity Estimation Using GOES-IR Imagery
June 17, 2003	G. Gayno (USAF AFWA)	An Overview of AFWA and the USAF AGRMET Land Surface Modeling System
June 27, 2003	P. Rayner (CSIRO)	Carbon Cycle Data Assimilation

NOTE:
CIRA also conducted various tours for corporations and local public and private schools. Some seminars were jointly sponsored with the CSU Department of Atmospheric Science.

PAPERS AND REPORTS
FOR PROJECTS ACTIVE

JULY 1, 2002 - JUNE 30, 2003

(Typical overview of CIRA's Peer-Reviewed and Non Peer-Reviewed Publications is shown in the table on the following page)

	Calendar Year		
Publications	2003	2002	2001
Peer-Reviewed			
NOAA Research Lead Authors	21	20	18
Other Lead Authors	78	77	53
Total	99	97	71
Non Peer-Reviewed			
NOAA Research Lead Authors	32	73	51
Other Lead Authors	44	108	46
Total	76	181	97
Citations			
NOAA Research Lead Authors	~~~~~~~~~~~not tracked~~~~~~~~~~~		
Other Lead Authors	~~~~~~~~~~~not tracked~~~~~~~~~~~		
Total Publications 2001-2003	175	278	168

ADVANCED ENVIRONMENTAL SATELLITE RESEARCH SUPPORT

Principal Investigators: T. Vonder Haar/J. Purdom

Sponsor: NOAA

Abstract - As a link among CIRA, NOAA/NESDIS, and the general population of satellite data users, this position will work toward the goal of advancing more comprehensive use of satellite data by all users. The aim is to highlight the value of satellite data for environmental applications. Several areas of attention have been identified for the position and are described below.

Liaise with such international groups as the Committee on Earth Observation Satellites, Coordination Group for Meteorological Satellites, and World Meteorological Organization, to educate them on the relevance of satellites as part of an Integrated Global Observing System (IGOS).

Carry out studies to promote the role of satellites within an IGOS context and accordingly prepare papers and present scholarly lectures that pertain to this subject matter.

Spearhead efforts to expand the uses of environmental satellite data through training programs and lectures in national and international arenas.

Connell, B. H., M. DeMaria, J. Sessing, V. Leon, and J. F. W. Purdom. 2002. Reconstruction efforts for meteorological offices in Central America in the wake of Hurricane Mitch. *AMS 29th International Symposium on Remote Sensing of the Environment*, TS-28.1.

Connell, B. H., K. Gould, and J. F. W Purdom. 2001. High resolution GOES-8 visible and infrared cloud frequency composites over northern Florida during the summers 1996-1999. *Weather and Forecasting* 16, no. 6: 713-24.

Levizzani, V., P. Bauer, D. H. Hinsman, A. Khain, C. Kidd, F. S. Marzano, F. Meneguzzo, A. Mugnai, J. P. Poiares-Baptista, F. Prodi, J. F. W. Purdom, D. Rosenfeld, J. Schmetz, E. A. Smith, F. Tampieri, F. J. Turk, and G. A. Vicente. 2001. EURAINSAT: European satellite rainfall analysis and monitoring at the geostationary scale. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 650-654.

Purdom, J. F. W. 2002. Environmental satellite remote sensing in the 21st century. *AMS 29th International Symposium on Remote Sensing of the Environment*, TS-13.5.

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1.2.

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Purdom, J. F. W., and A. Mostek. 2001. Virtual laboratory for satellite training in meteorology. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 324-27.

Uccellini, L., F. Einaudi, J. F. W. Purdom, D. Rogers, R. Gelaro, J. Dodge, R. Atlas, and S. Lord. 2001. Weather prediction improvement using advanced satellite technology. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 216-19.

AIR-SEA INTERACTION REMOTE SENSING PROCESSES

Principal Investigators: T. Vonder Haar/S. Frisch

Sponsors: NOAA/ETL

Abstract - Development of cloud radar-radiometer techniques for the measurement of stratus cloud microphysical quantities continued. Analysis of data sets from field experiments has begun to compare simultaneous radar-radiometer measurements of stratus cloud properties with aircraft observations.

Albrecht, B. A., C. Bretherton, R. H. Johnson, W. H. Schubert, and A. S. Frisch. 1995. The Atlantic Stratocumulus Transition Experiment-ASTEX. *Bull. Amer. Meteor. Soc.* 76: 889-904.

Banta, R. M., B. Grund C. J. Orr, D. H. Levinson, A. S. Frisch, and S. D. Mayer. 1997. Estimation of TKE and momentum flux profiles from Doppler lidar scans during LIFT. *AMS 12th Symposium on Boundary Layer and Turbulence Symposium*.

Branson, M D., and D. A. Randall. 1995. A new boundary layer cloud parameterization. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Cotton, W. R., S. M. Kreidenweis, P. Q. Olsson, J. Y. Harrington, M. J. Wiessbluth, and G. Feingold. 1995. Challenges to modeling arctic stratus clouds. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Eberhard, W. L., S. Y. Matrosov, A. S. Frisch, and J. M. Intriere. 1997. Microphysical retrievals from simultaneous radar and optical or microwave measurements. *WMO Workshop on Measurements of Cloud Properties for Climate Studies*.

Feingold, G., A. S. Frisch, B. Stevens, and W. R. Cotton. 1997. Drizzling stratocumulus as viewed by radar, radiometer and lidar. *12th Symposium on Boundary Layers and Turbulence* .

———. 1999. On the relationship among cloud turbulence, droplet formation, and drizzle as viewed by Doppler radar, microwave radiometer and lidar. *J. Geophys. Res.* 104: 22195-203.

Feingold, G., B. Stevens, W. R. Cotton, and A. S. Frisch. 1996. On the relationship between drop in-cloud resistance time and drizzle production in numerically simulated stratocumulus clouds. *J. Atmos. Sci.* 53: 1108-22.

Fowler, L. D., and D. A. Randall. 1995. Impact of mixed-phase clouds in the CSU GCM. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Frisch, A. S., C. W. Fairall, and J. B. Snider. 1995. Measurement of stratus cloud and drizzle parameters in ASTEX with a K-Band Doppler radar and a microwave radiometer. *J. Atmos. Sci.* 52: 2789-99.

Frisch, A. S., C. W. Fairall, J. B. Snider, and D. H. Lenschow. 1995. Ground based cloud radar and radiometer methods for measuring stratus cloud parameters. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Frisch, A. S., G. Feingold, I. Djalalova, and M. Poellot. 2000. On the retrieval of the effective radius in continental stratus clouds with cloud radars. *10th ARM Science Team Meeting*.

Frisch, A. S., G. Feingold, C. W. Fairall, and B. Orr. 1995. Drizzle parameter measurements with a cloud sensing radar during ASTEX. *AMS 27th Conference on Radar Meteorology*.

Frisch, A. S., G. Feingold, C. W. Fairall, and J. B. Snider. 1998. On cloud radar and microwave radiometer measurements of stratus cloud liquid water. *8th ARM Science Team Meeting*.

———. 1998. On cloud radar and microwave radiometer measurements of stratus cloud liquid water profiles. *4th Tropospheric Profiling Symposium*.

Frisch, A. S., G. Feingold, C. W. Fairall, T. Uttal, and J. B. Snider. 1998. On cloud radar and microwave radiometer measurements of stratus cloud liquid water profiles. *J. Geophys. Res.* 103: 23195-97.

Frisch, A. S., G. Feingold, T. Uttal, C. W. Fairall, and J. B. Snider. 1997. Stratus cloud properties with a cloud radar and microwave radiometer. *AMS 28th Conference on Radar Meteorology*.

Frisch, A. S., D. H. Lenschow, C. W. Fairall, W. H. Schubert, and J. S. Gibson. 1995. Doppler radar measurements of turbulence in marine stratiform cloud during ASTEX. *J. Atmos. Sci.* 52: 2800-2808.

Frisch, A. S., D. H. Lenschow, B. Martner, B. Orr, and D. Fitzgerald. 1997. Doppler radar measurements of vertical velocity statistics boreal forest. *Boundary Layer and Turbulence Symposium*.

Frisch, A. S., B. E. Martner, I. Djalalova, and M. R. Poellot. 1999. Comparison of radar/radiometer retrievals of stratus cloud liquid water content profiles with in-situ measurements by aircraft. *9th ARM Science Team Meeting*.

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Frisch, A. S., B. E. Martner, B. W. Orr, and D. H. Lenschow. 1999. The effect of cumulus cloud formation on boundary layer turbulence. *9th ARM Science Team Meeting*.

Frisch, A. S., W. H. Schubert, and D. A. Randall. 1995. "Compilation of ETL/CSU cloud-related process modeling and measurement workshop proceedings." *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*, Colorado State University, Fort Collins, CO.

Frisch, A. S., M. D. Schupe, I. Djalalova, G. Feingold, and M. Poellot. 2002. The retrieval of stratus cloud droplet effect radius with cloud radars. *J. Atmos. and Oceanic Tech.* 19: 835-42.

Frisch, A. S., M. Shupe, I. Djalalova, G. Feingold, and M. Poellot. 2002. On the retrieval of effective radius with cloud radars. *J. Geophys. Res.*: 19835-42.

Frisch, A. S., T. Uttal, C. W. Fairall, and J. B. Snider. 1997. On the measurement of stratus cloud properties with a cloud radar and microwave radiometer. *IGARS*.

Frisch, A. S., and P. Zuidema. 2003. On the vertical profile of liquid water flux in stratus clouds using a millimeter cloud radar. *AMS 31st International Conference on Radar Meteorology*.

Gossard, E. E., B. B. Snider, E. E. Clothiaux, B. Martner, J. S. Gibson, R. A. Kropfli, and A. S. Frisch. 1997. The potential of 8 mm-radars for remotely sensing cloud drop size distribution. *J. Atmos. and Ocean. Tech.* 14: 76-87.

Gossard, E. E., J. B. Snider, J. S. Gibson, A. S. Frisch, B. Martner, and R. A. Kropfli. 1995. The potential of 8-mm radars for remotely sensing cloud drop-size distributions. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Kropfli, R., S. Matrosov, T. Uttal, B. Orr, A. S. Frisch, C. Clark, B. Bartram, R. Reinking, J. B. Snider, and B. E. Martner. 1995. Cloud physics studies with 8mm wavelength radar. *J. Atmos. Res.* 35, no. 2-4: 299-313.

Kuan-Man, X., and D. A. Randall. 1995. Cloud ensemble simulation with observed large-scale data: Developing and evaluating cloudiness parameterizations. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Lasarus, K., and A. S. Frisch. 2000. Evaluation of a cloud fraction parameterization using observations and model data. *10th ARM Science Team Meeting*.

Lazarus, S. M., S. K. Krueger, and A. S. Frisch. 1999. An evaluation of the Xu-Randall cloud fraction parameterization using ASTEX data. *ARM Science Team Meeting*.

Martner, B., A. S. Frisch, and R. Banta. 1995. Diurnal evolution of boundary layer turbulence over a boreal forest as observed by Doppler radar. *AMS Conference on Radar Meteorology*.

Matrosov, S. Y., A. S. Frisch, R. S. Kropfli, and T. Uttal. 2000. Retrievals of cloud content and particle characteristic size using NOAA ETL cloud radars. *1st International Workshop on Spaceborne Cloud Profiling Radar*.

Randall, D. A. 1995. An overview of cloud measurements and models. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

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Reinking, R. F., B. W. Orr, L. R. Bissonnette, G. Roy, A. S. Frisch, S. Y. Matrosov, and C. C. Ryerson. 2000. Remote sensing of cloud droplets during MWISP. *2000 International Geoscience and Remote Sensing Symposium*.

Schupe, M. D., T. Uttal, S. Matrosov, and A. S. Frisch. 2001. Cloud water contents and hydrometer sizes during the FIRE-Arctic cloud experiment. *J. Geophys. Res.* 106, Fire ACE Special Issue: 15015-28.

Shao, Q., and D. A. Randall. 1995. Mesoscale circulations as driven by cloud-top cooling. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

Stevens, B. 1995. What does entrainment look like anyway: Some thoughts on entraining boundary layers. *ETL/CSU Cloud-Related Process Modeling and Measurement Workshop*.

White, A., C. W. Fairall, A. S. Frisch, B. Orr, and J. B. Snider. 1996. Recent radar measurements of turbulence and microphysical parameters in marine boundary layer clouds. *J. Atmos. Res.* 40: 177-221.

AMS GRADUATE FELLOWSHIP FOR 1999/2000 FOR JULIE DEMUTH

Principal Investigator: T. Vonder Haar

Sponsor: AMS

Abstract - Support from the American Meteorological Society for graduate students.

DeMaria, M., J. Demuth, and J. A. Knaff. 2001. Validation of an advanced microwave sounder unit (AMSU) tropical cyclone intensity and size estimation algorithm. *AMS 11th Conference on Satellite Meteorology and Oceanography*.

DeMaria, M., R. M. Zehr, C. S. Velden, J. A. Knaff, J. L. Demuth, and K. F. Brueske. 2002. An update on Joint Hurricane Testbed (JHT) projects at CIRA and CIMSS. *56th Interdepartmental Hurricane Conference*.

