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(The above roster, current when document is published, includes government, cooperative agreement, and commercial affiliate staff.)

Figure 1. FSL staff in the lobby of the David Skaggs Research Center.

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Message from the Director

The mission of the Forecast Systems Laboratory is transferring advances in science and technology to the nation's operational weather services. To keep pace with accelerating technological change, FSL has also changed its efforts to anticipate the needs of the nation related to the environment (weather and water information), public safety, and the economy. National priorities also change along with technological change. For example, in recent years there has been increasing emphasis on better short-range weather predictions for air quality, fire weather, and transportation, and the long-term potential of human-induced climate change. The events of 9/11 also resulted in a very strong impetus on homeland security. Although this annual report is mainly devoted to our accomplishments, I would like to use this introduction to mention some of the new technologies that we are pursuing and how they relate to our nation's newest priorities.

Much of FSL's expertise and effort is focused on implementation of the local, national, and global observing systems that NOAA needs to accomplish its mission. Locally, FSL's MADIS (Meteorological Assimilation Data Ingest System) program has become a leader in collecting available surface reporting stations from many different organizations and making them Web-accessible and available at National Weather Service (NWS) offices. We have acquired as many as 14,000 surface stations reporting as part of the MADIS network. Our goal, as always, is to transfer the system into NWS operations. Nationally, studies have been completed that prove the usefulness of the NOAA Profiler Network. Wind profilers improve short-range tropospheric wind forecasts by as much as 30%. This is especially important in severe weather situations such as tornadoes and flash floods. FSL is working with NWS on exciting concepts for the Integrated Tropospheric Observing System over the United States. Globally, FSL has been working with a large group of government, academic, and industry partners to investigate the role that Unmanned Aerial Vehicles (UAVs) could play in improvement of weather and climate understanding, diagnosis, and prediction. The recent emphases on earth observing systems and better measurements of the oceans are examples of areas where UAVs could be helpful.

FSL is playing a major role in improvement of the assimilation and modeling systems used by NWS and others. In collaboration with other organizations, FSL is heavily involved in implementation of the Weather Research and Forecast (WRF) model. This model will be used operationally at the NWS National Centers for Environmental Prediction (NCEP) for the first time next year after many years of development. The WRF model is designed as both an operational model and a research vehicle for the larger modeling community. A crucial part of the WRF development infrastructure is the Developmental Test Center (DTC) in Boulder, which is being implemented in cooperation with the National Center for Atmospheric Research. The FSL Real-Time Verification System is a valuable aspect of the DTC in assessing the various models being tested for WRF. The FSL-NCEP Rapid Update Cycle model is on track to be implemented at 13-km resolution during the coming year, with initial efforts on the future Rapid Refresh model aimed for use in the WRF model. FSL continues to work closely with the Federal Aviation Administration to improve NWS's ability to support aviation weather information needs related to convection, icing, turbulence, and ceiling and visibility.

Our local modeling effort involves conversion of the Hot Start model to the WRF. We are working with the Office of the Federal Coordinator and the Department of Transportation to improve the weather information available to the surface transportation system. It will soon be possible to run large domain (continental U.S.) WRF models at high enough resolutions (e.g., 4-km horizontal) to handle the convection expli citly. We hope to collaborate with other agencies to determine the value of such models. Investigatons are underway on the use of ensembles for both assimilation (the Ensemble Kalman Filter) and for improved short-range weather prediction. Our development of these high-resolution assimilation and prediction models is the key to better public, air quality, and fire weather predictions.

NOAA has made great progress this year in consolidating the management of its research and development supercomputing resources. FSL is participating in plans to acquire supercomputing systems that can be made available to all of NOAA's research and development community. We will be upgrading our current supercomputer with significantly more computational capabilities to meet our goals for the coming year, while phasing with the combined NOAA research and development system in Fiscal Year 2006. The big improvements in short-range weather prediction that can come from ensemble assimilation and modeling are clearly dependent on pushing the envelope in supercomputing.

Another exciting effort that FSL recently initiated is the development of the Advanced Linux Prototype System for AWIPS. This is a prototype AWIPS upgrade that would use Linux-based computers, high speed local and wide area communications, and improvements in display and database software to greatly increase performance and capability of the system. FSL and the NWS Meteorological Development Laboratory have worked for many years on the National Digital Forecast Database, which is now being used nationwide in NWS offices.

Finally, FSL is working on new concepts for highly specific weather warnings. New technology, such as Reverse 911, allows the public to be warned with high specificity in space, time, and required actions, for weather and other hazards. FSL is leading the testing of this technology in the Houston, Texas, area. We are also working with Homeland Security on a system to protect cities during potential terrorist release of toxic gases into the atmosphere. The FX-Connect workstation will allow different participants, such as Homeland Security authorities, NWS forecasters, and local emergency managers to have a common situational awareness during such incidents.

This report describes many other interesting topics, including our progress on the use of Science On a Sphere™ for public education, the many uses of the FX-Net workstation, our international projects, and the expansion of our GPS water vapor network. In reading this annual report, I believe you will see that FSL is applying the best of new science and technology to the problems that our nation faces in a changing world.

A E MacDonald

Alexander E. MacDonald
Director

Figure 2. (a, top photo) Sandy MacDonald (left) discussing activities at FSL with Dr. Ted Kassinger (center), Deputy Secretary, Department of Commerce, and Donald Mock (right), Boulder Laboratories Executive Director. (b, bottom photo) Sandy demonstrating Science On a Sphere™ to Georgia Governor Sonny Perdue at the G8 Summit International Media Center, Savannah, Georgia.

(NOAA Photos by Will von Dauster, FSL)

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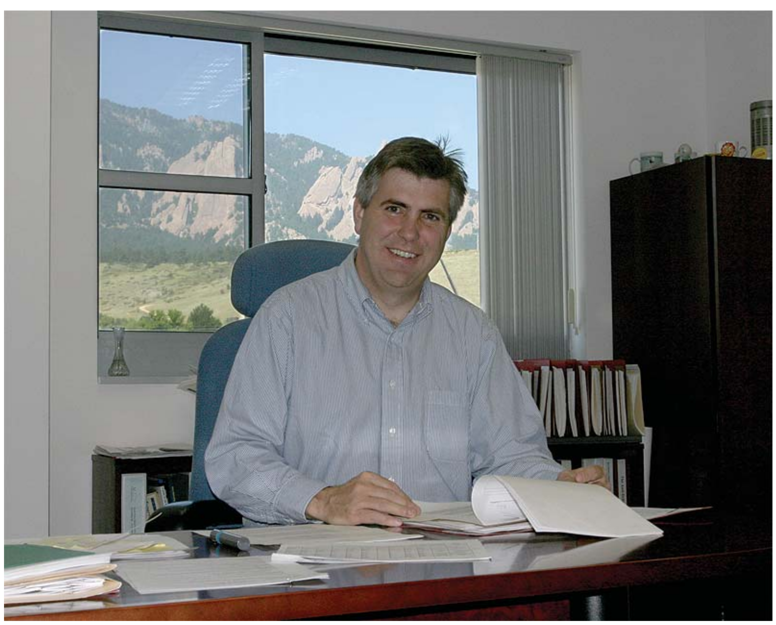


Figure 3. Director for FSL Administration and Research John P. Schneider, hired in 2003.

Background

FSL, established in October 1988, is one of 12 laboratories in NOAA Research under the National Oceanic and Atmospheric Administration (NOAA), within the Department of Commerce. The mission of FSL is to transfer new research findings in atmospheric, oceanic, and hydrologic sciences to the operational elements of NOAA and other domestic and foreign organizations. It conducts programs (involving the following activities) to integrate, evaluate, and apply developments to information and forecast systems.

- Bringing new atmospheric observing systems to maturity
- Assimilation and modeling to improve short-range weather predictions
- Investigating computer architectures as a vehicle for handling the huge computational demands of environmental models
- Developing environmental information systems for a variety of customers within and outside NOAA.

Organization

The **Office of the Director** manages FSL, in addition to special research programs conducted within the laboratory. The **Office of Administration and Research**, under the Office of the Director, provides management support, administrative support led by an Administrative Officer, IT support, contract administration, and visitor and information services. A photo of the new Director of the Office of Administration and Research is shown in Figure 3.

The **Information and Technology Services** (ITS) is also under the Office of the Director. The FSL Chief Information Officer manages the ITS, which is responsible for the computers, communications and data networks, and associated peripherals that FSL staff use to accomplish their research and systems development mission. The FSL Central Facility comprises dozens of computers ranging from workstations and servers to a High Performance Technologies, Inc. (HPTi) supercomputer. The facility contains a wide variety of meteorological data-ingest interfaces, storage devices, local- and wide-area networks, communications links to external networks, and display devices. Over 700 Internet Protocol-capable hosts and network devices include Unix/Linux hosts, PCs and Macintoshes, and network routers, hubs, and switches. These hardware and associated software enable FSL staff to design, develop, test, evaluate, and transfer to operations advanced weather information systems and new forecasting techniques. Data and products are also provided for research activities at other NOAA Research Laboratories, the National Center for Atmospheric Research (NCAR), and university laboratories. Also, in compliance with DOC and NOAA IT security policies and directives, ITS develops and implements the appropriate IT security measures for the FSL network and computers.

Six divisions carry out the research and development activities, as follows.

The **Forecast Research Division** (FRD) is home to most of the research in FSL on short-range forecasting and small-scale weather phenomena. High-resolution numerical models are developed by scientists in FRD to support the NWS and the aviation community with accurate short-range forecasts based on the latest observations. The Rapid Update Cycle (RUC), an operational system within the National Weather Service (NWS), provides hourly updated national-scale numerical analyses and forecasts. The portable Local Analysis and Prediction System (LAPS) can integrate data from virtually every meteorological observation system into a very high-resolution gridded framework centered on any operational forecast office's domain of responsibility. The quasi-nonhydrostatic multiscale model has been developed for use on any scale of motion. Scientists in FRD are also participating in the development of the Weather Research and Forecast (WRF) model, a next-generation mesoscale forecast model and assimilation system that will advance both the understanding and prediction of important mesoscale weather. The Global Air-ocean IN-situ System (GAINS) program is developing a global sounding system, particularly over data-sparse regions, such as the oceans. Dynamical studies of mesoscale processes are conducted to improve understanding of the atmosphere. These studies include analysis of turbulence measurements from special field observations, and the analysis of data from the International H_2O Project (IHOP-2002) to improve understanding of the mesoscale variability of water vapor and apply this knowledge to improving the prediction of warm-season precipitation events. Research-quality datasets are also developed to improve mesoscale analysis, data assimilation methods, and numerical weather prediction systems.

The **Demonstration Division** evaluates promising atmospheric observing technologies developed by NOAA and other federal agencies and organizations and determines their value in the operational domain. Activities range from the demonstration of scientific and engineering innovations to the management of new systems and technologies. Current activities include the operation, maintenance, and improvement of the NOAA Profiler Network (including three Alaska sites), which provides reliable hourly observations of winds from the surface to the lower stratosphere. The Radio Acoustic Sounding System (RASS) technique has been demonstrated and proved beneficial for remote sensing of temperatures at profiler sites. A more recent project, the GPS-Met Demonstration Network, has shown that the addition of ground-based GPS water vapor observations to a numerical weather prediction model improves forecast accuracy, especially under conditions of active weather. Wind and temperature data from Cooperative Agency Profilers operated by other organizations are also collected and distributed for research and operational use.

The **Systems Development Division** works closely with other FSL groups in providing technical expertise on functional specifications for new workstation and interactive display systems. FSL's continuing support to AWIPS includes an exploratory development project called FX-Collaborate (FXC), which provides interactive features such as drawing and annotation tools, a chatroom, and a capability for sharing local datasets between sites. FXC applications include weather forecast coordination between offices, classroom training, briefings from NWS to other government agencies, field experiment support, and research coordination. Other systems include the Quality Control and Monitoring System (QCMS) which provides users and suppliers of hydrometeorological observations with readily available quality control statistics. Two surface assimilation systems, the MAPS Surface Analysis System (MSAS) and the Rapid Update Cycle Surface Assimilation System (RSAS), provide direct measurements of surface conditions and give crucial indicators of potential for severe weather. In addition, the Meteorological Assimilation Data Ingest System (MADIS) provides quality-controlled observations and data access software to university and government data assimilation researchers.

FSL initiated the MADIS project to expand availability of value-added observations such as radiosonde, automated aircraft, wind profiler, and surface datasets. The MADIS API also provides access to all observation and QC information in the FSL database and other supported meteorological databases.

The **Aviation Division** promotes safer skies through improved aviation weather products. In collaboration with the National Weather Service (NWS) and the Federal Aviation Administration (FAA), it provides improved weather forecasting, product visualization, and verification capabilities to civilian and military forecasters, pilots, air traffic controllers, and airline dispatchers. Through research and development of high-performance computing techniques, including distributed computing on geographically and organizationally dispersed computational grids, the Aviation Division also ensures continued improvement of high-resolution numerical weather analysis and prediction systems, and greater efficiency in the use of NOAA's information technology resources.

The **Modernization Division** specifies requirements for advanced meteorological workstations, product and technique development, and new forecast preparation concepts and techniques. It manages the development and fielding of advanced prototype meteorological systems into operational NWS forecast offices, and performs objective evaluations of these operational systems. The Modernization Division plays a major role in development and operational use of AWIPS at over 100 NWS forecast offices. It provides management and direction for research in the latest scientific and technical advances, with special emphasis on their potential application to operational meteorology.

The **Technology Outreach Division** provides for FSL a resource to develop new project opportunities and to promote emerging FSL technologies to NOAA and other government agencies, organizations, and the private sector. In addition to serving in a support mode for FSL, the Technology Outreach Division is responsible for two specific technologies: Science On a Sphere™ and FX-Net. Science On a Sphere™ is a new concept for displaying specific data on a global platform. This system provides an ideal way to educate the public on many important issues, both environmental and economic, that face NOAA, the United States, and the entire world. FX-Net is a PC-based real-time meteorological workstation that makes AWIPS products accessible over the Internet via high and low bandwidth communication lines. Integral to the FX-Net technology is a wavelet compression technique that can reduce and transmit product file sizes with a minimal loss of resolution and also compress model grids with a prescribed maximum allowable error for each model parameter at all grid points. The Technology Outreach Division continues to be involved in several international cooperative technology transfer agreements, such as implementation of a totally updated forecast center at the Central Weather Bureau (CWB) of Taiwan and development of a Forecaster’s Analysis System for the Korea Meteorological Administration (KMA). These multiyear programs progressively benefit from advances in application development.

Staffing

FSL is staffed by a combination of Civil Service employees, Joint Institute staff, Commercial Affiliates, and Visiting Scientists/Guest Workers. The two Joint Institutes that support FSL are the Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins, Colorado, and the Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, Colorado. FSL is also supported by one Commercial Service Affiliate, the Systems Research Group, Inc., Colorado Springs, Colorado. As of October 2003, FSL employees totaled 210 in the following categories: 96 Civil Service (including 4 NWS employees and 1 EPA employee), 54 Joint Institutes (38 from CIRA and 16 from CIRES), 54 Commercial Affiliates, and 6 Visiting Scientists/Guest Workers (Figure 4).

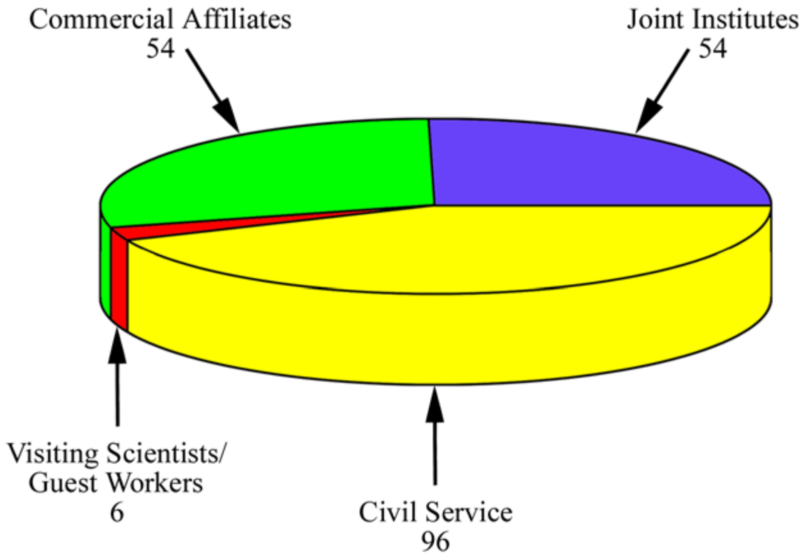


Figure 4. Categories of FSL's 210 employees as of October 2003.

Funding

Funding for FSL is received from a variety of sources. For Fiscal Year 2003, FSL received $26.6M from the following sources: $9.1M – NOAA's Office of Atmospheric Research (OAR) base funds, $11.3M – other NOAA funds, $4.7M – U.S. Government outside NOAA, and $1.5M – Non-Federal (Figure 5). The main components of "other NOAA funds" included $5.0M – NWS, $5.0M toward the purchase of a High-Performance Computer System and for research utilizing this system, and $1.6M for support of other NOAA projects. Other U.S. Government sources of funding included the Federal Aviation Administration (FAA) and Federal Highway Administration (FHWA) from the Department of Transportation (DOT), the Air Force and Army from the Department of Defense (DOD), the U.S. Forest Service (USFS) from the Department of Agriculture (DOA), the Bureau of Land Management (BLM) from the Department of the Interior (DOI), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA). Funding was also received from the Taiwan Central Weather Bureau (CWB), the Korea Meteorological Administration (KMA), the Hong Kong Observatory, the Harris Corporation, Lockheed Martin, and Colorado State University.

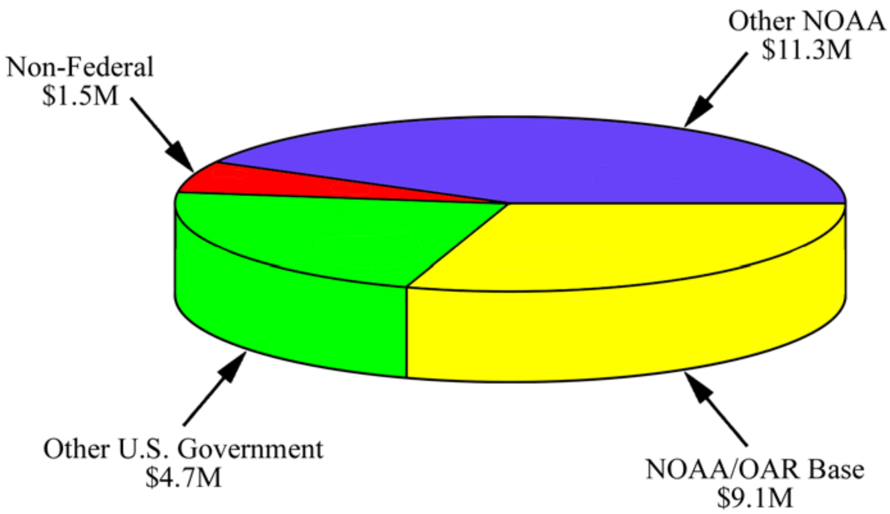


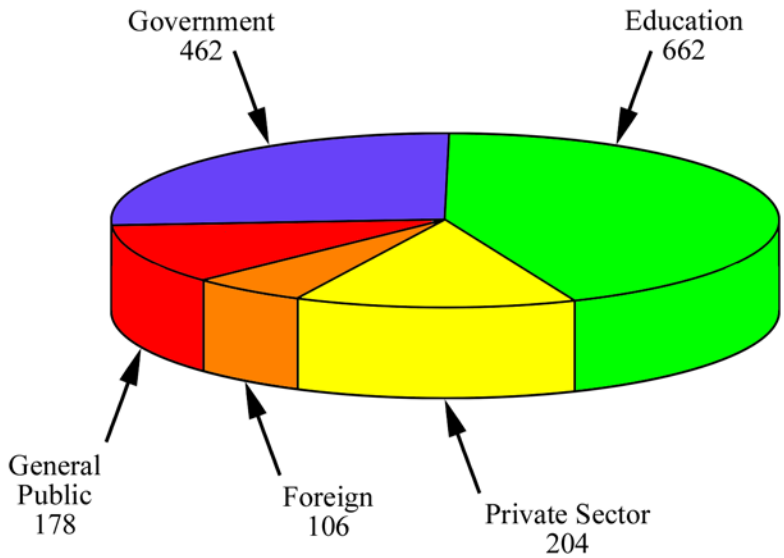
Figure 5. Funding sources totalling $26.6M for Fiscal Year 2003.

Visitors

The Visitor and Information Services program supports NOAA's educational and outreach goals. Tours and visits are scheduled with appropriate FSL staff to match special interests of the visitors. These services are provided for visitors from schools, the general public, government, private sector, and foreign countries. During 2003, the Office of Administration and Research accommodated at least 1,612 visitors (Figure 6), not including visits arranged directly with FSL staff outside this office. The largest category, 662 visitors, came from academia (educators and students). Other visitors included 462 from the federal government, 204 from the private sector, 178 from the general public, and 105 from foreign countries, including China, Australia, Africa, Korea, and Taiwan.

(Anyone interested in visiting FSL may contact Rhonda Lange at 303-497-6045 or by e-mail at *Rhonda.K.Lange@ noaa.gov*.)

Figure 6. Categories of the 1,612 recorded visitors during Fiscal Year 2003.



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Objectives

The Information and Technology Services (ITS) manages the computers, communications and data networks, and associated peripherals that FSL staff use to accomplish their research and systems-development mission. The FSL Central Facility comprises over 100 Dell, Sun Microsystems, Inc., Silicon Graphics, Inc. (SGI) computers ranging from workstations and servers to a High Performance Technologies, Inc. (HPTi) supercomputer. The facility also contains a variety of meteorological data-ingest interfaces, storage devices, including the FSL Mass Store System (MSS), local- and wide-area networks, communications links to external networks, and display devices. Over 600 Internet Protocol (IP)-capable hosts and network devices are connected to the FSL network. They include Unix/Linux hosts, PCs and Macintoshes, and network routers, hubs, and switches. This hardware and associated software enable FSL staff to design, develop, test, evaluate, and transfer to operations the advanced weather information systems and new forecasting techniques.

The group designs, develops, upgrades, administers, operates, and maintains the FSL Central Computer Facility. For the past 23 years, the facility has undergone continual enhancements and upgrades in response to changing and expanding FSL project requirements and new advances in computer and communications technology. In addition, ITS lends technical support and expertise to other federal agencies and research laboratories in meteorological data acquisition, processing, storage, distribution, and telecommunications.

The Central Facility acquires and stores a large variety of conventional (operational) and advanced (experimental) meteorological observations in real time. The ingested data encompass almost all available meteorological observations in the Front Range of Colorado and much of the available data in the entire United States. Data are also received from Canada, Mexico, and some observations from around the world. The richness of this meteorological database is illustrated by such diverse datasets as advanced automated aircraft, wind and temperature profiler, satellite imagery and soundings, Global Positioning System (GPS) moisture, Doppler radar measurements, and hourly surface observations. The Central Facility computer systems are used to analyze and process these data into meteorological products in real time, store the results, and make the data and products available to researchers, systems developers, and forecasters. The resultant meteorological products cover a broad range of complexity, from simple plots of surface observations to meteorological analyses and model prognoses generated by sophisticated mesoscale computer models.

Accomplishments

Central Computer Facility

FSL High-Performance Computing System and Mass Store System – During 2003, the Pentium IV-Xeon Cluster totaling 1,536 CPUs (Figure 7) was placed into production in the Central Facility to support FSL users and other NOAA users outside the laboratory. A 64-bit testbed system was acquired to investigate future technologies that may be available to NOAA in upcoming procurement activities. This testbed comprises 12 dual-processor Intel Itanium nodes and 12 dual-processor AMD (Advanced Micro Devices) Opteron nodes (Figure 8). The testbed, integrated into the SGE (Sun Grid Engine) batch system, is available to the user community.

The RAID (Redundant Array of Independent Disks) system, acquired from the Census Bureau, will be decommissioned. In preparation for this task, the Data Direct Networks (DDN) RAID system, acquired under the current contract, was expanded to provide the capacity previously supplied by the Census Bureau equipment, along with higher reliability and bandwidth.

The High-Performance Computing System (HPCS) provides computational capability for numerous FSL modeling efforts related to the atmosphere, ocean, climate, and air quality. In addition, other NOAA organizations take advantage of the HPCS for activities such as Weather Research and Forecasting (WRF) Model development and testing, North American Observing Systems (NAOS) testing, and high-performance computing software development. The research is carried out by some of the OAR (Office of Oceanic and Atmospheric Research) laboratories, the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP), and several Joint Institutes. The HPCS Management Team conducted many upgrades and enhancements to the system that resulted in a significant improvement in performance. For example, the improved backup performance for the NCEP Rapid Update Cycle (RUC) model is illustrated in Figure 9, which charts the percentage of uptime during 2003 through February 2004.

The reliability and performance of the Mass Store System (MSS) has improved significantly over the past year. The upgrades incorporating IBM Linear Tape-Open (LTO) tape drives coupled with the Advanced Digital Information Corporation's StoreNext software provided a robust system to accommodate the needs of FSL and non-FSL users of the HPCS.

Figure 7. (above) High-Performance Computing System with 1,536 Intel Pentium IV-Xeon CPUs.

Figure 8. (right) HPCS testbed comprising 12 AMD Operton nodes (upper half) and 12 Intel Itanium nodes (lower half).

Laboratory Project, Research, and External Support – FSL's HPCS supercomputer provided computational capability for FSL modeling efforts, high-performance computing software development, and supported numerous other NOAA organizations. More than half of NOAA's 12 Research Laboratories are currently using HPCS resources: the Aeronomy Laboratory (AL), Atlantic Oceanographic and Meteorological Laboratory (AOML), Air Resources Laboratory (ARL), Climate Diagnostics Center (CDC), Environmental Technology Laboratory (ETL), National Severe Storms Laboratory (NSSL), and Pacific Marine Environmental Laboratory (PMEL), and the National Environmental Satellite, Data, and Information Service (NESDIS) National Geophysical Data Center. All HPCS projects are reviewed on the basis of scientific merit and appropriateness for a commodity, distributed-memory machine.

Central Facility Systems, Enhancements and Upgrades – The ITS Systems Administration group consists of six highly trained individuals with more than 60 combined years of experience in systems administration. Each team member is dedicated to customer service and responds to the needs of not only ITS staff but also the entire laboratory. Services include DNS (Domain Name System), E-mail, PC, backup administration; and maintenance of the Central Facility computer systems, which are responsible for most of the data processing within FSL. ITS Systems Administrators provide backup coverage for all other divisions and maintain a 12-hour window of service throughout the day.

During the past year, many changes were implemented within the Central Facility infrastructure. All Hewlett Packard systems and most SGI systems have been retired, with only a few Sun computer systems remaining. Most of the Central Facility processing is now accomplished on Dell hardware running the Linux operating system.

The Systems Administration (SA) staff completed the major project of upgrading all desktop and server systems within ITS to Red Hat Enterprise Linux version 3.0. This time-consuming undertaking was necessary after Red Hat, Inc. discontinued support of its freely available Linux versions 9 and below. This decision prompted in-house testing of other Linux versions to suit FSL's needs, and eventual selection of the best candidate – the WS version (desktop/client) of Red Hat Enterprise 3.0.

With security always a top priority, all ITS Systems Administrators complete 40+ hours of security training each year. They continued to work closely with the FSL IT Security Officer to ensure that all systems maintain a high level of security. The team worked hard to provide resources to ease the transition to a more secure method of data transmission, both internally and externally.

FSL's ability to receive data from external sources is very integral to achieving its mission. The Systems Administration staff continued to seek ways to streamline this process. They set up an external host so that outside users can access an anonymous FTP server to drop off virus-scanned data for FSL scientists to retrieve at their conven-

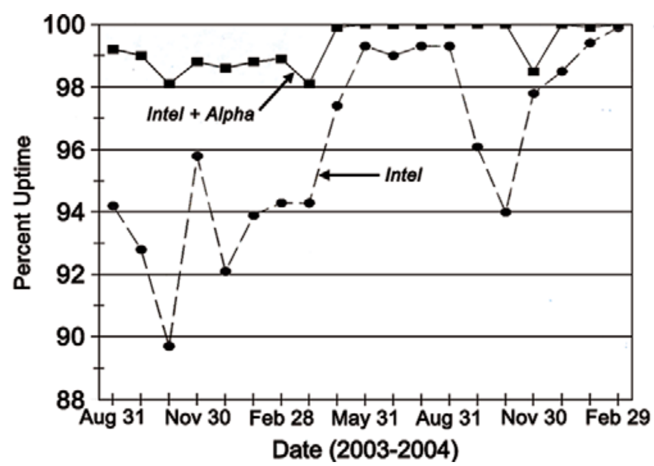

Figure 9. FSL High-Performance Computing System backup performance (31 August 2003–29 February 2004, center of chart) for the NCEP Rapid Update Cycle (RUC) model.

ience. Likewise, data must be easily transferred from FSL to an external system for public distribution. Each dataset is placed on the internal host, and from there, transferred to the external host. Unless changes are made to the file, it is transferred only once to ensure that the data transmission is as efficient as possible.

Managing all FSL source code and home directory backups is the primary responsibility of both the ITS Systems Support Group and SA staff. Together these ITS groups worked with the Systems Administrators in the other six FSL divisions to reduce the average daily backups from 500 Gigabytes to 300 Gigabytes. This was accomplished by backing up only source code and home directory files, not data, which resulted in a net average reduction of 40% in 9 months (Figure 10).

As data requirements increase, FSL is searching for better ways to provide users with more reliable, high-performance access to information. With online data storage a major issue for FSL in 2003, the SA team developed detailed plans for purchasing new, cost-effective storage systems. After evaluating several options, the decision was made to implement storage on Network Appliance (NetApp), NFS (Network File System) servers, and IDE- (Integrated Drive Electronics) based RAID units. Unfortunately, because of a number of failures with the IDE RAID systems, they had to be replaced and supplemented with increased storage capacity of the NetApp servers.

Another accomplishment that helps FSL access data faster is upgrades of one NetApp F740 server and two F760 servers to the NetApp F940 model (Figure 11). These upgrades offer several important improvements. First, the number of NFS operations per second nearly tripled due to faster processors. Second, the network interfaces were upgraded from ATM OC-12 (622 Mbps) connections to Gigabit Ethernet connections. Finally, the total amount of storage was increased by 4.2 Terabytes. Other related tasks begun last year have been completed despite the loss of one Senior Systems Administrator. Through "multitasking," the Systems Adminstration staff have been able to work at peak efficiency, with strong attention to customer service.

Systems Support and Computer Operations – The System Log, maintained by the Systems Support Group (SSG), provides effective intercommunication among the SSG Operators, Data Systems Group, System and Network Ad-

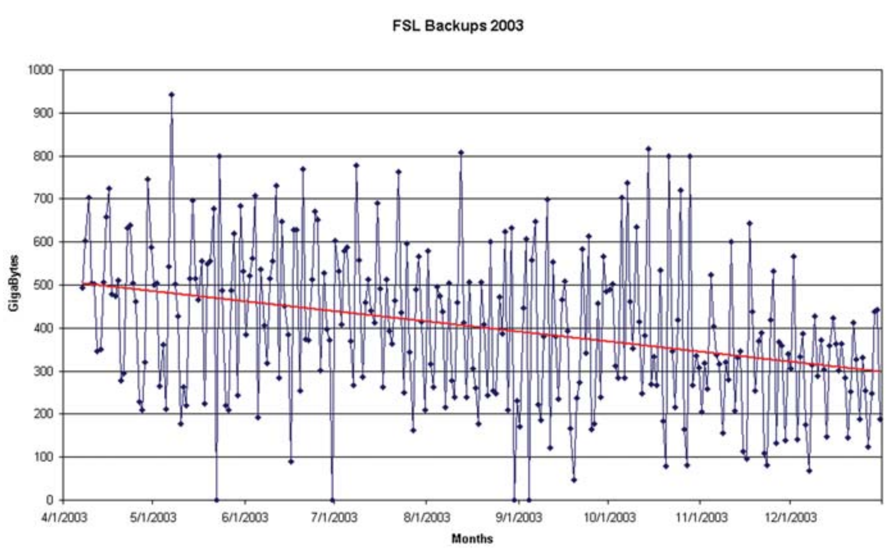

Figure 10. Chart showing a 40% reduction in monthly backups, from April–December 2003, on the FSL Backup System.

ministrators, and others. This, in turn, results in a higher level of service as SSG responds to numerous and varied issues related to the FSL Central Facility. The System Log also provides a means for recording a history of events and tracking procedures used to correct problems. SSG initiated and resolved about 2,500 Log tickets last year, and serviced at least 175 customer FSLHelp requests to complete tasks such as data compilation, basic file update/file restoration, user account management, client addition/deletion from the backup system, and system reboot.

The Web database that documents the procedures for maintaining the FSL Central Facility grew to 150 documents. SSG Operators use this database to efficiently troubleshoot and resolve issues involving, for example, real-time data or Central Facility equipment. The documents are refined and updated regularly in conjunction with new procedures, system changes, and outdated information. The SSG documentation was transferred into the open-source Concurrent Versions System (CVS), which allows more efficient updating, editing, and tracking of the documents.

SSG staff provided 100% computer coverage (all shifts) for the entire year, and accommodated computer system (source code and home directory) backups amounting up to 500 GB of information written each night for about 250 clients. Critical quarterly offsite backups were completed on time. Frequently failing client backups were identified, the cause of failures tracked down, and corrective measures were implemented to reduce future failures. SSG staff also began tracking and recording the daily volume of backups and daily tape usage. When problems arose with the main backup server and/or FSL's four backup robots, each situation was handled promptly.

In coordination with the Data Systems Group, new products and systems were added to the Facility Information and Control System (FICS) monitor. The FICS code and configuration files, support documents, and Help documentation were all updated to support SSG's basic functions: to monitor, troubleshoot, and resolve real-time data issues. Other tools were implemented to ensure consistent support, such as additional links to the FICS monitor to allow quick, consistent generation of SSG Log tickets and notification of data outages. The Data Outage Notification Generator (DONG) form was created and implemented. The Central Facility Data Availability Status Webpage was upgraded to include automated updates to this important customer information source. Two e-mailers (JavaFicsMonitor and Java automatic) were developed and implemented to provide SSG staff instantaneous notification of data outages.

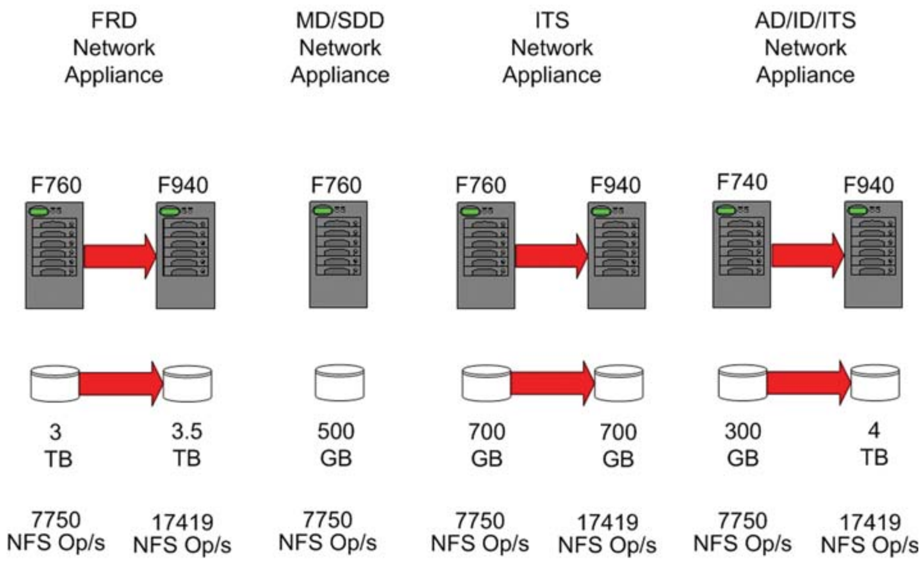

Figure 11. Diagram showing the results of data storage upgrades of the NetApp NFS servers.

To keep updated on the Computer Facility's physical protection systems, all SSG staff received refresher training on the Vesda Smoke Detection System and FM200 Fire Suppression System. The SCADA (Supervisory Control and Data Acquisition System) 3000 Temperature Monitor and Control System continued to be monitored and prompt action was taken in response to system-generated alarms. SCADA temperature set points were updated as required by changing conditions. Web-based and local SCADA software reporting tools (and subsequently documentation) were refined and upgraded to provide more detailed information. The PC on which the SCADA monitoring software runs was upgraded and placed on an Uninterruptible Power Supply (UPS) circuit to ensure continued functioning during power outages. Monitoring software for all facility UPSs was installed on the same PC, and a dual display arrangement was set up to facilitate monitoring of these critical systems.

FSL continued uninterrupted backup of RUC and RSAS products for the NWS National Centers for Environmental Prediction (NCEP), and tracked and responded quickly to all FSL production problems. These activities resulted in reliable delivery of required backup products to NCEP during scheduled backup tests and when unexpected problems occurred.

In support of NOAA/FSL's general computer security initiatives, SSG staff took the NOAA IT Online Security Awareness training and participated in other in-house security training, and also performed required quarterly password changes.

Facility Infrastructure Upgrades – Several significant infrastructure upgrades were completed within the Central Computer Facility to address power, cooling, and communications requirements related to asset protection and safety. Numerous other projects were completed to enhance facility operations and laboratory support.

Wall-mounted telephones were installed near the FM200 Fire Suppression System abort switches in the main computer room, so that the fire-suppression abort switch can be pressed while communicating with emergency personnel after an accidental fire suppression activation. Each phone also has emergency phone numbers posted nearby to address other power, cooling, and safety related concerns.

Communication and presentation capabilities were upgraded, including the Video Teleconferencing (VTC) system at FSL. The National Weather Service had already provided FSL with a VTC system, and then last year, upgraded it. The new system, capable of streamlined multipoint conferences viewable on a dual screen, is shared with other NOAA laboratories within the David Skaggs Research Center, thus saving travel expenses whenever possible.

To upgrade presentation capabilities, a digital satellite television and an audio system were installed in the FSL Weather Forecast Center. The Forecast Center hosts daily weather briefings as well as numerous presentations for visiting dignitaries, academia, and the public/private sector throughout the year. One of the FSL conference rooms was also upgraded with an overhead projector to enhance laboratory-specific presentations and improve collaboration among various groups.

The FSL-owned automated surface meteorological observation station (Figure 12) began delivering data via its Remote Processing Unit (RPU) to the Colorado Department of Transportation (CDOT), where the datasets are processed along with the other CDOT stations deployed throughout Colorado. Data from all stations are then delivered to the NWS Boulder Forecast Office and fed from there into FSL’s Meteorological Assimilation Data Ingest System (MADIS). The observing stations provide continuously updated temperature, wind speed and direction, as well as barometric pressure data every ten minutes.

FSL Network

In 2003, FSL established both a physical and logical network separation from the NOAA Boulder network by replacing the fully meshed ATM (Asynchronous Transfer Mode) uplink between the two organizations with redundant Gigabit Ethernet (GigE) links. This physical path separation of network traffic was required before two new firewall devices could be implemented. The new GigE topology with firewalls allows complete control and visibility of all network traffic in and out of FSL. This new arrangement clearly delineates the logical division of FSL network resources from the NOAA Boulder network for more effective resolution of data flow issues and management of resources, and also provided the structure needed for FSL to physically move publicly accessible resources to a separate, screened subnet. The integrated internal FSL ATM and GigE networks were also fine-tuned. Stability of the multivendor, multitechnology network environments was achieved by tuning the Spanning Tree Protocol configuration for 30 Virtual Local Area Networks (VLANs), and by relocating LAN Emulation Services from ATM/Ethernet ESX3000 edge devices to the ATM ASX1000 core devices. End-of-year funding enabled the upgrade of 10/100 Mbps and GigE port capacities on the network switches that serve two FSL computer rooms. These upgrades accommodated the growing number of servers, and provided redundant high-performance links to the NOAA supercomputer housed at FSL and other high-availability data servers (Figure 13).

The Network Administration team installed an 802.11b wireless network (11 Mbps) that encompasses all FSL office space. This provides network access for roaming government-owned laptops in offices, simplifies connectivity for presentations in conference rooms, and allows FSL visitors temporary Internet access. Wireless connectivity to the FSL network is granted at a point outside the FSL security perimeter, so only external or Internet access is provided by default. To connect to the internal FSL network, a secure Virtual Private Network (VPN) session must be established. In a demonstration to FSL staff, the wireless network performed superbly in looping weather model displays, even over an encrypted VPN session. Remote access to FSL was upgraded to include redundant VPN servers and redundant authentication servers. These upgrades were required to meet the growing need for reliable remote access with encrypted authentication through a centralized management interface. The Network Administration team provided user support for the expanded remote access capa-

Figure 12. Automated surface meteorological observing station at the FSL campus in Boulder, Colorado.

bilities through user awareness presentations, hands-on training, and extensive user documentation that was developed and posted on the FSL Intranet for internal downloading and viewing. All FSL remote access methods and procedures were verified to be in compliance with DOC and NOAA remote access policies. Network services were provided for 187 FSL staff and two computer rooms. Tables1 and 2 show that network device CPU utilization and port capacity were at reasonable levels, allowing room for node or performance growth as needed. Table 3 indicates that the maximum and minimum network link utilization also has ample room for bandwidth growth.

Table 1. Network Device CPU Utilization

Device	CPU Utilization
GigE Core (Cisco)	10%
ATM Core (Marconi)	25%
ATM/Ethernet Edge	20%

Table 2. Network Port Capacity

	Ethernet	Port Capacity
Service to	10/100BT	GigE
2B201 Computer Room	67%	53%
2B518 Computer Room	73%	46%
ITS/AD	61%	–
FRD/AD	67%	–
OD/A&R	67%	–
SDD/MD	70%	–
TOD	67%	–

Table 3. Network Link Utilization

Link	Maximum (Mbps)		Average (Mbps)	
FSL WAN Uplink	79	8%	18	2%
DMZ	55	6%	15	2%
GigE Core	106	11%	50	5%
ATM Core	112	18%	49	8%
ATM/Ethernet Edge	104	17%	30	5%
All NOAA Boulder	82	8%	30	3%

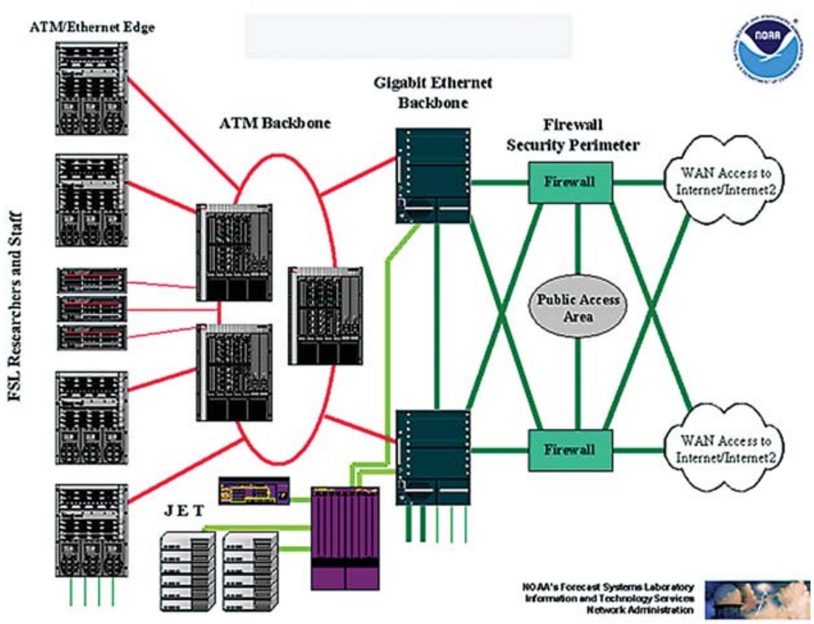

Figure 13. 2003 Network configuration.

Compared with other NOAA Boulder organizations, FSL remains the leader in network traffic utilization, at 64% for all traffic. The statistics in Table 4 show the top NOAA Boulder users, and traffic categorized by redundant WAN paths out of the NOAA Boulder site. Table 5 shows the top protocols used for connectivity to public and commercial sites (Internet) versus connectivity to government, educational, and research-oriented sites (Abilene).

Table 4. Top NOAA Boulder WAN Users

Top Labs	To Internet	To Abilene (I2)
FSL	27%	37%
NOC	22%	< .1%
NGDC	18%	5%
CDC	10%	33%
AL	1.5%	11%

Table 5. Top Protocols for NOAA Boulder WAN Traffic

Protocols	To Internet	To Abilene (I2)
LDM	6%	21%
HTTP	42%	12%
FTP	12%	43%

FSL benefitted significantly from WAN link changes instituted at NOAA Boulder last year. By changing one Internet Service Provider from MCI to ICG (InterCom Group Communications), FSL was able to save $22.5K in Fiscal Year 2003, and an estimated $82K in Fiscal Year 2004 for an equivalent total amount of Internet bandwidth (~40 Mbps) and service. In addition, by taking advantage of the dark fiber available in the Boulder Research and Administrative Network (BRAN), NOAA Boulder was able to upgrade its primary link to the Denver Front Range GigaPop from 155 Mbps to 1 Gbps, and the secondary MCI WAN link from 18 Mbps to the ICG 155 Mbps link through the University of Colorado.

Information Technology (IT) Security

A major IT Security activity during 2003 was the purchase and installation of Enterprise-class firewalls, selected on the basis of performance and reliability. These firewalls were installed in a redundant configuration for high availability. The initial performance test results were very promising: 1) this solution should accommodate FSL's aggressive growth in network capability for years to come, and 2) the physical separation of FSL's network into distinct security zones makes it possible to implement more advanced architectural goals.

Data Acquisition, Processing, and Distribution

The ITS Data Sytems Group continued to design and develop real-time meteorological data acquisition and processing systems required by FSL projects and data users. 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. These data services are provided to scientists and developers who use them in various modeling, application, and meteorological analysis/forecast workstation research and development activities. Users accessed raw, translated, and processed data according to their needs.

Data Acquisition and Distribution – Data received from operational and experimental sources included:

- National Weather Service –
  - – NWS/NCEP, including the Aviation Weather Center (AWC)
  - – WSR-88D narrowband and wideband Doppler radar data
- Aeronautical Radio Inc. (ARINC)
- Weather Services International Corporation (WSI) High-Capability Satellite Network (HCSN) supplying WSI NOWrad and NEXRAD products
- FSL Demonstration Division Profiler
- Geostationary Operational Environmental Satellite (GOES-10 and GOES-12)
- National Center for Atmospheric Research (NCAR)
- Meteorological Assimilation Data Ingest System (MADIS) data providers

Distributed datasets included:

- GOES imagery to the NOAA Environmental Technology Laboratory (ETL)
- Wind profiler data to the University Corporation for Atmospheric Research (UCAR) Unidata program
- MADIS data to many clients, including government agencies and universities

Data Processing Upgrades –

- Transferred the Aircraft Communication Addressing and Reporting System (ACARS) ingest system from the X.25 to the TCP/IP-based method.
- Implemented the Object Data System (ODS)-based GOES GVAR data acquisition and processing. Following the replacement of the legacy software, the new ODS method enabled the GOES acquisition system to be transferred to a Linux host, facilitating the decommissioning of two legacy IRIX computers.
- Introduced a generic BUFR (Binary Universal Form for the Representation of meteorological data) translation library to handle BUFR within ODS.
- Upgraded the ODS GRIB handling code to accommodate the format of the new GRIB Edition 2 by the World Meteorological Organization (WMO) and its implementation by the NWS.
- Purchased and implemented a second Planetary Data Incorporated (PDI) NOAAPORT Receive System (NRS) for NOAAPORT data acquisition redundancy.
- Redesigned the configuration of real-time "point data" processing software and eliminated the need for the legacy "Process Manager" and "Executioner" process-activation packages.
- Built and configured Open Radar Product Generator (ORPG) using Linux/GCC, which will produce derived radar products from the Level-II radar data.
- Continued to extend the use of CVS for maintaining and installing the run-time configuration and executable files for over 40 Central Facility hosts.

Project Support –

- Continued to support highly reliable backup of FSL-generated Rapid Update Cycle (RUC) and RUC Surface Assimilation Systems (RSAS) products for NCEP. The data transfer mechanism was moved to a high-availability server configuration.
- Implemented new methods to acquire and distribute MADIS Local Data Acquisition and Dissemination System (LDAD) datasets to improve troubleshooting and system maintenance. Improved the method for transferring the NWS Cooperative Observer Program (COOP) dataset into the MADIS LDAD system. Devised an improved file transfer method to help reduce throughput latency. Added a new radiometer dataset to the MADIS data-acquisition system. Initiated plans for transferring the MADIS system to a high-availability Linux arrangement and for transferring the MADIS FTP distribution system to an external application hosting service computer.