Demuth, J. L. 2001. "Objectively estimating tropical cyclone intensity and wind structure using the Advanced Microwave Sounding Unit." MS Thesis. Colorado State University, Fort Collins, CO.

Demuth, J. L., K. Brueske, J. A. Knaff, C. Velden, and M. DeMaria. 2002. An evaluation of CIMSS and CIRA AMSU tropical cyclone intensity estimation algorithms. *AMS 25th Conference on Hurricanes and Tropical Meteorology*, 27-28.

Demuth, J. L., M. DeMaria, J. Knaff, and T. H. Vonder Haar. 2000. An objective method for estimating tropical cyclone intensity and structure from NOAA-15 Advanced Microwave Sounding Unit (AMSU) data. *AMS 24th Conference on Hurricanes and Tropical Meteorology*, 484-85.

Demuth, J. L., M. DeMaria, J. A. Knaff, and T. H. Vonder Haar. 2002. Evaluation of Advanced Microwave Sounding Unit (AMSU) tropical cyclone intensity and size estimation algorithms. *J. Applied Met. (Submitted)*.

Knaff, J. A., M. DeMaria, and J. L. Demuth. 2000. Tropical cyclone forecast products derived from the Advance Microwave Sounding Unit. *Interdepartmental Hurricane Conference*.

ANALYSIS OF DATA FROM THE BRAVO STUDY

Principal Investigators: S. Kreidenweis/J. Collett, Jr.

Sponsors: NPS

Abstract: This proposal seeks funds to perform analyses of data from the 1999 Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study. This group was supported in 1999-2000 to participate in BRAVO, to collect samples and make observations, and to perform chemical analyses and data reduction. The overall project goal was to examine the chemical composition, degree of internal mixing, and scattering and absorption properties of aerosols at Big Bend National Park during July-October, 1999. The ultimate goals of our data analyses are: 1. characterize summer and fall aerosols at the surface at Big Bend, including chemical composition, size distribution, and optical properties; 2. develop an understanding of aerosol sources and transformations by combining the characterization with meteorological and source information; 3. determine whether known organic tracers can be used for aerosol source apportionment in BRAVO; 4. investigate the contributions of secondary organic species to aerosol mass and evaluate their potential use as tracers for source apportionment.

In this proposal, we are specifically requesting funds to support personnel to perform the analysis work needed to address our goals. We have already completed most of our initial data processing and submitted results to the BRAVO data base. We are now prepared to work on data interpretation, including collaborating with other BRAVO investigators to share data needed to address BRAVO study objectives. Our proposed work will also include additional laboratory studies of organic identification methods and applicability to the Big Bend site during these seasons. As part of this, we will analyze for organic compounds in numerous source samples obtained for us by DRI during their work on BRAVO source characterization.

Arnott, W. P., H. Moosmuller, C. F. Rogers, J. L. Hand, D. E. Sherman, S. G. Brown, S. M. Kreidenweis, and J. L. Collett. 2000. Light absorption measurements during the BRAVO project at Big Bend National Park, Texas, Fall 1999. *Conference on Visibility, Aerosols, and Atmospheric Optics*.

Arnott, W. P., H. Moosmuller, P. J. Sheridan, J. A. Ogren, R. Raspet, W. V. Slaton, J. L. Hand, S. M. Kreidenweis, and J. L. Jr. Collett. 2003. Photoacoustic and filter-based ambient aerosol light absorption measurements: Instrument comparisons and the role of relative humidity. *J. Geophys. Res.* 108, no. D1: 4034.

Brown, S. 2001. "Characterization of carbonaceous aerosol during the Big Bend Regional Aerosol and Visibility Observational Study." *M.S, Thesis*, Colorado State University, Fort Collins, CO.

Brown, S. G., P. Herckes, L. Ashbaugh, M. P. Hannigan, S. M. Kreidenweis, and J. L. Jr. Collett. 2002. Characterization of organic aerosol present in Big Bend National Park, Texas during the Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study. *Atmos. Environ.* 36: 5807-18.

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Collett, J. L., S. Brown, P. Herckes, T. Lee, M. Hannigan, and S. M. Kreidenweis. 2001. The molecular composition of BRAVO organic aerosol. *BRAVO Data Analysis Meeting*.

Collett, J. L. Jr., T. Lee, J. L. Hand, D. E. Sherman, J. E. Reilly, M. P. Hannigan, S. G. Brown, and S. M. Kreidenweis. 2000. Chemical and physical properties of aerosol sampled at Big Bend National Park during the 1999 Big Bend Regional Aerosol and Visibility Observational Study (BRAVO). *2000 Annual Meeting of the American Association for Aerosol Research*.

Collett, J. L. Jr., T. Lee, D. E. Sherman, J. E. Reilly, S. G. Brown, and S. M. Kreidenweis. 2001. The composition of aerosol sampled at Big Bend National Park during the 1999 Big Bend Regional Aerosol and Visibility Observational Study (BRAVO). *AWMA Conference*.

Hand, J. L. 2001. "A new technique for obtaining aerosol size distributions with applications to estimates of aerosol properties." Colorado State University.

Hand, J. L., and S. M. Kreidenweis. 2001. "A new technique for obtaining aerosol size distributions with applications to estimates of aerosol properties." *CIRA Technical Paper No. 0737-5352-49*, Colorado State University, Fort Collins, CO.

Hand, J. L., S. M. Kreidenweis, N. Kreisberg, S. Hering, M. Stolzenburg, W. Dick, and P. H. McMurry. 2002. Comparisons of aerosol properties measured by impactors and light scattering from individual particles: Refractive index, number and volume concentrations, and size distributions. *Atmospheric Environment* 36: 1853-61.

Hand, J. L., S. M. Kreidenweis, D. E. Sherman, and J. L. Jr. Collett. 2002. A new method for retrieving particle refractive index and effective density from aerosol size distribution data. *Aerosol Science and Technology* 36, no. 10: 1012-26.

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Hand, J. L., S. M. Kreidenweis, D. E. Sherman, J. L. Jr. Collett, T. Lee, J. R. Slusser, G. Scott, and L. L. Ashbaugh. 2001. Investigations of aerosol optical properties using ground based remote sensing, aerosol size distributions and chemical measurements at Big Bend National Park, Texas. *IAMAS 8th Scientific Assembly*.

Hand, J. L., S. M. Kreidenweis, J. Slusser, W. Gao, and G. Scott. 2000. The relative contributions of accumulation and coarse mode particles to aerosol optical depth and their effect on the spectral variation of the Angstrom coefficient during BRAVO. *2000 Annual Meeting of the American Association for Aerosol Research*.

Hand, J. L., D. E. Sherman, S. M. Kreidenweis, J. L. Collett, T. Lee, D. E. Day, and W. C. Malm. 2000. Characterization of aerosol physical and optical properties during the Big Bend Regional Aerosol and Visibility Observational Study (BRAVO). *2000 Annual Meeting of the American Association for Aerosol Research*.

Hand, J. L., D. E. Sherman, S. M. Kreidenweis, J. L. Jr. Collett, T. Lee, D. E. Day, and W. C. Malm. 2001. Aerosol physical and optical properties during the Big Bend Regional Aerosol Visibility Study (BRAVO). *AWMA Conference*.

Herckes, P., S. Brown, T. Lee, M. P. Hannigan, S. M. Kreidenweis, and J. L. Jr. Collett. 2001. Molecular composition of organic aerosol sampled at Big Bend National Park, Texas during the 1999 Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study. *AWMA 20th Conference*.

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Herckes, P., M. P. Hannigan, D. E. Sherman, S. M. Kreidenweis, and J. L. Jr. Collett. 2000. Molecular composition of organic aerosol sampled at the Big Bend National Park (U.S.A.) during the 1999 Big Bend Regional Aerosol and Visibility Observational study (BRAVO). *7th International Conference on Carbonaceous Particles in the Atmosphere*.

Herckes, P., T. Lee, J. E. Reilly, M. P. Hannigan, D. E. Sherman, S. M. Kreidenweis, and J. L. Collett. 2000. Chemical characteristics of aerosol sampled at the Big Bend National Park (U.S.A.) during the 1999 Big Bend Regional Aerosol and Visibility Observational study (BRAVO). *Conference on Visibility, Aerosols, and Atmospheric Optics*.

Lee, T., J. E. Reilly, M. P. Hannigan, D. E. Sherman, J. L. Hand, S. M. Kreidenweis, and J. L. Collett. 2000. Comparison of observed and model-predicted aerosol composition during the Big Bend Regional Aerosol and Visibility Observational Study (BRAVO). *2000 Annual Meeting of the American Association for Aerosol Research*.

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ANALYSIS OF FINDINGS FROM THE YOSEMITE AEROSOL AND VISIBILITY SPECIAL STUDY AND CHARACTERIZATION OF NITRATE AND OTHER ION MEASUREMENTS AT IMPROVE

Principal Investigators: S. Kreidenweis/J. Collett, Jr.

Sponsor: NPS

Abstract: The purpose of this project is to analyze data from the YOSEMITE special study, to examine the physical and chemical properties of smoke aerosol from prescribed and/or wildfires, to document the short-term variability of the aerosol size distribution and aerosol hygroscopicity and their impacts on regional haze, and to link aerosol hygroscopicity to chemical composition. Samples for wood smoke markers will also be analyzed.

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ASSISTANCE FOR VISIBILITY DATA ANALYSIS AND IMAGE DISPLAY TECHNIQUES

Principal Investigators: D. Fox/T. Vonder Haar

Sponsor: NPS

Abstract - The National Park Service has the responsibility of assessing the visual impact of pollutants on various scenic vistas. This assignment is accomplished through monitoring scenic vistas with various electro-optical devices. However, it is difficult for decision makers and other interested parties to visually interpret the meaning of changes in electro-optical variables used to quantify changes in scenic appearance under different atmospheric particulate loading conditions. The most effective way to present effects of pollutants on scenic vistas is through the use of photographic imaging techniques that accurately depict how the scene will appear under various illumination, meteorological and pollutant conditions. In order to meet the National Park Service's needs for computer imaging, the project staff will: 1) continue development and documentation of existing computer software codes and 2) develop new and refined techniques for "digitizing" color transparencies for purposes of accurately deriving quantifiable visibility indices from slides.

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ATMOSPHERIC TRACER TRANSPORT INVERSION INTERCOMPARISON PROJECT (TransCom 3)

Principal Investigator: S. Denning

Sponsors: NOAA/OGP/NSF

Abstract - Atmospheric chemical tracer transport models (CTMs) can be used to calculate surface fluxes of trace species from spatial distributions of concentration, by a set of methods collectively known as "inversion." This technique has been applied to the study of sources and sinks of CO_2, and the results have important implications for policy responses. Different CTM groups have produced conflicting results using the same observational data. We will conduct a three-year series of experiments in which leading chemical tracer transport models from around the world are used to calculate the global carbon budget of the atmosphere. The objectives of the proposed research are (1) to quantify the uncertainty in the O_2 budget that arises from differences in simulated transport; (2) to diagnose the mechanisms that produce these differences; and (3) to recommend and prioritize improvements to the models and observing network to reduce this source of uncertainty in the future.

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CENTER FOR GEOSCIENCES/ATMOSPHERIC RESEARCH

Principal Investigator: T. Vonder Haar

Sponsor: DoD

Abstract - The Cooperative Institute for Research in the Atmosphere at Colorado State University has conducted Army and DoD-relevant research in the area of meteorology and hydrology since 1986. This research, totaling over $1 8M, has a successful history of results. Research is performed by a multi-disciplinary group of faculty, staff, and students from CSU, with a few collaborators from other universities, NCAR, and federal labs. The first two phases of Center for Geosciences were funded through the Army Research Office; both basic and related, applied research was conducted. As a result of this earlier funding, many research topics have matured and have already been, or are ready for technical transition to operational users within the DoD. Phases III and IV of the Center for Geosciences/Atmospheric Research have been funded through the Army Research Laboratory with focus on further work and technology transfer in five research theme areas: Hydrometeorology; Cloud Structure, Dynamics and Climatology; N-Dimensional Data Assimilation and Fusion; (recently renamed) Boundary Layer Atmospheric Chemistry and Aerosols; and (recently renamed) Derivation of Battlespace Parameters. A new, cross-cutting theme area has recently been identified, Urban Environment.

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CIRA ACTIVITIES AND PARTICIPATION IN DMSP SATELLITE DATA PROCESSING AND ANALYSIS

Principal Investigators: T. Vonder Haar/C. Matsumoto

Sponsor: NESDIS

Abstract - This program at CIRA is being undertaken to support NOAA's Defense Meteorological Satellite Program (DMSP) Program at National Geophysics Data Center (MGDC) in Boulder, CO. This effort emphasizes the use of current technology in the use and interpretation of meteorological satellite imagery, the development of new applications like the early detection of forest fires, the preparation of research quality data from DMSP satellites for the national archives, and the preparation and distribution of data and products to the user community.