• Continued collaboration and support for the FX-Net project by helping project staff set up new data servers and add them to FICS monitoring. Assisted with getting new datasets (AVN global and WRF Chemistry) displayable on FX-Net. Performed activities related to real-time troubleshooting and planning for support of the National Interagency Fire Center (NIFC) during the fire season.
• Completed migration of the Central Facility Advanced Weather Interactive Processing System (AWIPS) data server from Hewlett Packard (HP) to Linux, along with all LDAD processing.
• Assisted with the set up of a Northrop Grumman Information Technology (NGIT) NOAAPORT Receive System (NRS) Communication Processor (CP).
• Wrote tools for packaging and saving AWIPS cases to the FSL StorNext Mass Store System (MSS), and copied old cases from the Unitree MSS to the StorNext MSS.
• Supported the National Weather Service (NWS) implementation of compressed NOAAPORT image data.
• Transferred Temperature and Air Quality (TAQ) and International H2O Project (IHOP) datasets to an FTP server to ensure continued access to these data by FSL scientists and their external collaborators.
• Supported the Central Weather Bureau (CWB) of Taiwan in proposing, developing, and implementing a system to acquire and process GOES-9 data. Worked with CWB counterparts to install and configure a highly successful system at CWB patterned after the FSL-developed GOES Data Acquisition system.
• Initiated work to implement a Unidata Local Data Manager (LDM) server at FSL to provide selected NOAAPORT datasets to CWB.
• Replaced the FTP method with a new, more reliable LDM-based data acquisition and processing method for acquiring turbulence datasets from NCAR/RAP for the Real-Time Verification System (RTVS) project.
• Configured the FSL NOAA Operational Model Archive and Distribution System (NOMADS) data servers to provide real-time RUC and MADIS datasets via the Open-source Project for a Network Data Access Protocol (OpeNDAP).
• Built AWIPS review cases for the Tropospheric Airborne Meteorological Data Reporting (TAMDAR) project, including Hurricane Isabel and the March 2003 Front Range blizzard.

Facility Information and Control System (FICS) –
• Implemented a method to emulate the FSL High-Performance Computer Activity Monitor within FICS.
• Implemented a System Load Monitor to alert operations staff to potential problems on ~35 real-time hosts.
• Began transferring FICS to a high-availability Linux system.
• Added FICS software into the Concurrent Versions System (CVS) repository versioning system.
• Added monitoring of LDAD data by provider.

FSL Data Repository (FDR) –
• Implemented new ODS-based methods for transferring real-time datasets to the Mass Store System (MSS). Configured and began operating the new system, which captures all NOAAPORT and ACARS data, as well as many other real-time datasets from the /public NFS. This new system is a major improvement over the previous data-saving method, because it tars and compresses multiple data files before they are moved to the MSS, thus greatly reducing the number of individual files transferred.

Web-Related Services – Relocation of the FSL Web Manager to the ITS Data Systems Group (DSG) substantially enhanced the Web support provided for the laboratory. For the first time, a list of all FSL Websites was created that includes pertinent information such as where each Website resides (name of machine), whether it is protected, and the name of the person responsible for maintenance of its contents. This information gathering process also increased communication with all FSL Web authors and raised many other related issues for discussion.

Improvements to the quality and usability of the entire FSL Website included redesigning and/or updating all division Websites, adding a user feedback form, updating the FSL Publications Webpages, and rewriting the FSL staff listings using the Lightweight Directory Access Protocol (LDAP). Other significant Websites were created, for example, the NOAA HPCS for Research Applications (NHRA) and the NOAA High-Performance Computing (HPC) study sites. The public NHRA Website (*http://nhra.fsl.noaa.gov/*) contains information about the HPCS procurement project and allows vendors to query FSL staff directly. The internal NHRA site contains restricted information and enables the NHRA Acquisition Team to answer, approve, and post vendor questions. The HPC Study Website contains the interactive, database-driven current baseline survey and future requirements survey, which are updated annually by the HPC users.

FSL, OAR, and NOAA Support – ITS staff continued to advise FSL management on the optimal use of laboratory computing and network resources, and participate in cross-cutting activities that extended beyond FSL. Through workgroups, committees, and other means, ITS staff supported FSL, OAR, and NOAA planning efforts, developed cooperative projects, and designed and developed IT architectures. They served as Chair of various committees, such as the FSL World Wide Web Working Group; FSL Technical Steering Committee, which reviews all FSL equipment fund requests and provides the FSL director and senior staff with technical recommendations for equipment procurements; FSL Data Policy Committee; and Boulder IT Council. ITS staff also served as members of the FSL Technical Review Committee; FSL HPCS Allocation Committee, which reviews proposals for the use of FSL's HPCS and provides recommendations for management approval; U.S. High End Computing Revitalization Task Force; Cooperative Opportunity for NCEP Data Using Internet Data Distribution Technology steering committee; Collaborative Radar Acquisition Field Test steering committee; and the NOAA Operational Model Archive and Distribution System steering committee. Other advisory and representative activities involved the Core Team and Advisory Team for the NOAA HPCS for Research Applications Concept of Operations and FSL representation on the OAR Technical Committee for Computing Resources.

Projections

Central Computer Facility

FSL High-Performance Computer System and Mass Store System – Plans for 2004 include continued testing of the 64-bit testbed and investigation of the feasibility of commercially available file systems, such as Lustre and the Parallel Virtual File System 2 (PVFS2). In collaboration with the Aviation Division, Grid Computing software will continue to be tested and evaluated. Of particular importance will be research into providing a uniform security model for Grid Computing and high-performance network tuning. By late 2004, the 280 Alpha processor-based Cluster should be decommissioned.

NOAA is corporately studying options for replacing and/or augmenting the computational capacity located at FSL to meet the needs of researchers both in FSL and other NOAA organizations. During 2004, FSL will be heavily involved in this study and related procurement activities.

Since the upgraded MSS is performing very well, the older version, based upon ADIC's FileServ/VolServ software and Sony AIT tapes and drives, will be decommissioned. Appropriate datasets will be transferred to the upgraded MSS to free space within the ADIC AML/J automated storage library robot for more LTO (Linear Tape-Open) tape slots, allowing for growth in storage over the next two years.

Laboratory Project, Research, and External Support

ITS staff will continue to support FSL users and projects along with the many external FSL collaborators and data users. This support involves real-time and retrospective FSL data, meteorological products, and technical data-handling expertise. HPCS support, assistance, and recommendations will continue for FSL and other NOAA users, and outside users.

Central Facility Systems, Enhancements and Upgrades – A major transformation of FSL's external Web presence will involve consolidating and securing the Web servers. Completion of this undertaking will reap many benefits, such as reducing the number of externally visible servers, which must be regularly maintained and patched. Also, implementation of a method to filter all external Web requests through a proxy server will help ensure their appropriateness.

Since FSL's current source code and home directory backup system is almost seven years old, a new backup system will be designed and replacement equipment recommended. The Systems Administration staff proposed that the existing four separate robots be replaced with one central robot with six high-speed LTO-2 drives. This robot will then be connected via fiber channel to the Linux backup server and the Network Appliance NFS servers (Figure 14), and by using existing backup software, a cost savings will be realized. A key component of the new backup system will be a second remote robot to be located off-campus, which will act as a disaster recovery system. Currently, a manual process is used for creating and moving disaster recovery backup tapes offsite. The new system will automate this process by splitting the current backup stream, hence eliminating the need to back up files more than once.

FSL purchases new equipment in cycles, about every three years, as shown in Figure 15. ITS Systems Administration will work with procurement staff and other FSL Systems Administrators to prepare a list of all computer and other equipment and when it will need to be replaced. Expenses can be significantly reduced by taking advantage of quantity discounts or possibly even leases.

Systems Support and Computer Operations – A major ITS budget reduction in Fiscal Year 2004 forced a reduction in the SSG staff, necessitating a reduction in the hours of coverage. Facility operations coverage will be reduced to 12 hours Monday through Friday, and 8 hours on weekends and holidays. The new schedules will provide maximum coverage for the standard work hours with a focus on minimizing overtime. SSG Operations will extend coverage when deemed necessary, for example, during emergency situations or when FSL is in active NCEP backup mode.

The SSG will continue to work on improving communications and handling issues and problems associated with the FSL Central Facility. The number of SSG Log tickets initiated and resolved should only increase slightly as more products and systems are added, changed, and/or replaced in the FSL Central Facility, but more FSLHelp requests should be serviced than last year.

Regularly failing backups will continue to be identified and corrected, and clients who back up excessive amounts of data will be referred to Systems Administrators for correction. This approach will provide more effective use of system/network resources with a higher level of service to all FSL users, and decrease the number of failing backups and the total volume of nightly backups. The tracking and recording started last year will be continued and will be made available to all interested parties via Web-based graphs and spreadsheets. Any problems that arise with the main backup server and FSL's four backup robots will be promptly handled. SSG staff will work with ITS Systems Administration in researching, proposing, and, if approved by management, implementing a new backup system.

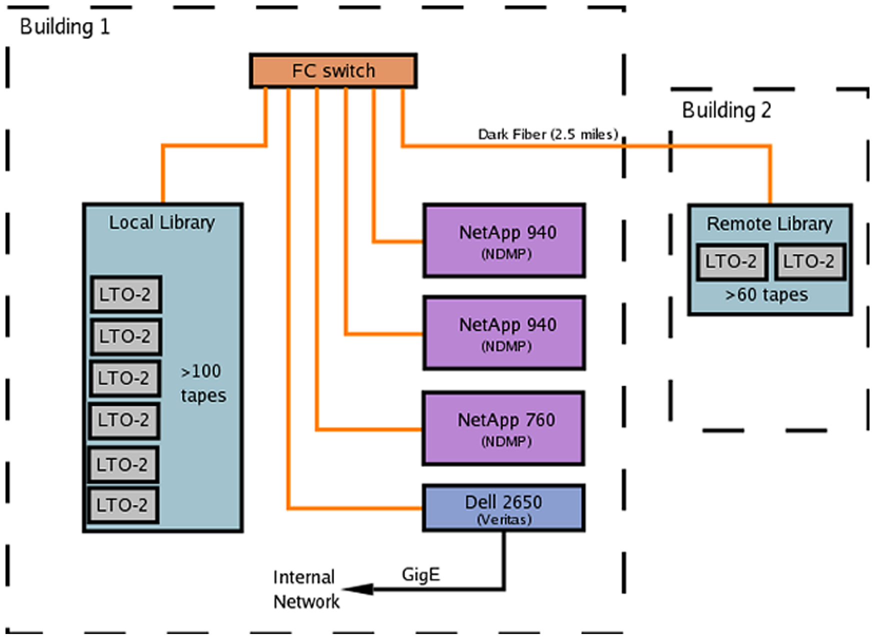

Figure 14. Proposed new FSL source code and home directory backup hardware.

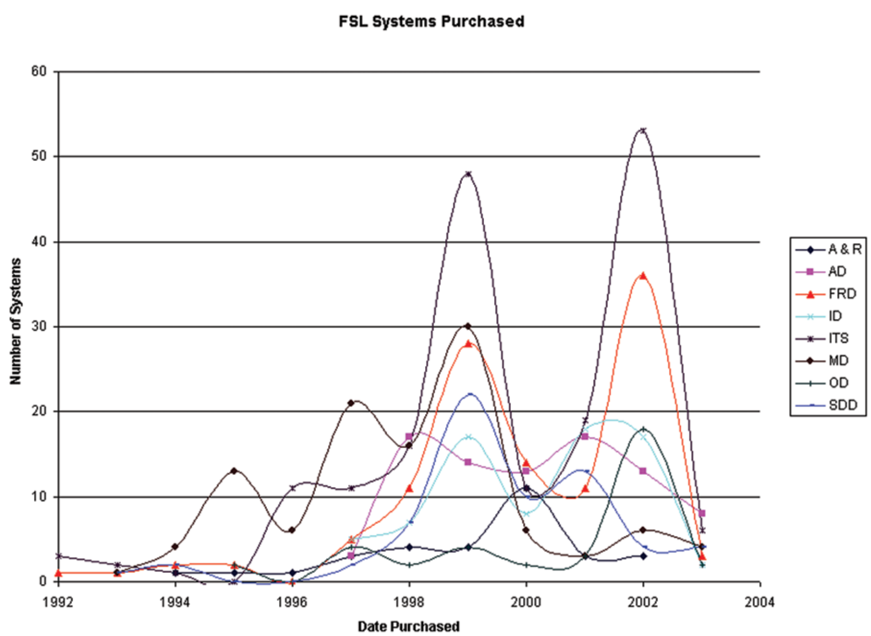

Figure 15. Cycles of new equipment purchases in FSL.

Additional new products and systems will be added to the FICS monitor, and associated online operational/infrastructure responsibilities will continue to be performed. The Java-based tools will be further modified for more efficiency, consistency, and accuracy.

SSG staff will receive refresher training sessions for the Vesda and FM200 fire protection systems as well as additional training in normalizing the Vesda smoke-detection system response. The related documentation will be updated, and other training devices and additional aids for quickly resolving issues with these systems will be developed. A Vesda Smoke Detection System Stage 3 level alarm for automatic electrical Emergency Power Off (EPO) will be added for key FSL computer rooms in case a preset maximum temperature is reached. Programming for this EPO feature will be done by an outside contractor, but SSG staff will perform needed updates of the configuration of the FSL SCADA system software, along with accompanying documentation and monitoring tools.

SSG staff will continue to provide high-level service for the critical NCEP RUC/RSAS backup function. Documentation will be updated promptly to incorporate any changes that affect the functioning and monitoring of the FSL backup system.

Staff will be updated on the latest version of the NOAA Security Awareness plan, and will receive in-depth SANS Institute security online training and other appropriate security classes.

Facility Infrastructure Upgrades – An important upgrade will involve connecting the SCADA temperature monitoring system to the Emergency Power Off (EPO) system. Because of budget cuts, 24-hour computer operations coverage will no longer be available. To ameliorate the risk of high-temperature damage to equipment within the computer room after normal working hours, an automated system will be implemented to protect FSL's very valuable computer assets. After three incremental phases of high-temperature notification by the Vesda system, the SCADA system will automatically shut down all equipment in the computer room.

Pending management approval, the following additional infrastructure upgrades will be performed:

- The Central Facility computer room will be prepared to support the new NOAA High Performance Computing System for Research Applications (NHRA).
- A Pre-Action Fire Sprinkler system will be installed in the FSL computer rooms.
- The Fire Sprinkler shutoff valves for the Central Facility Annex will be configured to conform to computer room building standards.
- The computer room UPS systems will be upgraded for improved reliability.

FSL Network

During 2004, Network Administration plans to replace the remaining ATM components in the FSL network with switched Ethernet and Gigabit Ethernet devices. This upgrade will finalize FSL's migration from an integrated ATM and GigE network to a unified GigE solution throughout the laboratory, standardizing the more ubiquitous and cost-effective network technology. The upgrade will be a phased installation of six GigE network devices to replace ten ATM devices over a six-week period. The resultant topology will yield an array of redundant 32 Gbps switches in the network core, supporting scalable backbone links from one to eight Gbps, and GigE links to each of the wiring closets that house switches for network connections to office workstations. (Figure 16 shows the planned 2004 FSL GigE network configuration.) The major benefits of this planned upgrade for FSL are simplified network management based on a single technology and common network operating system, enhanced router support that builds on the Hot Standby

Routing Protocol already in place at FSL, and an extension of the GigE network core into the NOAA Boulder Main Distribution Facility (MDF). Extending FSL's network core into the MDF is important because it provides "third room redundancy" that will enable Network Administration to maintain network connectivity to office workstations and critical services during times when both FSL computer rooms must be powered down for annual facilities maintenance. In addition, the unified GigE network will provide a greater level of network monitoring for increased visibility into real data flow for all internal networks. This will enable the analysis of top applications and protocols, top source and destination addresses, top flows and network conversations on every port for every device in the network. Access to this level of network utilization data was not previously available due to the multivendor, multitechnology network. These data will be valuable for resource management and for performance enhancement of applications, computer systems, and information flow at FSL.

Two other important network improvements are slated for the coming year. The first is designed to strengthen remote access security with the implementation of a token-based authentication system. This will simplify and improve security for remote access users such as travelers, telecommuters, and remote collaborators. The token-based system will utilize a two-factor system for authentication to FSL networks. Several potential token-based solutions are being considered to determine the best one for the FSL network environment. The second planned improvement will be to increase the range of the wireless network by a factor of four. By working with the NOAA Boulder Network Operations Center (NOC), FSL will integrate our current wireless network capacity with additional access points being provided by the NOC to obtain wireless service throughout the David Skaggs Research Center. Wireless authentication will be combined into a NOAA-approved "roaming gateway" system that utilizes the NOAA LDAP (Lightweight Directory Access Protocol) system for user sign-on and security, and access to FSL internal networks will be controlled via VPN services managed at FSL. This building-wide wireless service will both simplify and improve the range of service to FSL users with roaming laptops.

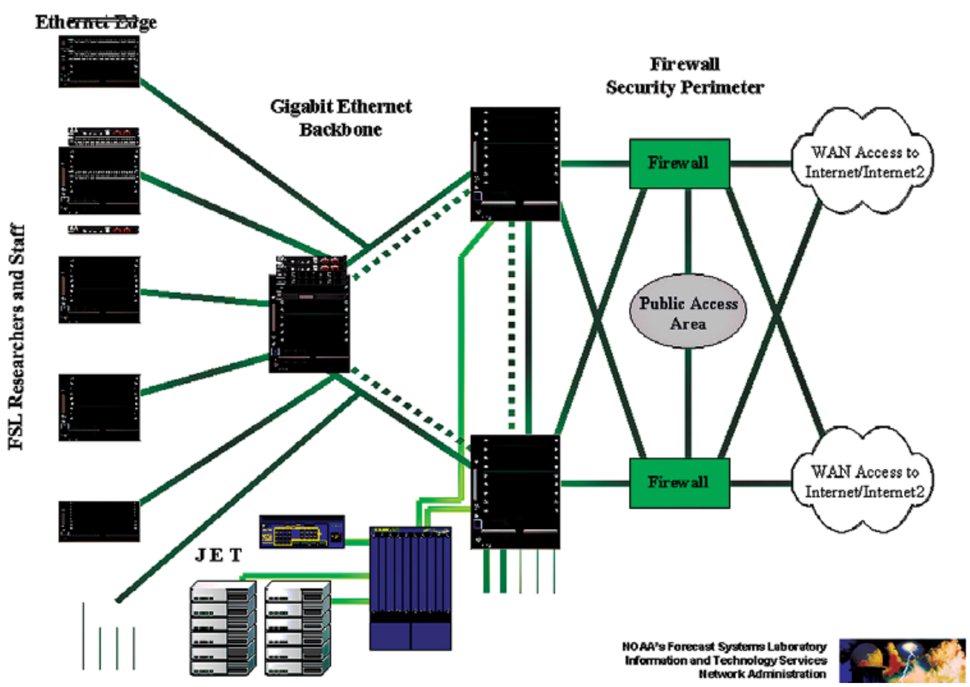

Figure 16. The FSL 2004 GigE network configuration.

Through continued collaboration with the BPoP (Boulder Point-of-Presence) network community (comprising NOAA, NCAR, the University of Colorado-Boulder, Colorado State University, and the City and County of Boulder), FSL and NOAA Boulder have an opportunity to join the research development of a new national fiber-optic network, the National Lambda Rail (NLR). Labeled "Internet3," the NLR is similar to the national TeraGrid network, with the important difference that this network will be open to the wider research community. The NLR will utilize dark fiber (fiber leased from cable providers without additional cost of service), and will support 40 channels of 10 Gigabit Ethernet using Dense Wave Division Multiplexing (DWDM) technology. This network will be owned and managed by the research community, and will connect vital centers of high-performance computing sites with geographically distributed computer resources and clients. Both research and production network data flows will be able to run simultaneously side by side on dedicated NLR wavelengths, enabling potentially significant advancements in the new era of "e-Science." FSL plans to take advantage of this opportunity to support development of high-performance computing for NOAA weather research. Some initial applications are likely to be storage area network (SAN) solutions over WAN distances, and GRID computing among NOAA and other supercomputing sites. (GRID computing is aimed at providing seamless and scalable access to wide-are distributed computing resources.) Advancement in these areas will immediately lend to development of more integrated weather research methods, and to the proposed NOAA enterprise network backbone infrastructure.

Information Technology (IT) Security

As grid computing and other high-performance network initiatives continue to grow and evolve, the need for larger network frame sizes is now becoming critical to their continued success. A partnership is being formed with the firewall vendor to evaluate and implement jumbo frame technology. It is hoped that FSL can implement, or at least test, jumbo (9 kilobyte) frames at Gigabit Ethernet speeds through the firewalls to partner sites on the Abilene network. The Intrusion Detection System (IDS) continues to grow in complexity and scope. It is necessary to upgrade the aging central system logging infrastructure with new hardware and logging software. Another task is to make alert data accessible from both IDS and centralized system logging to system and network administrators through a secure, but friendly interface. A token-based authentication system will be implemented to improve the security of existing remote access methods, which should greatly reduce the risk of stolen-credential attacks. One of the largest remaining security obstacles is the problem of physical access to FSL's network. Work will begin on the implementation of port-level security to better react to unauthorized or misconfigured network devices.

Data Acquisition, Processing, and Distribution

During 2004, the Data Systems Group plans to:

- Prepare the FSL NOAAPORT receiving system for transition to NOAAPORT Digital Video Broadcast-Satellite (DVB-S) transmission technology.
- Upgrade the Operational Build 2 (OB2) Central Facility AWIPS data servers to use the Red Hat Enterprise Linux (RHEL) 3 operating system.
- Implement a high-availability arrangement for the Central Facility AWIPS data server for better redundancy.
- Complete implementation of the Unidata Local Data Manager (LDM) server at FSL to provide selected NOAAPORT datasets to the Taiwan Central Weather Bureau.

Forecast Research Division

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Objectives

The Forecast Research Division (FRD) is home to most of the research in FSL on short-range numerical weather prediction (NWP), development of advanced modeling and data assimilation techniques, diagnostic studies of mesoscale weather phenomena, and applications of NWP to nonmeteorological uses. A major emphasis involves the assimilation of operational, research, and future meteorological observations for analyzing current atmospheric conditions and the subsequent generation of short-range numerical forecasts. Produced in real time at frequent intervals on national and local scales, these analyses and forecasts are valuable to commercial aviation, civilian and military weather forecasting, the energy industry, regional air pollution prediction, and emergency preparedness. FRD also has supported several large meteorological field experiments and continues to perform this service to the community.

The Forecast Research Division is comprised of the following organizational structure:
Regional Analysis and Prediction Branch (RAPB)
Local Analysis and Prediction Branch (LAPB)
Special Projects Office (SPO)

The Regional Analysis and Prediction Branch supports the following research programs:

Rapid Update Cycle (RUC) – A complete analysis/forecast system for hourly assimilation of meteorological observations over the United States into a numerical prediction model, the RUC has been implemented as an operational forecast system at the National Centers for Environmental Prediction (NCEP). The branch develops and tests improvements to the RUC and its research counterpart, the Mesoscale Analysis and Prediction System (MAPS), in the following areas:

• *Data Assimilation* – Improved techniques for estimating meteorological parameters on a regular grid, combining information from in situ and remote observations with that from a forecast model, and investigation of uses for new data sources, such as rapid updating using Geostationary Operational Environmental Satellite (GOES) raw radiances and derived products. The latter task is being performed partly in collaboration with other members of the Joint Center for Satellite Data Assimilation, National Envirionmental Satellite, Data, and Information Service (NESDIS); National Aeronautics and Space Administration (NASA); and National Centers for Environmental Protection (NCEP).

• *Numerical Prediction* – Design, testing, and implementation of improvements to the RUC/MAPS numerical prediction model, with a major emphasis on improving representation of processes near the surface and in clouds, which exert a strong control on mesoscale forecasts.

• *Analysis and Model Verification* – Statistical and subjective evaluations of RUC/MAPS analysis and forecast products for standard atmospheric variables, surface conditions, aviation-impact variables, clouds, and precipitation.

• *Data Sensitivity Studies* – Using the RUC, conducted studies to determine the effects of different types of observations on short-range numerical forecasts, including wind profilers, GPS, and space wind lidar systems of the future.

RUC Applications – Development of coupled atmospheric/land surface model capability in support of the Global Energy and Water Cycle Experiment (GEWEX) programs and the NCEP implementation of the RUC, forecasting of aviation impact variables (icing, turbulence, ceiling, and visibility) in support of the Federal Aviation Administration (FAA), wind forecasting applied to wind energy utilization, and real-time support for field projects in which NOAA is engaged.

Collaborative Modeling Projects – Lead role in the development and evaluation of the coupled MM5/Air Chemistry model and the WRF/Air Chemistry model, continued collaboration with NCAR in the advancement of the science of modeling precipitation physics, participation in the development and application of the Weather Research and Forecasting (WRF) model system and nonhydrostatic generalized vertical coordinate model, and, finally, development of a RUC Short-Range Ensemble Forecast (SREF) system in collaboration with NCEP.

The Local Analysis and Prediction Branch is engaged in the following efforts:

Local Analysis and Prediction System (LAPS) – Incorporation of local datasets into numerical models (e.g., MM5, RAMS, WRF) for the production of very detailed analyses of local weather conditions and short-range forecasts. The model is updated using variational methods and Kalman filtering techniques with new observations at least hourly. A diabatic initialization procedure known as the "Hot tart" has been developed for reducing the problem of cloud and precipitation "spinup" in the early hours of model integration. LAPS supports a broad clientele of mostly government and military entities, including the National Weather Service (NWS), Federal Aviation Administration (FAA), Federal Highway Administration (FHWA), U.S. Air Force Weather Agency (AFWA), Department of Defense (DOD/Army, Lockheed Martin, the Central Weather Bureau of Taiwan, and the Korean Meteorological Administration.

LAPS Observation Simulation System (OSS) – Evaluation of new observation technology or siting of existing observational systems. This system has been employed to assess the potential of new satellite systems for instrument placement around eastern and western space centers of the U.S. Air Force and spaceborne wind lidar systems for NOAA.

Satellite Products – Utilization and evaluation of raw radiances and products derived from GOES atmospheric soundings, for the purpose of developing a complete national-scale moisture analysis useful for high-resolution model initialization. The branch also participates in the Joint Center for Satellite Data Assimilation.

Weather Research and Forecasting (WRF) Model Support – Development of a Standard Initialization procedure for community use in initializing the WRF model with background fields obtained from other models and static data defining the surface properties. High-resolution local applications of WRF are being developed and tested, including evaluation during the International H_2O (IHOP-2002) field experiment in the Southern Plains and application for the Coastal Storms Initiative.

WFO-Advanced Support – Full support of an operational version of LAPS on the WFO-Advanced workstation, including both analysis and prediction. The WFO-Advanced forecaster workstation is used to demonstrate Advanced Weather Interactive Processing System (AWIPS) functions in support of future Weather Forecast Office (WFO) operations.

Local Model Implementations and Demonstrations – Configuring and installing modeling systems that take advantage of local datasets, advancements in affordable parallel computing, and the results of weather modeling research and developments from FSL and elsewhere. Current and upcoming applications of various models on different computing platforms all take advantage of LAPS initialization. Ensembles of local models will be an increasingly useful approach to numerical weather forecasting problems and applications to a broad spectrum of uses ranging from fire weather prediction to ground transportation needs.

Research efforts in the Special Projects Office consist of the following:

Diagnostic Turbulence Forecasting – Development, testing, and verification of diagnostic tools using the RUC model for forecasting turbulence in support of the Aviation Weather Research Program.

Mesoscale Diagnostic Studies – Research performed to increase the understanding of weather systems, improve conceptual and diagnostic models of the atmosphere using data from conventional instruments and new state-of-the-art sensors, and investigate mesoscale dynamical processes. Current studies include potential vorticity streamers, the structure and dynamics of the low-level jet and its role in moisture transport, the role of gravity waves in turbulence generation and convection initiation, and the dynamics and structure of bores and solitons.

Research Quality Datasets – Production of quality-controlled hourly precipitation data, meteorological data from commercial aircraft (ACARS and AMDAR), and North American radiosonde data for access on CD-ROMs and the Web. Assessments of and improvements to the set of hourly precipitation measurements are utilized for verification purposes by the Real-Time Verification System (RTVS).

Websites for FSL Data – Development of Websites for the NOAA Chemical Weather Research and Development program, national precipitation data, ACARS data, interactive soundings, national mesonetwork data, and FSL publications.

Regional Analysis and Prediction Branch

Stanley G. Benjamin, Chief

Objectives

The primary focus of the Regional Analysis and Prediction (RAP) Branch is research for and development of the Rapid Update Cycle (RUC), which provides high frequency, hourly analyses of conventional and new data sources over the contiguous United States, and short range numerical forecasts in support of aviation and severe storm forecasting and other mesoscale forecast users. The RUC runs operationally at the National Centers for Environmental Prediction (NCEP) at the highest frequency among its suite of operational models. The branch works closely with NCEP in developing, implementing, and testing RUC improvements at FSL, and transferring them to NCEP. A variety of model and assimilation development, verification, and observational data investigation activities are carried out under the RUC focus. Applications of the RUC include contributions to the GEWEX (Global Energy and Water Cycle Experiment) program toward improved climate forecasting (GEWEX Americas Prediction Project, GAPP), forecasting detailed wind fields in collaboration with the National Renewable Energy Laboratory, support for a number of field experiments, and the Short-Range Ensemble Forecast system being developed at NCEP. The RUC has a unique role within the NWS in that it is the only operational system that provides updated national scale numerical analyses and forecasts more often than once every 6 hours. It was developed in response to the needs of the aviation community and other forecast users for high frequency, mesoscale analyses and short range forecasts covering the conterminous United States. It is widely used in NWS Forecast Offices, NWS centers for aviation weather and storm prediction, the FAA, and other facilities. Evaluations of the RUC have clearly demonstrated its advantage in providing high frequency, recently initialized forecasts based on the latest observations. The RUC is a key part of the FAA Aviation Weather Program, since commercial and general aviation are both critically dependent on accurate short range forecasts. The RUC will continue to improve over the next few years, perpetuating the successful collaboration between FSL and NCEP, but a shift in primary focus has been to develop a rapid update component to the WRF model by 2007.

In collaboration with other government agencies (e.g., NCAR, NCEP, NESDIS) and universities (e.g., University of Miami, University of Oklahoma), RAP branch scientists develop improved data assimilation and modeling methods for use in the RUC and the Weather Research and Forecasting (WRF) model. Techniques for assimilating new observational datasets are developed toward the goal of the best possible estimate of current atmospheric and surface conditions, as well as the best possible short-range forecast. The branch also interacts with other FSL staff in implementing optimal computing methods with RUC and WRF software, making the model as efficient as possible on modern computing platforms.

A second primary focus of the branch is the development, real-time implementation, and evaluation of a fully coupled atmospheric/air chemistry mesoscale model prediction system. An MM5-based, fully coupled system was run in support of the 2002 NOAA Temperature and Air Quality (TAQ) Pilot Project in New England (and other previous experiments). An increasingly important focus of research involves regional air pollution studies. Currently, a fully coupled WRF-based chemistry modeling system is being run experimentally.

Accomplishments

Upgrading RUC to 13-km Resolution – Following the operational implementation of the 20-km RUC model at NCEP (April 2002) and the RUC three-dimensional variational (3DVAR) analysis (May 2003, see below), the RAPB scientists began work on a 13-km version of the RUC model and analysis system. Scheduled for operational implementation in spring 2005, this upgraded version of the RUC will utilize planned computer increases at NCEP. The goals of this upgrade are fourfold:

- Improved precipitation, cloud, ceiling, visibility, icing , and turbulence forecasts.
- Improved surface forecasts near coasts and surface wind forecasts over land.
- Improved moisture forecasts in the lower troposphere and near surface.
- Improved forecasts of near-surface conditions from assimilation of new observation types.

The 13-km spatial resolution allows more accurate depiction of the actual terrain and more faithful representation of coastlines and lakes compared to the current 20-km RUC. In addition to improved depiction of terrain-related flows and sea/lake breeze flows, the enhanced horizontal resolution is expected to produce improvements in forecasts of aviation related fields, including convection, icing, ceiling, visibility and turbulence. The RUC13 continues to use 50 vertical levels and retains the same isentropic-sigma hybrid coordinate found advantageous in previous RUC versions. The horizontal resolution increase from 20-km to 13-km is complemented by a number of enhancements to both the model physics and 3DVAR analysis procedure. Development and testing work for these enhancements is either completed or ongoing at FSL. Specific components of the upgrade package include:

- Increase horizontal resolution from 20 km to 13.3 km.
- Use new higher resolution (also 13 km) fixed files for terrain elevation, land use (with land-sea mask), soil type, and roughness length.
- Modify Grell-Devenyi convective parameterization to use optimized weighting for multiple closures.
- Implement updated version of RUC/NCAR bulk mixed-phase cloud microphysics designed to produce more accurate depiction of supercooled liquid water needed for icing forecasts.
- Modify moisture analysis variable from log of water vapor mixing ratio (ln q) to pseudo-relative-humidity.
- Modify RUC model digital filter initialization to improve initial moisture fields.
- Add soil temperature and moisture nudging in analysis, only included under certain conservative conditions, based on near-surface analysis increments of temperature and moisture.
- Assimilate new observations from GPS precipitable water, mesonet surface stations, and boundary-layer wind profilers.
- Improve quality control for precipitable water observations.
- Assimilate METAR observations of cloud levels and visibility to improve initial conditions for RUC 3D hydrometeor fields.

In fall 2003, FSL started 13-km full CONUS domain RUC model tests initialized from the 20-km RUC analysis. Real-time testing of a fully configured RUC13 (including the RUC 3DVAR and cycling of all initial fields at 13-km resolution) began in spring of 2004. Statistical verification of RUC13 forecasts has been performed against surface and precipitation observations, for which RUC13 forecasts are showing improved skill over those from 20-km RUC runs. These improvements appear to result from both enhanced horizontal resolution and from revised microphysics and convection parameterizations.

An example of a precipitation forecast from 28–29 July 2004 is presented in Figure 17. Twelve-hour forecasts valid at 0000 UTC 29 July are shown for both the RUC13 and RUC20 (backup RUC run at FSL, very similar to the operational RUC20). The sharper definition of convective storm systems is evident with the 13-km RUC, typical of its behavior for warm-season precipitation. A radar summary valid at 2315 UTC is also provided in Figure 18 to allow subjective verification. The precipitation in the RUC13 is sharper than RUC20 overall, particularly for convective systems in northern Kansas and from southwestern Minnesota to the southeastern tip of South Dakota.

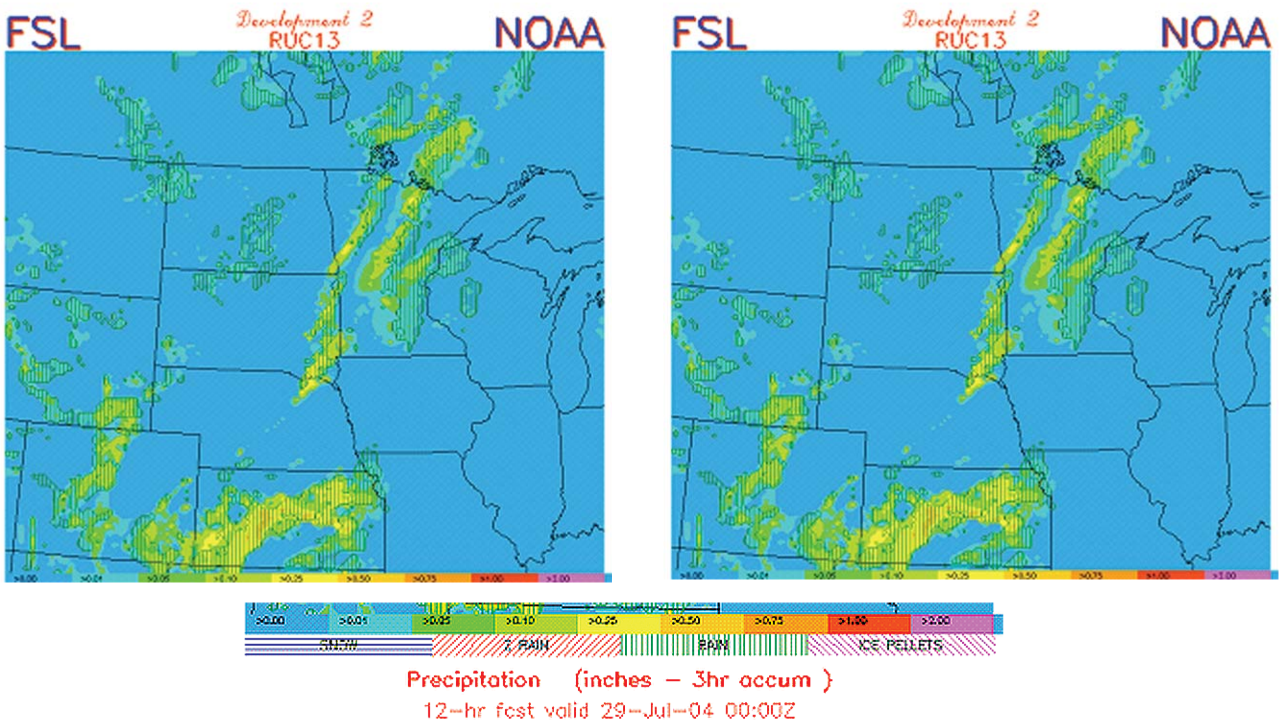


Figure 17. above) Precipitation forecast comparison between RUC13 (left) and RUC20 (right) 12-hour forecasts valid 0000 UTC 29 July 2004.

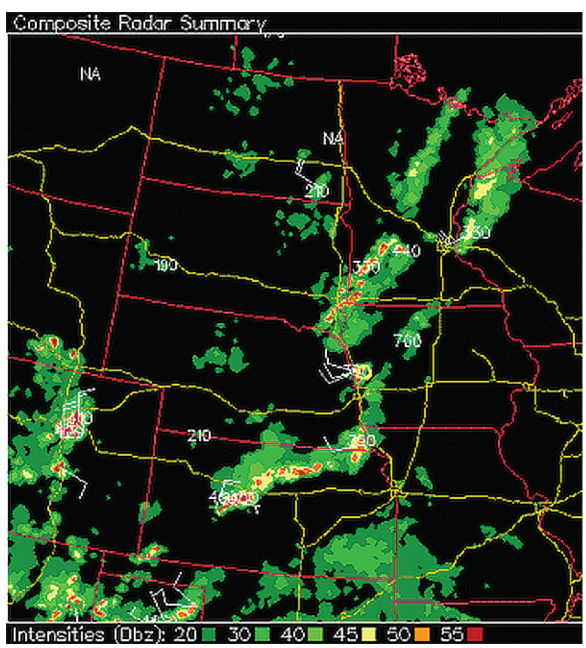


Figure 18. (right) Radar summary (courtesy Unisys) valid 2315 UTC for the precipitation forecast comparison in Figure 17.

The following improvements have been made to the RUC20 since its original implementation at NCEP in 2002.

3D Variational Analysis – After several years of development and real-time testing at FSL, on 27 May 2003, the RUC three-dimensional variational (3DVAR) analysis was introduced into operations at NCEP as one of the components of the RUC system. The major advantage of a 3DVAR-based data assimilation system is the capability of assimilating observations not carried in the model, such as radiances measured by a satellite or radar velocities and reflectivity observations. Assimilation of these data by the traditional optimum interpolation (OI) method is difficult and cumbersome. The RUC 3DVAR is designed for an operational environment, adhering to strict performance requirements, of which the most important ones are:

- The 3DVAR analysis should fit observations as closely as the OI. Figure 19 demonstrates in the wind field case that the RUC 3DVAR fits observations even better than the OI.
- Forecasts based on 3DVAR analyses should be at least as good as OI analyses-based ones. Figure 20 illustrates in the 3- and 12-hour RUC wind forecast similar performance based on OI (red curves) and 3DVAR (blue curves) analyses during the period of 18 November 2002–14 January 2003.

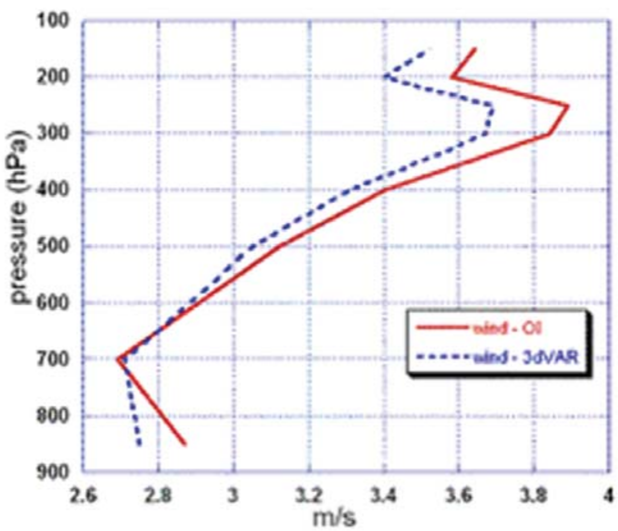


Figure 19. Fit to observations for wind field case from 16 November 2002–30 January 2003. RUC 3DVAR, dashed blue line; OI, contiguous red line.

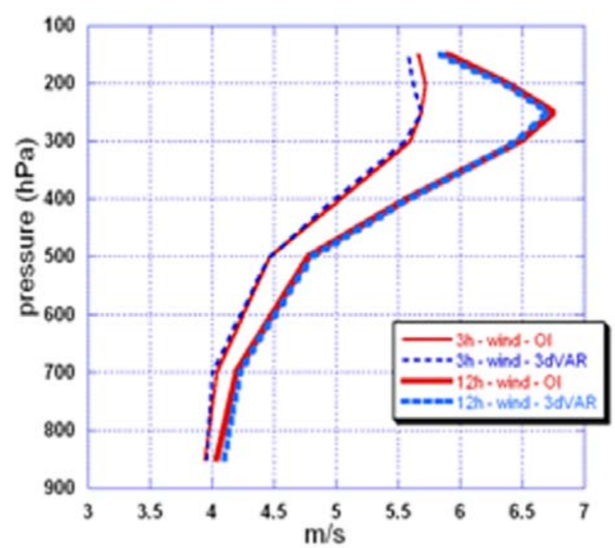


Figure 20. RUC 3- and 12-hour wind forecast errors rms vector difference compared with radiosondes (full RUC domain of 92 stations): OI-based results (solid red lines); 3DVAR results (dotted blue line).

• 3DVAR solutions must not require much more computer time than OI-based solutions. In fact, present RUC 3DVAR requires less computer runtime than earlier OI scheme.

In order to support the RUC 1-hour forward intermittent data assimilation cycle, many different observations are assimilated by the RUC 3DVAR. These include radiosondes (RAOBs), aviation meteorological reports (METARs), buoy observations, commercial aircraft, wind profilers, geostationary (GOES) and polar-orbiting (SSM/I) satellites, ground-based GPS and radars (radial wind and reflectivity). Different kinds of observations require different observation (forward) operators, and the definition of appropriate observation and representativeness errors. The observation error terms in the RUC 3DVAR mostly are from OI, and the background error covariances are applied by computationally efficient digital filters.

The RUC 3DVAR design closely follows the one originally used in OI. The analysis is performed in a generalized vertical coordinate system defined for the case of RUC as a hybrid sigma-isentropic system. It is a 56-level modification of the 50 native coordinate levels of the RUC forecast model. The analysis is performed in three steps: 1) a multivariate mass/wind analysis is performed, with balancing provided by a linear regression scheme; 2) the analysis of virtual potential temperature analysis is computed; and 3) moisture is analyzed univariately.

Because 3DVAR methods do not use station selection, 3DVAR-based analyses behave much more smoothly than OI ones. Figure 21 shows the time evolution of a noise term (domain averaged absolute pressure tendency) comparing OI and 3DVAR for the case of 1200 UTC 19 November 2002. There is a clear indication of less noise in 3DVAR both with and without digital filter initialization (DFI). The difference in noise is diminishing in time, though it exists up to five hours.

FSL is an active participant in the Weather Research and Forecasting (WRF) model development, including a new 3DVAR method designed according to WRF standards and requirements. The basic version of the WRF 3DVAR was released on 1 July 2003. This version is capable of analyzing the standard set of observational data, excluding (at this writing) satellite and radar information. Preliminary tests at FSL demonstrate the stability and capability of the new code, but further development is necessary to make it available for use in the operational RUC or Rapid Refresh, RUC's subsequent version.

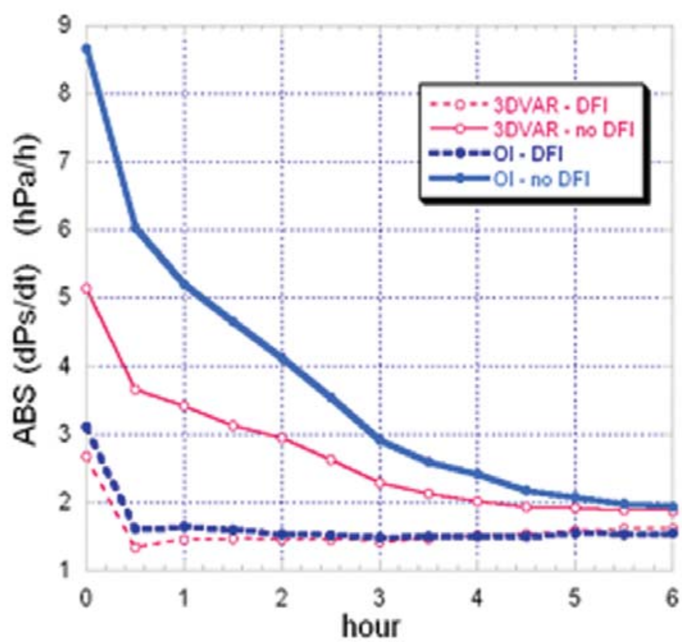


Figure 21. Time development of noise parameter values for both OI (blue) and 3DVAR (red) with and without digital filter initialization with initial conditions at 1200 UTC 19 November 2002.

Improved Version of the Land-Surface Model – The most recent version of the Land-Surface Model (LSM) implemented in the RUC20 has a number of improvements in treatment of snow cover. It allows evolution of snow density as a function of snow age and depth, the potential for refreezing of melted water inside the snowpack, and simple representation of patchy snow through reduction of the albedo when the snow depth is small. If the snow layer is thinner than a 2-cm threshold, it is combined with the top soil layer to permit a more accurate solution of the energy budget. This strategy gives improved prediction of nighttime surface temperatures under clear conditions and melting of shallow snow cover. The differences in skin temperature before and after the changes to the snow model could be as large as 10–12^o, and the experimental RUC is significantly more accurate (see the location with the snow depth below 1 inch shown with the white arrows on Figure 22).

Volumetric soil moisture and soil temperature at the 6 soil model levels, as well as canopy water, snow depth, and snow temperature, are cycled in the RUC LSM applications in current and previous versions of the RUC. In the 20-km horizontal resolution RUC (RUC20), cycling of the snow temperature of the second layer (where needed) is also performed. The RUC continues to be unique among operational models in its specification of snow cover and snow water content through cycling. The 2-layer snow model in the RUC20 improves the evolution of these fields, especially in springtime, more accurately depicting the snow melting season and spring spike in total runoff.

Support of the Operational RUC at NCEP – FSL monitors performance of the RUC running operationally at NCEP and works with NCEP to make necessary modifications. As part of this work, FSL must maintain expertise on the IBM SP computing system at NCEP and maintain a close, long-term collaboration with many groups in NCEP. FSL also supports a related major ongoing task, that of running in real time a backup version of the 20-km RUC in a "hardened" computer environment on the FSL Jet supercomputer to assure high-level reliability. During NCEP outages, RUC grids from FSL are substituted through NWS distribution channels to support all real-time RUC users. This task involves both the RAP Branch and FSL's Information Technology Services, along with NCEP and other organizations of the National Weather Service. A backup for the RUC20 was developed and implemented during 2002. Ongoing enhancements continue on the RUC Website, *http://ruc.fsl.noaa.gov*, including products from the test version of the 20-km RUC, and the use of the 20-km RUC grids in the FSL Interactive Sounding program.

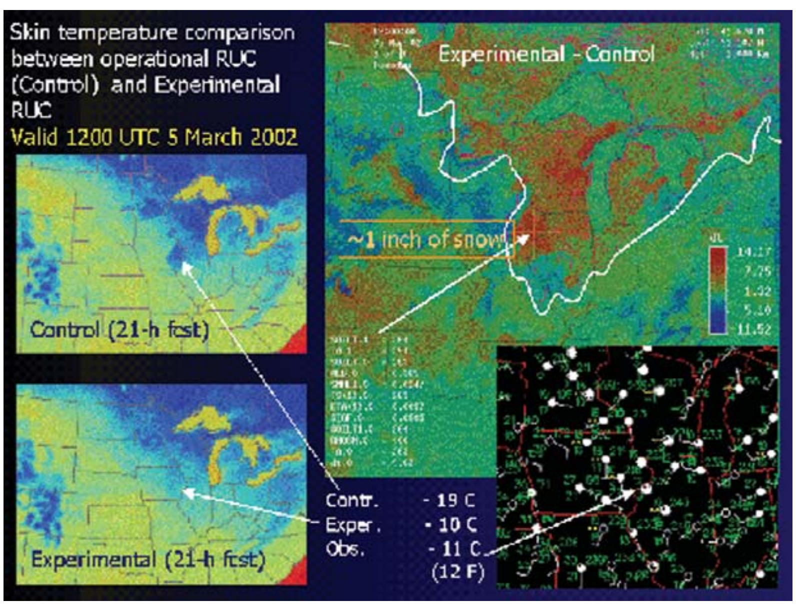


Figure 22. Skin temperature predictions from the Control RUC (old snow model) and Experimental RUC (new snow model) valid at 1200 UTC 5 March 2002 as verified against the METAR observations.

Improved Verson of the Grell-Devenyi Convective Parameterization – The RUC20 uses a new Grell-Devenyi convective parameterization, based on a very simple convective scheme developed by Grell. For the RUC20 implementation, the original scheme was first expanded to include lateral entrainment and detrainment, including detrainment of cloud water and ice to the microphysics scheme discussed in the previous section. In addition, the scheme draws on uncertainties in convective parameterizations by allowing an ensemble of various closure and feedback assumptions (relating to how the explicitly predicted flow controls the parameterized convection, which in turn modifies the environment) to be used every time the parameterization is called. The four main groups of closures that are used in the RUC20 application are based on removal of convective available potential energy (CAPE), destabilization effects, moisture convergence, and low-level vertical velocity. These four groups are then perturbed by 27 variations of sensitive parameters related to feedback as well as strength of convection, giving a total of 108 ensemble members that contribute to the convective scheme. Output from the parameterization includes the ensemble mean, the most probable value, and a probability density function, as well as other statistical values. Currently, only the ensemble mean is fed back to the dynamic model.

The application of the Grell-Devenyi convective scheme in the RUC model also includes a removal of the negative buoyancy capping constraint at the initial time of each model forecast in areas where the Geostationary Operational Environmental Satellite (GOES) sounder effective cloud amount indicates that convection may be present. This technique can aid modeled convection in starting at grid points where observed if there is positive CAPE, although it cannot create positive CAPE. In addition, an upstream dependence is introduced through relaxation of stability (convective inhibition) constraints at adjacent downstream points based on 0–5 km above ground level mean wind and through allowing the downdraft mass flux at the previous convective time step to force convection at the downstream location.

Applications of RUC

RUC Probabilistic Forecasts of Convection for the Aviation Community – In response to needs of the aviation community for convective guidance products, the Regional Analysis and Prediction Branch has been producing experimental real-time convective probability forecasts from the RUC model since July 2003. The choice of a probabilistic format was motivated by the extreme difficulty in making accurate deterministic thunderstorm forecasts with long lead-time (>2 hours) coupled with the strong need for long lead-time thunderstorm risk information by aviation flow managers. The RUC forecasts were designed to complement the Collaborative Convective Forecast Product (CCFP), a human-generated thunderstorm risk forecast produced by the Aviation Weather Center (AWC). The core of the RUC probabilistic forecast generation process is the use of various ensemble forecast techniques. At present, a very simple gridpoint ensemble method is being used, whereby convective rain rate intensities from neighboring model gridpoints are used to determine the percent coverage of convection within a certain distance of each model gridpoint. Using this technique, very detailed deterministic convective forecasts can be aggregated to larger spatial scales that possess more useful information for forecasters.

Figure 23 illustrates the probability generation technique for a sample case of a 7-hour forecast valid 1900 UTC 4 August 2003. Panel a) shows the 3-hour accumulated convective precipitation from the deterministic RUC forecast. Using the gridpoint ensemble technique, a probability forecast is generated as shown in b). This convective probability forecast is the product provided to users, and likely better represents the present state of thunderstorm forecast skill than the deterministic forecast. For the purpose of verification, the probability forecast is thresholded at the 40% level and converted to a categorical forecast of convection as shown in c). Comparison of this categorical forecast with the National Convective Weather Diagnostic (NCWD) verification shown in d) indicates encouraging skill for this challenging summertime convection case as indicated by the probability of detection (POD), bias, and critical success index (CSI) scores.

Statistical verification of the RUC convective probability forecast (RCPF) is being completed in real-time by the Aviation Division's Forecast Verification Branch. Analysis of the verification statistics for a two-month period (July, August) from 2003 indicates that the RCPF will likely provide useful guidance to traffic flow managers. The average diurnal cycle of three standard skill scores (POD, bias, and CSI) for 7-hour RCPFs is shown in Figure 24. Readily apparent in the plot is the enhanced skill for early morning forecasts valid in the midafternoon. This morning forecast of initial convective development is extremely important, as it can provide the basis for strategic reroutes of transcontinental plane flights, around which other shorter duration flights are planned.

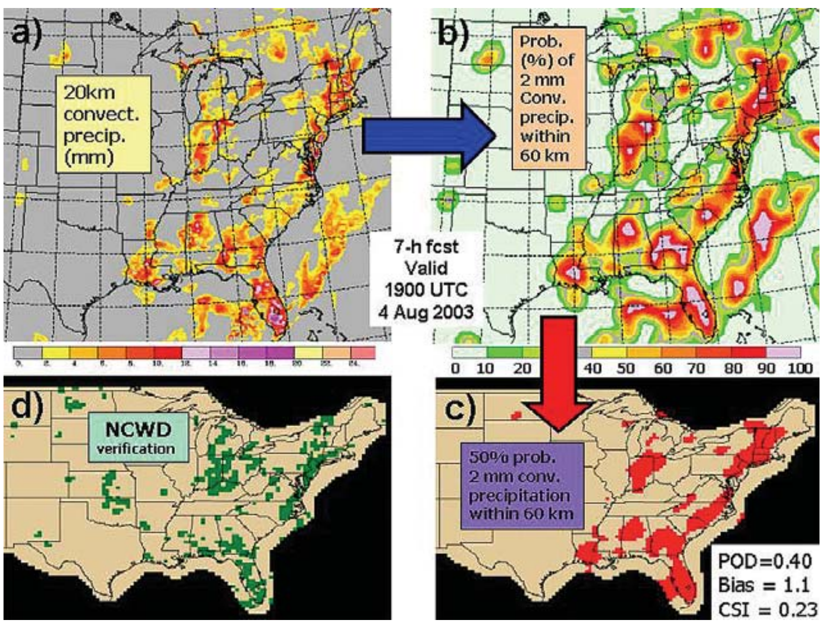


Figure 23. Graphical depiction of the creation of the RUC convective probability forecast (RCPF) for a sample 7-hour forecast valid 1900 UTC, 4 August 2003. a) Raw convective (subgrid-scale) 3-hour accumulated precipitation (mm). b) Convective probability forecast obtained from the gridpoint ensemble. c) Categorical thunderstorm forecast obtained by thresholding the probability forecast at 40%. d) National Convective Weather Diagnostic (NCWD) used for verification of the RC. Skill scores shown for the RCPF are computed with respect to the NCWD verification.

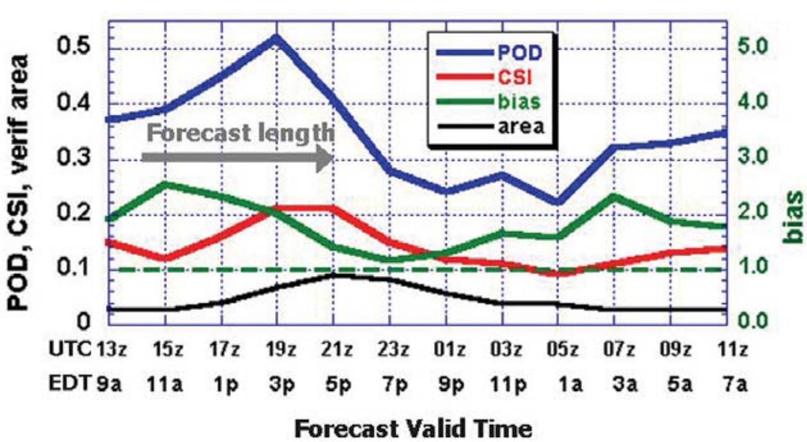


Figure 24. Diurnal cycle of average skill scores (during July and August 2003) for 7-hour RUC convective probability forecasts (RCPFs). Shown are the probability of detection (POD), critical success index (CSI) and bias, as well as the areal coverage of the verifying convection (area). The dashed green line (bias = 1.0) is included for reference.

Use of RUC Wind Forecasts for Estimated Wind Power Potential – FSL continues a collaborative wind energy study with the National Renewable Energy Laboratory (NREL, Department of Energy) now using 20-km RUC/MAPS forecasts. Time-lagged ensembles produced from 20-km RUC forecasts out to 48 hours are used to estimate near-surface wind power potential, while variance among forecast ensemble members provides a measure of uncertainty in those forecasts. The high vertical resolution in the RUC near the surface and frequent update cycling makes it well suited to wind energy forecasting.

Testing RUC's Time-Lagged Ensemble Forecasts – The RUC forecast system has been consistently putting out regional weather forecasts in the short range over the years. Because the RUC system ingests a lot of new observational data in an hourly cycle, its 1–3-hour forecasts provide a valuable reference and complement to the forecast community around the United States. Researchers are checking out whether forecasts from these hourly initializations vary, and, if so, what consequences may result from using these forecasts as a set of ensemble members. In the past year, FSL developed a time-lagged ensemble forecast system based on various RUC forecasts initialized at different times. Verification of the ensemble forecasts compared to the deterministic forecasts in the short range of 1–3 hours showed improved forecast skills, generally about 3–15%. This improvement is attributed to the ensemble forecast correction of initial spinup error in the RUC forecasts.

New England High-Resolution Temperature Project – Special high-resolution RUC forecasts for a NOAA/NWS experiment, New England High-Resolution Temperatures (NEHRT), have been run at FSL since summer 2002. The special configuration consists of a 10-km grid covering the Northeast United States, eastern Seaboard and Great Lakes areas nestled within a CONUS 20-km RUC domain. The 20-km RUC utilizes a 1-hour assimilation cycle to ingest all available observations, including special wind profiler and mesonet sites. From a 20-km analysis, 10-km forecasts out to 48 hours were produced every 6 hours. FSL distributes forecast fields to the NWS Eastern and Central Regional Headquarters for real-time AWIPS display at local offices. Additional fields are available through the RUC Webpage, *http://ruc.fsl.noaa.gov.*

Observation Sensitivity Experiments Using RUC to Examine the Impact of GPS – In collaboration with the Demonstration Division, the RAP Branch continues to run 60-km RUC parallel cycle experiments with and without assimilation of GPS precipitable water observations. Positive impact (leading to more accurate forecasts) of GPS precipitable water observations on short-range (3-hour) relative humidity forecasts seen in earlier sensitivity experiments with the original 60-km RUC continues to increase as more stations are added to the network (Table 1).

Table 1.
RUC Improvement Using GPS Precipitable Water Observations for 3-hour RH Forecasts

No. Sta		18	56	67	100+	200+
Year		1998-99	2000	2001	2002	2003
Level		% improvement (normalized by total error)				
850		1.5	3.8	3.9	5.0	5.4
700		1.1	4.1	6.3	6.5	7.0
500		0.7	2.1	2.0	2.4	3.1
400		0.3	0.1	-0.4	-0.5	1.0
Mean (850–400)	0.9	2.5	2.9	3.3	4.1	
Mean (850–500)	1.1	3.3	4.1	4.6	5.2	

The ongoing assessment of the 20-km RUC continues, using a Web interface created by the Demonstration Division. Interactive, real-time displays allow for immediate analysis of the impact of over 200 GPS observations being used every hour by the 20-km RUC run at FSL. Long-term statistics can also be calculated, as seen in Figure 25. These figures represent bias and RMS error calculated for every hour over the period 25 July–22 October 2003. There is a strong impact in the analysis and 3-hour forecasts from inclusion of profiler data, and the significant impact at 6 hours, with a slight impact still discernable at 9 hours. By 12 hours, the forecasts are nearly identical.

Development of Wavelet-Based Diagnostic Tools for Aviation Weather Research – The combined aircraft data obtained during the SCATCAT (Severe Clear Air Turbulence Colliding with Aircraft Traffic) field program and Rapid-Update Cycle (RUC) model simulation of the SCATCAT case indicated the presence of both gravity waves and moderate-or-greater (MOG) turbulence events. Though customary spectral techniques applied to these data do not lend themselves well to a proper understanding of the highly intermittent and nonstationary nature of interactions between waves and turbulence, the wavelet technique can localize these temporally evolving phenomena via a frequency-time (or wavelength-space) display. FSL is developing wavelet-based diagnostic tools to offer a better understanding of wave-wave and wave-turbulence interactions that may improve the forecast skills of occurrence of clear-air turbulence in the atmosphere.

The research and development work conducted during the last year includes many activities. Development of a one-dimensional continuous wavelet package is underway. When this package was applied to aircraft observational data,

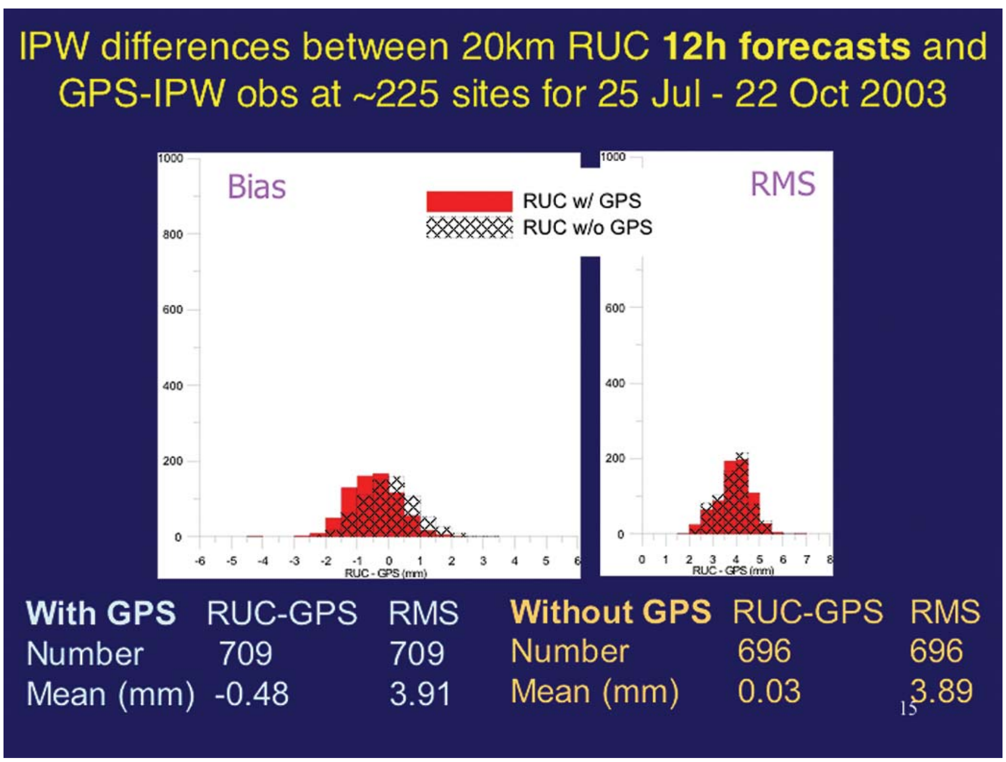


Figure 25. Integrated precipitable water differences between the 20-km RUC analyses and GPS-IPW observations at ~225 sites for 25 July–22 October 2003.

the result was a close relationship between gravity-wave intensification and turbulence bursts (Figure 26, panel a). By combining the cross-spectral method and wavelet transformation, we were able to reconstruct monochromatic and polychromatic gravity waves with localized characteristics in amplitude and phase (Figure 26, panel b and c), and turbulence intensity (Figure 26, panel d). Another task involved development of a wavelet-based cross-spectral analysis package, which can project bivariate data onto both frequency and time subspaces. This feature is ideal for studying polarization characteristics of gravity waves and turbulence. Branch researchers have also developed a two-dimensional wavelet analysis that can localize an atmospheric wave in space, and decompose wave energy into various spectral components. This package is used for analyzing RUC and MM5 model simulations to identify wave propagation and wave-wave interactions (Figure 27).

Continued research and development of wavelet-based diagnostic tools are planned in accordance with FAA's turbulence projects. In particular, we will apply the 2D wavelet diagnostic tools to analyze the high-resolution model simulations of gravity waves and turbulence, to determine the atmospheric conditions for the generation of turbulence by mesoscale gravity waves.

Collaborative Modeling Projects

Development of a Coupled Weather/Air Chemistry Prediction System Based Upon the WRF Numerical Model – FSL is developing and applying a next-generation coupled weather/air quality numerical prediction system based

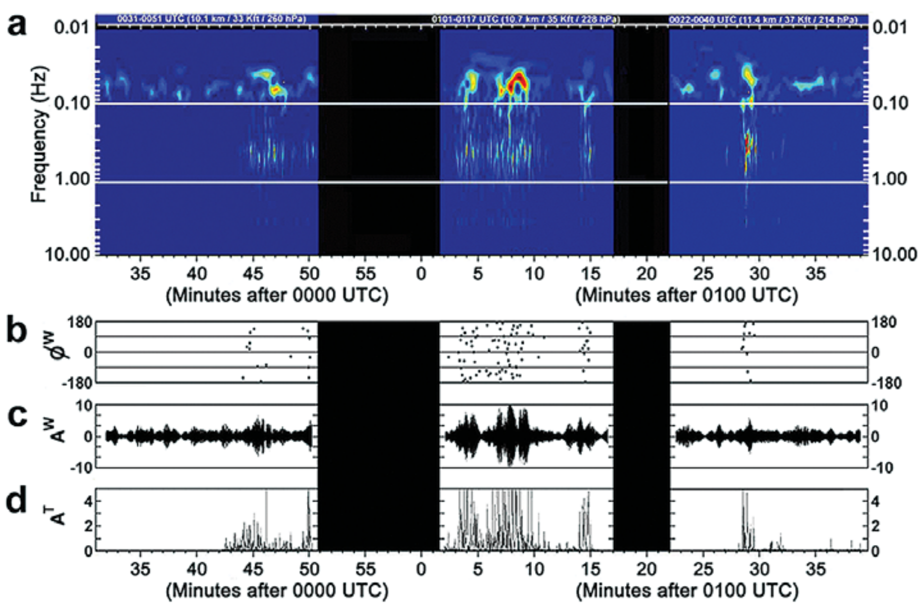


Figure 26. (a) Time-frequency display of wavelet analysis of aircraft vertical acceleration data at 10.1, 10.7, and 11.4 km flight altitudes (cm s^{-2}). (b) Phase of gravity waves (degree) at which maximum turbulence intensity occurred for turbulence > 0.5 cm^2 s^{-4}, (c) Gravity waves reconstructed from wavelet analysis in the 0.07 frequency band, and (d) Turbulence intensity (cm^2 s^{-4}) reconstructed from wavelet analysis in the 0.65 Hz frequency band. Background noise level of wavelet amplitudes is depicted by blue, with increasing intensity shown by yellow and red shading. Black segments indicate times when the aircraft was going through maneuvers (primarily changes in altitude) that invalidated the measurements.

upon the Weather Research and Forecasting (WRF) model. In this numerical model system, the chemical kinetic mechanism is embedded within the meteorological model structure, and thus the integration of the chemistry is performed as part of WRF (WRF-Chem). Low-level and surface biogenic emissions are also integrated online since they are strongly modulated by meteorology.

Evaluation of the WRF-Chem model is being performed using a 2-month testbed dataset obtained during the 2002 New England Air Quality Study (NEAQS-2002), an intensive meteorological and air quality observation and modeling program. The goals of this program included developing a better understanding of the chemical and meteorological transport processes associated with high ozone events, and also to assess the ability of present operational and research WRF-Chem model evaluation. To better compare the WRF-Chem model to the MM5 chemistry model (MM5-Chem) used for real-time forecasts, WRF-Chem was configured with a nearly identical domain and anthropogenic emissions data. Because of the similarities of the chemical modules within the WRF-Chem and MM5-Chem, most of the differences in the comparison of the two models should be caused by differences in the meteorological simulation.

The model evaluation is being done in three distinct ways. Operational evaluation compared the model outputs against measurements taken by operational ozone monitors. Statistics show how the model forecasts related to each other as well as to measured ozone. Diagnostic evaluation examined ozone and its precursors at particular locations and time periods in detail. Meteorological evaluation focused on differences in the meteorological forecasts. The measurements used for comparisons were primarily from research sites. It should be noted that model comparisons are complex and

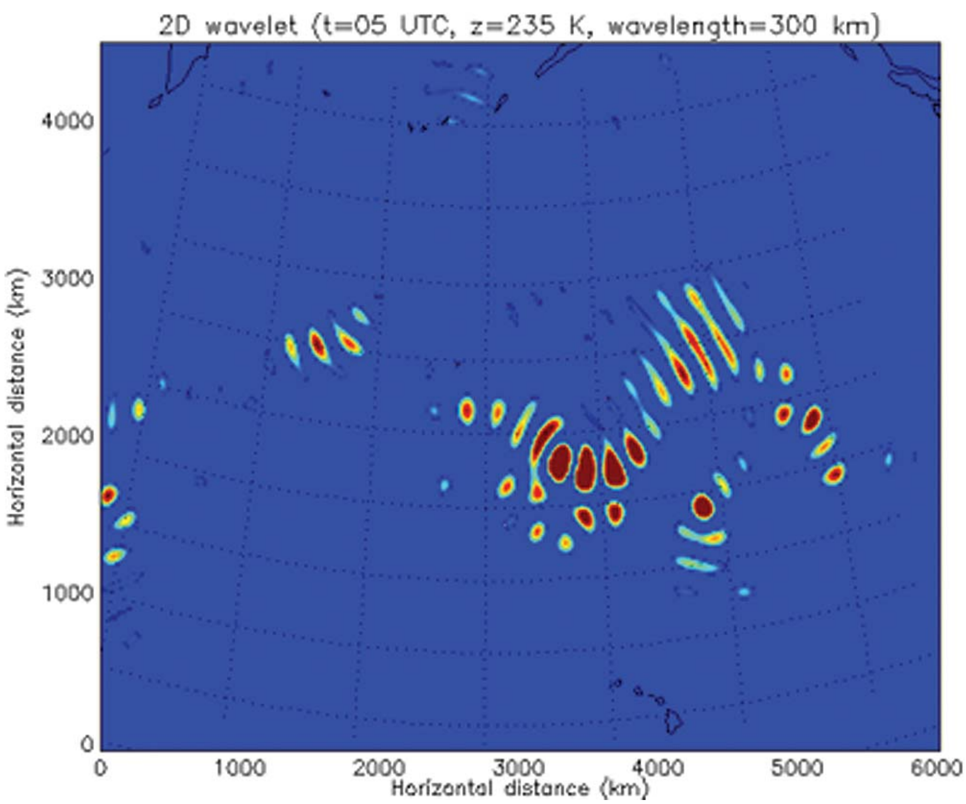


Figure 27. A two-dimensional wavelet analysis of vertical velocity field from the RUC model simulation of a SCATCAT case.

difficult. Many factors such as physical parameterizations or vertical grid resolution, etc. affect model performance. Statistics should therefore be interpreted with care, and small differences in performance should not receive undue emphasis.

The square of the correlation coefficients (r^2) and median error statistics for all of the WRF-Chem and MM5-Chem ozone (O_3) predictions are summarized graphically in Figure 28a. The r^2 coefficients derived from 8-hour averages are also included in these plots. The most relevant comparisons are between the WRF-Chem results and the MM5-Chem results. For O_3, the WRF-Chem r^2 coefficients (based on hourly averages) are slightly to significantly higher than those of MM5-Chem for 12 out of the 15 possible lead-time/observation site combinations. Biases are generally indistinguishable between all of the model cases. One can conclude that the WRF-Chem model exhibits improved model skill relative to MM5-Chem for O_3. Although there is less confidence associated with the r^2 values derived from 8-hour averages (only 38 points in the linear regressions), they are always as large or larger than the r^2 values derived from 1-hour averages. This implies that model/observation correlations at each site are driven by the models' ability to simulate the day-to-day variability in O_3, as opposed to hourly O_3 variations.

Unlike O_3, CO and NO_y have negligible photochemical sources, and provide a more direct link between anthropogenic source regions and transport to the various sites. Figure 28b shows the forecast skill and model biases for NO_y.

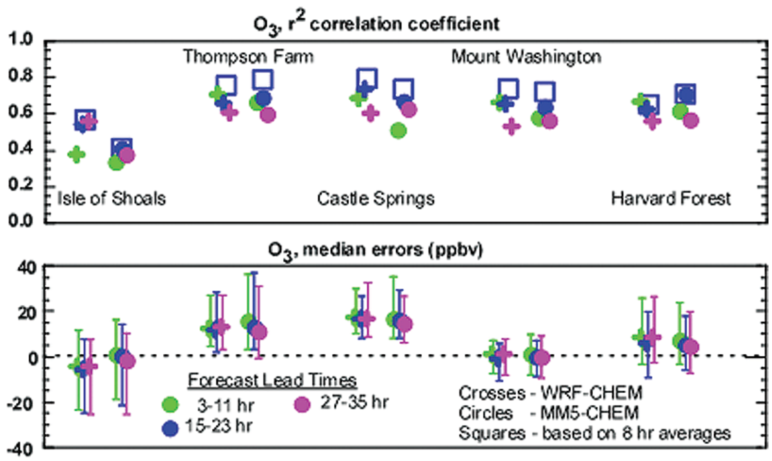
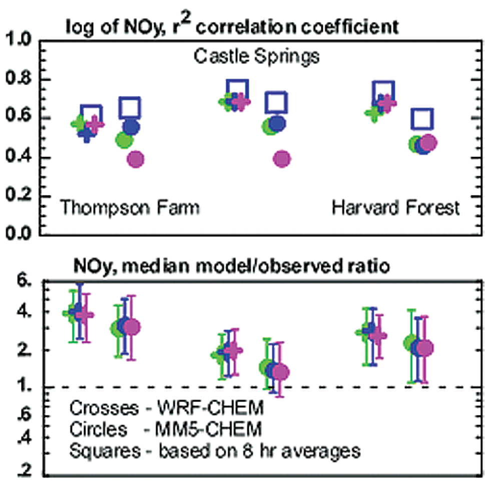


Figure 28. a) left, Ozone (O_3) correlation coefficient and median errors obtained using MM5-Chem and WRF-Chem forecast data and compared with five ozone observation sites in the New England region. Values are computed for 13 July 2002–7 August 2002 and are separated into 12-hour forecast periods shown by the colored dots. Correlations and median errors based on 8-hour averages are shown by the blue squares. WRF-Chem ozone forecasts have slightly better correlation than MM5-Chem ozone forecasts and have little bias.



28. b) NO_y correlation coefficient and median error ratios for the MM5-Chem and WRF-Chem forecasts for three observation sites. Values are computed for 13 July 2002–7 August 2002 and are separated into 12-hour forecast periods shown by the colored dots. Correlations and median errors based on 8-hour averages are shown by the blue squares. The WRF-Chem NO_y forecast was slightly better, but has a large bias.

The r^2 values based on hourly averages are generally lower than for O_3. For 8 of the 12 lead-time/site combinations, the WRF model shows increased forecast skill over the MM5-Chem model. With the exception of a slight decrease in r^2 values at Castle Springs, VT, the WRF model outperforms MM5-Chem. However, the CO model bias for WRF-Chem is always larger than that of MM5-Chem, and significantly higher at the Isle of Shoals and the Harvard Forest sites. The large biases can be explained by the coarse treatment of land use and emissions along the New England coastline. Smaller horizontal grid spacing has been shown to reduce the forecast biases to near zero.

In addition to chemical species, WRF-Chem is capable of forecasting the concentration of particulate matter the size of 2.5 microns (PM2.5). These atmospheric aerosols are generated by chemical reactions and significantly influence visibility and smog forecasts. Figure 29 shows a scatterplot of hourly averaged PM2.5 concentration from the WRF-Chem model and the observations of PM2.5 collected at Thompson Farm, Vt. There is clearly a correlation between the model and observations, particularly at the high end. However, the model tends to under-predict high aerosol concentration by roughly a factor of 2. It is anticipated that updating the surface chemical emissions database and improving the aerosol chemical production will greatly improve the PM2.5 concentration forecast.

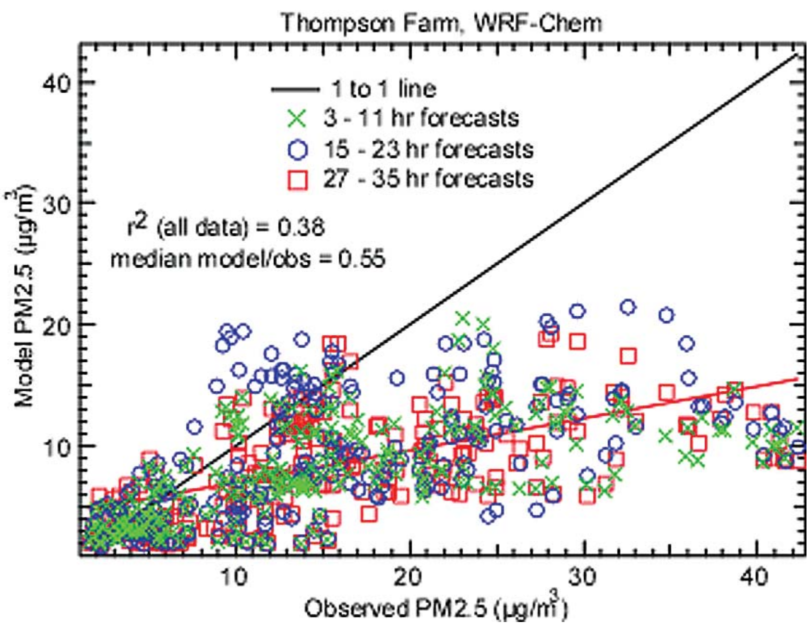


Figure 29. Scatterplot of PM2.5 forecasted by WRF-Chem for the Thompson Farm location compared to the observed PM2.5 concentration. Values computed for 13 July 2002–7 August 2002 are separated into 12-hour forecast periods shown by the colored dots. WRF-Chem tends to underpredict large concentrations of aerosols.

Participation in Development of the Weather Research and Forecast (WRF) Model System – The overall goal of the WRF model project is to develop a next-generation mesoscale forecast model and assimilation system that will advance both the understanding and prediction of important mesoscale weather, and promote closer ties between the research and operational forecasting communities. The model and associated system are being developed as a collaborative effort among NCAR, NCEP, FSL, the Center for the Analysis and Prediction of Storms (CAPS), and other research institutions together with the participation of a number of university scientists.

WRF Model Precipitation Testing – In preparation for replacement of the RUC model by a yet-to-be determined version of the WRF model in the "Rapid Refresh" slot at NCEP, we have been comparing the performance of RUC and WRF in real-time runs over the continental U.S. The two models are run on identical domains and horizontal grid configurations, and the WRF is initialized from the RUC 3DVAR. The physics in WRF is being configured as close to the operational RUC as is currently possible in order to better discern effects related to the fundamental differences between the two models, particularly their vertical coordinate. The RUC Grell-Devenyi convective scheme and RUC land-surface model are used along with other parameterizations, such as the Mellor-Yamada-Janjic PBL and surface layer formulations used in the operational Eta and the NCEP 5-class bulk microphysics scheme. There is no WRF option for the Dudhia longwave radiation scheme used in RUC (the Rapid Radiative Transfer Model (RRTM) is used in WRF).

Overall, the WRF runs, as compared with the RUC (development code) runs, appear to consistently have more precipitation. This is demonstrated in Figure 30, which shows a comparison of 3-hour accumulated total precipitation and snow precipitation from WRF and RUC for the south Atlantic states. The differences between the 10-km WRF and RUC versions could be even more substantial.

Real-Time Air Quality and Weather Forecasts Using the WRF-Chem Numerical Model – Real-time forecasts using the WRF-Chem model are being conducted at FSL. These simulations are run to ensure model robustness, to perform subjective analysis of ozone (O_3) and PM2.5 (particulate matter at 2.5 microns) forecasts, and to prepare the WRF-Chem model for a direct comparison with the NWS operational air quality forecast model suite. The forecasts are made for a 36-hour time period on a numerical grid that is approximately 3600 km x 3000 km and covers the eastern two-thirds of the United States. The numerical grid uses 27-km horizontal grid spacing and is centered at 86°W longitude and 34.5°N latitude. The model domain extends vertically to 18 km with a vertical mesh interval smoothly increasing from 7 m near the surface to approximately 500 m at the domain top.

Forecasts are produced every 12 hours starting at 0000 and 1200 UTC. The meteorological initial conditions are obtained from the Rapid Update Cycle (RUC) model analysis fields generated at FSL, and lateral boundary conditions are derived from the NCEP Eta model forecast. Atmospheric chemical constituents are initialized from the previous 12-hour forecast, and the chemical lateral boundary conditions for inflow along lateral boundaries are obtained from an idealized atmospheric chemistry profile. Hourly updates are made to the anthropogenic emissions using the EPA NET-96 emission database that is interpolated to the three-dimensional model grid. Information about the configuration of the WRF-Chem model is provided in Table 1.

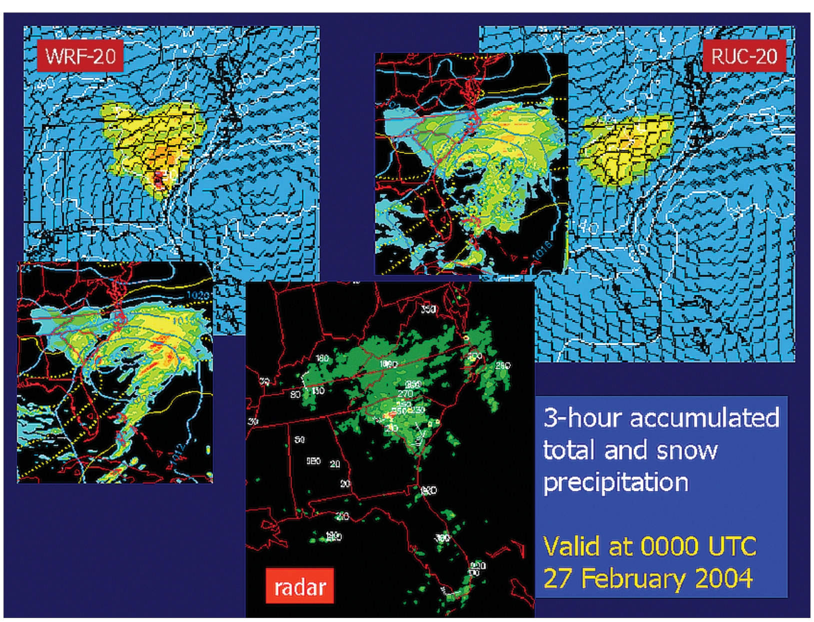


Figure 30. Comparisons of 3-hour accumulated total and snow precipitation from 12-hour forecasts of 20-km WRF and RUC against the radar valid at 0000 UTC 27 February 2004.

Table I.
WRF-Chem Real-Time Forecast Configuration

Advection scheme	5th horizontal /3rd vertical
Microphysics	NCEP 3-class simple ice
Longwave radiation	RRTM
Shortwave radiation	Dudhia
Surface layer	Monin-Obukhov (Janjic Eta)
Land-surface model	OSU
Boundary layer scheme	Mellor-Yamada-Janjic TKE
Cumulus parameterization	Betts-Miller-Janjic
Chemistry option	RADM2
Dry deposition	Weseley, 1989
Biogenic emissions	Gunther, 1994 and Simpson, 1995
Photolysis option	Madronich, 1987
Aerosol option	MADE/SORGAM

Graphical forecast products are generated from hourly model output data and freely distributed to federal and state Air Quality offices at Webpage *http://www-frd.fsl.noaa.gov/aq/wrf* (Figure 31). The two images show the concentration of O_3, NO_y, CO, PM2.5 and several meteorological fields. In addition, universities and national forecast offices receive the forecast model data through the FX-Net (*http://www-id.fsl.noaa.gov/fxnet.html*). This FSL-developed application allows the forecaster/researcher to simultaneously visualize the three-dimensional structure of the meteorological and chemical forecast, as well as surface observations of the same fields.

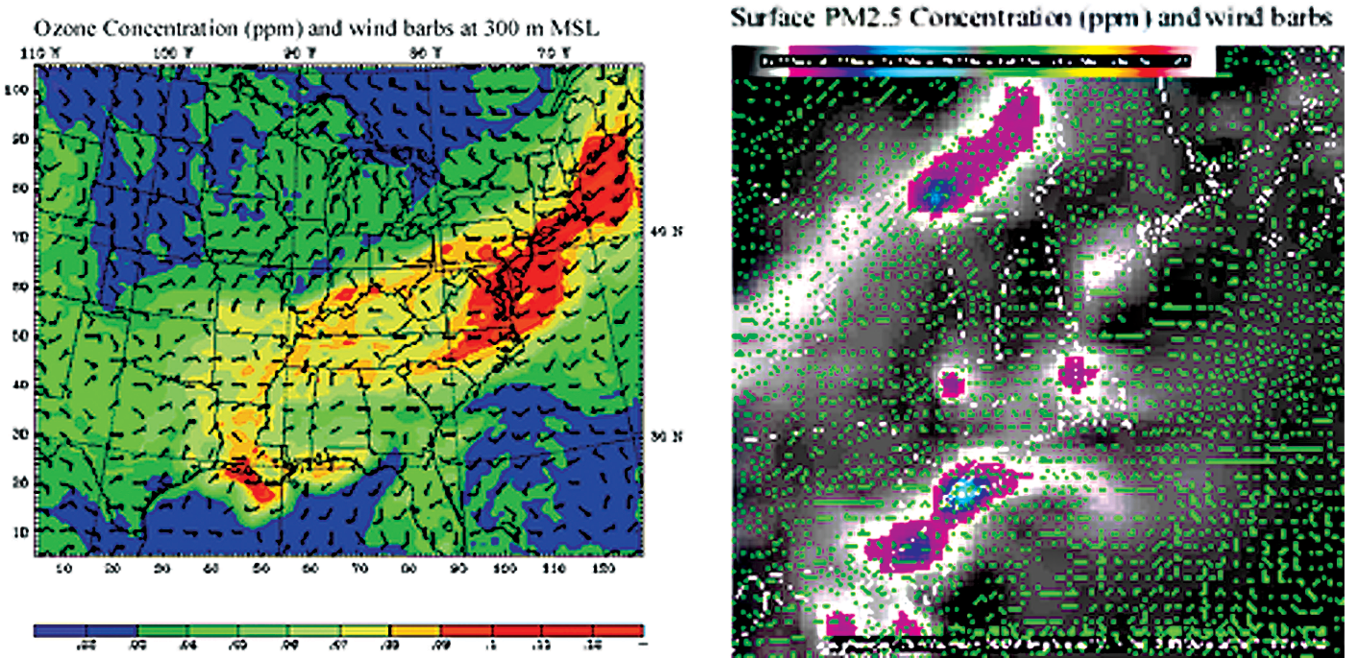


Figure 31. a, left) Example WRF-Chem forecast image showing ozone concentration and winds. O_3 concentrations (ppmv) are shown by the color bar. b) FX-Net image of a WRF-Chem forecast of surface PM2.5 and winds. PM2.5 concentrations are shown by the color bar.

Projections

Scientists within the Regional Analysis and Prediction Branch and other FRD branches will continue to work with colleagues at NCEP, NCAR, and other organizations to improve the RUC and WRF models over the next few years. An overview of the primary near-term tasks follows.

RUC Upgrade to 13-km – The next (and final) major upgrade to the hybrid-isentropic model that forms the foundation of the RUC is intended for implementation at NCEP sometime in 2005. This will be made possible by a major increase in computing resources at NCEP in 2004–2005. The chief model upgrade will be reduction in the horizontal grid spacing to about 13 km to allow improved representation of effects of terrain and land sea contrasts. This includes orographic precipitation enhancements and shadowing, improved prediction of mesoscale, terrain-induced airflow perturbations, as well as land-sea breezes. A secondary benefit, based in part on our extensive experience running the RUC model at 10-km horizontal resolution over sub-CONUS domains, is improved representation of cloud and precipitation processes. Plans are underway to update the Grell-Devenyi ensemble convective parameterization with ensemble weighting based on data assimilation techniques to optimize prediction of convective rainfall, as well as an improved version of the NCAR mixed-phase, bulk microphysics package. In addition, further enhancements will be made to the LSM along with a careful evaluation of turbulence schemes (that currently used in RUC as well as possible replacements).

WRF model enhancements in preparation for Rapid Refresh (RR) – Improvements will be made to WRF performance as we gain further experience, and particularly as we go to full, self-contained cycling of WRF. A digital filter initialization will be introduced into WRF to improve dynamical balance during the first few hours of the forecast. Extensive comparative evaluation of WRF performance relative to RUC will continue, and will form the basis for the decision on whether an enhanced version of the current RUC model (adapted to the WRF coding framework) or a nonhydrostatic version of the WRF will be used as the initial RR model. Plans are to replace the RUC with the WRF RR model by early 2007, thus the reason for why the next upgrade of RUC is to be the last.

RUC contribution to the New England High-Resolution Temperature Project – An FSL RUC13 cycle, as well as 13-km WRF model forecasts spawned off this RUC cycle, will be run in support of this project during summer of 2004. Assessment of model performance, particularly at the surface and in the PBL and using project special observations, will contribute to identifying model weaknesses and ways to alleviate them.

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RUC Probabilistic Convective Forecasts for the Aviation Community – For the 2004 convective season, additional ensemble information will be utilized, including time-lagged output from different RUC forecast cycles, different RUC model versions (data assimilation and model physics differences), and modulation of the convective probabilities by other convection-related fields (lifted index, vertical velocity, terrain, etc.). Development of the time-lagged ensemble system using RUC forecasts is planned in accordance with FAA's requirement.

Refinement and Testing of Improved Physical Parameterizations for Soil/Vegetation Processes, Turbulence, Convective Clouds, and Cloud Microphysics – Some of this work will be done in collaboration with NCAR, since the RUC model uses some of the MM5 parameterizations that will be options for the WRF model.

National Observing System – FSL will continue its efforts with a team working toward an initiative to develop a national mesoscale observing system consisting of tropospheric and boundary layer profilers, ground GPS receivers, and radiosondes with ground tracking systems. This is an initiative with great potential impact for mesoscale forecasting. Also under development is an observation system simulation experiment (OSSE) with a practical observation network design and numerical model to verify the budgets and applicability.

Data Assimilation – Work will commence to test the WRF 3DVAR system within the RUC assimilation cycle.

Contribution of RUC Forecasts to the NCEP Short-Range Ensemble Forecast System – As part of an expansion to NCEP's Short-Range Ensemble Forecast (SREF) project, FSL will complete its effort begun this last year to set up an ensemble version of the RUC model running out to 63 hours on a 48-km grid over the Eta domain. The RUC SREF is spawned from a set of five members bred from the NCEP Eta model, and is a candidate for inclusion in the NCEP SREF set currently composed only of Eta and Regional Spectral Model bred members. Tentative results from the RUC SREF show substantial spread in the ensemble, but it needs to be determined whether the forecast skill for the ensemble mean exceeds that of the operational RUC20 model, and statistical techniques must be developed to assess the results.

Joint Center for Satellite Data Assimilation Activities – Work will continue in running and testing the Optical Test Transmittance (OPTRAN) radiative transfer model to replace the European Centre for Medium-Range Weather Forecasts' RTTOV code that has been used in all RUC forward model calculations thus far. OPTRAN has been chosen as the community radiative transfer model by the Joint Center for Satellite Data Assimilation. Outgoing radiances from the RUC will then be subjected to OPTRAN forward model calculations to compare with the GOES radiances. The imager data will be used to determine clear-air radiances with greater resolution than using the sounder estimates. Eventually, the goal is to incorporate the adjoint of the forward calculations into the RUC three-dimensional variational (3DVAR) analysis and to begin using this to rapidly update the radiance data in the RUC and, later, the WRF models.

Use of Radar Data in a National-Scale Cloud/Hydrometeor Analysis – A highlight of this work will be the availability of CONUS Level-2 88D data at NCEP. Our current reflectivity assimilation will be upgraded to use this data. Improvements will be made to the current ceiling and visibility translation algorithm. There is promise that RUC or RR analyses and, particularly, forecasts can form a basis for CONUS ceiling and visibility analyses/forecasts; fruitful interactions with scientists at NCAR and MIT Lincoln Laboratories are anticipated toward this end.

Continued Development of a National-Scale Cloud/Hydrometeor Analysis – Development and real-time testing will continue for further improvements to the RUC national-scale cloud analysis, with the addition of radar, lightning, and surface observations to satellite cloud-top data. Experiments will be carried out testing assimilation of a GOES imager-based multilevel cloud product, as described below under the JCSDA plans.

Local Analysis and Prediction Branch

John A. McGinley, Chief

Objectives

The Local Analysis and Prediction (LAP) Branch responds to the needs of many government agencies and the private sector in the areas of local and mesoscale data analysis, data fusion, data assimilation, quality control, three-dimensional display and visualization, and numerical modeling. Research and development involving the Local Analysis and Prediction System (LAPS) and the implementation of mesoscale forecast models form the primary focus of the branch. The overarching objective is to provide real-time, three-dimensional, local-scale analyses and short-range forecasts (0–24 hours) for domestic and foreign operational weather offices, facilities, and aviation and other field operations. Activities cover four broad areas:

Data Acquisition – Includes identifying, collecting, and quality-controlling any atmospheric or earth surface measurements of utility to LAPS, such as those provided by satellites, radars, mesonets, aircraft, GPS, rawinsondes, and profilers. This activity also includes developing interfaces to national datasets, such as the gridded data services provided via the Satellite Broadcast Network (SBN) data feed and similar military systems. LAPS is coupled with the Local Data Acquisition and Dissemination (LDAD) System and the Meteorological Atmospheric Data Ingest System (MADIS), as well as the Taiwanese and Korean data sources.

Data Analysis – Accomplished using an integrated software package containing well-documented objective analysis schemes that apply quality control criteria to the data, spatially represent atmospheric conditions, perform spectral filtering, and ensure vertical consistency. The data analysis system is running within AWIPS in National Weather Service (NWS) forecast offices; at the eastern and western space ranges at Cape Canaveral, Florida, and Vandenberg Air Force Base (AFB) California, for the U.S. Forest Service (USFS) in support of fire mitigation and firefighting; for the U.S. Army in support of precision parachute airdrop activities; and for the Taiwan Central Weather Bureau. The LAPS analysis system is freely distributed and has been downloaded by over 90 users worldwide over the last year.

Mesoscale Model Implementation – Accomplished using an expanding variety of mature nonhydrostatic modeling systems, such as the Regional Atmospheric Modeling System (RAMS) developed at Colorado State University, MM5 developed jointly by NCAR and Pennsylvania State University, the hydrostatic version of Eta developed at NCEP, and the Weather Research and Forecast (WRF) model under joint development by FSL, NCAR, and NCEP. These models have been configured to be initialized by LAPS analyses and with time-dependent boundary conditions furnished by all operationally available gridded datasets (RUC, Eta, Global Forecast System, the U.S. Navy Operational Global Atmospheric Prediction System, and the Taiwan NF system). Implementation of the LAPS system at some NWS forecast offices has demonstrated the portability and effectiveness of running models locally. One such demonstration at the Jacksonville, Florida Weather Forecast Office, sponsored by NWS, tests the feasibility of local modeling in NWS WFOs. FSL continues to collaborate with the Denver-Boulder NWS Forecast Office to demonstrate the effectiveness of locally run models. LAPS-initialized mesoscale models have been run both on the local AWIPS application server and on FSL’s High-Performance Computing System for operational evaluation. Models have the option of being initialized using the LAPS diabatic analysis that allows a full representation of clouds and vertical motion in the initial state. During winter 2002–2003, an ensemble of mesoscale models supported the weather forecast input to a road maintenance decision support system for the Federal Highway Administration. This was the third year that FSL participated in providing ensemble model output. This time the ensemble included only the MM5 and WRF, and used a number of forecasts valid at the same time to populate the "time-lagged" ensemble.

Dissemination – Includes delivery of weather products and basic fields developed from LAPS to users in operational forecast offices and state and local government agencies, including emergency managers and other users specializing in fields such as winter highways operations, fire weather, aviation and space operations, and military operations. Figure 32 shows the U.S. Forest Service (USFS) main Website for acquisition of LAPS products by fire managers in the Rocky Mountain and Southwest Area Coordination Centers. For fire weather support, LAPS analysis and model fields can be dynamically located to specific fire locations. This text format for 24-hour point forecasts proved to be popular with USFS personnel during the past 2003 fire season. LAPS fields are compatible with AWIPS file formats and appear in dedicated Webpages for specified customers. Last year LAPS was installed as a key part of the Precision Airdrop System (PADS) developed at MIT Draper Laboratory and Planning Systems Inc. Data from LAPS feed PADS with internal file sharing on a laptop. PADS provides real-time wind analyses and short range forecasts to compute accurate parachuted cargo trajectories for U.S. Army/Air force operations. LAPS can be displayed in three dimensions using the experimental D3D (Display Three-Dimensional) add-on to AWIPS. Such three-dimensional displays can help forecasters achieve a better conceptual view of complex meteorological processes. The LAP Branch, along with some NWS Forecast Offices, continues to explore the potential of three-dimensional displays for operational use, perhaps eventually as a part of AWIPS within the NWS. The D3D software was distributed to many sites within the NWS Regional Offices as well as other operational environments.