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CIRA ACTIVITIES AND PARTICIPATION IN THE GOES I-M PRODUCT ASSURANCE PLAN

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Sponsors: NOAA/NESDIS

Abstract: - In April 1994, NOAA introduced a new geostationary satellite series with the launch of GOES-8: the new series is called GOES-I/M. In May 1995, the second in the series, GOES-9, was launched and in April 1997, GOES-K was launched. In response to the need to insure transition from GOES-7 to GOES-8 and GOES-9 day-1 products and beyond, CIRA has been involved in NESDIS' GOES-I/M Product Assurance Plan, GIMPAP. The GIMPAP provides the means to checkout the performance of GOES satellites immediately after launch, to assure the viability of GOES-I/M day-1 products, to improve operational products, to develop advanced products, and to ensure integration of the results into NESDIS operations. As a part of this effort, CIRA developed a system that allows for the display and analysis of digital satellite imagery at selected field sites. This system, known as RAMSDIS (RAMM Advanced Meteorological Satellite Demonstration and Interpretation System), is a prototype satellite imaging system which allows for menu-driven collection, display and manipulation of full-resolution digital satellite imagery. The system is allowing for interaction between RAMM/CIRA and NWS field offices (as well as selected OAR sites) in a virtual laboratory atmosphere. Techniques and algorithms developed at RAMM/CIRA are being tested and critiqued by both the research and operational community via this system, which is leading to technique and algorithm improvements.

Recently, most RAMSDIS systems at NWS offices have been retired now that the AWIPS deployment is completed. CIRA is continuing to develop GOES algorithms and products for severe weather, tropical cyclones and mesoscale aspects of mid-latitude cyclones, and fire and volcanic ash detection. These products are being tested and distributed using web-based applications, and eventually through the AWIPS system.

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———. 2001. Characteristics of 23 Atlantic intense hurricanes-1995-2000: Satellite and aircraft observations. *55th Interdepartmental Hurricane Conference*.

———. 2001. Tropical cyclone surface wind analysis using satellite sensors. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 296-99.

Zehr. R.M. 2002. Vertical wind shear characteristics with Atlantic hurricanes during 2001. *AMS 25th Conference on Hurricanes and Tropical Meteorology*, 170-171.

Zehr, R. M. 2003. Environmental vertical wind shear with Hurricane Bertha (1996). *Wea. Forecasting* 18, no. 2: 345-56.

———. 2003. Tropical cyclone surface wind analysis using satellite data: Dvorak, microwave, scatterometer, and cloud motion winds. *57th Interdepartmental Hurricane Conference*.

Zehr, R. M., M. DeMaria, F. Horsfall, and J. Knaff. 1999. Observational tropical cyclone data archive and research. *53rd Interdepartmental Hurricane Conference*.

CIRA ACTIVITIES IN THE U.S. WEATHER RESEARCH PROGRAM

Principal Investigators: T. Vonder Haar/M. DeMaria

Sponsors: NOAA/NESDIS

Abstract - Over the past several years, the CIRA Regional and Mesoscale Meteorology (RAMM) Team has performed research under funding from NOAA's Severe Weather Prediction Initiative (SWPI). Efforts have focused on the use of satellite data for mesoscale analysis of high-impact weather events, and on forecast product development. Beginning in 2000, the SWPI program was combined with the ongoing U.S. Weather Research Program (USWRP). For 2001-2002, contributions to the Joint Hurricane Testbed (JHT) effort have been emphasized by the USWRP. Two NESDIS/CIRA research projects were ranked as high priorities for the JHT. These include research related to improvements to the operational Statistical Hurricane Intensity Prediction Scheme (SHIPS) using satellite altimetry and GOES data, and the development of an Advanced Microwave Sounder unit (AMSU) algorithm for tropical cyclone intensity and size estimation. The second project is a joint effort with the Cooperative Institute for Meteorological Satellite Studies (CIMSS), located in Madison, Wisconsin. This continuation proposal describes the CIRA research contributions to the JHT for the second year of these two projects. The proposed research contributes directly to two of the eight primary themes of CIRA: 1. Local and Mesoscale Area Weather Forecasting and Evaluation, 2. Applications of Satellite Observations.

No publications to date associated with this project.

CIRA'S CROSS-SENSOR PRODUCTS FOR IMPROVED WEATHER ANALYSIS AND FORECASTING

Principal Investigators: S. Kidder/A. Jones

Sponsor: NOAA

Abstract - In the forty+ years since the beginning of weather satellites, satellite imagery has revolutionized weather analysis and forecasting. Satellite "pictures" and "movie loops" are routinely and extensively used to analyze the current weather and to make short-term forecasts. Yet a brief analysis of how the data are used reveals that much more could be learned about the weather from satellite data.

One of the problems is that, except in atmospheric sounding retrievals, data from separate satellite sensors is almost never combined to make an improved product. An example of this concerns precipitable water observations. While most components of the atmosphere have relatively fixed concentrations, water vapor varies from near zero percent to in excess of four percent of atmospheric molecules. Further, the spatial variation of water vapor concentration is also quite variable. Forecasters need to know where the water vapor is to make precipitation forecasts, and several satellite instruments have been flown to make these vital measurements. However, data from different satellite sensors are not combined to make a unified water vapor product. Instead, separate water vapor products are created for each sensor, and the forecaster is left to sort through them to discover the truth.

No publications to date associated with this project.

A COMPARISON OF ROOFTOP AND STANDARD GROUND-BASED TEMPERATURE

Principal Investigators: T. McKee/N. Doesken

Sponsor: NOAA

Abstract - Accuracy and continuity of surface air temperature measurements are critical for many NOAA activities including short term weather forecasting and warning, climate monitoring and the prediction and assessment of decadal to centennial climate change. This project will study biases and uncertainties in temperature records caused by rooftop instrument locations. Both National Weather Service stations and non-NOAA sources will be investigated. Ground level to rooftop temperature differences will be studied to show what, if any, differences occur and whether these differences are significant, systematic, predictable and a function of current weather conditions or if differences are highly variable and inconsistent. Work will be performed at the National Climatic Data Center (NCDC) to better document where and when NWS weather stations have been situated on rooftops.

Davey, C., N. Doesken, R. Leffler, and R. Sr. Pielke. 2001. Are temperatures going through the roof: Differences between rooftop and standard ground-based temperatures. *Colorado Climate Magazine* 2, no. 4.

Davey, C. A., J. J. Doesken, R. J. Leffler, and R. A. Sr. Pielke. 2002. Differences between rooftop and standard ground-based temperatures. *AMS 6th Symposium on Integrated Observing Systems*.

Davey, C. A., N. J. Doesken, R. J. Leffler, and B. Marshall. 2003. Rooftop temperatures: How do they compare with ground temperatures. *Bull. Amer. Meteo. Soc. (in Prep)*.

Doesken, N. J., C. A. Davey, B. G. Griffith, and T. B. McKee. 2001. Rooftop temperatures and how they compare with standard surface observations. *AMS 11th Symposium on Meteorological Observations and Instrumentation*.

Griffith, B., T. B. McKee, N. J. Doesken, and R. J. Leffler. 2000. A comparison of rooftop and surface temperature observations. *Preprints, 12th AMS Conference on Applied Climatology*.

COPING WITH FLASH FLOODS

Principal Investigator: K. Eis

Sponsor: NATO

Abstract - The Flash Flood Laboratory has been funded by NATO to offer a NATO Advanced Studies Course to be held in Ravello, Italy November 8-17, 1999, entitled "Coping with Flash Floods". Our meeting will follow up on recommendations from a 1992 ASI "Coping with Floods". The 1992 session findings provide a solid understanding of how technology can and is being applied to reducing flood losses. Our 1999 ASI will focus on flash floods and will include participation from engineers, geographers, hydrologists, meteorologists, emergency managers, social scientists, and others addressing the challenges of reducing flash flood vulnerability. After presentations of the state of the art in the fields, the group will divide into groups. These groups will discuss within international and interdisciplinary contexts, a new research agenda and the best ways to learn from and apply current scientific and technological advancements to reducing vulnerability. Bold recommendations will be made.

Adams, C. R., and W. Hooke. 2001. Chapter 29: Improved flash flood predictions. *Coping with Flash Floods.* Eds. E. Gruntfest, and J. Handmer, 309-15. Dordrecht, Netherlands: Kluwer Academic Publishing.

Gruntfest, E. 1999. Flash floods in the United States. *Storms.* eds. R. Jr. Pielke, and R. Sr. Pielke, 192-207. New York, NY: Routledge.

Gruntfest, E. 2000. Nonstructural mitigation of flood hazards. *Inland Flood Hazards: Human, Riparian, and Aquatic Communities.* ed. E. Wohl, 394-410. Cambridge, England: Cambridge University Press.

Gruntfest, E. 2001. Chapter 17, Beyond flood detection: Alternative applications of real-time data. *Coping with Flash Floods.* Eds. E. Gruntfest, and J. Handmer, 167-79. Dordrecht, Netherlands: Kluwer Academic Publishers.

Gruntfest, E., C. R. Adams, and K. E. Eis. 2001. Chapter 28: The Flash Flood Library at Colorado State University's Cooperative Institute for Research in the Atmosphere. *Coping With Flash Floods.* Eds. E. Gruntfest, and J. Handmer, 303-7. Dordrecht, Netherlands: Kluwer Academic Publishers.

Gruntfest, E., and J. Handmer. 2001. Chapter 1, Dealing with flash floods: Contemporary issues and future possibilities. *Coping with Flash Floods.* Eds. E. Gruntfest, and J. Handmer, 3-11. Dordrecht, Netherlands: Kluwer Academic Publishers.

———. 2001. Chapter 30, Where we go from here: Policy and research recommendations. *Coping with Flash Floods.* Eds. E. Gruntfest, and J. Handmer, 317-22. Dordrecht, Netherlands: Kluwer Academic Publishers.

———, Eds. 2001. *Coping with flash floods*. Dordrecht, Netherlands: Kluwer Academic Publishers.

Gruntfest, E., and B. Montz. 2000. Flash flood research agenda: Following up on the NATO Advanced Study Institute findings. *European Geophysical Society Meeting*.

Gruntfest, E., and A. Ripps. 2001. Reducing loss susceptibility in flash floods. *Flood Hazards and Disasters.* ed. D. Parker, 377-90. London, England: Routledge.

Jennings, S., and E. Gruntfest. 2002. Flooding. *Handbook of Weather, Climate and Water*, 154-71. Columbus, Ohio: McGraw Hill.

Montz, B., and E. Gruntfest. 2002. Flash flood mitigation: recommendations for research and applications. *Environmental Hazards* 4, no. 1: 15-22.

Weaver, J. F., G. Levy, and E. Gruntfest. 2000. Two floods in Fort Collins, Colorado: Learning from a natural disaster. *Bulletin of the American Meteorological Society* 81, no. 10: 2359-66.

COUPLING BETWEEN MONSOON CONVECTION AND SUBTROPICAL HIGHS IN THE PACS REGION ON SUBSEASONAL TO INTERANNUAL TIME SCALES

Principal Investigators: R. Johnson/W. Schubert

Sponsor: NOAA

Abstract - Recent analyses have shown a dynamical coupling between subtropical highs and monsoon convection. The hypothesis for this coupling over the PACS region has yet to be fully explored. In this proposal we outline a research plan to document the nature, extent and mechanisms for the coupling between the monsoon heat sources and adjacent subtropical anticyclones with their associated low-level jets using both modeling and observational approaches. The observational part of this research will supplement the sparse sounding network over adjacent oceans with profiler and NCEP reanalysis data. The modeling component will primarily use a well-tested general circulation model with realistic topography and a variety of specified heating profiles.

Since potential vorticity (PV) concepts have been shown to be useful in understanding the Asian monsoon circulation, we propose to apply PV concepts to the PACS region. In particular, we plan to investigate how PV is modified in the cross-equitorial flows that feed into the monsoon convection over Amazonia and into the eastern Pacific ITCZ and Central American convection.

Ciesielski, P. E., R. H. Johnson, P. T. Haertel, and J. Wang. 2003. Corrected TOGA/COARE sounding humidity data: Impact on diagnosed properties of convection and climate. *J. Atmos. Sci. (in Press)*.

Hausman, S. A., K. V. Ooyama, and W. H. Schubert. 2003. Potential vorticity structure of hurricanes. *J. Atmos. Sci. (Submitted)*.

Ito, T., E. P. Gerber, and W. H. Schubert. 2003. Formation and maintenance of black holes of water vapor in an idealized model of the tropical atmosphere. *J. Meteo. Soc. (in Prep)*.

Randall, D. A., and W. H. Schubert. 2003. A stratocumulus sleeper. *(in Prep)*.

DESIGN, DEVELOPMENT AND MAINTENANCE OF THE GLOBE PROGRAM WEBSITE AND DATABASE

Principal Investigators: R. Brummer/C. Matsumoto

Sponsors: NASA

Abstract - This program is undertaken to design and develop enhancements, implement improved efficiency and reliability, and provide responsive maintenance for the operational GLOBE (Global Learning and Observations to Benefit the Environment) Program website and database. The GLOBE Program was established in 1994 with goals to increase environmental awareness of countries throughout the world, contribute to a better understanding of the earth, and help all students reach higher levels of achievement in science and mathematics. Under the guidance of their teachers, K-12 students worldwide collect environmental data around their schools and post these findings on the Internet. GLOBE scientists design protocols for measurements by students that are also useful in scientific research. CIRA, under the auspices of its cross-cutting research area of education, outreach, and training, has been a key contributor since the program's inception and continues to provide enhancements to its website and database.

No publications to date associated with this project.