Figure 32. Web homepage for the U.S. Forest Service (USFS) Rocky Mountain Center FCAMMS. LAPS/MM5 products support both analyzed and forecast fire products for six different domains as indicated by the selector buttons on the left. Also on the left is a selector for smoke trajectories. This Webpage serves as the dissemination source for many fire-related agencies in the USFS and the Bureau of Land Management.

Accomplishments

Basic Analysis System Development:Three-Dimensional Analysis Methods – LAPS applies variational methods at various stages in its analysis. The variational approach to the LAPS moisture analysis remains the method of choice to integrate GOES sounder radiances, GOES-derived products, GPS, boundary layer moisture, cloud information, radiosonde, and profiler data. In LAPS the variational step was previously used only with GOES sounder radiances. The variational adjustment now includes GOES radiances, GOES three-layer precipitable water vapor, GPS total column water vapor, and cloud information from the LAPS cloud analysis in one variational formulation. An ongoing data denial experiment provides insight into the impacts of the various data sources on the analysis. In addition, this assessment tool can be used to gauge the strength and weakness of the different data sources, in order to optimize their respective weights in the variational equation. The statistics used in this study result from a comparison of analysis output to radiosonde data (taken as referenced truth). This is possible since radiosonde data are not typically used in the operational LAPS system due to their latency (poor timeliness). The goal of the moisture variational application is to provide a complete product that describes the atmospheric water distribution from vapor to cloud droplets to precipitation, both liquid and frozen. This analysis, used to improve model initialization, utilizes all conventional data, along with satellite, radar, and GPS data. The routine is based on the LAPS cloud analysis, but then seeks to quantify all water substances. Variational methods are then used to impose dynamic balance and continuity on the first-stage analyzed fields to accommodate the "Hot Start" analysis described below.

Under investigation is the relative value of direct radiance data assimilation versus 3-layer GOES derived product imagery (DPI) data. An important question is whether DPI data, which are more easily assimilated than direct radiances, would be a valuable alternative in situations where CPU cost or timeliness could not afford the more CPU-intensive direct radiance assimilation. Early results show that DPI imagery is performing on par or slightly better than the LAPS direct radiance assimilation. Figure 33 shows a test that compares the "error" differences (abs[direct–raob] and abs[DPI–raob]). Though only the afternoon (0000 UTC) data comparison is shown here, the morning comparison is similar. The student-t test results in the center plot shows points of less than 2.0×10^{-10}, indicating that the two compared populations have different mean values with significance better than 99.95%. The Student-f test plotted to the right shows that all values are larger than 0.95, indicating similar variances of the two populations (desirable when comparing mean values). In the plot to the left, the differences are very small, but slightly better for the derived product image data, especially in the lower levels of the atmosphere (with their strong significance related to the student-t statistic). The region above 500 hPa has a much better student-t statistic (smaller yet), but differences are also nearly zero, because moisture is most abundant in the low atmosphere where DPI data show a favorable impact. It should be noted that the results of ongoing comparison, begun in late fall 2003 and spanning a climatologically dry season, may change over the moist convective months. Further, for reasons of computational efficiency, the LAPS system assimilates only 7 of the 18 IR channels, namely those channels whose eigenvalues demonstrate that they are responsible for most of the radiance information in the moisture problem. It should also be noted that these statistics are computed for synoptic times but GOES moisture retrievals appear to perform better at such times than the asynoptic times, a subject to be covered later in this report.

LAPS Advanced Quality Control – Quality control of observations is a continuing focus of LAPS analysis development. A Kalman filtering scheme is used to improve the quality and timeliness of surface observations. The method allows users to optimally exploit local model output and past station trends and buddy trends to produce check values for surface stations. In conjunction with a LAPS 30-minute analysis cycle, the Kalman scheme allows the merging of mesonetworks with varying cycle times. Working exclusively in data space, the Kalman filter scheme is economical for use in the local computing environment and provides a continuously updated and accurate set of observations where all stations appear at each cycle. This is an appropriate approach for instances when a user requires good product time continuity, but has high variability in observation count from cycle to cycle. The Kalman scheme is currently being configured for use in a wavelet-based, mesoscale surface analysis scheme with a 15-minute cycle on a 5-km grid over the CONUS.

LAPS Diabatic Initialization (Hot Start) Procedure – The LAP Branch continues to improve the Hot Start procedure for diabatic initialization of mesoscale models. The Hot Start initialization scheme is designed to develop initial conditions for mesoscale models such as the MM5, RAMS, and the Eulerian mass-coordinate version of the WRF model. This scheme is unique in that it runs on small PC clusters with Linux operating systems and is ideal for applications in local weather offices where accurate short-term cloud and precipitation forecasts are needed. It depends greatly on the accuracy of the background modeling system, currently the NCEP versions of the RUC or Eta models or the Taiwan NF model. The Hot Start scheme uses estimates of vertical motion and cloud water and ice mixing ratios from the LAPS cloud analysis. A variational analysis that applies both mass continuity and mass-momentum balance makes small adjustments to the wind and temperature field to accommodate and sustain the clouds in the first few time steps of the model integration. The cloud retrieval algorithm includes a broad range of microphysical species, cloud-type dependent estimates of cloud vertical motion, and saturation of the cloud environment. The Hot Start procedure has been subject to long-term verification compared to standard models.

The Hot Start method is used as part of the process of initializing the MM5 and/or WRF models over a variety of domains including the local Denver forecast area, where forecasters use it as an operational tool; the U.S. Air Force Western Range at Vandenberg Air Force Base as part of the Range Standardization and Automation (RSA) implementation discussed below, and IHOP field postanalysis areas at 12- and 4-km grid resolution. The Hot Start system has been coupled to the WRF-mass coordinate model for testing in a local weather service office in conjunction with the Coastal Storms Initiative carried out with the NWS and National Ocean Service (see below). It is part of the MM5

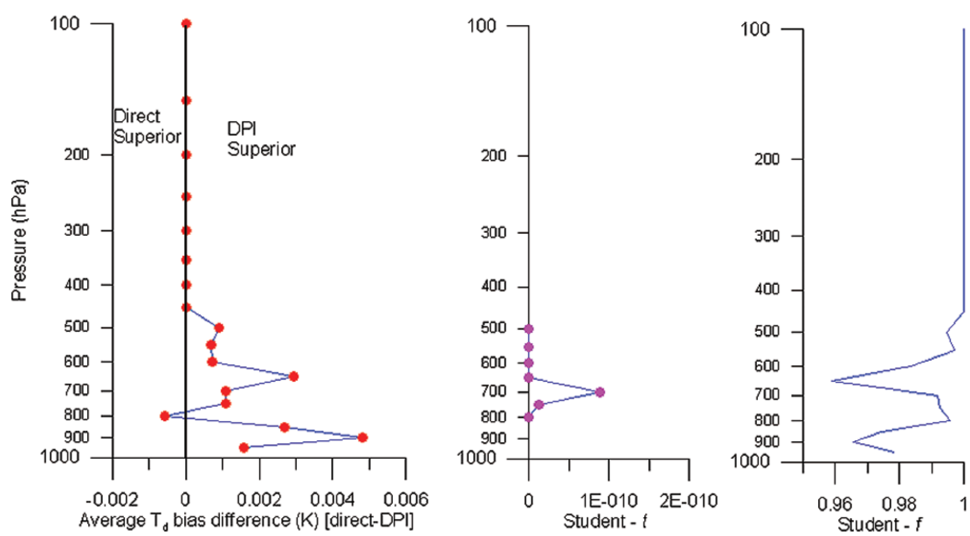


Figure 33. Plots comparing the use of direct radiances to the use of DPI data in LAPS: average dewpoint bias difference (K) using radiosonde data as "truth" (left), student-t statistical results of the levels displaying "significance" in the measured difference (center), and student-f statistic showing that populations at all levels possess similar variance.

modeling system at the Central Weather Bureau of Taiwan, and the ensemble runs for the Federal Highways Road Maintenance Demonstration. The Hot Start is utilized to improve the accuracy of short-range precipitation forecasts in the 0–12-hour period.

GOES Improved Measurements and Product Assurance Plan (GIMPAP) – The GIMPAP project has been a key part of the moisture algorithm development for integrating the high spatial structure of GOES imagery and sounder data into the LAPS system. GIMPAP includes NESDIS cloud-top pressure and layer-precipitable water products.

The use of data collected during the 2002 International H_2O Project (IHOP) has enhanced the development of the LAPS moisture algorithm. This is an unprecedented dataset for studying comparisons of GOES-derived moisture product data with GPS data, which show that GPS data are at least as representative as radiosonde data – the "gold standard"– for vapor validation. Hourly comparisons were made between the GOES-8 3x3 pixel-averaged IHOP data, produced by the Cooperative Institute for Mesoscale Satellite Studies (CIMSS) and GPS data. This research revealed some interesting results, primarily that a synoptic comparison is not representative of errors at asynoptic times; in fact, errors grow to considerable levels after 1200 UTC. Figure 34 shows bias, standard deviation, and RMSD at hourly values for total moisture (precipitable water, cm). A similar comparison between GPS and GOES surface pressure is shown on the right side of the figure. In the case of GPS, pressure is a highly accurate measurement. In the case of GOES, the surface pressure is used for the lower boundary in the integration of the derived GOES moisture profile from which total precipitable water is computed. Initially the possible influence of biases in surface pressure was investigated to help explain the unexpected moist bias observed in the GOES product. The original assumption was that a possible "high" pressure bias in the GOES data might have contributed to this moist bias. This is now deemed unlikely for two reasons: first, as shown in Figure 34, the pressure bias is low and averages to a value very close to 0; second, the magnitude of the pressure bias is about an order of magnitude too low to explain the observed moist error. FSL is collaborating with CIMSS to better understand the observations derived from this IHOP test.

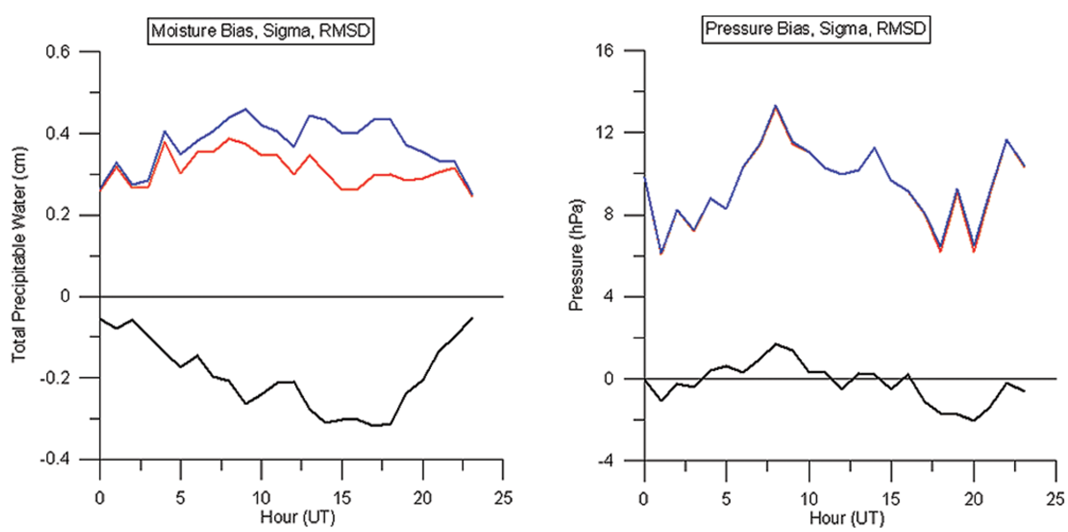


Figure 34. Plots showing computed bias (black), standard deviation (red), and RMSD (blue) for both moisture (total precipitable water, cm) left, and surface pressure (hPa) right. Note that portions of the red sigma line in the right hand plot are obscured by the blue RMSD line in small bias situations.

Joint Center for Satellite Data Assimilation (JCSDA) – NCEP's OPTRAN forward radiance model, now referred to as the Community Radiative Transfer Model (CRTM), was produced for Linux platforms. However, in order for the CRTM to be useful to models initialized by the LAPS system, interfaces to other platforms, including IBM AIX to render LAPS and model output as satellite radiance or brightness temperature had to work. To illustrate this capability, Figure 35 shows two brightness temperature images: comparing the synthetic 11-micron longwave sounder channel 8 to observed GOES 12 imager channel 4 (11-micron). Both images are valid for the same time; the synthetic image was computed from a 10-km MM5 model 1-hour forecast. Cloud structure in the synthetic image appears in the bright areas. Since both images show identical grayscales, brightness values can be directly compared. The model missed the low-level clouds in Iowa and northern Illinois, but the general features are in the right place including the cool streak in central Iowa. Also, the satellite image shows warmer brightness temperatures lacking in the model over the central Great Plains. Satellite- and model-generated radiance fields can be used in tandem to validate model performance. Under JCSDA support, work will continue in the exploration of the mesoscale nature of the background and observed error covariances for moisture analysis.

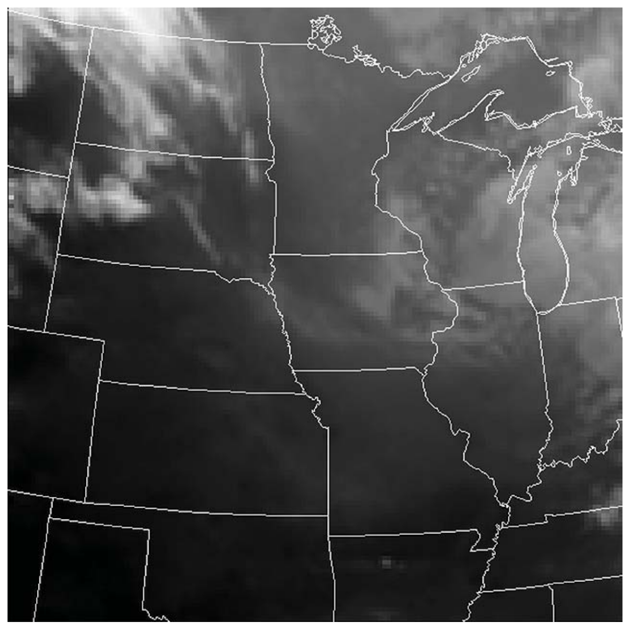
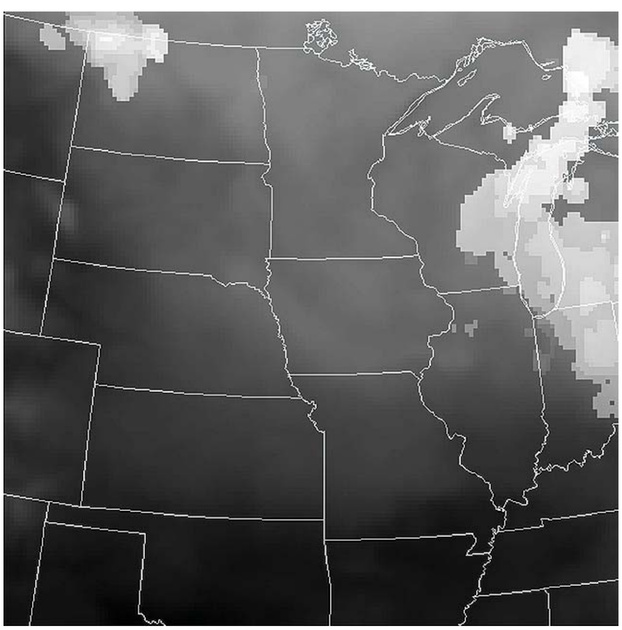


Figure 35. a, right). GOES-12 channel 4 (11-micron) longwave window IR brightness temperature image observed at 2200 UTC 18 March 2004.



35. b, left) Synthetic GOES sounder channel 8 (11 micron) longwave IR brightness temperature image generated using MM5 1-hour forecast atmospheric profiles as input to the OPTRAN forward model, valid at the same time as in Figure 35a.

Applications of LAPS

LAPS in AWIPS – The LAPS package has long been an integral element of the WFO-Advanced workstation, running as an application within AWIPS to produce a variety of gridded fields that may be combined with satellite imagery and radar on state- and local-scale displays. The LAPS in AWIPS operates off the LDAD system that acquires data outside the AWIPS network. Work continues in support of new AWIPS builds and updates the software as needed.

MM5/WRF on AWIPS – The WFO-Advanced workstation in Boulder receives 10-km resolution MM5 model output from four-times daily LAPS-initiated model runs. Likewise, the WRF model is being run at the Jacksonville WFO under sponsorship of the Coastal Storms Initiative (see below). Both implementations permit the display of mesoscale model output in a fully integrated fashion, along with radar, satellite, and surface data. Forecasters can check the quality of a model run by directly comparing model output with observations.

U.S. Army Precision Air Drop Project – Two years ago the Local Analysis and Prediction Branch became involved with a U.S. Army-sponsored development to improve the accuracy of mid- and high-level parachute delivery of logistical material to military units (Precision Air Drop Systems, PADS). Because of the complexity of wind profiles and air being channeled by terrain, computed air drop release points (CARP) were often inaccurate, resulting in cargo being substantially off target. In conjunction with Planning Systems Inc., of Reston, Virginia, FSL ported the LAPS analysis onto a laptop taken on drop missions. The concept of operations is for the aircraft to make a close proximity pass over the drop zone, release a dropsonde, and circle back while the software processes and assimilates the dropsonde with model background fields, thus creating a high-resolution profile that accommodates time and space displacements from the dropsonde position and time to cargo impact point and drop time, while accounting for flow channeling over rugged terrain.

The LAPS procedure in PADS is a four-step process: 1) perform an analysis at dropsonde release; 2) move the analysis forward in time to the proposed drop time utitilizing model trends at each grid point; 3) run the wind channeling algorithm on these forecast winds for the drop zone, and 4) extract a profile. The laptop computes an updated CARP within minutes, reducing the time exposure to potential hostile fire for the aircraft. The PADS system paired with LAPS showed big improvements over the past year: the system reduced a mean drop error from 838 m to 321 m by the summer performance tests. As an example, Figure 36 shows results of 19 low-level drops performed in late 2002 and 2003. PADS underwent rigorous testing with very high marks in Operational User Evaluation (OUE) last August and September. Table 1 shows the performance of the system during the drops in 2003. Trajectory error or error related to the wind profile and parachute dynamics accounts for most of the error. The Army unit requirement and goal for the project is to bring cargo to within 400 m of the desired impact point. For high-level drops (greater than 2,000 ft), potential error is much higher, but even for these drops, error was reduced to 377 m. A demonstration drop for dignitaries during the OUE were within 50 m of the aiming point. The importance of the dropsonde and LAPS assimilation is further supported by the fact that CARPS computed with model-only profiles have errors well above 1000 m. Success during the demonstration has prompted big interest among allied military planners.

Participation in IHOP – The LAP Branch continued to be involved in research studies using IHOP data since the end of the field phase of IHOP. A major focus has been rerunning analyses and forecasts to ensure that all data, experimental and operational, were included. This entailed significant code and script modication to handle the data in archived form. Setting up the infrastucture for archive model runs was another significant effort, since this need had not existed for past research activities. In addition to the reruns, a number of important days were selected to study in greater detail the evolution of low-level jets, moisture transport, and organized and single cell convection. Particular attention was directed at these cases to ensure accuracy of planned budget calculations. LAPB researchers interacted frequently with IHOP collaborators from Iowa State University during their summer 2003 visit to FSL.

Table 1. Summary of all Test Drops During 2003

Error Component	*Average Error (m)	Scalar % of Total Error	Error Standard Deviation (m)
Complete System	321	100	223
Green Light Postion	134	42	85
Payload Release	104	32	120
Payload Trajectory	264	82	208

Legend: The top row in Table 1 summarizes the complete system error. Three major components of error are shown on the far left column. Green light error is related to errors in navigating to the CARP; payload release error is related to the tilt of the aircraft and mechanics of cargo roll out. The aircraft is traveling about 150 m s^{-1}, so a 1-second delay can be significant. Trajectory error is related to errors in the wind profile, density, and parachute performance. Complete system error is less than the sum of the contributing errors related to cancellation. The percent of error shows each component's significance relative to the total mean error. For example, trajectory error can be as much as 82% of the total error for an average drop. The standard deviation is useful for estimating the probabilistic ellipses shown in Figure 36. This table combines high-level (>25,000 ft) and low-level (10,000–15,000 ft) drops. The mean low level drop error was 260 m, with the high-level drop error at 377 m.

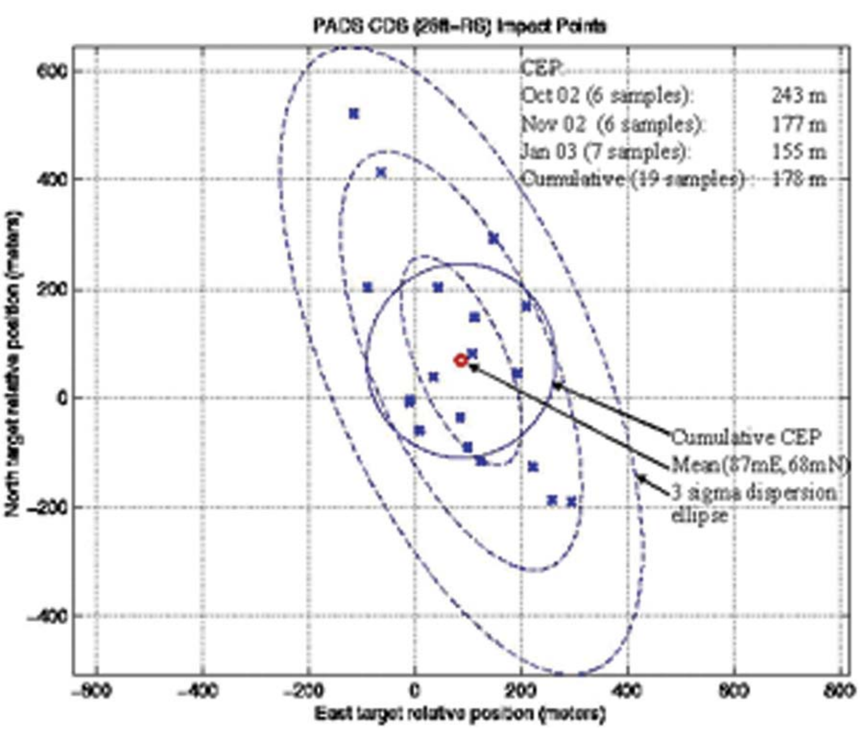


Figure 36. Sample error analysis for 19 quite successful low-level drops during late 2002 and early 2003. The intersection of x and y axis ("0" lines) is the desired impact point; the blue "x's" are the actual impact points. Scale at bottom and left are in meters. The red circle is the mean of the 19 drops. The ellipses show the 95th, 90th, and 50th percentile of possible error from outward to inward.

The Range Standardization and Automation (RSA) Project – Several years ago, the Air Force initiated the Range Standardization and Automation (RSA) program to modernize and standardize the command and control infrastructure of the two U.S. Space Launch facilities (ranges), located at Vandenberg Air Force Base, California, and Cape Canaveral Air Station, Florida. During this past year, in cooperation with Lockheed Martin Mission Systems, Phase I of an integrated local data assimilation and forecasting system was installed at both ranges. The RSA system runs on Linux "Beowulf" clusters from IBM at each range and a test cluster at FSL for use in system development. The clusters consist of 8 dual-processor Pentium III nodes and 1 dual-processor front-end node, totaling 18 processors. A Myrinet interconnect is used for high-speed message passing between nodes.

The final version of the RSA Data Assimilation and Forecast System is based on LAPS coupled with the NCAR fifth-generation Mesoscale Model (MM5). The system produces hourly LAPS analyses and a new MM5 forecast run every 6 hours on a triple-nested domain with 10-km, 3.3-km, and 1.1 km-grid spacing, respectively. These analyses make use of the AWIPS Local Data Acquisition and Dissemination (LDAD) interface to incorporate data sources unique to the launch facilities, in addition to the radar, satellite, and other datasets available via the AWIPS data feed. Every 6 hours, these analyses are used to perform a diabatic initialization of an MM5 forecast run. The forecast model outputs hourly forecast fields out to 24, 12, and 9 hours for the 10-km, 3.3-km, and 1.1-km grids, respectively, using 2-way nested feedback. The entire system is integrated with the Linux version of AWIPS installed at the Air Force ranges. Figure 37 (a,b) shows an example of a forecast radar reflectivity pattern associated with dual sea breezes at 12 hours on the interior (1-km mesh). The accompanying graphic shows the radar at Melbourne, Florida, for the same time. Though qualitative success is frequently demonstrated, the RSA system is in critical need of a quantitative verification system, which is being developed under maintenance support.

The RSA project established a number of firsts including the first operational installation of a local modeling system completely integrated with AWIPS in a WFO-like environment, the first operational installation of the LAPS diabatic initialization-Hot Start method, and the first operational use of a Linux-based AWIPS system. Ongoing RSA maintenance work will be aimed at ingesting and optimizing the use of new local meteorological datasets, incorporating new capabilities such as online verification of the forecast grids, enhancing utilization of the satellite data to improve cloud analyses, and improving the LAPS diababic initialization method.

High Performance Computing – The FSL High-Performance Computing System (HPCS) has been a critical resource for all of the numerical modeling activity in the branch, including the unique mesoscale model ensemble used for the Federal Highways Project described below. This experience continues to provide important feedback to the system developers and computer specialists regarding configuration issues and future upgrade plans.

Collaborative Modeling Projects

Ensemble Modeling of Winter Road Conditions – Branch scientists participated in the fifth and final year of the Maintenance Decision Support System (MDSS), initiated by the Federal Highway Administration (FHWA) to provide optimized weather forecasts and decision support for snowplow operations. Data are taken from an ensemble of mesoscale forecast models (MM5 and WRF) generated by FSL and integrated into NCAR's Road Weather Forecast System, which uses statistical methods to refine forecasts at many points along roadways in the system domain.

These point forecasts are used in pavement condition modules (developed by the Cold Regions Research and Engineering Laboratory of Hanover, New Hampshire) and encoded rules of practice (produced by the Massachusetts Institute of Technology/Lincoln Laboratory) to recommend treatments for road surfaces during snowstorms. For example, the Graphical User Interface might suggest plowing a certain stretch of pavement three times during the period from noon to sunrise, and spread 150 pounds of salt per lane-mile to keep the surface melted.

The configuration of the FSL ensemble has changed each of the three years that the MDSS project has conducted field projects. The 2003 demonstration, again centered on Iowa, used a pair of 15-hour forecasts initialized each hour as the basis for weather prediction. The NCAR software used a lagged ensemble approach, in which a tuned forecast valid in, say, four hours, used the most recent 4-hour forecast, the previous 5-hour forecast, and the 6-hour forecast from the model run before that (i.e., all model runs are valid at the same time). Combined appropriately, the resultant forecasts are better than any of the individual model runs in the ensemble (Figure 38).

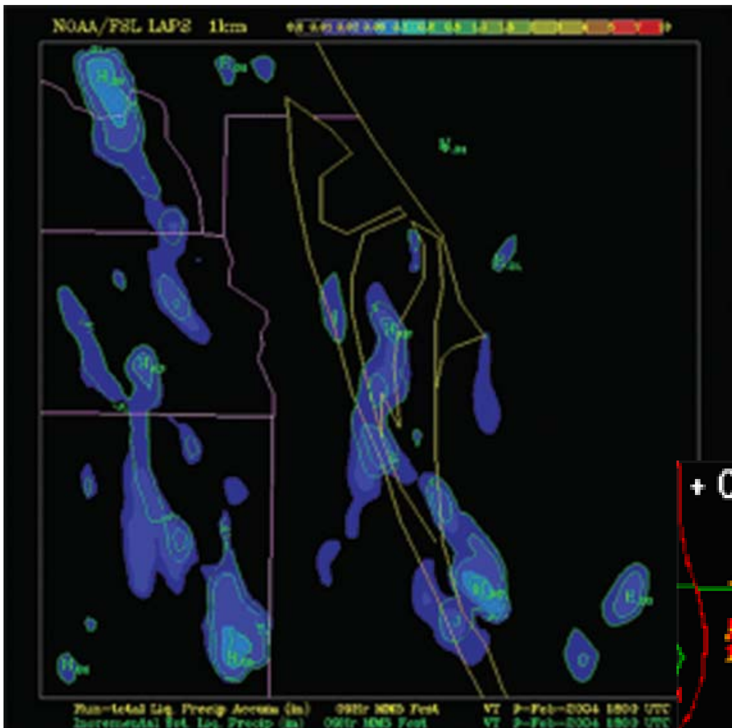


Figure 37. a, left) RSA MM5 9-hour forecast VT 1800 UTC 9 February 2004. Figure shows run total precipitation (solid colors) and 1-hour accumulation (1700–1800 UTC) in contours. Two bands are evident, one 20 km inland and a second right on the Florida Coast.

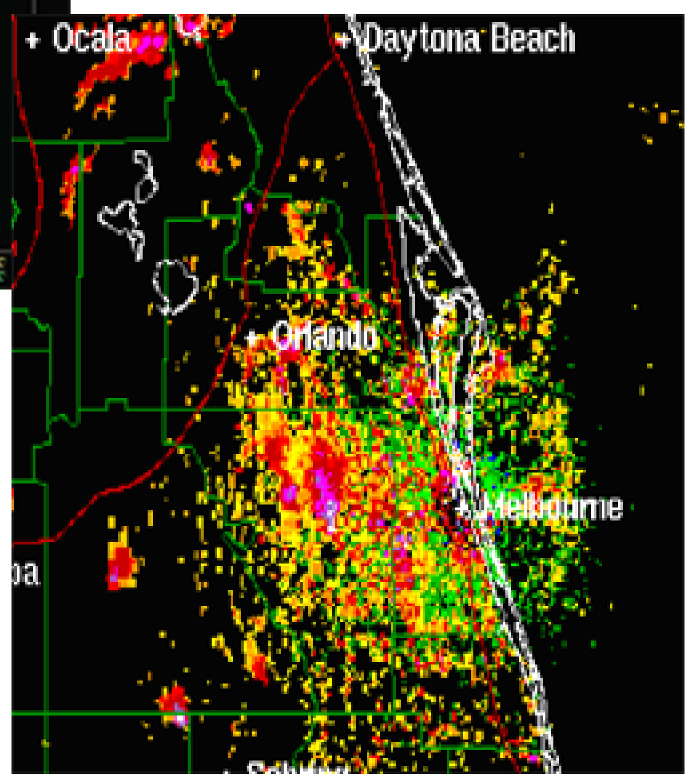


Figure 37. b, right) Melbourne, Florida, radar reflectivity for 1800 UTC 9 February 2004. Reflectivity field is a bit noisy. The radar indicates stronger echoes in pink/red. Note the line of convection onshore and another on the coast. Cyan box indicates 1-km gridded forecast domain to compare with the domain in Figure 39a. Model did well in handling double sea breeze boundaries on this day.

A key aspect of the FSL model runs is the use of the LAPS "Hot Start" diabatic initialization discussed previously. Since the ensemble cannot afford to waste computer cycles spinning up precipitation, the Hot Start procedure is utilized to provide precipitation forecasts in the 0–3-hour time period. The Hot Start provides forecast models an accurate, well-balanced representation of clouds and precipitation processes at startup time by taking advantage of radar and satellite data. The cloud-bearing analysis is dynamically balanced, using variational methods to generate LAPS analyses of the atmospheric state, suitable for initialization of the ensemble members. Other initialization methods require 2–3 hours for "spinup" time to generate realistic cloud and precipitation forecasts.

Developments for the Weather Research and Forecast Model – The LAP branch is involved in three key areas of the WRF modeling system. First, the Standard Initialization software creates model start-up grids from the NCEP national AVN, RUC, or Eta models. Recently, nested grids have been established as an option of the SI. Second, the SI also handles the land-surface module (LSM) of WRF required "static" fields (such as vegetation greenness, albedo, land use, terrain height, and land fraction) by assembling and reformatting the fields, and making them available with efficient interface software. The third area is developing a graphical user interface (GUI) for the localization of the WRF to be used by the WRF community. The upgraded versions of the GUI were released to the WRF user community in the spring and fall of 2003. These software components – developed by the LAP Branch and sponsored jointly by the Air Force Weather Agency, FHWA, and FAA – are released routinely to the WRF user community.

NOAA Coastal Storms Initiative – Under the auspices of a nationwide effort led by NOAA, the Coastal Storms Initiative (CSI), a locally run version of the new WRF mesoscale numerical weather prediction (NWP) model, was installed at the Jacksonville (JAX), Florida, National Weather Service Weather Forecast Office (WFO). CSI is a

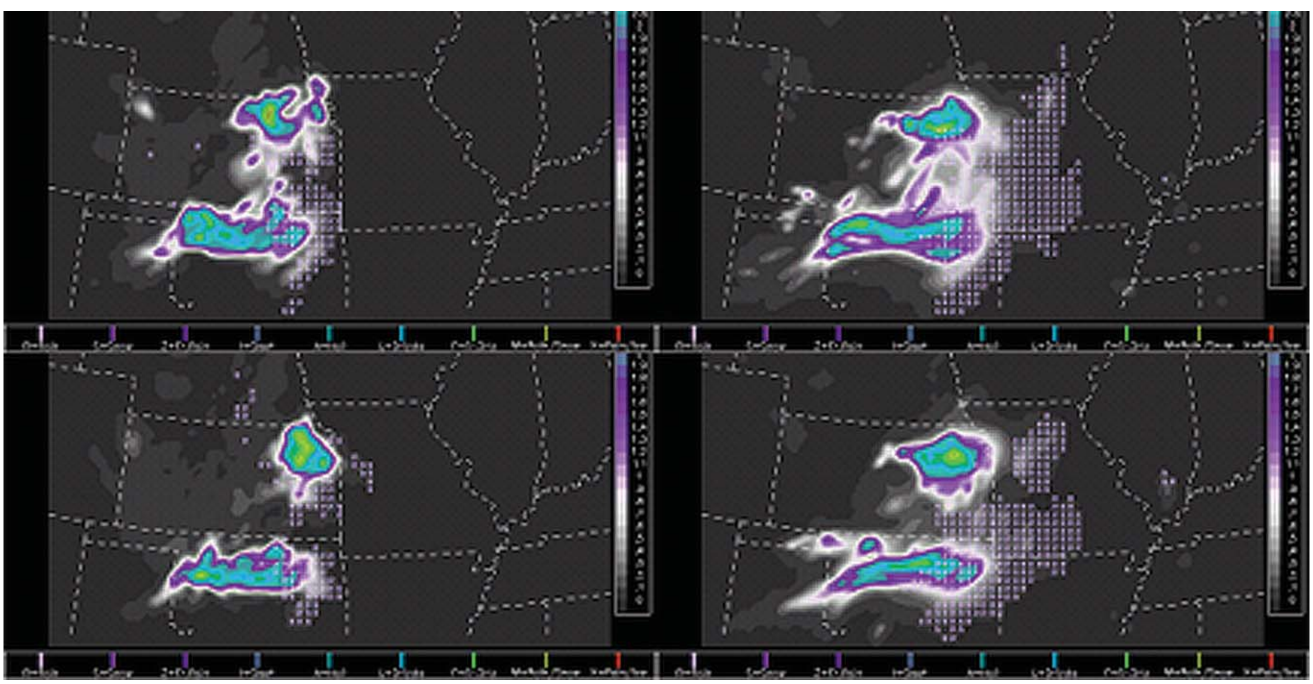


Figure 38. Four forecasts all valid at the same time. The top two panels are 15-hour forecasts (MM5 and WRF) initialized at 1200 UTC; the bottom two are 14-hour forecasts initialized at 1300 UTC. These forecasts can be statistically combined to create a single forecast more skillful than any of these four.

collaborative effort with various local, state, and federal organizations to lessen the impacts of storms on coastal communities. The effort to install WRF at Jacksonville is but one component of the initiative, designed to improve accuracy and detail of forecasts of coastal winds, precipitation, and visibility. This local modeling effort represents collaboration between the NWS Office of Science and Technology, the Jacksonville WFO, NOAA/FSL, and the Florida State University (FSU) Department of Meteorology.

The LAPB contribution included assisting the NWS in selecting an appropriate computing system, integrating the LAPS diabatic initialization technique with the WRF model, integrating the LAPS-WRF system on the NWS computer; integrating the modeling system with AWIPS, and scripting to manage data flow to/from AWIPS as well as FSL and FSU. Additionally, the staff collaborated with colleagues in the Aviation Division, Forecast Verification Branch, who performed objective point-based verification of surface temperature, relative humidity, wind speed, and precipitation using the Real-Time Verification System (RTVS).

For this project, three pertinent questions were addressed that relate to local modeling within the NWS WFO environment: 1) Can public forecast services provided by a WFO be enhanced through the use of a locally run mesoscale modeling system? 2) Does the use of a data assimilation component improve local model forecasts compared to simply initializing a local model directly from the NCEP national forecast models? 3) Can the new WRF model serve as the local model component in the WFO environment in a similar manner to the workstation Eta system in other WFOs?

The WRF CSI system runs on a Linux cluster consisting of nine dual-Athlon processor nodes. The Jacksonville WFO is able to run four 24-hour forecasts per day with this computer system. Two of these forecasts are both initialized at 0600 UTC, one with LAPS and the other with only the model first guess (6-hour forecast from the 0000 UTC NCEP Eta). The LAPS-initialized version is run first and used for operations. The Eta-initialized forecast is used as a comparison run to ascertain the value of local data assimilation with LAPS, which incorporates additional data from surface mesonetworks, METARs, maritime observations, regional narrowband WSR-88D, and GOES imagery. Both of these runs are verified using RTVS and compared to the 0600 UTC NCEP Eta. Thus, the 0600 UTC cycle provides the foundation of model simulations to address the questions posed earlier. The remaining two runs are initialized at 1500 and 2100 UTC using the LAPS initialization. These runs are done solely for the benefit of the forecaster, and the initialization times are optimized for the Jacksonville daily product cycle.

The dynamic core used for the CSI system is the third-order Runge-Kutta solver formulated by NCAR scientists for the mass-based vertical coordinate. The model initial and lateral boundary conditions are provided via the WRF Standard Initialization (WRFSI) package, discussed above. The WRFSI is configured to read analysis grids from the LAPS or other grid sources for the initial and lateral boundary conditions. At Jacksonville, the NCEP 12-km Eta tiles are used for lateral boundary conditions for all forecast cycles, regardless of the initialization. The horizontal model domain shown in Figure 39 utilizes a grid spacing of 5 km, which was chosen to match the resolution of the grids used to populate the National Digital Forecast Database (NDFD) via the NWS Interactive Forecast Preparation System (IFPS).

The most important measure of success when testing a new application in a WFO environment is whether or not the forecasters find the application useful. Making the WRF grid available on AWIPS provided the incentive for the forecasters to look at the model forecasts, and over time more and more of the forecasters have become comfortable with the WRF model and have begun to rely on it in various situations. In particular, early in the experiment, forecasters discovered that WRF forecasts of visibility reductions due to fog were very accurate. Surface winds are another important forecast parameter within the Jacksonville WFO area of responsibility. The CSI project specifically calls for improved forecasts of wind speed and direction for input into a new estuarine flow model being developed under CSI. Quantitative verification of the WRF wind speed forecasts using the RTVS shows that the WRF forecasts significantly outperformed the NCEP Eta forecasts at all hours of the 24-hour forecast period. Root mean square error (RMSE) and bias of the surface wind forecasts for the 0600 UTC run of Eta, WRF-LAPS, and WRF-Eta are shown in Figure 40.

The southeast U.S. and adjacent coastal areas are dominated by convective activity during much of the year. Quantitative precipitation forecasts (QPF) using numerical methods are traditionally poor for these types of events because of lack of model resolution and the inherent chaotic nature of air mass thunderstorm development and evolution. The LAPS diabatic initialization attempts to improve explicit short-range QPFs by initializing the NWP models with active clouds and precipitation. This experiment provides further evidence that finer scale models coupled with advanced initialization techniques using satellite and radar information can provide improvements. Figure 41 depicts the ESS and frequency bias scores for the 0–6 hour QPF for various thresholds of precipitation from the 0600 UTC run of the NCEP Eta, the WRF-Eta, and the WRF-LAPS. The WRF-LAPS demonstrates better ESS and a more consistent bias across all thresholds of precipitation than either the NCEP Eta or the WRF-Eta run. This figure also shows the benefit of adding local data to the initialization using the LAPS diabatic method, since the WRF-Eta forecasts had a low bias for all thresholds, indicative of the typical model "spinup" problem for precipitation processes. The Eta suffers much less from the spinup problem, likely due to its advanced 3DVAR data assimilation cycle, but is still outperformed in the 0–6 hour forecast period by WRF-LAPS.

The WRF forecasts did not perform as well as the Eta model and other national guidance for surface temperature. Both the WRF-LAPS and WRF-Eta runs exhibit a negative temperature bias (too cool) during the afternoon hours (at peak heating) and a positive temperature bias (too warm) at night. This project has made progress in answering the questions posed earlier. The quantitative statistics and anecdotal evidence show that local models can and do add value in the local forecast process, particularly in the area of QPF and wind forecasts. For short-term forecasts (0–6 hours), initialization of these models using additional local data appears to provide even more value. For longer term forecasts, lateral boundary conditions tend to dominate the source of forecast error for such small domains as the CSI area, but in some cases (such as wind speed), the additional resolution of the model appears to still provide advantages.

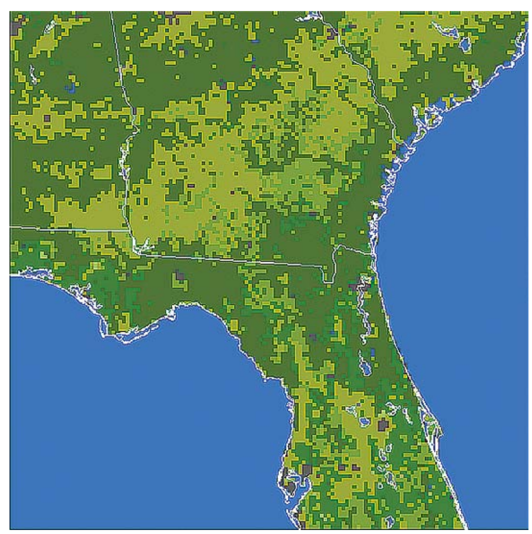


Figure 39. The LAPS-WRF 5-km CSI (Coastal Storms Initiative) domain. Image shows the land-use category as prepared by the WRF standard initialization system.

U.S. Forest Service Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) – During 2003, the LAP Branch sustained a project in support of an FCAMMS for the Rocky Mountain Research Station in Ft. Collins, Colorado. The goal of this project was to develop an analysis and modeling capability that encompassed needed fire-specific (both planning and incident) support products. The MM5 model was used to develop 12-km and 4-km nests for large sections of Arizona and New Mexico (the Southwest Area Coordination Center) and Colorado and Wyoming (the Rocky Mountain Area Coordination Center). These models and analyses were run over the 2003 fire season, and products were disseminated via *http://www.fs.fed.us.rmc/*. The fire manager/user had the option of initiating specific point forecasts for new fire locations by simply entering the latitude and longitude. During the next model cycle (4 times per day), a text product was generated with weather for the next 24 hours. New products were added to the suite of products including high-resolution gridded wind analyses and forecasts on 600-m and 90-m grids for Colorado and Arizona in areas of high concern. During 2003 the modeling software was ported to servers at the Rocky Mountain Center for eventual forecast product production and dissemination from that site. New members of the consortium are being sought among state and federal agencies with a need for high-resolution weather support.

International Collaborations – LAPB scientists continue an active collaboration with the Central Weather Bureau (CWB) of Taiwan. The branch hosts long-term visitors from Taiwan, forming working relationships that are very beneficial in improving the real-time data preprocessing for LAPS, the analyses, and the modeling components.

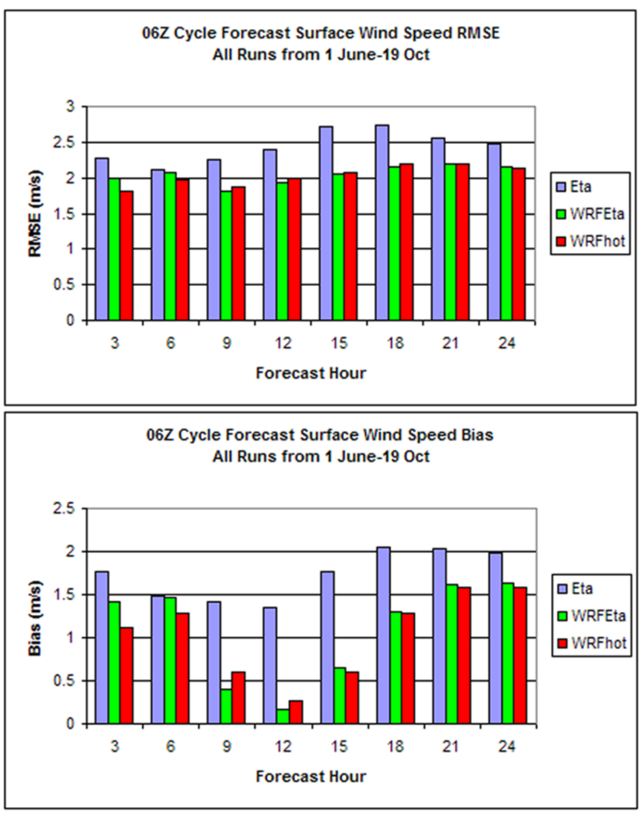


Figure 40. RMSE and bias for all 0600 UTC Eta, WRF-Eta, and WRF-LAPS forecasts of wind speed.

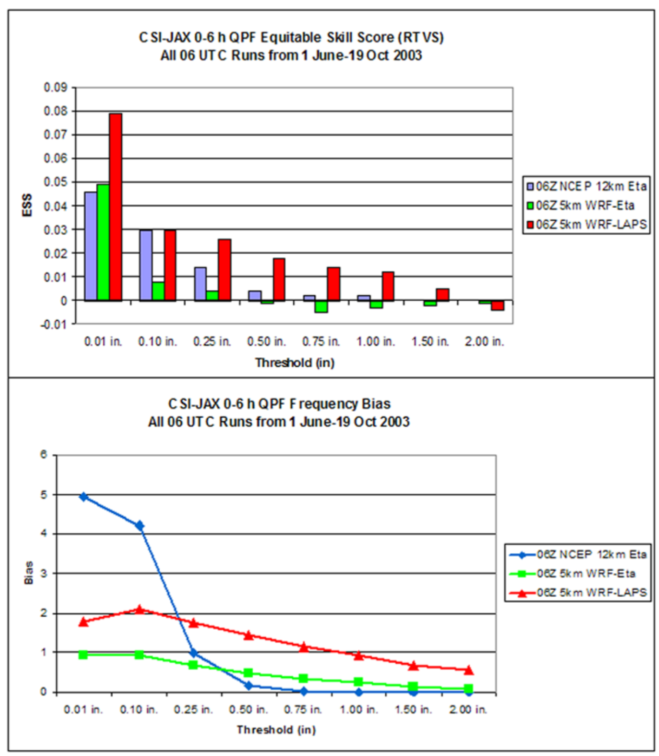


Figure 41. ESS and bias for the 0–6 hour forecast period from the NCEP Eta, CSI WRF-Eta, and CSI WRF-LAPS. Statistics are from RTVS for 1 June–19 October 2003.

Software has been enhanced for ingest of a large variety of surface and upper-air data, including rawinsonde, mesonet, cloud drift wind, METAR, ACARS, synoptic observations, and necessary adaptations to changing satellite data. One major accomplishment was configuring the CWB satellite ingest to accept GOES-9 data (the satellite was shifted westward to provide coverage during the gap in coverage by the Japanese Meteorological Agency). LAPS now runs with data ingest from a CWB model background, hundreds of mesonet surface stations, and four radars covering each of the four U.S. Coasts.