DEVELOPING CAPABILITY TO IMPLEMENT, EVALUATE & USE MODELS-3/CMAQ FOR VISIBILITY, PM2.5 & ASSOCIATED WESTERN US AIR QUALITY ISSUES INCLUDING CONTRIBUTIONS FROM FOREST & AGRICULTURE BURNING

Principal Investigator: D. Fox

Sponsors: CIRA and NPS, supported additionally by United States EPA

Abstract - CIRA will conduct the following research work: 1. Install and operational test the current release of Models3/CMAQ at CIRA; 2. Evaluate functionality and general performance capability of Models3/CMAQ; 3. Initiate research studies to link existing and next generation fire emissions models with the Models3 emissions processing capability, including the new Space Matrix Operator Kernel Emissions (SMOKE) processor; 4. Pursue development of the capabilities at CIRA for using and developing Models3 and associated scientific components to address contemporary air quality issues in the Western United States.

No publications to date associated with this project.

DEVELOPMENT AND EVALUATION OF GOES AND POES PRODUCTS FOR TROPICAL CYCLONE AND PRECIPITATION ANALYSIS

Principal Investigators: J. Knaff/L. Grasso/M. DeMaria/R. Zehr

Sponsors: PSDI/NOAA/NESDIS

Abstract - Over the past several years, the Cooperative Institute for Research in the Atmosphere (CIRA) has performed basic and applied research to better utilize data from NOAA Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES). The NOAA/NESDIS GOES Improved Measurements Product Assurance Plan (GIMPAP) has supported CIRA research on the use of GOES data for mesoscale analysis of high-impact weather events, including severe weather and tropical cyclones. Past POES research has focused on the utilization of the Advanced Microwave Sounder Unit (AMSU) for tropical cyclone intensity and structure analysis. Beginning in 2002, the NESDIS GIMPAP program has been supplemented with the Product System Development and Implementation (PSDI) program to provide research support for applications of satellite data that have a direct relationship with weather and climate forecasting. In this CIRA proposal to the PSDI program, applied research will be performed on applications of GOES and POE's data to three forecasting problems: estimating tropical cyclone intensity from POES data; predicting the formation of tropical cyclones in the Atlantic and east Pacific basins using GOES data; and estimating rainfall from GOES infrared satellite imagery. The proposal work involves development of research algorithms and testing and evaluation in an operational forecasting environment.

No publications to date associated with this project.

DEVELOPMENT AND IMPLEMENTATION OF GOES RAINFALL AND FIRE DETECTION PRODUCTS FOR GUATEMALA

Principal Investigators: B. Connell/M. DeMaria

Sponsors: SICA/AID Rio Lempa Project

Abstract - Under the Hurricane Mitch Reconstruction Efforts, a GOES ingest system will be installed in Costa Rica and satellite display systems will be installed in six additional countries in Central America (July-September 2001). When this occurs, GOES imager data will routinely be available in real time. One important application of this data in this region is the estimation of rainfall. A visiting scientist, Rosario Alfaro, is adapting the satellite rainfall estimation techniques to Central America under the Hurricane Mitch Reconstruction efforts. This project allows the implementation of the products on a web page before the operational systems are installed. This project also introduces monthly GOES infrared cloud frequency products to be used along with the rainfall estimates. Another important application of GOES imager data for Central America is the detection of fires. Although the spatial resolution of the GOES data is not as high as that of the polar-orbiting satellite data, the high time resolution of the data allows for more continuous monitoring of some of the larger fires. This project will adapt existing fire algorithms for the region and display the resulting imagery on the web page. The algorithms will be transferred to the operational systems after installation.

Alfaro, R. 2003. "Validation of GOES precipitation estimates over Central America." *CIRA Technical Report*, Colorado State University, Fort Collins, CO.

Connell, B. H., and V. Castro. 2001. The use of mesoscale climatologies for monitoring and forecasting weather in Costa Rica. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 157-60.

Connell, B. H., Fryer, M. K., Watson, D., and Alfaro, R. 2001. "Real-time Satellite Rainfall and Fire Products for Central America." Web page. Available at http://www.cira.colostate.edu/RAMM/sica/main.html.

DEVELOPMENT OF A FORWARD MODEL FOR HURRICANE INITIALIZATION

Principal Investigators: T. Vonder Haar/W. Schubert/M. DeMaria

Sponsors: NOAA/NWS

Abstract - To a first approximation, tropical cyclones are quasi-axisymmetric and the tangential wind rotates around a vertically oriented axis. Eliassen (1952) developed a set of equations that are appropriate for this type of flow. In the Eliassen vortex model, the flow is in hydrostatic balance in the vertical, and the tangential wind is in gradient balance with the mass field. The secondary circulation, i.e., the radial and vertical velocity, is diagnostic, given the tangential wind field and the radial and vertical distributions of friction and diabatic heating. The Eliassen balanced vortex model will be the basis of our forward model for hurricane initialization. Although the storm motion introduces a wavenumber one asymmetry even in very strong storms with well-developed eyes, it is assumed that the forward model will be used to provide increments relative to a background field obtained from an earlier model run. Since the primary contribution to the storm motion comes from the large-scale environmental flow, the asymmetry due to the storm motion will be included in the analysis when the symmetric flow from the forward model is added to the background field. This forward model will be tested in the NCEP Global Data Assimilation System (GDAS).

No publications to date associated with this project.

DEVELOPMENT OF A PARALLEL COUPLED OCEAN-ICE FORECAST MODEL

Principal Investigator: C. Matsumoto

Sponsors: NASA

Abstract - The objective of this research task was to parallelize a NASA version of the Princeton Ocean Model coupled to a sea ice model (referred to as NASAPOM) using the NOAA/FSL-developed Scalable Modeling System (SMS). SMS is a directive-based tool for parallelizing codes for ocean models.

No publications to date associated with this project.

DEVELOPMENT OF A STATISTICAL TROPICAL CYCLONE RAINFALL ALGORITHM

Principal Investigators: T. Vonder Haar/M. DeMaria

Sponsor: Insurance Friends of the National Hurricane Center, Inc.

Abstract - Over the past several decades considerable progress has been made in the ability to forecast the tracks of tropical cyclones. Some modest intensity forecast improvement has also been obtained. Since 1970, however, the largest loss of life in the U.S. from landfalling tropical cyclones has resulted from inland flooding. The primary tools for operational prediction of rainfall from landfalling tropical cyclones are dynamical models such as the operational version of the Geophysical Fluid Dynamics Laboratory (GFDL) hurricane model. Extrapolation of satellite-derived rainfall estimates are also sometimes used. However, the tropical cyclone rainfall forecasts from the GFDL model and other algorithms have not been systematically evaluated in the same way as the track and intensity forecasts have.

One of the primary methods for evaluating the skill level of a particular forecast is by comparison with a forecast based upon climatology and persistence (CLIPER). CLIPER-type models are currently available for track and intensity forecasting, but no such model is available for rainfall prediction. In the proposed research, a rainfall CLIPER-type model for U.S. landfalling tropical cyclones will be developed. The model will use U.S. rain gauge data to determine the climatological rainfall rate associated with landfalling storms. This rainfall rate can be extrapolated along the forecast track of the storm to provide an estimate of storm-total rainfall amounts. This model will be useful for providing guidance for operational forecasting, and will provide a benchmark to evaluate the skill of other rainfall techniques. We plan to implement this model at the Tropical Prediction Center in Miami for an operational evaluation during the 2001 hurricane season.

DeMaria, M., and R. E. Tuleya. 2001. Evaluation of quantitative precipitation forecasts from the GFDL hurricane model. *81st Annual AMS Meeting*.

Kidder, S. Q., S. J. Kusselson, J. A. Knaff, and R. J. Kugligowski. 2001. Improvements to the experimental tropical rainfall potential (TraP) technique. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 375-78.

Marks, F. Jr., G. Kappler, and M. DeMaria. 2002. Development of a tropical cyclone rainfall climatology and persistence (R-CLIPER) model. *AMS 25th Conference on Hurricanes and Tropical Meteorology*, 327-28.

DEVELOPMENT OF A VIRTUAL LABORATORY WEB SERVER FOR INTERNATIONAL SATELLITE METEOROLOGY TRAINING

Principal Investigators: B. Connell/D. Molenar/M. DeMaria

Sponsors: NOAA/NESDIS

Abstract - A meeting of an International Satellite Data Utilization and Training Focus Group was held at the European Meteorological Satellite (EUMETSAT) Agency in Darmstadt, Germany, 16-18 May, 2001. This meeting was organized by the World Meteorological Organization, and included representatives from NOAA/NESDIS and the international satellite community. A decision was made at this meeting to establish a Virtual Laboratory (VL) to foster the international exchange of satellite data and training material. For this purpose, web servers will be established at EUMETSAT, the Bureau of Meteorology (BOM) in Melbourne, Australia and at CIRA in Fort Collins, CO. This proposal is to purchase and configure the necessary hardware and software, coordinate the initial VL development with EUMETSAT and BOM, and to provide software support for the first year of the project. Relevant information regarding the CIRA contribution to the WMO Virtual Laboratory can be found in section 6 and Annex III and IV of the Final Report of the GGMS International Satellite Data Utilization and Training Focus Group.

No publications to date associated with this project.

DEVELOPMENT OF EFFICIENT SATELLITE DATA COMPRESSION TECHNIQUES: TRANSMISSION OF GOES IMAGERY TO THE NOAA WP-3D AIRCRAFT

Principal Investigators: J. Knaff/N. Wang/M. DeMaria

Sponsors: NOAA/NESDIS

Abstract - NOAA's two WP-3D aircraft are the primary tools for the annual hurricane field program of the Hurricane Research Division (HRD). The P-3 aircraft are also used for operational reconnaissance missions to supplement the flights of the U.S. Air Force Reserve, which operates out of Kessler Air Force Base in Mississippi. During the hurricane off-season, the P-3 aircraft are used for many other atmospheric research missions throughout the world. the P-3 aircraft are instrumented to collect flight-level atmospheric data, can release dropwindsondes to obtain vertical profiles of atmospheric parameters, and have on-board Doppler radars. However, the P-3s do not have the capability to display on-board satellite imagery in real-time. This capability would be instrumental in aiding the operational reconnaissance missions, especially for weaker systems where the storm center is often difficult to locate using radar data and lift-level winds. This imagery would also be very useful in research missions to adjust flight tracks to optimize data collection.

In this project, advanced data compression methods are being adapted to GOES satellite imagery so that the data can be sent to the P-3 aircraft and displayed in real-time.

Knaff, J. A., N. Wang, R. M. Zehr, M. DeMaria, J. S. Griffin, and F. D. Marks. 2003. A demonstration of real-time transmission and display of GOES imagery aboard the NOAA P-3 aircraft during the 2002 hurricane season. *AMS 12th Conference on Satellite Meteorology and Oceanography*.

DEVELOPMENT OF EXTEND-RANGE TROPICAL CYCLONE INTENSITY FORECAST TECHNIQUES

Principal Investigators: T. Vonder Haar/M. DeMaria

Sponsor: Insurance Friends of the National Hurricane Center, Inc.

Abstract - Since 1965, the National Hurricane Center (NHC) has had the responsibility of predicting the position and intensity of Atlantic tropical cyclones out to 72h. However, some specialized interests such as the evacuation of naval fleets, space shuttle operations, and the evacuation of particularly vulnerable regions such as the Florida Keys and New Orleans require some actions to be taken prior to three days in advance of a hurricane landfall. To address these needs, NHC is considering extending their track and intensity forecasts from three to five days. The primary tools for track forecasting are dynamical models, which can be modified to provide five-day predications without major changes in their formulations. In fact, many of these models already provide five-day forecasts. Because the processes that affect tropical cyclone intensity change involve a wider range of scales of motion, dynamical model intensity forecasts are usually less skillful than their track forecasts. For this reason, the NHC forecasters also rely on statistical models for the prediction of intensity. A current limitation of the statistical intensity models is that they only provide three-day forecasts. Because these models use empirical relationships, the extension to five days is more difficult than for dynamical models, since new relationships must be developed for the day four and five predictions. In this proposal, the operational SHIFOR and SHIPS intensity forecasts will be generalized to provide forecasts out to five days for the Atlantic and Eastern Pacific tropical cyclone basins.

DeMaria, M. 2001. Extension of statistical tropical cyclone intensity forecasts to Day 4 and Day 5. *55th Interdepartmental Hurricane Conference*.

Knaff, J. A., M. DeMaria, C. R. Sampson, and J. M. Gross. 2003. Statistical, five-day tropical cyclone intensity forecasts derived from climatology and persistence. *Wea. Forecasting* 18, no. 2: 80-92.

DEVELOPMENT OF TROPICAL CYCLONE WIND SPEED PROBABILITIES

Principal Investigators: J. Knaff/M. DeMaria

Sponsor: Insurance Friends of the National Hurricane Center, Inc.

Abstract: Every six hours the National Hurricane Center (NHC) provides forecasts of the track, maximum surface wind and radii of 34, 50 and 64 kt winds for all tropical cyclones in the Atlantic and east Pacific. If all of these parameters were perfectly forecast, it would be possible to determine in advance which regions along the storm path would experience hurricane force winds. However, forecast uncertainties result in the probability of a given point actually experiencing hurricane winds being less than one, even if that location is directly along the predicted storm track. Estimates of the probability of occurrence of wind speed thresholds at various lead times would be very useful for planning purposes. For example, decision-making tools that rely on quantitative probabilities of wind speed occurrences could be developed. Wind probabilities would also be useful for helping to determine the areas included in NHC coastal watches and warnings, and in high wind warnings issued by local National Weather Service (NWS) forecast offices for inland counties. In this proposal a method will be developed to estimate these probabilities using the error characteristics from a long-term sample of the official NHC track, intensity and size forecasts.