Work this year for the CWB involved creating a radar reflectivity mosiac product to integrate all radars within the Taiwan LAPS grid (Figure 42). Work on precipitation is ongoing. With the help of a CWB visitor, the cloud specification scheme was improved by ensuring deep convective updrafts extended through the depth of the cloud in question, and radar reflectivity was better used for positioning these updrafts. Recent work with CWB collaborators improved the specification of vertical motions in deep convection. Figure 43 shows important suggested modifications to the specification of deep convective clouds based on a series of model runs for heavy rain cases over Taiwan, with

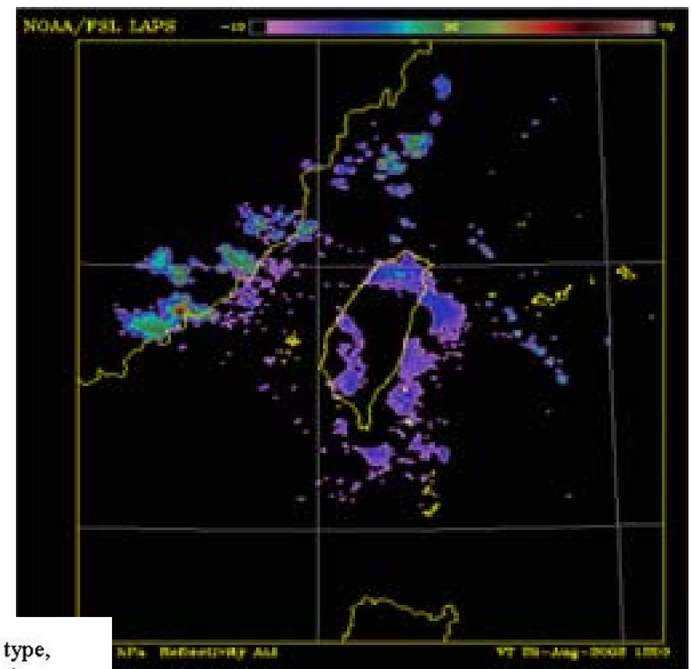


Figure 42. (right) Radar reflectivity mosiac within the Taiwan (Central Weather Bureau) LAPS grid.

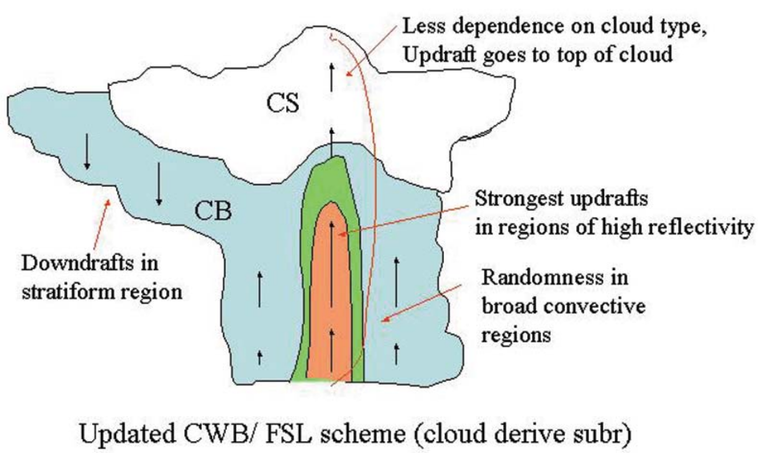


Figure 43. Planned changes in the CWB vertical motion and cloud specification, with the goal to generate heavy precipitation forecasts in the correct location over Taiwan.

the goal being to generate heavy precipitation forecasts in the correct location. Another visitor helped improve the radar processing in LAPS and is working on the precipitation estimation scheme with the LAPS staff. Collaboration continues on the CWB MM5 modeling effort. Branch staff visited with Central Weather Bureau forecasters and researchers in Taipei for consultation. A Webpage for training continues to be updated and supported.

Additional collaborative effort with the Korean Meteorological Agency (KMA) and Hong Kong Observatory (HKO) has continued with minimum support. Both agencies have sent personnel for training in LAPS high-resolution modeling and analysis capability. KMA has already developed a prototype LAPS/MM5 system, which is being tested, and HKO is working on a LAPS development for high resolution wind analysis.

Projections

During 2004, the Local Analysis and Prediction Branch plans to:

- Continue to support LAPS in AWIPS, interacting with the AWIPS contractor, Litton PRC Inc., and the NWS to achieve this goal.
- Support the U.S. Army Precision Air Drop System (PADS) by improving and expanding sources of data, ingest and use of climatology, improved estimates of model error and variance, and implementing a time-sequential assimilation scheme.
- Continue the cooperative effort with Lockheed-Martin in developing the RSA weather support systems for the Space Flight Centers at Cape Kennedy and Vandenberg Air Force Base. Implement a verification system and begin to compile performance statistics to drive future requirements and upgrades.
- Complete the evaluation of the FSL special model runs from IHOP with the goal of improving operational model prediction of convection initiation, evolution, and quantitative precipitation forecasts. Determine how forecast mesoscale convective systems compare with the type observed, including an analysis of the relative contributions of forecast displacement, intensity, and shape errors to the total error. Publish the results.
- Demonstrate LAPS capabilities on the new high-performance multiprocessor. Continue investigating and improving the Hot Start techniques.
- Continue development of the multimodel ensemble methodology, and determine the optimum configuration for best forecasts and user-friendly products. Improve the postprocessing to develop optimum ways to provide consensus forecasts and statistically based products. Seek new applications and projects requiring a mesoscale model ensemble approach.
- Support the WRF Standard Initialization and graphical user interface and distribute the model to the community. Complete acquisition of land surface fields for ingest into the land-surface model subsystem. Implement nesting. Install a Java wrapper on the GUI (in Perl) for Web transition in support of the WRF Developmental Testbed Center (DTC).
- Support the U.S. Forest Service FCAMMS project by improving the local model runs and analyses, and improving dissemination via the Web. Continue to transfer capabilities and data to the FCAMMS computational center, and enlarge the customer base for their products.
- Sustain the CSI project to serve as a data point in an NWS study on distributed local modeling the LAPS/WRF modeling system for the CSI project. Support product cycles and grid outputs for independent verification. Support NWS/OST in presenting results to the NWS Corporate Board.
- Support the Federal Highways Road Weather Program. Obtain support for a winter road maintenance demonstration in Colorado during winter of 2004–2005. Use ensemble to research optimum composite forecasts and probabilities.

Special Projects Office

Steven E. Koch, Acting Chief
303-497-5487

Objectives

The Special Projects Office (SPO) performs diagnostic studies of weather-related phenomena, including mesoscale convective systems, gravity waves, and clear-air turbulence. A springboard of these studies is the development of diagnostic tools that are applicable to routine observations, data from experimental networks or model grid-point data, and that utilize statistical methods, fundamental dynamical relationships, and derived parameters relating to unobserved variables. These studies often result in products of value to forecasters and are transferred to the National Weather Service (NWS). Research quality datasets of operational sounding and precipitation data and of commercial aircraft atmospheric data are assembled to support FSL modeling and diagnostic activities, and are shared with other NOAA laboratories and NWS research groups. The SPO also conducts field tests and computer simulations to study the impact of balloon-based, in situ observing systems on atmospheric and oceanic monitoring for environmental prediction and climate observations.

Accomplishments

Forecasting Clear-Air Turbulence

Field Studies – A combined observational and numerical investigation into the underlying causes of turbulence observed during the SCATCAT-2001 (Severe Clear-Air Turbulence Colliding with Aircraft Traffic) experiment has been completed over the past year. This experiment was funded in part by the FAA Aviation Weather Research Program. FSL scientists collaborated with colleagues at the Aeronomy Laboratory and NCAR in flying the NOAA Gulfstream-IV over the Pacific Ocean at various altitudes in search of turbulence. Inflight dropsonde observations showed moderate or great turbulence. These data were used to test the performance of the Rapid Update Cycle (RUC) model predictors of turbulence (particularly DTF3 and DTF5) and to better understand turbulence generation mechanisms. The G-IV was equipped with dropsondes and in situ high-frequency (25 Hz) measurements of variations in ozone and conventional meteorological data. The analysis of data from the 17–18 February 2001 SCATCAT event showed that coherent bands of high diagnosed turbulence flux (DTF) corresponded well to the observed in-flight turbulence regions just above and below the level of the upper-level jet core (see *FSL in Review 2003*).

Figure 44 shows how the Richardson Number, indicating spatial variations similar to the DTF as well as the turbulence itself, occurred in thin layers of strong vertical wind shear (all but the lowest layer occurred with shear associated with the upper-level jet located at 300 mb). The influence of the special dropsonde data on the RUC analysis is compared to the more conventional RUC analysis that did not benefit from these data, and to an analysis of just the raw dropsonde data in the absence of a RUC background. This comparison reveals that the dropsonde data have a pronounced influence on the ability of RUC to properly account for these regions showing a very low Richardson Number, and that even the process of assimilating these data (only available in a small part of the model domain) into the model, deteriorates the true character of such regions conducive to generating turbulence.

General trends in ozone measurements at 1-Hz sampling (230 m spatial resolution given the aircraft speed) compared favorably with the much coarser potential vorticity (PV) fields from the 20-km resolution RUC model data at the 33,000 ft flight level (Figure 45). Since ozone and PV should be strongly correlated, this finding was anticipated; however, the correlation broke down at 41,000 ft, suggesting the presence of "fossil turbulence" or remnants of earlier stratosphere-troposphere exchange. The ozone data revealed that the regions of active air mass exchange between the stratosphere and the troposphere varied with altitude across a "tropopause fold" seen in the RUC model forecasts.

The dropsonde data indicated the presence of vertically propagating gravity waves in the lower stratosphere above the jet core in the same region where moderate-or-greater turbulence was measured by the G-IV accelerometer. Similar gravity waves (though longer wavelengths) were present in the RUC simulations of this event. The turbulence encounters and the higher values of DTF both occurred in the vicinity of the strongest gravity waves within the upper-level front on the cyclonic shear side of the jet. Our investigation of the SCATCAT data also has used spectral, cross-spectral, and wavelet analysis to better understand the interactions between smaller-scale gravity waves (horizontal wavelengths of 6–20 km) and the turbulent episodes.

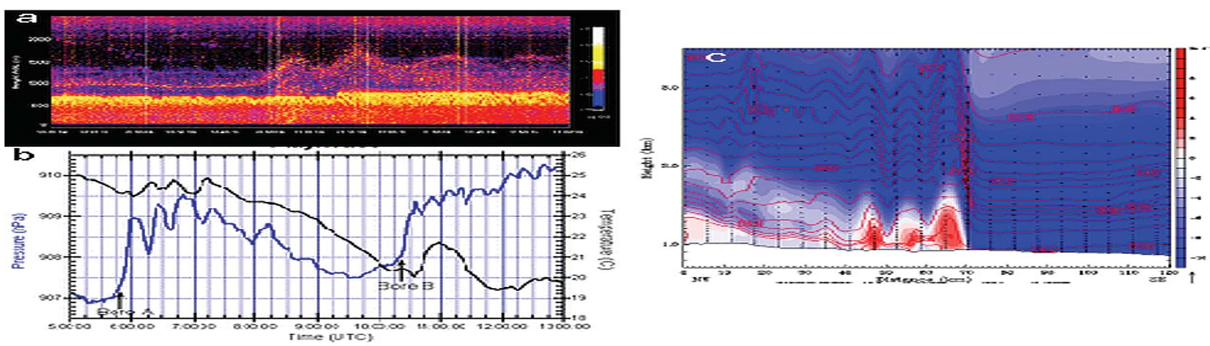


Figure 44. Analysis of the Bulk Richardson Number (red shading indicates Ri < 0.25, green is Ri < 1.0) at 0000 UTC 18 February 2001 in a vertical cross section taken perpendicular to the upper-level jet core: (a) RUC analysis not using dropsonde data, (b) RUC analysis using dropsonde data, and (c) analysis of the raw dropsonde data. The horizontal and vertical domains covered by all three analyses are identical (666 km and 800 mb).

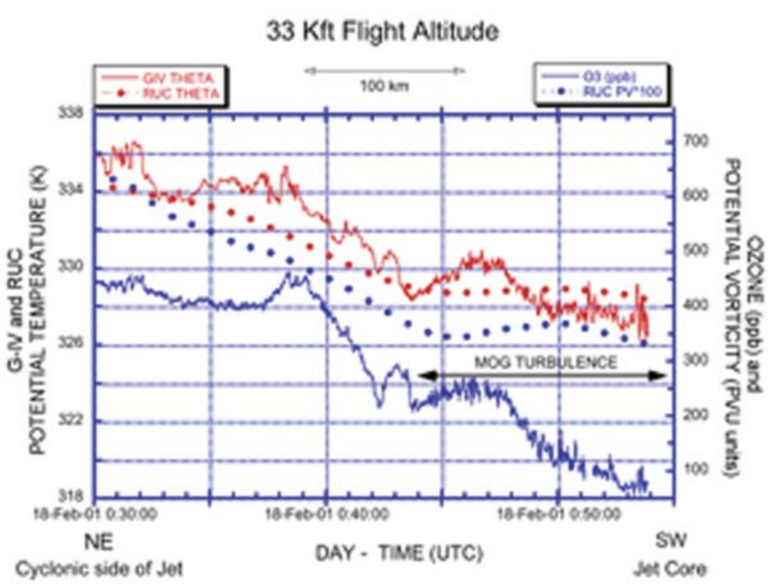


Figure 45. Time series of potential temperature (K, red line) and ozone (PPB, blue line) at the 33,000 ft flight altitude of the G-IV aircraft obtained from 1-Hz data (230 m spatial resolution), compared to potential temperature (K, red dots) and potential vorticity (PVU units, blue dots) in the RUC20 analyzed fields at 0000 UTC 18 February 2001. RUC data were produced using time-to-space conversion analysis of 20-km resolution model fields interpolated to the plane and level of the cross section. Aircraft flew from the cyclonic side of the jet in its left exit region northeastward to the jet core (right).

Diagnostic Algorithm Development – Studies at FSL of pilot reports of moderate-or-greater turbulence have shown that PIREPs often tend to fall in the margin areas of turbulence predicted by the Graphical Turbulence Guidance (GTG) product run operationally at the Aviation Weather Center. The GTG is a fuzzy logic technique applied to more than a dozen turbulence diagnostic algorithms computed using the RUC model forecast fields. Although aircraft are naturally directed to steer away from areas where pilots have earlier reported turbulence, there may be more physical explanations for this suboptimal performance of the GTG. Research at FSL has discovered that the leading component algorithms within the GTG predict patterns are quite similar to one another, suggesting that relatively little systematically new information is being added from all these algorithms. In an attempt to improve the GTG, a new turbulence prediction methodology is being investigated and developed based upon the concept of gravity wave generation of turbulence within regions of highly "unbalanced" flow, defined by diagnosed regions of large residual in the computed nonlinear balanced equation applied to RUC model fields.

In the development of our Unbalanced Flow (UBF) algorithm, we discovered that mass fields output from the RUC model are smoothed before making them available at NCEP, yet wind fields from these same models were handled differently. Smoothing eliminates irrelevant, noisy details from model output and gives them a more pleasing appearance; however, unequal smoothing of the mass and wind fields can produce artificial mass-momentum imbalances. For these reasons, computational methods were developed using the dry version of the Montgomery streamfunction on unsmoothed RUC20 model output fields on its own native "Hybrid-B" (sigma-isentropic) coordinate surfaces. The results of applying this algorithm to several months of cases show that in developing synoptic-scale cyclonic storm systems, PIREPs tend to cluster near the axis of the upper-level jet streak directly downstream from the diagnosed areas of largest imbalance. Such regions are often missed by the GTG. Unfortunately, the UBF algorithm is highly scale- dependent, such that imbalances resulting from deep moist convection are usually about an order of magnitude greater than those related to mountain-generated gravity waves, which themselves are roughly an order of magnitude greater than those imbalances associated with synoptic-scale jets and storm systems. This makes it difficult to detect the larger-scale imbalances when stronger mesoscale signals are present.

Our results show that the behavior of the UBF algorithm appears to be complementary to algorithms contained within the GTG (all of which essentially are rooted in measures of vertical wind shear). That is, the UBF predictor field is adding more independent information about the turbulence generation process. Thus, unbalanced flow should not be incorporated into the Graphical Turbulence Guidance in the same way as the other component algorithms, but should be brought in through some kind of union of current algorithms and the unbalanced flow field. Ongoing statistical case studies suggest that the UBF algorithm has potential for adding predictive value to ITFA, but it will require special handling because its utility is restricted to a subset of weather situations, primarily mountain wave activity and a relatively small number of highly unbalanced situations attending cyclogenesis. FSL and NCAR will continue this statistical examination.

Mesoscale Diagnostic Studies

Analysis and Modeling of a Bore Event in IHOP – The primary goal of the 2002 International H_2O Project (IHOP) field experiment in the U.S. southern Great Plains was to obtain an improved characterization of the time-varying three-dimensional water vapor field and determine its importance in the understanding and prediction of convective processes. Two objectives of an FSL study were to understand the role that bores played in initiating and maintaining nocturnal convection. Ground-based remote sensing (and other) instruments at the Homestead site in the Oklahoma Panhandle were complemented by WSR-88D radars, research aircraft equipped with water vapor differential absorption lidar, and a surface mesonet. The data gathered during IHOP may constitute the most comprehensive set of observations ever collected on the structure and dynamics of bores. An internal bore is a gravity wave that propagates on an interface between two fluids of different density. In the atmosphere, a bore typically develops when a gravity current enters a stably stratified boundary layer capped by a temperature inversion. This usually happens when a thunderstorm outflow, sea breeze, katabatic flow, or a cold front generates a perturbation in an interaction with a nocturnal or maritime inversion. The perturbation may become a solitary wave or a wave train traveling ahead of or behind the initial disturbance.

Different mechanisms of the origin and propagation of bores were suggested in our research, for example, wave trapping and reflection predicted by the linear theory due to the decrease of the Scorer parameter or nonlinear wave dispersion. The question of bore generation is addressed and the physics in the boundary layer is examined. This is the first attempt to reproduce and examine a bore using a mesoscale model with a comprehensive parameterization of the boundary layer and microphysics that is initialized with a three-dimensional analysis of the atmosphere.

In the early hours of 4 June 2002, a slowly moving cold front was positioned across the Oklahoma Panhandle. Behind the front, a series of rain-producing thunderstorms, and later multiple linear structures that were associated with a bore, could be seen in S-POL (s-band polarimetric) reflectivity. Existence of the bore was further confirmed by FM-CW (frequency modulated-continuous wave) radar profiles at Homestead, with pressure, temperature, and relative humidity traces showing passage of the bore at 1040 UTC at the mesonet station at Playhouse, Oklahoma (Figure 46). Based

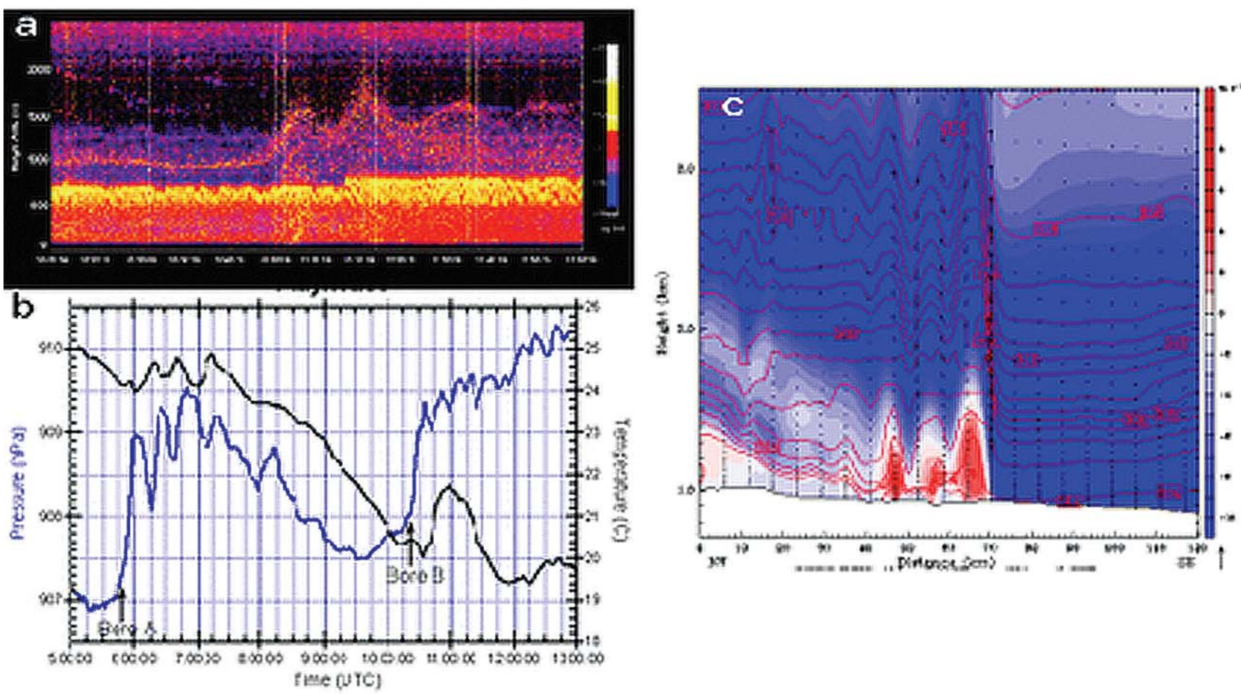


Figure 46. a) FM-CW profile of the structure function at Homestead, OK, 1000–1200 UTC 4 June 2002. b) surface pressure and temperature recorded at the Playhouse, OK, mesonet station; c) cross-front relative wind (m s^{-1}); and isentropes of potential temperature (K) showing gravity current and origin of a bore as simulated by the MM5 model.

on these circumstances, the bore likely originated when an outflow induced by the precipitation from a thunderstorm approached and strengthened the cold front, which pushed into a stable boundary layer ahead of the front.

Simulations with the MM5 were performed to model the bore event. Initial and lateral boundary conditions were provided by the 20-km resolution hourly analysis produced by the Rapid Update Cycle (RUC) three-dimensional variational (3DVAR) analysis. Four one-way computational domains, with resolutions of 18, 6, 2, and .666 km were employed. The domains had 32 vertically stretched levels except in the highest resolution domain, where 44 vertical levels were used with the lowest model level at 10 meters.

The MM5 model quite accurately reproduced the front's position, location, and timing of thunderstorms and precipitation. It also predicted a series of southeast propagating outflows from thunderstorms. Figure 46c shows a cross-front wind in the frame of references moving with the front, and outflow from the thunderstorms apparently steepened and strengthened the front which displayed a shallow elevated head similar to a gravity current. Interaction of this shallow cold front with the stable boundary layer ahead induced a bore. The amplitude and wavelength of the simulated bore corresponds well with the observations.

Examination of boundary layer fluxes and limited sensitivity of simulations to turbulence parameterization suggests that characteristics of the waves are not signficantly affected by turbulence. However, the structure of turbulence shows clear advantages of using TKE-based closures over the bulk approach. Simulations also reproduce observed surface variation of pressure, slight warming and drying and cooling and moistening aloft. FSL is investigating relative roles of entrainment fluxes, and vertical and horizontal advection in producing the observed pattern of temperature and humidity changes.

Moisture Transport by the Low-level Jet in IHOP – The Central Plains Low-Level Jet (LLJ) is a warm-season phenomenon that transports large amounts of moisture northward into the center of the U.S., thereby playing a critical role in the location and intensity of precipitation. The existing observational network is not well designed to describe the LLJ; for example, the radiosonde network often misses the period of maximum jet intensity in very early morning, and wind profilers often cannot observe low enough to capture the LLJ core. Also, neither radiosondes nor profilers can adequately observe detailed boundary layer moisture distribution. Thus, numerical initialization fields do not accurately represent transport of moisture by the LLJ, with negative implications for quantitative precipitation forecasting.

The 2002 International H_20 Project (IHOP) offered a unique opportunity to carry out two aircraft missions to observe the morning LLJ over Oklahoma and Kansas. Each mission utilized airborne dropsonde data, Differential Absorption Lidar (DIAL) data flown on the German *Falcon*, High-Resolution Doppler Lidar (HRDL) data from NOAA/ETL also flown on the *Falcon*, and in one of the cases, hyperspectral radiometric data from the NASA *Proteus* aircraft, to observe a strong LLJ in good atmospheric conditions (i.e., substantially free of clouds). These observations offer an excellent opportunity to prepare detailed three-dimensional meteorological fields of moisture and winds at a multitude of scales and the possibility to compute a moisture budget. The objective is to examine these data to determine the impact of fine-scale moisture observations on the numerical prediction of precipitation. Another ongoing task is combining datasets obtained from the two aircraft missions to compute moisture budgets and perform diagnostic and numerical modeling studies of these cases to test the hypothesis that warm-season QPF skill can be significantly improved by better characterization of the transport of water vapor by the LLJ.

During the IHOP project, FRD scientists led an effort to observe and simulate moisture transport by the Central Plains

LLJ. Follow-on research on the 9 June 2002 IHOP LLJ case during the last year has emphasized diagnoses of the multiscale structure of moisture transports. Central to these investigations are dropsonde observations along the aircraft flight patterns, which were rectangular "racetrack" patterns designed to bracket the core of the LLJ during the early hours of 9 June. Computations of net moisture transport into or out of the flight box at several scales are possible using operational observations from radiosondes, dropsonde profiles, and onboard DIAL mixing ratio and HRDL wind measurements.

An important preliminary step in this research is to assess both the quality and consistency of dropsonde measurements of winds and specific humidity, and the validity of an assumption of stationarity during the 1-hour periods when the two research aircraft completed their half-circuit sections of the flight box. The profiles of fluxes (u x q and v x q) in Figure 47 demonstrate that the consistency of computations between dropsonde aircraft is high, and that the moisture flux in the jet is remarkably stable during the hour between the two aircraft passes over the jet. Part of this stability is likely a result of benign meteorological conditions during the early morning flight.

With confidence in the quality of measurements, it is possible to infer physical meaning to fluxes measured at different scales. This confidence is suggested in the consistent flux profiles (Figure 48) observed by the following systems: radiosondes, dropsondes, and lidar instruments, which represent transports resolvable at the horizontal scale of short waves, mesoscale circulations, and large convective cloud processes, respectively. With these observations, subsequent research should be able to characterize the relative importance of these multiscale transports.

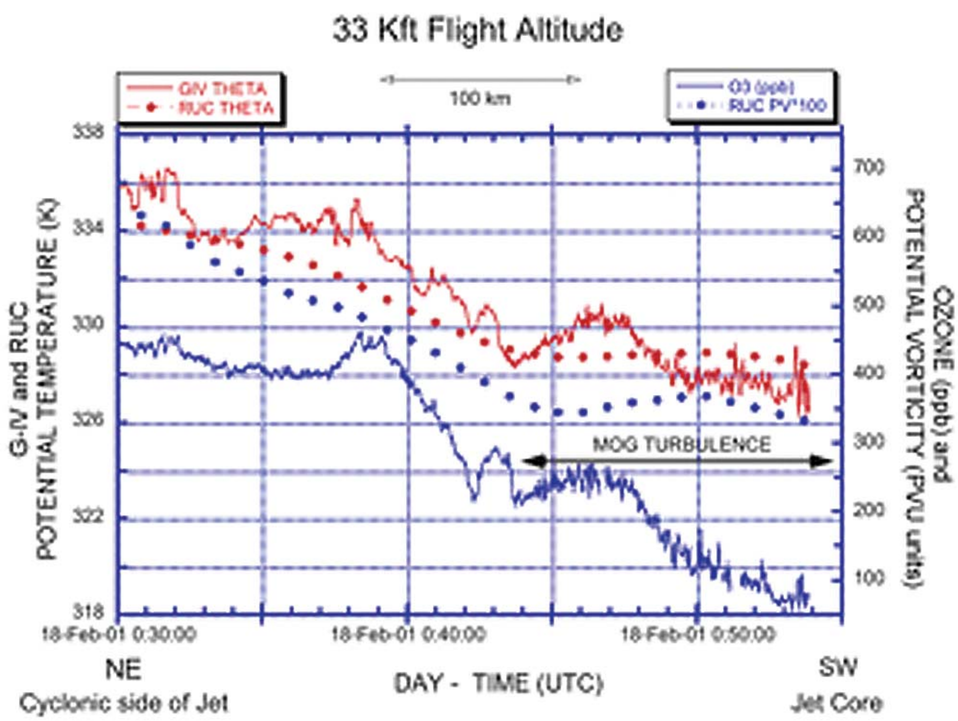


Figure 47. Profiles of fluxes (uq and vq) demonstrating that the consistency of computations between dropsonde aircraft is high, and that the moisture flux in the jet is remarkably stable during the hour between the two aircraft passes over the jet.

Numerical Prediction of Mesoscale Convective Systems in IHOP – Improvements in quantitative precipitation forecasting (QPF) skill, particularly during the warm season when flash floods and severe thunderstorms are most frequent, have lagged far behind those of other atmospheric variables. Studies have shown that water vapor is a key atmospheric variable for convective storm forecasting, yet its mesoscale variability is insufficiently measured. The overall objective of the International H_2O Project (IHOP-2002) is to ascertain whether or not improved characterization of the time-varying three-dimensional water vapor field will result in significant improvements in warm season QPF skill and understanding and prediction of convective processes.

Toward this goal,the IHOP-2002 experiment brought together many of the existing operational and new state-of-the-art research water vapor sensors and numerical models. The FSL Real-Time Verification System (RTVS) performed a standard grid-to-gauge verification of precipitation, and, in addition, RTVS was also expanded to include for the first time a grid-to-grid verification based on the Ebert and McBride (EM) method and the 2-km NCEP Stage IV grid product for precipitation verification. A very significant benefit of performing RTVS verification in real time was the early discovery of deficiencies in the application of the MM5 Hot Start diabatic initialization procedure that resulted in excessively heavy QPF amounts. A change to the scheme halfway through the IHOP project resulted in greatly improved results, and additional improvements to the Hot Start scheme since that time have benefited other Hot Start applications using both MM5 and WRF.

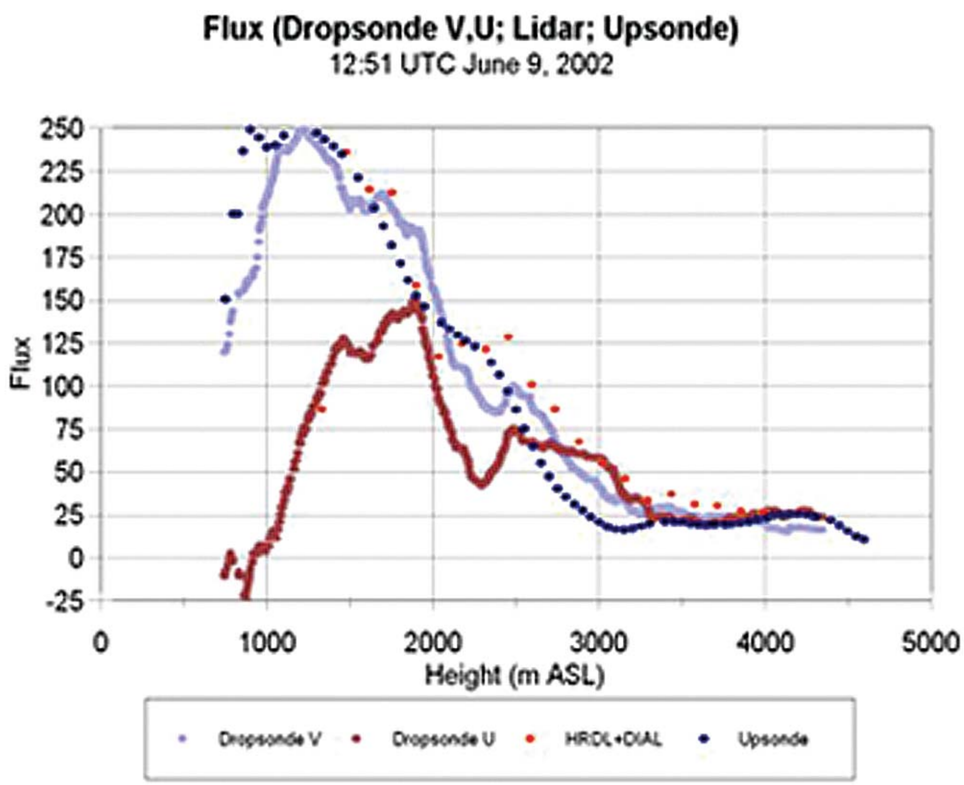


Figure 48. Comparison of cross-track transports observed at 1251 UTC near the eastern end of the southern leg of the flight box on 9 June. Brown curve describes along-track transports (uq) observed by dropsondes but not measured by the DLR Falcon HRDL system.

The EM technique partitions the total precipitation forecast error into spatial (displacement), magnitude (intensity), and shape (pattern) errors by determining "contiguous rain areas," defined as the union of the forecast and observed rain fields for a user-specified isohyet. Our experience indicates that this "object-oriented" verification method provides a more informative measure of the relative skill of two model forecasts than conventional equitable threat score, bias, and other such "measures-oriented" methods (Figure 49). The EM technique was originally developed for use with Australian rainfall systems evaluated on a time scale of one day. The models run in real-time during IHOP used grid resolutions of 10–12 km, a scale at which cumulus parameterization is generally believed to still be necessary in conjunction with explicit microphysics schemes, because convective updrafts cannot be resolved at this scale. For this reason, we recognized that the EM method would need to be modified and calibrated for use on mesoconvective systems in the IHOP region of the central U.S. Scientists at FSL collaborated with colleagues at Iowa State University and the Australian Bureau of Meteorology to make many needed changes and improvements to the technique.

We are currently collaborating with Iowa State University in an attempt to use the EM technique in combination with a morphological classification of Mesoscale Convective Systems (MCSs), to determine whether certain kinds of MCSs were better predicted by the numerical models (Eta, MM5, WRF, RUC) rather than by other types. This research is taking the traditional process for evaluating model rainfall prediction to a higher level by attempting to determine the maximum level of useful detail in current generation numerical weather prediction models. Our MCS classification begins with a distinction between linear and nonlinear MCSs, then subdivides systems into Continuous Linear, Continuous Linear Bowing, Continuous Non-Linear, Discontinuous Areal, Isolated Cells, and Orographically Fixed systems, and further classifies the linear systems into squall lines with trailing stratiform rain areas and other kinds of systems. The Eta model exhibited a very different behavior than the MM5 Hot Start system, as it forecast both average and maximum rain rates lower than observed for every MCS class except isolated cells, whereas MM5 was generally quite wet, even after the changes to the Hot Start. For both models, the largest displacement and pattern errors occurred for the linear MCS types. The research at FSL revealed that the models exhibited a dry bias with linear systems and a wet bias with nonlinear MCSs, especially for isolated cells. This result suggests that the models forecasted too little transport of condensate away from the more intense convective cells, a process known to be important in the upscale growth of organized linear systems. Results from this continuing research should benefit modelers at NCEP and elsewhere as they continue down the path of higher resolution and face the difficult issue of how to verify mesoscale precipitation patterns.

Research Quality Datasets

NCEP Gauge Observation Quality Control System – The Experimental Modeling Center (EMC) of the National Centers for Environmental Prediction (NCEP) uses the Hydrometeorological Automated Data System (HADS) to both calibrate radar precipitation estimates and produce CONUS analyses of precipitation. An effort is underway there to use hourly measurements in the Eta Data Assimilation System (EDAS) to initiate numerical simulations of, for instance, soil moisture. Unfortunately, telemetry and instrument errors in HADS observations have proven to be a substantial hindrance to these efforts. To address these needs, FSL, in collaboration with NCEP, has developed a system that automatically monitors and screens hourly gauge-site precipitation observations made by the HADS. The system utilizes two levels of screening algorithms. Since the HADS are susceptible to several kinds of systematic and persistent errors due to instrument and telemetry failures, one level examines 30-day observation histories for each gauge to determine if it has fallen victim to, or recovered from, any of these systematic errors. A particularly pernicious (and unfortunately common) systematic error occurs when gauges "lock" on small values (often .01 or 0.1 inch).

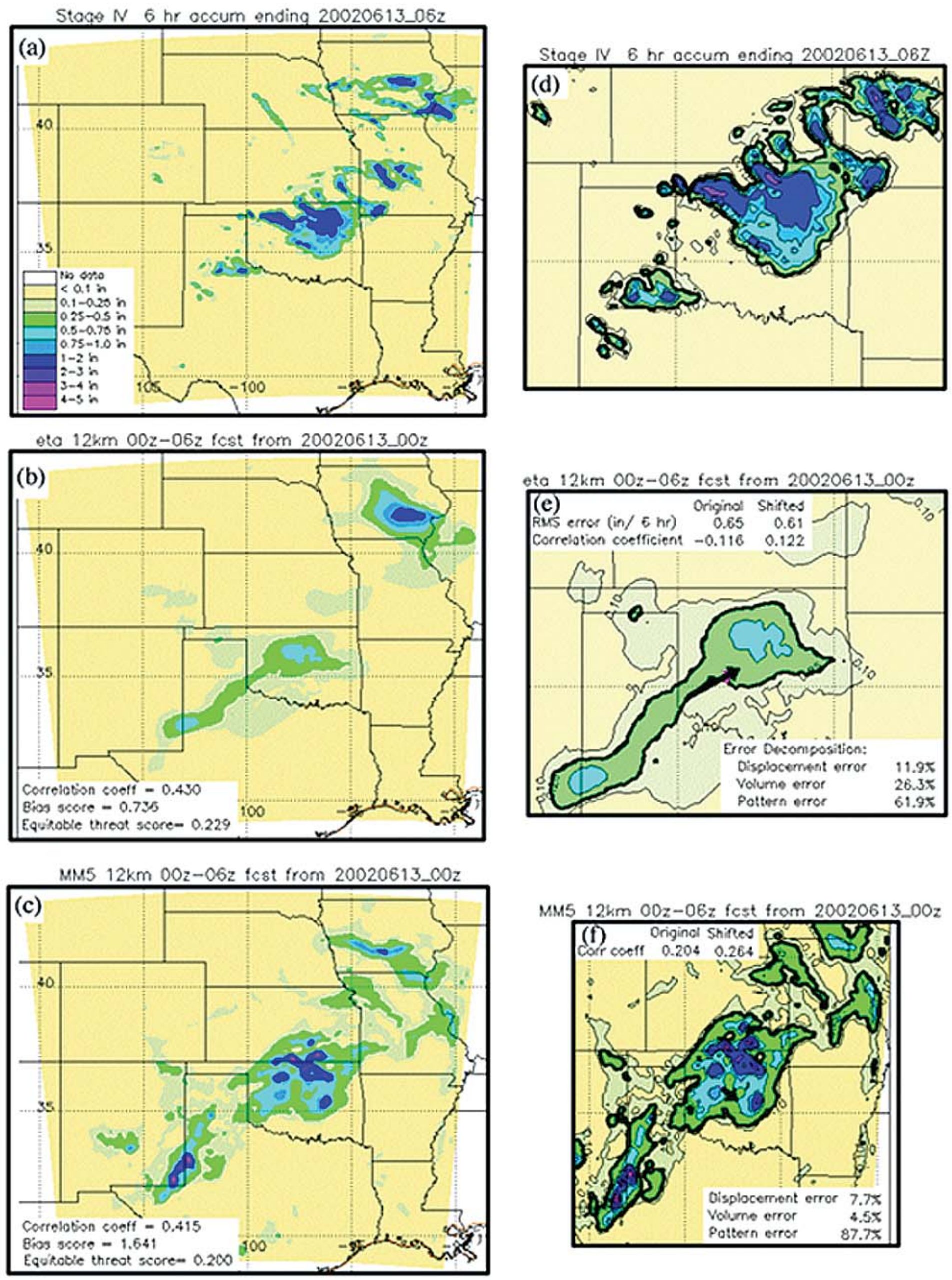


Figure 49. Application of the Ebert and McBride (2000) technique applied to 6-hour accumulated precipitation ending at 0600 UTC 13 June 2002: (a) Stage IV 4-km analysis, (b) Eta-12-km forecast, (c) LAPS/MM5 12-km forecast, (d) Contiguous Rain Area (CRA, thick lines) defined from Stage IV product, (e) CRA defined from Eta-12 forecast, and (f) CRA defined from MM5-12 forecast. Note the improvement in correlation coefficients resulting from displacing the forecast CRA over the observed CRA until a "best fit" criterion is achieved (displacement vectors are shown as broad arrows).

The circled stations along the Continental Divide in Figure 49, for example, show this error. Since these stations are difficult to identify on days with intermittent or scattered precipitation, the system searches gauge histories for the occurrence of several days of identical observations. When found, these stations are then flagged for removal from sensitive analyses. The same is true for hourly stations that continuously show the same hourly precipitation. An example of this latter error is the station located in the cluster of stations in the Denver metropolitan area. All of these stations were correctly identified and flagged.

The second level of screening involves immediate flagging of stations that exceed a set threshold of comparison failures with neighboring stations. In the present version the check is a simple binary comparison; that is, a nonzero (zero) target observation is flagged if it fails a threshold percentage of nonzero (zero) neighbor observations. To help ensure that target stations are not compared to faulty observations, the neighbor set is limited to sites that have been accepted by preliminary screening at River Forecast Centers, and an iterative screening process is used to identify and remove members of this neighbor set that are themselves faulty. Several of the stations in Figure 50 identified as "locked-on" by the first level of screening (see above) were also identified as "bad neighbors" by the neighbor check.

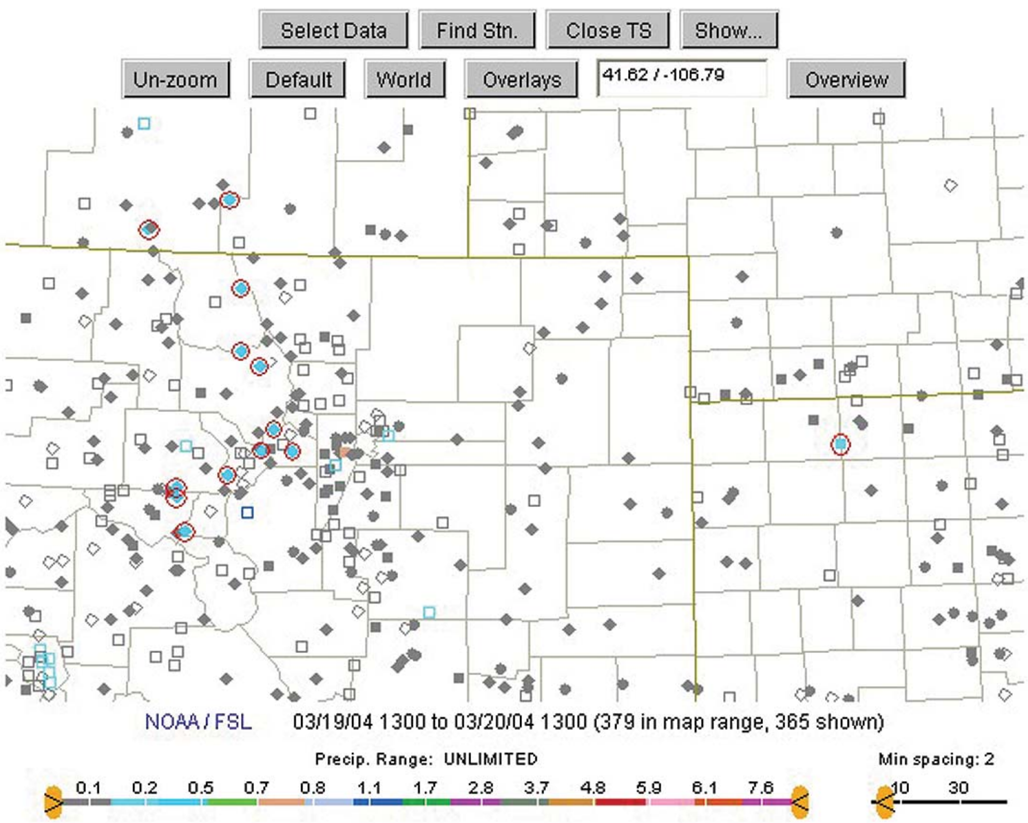


Figure 50. Circled stations along the Continental Divide show a systematic error that occurs when gauges lock on small values (often .01 or 0.1 inch).

ACARS/AMDAR Quality Control System – A computer program to flag and in some cases correct weather data from automated sensors on commercial aircraft (called ACARS in the U.S. and AMDAR in the rest of the world) was upgraded during 2003, as follows:

- Sounding information is now output in NetCDF files to facilitate display of soundings in AWIPS weather workstations.
- Binary data, used by the Java Web display, are now written in a machine-independent way, so that processing can be done on machines having any architecture.
- MDCRS data have been added to the data stream. These data are matched with data passed directly to FSL by the airlines wherever possible. Information about unmatched data was used to uncover a flaw in MDCRS processing that was preventing NCEP models from receiving data from many U.S. aircraft flying over Asia.
- An occasional error in the processing of turbulence data was identified and corrected.
- The software was ported from the Sun Solaris operating system to the Linux operating system. In making this port, several potential problems (buffer overflows, use of uninitialized variables, ambiguous sorting criteria) were identified and corrected.

RUC Upper-Air Verification Database – This database, using the open source MySQL Database Management System, was developed to store RUC skill scores (bias and RMS) verified against radiosondes. Verifications are available for the variables of height, temperature, humidity, and winds for levels from 850 hPa to 100 hPa. Time-histories of these skill scores are available on the Web as pregenerated or interactive plots.

RUC Ceiling-Visibility Database – This database, using the MySQL Database Management System, was developed to store RUC analyses and forecasts of ceiling, visibility and IFR/VFR flight condition at METAR locations, along with METAR observations. This database supports a Website that generates and displays verification statistics.

RUC-ACARS Database – This database, using the MySQL Database Management System, was developed to store RUC analyses and forecasts of wind and temperature, compared with in situ measurements from commercial aircraft (ACARS). These data may be displayed on the RUC-ACARS Website.

Websites for FSL Data

ACARS/AMDAR Website (http://acweb.fsl.noaa.gov/) – This site, which is restricted to government and certain other users, displays plan and profile views of automated weather reports taken by commercial aircraft. The following upgrades were made to this site:

- At the request of Environment Canada, soundings may now be shown as Tephigrams as well as Skew-T plots.
- The wind plot on the right of the soundings now has two selectable scales: 100 kts and 40 kts. The selected scale is also used for the hodograph.
- The display now accepts data in a new input format that can be easily generated on computers using different architectures.

This code is available under Open Source Definition (see *http://www.opensource.org/osd.html*), and has been successfully implemented by AirDat LLC. to use with data from their new aircraft-borne sensor.

Interactive Soundings Website (http://www-frd.fsl.noaa.gov/mab/soundings/java/) – This Website interactively displays past and forecasted soundings from the RUC model, profilers, radiosondes, and aircraft. This page continues to be popular, with more than 96,000 accesses from over 700 major domains (such as "noaa.gov" or "delta.com"). The easily adaptable Java code that runs this site has been requested by more than 80 organizations, and has been released to them under FSL's open source software license/disclaimer. The site was upgraded to display 20-km RUC data stored in GRIB format. This is the format that most RUC output is stored in, so the site can now show data from several developmental and operational versions of the RUC. This has been very helpful to the RUC developers as they improve model behavior.

National Mesonet Website (http://www-frd.fsl.noaa.gov/mesonet/) – This page interactively displays observations from 28 networks (up from 22 last year), including mesonets, maritime buoys, and the METAR network – more than 10,000 stations from around the world (up from 7,000 last year). The site displays weather data and quality control information from FSL's Meteorological Assimilation Data Ingest System (MADIS). During January 2004, the site was accessed more than 4,000 times from more than 700 unique domains.

RUC Upper-Air Statistics Webpage (http://ruc.fsl.noaa.gov/stats/) – This page provides pregenerated and interactive statistics for RUC analyses and forecasts, and persistence forecasts, verified against radiosondes. Plots are pregenerated weekly, and show a time-history of bias and RMS error for the past month. Interactive plots can show skill-history from the present back to 26 Jan 2001.

RUC Ceiling-Visibility Statistics Webpage (http://ruc.fsl.noaa.gov/stats/cvis/inter.html) – This page uses NOAA's Java Scientific Graphics Toolkit, developed at the Pacific Marine Environmental Laboratory, and the RUC Ceiling-Visibility database to interactively generate verification statistics. These statistics are based on RUC analyses and forecasts verified against METAR observations. Performance of three models, the operational RUC, the 20-km RUC, and the developmental RUC, can be viewed, and statistics generated based on the VFR/IFR category and several visibility and ceiling thresholds. Figure 51 shows a 56-day time series of the Critical Success Index for three versions of the RUC model analyzing ceilings < 3,000 ft.

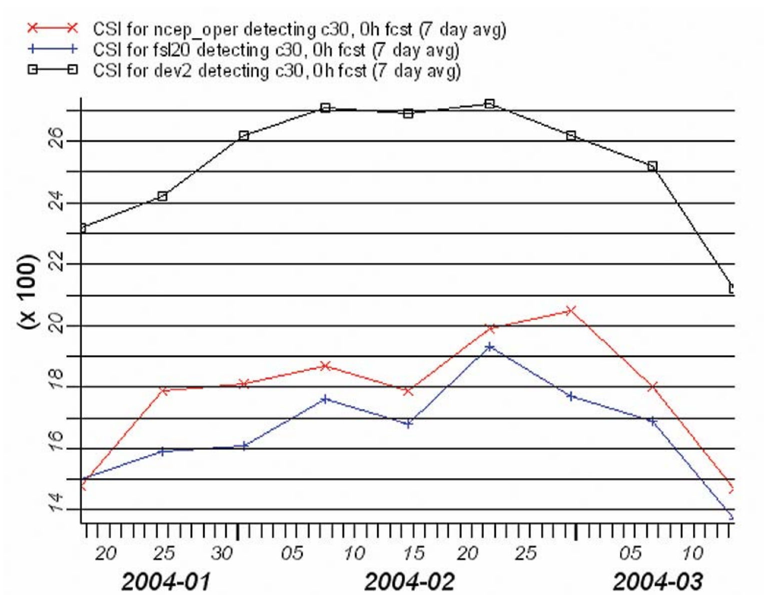


Figure 51. The RUC Ceiling-Visibility Statistics Webpage showing a 56-day time series of the Critical Success Index for three versions of the RUC model analyzing ceilings <3,000 ft.

RUC Ceiling-Visibility Plan-View Webpage (http://ruc.fsl.noaa.gov/stats/cvis/plan_view/) – This page provides a zoomable nationwide view of ceiling and visibility from METAR observations and RUC analyses and forecasts for several versions of the RUC. Data and forecasts at individual METAR sites can be interrogated, and regional patterns can easily be distinguished. Figure 52 shows a visibility analysis for the FSL development RUC for 0000 UTC on 10 March 2004. Only METAR sites from the RUC analysis with visibility of less than 20 miles are shown.

RUC GRIB Viewer Webpage (http://ruc.fsl.noaa.gov/view/) – This site, currently restricted to FSL, provides a zoomable nationwide view of all RUC 20-km model results that are stored in GRIB format. Individual fields can be loaded and compared with one another. Fields that are not routinely plotted may be interrogated on this page. Figure 53 shows 250-mb relative humidity (RH) from the RUC development model 6-hour forecast, isobaric output, valid at 1800 UTC 10 March 2004. Values of RH and other previously loaded fields for the point near the cursor are shown.

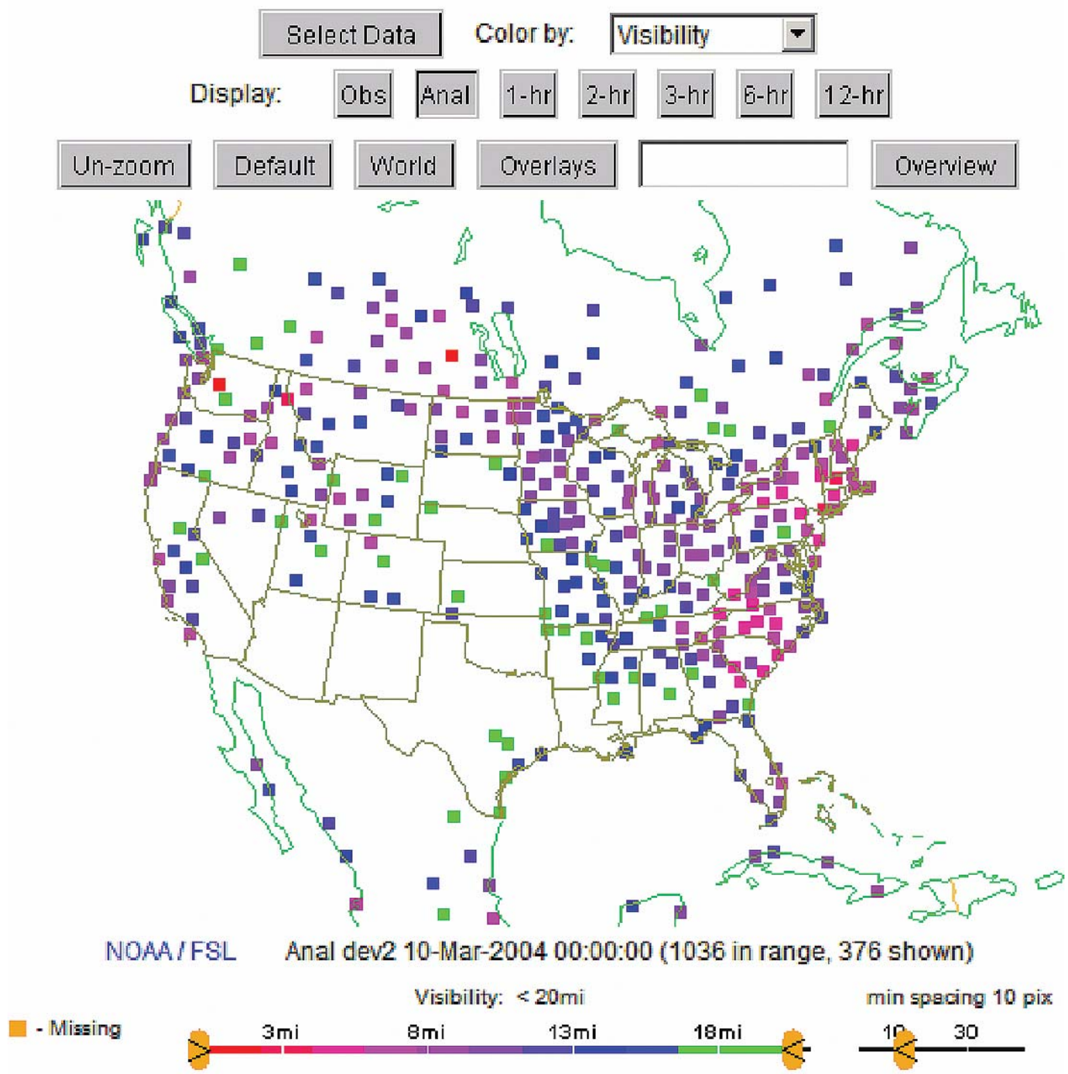


Figure 52. RUC Ceiling-Visibility Plan-View Webpage showing visibility analysis for the FSL development RUC for 0000 UTC 10 March 2004. Only METAR sites with visibility of less than 20 miles are shown.

RUC-ACARS Webpage (http://acweb.fsl.noaa.gov/ruc_acars/) – This page is similar to the ACARS/AMDAR website (above), and also restricted. It displays ACARS data along with RUC 1-hour forecasts interpolated to the location of the ACARS data. Standard meteorological variables (wind and temperature) from either the aircraft or the RUC model may be selectively displayed, along with ACARS-RUC differences in vector wind, wind speed, and temperature. The site, primarily used within FSL, is useful for identifying aircraft wind and temperature biases and RUC errors.

PIREPs-AIRMETS Webpage (http://www-ad.fsl.noaa.gov/fvb/rtvs/turb/2003/interrogation_tool/) – This page displays pilot reports (PIREPs) and AIRMETS (warnings issued by the Aviation Weather Center). Currently it displays only AIRMETS and PIREPs related to turbulence. Raw PIREP reports along with their decoded values are displayed when the cursor is moved over a data point. AIRMET skill statistics may be generated for each AIRMET,

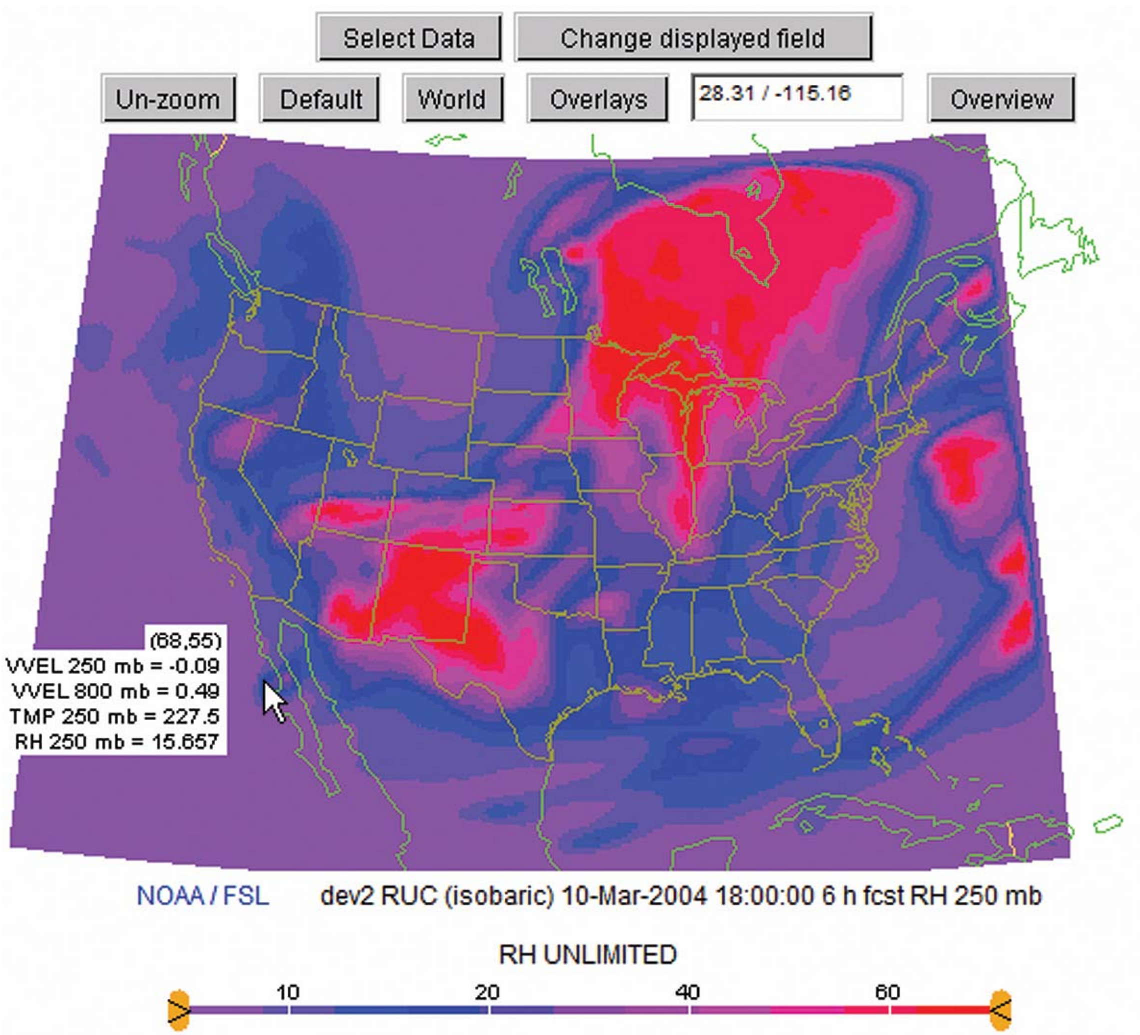


Figure 53. RUC GRIB viewer Website showing 250-mb relative humidity from the RUC development model 6-hour forecast, isobaric output valid at 1800 UTC 10 March 2004.

and for each Aviation Weather Center region, including Alaska. This site has been useful for understanding more deeply AIRMET turbulence skill statistics generated by FSL's Real-Time Verification (RTVS) project. Also, because this site allows displays of turbulence PIREPs reported since 21 January 2002, it has been useful in verifying turbulent events identified by other means, such as infrasound.

Projections

During 2004, the Special Projects Office will be involved in the following activities and studies.

Forecasting Clear-Air Turbulence

Field Studies – Analysis of the SCATCAT cases will be completed with the objective of deriving a comprehensive picture of the atmosphere producing turbulence. This interpretation will be built using the dropsonde data, meteorological data from aircraft flight level, ozone data from the Aeronomy Laboratory's experimental sensor flown during SCATCAT, and model analyses. In addition to the case study analyses, modeling studies will be completed with a 13-km version of the RUC to determine whether mesoscale features captured in the aircraft data are resolved in the model, where and with what intensity the model develops turbulence from both diagnostic and prognostic routines, how this model turbulence compares with that measured by the aircraft, and how tropopause folding in the RUC compares with the onboard ozone measurements.

Diagnostic Algorithm Development – The residual of the nonlinear balance equation and other methods will be further investigated to arrive at the optimum method for diagnosing imbalance and for determining the appropriate threshold values. Real-time evaluation of these approaches will continue to be performed in preparation for planned implementation and full evaluation within GTG by fall 2004. Idealized modeling studies will be performed to develop a basic understanding of the nonlinear-scale contraction process by which mesoscale gravity waves may steepen and saturate, leading to turbulence production at smaller scales.

Mesoscale Diagnostic Studies

Moisture Transport by the Low-level Jet – FSL will perform Weather and Forecasting (WRF) model runs assessing the impact of better representation of the Low-Level Jet (LLJ) in model initialization fields.

Research Quality Datasets

NCEP Gauge Quality Control System – A version of the monitoring system will be transferred to the Experimental Modeling Center at NCEP. Based on experience with the system, modifications and extensions will be made. Plans are also underway to develop measures and displays that describe the real-time performance of the screening algorithms.

ACARS/AMDAR Quality Control System – This system will be fully documented and passed on to a group of programmers so that there is no single point of failure for the system. Currently, it is fully understood by only one employee. Data from additional airlines, such as Air Canada Jazz, and from additional sensors, such as NASA's TAMDAR sensor, will be integrated into the system, and the error characteristics of these data will be investigated.

Numerical Prediction of Mesoscale Convective Systems in IHOP – Collaboration will continue with Iowa State

University in an attempt to use the EM technique in combination with a morphological classification of Mesoscale Convective Systems (MCSs), to determine whether certain kinds of MCSs were better predicted by the numerical models (Eta, MM5, WRF, RUC) rather than by other types.

ACARS-RUC Intercomparison Database – Once an entire year of data have been accumulated, detailed ACARS-RUC statistics will be generated and stratified by season. The database software will provide a productive environment for testing the data in a variety of ways, and generating results with known statistical significance.

Websites for FSL Data

Interactive Soundings Website (http://www-frd.fsl.noaa.gov/mab/soundings/java/) – This site will continue to be maintained and the data flow into it monitored. Pending identification of resources, scripts will be written to ease the reloading of past data cases, upon request. Currently, only about 16 hours of RUC data are available for display.

National Mesonet Website (http://www-frd.fsl.noaa.gov/mesonet/) – New mesonets will be added as they become available. Pending identification of additional resources, wind gust and precipitation amounts will be shown for those sites that support them.

RUC-ACARS Webpage (http://acweb.fsl.noaa.gov/ruc_acars/) – Pending identification of resources, this site will be expanded to include additional RUC forecasts longer than 1 hour, such as 3-, 6-, and 12-hour forecasts. Skill statistics will be generated.

PIREPs-AIRMETS Webpage (http://www-ad.fsl.noaa.gov/fvb/rtvs/turb/2003/interrogation_tool/) – This page is designed primarily to provide feedback for forecasters at the Aviation Weather Center. Feedback from these forecasters will be gathered, and future upgrades will be tailored to their needs.

Demonstration Division

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Objectives

The Demonstration Division evaluates promising new atmospheric observing technologies, such as the NOAA Profiler Network (NPN) developed by the NOAA Research Laboratories and other organizations, and determines their value in the operational domain. Activities range from the demonstration of scientific and engineering innovations to the management of new systems and technologies. In support of NOAA’s mission to serve society's need for weather and water information, new upper-air observing techniques are used to create and disseminate reliable assessments of weather, climate, space environment, and geodetic phenomena. The division also develops and implements data and techniques to support seasonal to interannual climate forecasts as well as the prediction and assessment of decadal to centennial climate change. Safe navigation is promoted by providing Global Position System (GPS) and other observations to the National Geodetic Survey network of continuously operating reference stations (CORS), the U.S. Coast Guard (USCG), U.S. Department of Transportation (DOT), and other GPS users in the public and private sectors.

These activities represent an investment in scientific research, the development of new technologies to improve current operations, and NOAA's preparation for the future. The division has successfully demonstrated all major elements of three reliable, low-cost continuous upper-air observing systems – wind profilers, Radio Acoustic Sounding System (RASS) temperature profilers, and the ground-based atmospheric water vapor sensing observing system (GPS-Met). These systems complement other operational and future ground- and space-based observing systems. New information network tools and techniques have been adapted to acquire and process Cooperative Agency Profilers (CAPs), GPS, and surface meteorological observations from NOAA and other public/private organizations and international partnerships. This capability allows rapid expansion of observing system coverage at extremely low cost. The division has been heavily involved in transferring environmental expertise and technologies to improve NOAA’s ability to serve its customers and forge stronger ties with its partners, especially the National Weather Service (NWS), DOT, and Department of Defense (DOD).

The NPN has been providing important upper-air data to a variety of customers since it began operation 13 years ago. For example, NWS forecasters routinely use data from the NPN, CAP, and GPS networks in computer-generated forecasts and numerical weather prediction (NWP) models, especially to tailor model guidance to local conditions. The datasets are accessible to interested users via the Global Telecommunication System (GTS), and to the public via the Internet. Many other federal, state, and local organizations need these data to support weather forecasting, aviation, and monitoring climate and air quality. As one example, the Lawrence Livermore National Laboratory uses NPN and CAP data as critical input to its dispersion model, which supports work under contract to DOD and the Department of Energy (DOE) for Homeland Security.

With news that funding for the NPN and all other programs within the division would be eliminated for Fiscal Year 2004, staff time and other resources were dedicated to responding to this potentially devastating situation. Though the reputation of the entire Profiler Program had been cemented during the last 20 years, it became necessary to justify its continued existence. Presentations and briefings to various levels of government stressed the many proven uses of the NPN and related programs. Weather forecasting is improved because wind profilers provide information not available through other observing systems. Some of the many advantages to the forecaster are: 1) increased lead time allows deployment of emergency response resources, 2) greater detail concerning storm onset and location results in public heeding warnings to seek shelter, 3) fewer false alarms generate higher public confidence in watches and warnings, 4) early identification of conditions supporting wind shear and turbulence increases the margin of safety for the aviation community, and 5) better precipitation forecasts for the public and agriculture limit flash flood impacts. Forecasters and other users voiced their concern about the potential loss of data from the NPN, CAP, and GPS networks, all of which are integrated into daily forecast activities and, most important, during periods of severe weather. The efforts of FSL staff and testimony from users of profiler data had a positive result late last year, when profiler funding was restored for Fiscal Year 2005. Along with this approval came other requests, namely, that a Cost and Operational Effective Analysis (COEA) of the profiler program be provided to the Senate Appropriations Committee. Additional personnel resources were needed to prepare this report by early 2004. Congress mandated that funding be provided from the NWS budget rather than from the Office of Oceanic and Atmospheric Research(OAR) budget.

The division is engaged in the following major projects:

- Operation, maintenance, and enhancement of the 35-station NOAA Profiler Network, which includes three systems in Alaska and the CAP sites (Figure 54).
- Collection, correction, and distribution of wind and temperature data from the CAP sites.
- Planning and support activities for an initiative for a national upper-air mesoscale observing system, which will include profilers and GPS-Met systems (Figure 55).
- Development, deployment, and evaluation of an all-weather integrated precipitable water (IPW) vapor observing system using radio signals from the satellite GPS.
- Evaluation of newly certified GOES high data rate (1200 baud) communication systems for network deployment.
- Assessment of alternative network data communication technologies, including satellite Internet.
- Upgrade of the surface meteorological sensor package at NPN sites to improve winds and precipitation measurement capability, such as replacement of all analog sensors with digital sensors to increase reliability.

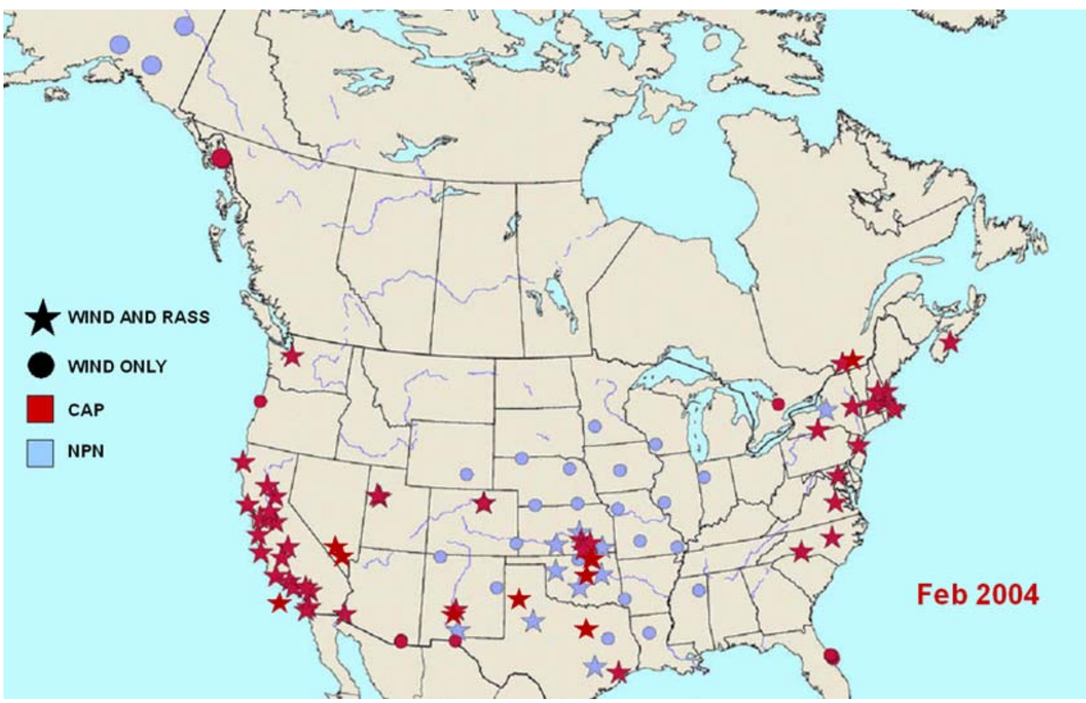


Figure 54. Location of all 35 NOAA Profiler Network (NPN) sites and Cooperative Agency Profiler (CAP) sites providing data via the Profiler Website.

Though organized into five branches, the division works in a fully integrated team mode to support our overall objectives, as follows.

Network Operations Branch – Monitors the health of the systems and data quality, and coordinates all field repair and maintenance activities.

Engineering and Field Support Branch – Provides high-level field repair, coordinates all network logistical support, designs and deploys engineering system upgrades, and redeploys GPS or profiler systems as needed.

Software Development and Web Services Branch – Provides software support of existing systems, and develops new software and database systems as needed, including new tools to assist in monitoring tasks and advanced quality control functions. Also provides Web support of the division's extensive Web activities, and designs software to support future upgrades of the current network and national deployment of additional profilers.

GPS-Met Observing Systems Branch – Supports development, deployment, and evaluation of the GPS-IPW Demonstration Network, and provides software development and scientific support.

Facilities Management and Systems Administration Branch – Manages all computers, data communications, network, and computer facilities used by the staff and projects of the division.

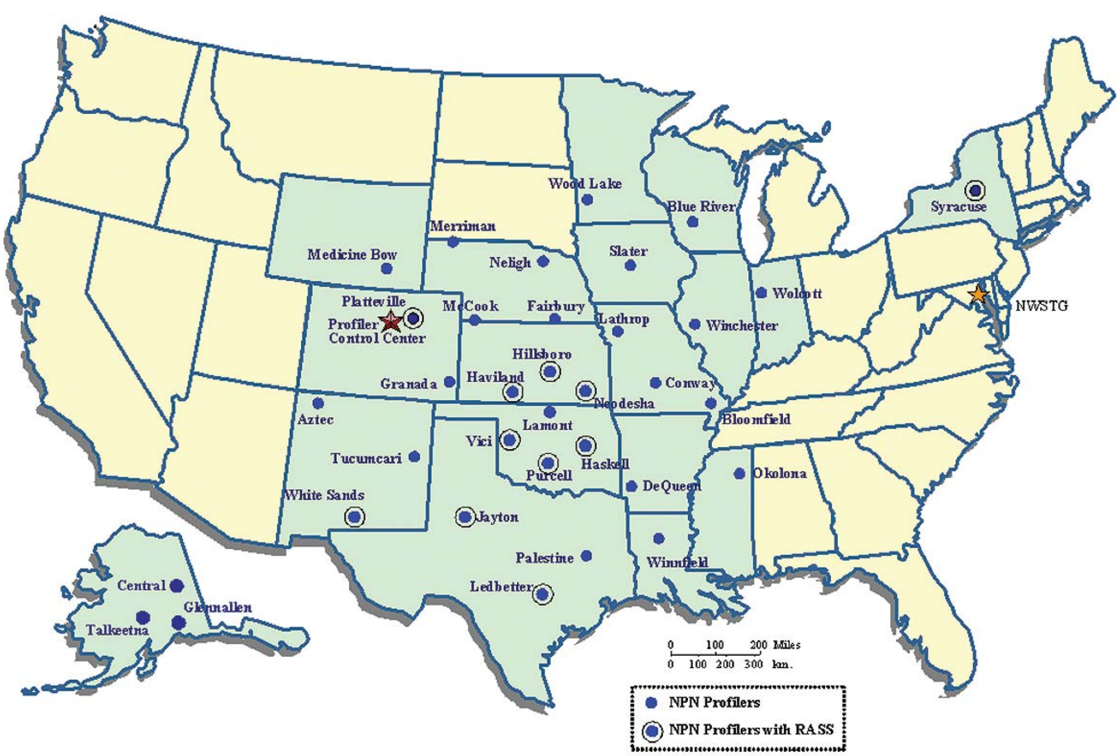


Figure 55. All NOAA Profiler Network sites, including Alaska (lower left), with radars and surface instruments.

Network Operations Branch
Douglas W. van de Kamp, Chief

Objectives

The Network Operations Branch is responsible for all aspects of NOAA Profiler Network (NPN) operations and monitoring, including the coordination of logistics associated with operating a network of 35 radars and surface instruments. The original concept for an operational profiler network envisioned the Doppler radar profiler as part of an integrated upper-air remote sensing system capable of measuring winds, temperature, and humidity. The Demonstration Division's progress toward these goals include the addition of the Radio Acoustic Sounding Systems (RASS) for temperature profiling in the lower troposphere at 11 NPN sites, and GPS integrated precipitable water (GPS-IPW) vapor systems for moisture measurements at all NPN sites. In addition to the 35 NPN sites, another 300+ NOAA and other-agency sites are monitored for timely GPS positions and surface observations to produce real-time IPW measurements. Additional wind and RASS data have been acquired from a growing number of independently operated profiler sites, now totalling about 90. These Cooperative Agency Profilers (CAPs) include mostly lower tropospheric boundary layer profiler sites. The data from these CAP sites are now available to the meteorological community in real time via the division's Website, *www.profiler.noaa.gov*. In cooperation with other branches in the division, we maintain and improve the NPN and CAP real-time data availability to the National Weather Service (NWS) and other worldwide users. We directly support NOAA's mission to improve weather products and services by providing real-time comprehensive, high quality upper-air and surface observations to NWS forecasters and numerical weather prediction models.

Accomplishments

A variety of tracking tools are used to assess the strengths and weaknesses of the NPN. The availability of hourly NPN winds to the NWS continued to increase during 2003, averaging slightly over 96%. Typical NWS-commissioned systems such as NEXRAD, ASOS, and radiosondes have a data availability of 97% or better. Figure 56 summarizes

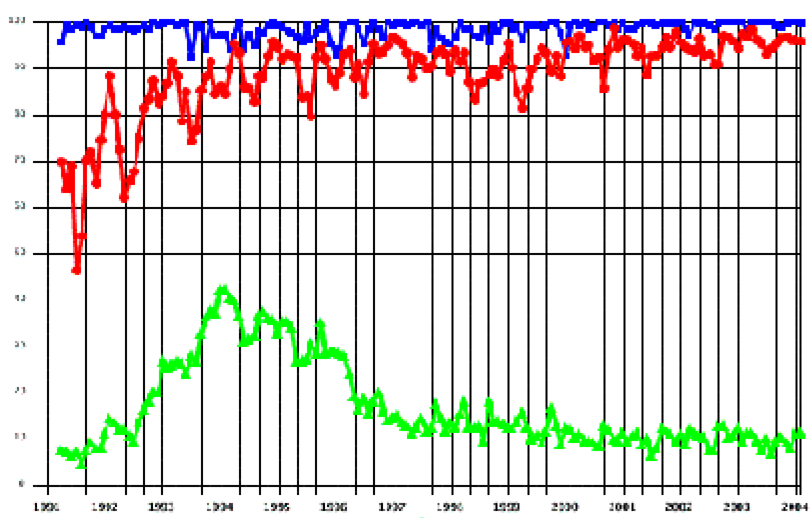
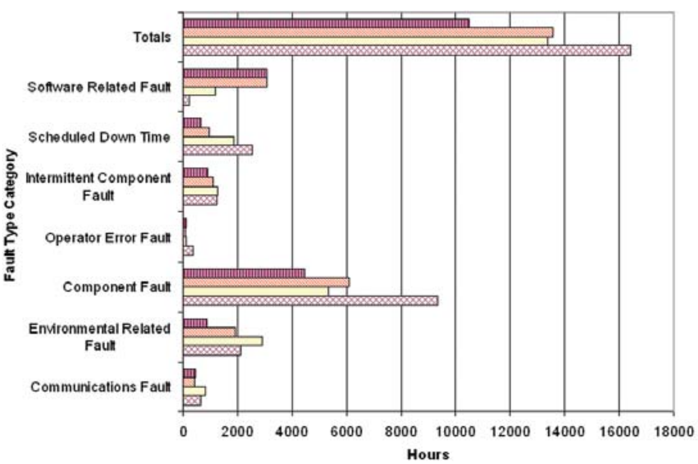


Figure 56. NOAA Profiler Network 404-MHz profiler data availability from January 1991–January 2004.

the overall performance of the network for the last 13 years. During 2003, the NPN average monthly data availability never fell below 93%. It is interesting to note the general pattern of decreased availability of hourly winds each year during the spring and summer months, compared to slightly higher availability during the fall and winter months. An analysis attributes this pattern to increased lightning activity and severe weather during the convective season (causing more commercial power failures and lightning-induced profiler site hardware damage) and air conditioner failures during the summer.

A significant portion of personnel time involves the day-to-day operations and monitoring tasks related to the NPN hardware, communications, and meteorological data quality. Constant attention to these tasks has resulted in high data availability rates for the past few years. Other ongoing work includes initial diagnosis of equipment failures, coordination of all field repairs and maintenance activities, and control of logs of all significant faults that cause profiler data outages. Figure 57a shows the total number of hours of profiler data lost by fault type (such as component failures, scheduled downtime for maintenance, and power and air conditioner failures) for the past four fiscal years. The duration of each data outage is broken down into many different categories, including how long it took to identify a failure, diagnose and evaluate the problem, wait for repair parts to be sent and received, restore commercial power or communications, and document when and how the fault was ultimately repaired. Figure 57b shows the distribution of these categories of downtime (normalized over the past seven years). Analysis of all these states reveals important



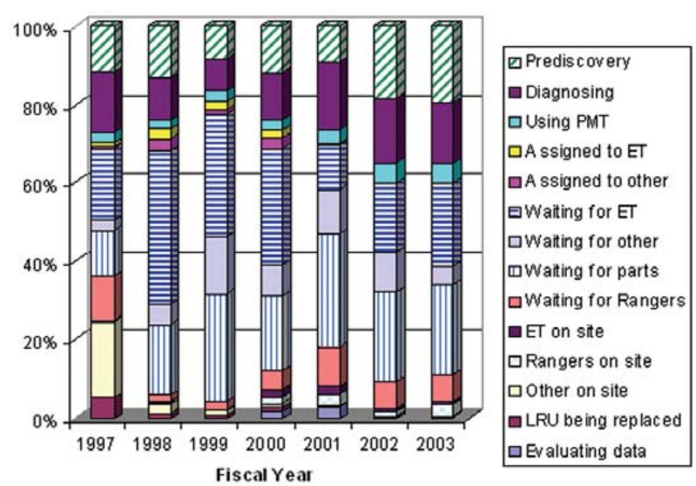


Figure 57. a) above. Hourly NPN data lost by fault type for the past four fiscal years, from 2000–2003; b, right) Distribution of NPN downtime by categories (normalized over the past seven years).

information on the operation of the network and allows the identification of its strengths and weaknesses. In addition to the data monitoring tasks, other work involves the financial aspects related to the continued operation of the NPN, including tracking land leases, communications, and local commercial power and phone bills for all the profiler sites.

Personnel in the Profiler Control Center (PCC) routinely monitor the NPN, whose data are used operationally by the NWS, only during normal working hours, 7:30 AM–4:30 PM local time (27% of the total hours in a week). The remainder of the time, the profilers, dedicated communication lines, and Profiler Hub computer system operate unattended. Significant improvements have been made in our ability to remotely monitor activity within the NPN, Hub processing, and data communications via Web displays and other tools. Routinely monitored activities on the Web include information on profiler real-time status, data flow to the NWS Telecommunications Gateway (NWSTG), and ingest of profiler data into the Rapid Update Cycle (RUC) model at the NWS National Centers for Environmental Prediction (NCEP). The use of these tools to remotely diagnose problems as they arise outside normal work hours has increased the availability of NPN data.

Examination of several years of data showed that a significant number of lost hours of data were attributed to the local main power breaker (200 amps) being tripped to the off position, usually the result of lightning related power surges. Simply resetting the breaker restores operation, but a site visit is still required, typically by an NWS technician or the local landowner. From this analysis, the division's Engineering and Field Support Branch designed and installed a device several years ago that allows the main breaker to be remotely reset via a phone call to the site. This method is routinely used to restore profiler operations, as well as to "power cycle" a site in an attempt to clear software "hangs" and other problems. During 2003, the breaker reset capability was activated 208 times outside normal work hours to restore operations. It was successful 168 times (81%), resulting in an additional 4,400+ hours of profiler and GPS-IPW data availability to our customers. These resets, performed outside normal work hours, alone increased data availability by 1.6%. This is quite impressive since our data availability is already normally >96%.

Eleven NPN sites have RASS capabilities that typically provide measurements from 2.5–4 km above the ground. In general, the velocity of the lower tropospheric wind limits the maximum height coverage of RASS by blowing the acoustic signal outside the radar beam. Each RASS-equipped site has four acoustic sources that are located inside the antenna field fence near the corners of the wind profiler antenna. Ongoing experiments are conducted at Platteville, Colorado, and Purcell, Oklahoma, to investigate the impact of acoustic sources placed 35–140 m upwind of the profiler sites. Typical improvements of 500–1,000 m in the RASS height coverage are observed when the 70–140 m upwind acoustic sources are activated, and the low altitude winds are from that direction.

Low-power profilers that measure winds and temperature in the boundary layer to the lower troposphere (60 m to ~3 km above ground) have begun operating in greater numbers around the Northern Hemisphere in recent years. These profilers, part of the CAP network primarily support air quality measurements and meteorological forecasting and research programs, and typically operate independently or in small groups. Approximately 90 CAP sites (for example, Figure 58) are currently operating and providing data to the Profiler Control Center in Boulder. Mostly located in coastal regions of the eastern and western United States, the CAP sites provide valuable additional geographic coverage outside the NPN. The division is collaborating with other agencies to acquire CAP wind and RASS temperature data that are processed into hourly and subhourly quality-controlled products, and are ultimately distributed along with products from the NPN. The CAP data are primarily used for air quality monitoring and forecasting, but have applications to homeland security, and numerical weather prediction and subjective weather forecasting in support of NOAA's mission.

To better understand how and when profiler data are used by the National Weather Service (NWS), the branch started monitoring the Area Forecast Discussions (AFDs) at the field offices. Forecasters at each NWS office typically write two AFDs every day which describe the current forecasting issues, both in the short-term and longer-term forecast period. These AFDs are generally technical in detail, and more of a “thought process” to share among the forecasters, both within a forecast office between shifts and in adjacent NWS forecast offices. A search was performed to see how many times the word "profiler" was used in all AFDs for a 199-day period. Forecasters at 77 (out of a possible 114) NWS offices mentioned the use of profiler data in at least one of their AFDs from 13 January–31 July 2003. The NWS offices located in the central United States are, of course, primarily using NPN data, while those offices near the East and West Coasts are all using CAP data. Of the 77 offices indicating the use of profiler data, a total of 1,014 AFDs (~5 per day) mentioned the use of profiler data in their decision-making process, thus demonstrating that the use of profiler data is well integrated into NWS operations.

Each AFD that mentioned profiler data was categorized by how the data were used. Though the data were used in a wide variety of ways, they were primarily used in conjunction with numerical model output, satellite imagery, and surface wind forecasts. The distribution of use of profiler data covers nine general categories, shown in Figure 59. We often noted two very specific uses, comparison with numerical weather prediction model output and satellite measured winds, about 25% of the time. These uses were usually in conjunction with profiler data to validate a model’s initial analysis fields, and to assess a model’s short-term forecasting skill. The “Lower Tropospheric” category represents the use of hourly or subhourly profiler data to identify and/or monitor the location of such features as low-level jets, increasing or decreasing wind speed with time, changing wind direction with time, etc. All of these categories are very important to severe weather forecasting, particularly between the times of the twice daily radiosonde ascents.

Figure 58. A 915-MHz CAP profiler located near and operated by Rutgers University at Rutgers, New Jersey.

Profilers provided critical information during the severe weather outbreak of early May 2003. Approximately 450 tornadoes were recorded during a 13-day period (28 April–10 May) of sustained severe weather. About 395 of these tornados occurred in a 7-day period (4–10 May), setting a new weekly record. The number of AFDs mentioning the use of profiler data increased during this period. Mesoscale Discussions from the Storm Prediction Center (SPC) and many AFDs identified the position and strength of the low-level jet in the profiler data, and its impact on providing moisture and vertical shear to the lower atmosphere.

Projections

Many of the tasks slated for 2003 were carried over to 2004 because staff resources were directed to the transition of the current VAX-based Profiler Hub to a PC-based processing and dissemination system. Limited resources related to this work, along with budget related distractions, thwarted progress in testing and implementing new ideas and tasks originally planned for last year.

The Bird Contamination Check algorithm will be examined for potential improvements. The original algorithm analyzed only the hourly averaged north and east beams to detect the broader spectral widths caused by migrating birds. The next significant improvement is likely to involve more sophisticated processing of the 6-minute moment data. Additional QC development is limited, since the current Profiler Hub cannot incorporate anymore processing at this time.

The division will continue to operate and maintain the 11 RASS-equipped profiler sites. Experiments will continue at Platteville and Purcell, Colorado, to investigate the optimum acoustic source locations (distance upwind) and acoustic output power. Improvements are expected in the quality control of RASS data, primarily during periods of internal interference, and in the presentation (i.e., contouring specific temperatures) of RASS data on the Profiler Webpage.

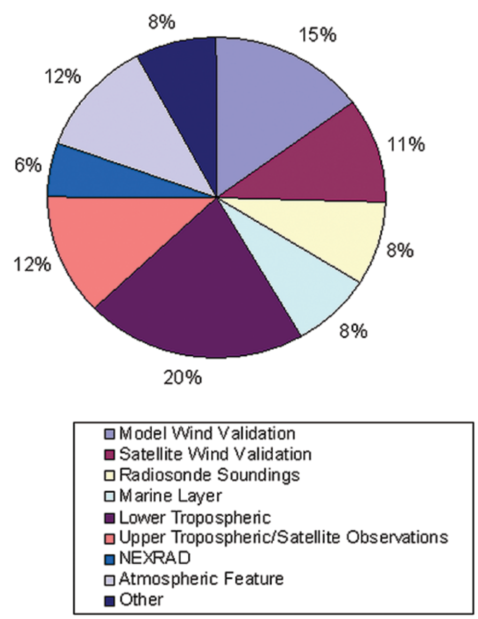


Figure 59. Wind profiler usage by National Weather Service offices.

The operations of the CAP Hub will be used to acquire additional tropospheric profiler data from targets of opportunity, provide quality control for these datasets, and distribute them to users via the Web and the NWS Telecommunications Gateway. Additional automated monitoring procedures will be investigated to handle the increasing number of CAP sites available and monitored by the PCC.

The capabilities of the new hybrid 449-MHz profiler at Platteville will be investigated further. This will include data quality and height coverage of different data processing methods (standard consensus versus a multiple peak tracking algorithm), three beams compared to five beams in terms of data quality and cost/complexity issues, higher temporal resolution data, and reduced height of the first sample height. All of these issues are related to the design and implementation of a national profiler network.

The capability to remotely reset the main breaker via a phone call to the site has proven so successful that the procedure will be automated. Data availability is manually checked typically each evening during weekdays, and mornings and evenings on weekends. Sites that are "hung" due to software failure or missing data for other reasons are reset at that time. The average time between a site shutting down and being reset is currently 5–6 hours. Plans are underway to automatically initiate a breaker reset after two hours of missing data. Initial testing of this capability failed last year due to the variable and lengthy time required to dial up and make a connection to a site, and the rather long sequence of codes and required intermediate delays required to reset a site.

The branch will continue to collaborate with other Demonstration Division staff in the operation and maintenance of the NPN to help maintain consistently high data availability statistics. This ultimately supports NOAA's mission of improving weather products and services, resulting in reduced loss of life and property damage from weather related events.

Engineering and Field Support Branch

Michael K. Shanahan, Chief

Objectives

The primary focus of the Engineering and Field Support Branch is to carry out the operation, maintenance, and improvement of the NOAA Profiler Network (NPN). Through collaboration with the FSL Profiler Control Center (PCC), the branch monitors the 35-site NPN network to assure data quality and reliability. Constant network upgrades, identification of network problems, using remote diagnostics analysis, and prompt corrective actions result in increased data availability.

Most of the preventive and remedial maintenance is performed by electronics technicians from the National Weather Service (NWS) in accordance with network maintenance agreements. The PCC uses remote diagnostic capabilities to recognize failed components, order line replaceable units, and coordinate with the NWS electronics technicians regarding field repairs. More complex problems are handled by a team of specialized engineer/technicians, called Rangers, who are experienced in the design and operation of the profiler systems. Based in Boulder, the Rangers can be mobilized to the field on short notice to repair the profilers.

Accomplishments

The Alaska 449-MHz Profiler Network has been operating continuously and delivering data to the NWS for over four years. A summary of the overall performance of the network from October 1999–February 2004 is charted in Figure 60. The transmitters' redesigned High Power Amplifier (HPA) at the Alaska sites have been operational for over a year without failure. We conducted a week-long training seminar for the electronic technicians in Anchorage and Fairbanks.

The 449-MHz profiler at Syracuse, New York, became operational in 2003. This site is a testbed for the Lockheed Martin Syracuse facility and supplies data to the NWS to help predict lake-effect snow events in the area.

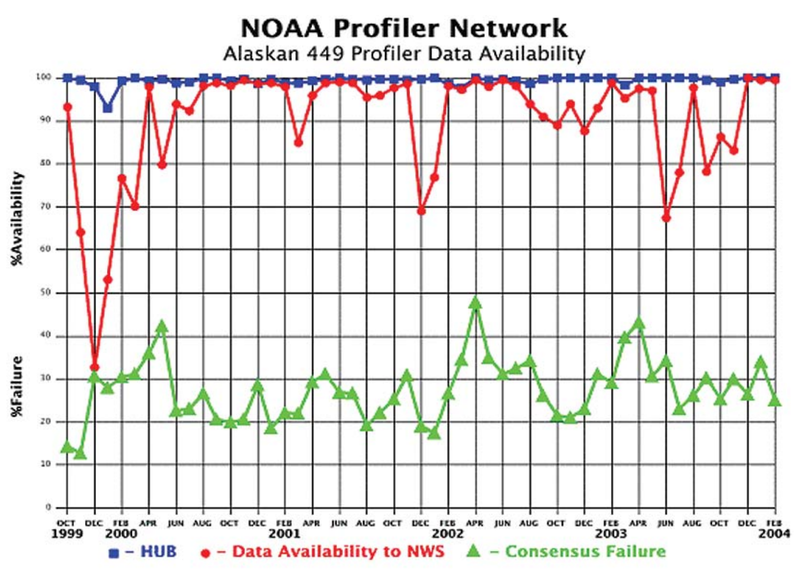


Figure 60. The Alaska NPN 449-MHz profiler data availability from October 1999–February 2004.

The NOAA Profiler Network was granted a 3-year extension to the 404-MHz Radio Frequency Authorization valid until September 2006. The main reasons for this decision were that no Search and Rescue Satellite (SARSAT) interference events have occurred in more than seven years, and the quality of profiler maintenance is indisputable.

New Profiler Surface Observing System (PSOS-II) equipment was acquired to upgrade the existing surface meteorological observing packages at each site. Most of the equipment has already been purchased except for some custom built pieces that must be hand-crafted to perform specific tasks.

The U.S. Air Force uses profiler data to support safe flight operations. Branch staff completed an Operations and Maintenance Manual (O&M) for the Air Force Tethered Aerostat Radar System (TARS). This manual is implemented to aid the repair technicians at each aerostat site.

A profiler electronics technician training seminar was provided for NWS employees associated with the NPN. The seminar was held at the Boulder Assembly Facility (BAF), which houses a working profiler without the antenna and serves as a local test bed, repair facility, and training center. The three-day event covered material from the “NOAA Wind Profiler Guide to LRU Replacement” manual, which was distributed to NWS offices in CD format to aid the technicians in profiler maintenance. The training also included the repair of GPS and GSOS/PSOS systems.

Projections

The Engineering and Field Support Branch will install an all-digital surface meteorological sensor package, the PSOS-II, to replace the GSOS and PSOS units operating at some profiler sites. A 10-meter mast with an anemometer and rain gauge will be added to sites currently without surface wind measuring capability. This mast is designed so that technicians can raise and lower instrumentation without the need for additional assistance. When this implementation is accomplished, each of the 35 profiler sites will have uniform equipment availability, resulting in additional meteorological data.

New signal processing techniques will continue to be tested at the Platteville, Colorado, profiler site to determine the best method for acquiring quality data. These techniques are expected to help alleviate the problems associated with ground and sea clutter and bird contamination.

Plans will continue toward the conversion of all 404-MHz profilers to the designated 449-MHz frequency, in support of the NWS Cost and Operational Effectiveness Analysis (COEA).

Repair and replacement of 404-MHz and 449-MHz parts will continue to be a top priority. Whether the repair work is outsourced or performed in-house with available parts, obsolescence requires constant perseverance and creativity in finding vendors who deal in outdated parts and technology. Without the ability to overcome these obstacles, the NPN would not be able to maintain the high performance and reliability it has achieved over the last 13 years.

Operations and maintenance support will be provided to the 10 quarter-scale profilers scheduled for installation for the Air Force TARS.

Training seminars for the National Weather Service technicians will continue to be conducted at the Boulder Assembly Facility.

Software Development and Web Services Branch

Alan E. Pihlak, Chief

Objectives

The Software Development and Web Services Branch provides software support for existing systems, develops new software and database systems as needed, provides Web support for the division's extensive Web activities, and designs software to support a national deployment of profilers. To help improve short-term warning and forecast services, up-to-the-minute profiler data are provided on the NOAA Profiler Network (NPN) Website, *http://profiler.noaa.gov* – the first place to go for wind profiler data. This Website also provides historical archives of wind, temperature, and other profiler information beneficial to researchers for forecasting and modeling both long- and short-term climate change. A perpetual goal is to improve the timeliness of profiler data delivery and distribution through work on existing software systems and development of new software.

The Cooperative Agency Profiler (CAP) network, comprising profiler sites operated by external agencies and organizations, is a primary user of branch resources. Profiler data produced in near real time by sources ranging from the Environmental Protection Agency to the Japanese Meteorological Agency are acquired by the branch and become part of the shared data system. CAP sites are operated in many different ways, owned by about 30 different agencies, and optimized for different applications. This requires the development of reusable, generalized software in order to make the most efficient use of branch resources. FSL acquires these data, applies its own quality control algorithms to the data, and makes the value-added data available on the Web and to the National Weather Service (NWS). The data from these profilers, distributed primarily via the Profiler Website, contribute significantly to NWS forecasts in areas, primarily along the coasts, where the NPN does not operate tropospheric profilers.

Accomplishments

When the NPN was cut from the 2004 budget, an unusual amount of Demonstration Division resources was directed toward finding and preparing data for presentations, attending meetings, and assuming duties of others involved in the process of justifying restoration of the program on the 2004 budget. These unexpected activities along with additional work on the Cost Operational Effectiveness Assessment for the U.S. Senate placed many branch goals on hold for 2003.

A major ongoing task is the removal of the 1980s-era Hub system: data collection, processing, monitoring, displays, software quality control and quality assurance, and distribution. An aging GOES data collection system was replaced with a Local Readout Ground Station (LRGS) acquired from a commercial source. The NPN's core profiler instrumentation remains the Lockheed Martin wind profiler. This instrument was designed around, and is completely dependent on, communications with a GOES Data Collection Platform (DCP) transmitter produced by Synergetics, no longer in existence. Regarding data collection, software was produced to emulate the communications protocol of the Synergetics unit to the Lockheed profiler, while allowing any modern GOES DCP unit to actually be connected to the system. In 2003 it was necessary to acquire and produce software for the three GOES transmitters certified for high data rate (1200 baud) operations.

The CAP central processing system was re-engineered using modern technology and moved from an aging Sun workstation onto newer Intel-based hardware running Red Hat Linux. Every attempt was made to produce reusable, platform-independent code. This is expected to be the first of other such types of upgrades in the future.

In the area of software quality control, all programs written by the branch over the last several years have been consolidated into a source code tracking and versioning system. A unified build and distribution process has been created to simplify the installation of software and decrease the possibility of configuration errors. Figure 61 shows the Software Build Guide on the NPN Intranet. Software quality assurance is based on the idea of unit testing, which presents a challenge in trying to find the resources to retrofit this concept to existing code.