DeMaria, M. 2003. A Monte Carlo method for estimating surface wind speed probabilities. *57th Interdepartmental Hurricane Conference*.

ENHANCED COMMUNICATIONS AT CIRA: UPGRADE OF THE CIRA COMPUTER LABORATORY

Principal Investigators: T. Vonder Haar/M. DeMaria/D. Molenar

Sponsors: NOAA/NESDIS

Abstract - Over the past several years, CIRA has provided satellite data and experimental products to a wide variety of users. A low-cost PC-based workstation was developed (RAMSDIS) that allows outside users to obtain, display and manipulate digital satellite data. During the late 1990s, RAMSDIS systems were used at up to 50 National Weather Service (NWS) forecast offices throughout the U.S. In the past year, the RAMSDIS project within the NWS ended, due to the implementation of the Advanced Weather Interactive Processing System (AWIPS). More recently, RAMSDIS systems have been implemented at many international locations to enhance cooperative research and training efforts. These systems are also used at several research laboratories within the U.S., including CIRA. The Internet has continued to have an increasingly important role in the provision of satellite data and experimental products. For example, a web-based version of RAMDIS (RAMSDIS On-Line) provides animated loops of satellite imagery and products for a wide variety of applications.

The original RAMSDIS systems were developed in the context of an OS/2 operating system. The OS/2 operating system is rapidly becoming archaic, and is no longer supported by the McIDAS Users Group. If the CIRA laboratory is not upgraded, we will lose our ability to generate data and experimental products, and to continue our cooperative research and training efforts within the U.S. and internationally. We propose to upgrade the OS/2 systems in the CIRA computer laboratory to a more modern and supportable operating system (Windows 2000). This upgrade will allow us to continue to distribute data and experimental products to many outside agencies, and to continue our communications and collaborative research projects within and outside of CIRA. In addition, we plan to enhance the local AWIPS capabilities at CIRA, which will allow us to continue to collaborate with the NWS now that their modernization is completed. In particular, we plan to establish mass storage capabilities, which will be necessary to install the AWIPS Warning Event Simulator (WES) at CIRA. The WES adds case study capabilities to AWIPS, and will become an important component of the NWS training program.

No publications to date associated with this project.

ENHANCEMENT OF SATELLITE DATA PROCESSING AND ANALYSIS CAPABILITIES IN CENTRAL AMERICA

Principal Investigators: T. Vonder Haar/M. DeMaria/D. Molenar

Sponsors: NOAA/NESDIS/IA

Abstract - On October 29, 1998, Hurricane Mitch came ashore near La Ceiba, Honduras with high winds and heavy rainfall. Mitch was a large and slow moving storm, and several locations in Central America received extreme amounts of rainfall (up to 36 inches) over a three-day period. This rainfall resulted in more than 9,000 fatalities, and had devastating effects on the infrastructure of several countries in Central America. In response to this disaster, an Interagency Agreement was signed between the U.S. Agency for International Development (USAID) and the U.S. Department of Commerce for Hurricane Mitch Reconstruction Activities in Central America.

As part of the Mitch Reconstruction Activities, the National Environmental Satellite, Data and Information Service (NESDIS) has provided a work plan for the development of a satellite data receiving, processing and analysis capability in Central America. This plan was developed to address deficiencies in the ability to receive and use satellite data identified during site visits to several countries in Central America (Guatemala, Nicaragua, Honduras, and El Salvador) in October of 1999. The NESDIS activities will be implemented by the Office of International and Interagency Affairs in coordination with the NOAA cooperative institute at Colorado State University (CIRA). A GOES ingest system will be installed in Costa Rica by a private contractor, to supply the data necessary for this project. The contractor funding will be provided by NOAA. CIRA will provide RAMSDIS workstations in Costa Rica, Guatemala, Honduras and Nicaragua (two per country) to analyze and display the GOES data that is ingested in Costa Rica. Training sessions in Costa Rica for the participating countries will also be provided by CIRA as part of this project. A CIRA visiting scientist from the Central America region will be supported to improve satellite rainfall estimation techniques for the region.

Alfaro, R. 2003. "Validation of GOES precipitation estimates over Central America." *CIRA Technical Report*, Colorado State University, Fort Collins, CO.

Connell, B. H., and V. Castro. 2001. The use of mesoscale climatologies for monitoring and forecasting weather in Costa Rica. *AMS 11th Conference on Satellite Meteorology and Oceanography*, 157-60.

ENVIRONMENTAL APPLICATIONS RESEARCH

Principal Investigators: T. Vonder Haar/C. Matsumoto

Sponsors: NOAA/FSL

Abstract - This project involves scientific research collaborations performed at the Forecast Systems Laboratory (FSL). On-going collaborations fall under virtually all of CIRA's research themes and cross-cutting areas: Global and Regional Climate Studies; Local and Mesoscale Area Weather Forecasting and Evaluation; Cloud Physics; Applications of Satellite Observations; Air Quality and Visibility; Societal and Economic Impacts; Numerical Modeling; and Education, Training, and Outreach. Much of this research is also relevant to FSL's mission areas and benefits all phases of the Lab's essential functions--Exploratory System Development, Research Applications, System Validation, and Technology Transfer. In addition to NOAA and other government agencies, beneficiaries of many of the collaborative research and development efforts undertaken at FSL under this cooperative agreement include the university community--in particular, Colorado State University--private industry, and the general public.

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EXAMINATION OF LINKAGES BETWEEN THE NORTHWEST MEXICAN MONSOON AND GREAT PLAINS PRECIPITATION

Principal Investigator: W. Cotton

Sponsors: NOAA/OGP

Abstract - This project addresses two areas of the PACS North American Monsoon System (NAMS) initiative: (1) the apparent link between the summer monsoon in Northwest Mexico and precipitation in the U.S. Great Plains and its predictability based on antecedent ocean and land surface conditions; and (2) the influence of regional hydrometeorological land-surface processes on large scale precipitation over North America. Using a global coupled atmospheric-land surface model with two-way nested grids, we examine the following hypotheses for interactions between the northwest Mexican monsoon (NWMM) and precipitation over the Great Plains: 1. A burst phase of the NWMM provides a mid-level source of moisture conducive for heavy precipitation over the Great Plains; 2. the subsiding branch of the NWMM alters the low-level stability over the Great Plains; 3. NWMM bursts generate cloud plumes and excite upper tropospheric jet streaks favoring convection over the Great Plains; 4. NWMM convection influences the moisture carrying capability of the low-level jet over the Great Plains; 5. The onset and strength of the NWMM is modulated by antecedent precipitation, and by SST anomalies over the Pacific basin and in the Gulf of California.

The investigation of these hypotheses will be based on several selected monsoon seasons, wherein anomalously high or low seasonal precipitation, or unusually variable intraseasonal precipitation, over the NWMM region is associated with anomalously high, low, and/or variable precipitation over the Great Plains. Control simulations covering the onset and progression of the entire monsoon season will be run for each selected case, wherein SST and other boundary conditions are based on observed and modeled datasets. A high-resolution soil moisture estimation technique based on antecedent precipitation estimates is an important aspect of these boundary conditions. The control simulations are followed by various model sensitivity experiments with altered SSTs, soil moisture, and diabatic heating over the NWMM region. These will be used to examine the inter-related variability, both interannual and intraseasonal, of the NWMM and precipitation over the central U.S. The use of telescopically nested grids from regional scale to cloud resolving scale will be critical for identifying causal mechanisms for any subtle linkages and sensitivities on thunderstorm and MDS structure.

Saleeby, S. M., and W. R. Cotton. 2001. Examinations of linkages between the northwest Mexican monsoon and Great Plains precipitation: Model configuration and performance for initial test simulations. *AGU Fall Meeting*.

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FAST FLUXES AND SLOW POOLS: INTEGRATED EDDY COVARIANCE, REMOTE SENSING AND ECOSYSTEM PROCESSES DATA WITHIN A DATA ASSIMILATION FRAMEWORK

Principal Investigator: T. Vukicevic

Sponsor: NASA

Abstract - A terrestrial Carbon cycle model is designed to analyze slow and fast processes in conjunction with in-situ measurements and remote sensing observations using data assimilation methodology. The data assimilation methodology is employed to estimate states and parameters that control surface carbon fluxes on time scales from daily to interdecadal. A variety of data assimilation methods are applied to test information content of observations relative to the states and parameters that are represented in the model.

No publications to date associated with this project.

FIELD INVESTIGATION OF SMOKE PLUMES: AEROSOL CHARACTERIZATION AND TESTING

Principal Investigators: J. Collett/S. Kreidenweis

Sponsor: NPS

Abstract - In order to understand the impacts wild and prescribed fires exert on regional visibility in National Parks and other scenic areas, it is necessary to have a fundamental understanding of the aerosol particles present in smoke plumes. It is also important to understand how these particles change as the plume ages and dilutes and as the environmental relative humidity varies. We propose here a field study to characterize the size distribution and hygroscopicity of smoke aerosol in the western U.S. Results from this first investigation will enable evaluation of IMPROVE program assumptions regarding the effect of carbonaceous aerosol on visibility and provide needed experience to plan larger smoke investigations in the future.

Hering, S. V., M. R. Stolzenburg, J. L. Hand, S. M. Kreidenweis, T. Lee, J. L. Jr. Collett, D. Dietrich, and M. Tigges. 2003. Hourly concentrations and light scattering cross sections for fine particle sulfate at Big Bend National Park. *Atmos. Environ.* 37: 1175-83.

Malm, W. C., D. E. Day, S. M. Kreidenweis, J. L. Collett, and T. Lee. 2003. Humidity dependent optical properties of fine particles during the Big Bend Regional Aerosol and Visibility Observational (BRAVO) study. *J. Geophys. Res.* 108: article #4279.

FIRE EFFECTS ON REGIONAL AIR QUALITY INCLUDING VISIBILITY

Principal Investigator: D. Fox

Sponsor: NPS

Abstract - While considerable research has been done on coarse particulate emissions (PM_{10}), there is less information on fine particulates and aerosols that contribute to regional haze. To meet new air quality regulations, there will be a need for improved information on fire emissions and their fate in the atmosphere and for consistent approaches to adequately identify and document the contribution of wildland fire to regional haze. This proposal works to quantify the impacts of smoke on regional air quality, especially regional haze, using tools that will be used by the regulatory community for its development of emissions restrictions on fire and other sources. We will develop a fire smoke emissions inventory for selected periods and regions in support of regional air quality modeling and update the existing NEI emissions inventory to include smoke from fire. We also propose to process the updated fire emissions inventory through SMOKE to generate the necessary input data for regional air quality models, and the third task proposes to add fire emissions to an ongoing regional air quality modeling activity. Finally, we will evaluate results of these simulations against regional measurements of visibility and aerosol species concentrations at IMPROVE monitoring locations throughout the western United States. Models or systems developed will be broadly applicable and acceptable to Federal, State, Tribal, and local wildland and air quality managers. They will also be compatible with the computing capabilities of users (e.g., Federal, State, Tribal, and local managers) through the WRAP website and with implementation in a query-able national data base structure.

Fox, D., M. Barna, M. Sestak, and S. O'Neill. 2002. Community smoke emissions modeling system: tracking fire emissions. *National Park Service Air Quality Summit*.

FUNDS FOR THE COOPERATIVE INSTITUTE FOR RESEARCH PROGRAM

Principal Investigator: T. Vonder Haar

Sponsor: NOAA

Abstract - This project provides for the general operation of the Cooperative Institute for Research in the Atmosphere (CIRA). In realizing its goals, CIRA emphasizes research and graduate education. It has three major purposes: 1) To enhance the effectiveness of research and graduate-level teaching through the close collaboration of both CSU and NOAA; 2) to serve as a focal point for research in the atmosphere on specified programs by scientists from Colorado, the Nation, and the world; and 3) to train personnel for research in the atmospheric sciences and to accumulate experience with multifaceted research programs.

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GETTING READY FOR NOAA'S ADVANCED REMOTE SENSING PROGRAMS: A SATELLITE HYDROMETEOROLOGY (SHYMET) TRAINING AND EDUCATION PROPOSAL

Principal Investigators: B. Connell/M. DeMaria

Sponsors: NOAA/NESDIS

Abstract - To understand the earth's meteorological and hydrological systems and their variability, we need to efficiently use and interpret data from new technologies made available through satellite sensing. New satellite technologies hold the promise of providing data that will allow better assessment of weather parameters. The National Oceanic and Atmospheric Administration's (NOAA) space-based remote sensing program will go through a major increase in observing capability over the next decade. NOAA is preparing for the next generation of both the National Polar-orbiting Environmental Satellite System (NPOESS) and Geostationary Operational Environmental Satellites (GOES-R+) with initial launches scheduled for 2009 and 2012 respectively.