A new design for monitoring and processing data provides a database model that employs software to find problems at product creation time, instead of relying on end-users to notify the Demonstration Division of problems.

Another integral goal reached in 2003 was to extend and enhance a Web-based operational control interface to programs, using the Web-based Heartbeat Control Processes interface shown in Figure 62.

A strategy for processing profiler and other meteorological data was implemented that allows data to flow through a chain of processes that can be modified while running, as shown in Figure 63. Thus, the system does not have to be stopped to implement changes; instead a prompt, "Error! Reference source not found," shows the general data path of the system.

An assessment of the reusability of existing display software was completed.

NPN and CAP data covering one year became available on the NPN Website.

Commercial satellite Internet communications were installed at four NPN sites as part of a High-Performance Computing and Communications (HPCC) grant to evaluate the effectiveness of this method as a replacement for direct-connect phone lines.

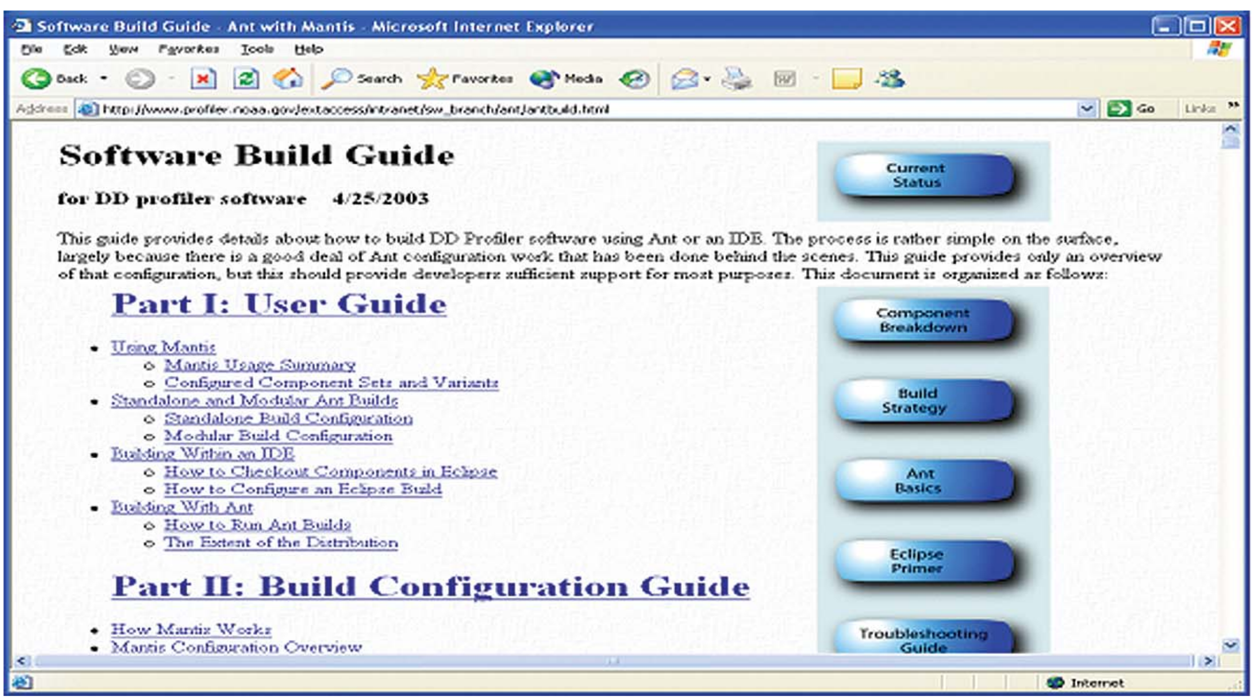


Figure 61. Demonstration Division Website of the Profiler Software Build Guide.

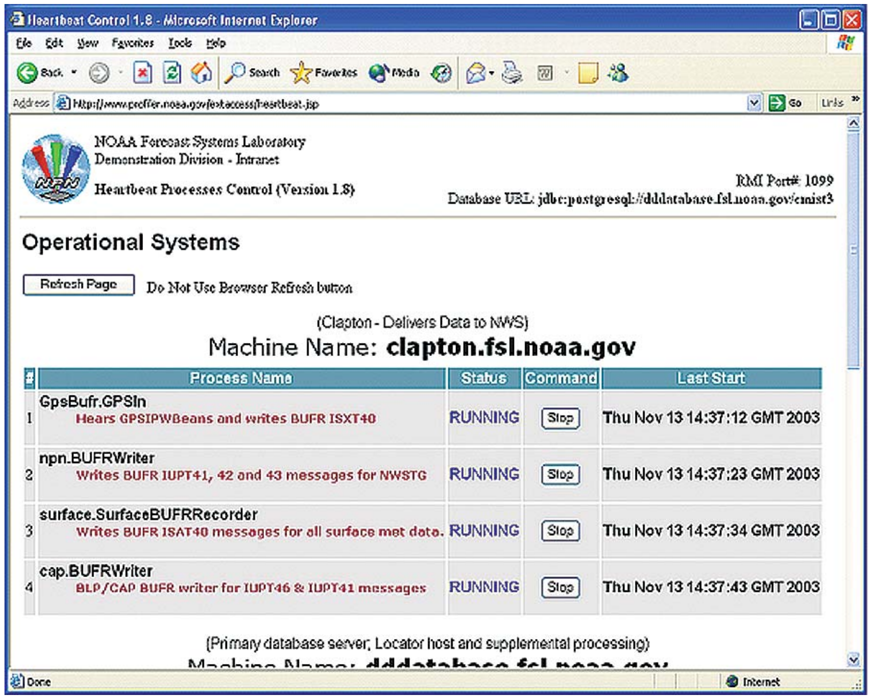


Figure 62. Demonstration Division Intranet Website of the Heartbeat Processes Control interface for operational systems.

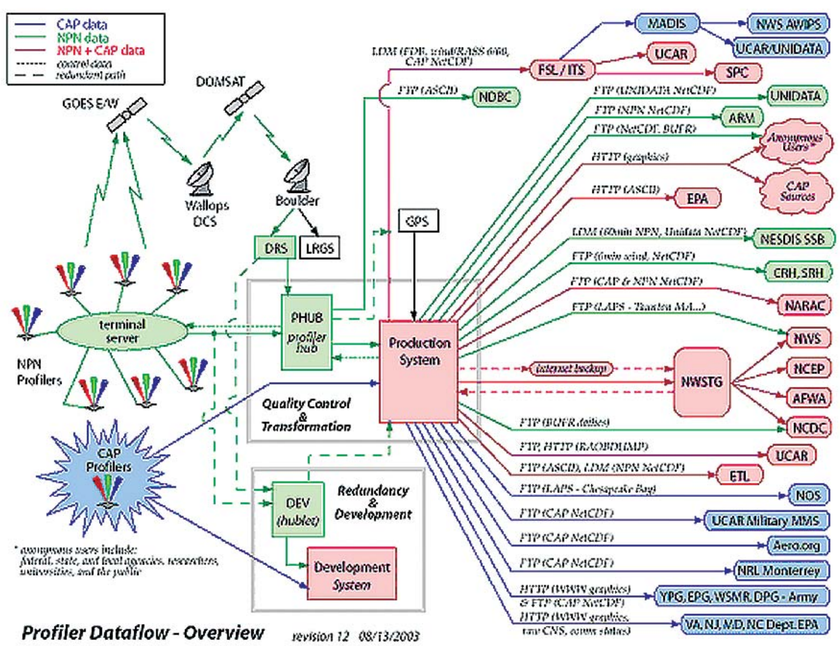


Figure 63. NOAA Profiler Network and Cooperative Agency Profiler data flow.

An integral part of the HPCC feasibility evaluation involved completion and testing of a general purpose serial data client-server component.

Datasets to the National Weather Service Telecommunications Gateway (NWSTG) were unified through consolidation of CAP data messages and NPN data messages under a single header.

Projections

The VAX Cluster Hub is being replaced with a modern distributed data collection and processing system. The long list of remaining milestones below is expected to be met during 2004:

- Move CAP operations out of the Engineering and Field Support Branch into the Network Monitoring Branch
- Design the interface for the processing chain
- Translate averaging "raw" data into hourly averages
- Compute Hub-style surface meteorological quality control
- Calculate Bird Algorithm quality control
- Perform Nyquist velocity interval unfolding
- Implement coherent interference removal
- Assist in finishing the design of the product subsytem
- Collect and send 6-minute raw "product instance"
- Record the receipt and location of the raw data product and monitoring information
- Collect and send 60-minute raw GOES "product instance"
- Design and integrate scheduling into product database
- Compose "old style" WMO BUFR messages
- Schedule tasks chronologically
- Monitor raw 6-minute and GOES 60-minute NPN products
- Monitor new-style and old-style WMO BUFR messages

Several GOES DCP transmitters will be added to the list of those supported by the general purpose GOES transmission package.

The HPCC Satellite Communications Study and Evaluation will be completed, and recommendations will follow regarding its viability as a replacement for dedicated phone lines. This evaluation will center on the effect of weather on the transmission of data in varying locations across the United States. The correlation of satellite-transmitted data to landline-transmitted data will also be examined.

GPS-Met Observing Systems Branch

Seth I. Gutman, Chief

Objectives

The GPS-Met Observing Systems Branch was formed in response to the need for improved moisture observations to support weather forecasting, climate monitoring, and research within NOAA. Reliable assessments of weather, climate, the space environment, and geodetic phenomena are created and disseminated using a new upper-air observing system technique to support advanced short-term warning and forecast services. The data and techniques that the branch develops and implements also support seasonal to interannual climate forecasts and the prediction and assessment of decadal to centennial climate change. Due to an unanticipated synergy between the requirements for atmospheric remote sensing and the more traditional applications (positioning, navigation, and time transfer) of the Global Positioning System (GPS), safe navigation is promoted by providing GPS and other observations to the National Geodetic Survey (NGS) Continuously Operating Reference Station (CORS) network, the U.S. Coast Guard (USCG), U.S. Department of Transportation (DOT), and other GPS users in the public and private sectors.

The primary objectives are to define and demonstrate the major aspects of an operational ground-based GPS integrated precipitable water vapor (IPW) monitoring system, facilitate assessments of the impact of GPS meteorological data on weather forecasts, assist in the transition of GPS-Met to operational use within NOAA, and encourage the use of GPS in atmospheric research and other applications. The branch utilizes the resources and infrastructure established to operate and maintain the NOAA Profiler Network (NPN) to achieve these objectives at low cost and risk. The branch collaborates with other FSL divisions to achieve objectives of mutual interest and benefit the laboratory, its customers, and its partners.

The branch has successfully demonstrated all major elements of a reliable, low-cost continuous upper-air observing system that complements other operational and future ground- and space-based observing systems. Newly adapted information network tools and techniques acquire and process GPS and surface meteorological data from NOAA and other public, private, and international partners. This capability has permitted rapid expansion of GPS-Met coverage at extremely low cost. The branch has been heavily involved in developing and implementing environmental expertise and technologies to improve NOAA's ability to serve its customers and forge stronger ties with its partners, especially the National Weather Service (NWS), National Environmental Satellite Data Information Service (NESDIS), Department of Transportation (DOT), and National Aeronautics and Space Administration (NASA). In the past year, our collaborations have extended to government agencies and institutions in Canada, Europe, and Japan.

Accomplishments

The GPS-Met project concentrated on the following activities in 2003:

- Expansion of the GPS-Met network to facilitate assessment of GPS-IPW observations on weather forecast accuracy
- Investigation of how integrated observations (of which IPW is just one of many) are handled in numerical weather models
- Evaluation of the feasibility of using meteorological models to improve GPS positioning accuracy
- Demonstration of the use of GPS observations to quality control rawinsonde moisture profiles
- Investigation of the relationships between GPS-IPW retrievals and TPW estimated from satellite (GOES and Aqua/AIRS) instruments.

An invited paper was presented at an international workshop in Tsukuba, Japan, two peer reviewed papers were published in refereed journals, papers were presented at the Annual American Meteorological Society Meeting, and briefings and presentations were made to numerous organizations throughout the year.

Expansion of the GPS-Met Network

GPS Surface Observing System (GSOS) meteorological packages were installed at 3 Nationwide Differential GPS sites and 4 U.S. Coast Guard sites during 2003. This brought the number of "backbone" sites in the network to 117, with a goal of reaching about 200 sites nationwide by 2005. An additional 72 "infill" sites were added (mostly belonging to state departments of transportation), bringing the total number of sites in the network to 289 by the end of 2003. Figure 64 shows the configuration of the GPS-Met network, including backbone sites operated by U.S. federal agencies (identified by triangles) and infill sites operated by other government agencies, universities, and the private sector (identified by circles). The growth of the network in 2003 is illustrated in Figure 65.

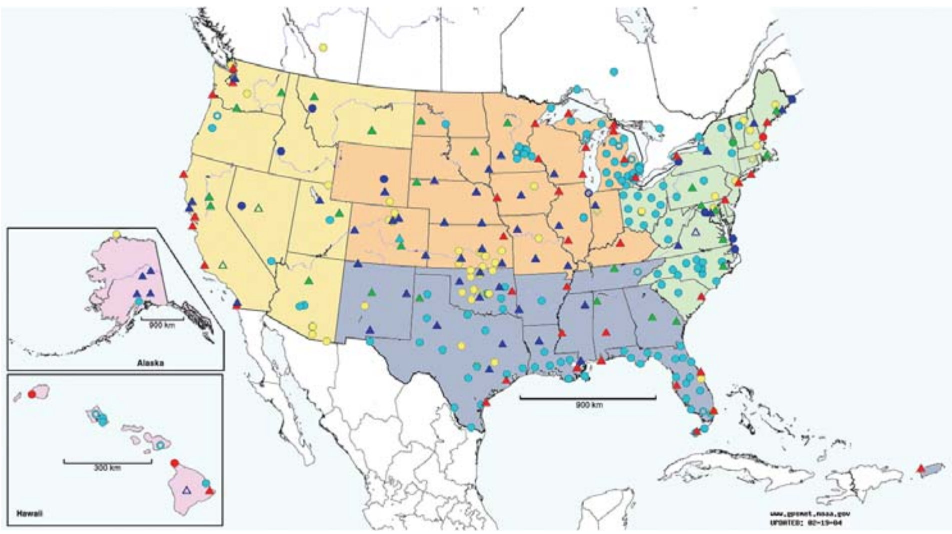


Figure 64. GPS-Met Network at the end of 2003. Triangles identify "backbone sites" owned and operated primarily by U.S. federal agencies. Circles identify "infill sites" used for network densification.

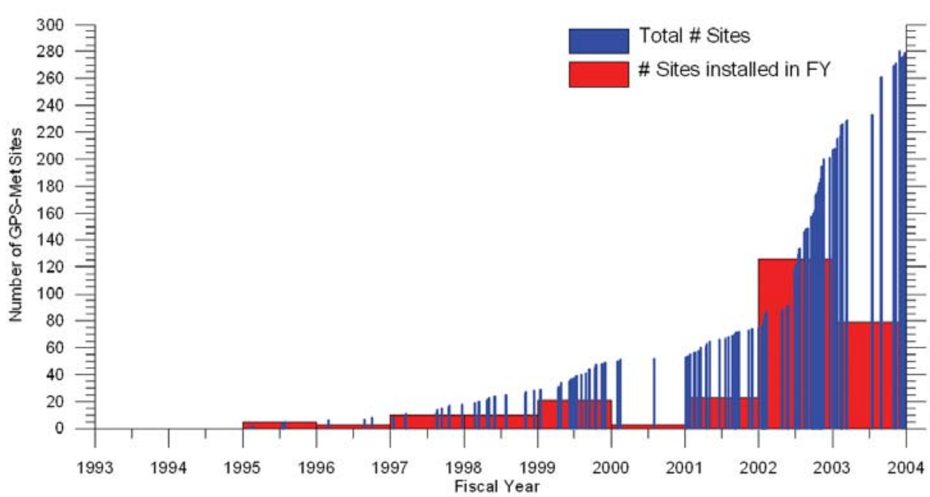


Figure 65. Growth of the GPS-Met network in 2003.

Impact of GPS Water Vapor Data on Weather Forecast Accuracy

The GPS-Met Observing Systems Branch assisted FRD's Regional Analysis and Prediction Branch in performing the sixth consecutive assessment of the impact of GPS IPW retrievals on weather forecast accuracy. The annual assessments are data denial experiments using the 60-km version of the Mesoscale Analysis and Prediction System (MAPS), a research version of the operational Rapid Update Cycle numerical weather prediction model (RUC2) currently running at the National Centers for Environmental Prediction (NCEP). The 60-km MAPS model was again run in a 3-hour data assimilation/forecast cycle over the central U.S. Each forecast cycle used the same boundary conditions and observations (including rawinsondes, surface, aircraft, wind profiler, and GOES precipitable water). The only difference was the addition of GPS IPW (integrated precipitable water) observations in a second "parallel" run. The 3-hour relative humidity forecasts (with and without GPS) were compared with twice daily rawinsonde observations at 17 NWS upper-air sites to assess the improvement in the relative humidity (RH) forecast accuracy at 4 pressure levels (850 hPa, 700 hPa, 500 hPa, 400 hPa, and 300 hPa). A summary of GPS-Met impact assessment comparisons over the past 6 years showed improvement in 3-hour forecast accuracy as a function of the number of GPS stations used in the data denial experiments: 18 in 1998 and 1999, 56 in 2000, 67 in 2001, over 100 in 2002, and over 200 in 2003. The improvement in 3-hour RH forecast skill in 2002 as a function of the month of year is shown in Figure 66. Note that there is a definite seasonal modality on the magnitude of the impact at 850 hPa that is not seen at 700 hPa. The reasons for this are under investigation, but run-by-run verification clearly shows that impact at this level varies widely and is greatly affected by local weather regimes.

The magnitude of 3-hour forecast improvement is relatively small in absolute terms (5.4% at 850 hPa) because results from all days, including those when the addition of GPS has little or no impact on the forecast, are included in the calculation of the statistics. In fact these low (and occasionally negative) impact cases constitute the majority of the events, and occur whenever the moisture field is not changing rapidly and is well described by the model using the current suite of operational observing systems. However, since a major goal of modern weather prediction is to improve forecasts of severe weather, and this is precisely when GPS makes its greatest contribution, all-weather high temporal frequency precipitable water vapor observations from GPS will make a significant contribution to the composite upper-air observing system of the future.

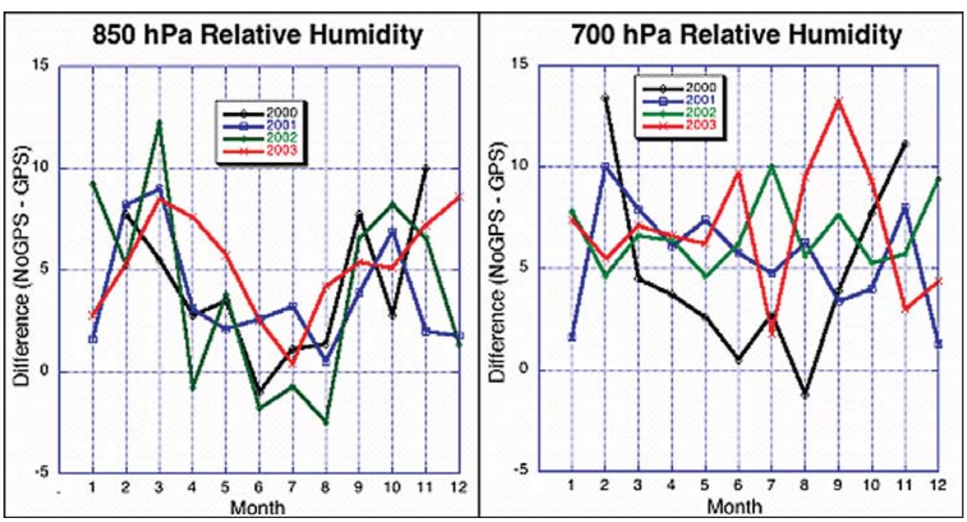


*Figure 66. Improvement in 3-hour RH forecast skill in 2002 as a function of month of year. Percent improvement in RH is defined as 1-*100 (3 hour forecast error with GPS, 3-hour forecast error without GPS). There is a definite seasonal modality on the magnitude of the impact at 850 hPa that is not seen at 700 hPa.*

A Web-based application was developed to facilitate the evaluation of GPS observations and NWP model performance over the RUC CONUS region. As shown in Figure 67 *(http://waylon.fsl.noaa.gov/cgi-bin/ruc20/ruc20.cgi)*, this application allows users to interactively compare GPS-IPW retrievals with various satellite images and PW analyses and forecasts from the 20-km version of the RUC (RUC20) model. An online archive contains approximately 2 months of data to facilitate investigations of interesting cases or events. This application is also useful for comparing precipitable water forecasts with and without GPS-IPW retrievals. Figure 68 shows a comparison of 3-hour RUC20 precipitable water forecasts with and without GPS-IPW over a 90-day period, between 25 July and 22 October 2003. The 3-hour forecasts from the RUC model version that assimilates GPS not only have smaller RH errors at levels below 500 hPa but also have smaller IPW errors.

Quality Control of Rawinsonde Moisture Observations

Most of our information about the distribution of moisture in the upper atmosphere comes from the global network of nearly 900 upper-air stations that launch rawinsondes on a regular basis. About 600 of these stations, located mostly in the Northern Hemisphere, launch rawinsondes at 0000 UTC and 1200 UTC each day. The NOAA National Weather Service launches rawinsondes from 92 stations: 69 in the conterminous United States, 13 in Alaska, 9 in the Pacific, and 1 in Puerto Rico. Although quality control of all atmospheric observations is important, it is essential for rawinsondes, because our principle understanding of the distribution of moisture in the upper atmosphere comes from these in situ measurements, and they form the basis of intercomparison, calibration and validation of most other measurements, observing systems, and atmospheric models.

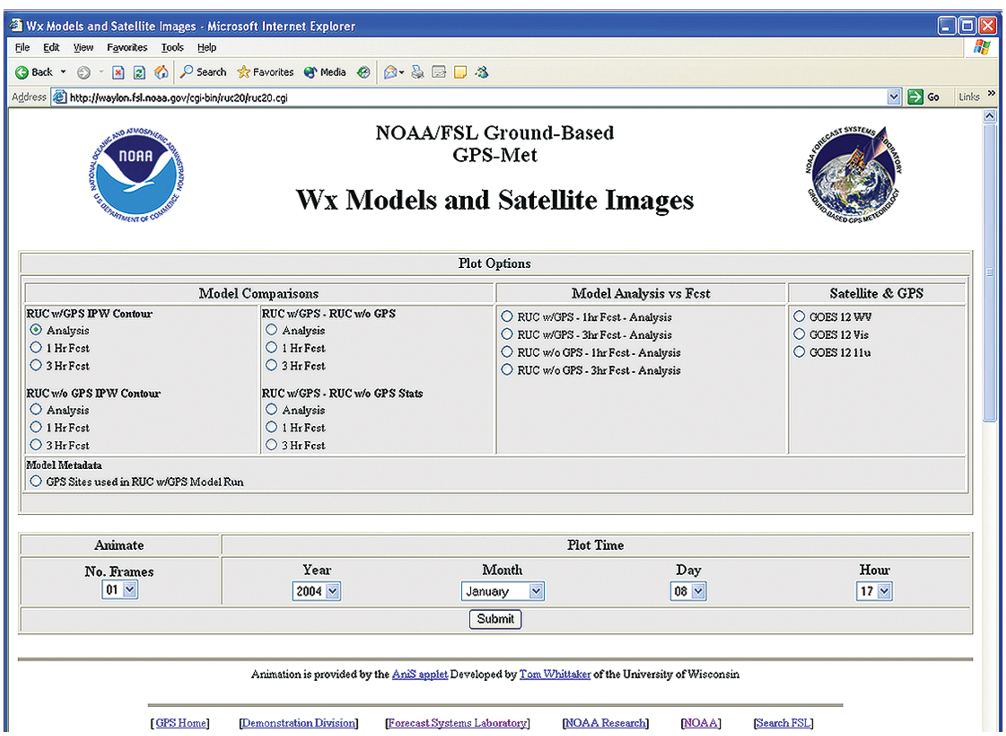


Figure 67. Web-based application to assist users in comparing GPS retrievals with satellite images and RUC model precipitable water estimates, at http://waylon.fsl.noaa.gov/cgi-bin/ruc20/ruc20.cgi.

The characteristics of GPS water vapor observing systems and the accuracy of GPS-IPW retrievals come from long-term comparisons with other moisture observing systems, especially rawinsondes. Most of the NOAA GPS-Met studies have been carried out at the Department of Energy Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART) facility near Lamont, OK. Comparisons between GPS and radiosonde-derived precipitable water at the ARM CART site between 1996 and 1999 reveal no long-term bias, and a standard deviation of the differences of about 2 mm for precipitable water. Comparisons by other institutions around the world are fully consistent with this result, and together indicate that the accuracy of GPS-IPW retrievals is comparable to radiosonde precipitable water measurements made under research or experimental conditions.

The expansion of the GPS-Met network in 2002 and 2003 resulted in a relatively large number of GPS-Met sites (about 40) falling within 50 km of an NWS upper-air site. This fortuitous situation provided, for the first time, an opportunity to compare GPS IPW retrievals with operational rawinsondes on a regular basis. The locations of 9 upper-air sites within 50 km of a GPS receiver were evaluated for 90 days between 24 July and 21 October 2003. The results indicate that when outliers (defined as a sonde measurement that exceeds 2* RMS difference) are removed from the dataset, the statistics are closer to those obtained over several years of independent tests at the ARM CART site, as well as during the IHOP 2002 campaign. Remaining differences can be explained in terms of GPS measurement errors, rawinsonde moisture measurement errors, and/or real differences in the observed atmospheric moisture structure

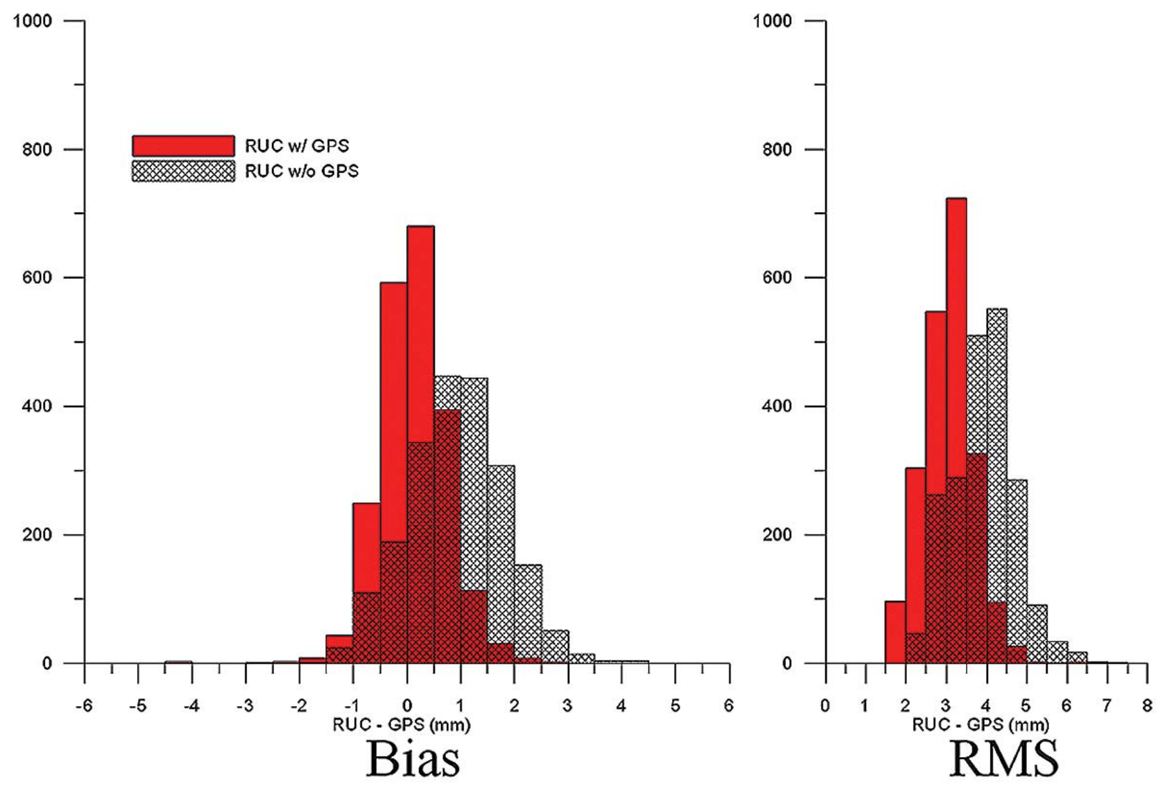


Figure 68. Comparison of 3-hour RUC20 model precipitable water forecasts with and without GPS IPW retrievals for the 90-day period from 25 July to 22 October 2003. Plotted data derived from same Web-based application mentioned in Figure 68. The vertical axis represents the number of comparisons.

between the GPS receivers and the NWS upper-air sites (<50 km), compared with those conducted at the ARM CART site (<10 km). Though the best way to minimize measurement error and uncertainty is to collocate the GPS and upper-air site, and use accurate surface meteorological sensors at the GPS site to retrieve PW from the tropospheric signal delay, we propose that this result (difference <2.5 mm) constitutes an upper limit on the expected difference between an operational rawinsonde moisture sounding and a GPS observation at synoptic times.

With this criterion, it was possible to evaluate an actual case that occurred on 1 November 2003, namely the launch of the 1200 UTC rawinsonde at Blacksburg, Virginia. Figure 69 shows a plot of PW differences between the RUC20 model analysis (with GPS) made at 1200 UTC and a 1-hour forecast valid at 1200 UTC, but made at 1100 UTC. The main features on this map are the large bull's eye in the vicinity of the NWS upper-air site at Blacksburg (RNK), and the smaller one in the vicinity of the Detroit/White Lake, Michigan, upper-air site (ILN). This plot highlights differences between the 1-hour predictions of PW (calculated by integrating RH at all levels in the model) and PW calculated using the analyzed moisture field that included RH measurements from the 1200 UTC radiosondes. As such, it represents the departure from expected PW caused by information available at 1200 UTC that was unavailable an hour earlier. In both cases, the color of the bull's eyes indicates that the forecast IPW was more than 9 mm drier than the analysis. The conclusions in this case are also applicable to ILN, located approximately 400 km northwest of RNK.

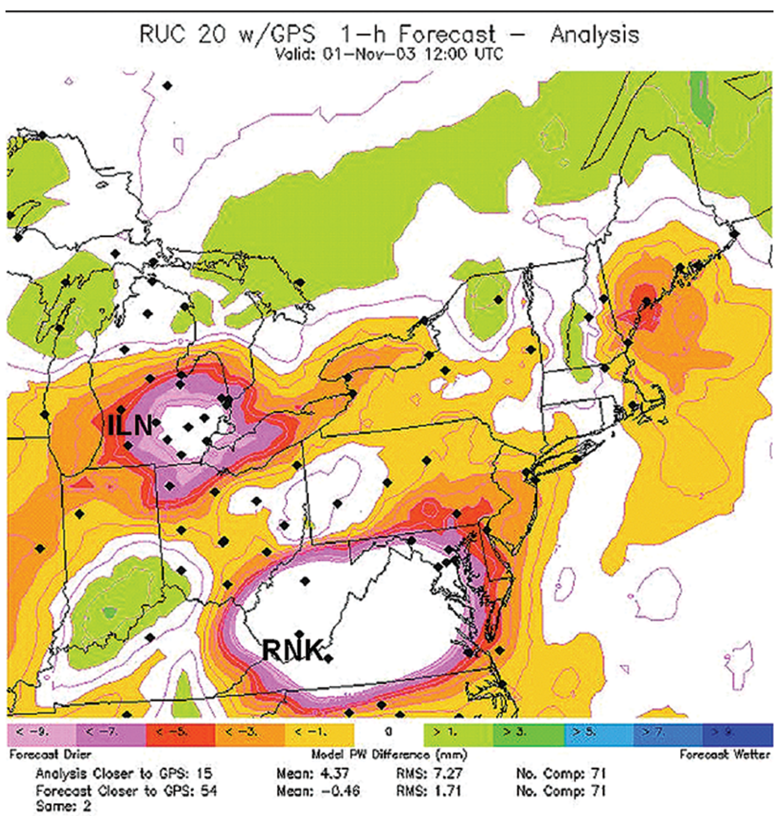


Figure 69. Precipitable water differences between the RUC 1-hour forecast valid at 1200 UTC (but made at 1100 UTC), and the PW analysis made at 1200 UTC 1 November 2003.

Figure 71 shows the impact of the 1 November 1200 UTC moisture sounding on the RUC20 model. GPS-IPW values are plotted in black, the 1-hour RUC prediction is plotted in blue, and the RUC analysis is plotted in red. PW calculated from the RNK rawinsondes are plotted as green diamonds. At 1200 UTC, the sonde provides a PW observation that is about 4 times higher than the value observed by the GPS or predicted by the model. Since rawinsonde moisture observations are highly weighted, the model honors this observation and the analysis spikes. An hour later, the 1-hour forecast includes the moisture information from the analyzed field, and it too spikes. Except for the GPS observations that are independent from the rawinsondes, no other information is available to validate the accuracy of the 1200 UTC sounding. The region of influence of this event encompasses almost all of Virginia and West Virginia, an area of approximately 174,000 square kilometers (67,000 square miles).

Finally, the impact of this event on subsequent precipitable water forecasts is illustrated in Figure 70a. The version of the RUC not assimilating GPS data (plotted in blue) spikes toward the sonde observation at 12 UTC and, in the absence of significant additional information, starts to descend (albeit slowly) toward the GPS IPW values of which it has no knowledge. Twelve hours later (0000 UTC on 2 November), another rawinsonde is launched at RNK and, once again, the magnitude of the moisture sounding exceeds the GPS observation, this time by about a factor of two. Following this, 3-hour precipitable water forecasts continue to decrease in magnitude. At 1200 UTC on 2 November, the rawinsonde PW measurement is in close agreement with the GPS observations, and the model without GPS closely tracks the GPS observations until 0000 UTC on 4 November, where it again encounters a moisture spike in the sounding and the cycle repeats itself.

It is instructive to compare the 3-hour forecast behavior of the RUC20 not assimilating GPS with the version that is doing so. One can see in Figure 70b that the forecast derived from the model assimilating GPS IPW spikes 3 hours after the 1200 UTC rawinsonde on 1 November and quickly returns to the level of the GPS observations. The same is true of the 0000 UTC events on 2 and 4 November. The tentative conclusion therefore is that the GPS observations made close to upper air facilities are capable of detecting questionable rawinsonde moisture soundings with high reliability and virtually no false alarm rate.

Projections

In 2004, we will concentrate on further expansion of the GPS-Met network. The emphasis will be on adding backbone sites to the network, and infill sites in the western United States.

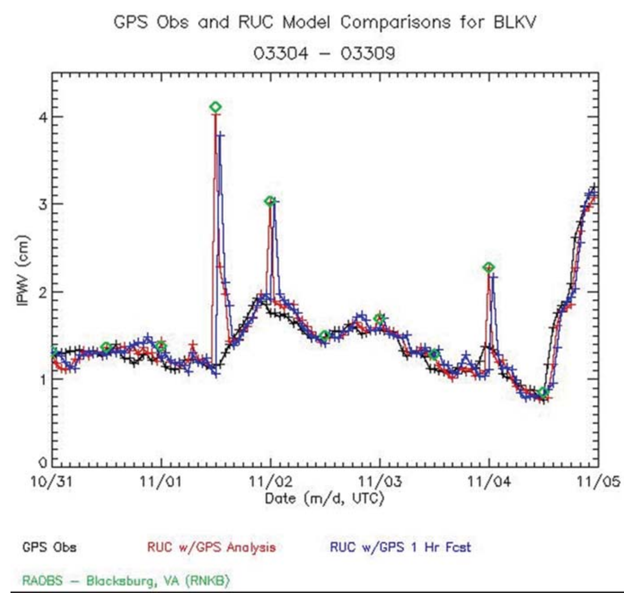
In collaboration with the Forecast Research Division (and hopefully with NCEP), research will continue on the assessment of GPS impact on weather forecasts, and incorporation of GPS water vapor observations into NOAA operational models.

Work on GPS-Met applications will continue, with a high priority given to understanding the events/causes of erroneously high rawinsonde moisture observations.

High priority will also be given to working with the NWS Storm Prediction Center to produce GPS precipitable water change maps to assist them in tracking the return flow of moisture off the Gulf of Mexico over a stable layer, and in trying to improve their forecasts of where severe elevated convection will form. Water vapor time change fields (1, 2, and 3 hours) are expected to give forecasters an idea of where moisture is converging, which will help them infer where the moist boundary layer is deepening with time and where the first storms are likely to form.

Another application of GPS-Met that has significant operational utility for NOAA is the use of GPS observations for global satellite calibration and validation. GPS provides a totally independent estimate of integrated moisture, and is a powerful constraint on the simultaneous retrieval of moisture and temperature from satellite radiances. To accomplish this, we will continue to work with NESDIS Office of Research and Applications on AIRS comparisons and with FSL/FRD on GOES sounder comparisons. In both cases, the goal is to try to make a significant contribution to NPOESS and GOES-R risk reduction activities.

Finally, the branch will collaborate with the Space Environment Center (SEC) in two areas of mutual interest. The first is development of an operational ground-based GPS observing system for space and tropospheric weather observations. The second is on the use of space and tropospheric weather models to improve lower-accuracy (10–100 cm) real-time GPS positioning and navigation accuracy.



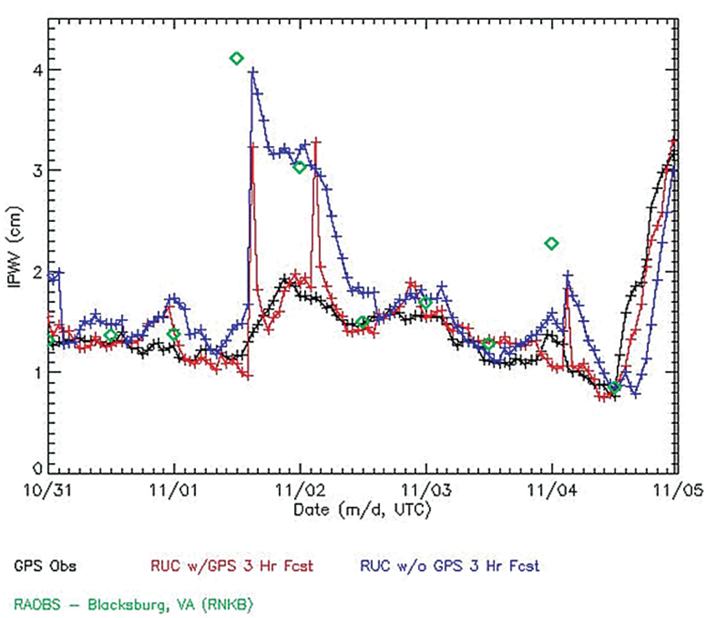


Figure 70. a, above) A precipitable water (PW) forecast time series created from the RUC version assimilating GPS. The analyses are plotted in red, 1-hour forecasts in blue, GPS observations in black, and PW from the Blacksburg, VA, (RNK) sondes as green diamonds;
b, left) A 3-hour PW forecast time series created from the RUC version assimilating GPS (red), and the version without GPS (blue). GPS observations are plotted in black, and PW from the RNK sondes as green diamonds.

Facilities and Systems Administration Branch

Bobby R. Kelley, Chief *(through March 2004)*

Objectives

The objectives of the Facilities and Systems Administration Branch are to manage and support the Demonstration Division communications and computer requirements. Duties involve systems operations, systems maintenance, systems administration, network administration, NOAA Profiler Network (NPN) telecommunications administration, and GPS-Met project support.

Accomplishments

Progress is underway toward decommissioning two micro-VAX clusters, running VMS 5.5, that have been used for processing and distributing NPN data for about 15 years. This work, to be completed late 2004, is part of a plan to modernize the NPN processing system (Figure 71) for more robust production, backup, and development environments. The backup environment is a mirror image of the production environment. Any component of the backup environment can be implemented in place of production components when needed, providing the ability to perform routine or urgent system maintenance. Also, real-time processing can be switched to the entire backup environment if and when necessary. The development environment comprises a separate set of equipment used for software development, modification, maintenance, and testing. The processing systems in each environment are off-the-shelf PC workstations or servers usually running Red Hat Linux, except for one workstation running Microsoft Windows XP Professional in each environment that handles interprocess communication. As a first step toward configuration management of the new processing system, baseline system configurations were established to ensure stability and reliability. Ongoing configuration management requires testing of system and application software installations, updates, and patches in the development environment before installing on the production and backup environments, and before creating a new system configuration baseline.

Figure 71. New NPN processing system construction in progress.

All Sun Microsystems equipment has been decommissioned, and as noted above, PC hardware is the platform of choice because it is capable of great performance at reasonable cost. This is true for both the NPN processing environments and the GPS-Met project.

Another implementation is new network hardware to replace hardware that was beyond end-of-life support. The new components allow connectivity to the new Gigabit Ethernet infrastructure that is now the backbone of the network at the David Skaggs Research Center. Network configuration and management were also improved with a browser-based user interface on the new hardware. These new components also enable low-cost expansion of the division network as needed.

Day-to-day work includes new component installations and system configuration on the division network, network problem isolation and maintenance, system configuration modifications to meet division requirements, system problem isolation and maintenance, in-house telecommunications maintenance or coordination of contracted maintenance, peripheral installation and configuration, computer and network security, preventive maintenance, information technology purchasing, and routine file system backups. After five years of service, all desktop workstations were replaced with new systems running Microsoft Windows XP Professional.

A primary focus of the Facilities Management and Systems Administration Branch is computer and network security responsibilities: ensuring system and data integrity and maintaining dependable NPN and GPS-Met data acquisition, processing, and distribution. Information Technology security requires constant vigilance by the branch staff and division investment in firewall hardware that has been implemented in the FSL network. Full-time (24/7) operations coverage is provided during normal workdays through the Boulder Profiler Control Center and via pager during nights, weekends, and federal holidays.

Data telecommunications responsibilities cover 38 NPN data circuits within the lower 48 states and in Alaska. These circuits are point-to-point landline connections provided by AT&T through a contract held by the Department of the Interior, Minerals Management Service. Investigation is ongoing to determine the viability and cost effectiveness of alternatives such as satellite-based Internet to provide future communications services. Satellite-based communications testing is ongoing at four geographically dispersed sites in order to determine the effects of varying meteorological conditions. The sites are Medicine Bow, Wyoming; Wood Lake, Minnesota; Haviland, Kansas; and DeQueen, Arkansas. Satellite-based Internet could provide excellent flexibility for adding new sites, providing greater bandwidth than existing landline circuits, and reducing communications costs by as much as 50%.

Projections

The branch will maintain current operations and ensure continuous and dependable acquisition, processing, and distribution of NPN and GPS-Met data to all customers. Work will continue on development and testing of the modernized NPN processing system, with initial parallel operations with the legacy processing system beginning in June 2004. IT security is a necessary and ongoing commitment. Alternative communications options will be evaluated for NPN and GPS-Met data acquisition and remote system control, with the goals of increasing bandwidth and reducing future communications costs.

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Objectives

The Systems Development Division performs exploratory development of advanced system concepts and technology for meteorological display systems, and works closely with other divisions in transferring these into operations. Past explorations have included investigation of new techniques for user interfaces, data display, system architectures, and software design and programming. The most recent exploratory work includes the use of Linux for meteorological workstation development, interactive 3D data visualization, and graphic tool development for remote collaboration. SDD develops operational prototype systems using these new techniques and technologies, and performs limited operational evaluation and testing of these systems. This division collaborates with other FSL groups to extend these prototype systems and to incorporate capabilities developed in other divisions to meet the operational needs of forecasters. Customers of these systems are domestic agencies such as the National Weather Service (NWS) and the U.S. Air Force (USAF), and international organizations such the Taiwan Central Weather Bureau (CWB) and the Korean Meteorological Administration (KMA).

Another focus is the development of scientific applications for these meteorological display systems. A key activity is the development of advanced analysis and quality control techniques for real-time observational data. The objective is to provide real-time observations, dependable quality control information, and the necessary tools to access and view the data. The Quality Control and Monitoring System (QCMS) provides users and suppliers of hydrometeorological observations with readily available quality control statistics. Two surface assimilation systems, the MAPS Surface Analysis System (MSAS) and the Rapid Update Cycle Surface Assimilation System (RSAS), provide direct measurements of surface conditions and give crucial indicators of potential for severe weather. In addition, the Meteorological Assimilation Data Ingest System (MADIS) provides quality-controlled observations and data access software to university and government data assimilation researchers.

FSL's continuing support to AWIPS includes an exploratory development project called FX-Collaborate (FXC) which provides interactive features such as drawing and annotation tools, a chatroom, and a capability for sharing local datasets between sites. FXC applications include weather forecast coordination between offices, classroom training, briefings from NWS to other government agencies, field experiment support, and research coordination.

The division comprises three branches and one group:

Advanced Systems Development Branch – Designs and develops interactive weather display systems for operational use and prototype systems for operational demonstration.

Scientific Applications Branch – Develops and implements scientific software systems designed to improve weather forecasting by taking advantage of opportunities offered by recent advances in meteorological observations and information systems.

System Evaluation and Support Branch – Provides software testing, configuration management, and support services to the division that include staging of major new systems and assisting project leaders with their data and display needs.

NWS Projects Group – Conducts research and develops technology for the exchange of critical weather information among the NWS offices and between the NWS and the community.

Advanced Systems Development Branch

Darien Davis, Chief

Objectives

The Advanced Systems Development Branch designs and develops software that enables weather forecasters to display and interpret meteorological data, and efficiently monitor and control the functions of ingest and display systems. State-of-the-art hardware and software technology is explored while also supporting operational National Weather Service (NWS) systems.

Accomplishments

FX-Advanced/AWIPS

During 2003, work continued, in cooperation with the NWS, on the D2D meteorological display and text components of the AWIPS Weather Forecast Office (WFO) system. AWIPS Operational Builds (OB) 1, 2, and 3 were all addressed, as follows.

AWIPS OB1 was installed at most NWS field offices in the spring of 2003. Key features developed by FSL include:

- Added polar orbiter (POES) soundings to the list of soundings available for display.
- Ingested a new product available from the WSR-88D radar to display high-resolution (8-bit) storm-relative motion (SRM) data. SRM is now computed from the 8-bit velocity, and the last motion is tracked using either the Distance Speed tool or WarnGen.
- Added fire weather product support to the WarnGen tool, including a fire weather danger statement, red flag watch/warning, and a new fire weather zones map.
- Enabled the LDAD function to process data from local profilers and rawinsondes.
- Created the ability to process MDCRS (automated aircraft reports), including availability plots, plan view plots, and ascent/descent soundings.
- Added a new meteogram feature that allows one to look at a collection of common surface weather parameters in a stacked time series form.

AWIPS OB2 was installed at most NWS field offices in the fall of 2003. Key features developed by FSL include:

- Added GOES high-density winds on the Satellite menu. Plots are stratified by reference dataset (e.g., WV, vis, 7 micron sounder) and by level (200 mb, 300 mb, etc.).
- Added a new high-resolution mesocylone graphic product available from WSR-88 radar, with updates after each tilt is processed.

AWIPS OB3 software was completed late 2003, and will be deployed by mid-2004. The main upgrades developed by FSL include:

- Replaced the dialout mechanism for AWIPS radar products with a request from neighboring sites on the AWIPS network.
- Added plots of winds from the QuikSCAT satellite to the observations (Obs) menu. These scatterometer winds appear over ocean areas.
- Added new Climate Prediction Center (CPC) temperature and precipitation anomaly forecast displays.
- Now provide support for new radar volume coverage patterns (VCPs).

Range Standardization and Automation (RSA) Program

As part of the Air Force Range Standardization and Automation (RSA) project, FSL is working with Lockheed Martin to provide an AWIPS-like weather workstation supporting space launch operations. During 2003, additional local datasets were added to the RSA OB1 system, especially products supporting lightning display and detection. The system integrated three types of lightning displays – a field mill instrument outputting electric voltage, a local lightning position analyser, and a lightning detection system. This system integrates a highly real-time dataset with a 3-D display of the lightning detection output. More than 30,000 points can be detected every minute, warranting a display within seconds of database population. It was a huge challenge to integrate this system into the AWIPS software, and it has been deployed and is being tested.

Linux Developments

FSL continues to develop low-cost meteorological workstation capabilities. A Unix PC workstation developed over 10 years ago is still being used (with moderate enhancements) by the Central Weather Bureau in Taiwan to support their daily forecast operations. NWS has fully embraced using Linux on low-cost computers as its next-generation AWIPS processors. FSL continues to support this transition by exploring architectural improvements to accommodate changes in technology and user requirements. Software was developed to assist in the transition of field systems from Hewlett-Packard workstations and servers to Linux PCs. New architecture concepts were explored, including the use of RAM disks and multicast technology for distributing data to workstations in order to make the system more responsive in servicing user requests.