In this project, current satellite training activities are being expanded to develop comprehensive distance learning courses on hydrology and meteorology. The activity in fiscal years 2003-2004 is to prepare a detailed proposal for an expanded Satellite Hydrometeorology (SHyMET) training course.

No Publications to date associated with this project.

GLOBE: INSPIRING THE NEXT GENERATION OF EXPLORERS

Principal Investigator: C. Matsumoto

Sponsor: NASA

Abstract - The GLOBE Program, widely recognized as one of the most successful international K-12 education and science programs of its kind, has grown from an initial 450 participating US schools in 1994 to more than 12,000 participating schools representing 102 countries around the world. UCAR and CIRA have contributed to this program since its inception, and now have partnered to continue managing and enhancing the program. CIRA designed, developed, and implemented the GLOBE website, database, and all of the key data distribution functions. They will continue to support, maintain, and enhance the core hardware and software systems for the program, including the visualization of the GLOBE data through additional incorporation of GIS applications.

No publications to date associated with this project.

Harnessing the Spare Computing Power of Desktop PCs for Improved Satellite Data Processing and Technology Transition

Principal Investigators: A. Jones/T. Vonder Haar

Sponsors: NOAA/NESDIS

Abstract - This is a collaborative project with NESDIS/OSDPD (lead: Ms. Ingrid Guch) to harness the idle computing cycles of desktop PCs for satellite data processing. The work is funded by the NOAA High Performance Computing and Communications (HPCC) Program. Atypical office PC can be idle more than 80% of the time. This work uses an innovative PC-based grid computing system developed at CIRA called the Data Processing and Error Analysis System (DPEAS). The new system enables the previously wasted computing cycles to be used for NOAA data processing efforts in a secure and efficient manner.

Because the hardware, operating system and maintenance of NOAA Office PC’s are already paid for, the cost-savings are significant both in terms of short term (hardware purchases) and long term (staff hours for maintenance and upgrades) costs when compared to an equivalent Linux-cluster of machines. A preliminary cost-benefit analysis compared a cluster of 100 Office PCs to a cluster of 40 dedicated dual-processor Linux machines and found the Office PCs provided a savings of over $1,000,000 during a 5 year period ($2,214 per Office PC per year)

The technology transition process is also now simplified. NOAA and CIRA have had a long-standing cooperative agreement for research in the atmosphere. However, until now, it has been significantly difficult to transfer research at CIRA (and other research institutions) to operations in NOAA. Now, both groups have access to Windows-based office machines that can process satellite data. A single executable from CIRA can be transferred to NOAA in a matter of hours rather than having to rewrite and recompile over a period of weeks or even months, leaving more time for NOAA to understand, optimize and document the code for operations.

Guch, I. C., A. S. Jones, R. Ferraro, S. Q. Kidder, M. Kane, and C. Karlburg. 2003. Harnessing the spare computing power of desktop PCs for improved satellite data processing and technology transition. *Preprints, AMS 19th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology (submitted)*.

Guch, I. C., A. S. Jones, I. Tcherednitchenko, M. Kane, R. Ferraro, C. Karlburg, and S. Q. Kidder. 2003. "Harnessing the spare computing power of desktop PCs for improved satellite data processing and technology transition." *NOAA HPCC Final Report*, National Oceanic and Atmospheric Administration (NOAA).

Jones, A. S. 2002. Cross-sensor challenges. *Report to NESDIS/OSDPD*.

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IMPACT ASSESSMENT OF MEASUREMENTS OF CO2 FROM SPACE, INCLUDING CrIS AND HIRS/(A)MSU

Principal Investigators: G. Stephens/R. Engelen

Sponsors: NOAA/NESDIS

Abstract - The goals of this proposal are assessing the extent to which existing satellite data, HIRS and MSU, and future satellite instruments, CrIS, contribute to our knowledge on CO_2 sources and sinks by flying simulated satellites over a simulated climate, analysis of the information content of the data so produced, and assessment of the impact of such data on our knowledge of the sources and sinks of CO_2.

Christi, M. J. 2002. "Retrieving profiles of CO2 in the lower atmosphere using spectroscopy in the near and far infrared: A preliminary study." Colorado State University.

Christi, M. J., and G. L. Stephens. 2002. Retrieving profiles of atmospheric CO2 in clear sky and in the presence of thin cloud using spectroscopy from the near and thermal infrared: A preliminary study. *J. Geophys. Res. (in Prep)*.

Engelen, R. J., A. S. Denning, K. R. Gurney, and TransCom3 Modelers. 2002. On error estimation in atmospheric CO2 inversions. *J. Geophys. Res.* 107, no. D22: 4635.

IMPACT OF INTERACTIVE VEGETATION OF PREDICTIONS OF NORTH AMERICAN MONSOONS

Principal Investigator: S. Denning

Sponsor: NOAA

Abstract - Representing the strong seasonal and interannual variability of the North American Monsoon (NAM) system and variations in its complex spatial pattern in predictive models is a major challenge. One significant feature of the NAM is its sudden onset and the accompanied rapid greening of vegetation cover. Atmospheric processes can be highly dependent on surface heat and moisture fluxes, which are largely determined by live and dead vegetation, snow cover, and soil-moisture storage. Vegetation plays a major role in determining the surface energy partition and the removal of moisture from the soil by transpiration. We propose using a coupled RAMS and CENTURY modeling system in which both atmospheric variables and ecosystem variables are prognostic variables in the linked system to realistically represent vegetation's response to atmospheric and hydrologic influences, and therefore to achieve at least incremental and perhaps substantial improvement in numerical weather forecasting and climate predictions for North American Monsoon regions.

Lu, L., and J. W. Shuttleworth. 2001. Assimilating NDVI-derived LAI into the climate version of RAMS and its impact on regional climate. *GAPP PI Meeting*.

Lu, L., W. J. Shuttleworth, R. A. Pielke, G. E. Liston, M. Hartman, D. Ojima, W. Parton, and A. S. Denning. 2002. The impact of realistic vegetation description on regional climate simulation. *Mississippi River Climate and Hydrology Conference*.

IMPLEMENTATION OF OPERATIONAL ENSEMBLE INTENSITY FORECASTS

Principal Investigators: J. Knaff/M. DeMaria

Sponsor: Insurance Friends of the National Hurricane Center, Inc.

Abstract - The skill of operational intensity forecasts is considerably less than that of track forecasts (Lawrence and Gross 2001). In recent years, the Statistical Hurricane Intensity Prediction Scheme (SHIPS) has shown some intensity forecast skill (DeMaria and Kaplan 1999). Beginning in the 2001 season, the SHIPS model was generalized to include intensity forecasts out to five days. Preliminary results indicate that the track errors after 72 hours may be the primary limitation in the skill of the intensity forecasts. For example, the forecast track may take a storm over cool water, when the actual track remains over warm water. To provide forecasters with a range of possibilities, a method to provide an ensemble of intensity forecasts from the SHIPS model will be developed.

No publications to date associated with this project.

INTERACTIONS OF THE MONSOONS AND ANTICYCLONES IN THE COUPLED ATMOSPHERE-OCEAN SYSTEM

Principal Investigators: D. Randall/T. Ringler

Sponsor: NOAA

Abstract - The summertime subtropical circulation can be loosely characterized as a sequence of thermal cyclonic flows located predominantly over land and anticyclones located predominantly over ocean. The cyclonic flows over land are often correlated with regions of heavy precipitation which can be labeled as monsoons. The subtropical anticyclones are characterized by relatively dry sinking air and are often accompanied by vast regions of marine stratocumulus clouds. As with the South American monsoon and eastern Pacific anticyclone, subtropical anticyclones are almost always found to the west of monsoon lows. Given the proximity of these two features, it is appropriate to study the monsoon and anticyclone as a single dynamical system. A great deal of attention has been given to the monsoon flows, with a smaller amount of attention given to the summertime subtropical anticyclones. Expect for the recent work of Hoskins et al., almost no attention has been given to how these neighboring large-scale circulations interact. We propose to study the South American monsoon and the subtropical eastern Pacific climate in the single framework of a monsoon-anticyclone pair.

We will study the mechanisms that control the strength of the monsoon-anticyclone system by using a full-physics coupled GCM. We intend to isolate specific feedback mechanisms to ascertain their influence on the amplitude, structure, and variability of the monsoon and the subtropical anticyclone. Specifically, we will focus on four feedback mechanisms. The first is the sensitivity of the monsoon-anticyclone system to enhanced longwave cooling in the region of the anticyclone. The dry sinking air radiates efficiently to space and promotes more sinking. The enhanced sinking leads to a stronger anticyclone and, possibly, a stronger monsoon flow. Closely related to the longwave feedback mechanism is the water vapor feedback mechanism. Even though a relatively small amount of water is present in the upper levels of the subtropical anticyclone, the thermal state of the anticyclone is sensitive to the amount of water present. The water enters the region of the anticyclone via convective outflows and some of these outflows are from monsoon convection. The third feedback mechanism involves the interaction between stratocumulus clouds, the ocean, and the monsoon-anticyclone pair. A variety of mechanisms can affect the extent of stratocumulus cloud cover. These mechanisms include enhanced SST cooling by stress-induced coastal upwelling, and other mechanisms which increase the atmospheric static stability. The final feedback mechanism we propose to study is the influence of available soil-moisture on the structure and amplitude of the monsoon-anticyclone system. To a large extent, the partitioning of the surface energy flux between sensible and latent heat is determined by the

amount of moisture available for evaporation. As a result, the thermal structure of the monsoon and the properties of the low-level monsoon jet are also strongly related to available soil moisture.

Ringler, T. D., and D. A. Randall. 2002. Interactions of monsoons and subtropical anticyclones. *AMS 13th Symposium on Global Change and Climate Variations*.

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT SECTOR PROCESSING CENTER FOR GOES

Principal Investigators: T. Vonder Haar/G. Campbell

Sponsors: NOAA/OGP

Abstract - Continuation of ISCCP data preparation and research associated with ISCCP. The Sector Processing Center work includes completion of the INSAT B2 data and histograms in support of the World Climate Research Programme rainfall estimation project . Continued analysis of ISCCP C1 or C2 products in the context of climate model simulations.

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INVESTIGATIONS OF BOUNDARY CONDITIONS AND NUMERICAL METHODS FOR LITTORAL FLOWS

Principal Investigator: G. Browning

Sponsor: ONR

Abstract - Littoral flows pose a number of challenges for numerical modeling. Because of the scale of these flows, they must be modeled using a fine mesh limited area model that allows open boundaries at the deep ocean interface and for any rivers entering the area of interest. The use of a well-posed differential system is essential in such a model to allow information to be transmitted properly between the deep ocean and rivers on the boundaries of the region of interest and the interior of that region. The proper treatment of other sloping bottom as it approaches the shore also needs to be understood.

Gravel, S., G. L. Browning, F. Caracena, and H. O. Kreiss. 2002. The relative contribution of forcing components and data sources to the large-scale forecast accuracy of an operational model (in prep.). *Tellus*.

INVESTIGATIONS OF STRESS AND TKE PROFILES IN THE CONVECTIVE BOUNDARY LAYER USING WIND AND THERMODYNAMIC RETRIEVALS FROM SINGLE-DOPPLER LIDAR DATA

Principal Investigator: R. Newsom

Sponsor: NSF

Abstract - Vertical profiles and budgets of turbulence kinetic energy (TKE), and to a lesser extent of the turbulent momentum flux or stress, have received considerable attention for the barotropic convective boundary layer (CBL) and for the neutral boundary layer under stationary, horizontally homogeneous conditions. This proposal is to apply to the study of the CBL new technology and new analysis procedures that have the potential to address a wider range of conditions. The plan is to first apply these techniques to the cases that have been studied, i.e., strongly convective and neutral, and then to begin building a database with which to broaden to other conditions. In addition to these profiles and budgets, the kinematics and dynamics of flow features (fronts, dust devils, terrain-forced updrafts or thermals, cloud updrafts or downdrafts, boundary-layer coherent structures, etc.) of opportunity that occur while taking data will also be studied.

The new technology is a scanning Doppler lidar, the High-Resolution Doppler Lidar (HRDL) designed by NOAA/ERL's Environmental Technology Laboratory (ETL) for boundary-layer work. The new analysis techniques are the four-dimensional data assimilation (4DDA) adjoint retrieval algorithms that have been developed for Doppler radar. These procedures produce a 'grid volume' of the 3 velocity components and the thermodynamic variables (p and T_v) from repeated volume scans of the radial wind component u_r. Both have been proven, and what remains is to blend the two and adapt the retrieval algorithms to use lidar data.

Once this is accomplished the technique will be applied to real lidar datasets, which are either existing or will be obtained at no additional cost to this project. The first goal of these studies is as a proof of concept, to verify the retrieved wind and temperature fields. Once established, these techniques offer a powerful tool for understanding the dynamics of the boundary layer as well as other small-mesoscale flows. The second goal is to use the retrieved data fields to study the turbulence properties of the CBL under the various conditions encountered and to study the dynamics of the features of opportunity.

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MONITORING AND MODELING ISOTROPIC EXCHANGE BETWEEN THE ATMOSPHERE AND THE TERRESTRIAL BIOSPHERE

Principal Investigator: S. Denning

Sponsors: NOAA/OGP

Abstract - The concentration and isotopic composition (13C, 18O) of atmospheric CO2 are key variables used in top-down analysis of the global carbon cycle. Isotopes in particular play a key role in distinguishing ocean from terrestrial sinks. Recent studies indicate that on a regional terrestrial basis it should be possible to further partition among landscape elements using isotope analyses. To better understand terrestrial carbon cycle dynamics, we have initiated a modeling and measurement program focused on carbon and oxygen isotope exchange by terrestrial ecosystems. We are conducting this research at the WLEF tower in northern Wisconsin, where long-term atmospheric measurements of CO2 are already underway by NOAA investigators, and in surrounding forest ecosystems.

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NESDIS/CIRA POSTDOCTORAL PROGRAM

Principal Investigator: T. Vonder Haar

Sponsors: NOAA/NESDIS

Abstract - Program to support CIRA Postdoctoral Fellows working at NOAA/NESDIS

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PARAMETERIZING SUBGRID-SCALE SNOW-COVER HETEROGENEITIES FOR USE IN REGIONAL AND GLOBAL CLIMATE MODELS

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Sponsor: OGP

Abstract - To improve the depiction of winter land-atmosphere interactions and feedbacks within regional and global climate models, we are developing a snow-cover submodel that explicitly includes the influence of subgrid-scale snow-cover variability. A primary objective of this study is to improve our understanding and ability to describe and model the complex interactions among the atmosphere, snow and land during winter and spring seasons, within the context of climate models. To accomplish this we have implemented a climate version of the Regional Atmospheric Modeling System (RAMS), developed at Colorado State University, for a domain which includes the Rocky Mountains and Central States. The research takes advantage of recent improvements in the model's ability to perform full annual integrations, and makes additions which are designed to improve the model's representation of relevant snow-related processes, such as appropriate energy flux partitioning during the melt of patchy snow covers, and the relationships between melt and subgrid-scale snow distributions. The snow submodel also takes advantage of remotely-sense snow-cover distribution products produced by the NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC). In addition, the submodel is formulated to assimilate future snow-distribution data sets generated as part of the SNOMAP algorithm being developed to map high-resolution (500m) daily global snow cover using the Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS). This research is expected to lead to Substantial improvements in gridscale and subgrid-scale representations of atmospheric and snow-related processes within regional and global climate models.

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PRECIPITATION AND SEDIMENT TRANSPORT IN THE RIO PUERCO BASIN

Principal Investigators: W. Cotton/T. McKee/J. Ramirez

Sponsor: USGS

Abstract - Colorado State University (CSU) is performing cooperative research with the U.S. Geological Survey (USGS) to improve quantitative estimates of flash flooding, erosion, and sedimentation transport in the Southwestern United States. In the short term, flash flood events are direct hazards to people and structures; in the longer term, their cumulative effects alter hydrological and ecological conditions, frequently harming local agriculture and incurring substantial civil works costs. The research is designed to improve the capability to assess short-term hazards and longer-term risks to hydrologic, ecological, and civil-works assets, particularly under condition of varying climate.

Flash-flood generation and associated erosion and sediment transport involve complex interactions among meteorology terrain, vegetation, and water transport. CSU has unique ability to assist USGS in developing quantitative descriptions of these components and their interactions; among CSU's unique assets are 1) interpretation of cloud heights and extent in terms of precipitation distribution, 2) models of the movement of water and sediment on the land surface, 3) models of the dependence of vegetation on grazing and on meteorological and soil conditions, and 4) the RAMS model to simulate large rainstorms.

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RESEARCH TO IMPROVE TROPICAL CYCLONE INTENSITY ANALYSES AND PREDICTIONS USING SATELLITE DATA

Principal Investigators: T. Vonder Haar/M. DeMaria

Sponsors: NOAA/USWRP

Abstract - Over the past several years, the CIRA Regional and Mesoscale Meteorology (RAMM) Team has performed research under funding from NOAA's Severe Weather Prediction Initiative (SWPI). Efforts have focused on the use of satellite data for mesoscale analysis of high-impact weather events, and on forecast product development. Beginning in 2000, the SWPI program was combined with the ongoing U.S. Weather Research Program (USWRP). For 2001-2002, contributions to the Joint Hurricane Testbed (JHT) effort have been emphasized by the USWRP. Two NESDIS/CIRA research projects were ranked as high priorities for the JHT. These included research related to improvements to the operational Statistical Hurricane Intensity Prediction Scheme (SHIPS) using satellite altimetry and GOES data, and the development of an Advanced Microwave Sounder Unit (AMSU) algorithm for tropical cyclone intensity and size estimation. The second project is a joint effort with the Cooperative Institute for Meteorological Satellite Studies (CIMMS), located in Madison, Wisconsin.

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THE RESPONSE OF NORTH AMERICAN MONSOON TO BOUNDARY AND REGIONAL FORCING MECHANISMS AS SIMULATED BY CLIMRAMS

Principal Investigators: R. Pielke/T. McKee/G. Liston

Sponsors: NOAA/OGP

Abstract - The principal control on warm season precipitation in the western U.S. is the North American Monsoon (NAM). We have confirmed that a relationship exists between the NAM and the El Nino Southern Oscillation (ENSO) and the North Pacific Oscillation (NPO). Time-evolving daily Z-scores of moisture flux convergence and 500 mb height have been correlated with a new SST index that relates the combination of temporal variability of ENSO and NPO. New time-evolving regional precipitation indices for the Great Plains and southwest were also correlated with the index. These analyses show that the combination of ENSO-NPO favor the large-scale circulation response of the Pacific Transition pattern. Either a rough or ridge is centered in the vicinity of the northern Rockies and Great Plains. Whether a trough or ridge occurs determines the direction of moisture transport from the Gulf of California and Gulf of Mexico sources; either to the Great Plains (El Nino, high NPO) or to the southwest (La Nina, low NPO). There is a statistically significant response in moisture flux convergence and precipitation in these regions. These responses are most likely near NAM onset and diminish in the latter part of the summer. At this time the large-scale circulation may be affected by tropical systems or surface moisture feedback, or may undergo a transition to a winter ENSO regime. The proposed research will provide insight into the boundary and regional forcing on the NAM and how these factors vary in importance over the summer season. More important, it will also provide substantial socioeconomic benefits through improved understanding of the interrelationships between summer climate and environmental extremes such as droughts and floods.

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THE ROLE OF ATMOSPHERIC WATER CONTENT IN CLIMATE AND CLIMATE CHANGE (CLOUDSAT)

Principal Investigators: G. Stephens/T. Vonder Haar

Sponsors: NASA/Goddard Space Flight Center

Abstract - CloudSat is a pathfinder mission designed to provide the information needed by Numerical Weather Prediction (NWP) models and Global Circulation Models (GCMs) to validate and improve their predictions of clouds. This new information about the vertical distribution of cloud systems and their ice and water contents cannot be obtained from either existing or approved future spaceborne measurements. CloudSat will provide measurements of those properties of clouds that are directly predicted by NWPs and GCMs. In addition, CloudSat will provide the quantitative measurements of optical depth, layer thickness, base height and ice and liquid water contents of clouds, facilitating accurate determination of the radiative properties of clouds and their roles in the radiative heating of the atmosphere. The knowledge of this heating is critical to improving understanding of the cloud-climate feedback phenomenon.

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THE ROLE OF STRATOCUMULUS CLOUDS IN MODIFYING POLLUTION PLUMES TRANSPORTED TO THE NORTH AMERICAN CONTINENT

Principal Investigator: S. Kreidenweis

Sponsor: NOAA

Abstract - *Analyze historical IMPROVE data for significant events of transport from Asia to the western U.S*. In particular, evidence of springtime Asian dust transport will be looked for in mineral species concentrations, and signatures from fires (local and long-range smoke transport) will be sought in organic carbon and potassium species.

Participate in DYCOMS data analysis activities. G. Feingold will participate in the Summer 2001 DYCOMS field experiment, and has initiated discussions with data PIs to collaborate on data analyses. The DYCOMS cloud and aerosol microphysics and chemistry data set is expected to be more complete and will include information on aerosol hygroscopicity and precipitation scavenging. We propose to conduct studies of how various types of data that are obtained can be used in the modeling framework, what model features need to be better developed to make full use of the data, and what new data need to be collected in future experiments to help elucidate aerosol processing mechanisms.

Modeling of aerosol processing pathways. Our prior work has focused on the role of clouds in aerosol processing. Heterogeneous chemistry also plays a role in creating mixed aerosols and in modifying the aerosol size distribution and particle lifetime. We will modify our existing codes that simulate aerosol processing to include some key effects from condensation onto aerosol particles and, where appropriate, surface reactions that modify the particles as well.

Involvement in ITCT field project(s), data interpretation and use of modeling. We expect to be fully-involved participants in all aspects of the ITCT experiment planning, conduct, and data analyses. Our specific contribution will be to assist in planning of observation and in data interpretation of aerosol processing as plumes are transported from Asia across the Pacific Ocean to the U.S.

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SEVERE WEATHER RESEARCH

Principal Investigators: T. Vonder Haar/M. DeMaria

Sponsors: NOAA/NESDIS

Abstract - CIRA's efforts under this proposal focus on the utilization of digital satellite data, in conjunction with other modernization era data, to improve weather forecasts for height impact weather. This focus takes on increasing importance with the advent of the new GOES series of satellites, whose dedicated five channel imager provides information at significantly greater temporal and spatial resolutions. Activities undertaken here will help improve fundamental understanding of mesoscale weather systems, will continue technique development using satellite and conventional data sources, and will demonstrate in both a research and operation mode improved prediction capability as a part of this research. The activity at CIRA will address portions of the USWRP's Initial Scientific Foci of studies related to: a) importance and mix of observations; b) quantitative precipitation forecasting; and c) hurricane forecasts near landfall. The CIRA effort will also continue to further the original goals of the Severe Weather Prediction Initiative of training forecasters (and researchers) in the use of GOES data for mesoscale weather prediction. For example, CIRA developed a system that allows for the display and analysis of digital satellite imagery and selected field sites. This system, known as RAMSDIS (RAMM Advanced Meteorological Satellite Demonstration and Interpretation Systems), is a prototype satellite imaging system which allows for menu-driven collection, display and manipulation of full-resolution digital satellite imagery. The system is allowing for interaction between RAMM/CIRA and NWS field offices (as well as selected ERL sites) in a virtual laboratory atmosphere. Techniques and algorithms developed at RAMM/CIRA are being tested and critiqued by both the research and operational community via this system, which is leading to technique and algorithm improvements. Many of the findings regarding the application of satellite data to the problem of short range severe weather prediction -- findings which resulted from research performed under the Severe Weather Prediction Initiative -- are now being utilized routinely by National Weather Service forecasters that have access to the RAMSDIS. CIRA has also taken the lead in providing satellite support to the Fronts and Atlantic Storm Track Experiment (FASTEX), and, more recently, the Pacific Landfalling Jets (PACJET) experiment. Investigations are also under way that make use of data from NOAA's polar orbiting satellites, with emphasis on the Advanced Microwave Sounder Unit (AMSU).

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SOCIAL SCIENCE RESEARCH SUPPORT FOR IMPLEMENTING ADVANCED HYDROLOGIC PREDICTION SERVICE OF NOAA'S NATIONAL WEATHER SERVICE

Principal Investigators: T. Vonder Haar/S. Deo

Sponsors: NOAA/NWS

Abstract - The Cooperative Institute for Research in the Atmosphere (CIRA) at the Colorado State University is working with the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service Hydrologic Services Division in implementing Advanced Hydrologic Prediction Service through social science research in the areas of communication of scientific information, design of data graphics, user response evaluation, structure of information on the web, and training.

This research began in 2000 as a demonstration project to show how social science input can provide better understanding of the processes of implementation, coordination, and communication to the hydrologists in the field offices in the Central Region. Currently the work continues in close consultation with the Central Region and the headquarters. Over the last two years the social input has expanded to the areas mentioned above and other layers in the NWS organizational structure.

Publications consist of presentations to scientific, sociological, and hydrologic professional organizations.

STATISTICAL ANALYSES RELATED TO AIR QUALITY AND ATMOSPHERIC VISIBILITY

Principal Investigator: H. Iyer

Sponsor: NPS

Abstract - This research involves cluster analysis of back-trajectories and cluster relationships with aerosol concentrations at receptor sites; formulation of finite population models for air quality data and associated analysis methods; and data analyses for the Mojave Project.

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STOCHASTIC MODELING, SIMULATION AND FORECASTING OF HYDROMETEORLOGICAL PROCESSES

Principal Investigator: J. Salas

Sponsor: NOAA

Abstract - The stochastic characteristics of the Great Lakes Net Basin Supplies (NBS) have been shown by many hydrologists to be quite complex. They include spatial and temporal variability with important high and low frequency components and possibly non-stationary, in addition to the usual seasonality (periodicity) and variance-covariance properties. A number of approaches has been suggested in the past decades for stochastic modeling and simulation of the NBS of the Great Lakes system. Alternative models and modeling schemes for single-site and multi-site data; models for annual, monthly, and quarter-monthly time scales; and temporal and spatial disaggregation models have been used with various degrees of success. Also well known models such as autoregressive (AR), AR with moving average terms (ARMA), and their multisite versions thereof have been utilized. The main objective of the study proposed herein is to develop a multivariate shifting level model at the annual time scale so that it can be capable of simulating annual series of NBS at more than one site. The multivariate model will be contemporaneous in that only lag-zero cross-correlations will be explicitly preserved and it will include a direct persistence feature that is beyond the persistence that is normally induced by the shift. In addition, the model will have the flexibility of using shifting levels at a number of sites while other sites can be modeled based on ARMA models. Furthermore, the main approach for parameter estimation will be the method of moments.

No publications to date associated with this project.

SUPPORT OF THE VIRTUAL INSTITUTE FOR SATELLITE INTEGRATION TRAINING (VISIT)

Principal Investigators: T. Vonder Haar/M. DeMaria/D. Lindsey

Sponsors: NOAA/NWS/OCWWS

Abstract - The purpose of the VISIT program is to provide remote education and training to NWS forecasters on the utilization and integration of modernized data sources. These efforts are aimed at meeting the objectives stated in the NWS Office of Meteorology Strategic Plan, which includes the incorporation of new advances in science and technology into the forecast process. CIRA's efforts under VISIT are also a component of the training and advanced product development effort as stated in the GIMPAP proposal.

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TECHNOLOGICAL TRANSFER AND VALIDATION OF THE CIRA SCHEME FOR THE TROPICAL RAINFALL POTENTIAL (TRAP) TECHNIQUE

Principal Investigator: S. Kidder

Sponsors: NOAA/NESDIS/ORA

Abstract - As discussed by Kidder et al. (2001a), heavy rainfall from landfalling tropical cyclones is a major threat to life and property. Rappaport (2000) found that in the contiguous United States during the period 1970-1999, freshwater floods accounted for more than half of the 600 deaths directly associated with tropical cyclones.

Forecasting rainfall from landfalling tropical cyclones is a difficult task. While the storm is offshore, few rainfall observations are possible, and initializing NWP models with sufficient details of the storm so that accurate rainfall forecasts can be made is extremely difficult. Radar observations of storm rain rate and rain area are valuable, but only when the storm is within radar range of the coast.

Since 1992, the Satellite Services Division (SSD) of the National Environmental Satellite, Data and Information Service (NESDIS) has experimentally used the operational Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) rain rate product (Ferraro 1997) to produce a rainfall potential for tropical disturbances expected to make landfall within 24 hours. The launch in 1998 of the first Advanced Microwave Sounding Unit (AMSU) on the NOAA-15 satellite provided an additional rainfall data source.

The NESDIS/SSD technique (Kidder et al. 2000) was performed manually by an analyst and resulted in a single number called the tropical rainfall potential, defined as TRaP = $R_{av}DV^{-1}$, where R_{av} is the average rainfall rate of the storm, D is the diameter of the storm, and V is the speed of the storm. At CIRA, the technique was improved by automating it and by calculating the rainfall at every point in an image, so that the location as well as the amount of the precipitation could be estimated (Kidder et al. 2001a). NOAA 15 AMSU-A rain rate images were used. The TRaP technique was further improved in 2001 by (1) adding a second satellite (NOAA 16), (2) using higher-resolution AMSU-B rain rate images (Weng et al. 2002), and (3) acquiring more track forecasts to be able to use the technique over a larger fraction of the globe. Kidder et al. (2001b)

A similar but not identical TRaP method was developed by NESDIS/SSD and is now used semi-operationally by analysts to calculate TRaP images. This technique has been quite useful in the preparation of heavy rain forecasts associated with tropical cyclones. The purpose of this proposal is to transfer the CIRA technology into the NESDIS technique to produce an operational technique.

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VALIDATION OF NESDIS MICROWAVE LAND EMISSIVITY MODEL

Principal Investigator: D. McKague

Sponsor: NOAA

Abstract - The NESDIS Microwave Land Emissivity Model (MEM) is used as an important radiative boundary condition for 3D satellite data assimilation within the NCEP Global Data Assimilation System (GDAS). The purpose of this project is to develop advanced techniques to validate the MEM using satellite data sources and other ancillary data sets such as water vapor profiles and land surface temperature fields.

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VARIABILITY AND TRENDS IN GLOBAL PRECIPITATION

Principal Investigators: C. Kummerow/W. Berg

Sponsor: NOAA

Abstract - Predictions of future climate scenarios by General Circulation Models (GCMs) forced with increased concentrations of greenhouse gases all show an enhanced global mean hydrologic cycle. The models also all show increased rainfall variability with a greater occurrence of floods and droughts. A comparison by Soden (2000) of 30 GCMs with satellite derived precipitation estimates from MSU reveals substantial disagreement between the magnitude of predicted variations in tropical mean precipitation and that indicated by the satellite observations.

Even more disconcerting, is a dramatic disagreement in tropical mean rainfall between more recently developed long-term global rainfall datasets with regard to both inter-annual variability and long-term climate trends. Based on striking differences between the time series of mean global tropical rainfall between the Climate Prediction Center's (CPC Merged Analysis of Precipitation (CMAP) and the Global Precipitation Climatology Project's (GPCP) combined precipitation dataset, it is clear that the current long-term global rainfall datasets are inadequate for monitoring variability associated with the El Nino-Southern Oscillation (ENSO) or for detecting trends associated with increases in global mean temperatures.

Because both the CMAP and GPCP merge many of the same component datasets, we propose to examine time-dependent regional biases in the individual retrievals and to determine how they affect the resulting tropical mean rainfall variability. The fact that these biases are both regionally and temporally dependent means that it is not possible to apply simple bias correlations based on a limited region or period of corresponding unbiased rain estimates. Instead, we propose to investigate the underlying physical basis for the various algorithm and sensor-dependent biases using a variety of datasets including recent observations from the Tropical Rainfall Measuring Mission's (TRMM) Precipitation Radar (PR). The ability of the PR to provide information on the vertical structure of rainfall systems will be used to identify and quantify biases in the component satellite retrievals used by the CMAP and GPCP products, and determine how these component biases lead to overall differences in both the inter-annual variability and climate trend.

No publications to date associated with this project.

VISIBILITY INFORMATION EXCHANGE WEB SYSTEMS

Principal Investigator: D. Fox

Sponsor: Western Governors' Association

Abstract - The Visibility Information Exchange Web System (VIEWS) is an online database and website application being developed by CIRA for the five multi-state Regional Planning Organizations (RPOs) that are working to support the U.S. Environmental Protection Agency's Regional Haze Rule guidelines. In 1999, the EPA enacted the Regional Haze Rule in a major effort to improve visibility and air quality in 156 national parks and wilderness areas across the nation. As part of this effort, the RPOs established a contract with the National Park Service's research group at CIRA to develop VIEWS. The primary purpose of the VIEWS system is to aid the five RPOs and the EPA in the analysis and interpretation of air quality data in support of the Regional Haze Rule and visibility improvement in general.

The Visibility Information Exchange Web System consists of a back-end online transaction processing database, a front-end data warehouse, data ingest and analysis software, and an extensive website for accessing and analyzing the data. At present, VIEWS has over six hundred registered users and receives in excess of one thousand unique visitors a month. In addition, over forty different countries are represented in the VIEWS user base, and VIEWS is listed in the top spot on Google.com for "visibility information" and in the second spot for "visibility data." The VIEWS database currently has over eighteen million records in its air quality database, and is growing rapidly. VIEWS can be accessed over the web at http://vista.cira.colostate.edu/views.

No publications to date associated with this project.

GLOSSARY

4-DVAR	4-Dimensional Variational Analysis
AAAR	American Association for Aerosol Research
ACR	Airborne Cloud-Profiling Radar
ADDS	Aviation Digital Data Service
AFGWC	Air Force Global Weather Center
AFWA	Air Force Weather Agency
AGFS	Aviation Gridded Forecast System
AHOS-T	Automated Hydrologic Observing System
AIRMET	Airmen's Meteorological Information Bulletin
AIV	Aviation Impact Variables
AMOS/T	Automated Meteorological Observing System-Telephone
AMS	American Meteorological Society
AMSR	Advanced Microwave Scanning Radiometer
ANL	Argonne National Laboratory
ARTCC	Air Route Traffic Control Center
ASOS	Automated Surface Observing System
ASTEX	Atlantic Stratocumulus Transition Experiment
ATCSCC	Air Traffic Control Systems Command Center
AVARs	Aircraft Vertical Accelerometer Reports
AVHRR	Advanced Very High Resolution Radiometer
AWC	Aviation Weather Center
AWN	Automated Weather Network

AWIPS	Advanced Weather Interactive Processing System
BDI	Bounded Derivative Initialization
BRAVO	Big Bend Regional Aerosol and Visibility Observational Study
CASTNET	Clean Air Status and Trends NETwork
CDoT	Colorado Department of Transportation
CIDOS	Cloud Impact on DoD Operations and Systems
CIRA	Cooperative Institute for Research in the Atmosphere
CLEX	Cloud Layer Experiment
CLW	Cloud Liquid Water
CM	Configuration Management
CMI	Caribbean Meteorological Institute
CNN	Cloud Condensation Nucleus
COAMPS	Coupled Ocean/Atmosphere Mesoscale Prediction System
COARE	Coupled Ocean Atmosphere Response Experiment
COHMEX	Cooperative Huntsville Meteorological Experiment
COMET	Cooperative Program for Operational Meteorology, Education and Training
CONUS	Continental United States
CWB	Central Weather Bureau
D2D	Display 2 Dimensions
D3D	Display 3 Dimensions
DBSS	Direct Balloon Sounding System Project
DMSP	Defense Meteorological Satellite Program
DNS	Domain Name Server

DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DRI	Desert Research Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
EFF	Experimental Forecast Facility
EMDS	Emergency Management Decision Support
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
ETL	Environmental Technology Laboratory
EUMETSAT	European Meteorological Satellite Agency
FAA	Federal Aviation Administration
FASTEX	Fronts and Atlantic Storm Track Experiment
FD	Facility Division
FEMA	Federal Emergency Management Agency
FIRSTT	Facility for Integrated Remote Sensing Technology Training
FSL	Forecast Systems Laboratory
GAC	Global Archive Center
GAINS	Global Air-ocean IN-situ System
GCIP	GEWEX Continental Scale International Project
GCM	Global Circulation Model
GEWEX	Global Energy and Water Cycle Experiment
GFS	Global Forecast System

GIMPAP	GOES I/M Product Assurance Plan
GINI	GOES-1 NOAAPORT Interface
GLOBE	Global Learning and Observations to Benefit the Environment
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
HIRS	High-Resolution Infrared Radiation Sounder
IPC	Inter-Process Communications
IIPS	Interactive Information and Processing Project
ISCCP	International Satellite Cloud Climatology Project
JGR	Journal of Geophysical Research
JPL	Jet Propulsion Laboratory
KDoT	Kansas Department of Transportation
LAN	Local Area Network
LAPB	Local Analysis and Prediction Branch
LAPS	Local Analysis and Prediction System
LARC	Limited Area Remote Collector
LDAD	Local Data Acquisition and Dissemination System
LES	Large Eddy Simulation
LWP	Liquid Water Path
MAPS	Mesoscale Analysis and Prediction System
McIDAS	Man-Computer Interactive Data Acquisition System
MSAS	MAPS Surface Analysis System
NAOS	North American Atmospheric Observing System

NAPAP	National Acid Precipitation Assessment Program
NASA	National Aeronautical & Space Administration
NASDA	National Space Development Agency of Japan
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDDN	National Dry Deposition Network
NEXRAD	Next Generation Weather Radar (WSR-88D)
NESDIS	National Environmental Satellite, Data and Information Service
NFRAQS	Northern Front Range Air Quality Study
NIMBUS	Networked Information Management client-Based User Service
NNT	Nearest Neighbor Tool
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction System
NPS	National Park Service
NPOESS	National Polar Orbiting Environmental Satellite System
NREL	National Renewable Energy Laboratory
NRC	National Research Council
NSF	National Science Foundation
NWS	National Weather Service
OAR	Oceanic and Atmospheric Research
OLR	Outgoing Longwave Radiation
PIREP	Pilot Report
PMS	Particle Measurements Systems

POD-N	Probability of Detection of No-Turbulence
PPP	Parallelizing Pre-Processor
QPE	Quantitative Precipitation Estimates
QPF	Quantitative Precipitation Forecast
RAMMT	Regional and Mesoscale Meteorology Team
RAMOS/T	Remote Automated Meteorological Observing System-Telephone
RAMS	Regional Atmospheric Modeling System
RAMSDIS	RAMM Advanced Meteorological Satellite Demonstration and Interpretation System
RMTC	Regional Meteorological Training Center
ROC	Regional Observation Cooperative
RTVS	Real Time Verification System
RUC	Rapid Update Cycle
SAB	Satellite Analysis Branch
SDD	Systems Development Division
SIGMET	Significant Meteorological Information Report
SMS	Scalable Modeling System
SOCC	Satellite Operations Control Center
SOO	Science Operations Officers
SRS	Scalable Runtime System
SSM/I	Special Sensor Microwave Imager
SST	Scalable Spectral Tool
SSM	Special Sensor Microwave (DMSP)

TIROS	TV and Infrared Radiation Observation Satellite
TKE	Turbulence Kinetic Energy
TPW	Total Precipitable Water
TRACON	Terminal Radar Approach Control
UCAR	University Corporation for Atmospheric Research
WDoT	Wyoming Department of Transportation
WFO	Weather Forecast Office
WV	Water Vapor