Projections

FX-Advanced/AWIPS

Continuing support will be provided to the National Weather Service during the fielding of AWIPS Builds OB3 and OB4, and development and testing of OB5. Key development tasks will include implementing new VTEC warning support and ingesting TDWR (Terminal Doppler Weather Radar) data. System performance issues will continue to be addressed.

Linux

A full Linux-based WFO architecture for testing at the Boulder office will be implemented during 2004. Plans are to collaborate with all laboratories contributing to the AWIPS baseline architecture to demonstrate the enhanced performance gains from this hardware technology infusion.

RSA

Software based on AWIPS OB4 will be installed at the Ranges, and the Advanced Systems Development Branch will assist Lockheed Martin with installation and testing. Development of additional functionality (archiving, additional data displays) will continue, and user training and documentation will be provided.

Scientific Applications Branch

Patricia A. Miller, Chief

Objectives

The Scientific Applications Branch was established to develop and implement scientific software systems designed to improve weather forecasting by taking advantage of opportunities offered by recent advances in meteorological observations and information systems. Support is provided for the AWIPS Mesoscale Analysis and Prediction System (MAPS) Surface Assimilation System (MSAS), the NCEP Rapid Update Cycle (RUC) Surface Assimilation System (RSAS), and FSL's Meteorological Assimilation Data Ingest System (MADIS).

MSAS and RSAS

The MSAS and RSAS exploit the resolution of surface data by providing timely and detailed gridded fields, or analyses, of current surface data. Surface analyses are critical to weather forecasting because they provide direct measurements of surface conditions, permit inference of conditions aloft, and often give crucial indicators of the potential for severe weather. MSAS runs operationally at modernized NWS Weather Forecast Offices (WFOs) as part of the AWIPS workstation. RSAS runs operationally at NCEP.

As surface analysis-only systems, MSAS and RSAS have the advantages of speed and closer fit to the observations. The systems produce one-level, analysis-only grids and therefore require very few compute resources. Also, because the systems do not initialize a forecast model, their analysis is performed on the actual surface terrain and not along a model topography. Hence, no model surface-to-station elevation extrapolations are required, all surface observations may be used, and the fit to the observations is maximized. In addition, MSAS and RSAS incorporate elevation and potential temperature differences in the correlation functions used to model the spatial correlation of the surface observations, which help to take into account physical blocking by mountainous terrain, and improve the representation of surface gradients.

Stations typically ingested by MSAS and RSAS include Meteorological Aviation Reports (METARs), Surface Aviation Observations (SAOs), Coastal Marine Automated Network (C-MAN) observations, surface reports from fixed and drifting buoys, ships, and the NOAA Profiler and Ground-based GPS Networks, as well as surface observations from available local mesonets. Sophisticated quality control techniques are employed to help screen the surface observations. On AWIPS, the results of these techniques are passed to the AWIPS Quality Control and Monitoring System (QCMS).

MADIS

MADIS was established at FSL for the purpose of supporting meteorological research and operations by sharing observations and observation-handling technology with the greater meteorological community. Observations are essential to all areas of weather analysis and prediction. When viewed by trained forecasters, for example, they provide a direct indication of the current atmospheric conditions and enable the forecasters to detect and follow weather disturbances and to interpret critical detail about the formation and movement of major meteorological phenomena such as precipitation, severe storms, and flight-level turbulence. Observations also form the "initial" conditions for data assimilation systems which produce the objective, numerical weather prediction outputs heavily used in all areas of weather forecasting. Outside the world's major meteorological centers, however, access to these observations has not always been readily available.

To fill this need, MADIS was established to make value-added data available from FSL's Central Facility with the goal of improving weather forecasting, by providing support for data assimilation, numerical weather prediction, and other meteorological applications and uses.

Observations in the database are stored with a series of flags indicating the quality of the observation from a variety of perspectives (e.g., temporal consistency and spatial consistency), or more precisely, a series of flags indicating the results of various quality control (QC) checks. Users of MADIS can then inspect the flags and decide whether or not to ingest the observation.

MADIS also includes an Application Program Interface (API) that provides users with easy access to the observational information. The API allows each user to specify station and observation types, as well as QC choices and domain and time boundaries. Many of the implementation details that arise in data ingest programs are automatically performed. Users of the MADIS API, for example, can choose to have their wind data automatically rotated to a specified grid projection and/or choose to have mandatory and significant levels from radiosonde data interleaved, sorted by descending pressure, and corrected for hydrostatic consistency.

Accomplishments

MSAS and RSAS

Staff in the Scientific Applications Branch released several versions of MSAS and RSAS in 2003 to support the operational requirements of the NWS at NCEP and on AWIPS. The most significant accomplishments last year, however, were the configuration and implementation of an MSAS version for the Korean Meteorological Administration (KMA) Forecaster’s Analysis System (FAS), and the continued development of the QCMS Browser, a new AWIPS software package for the display of observation quality control results produced by MSAS for the AWIPS QCMS.

Based on FSL's WFO-Advanced meteorological workstation, the KMA FAS is integral to meteorological modernization efforts in Korea. In 2002, the FAS became operational at KMA and was also deployed at six Regional Offices. In 2003, the branch collaborated with KMA to complete porting of the MSAS quality control and analysis capabilities to a Korean domain and to the FAS system. Extensive software documentation was also generated and provided to KMA personnel. MSAS is now running operationally on the KMA FAS, ingesting, quality controlling, and analyzing Korean surface observations. Figure 72 shows a 15-km MSAS wind analysis over Korea produced by the KMA MSAS system.

In 2003, staff also worked closely with NWS personnel on the continued design and testing of a user interface and display component for the AWIPS QCMS. The QCMS has been running at WFOs as part of the AWIPS workstation, since 1999, to provide forecasters and suppliers of hydrometeorological observations with quality control information and statistics. Two types of automated QC checks are utilized: static checks, which are single-station and single-time checks such as validity checks; and dynamic checks that take advantage of other hydrometeorological information, such as temporal and spatial consistency checks. The QCMS also provides the capability for users to override the results of the automated checks through subjective intervention procedures, and keeps hourly, daily, weekly, and monthly statistics on the frequency and magnitude of the observational errors encountered for all surface stations ingested into AWIPS.

The newly designed user QCMS interface, called the QCMS Browser, is an essential part of the D2D (Display Two-Dimensional) component of AWIPS, and will enhance QCMS capabilities by implementing an interactive text and graphics display system to improve quality control visualization and subjective intervention. Users of the QCMS Browser can select all or portions of the AWIPS quality control information provided by MSAS and display the information on D2D as a plan view and/or time series plot, or also see the same information in tabular form on the user interface. Overall, the Browser allows NWS personnel easy access to the QCMS information for 1) monitoring station performance, 2) locating persistent biases or failures in surface observations, 3) evaluating observation/QC accuracy, and 4) subjectively overriding QC values. The branch also continued to work with the NWS to develop the AWIPS QCMS Browser, and also organized and conducted a two-day NWS QCMS Browser training course attended by representatives from five NWS regions. Initial versions of the Browser were also installed at several WFOs for evaluation purposes. Figure 73 shows QCMS Browser-produced AWIPS displays detailing the detection and correction of a persistent bias in the sea-level pressure observations reported by a METAR station in Ypsilanti, Michigan. The quality control statistics gathered before the correction indicated that the Ypsilanti sea-level pressure observations failed the quality control checks 100% of the time, and exhibited persistent root mean square (RMS) and mean errors of approximately 2.1 mb. After the observations were corrected, both the errors and the percentage failure fell to zero.

MADIS

MADIS now supports observation distributions to many government, research, education institutions, and private companies. Organizations already receiving MADIS datafeeds include NWS forecast offices, NCEP, the National Center for Atmospheric Research (NCAR), the National Ocean Service (NOS), NASA's Marshall and Kennedy Space Flight Centers, the Massachusetts Institute of Technology Lincoln Laboratory, and universities, meteorological companies, and local government agencies. All MADIS subscribers have access to a reliable and easy-to-use database containing real-time and archived datasets available via either ftp or by using Unidata's LDM software.

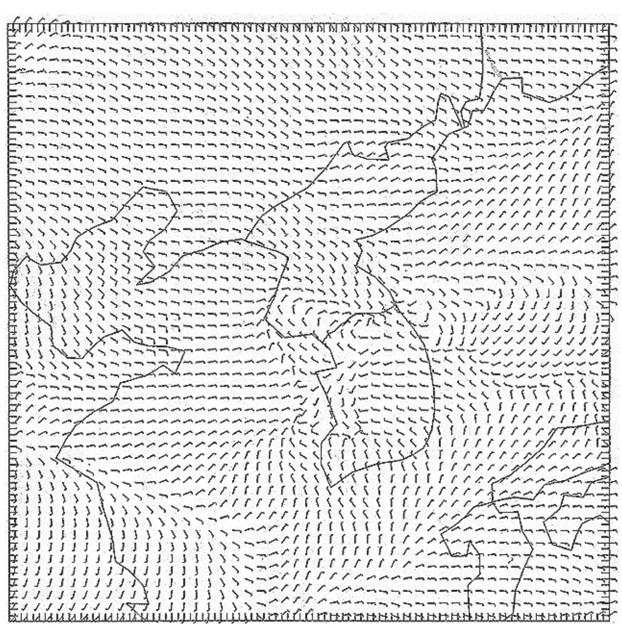
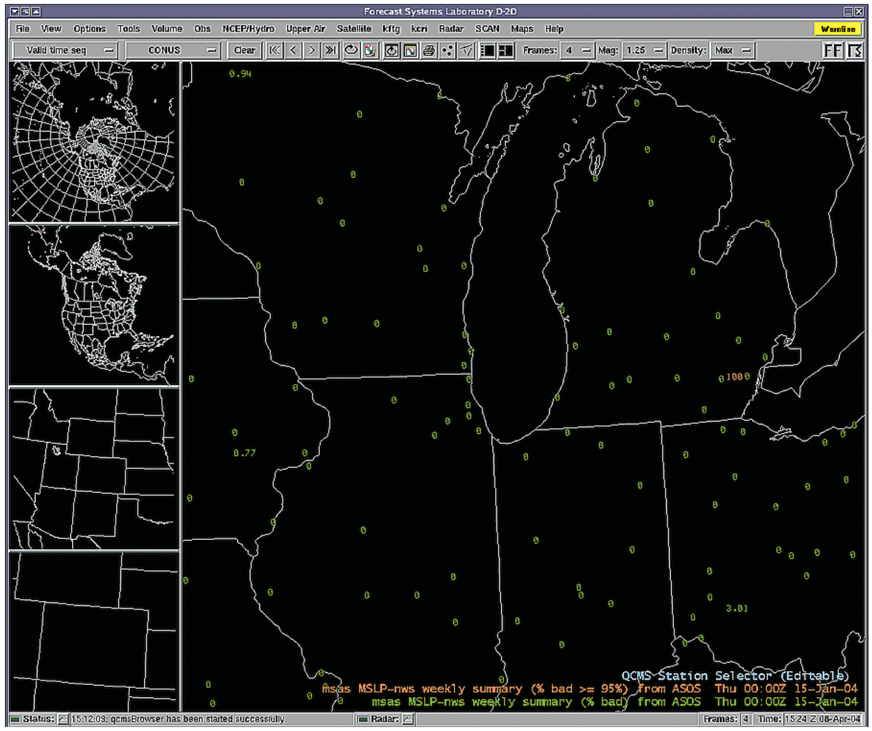


Figure 72. A 15-km MSAS wind analysis over Korea.



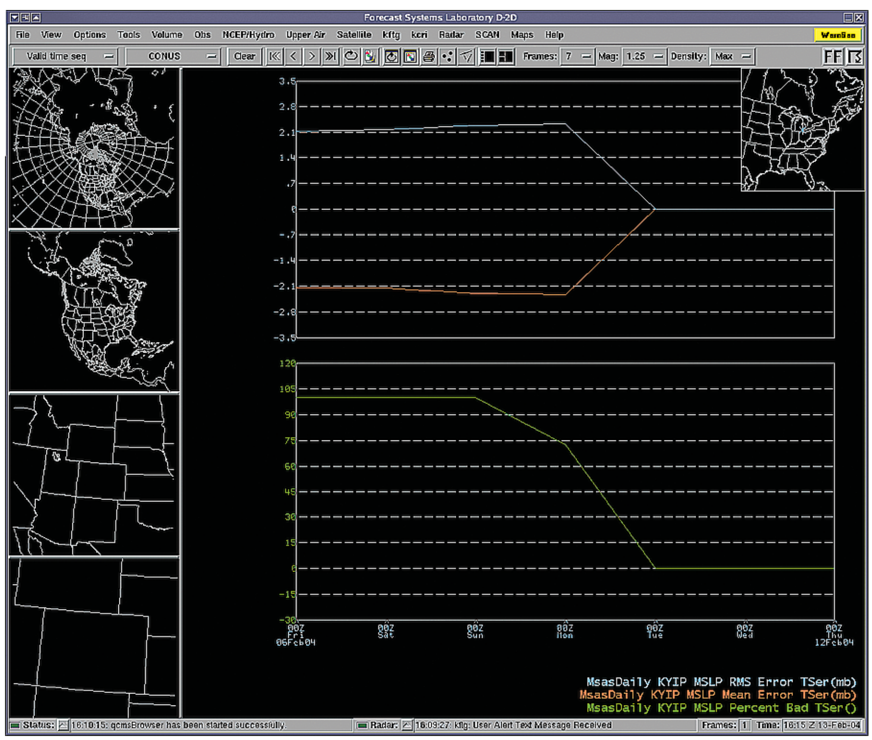


Figure 73. QCMS Browser-produced AWIPS displays detailing the detection and correction of a persistent bias in the sea-level pressure observations reported by a METAR station in Ypsilanti, MI. a) top, Plan view display of the weekly percentage of QC failures indicating a 100% failure for the Ypsilanti, Michigan, sea-level observations before NWS personnel were alerted to the problem. Percentage failures above 95% are highlighted in red. b) below, Time series display of the daily RMS (blue) and mean (red) errors for the observations, and the percentage failure (green) over the days both before and after NWS personnel corrected the problem. The QC information before the correction indicated a persistent RMS and mean errors of approximately 2.1 mb and a continuous failure rate near 100%. After the observations were corrected, both the errors and the percentage failure fell to zero.

In 2003, access to the MADIS database through the Web-based Open Source project for Network Data Access Protocol (OPeNDAP) was added as a distribution mechanism, and the MADIS API was upgraded to include OPeNDAP capabilities. In addition, satellite wind and radiometer datasets were added to the MADIS database. The satellite wind dataset is composed of multiple wind products from different satellites that are integrated into a single dataset at FSL. Currently these products consist of data from the GOES satellites, and include 3-hour winds that are produced on an operational basis by NESDIS, as well as rapid scan experimental winds that are produced hourly. The radiometer dataset contains observations from ground-based, microwave radiometers that report profiles of atmospheric temperature, water vapor, and cloud liquid up to 10 km in height. Radiometer data are currently supplied by the Department of Energy (DOE) Atmospheric Radiation Measurement Program (ARM) and Radiometrics, Inc. In addition to the new datasets, over 6,300 new stations were added to the existing MADIS mesonet dataset, a unique collection of surface stations provided by local, state, and federal agencies and private firms. Major contributors to the mesonet dataset are the NOAA Cooperative Institute for Regional Prediction (CIRP) at the University of Utah, which provides "MesoWest" data from the Cooperative Agency Profiler (CAP) mesonets in the western United States, the Boulder NWS Forecast Office, which provides mesonet data from the local Denver/Boulder area, and also data from the Remote Automated Weather System (RAWS) network run by the National Interagency Fire Center (NIFC), and volunteer citizen weather observers who report observations from commercially available weather stations through the Amateur Radio Operators Automated Position Reporting System (APRS). New data providers in 2003 included the Colorado Department of Transportation, the Iowa Environmental Mesonet, the Oklahoma Mesonet, and AWS Convergence Technologies, Inc. Also included in the dataset are real-time observations from the NWS Cooperative Observer Program (COOP) network, currently undergoing modernization efforts. Modernization efforts in 2002 and 2003 included automating the collection and dissemination of temperature observations from over 100 stations in the New England area using MADIS ingest, integration, quality control, and distribution capabilities.

With all of the new observations added in 2003, MADIS now supports standard maritime and land surface observations, such as METARs, SAOs, C-MAN, ship, and buoy observations, as well as mesonet observations from over 13,000 surface stations. Upper-air observations supported by MADIS include satellite winds, radiosonde and radiometer observations, automated aircraft reports, wind profiler data from the NOAA Profiler Network (NPN), and multiagency profiler data contributed by a number of different organizations such as the Environmental Protection Agency (EPA), NOAA research laboratories, and several major universities. The latter dataset is supported by MADIS as a joint effort with the Cooperating Agency Profiler (CAP) project in FSL's Demonstration Division, and consists largely of data from 915-MHz boundary layer profilers.

MADIS data files are compatible with AWIPS, with the FX-NET workstations developed by FSL's Technology Outreach Division, and with the analysis software provided by the FSL Forecast Research Division's Local Analysis and Prediction System (LAPS). In 2003, SAB personnel also completed a MADIS software interface for the data ingest system of the community-developed Weather Research and Forecasting (WRF) Model 3D-Variational (3DVAR) Data Assimilation System. By downloading and installing the MADIS WRF 3DVAR interface, users of the WRF 3DVAR packages can now ingest MADIS observations supplied by FSL directly into the 3DVAR analysis.

The FSL MADIS database and API are freely available to interested parties in the meteorological community. For more information on MADIS, or to apply for a real-time MADIS datafeed, or access to the MADIS on-line archive (which supports observations from 1 July 2001 to the present), see *http://www-sdd.fsl.noaa.gov/MADIS*. Also available to NWS WFOs are instructions on how to ingest and display MADIS datasets on their AWIPS systems. Figure 74 shows the MADIS observations available for a 1-hour period over the Great Lakes region.

Projections

Staff will continue to support NWS staff in the operational implementation of the MSAS and RSAS systems. Development of new capabilities, including the implementation of the QCMS Browser on AWIPS, will also be supported. Scientific Application Branch members will also continue to add observations and capabilities to MADIS. Emphasis will be on increasing the number of observations in the mesonet database, working with the FSL Demonstration Division to continue support for multiagency profiler data, and continued support to the NWS in their COOP modernization efforts. Access to MADIS will continue to be provided through the Web interface which provides the forms necessary to request real-time and archived data, and also allows users to download the MADIS API, a "README" installation guide, documentation, and sample programs and data.

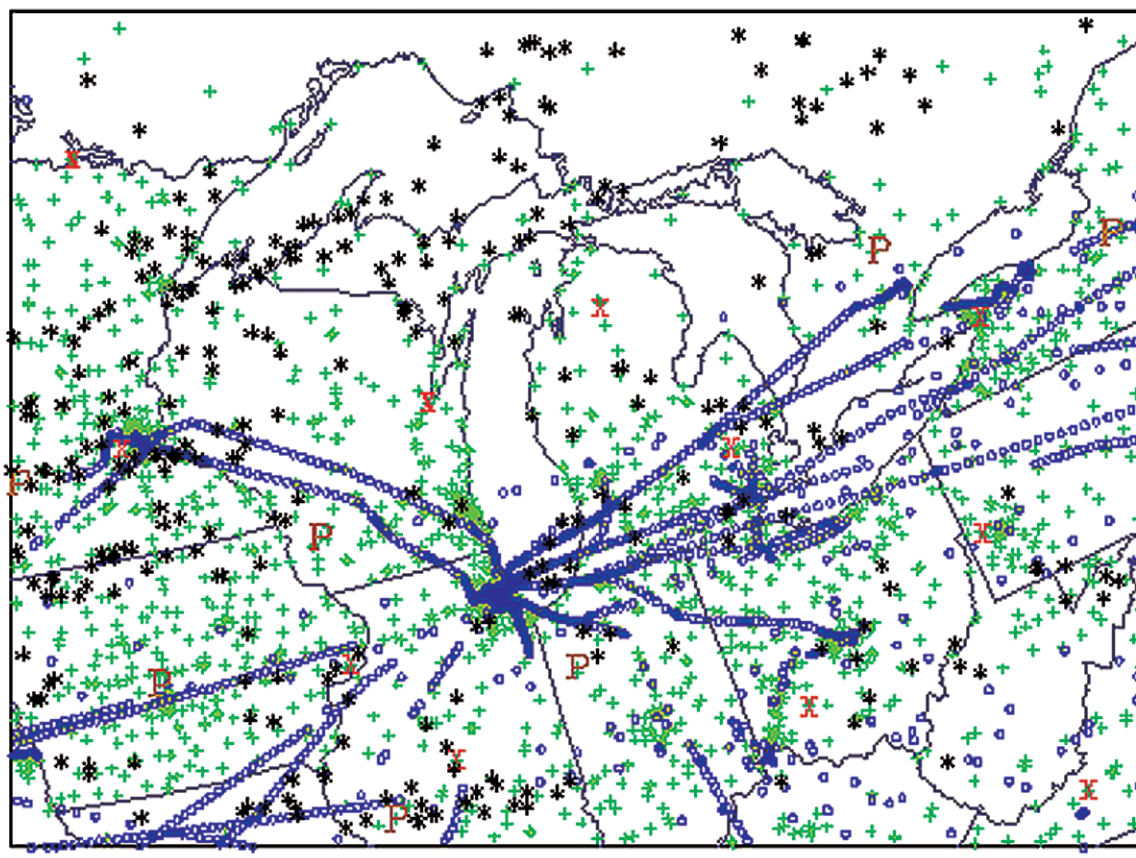


Figure 74. MADIS observations available in the Great Lakes region.

System Evaluation and Support Branch

Joseph S. Wakefield, Chief

Objectives

The System Evaluation and Support Branch provides testing, configuration management, and support services for the Systems Development Division.

Accomplishments

During 2003, development versions of AWIPS Builds Operational Build (OB) 1, OB2, and OB3 were installed on FSL test systems. The development cycle for each Build includes receipt of requirements from the National Weather Service (NWS), preparation and review of a design approach (including user interface issues, when appropriate) for each requirement, development of the software and test plans, testing, refinement of the software, and system and user documentation of the capabilities. Branch staff continue to participate in the design/UI review and documentation tasks, and are responsible for developing and executing test plans. The AWIPS test plans are also used at NWS and Northrop Grumman Information Technology (NGIT), the AWIPS prime contractor.

Numerous iterations of each version were tested, at several-week intervals, as development proceeded. In each case, two types of systems were tested – one like the current NWS field installation, on mostly Hewlett Packard equipment, and one on an all-Linux set of machines, representing the expected future AWIPS field architecture. FSL also maintains a field-release system, connected to the NWS AWIPS network, on which is installed an official copy of the AWIPS software. This is used to verify documentation, investigate problems reported by users, and test patches.

A staff member continues to serve as FSL's liaison to NGIT/NWS, and performs duties such as tracking problems discovered during AWIPS testing, maintaining our local software development environment, and keeping file versions synchronized between FSL and NGIT/NWS software repositories.

Similar support activities were carried out in 2003 for the Range Standardization and Automation (RSA) program and a customized AWIPS setup for the Johnson Spaceflight Center. Figure 75 shows the RSA 3D lightning application.

As in past years, a branch member designed the layout of FSL's exhibit space at the 2003 American Meteorological Society's annual meeting. In addition to coordinating the collection, shipping, and setup of all FSL equipment and furnishings, this included working with AMS and the Long Beach Convention Center staff to ensure that power and data communication requirements were met.

Other tasks carried out during the past year concern systems administration functions, such as overseeing hardware installations and maintaining and updating the utility and operating system software on computers used by the Systems Development and Modernization Divisions. Some user machines in these two divisions (principally, those supporting the RSA project) were upgraded to Red Hat Linux v7.3, while most stayed at RH 7.2, which is the version used at NWS field offices. Our Systems Administration staff applied security patches and other upgrades as necessary to allow development work to continue at high efficiency. We also maintain the configuration files for our data ingest machines in order to deliver appropriate data to our test systems, as well as to occasionally assist other FSL divisions by providing temporary data feeds for special projects, testing, etc.

Projections

During 2004, new software repositories will be created for AWIPS Operational Builds 4 and 5 (OB4 and OB5) development. Branch staff will support the development, testing, and documentation of these Builds as described above, with OB3 testing and predeployment support occupying the first half of the year, and OB4 testing expected to commence in early summer. As new tasks are also completed for the RSA and JSC systems, test plans and testing will continue in support of those projects, as well. NWS is moving more and more functions off of the aging Hewlett Packard systems. By early 2004, all HP forecaster workstations are expected to be replaced by newer-generation IBM workstations running Linux. We will mirror this trend at FSL, and continue to upgrade the software as new AWIPS releases are made available by NWS.

A customized system will be delivered to the Johnson Space Center (JSC), and installation support and some training will be provided for JSC staff to help them integrate the system into their standard AWIPS network. Installation and integration support will also be provided to the RSA project following delivery of upgraded software and documentation for use at the Eastern and Western Ranges.

We will once again coordinate FSL exhibits for the 2004 American Meteorological Society Annual Meeting. The scope of this work will be smaller in 2004, since FSL will occupy only a portion of a consolidated NOAA display rather than having its own space.

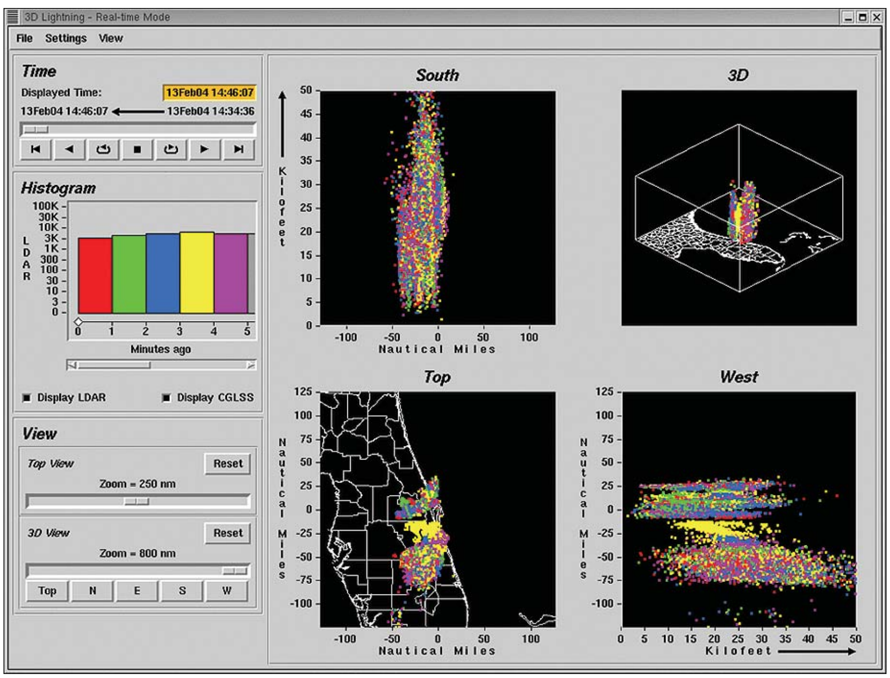


Figure 75. RSA 3D lightning application. The left side shows mostly controls, but the olored bars show the count of lightning events in each minute. To the right are four views of the space over southern Florida. At upper left is a view from the south; at lower left, from the top; and at lower right,from the west. At upper right is a 3D view of the data, which can be examined in detail by zooming in and changing the point of view, i.e., "flying" around or through the volume.

NWS Projects Group

Richard T. Jesuroga, Lead

Objectives

The NWS Projects Group conducts research and develops technology for the exchange of critical weather information among the National Weather Service (NWS) offices, and between NWS and the community. Evolving technologies are explored for disseminating critical weather information to the emergency management community and the public.

The current focus is on two new types of weather dissemination systems: FX-Collaborate (FXC) and reverse 911 technology. The FXC application (Figure 76) supports shared awareness of critical weather situations among numerous remote users. As an interactive meteorological display system, FXC provides users access to a variety of meteorological data stored in remote AWIPS databases on Web servers, and on local disks. Its strength is its ability to interlink a number of remote systems to conduct real-time weather briefings, live meteorological discussions, or long distance learning through its collaborative capabilities. Another area of exploratory research involves dissemination of life threatening warnings via reverse 911 phone calls from WFO forecasters. This technology is rapidly evolving in the U.S., and may provide a rapid means of disseminating information on severe life threatening weather events.

Accomplishments

FXC – The Texas Department of Public Safety and the NWS Southern Region Headquarters have chosen FXC as their weather display and coordination tool to help improve communication with the NWS during severe weather situations. Redundant FXC servers have been installed at NWS Southern Region Headquarters which will provide weather information to FXC client systems at Denton, Texas, and other yet to be designated Texas emergency management offices. A temporary server had been set up at FSL to test various aspects of network security and to allow system preparation and testing. The test system was very useful in resolving firewall issues and properly configuring the FXC menu and displays for the Texas application.

An increasing number of NWS offices are also using FXC to meet their graphical annotation requirements. Of particular interest is FXC's ability to access real-time data on the AWIPS database, annotate the meteorological display, and then create JPEG images. The Norman, Oklahoma, office and others have used this capability very effectively to generate Web displays during severe weather situations.

Several significant changes were made to the FXC system architecture during 2003 to improve network communications. A major change was the introduction of a message repeater to distribute network loading based on the network topology. The concept of message repeaters is deemed particularly useful for network architectures, such as the AWIPS WAN, with several communications hubs across the country.

Reverse 911 Dissemination – The NWS has increased its tornado warning lead time from 7 to 14 minutes (warning lead times of up to 26 minutes have been achieved during tornado outbreaks in the Midwest). As warning areas and lead times improve, a newly targeted call-for-action warning using reverse 911 telephone technology may help save lives in the future. We have conducted various proof-of-concept experiments to determine how targeted warnings and reverse 911 technology can be used in future AWIPS software releases. These experiments centered around the basic concept that specific residences and businesses that are in the direct path of a life threatening weather event, such as a tornado or flash-flood, could be targeted by a forecaster for a reverse 911 call-to-action message.

The message would contain information on what actions should be taken to avoid injury or death due to a tornado or flash flood. The premise driving our experiments was that these targeted warnings, generated on AWIPS would be disseminated to a reverse 911 commercial provider. During our experiments, a forecaster would draw a targeted warning area (an area much smaller than that of a typical severe thunderstorm warning) on their workstation that identified the specific addresses located in the path of a tornado. A list of telephone numbers corresponding to the addresses within the targeted warning were derived and a test verbal message was sent out. The test message was sent to a few phone numbers preselected to participate in the test that fell within the warning area.

Projections

Various activities will be undertaken to validate the utility of using the FX-Collaborate workstation as a means to coordinate federal, state, and local government awareness and response to severe weather outbreaks during late 2004. FXC client workstations will be installed in four Texas Department of Public Safety emergency management offices and will be connected to an FXC server located at NWS Southern Region Headquarters. During a hurricane or severe weather event, emergency managers using the FXC client workstations will participate in live weather briefings hosted by forecasters at Southern Region Headquarters, and perhaps another NWS WFO near the severe weather outbreak. Additionally, three WFOs within the NWS Southern and Central Regions will be selected to participate in a pilot project to disseminate severe "Life Threat" warnings via reverse 911 telephone technology. Forecasters at these selected offices will be trained in the issuance of severe Life Threat warnings using reverse 911. The pilot project will be used to demonstrate the utility of using reverse 911 calling systems to disseminate critical warning information to the public.

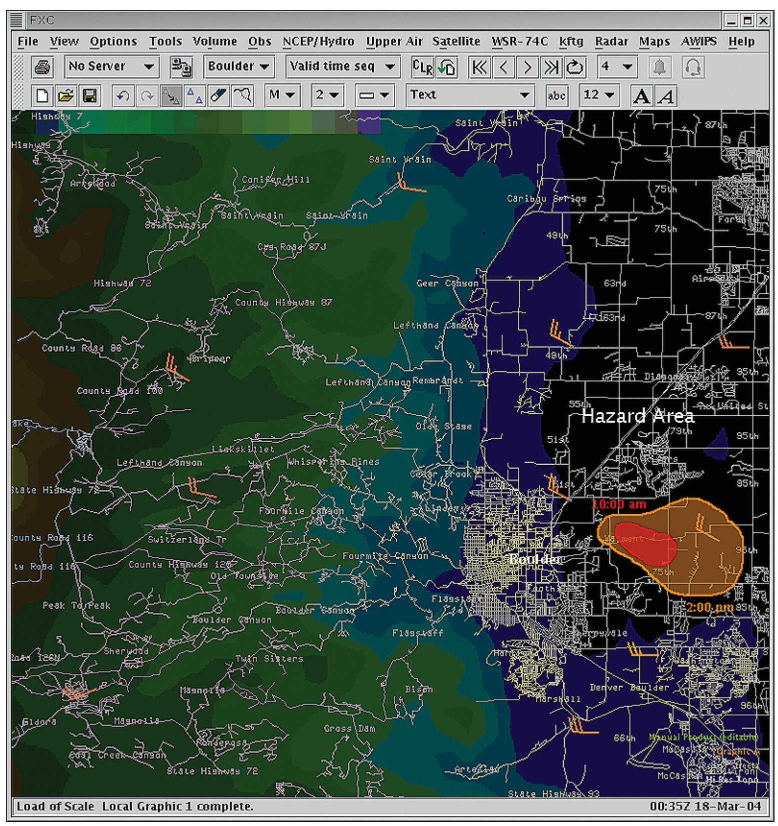


Figure 76.A display of the FXC workstation showing the Boulder area with a hand-drawn Hazard Area at far right. The hazard area demonstrates how users can identify a specific "call for action" warning to the public. FXC can send these warning areas to private sector 911 call-back providers.

Aviation Division

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Objectives

The Aviation Division collaborates with the Federal Aviation Administration (FAA), the National Weather Service (NWS), and the Department of Transportation. The product of these collaborations is an improved weather forecasting and visualization capability for use by forecasters, air traffic controllers, air traffic managers, airline dispatchers, and general aviation pilots. More opportunities to develop better weather products now exist because of new observing systems, recent advances in understanding the atmosphere, and higher performance computing capabilities.

The division comprises four branches:

Aviation Requirements and Applications Branch – Defines requirements for generating and disseminating aviation weather products; develops the capability to assess the quality of products generated automatically and by aviation weather forecasters, and the "guidance" forecasters use to generate those products.

Aviation Systems: Development and Deployment Branch – Manages enhancement, testing, fielding, and supporting of advanced meteorological workstations for the NWS Aviation Weather Center (AWC) and Center Weather Service Units (CWSUs); develops Traffic Management and Volcanic Ash Coordination products for use by the aviation community.

Advanced Computing Branch – Assures the continuing improvement of high-resolution numerical weather analysis and prediction systems through research and development in high-performance computing.

Forecast Verification Branch – Develops verification techniques, mainly focusing on aviation weather forecasts, and tools that allow forecasters, researchers, developers, and program leaders to generate and display statistical information in near real time using the Real-Time Verification System (RTVS).

In addition to its own activities, the Aviation Division provides funding for other FSL divisions to assist in achieving these goals.

Aviation Requirements and Applications Branch

Lynn A. Sherretz, Chief

Objectives

The Aviation Requirements and Applications Branch develops requirements for advanced products and software tools for the aviation community. Software tools include flight planning tools for pilots, air traffic controllers and managers, and airline dispatchers, and product generation and grid interaction tools for aviation weather forecasters.

The branch serves as the focal point for coordinating activities with the FAA Aviation Weather Research Program (AWRP) and the National Weather Service (NWS) Aviation Services Branch, funding organizations for the development efforts. Another key function is leading the AWRP Product Development Team for Aviation Forecasts.

Flight Planning Tools

In collaboration with the National Center for Atmospheric Research (NCAR) and the NWS Aviation Weather Center (AWC), we continue to develop the Aviation Digital Data Service (ADDS). Aviation decision-makers use this Internet-based system to access text, graphics, grids, and images of up-to-the-minute weather observations and forecasts tailored to specific flight routes. The operational ADDS is available at *http://adds.aviationweather.noaa.gov* (Figure 77). The experimental ADDS includes advanced forecasts undergoing final testing/evaluation, and is available at *http://weather.aero*.

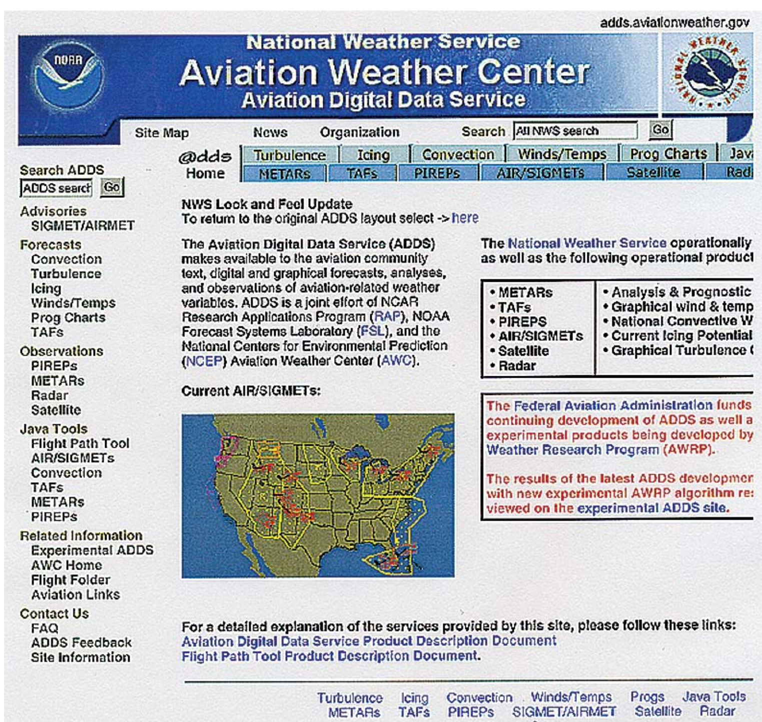

Figure 77. Screen showing the operational ADDS, available at http://adds.aviationweather.noaa.gov.

Product Generation and Grid Interaction Tools

The branch serves as a focal point in developing and evaluating the utility of advanced weather display products for the FAA Traffic Management Units (TMUs), tasked with management of air traffic in enroute and terminal environments. This effort includes creating and testing software that enables forecasters at any of the NWS Center Weather Service Units (CWSUs) to view identical data and collaborate in real time to generate products for TMUs.

We are also working with NWS Aviation Services Branch, National Centers for Environmental Prediction (NCEP), and Meteorological Development Laboratory (MDL) to develop and test concepts for a National Digital Forecast Database (NDFD) for aviation use. The aviation version will be patterned after the NDFD for public forecasts, which has recently been implemented at the NWS Weather Forecast Offices. A particular challenge in developing the NDFD for aviation is including the vertical dimension, not included in the NDFD version for public forecasts.

Volcanic Ash Coordination Tool

Responding to the need for better coordination among operational organizations that forecast volcanic ash, the branch coordinates development of the Volcanic Ash Coordination Tool (VACT). This technology will enable forecasters to simultaneously view identical displays of meteorological information and collaborate in real time to generate consistent time-critical advisories and forecasts for ash. Figure 78 shows active volcanoes in the Alaska Peninsula and Aleutian Islands.

Figure 78. Active volcanoes in the Alaska Peninsula and Aleutian Islands. (Courtesy Alaska Volcano Observatory.)

Accomplishments

Flight Planning Tools

During 2003, we worked with NCAR to implement ADDS operationally at the NWS Aviation Weather Center (AWC). Results of a user assessment survey at the AWC prior to operational implementation of ADDS showed that, of the 1,100 comments received, 66% were judged as very good, 33% as good, and only 1% as not so good.

Product Generation Tools and Grid Interaction Tools

The branch continued developing and testing a prototype graphical convective forecast, the Tactical Convective Hazard Product (TCHP), for FAA traffic managers. This product combines into a single graphic key attributes of 1) Convective SIGMETs, which are generated each hour by forecasters at NWS AWC, and 2) the National Convective Weather Forecast (NCWF), an automated product generated every 5 minutes, and is based on NEXRAD and lightning observations. Additional information on TCHP is provided in the Development and Deployment Branch section.

Additional tasks included working with NCEP to develop the capability to generate text messages from graphical aviation forecasts which AWC forecasters will generate on their operational National AWIPS (NAWIPS) workstations, beginning in early 2006. A capability will be developed to enable WFO forecasters to generate more accurate forecasts for ceiling and visibility via AWIPS. We will also explore concepts that will enable the Graphical Forecast Editor (GFESuite), currently implemented at Weather Forecast Offices, to support the generation of the aviation National Digital Forecast Database along with NAWIPS.

Volcanic Ash Coordination Tool

A major focus of FSL is to work with other agencies to help create technology to improve forecasts related to volcanic ash, which is a severe hazard to aviation because it causes engines and critical instruments to fail. In collaboration with representatives from the Anchorage Air Route Traffic Control Center (ARTCC), Anchorage Volcanic Ash Advisory Center (VAAC), and Alaska Volcano Observatory (AVO), we developed requirements for VACT. The initial version and an enhanced version of VACT were implemented in 2003. More details about these versions are also in the Development and Deployment (DAD) Branch section.

Projections

Flight Planning Tools

The primary focus during 2004 is to collaborate with NCAR to develop an "application" version of the ADDS Flight Path Tool. Based on the latest version of Java, this new version will provide faster starting, common look and feel across platforms, many new capabilities such as printing and saving preferred configurations, and provide an environment to build custom graphics for specific flight routes.

Product Generation Tools

The utility of an enhanced version of the Tactical Convective Hazard Product will be assessed, and further efforts will be undertaken commensurate to the results of the survey.

We plan to develop software to display prototype inflight icing products for FAA traffic managers. The initial product will be an automated Current Icing Potential (CIP) and Forecast Icing Potential (FIP) that complements conventional AIRMETs and SIGMETs for icing.

The branch will continue working with NCEP to develop the capability for NAWIPS to support the generation of graphical forecasts for aviation, and enable the Graphical Forecast Editor and NAWIPS to generate the aviation National Digital Forecast Database. Collaboration will continue with the Meteorological Development Laboratory to incorporate a capability into the AWIPS Aviation Forecast Preparation System that will help WFO forecasters to generate more accurate forecasts of ceiling and visibility.

Volcanic Ash Coordination Tool

During 2004, we will improve the Volcanic Ash Coordination Tool so that it can display additional products required by the Anchorage Air Route Traffic Control Center, Anchorage Volcanic Ash Advisory Center, and Alaska Volcano Observatory. Assuming that VACT proves to be as useful as planned, consideration will be given to implementing it at the Washington, D.C. VAAC (which is supported by meteorologists at AWC). These plans are further detailed in the Development and Deployment (DAD) Branch section.

Aviation Systems: Development and Deployment Branch
Greg Pratt, Chief

Objectives

The Aviation Systems: Development and Deployment Branch prototypes new or enhances existing meteorological information systems for use by the aviation community. To address the safety and use of the National Air Space (NAS), the goals are to improve the tools that aviation forecasters use, create temporally and spatially seamless aviation weather forecasts through forecaster collaboration, and deliver aviation weather products tailored for nonmeteorologists to support air route traffic controllers, dispatchers, and pilots in their decision-making process. The branch currently concentrates on four projects involving the Aviation Digital Data Service (ADDS), the Traffic Management Unit (TMU), Volcanic Ash Coordination Tool (VACT), and Data Link Dissemination (DLD).

Aviation Digital Data Service Project

ADDS is a Web-based real-time aviation weather dissemination system that provides aviation decision-makers (pilots and dispatchers) with easy, inexpensive, real-time access to the latest operational aviation weather observations and forecasts, along with experimental products based on research funded by the Federal Aviation Administration (FAA) Aviation Weather Research Program (AWRP). Users can view and retrieve aviation weather information in a variety of formats that can be tailored to fit their individual needs. Text products and pregenerated graphics products can be viewed and printed, and the ADDS site (*http://adds.aviationweather.noaa.gov*) can be interactively queried by running Java applets and Web-based scripts.

A goal of the ADDS team is to rapidly release new and improved aviation weather products to the aviation community. To meet this goal, the user is involved at an early stage in the development cycle. User feedback from the ADDS Advanced User Group and e-mail determines design decisions and product functionality. Therefore, end-users become involved at the requirements phase, access the product during the experimental portion of the development cycle to determine whether it is useful, and then assess whether their needs have been adequately met.

We work jointly with the National Center for Atmospheric Research (NCAR) and the Aviation Weather Center (AWC) to add functionality and support the ADDS Website. Funding is provided for the development of ADDS by the FAA Aviation Weather Research Program (AWRP) through its Aviation Forecast Product Development Team.

Traffic Management Unit Project

The TMU project is currently in Phase 1 of a 4-phase effort designed to address TMU's unmet or newly identified weather information needs in the following air traffic weather-related hazard areas:

Phase 1: Convection
Phase 2: Icing
Phase 3: Turbulence
Phase 4: Ceiling and 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 Air Route Traffic Control Center (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 the Traffic Manager user.

The project is sponsored by FAA Air Traffic System Requirements (ARS-100), AWRP (AUA-430), FAA Southwest Region Headquarters, and National Weather Service (NWS) Southern Region Headquarters. The project addresses the requirements that were found in the in-depth study performed by FAA ARS-100 on "Decision-Based Weather Needs for the Air Route Traffic Control Center (ARTCC) Traffic Management Unit." In response to these needs, FSL is working closely with the Dallas/Fort Worth (ZFW) Traffic Management Unit and the Center Weather Service Unit (CWSU) on Phase 1's Aviation Tactical Convective Hazard Product (TCHP).

An aviation convective hazard is defined as the suite of products disseminated by the NWS, generated by forecasters or automated algorithms in response to predicted or occurring thunderstorm activity such as Convective SIGMETs, National Convective Weather Forecasts (NCWFs), and Center Weather Advisories (CWAs). A tactical convective hazard is defined as an NWS convective product predicted to occur within the next hour.

A TCHP is being created 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 Dallas/Fort Worth TMU and CWSU participants will help refine the content and presentation of the TCHP. The Demonstration and Evaluation (D&E) group will obtain operational input early in the process to expedite fielding of advanced products. When the participants are in agreement that a satisfactory product has been created, specific recommendations will be made for national implementation on FAA operational systems, such as the Enhanced Traffic Management System (ETMS) at the Volpe National Transportation Systems Center.

Volcanic Ash Coordination Tool Project

The National Weather Service and the FAA Aviation Weather Research Program are sponsoring the creation of a Volcanic Ash Coordination Tool (VACT). This tool represents a proof-of-concept effort to bring consistency, accuracy, and expediency to volcanic ash forecasting. FSL's FX-Collaborate (FXC) system can be enhanced to allow participants from the Anchorage Center Weather Service Unit (CWSU), Alaska Aviation Weather Unit (AAWU), and Alaska Volcano Observatory (AVO) to simultaneously view volcanic episodes to determine if a volcanic event has occurred, coordinate on forecasting the ash movement, and disseminate the required products.

A "requirements" team comprising the Anchorage CWSU, AAWU, AVO, Alaska Region Headquarters (ARHQ), and ASDAD will develop the requirements necessary to create a collaborative system that consists of the fundamental tools and displays for determining if a volcanic eruption has occurred, the ability to forecast the dispersion of ash, and the ability to create and disseminate volcanic ash products to end-users. The ASDAD team will work with the ARHQ and SDD to acquire and display the datasets that have been identified by the requirements team. Through a well-coordinated effort, it is hoped that frequent enhancements can be achieved on the FX-Collaborate system. User feedback will be gathered quickly and made available by the next release of the system software.

Data Link Dissemination Project

The Flight Information Services Data link (FISDL) is a partnership between the federal government and private industry to get affordable, near real-time weather data to the cockpit of general aviators. Private vendors and the FAA formally agreed that basic weather products would be broadcast without cost to the users. The FAA and industry have defined the following seven weather products as basic – METAR, TAF, SIGMET, Convective SIGMET, AIRMET, PIREP, and Alert Weather Watches. With the goal to make these products usable in the cockpit, the FAA has sponsored FSL and NCAR to jointly create decoders and test suites for decoders for each of these weather products.

Accomplishments

Aviation Digital Data Service Project

During 2003, the branch continued to work toward moving the operational support and maintenance of ADDS to developers and technicians at the Aviation Weather Center. On 30 September 2003, AWC officially started operational support of the ADDS project. A new ADDS experimental Website (*http://weather.aero/*; see Figure 79) was created that will allow for continued enhancements to the ADDS products and services. Work also continued in supporting and updating products on the operational ADDS, incorporating user feedback. A new task was initiated to design and develop an ADDS flight path tool application to handle all the current ADDS applet capabilities. The flight path tool will be designed to:

- Allow users to view all ADDS weather products from one tool.
- Allow users to set default attributes for the flight path tool, such as colors, map backgrounds, data to display, and zoom level.
- Provide quicker loading times by placing the executables on the user's machine.
- Decrease maintenance costs associated with how the applet ties to browser limitations.

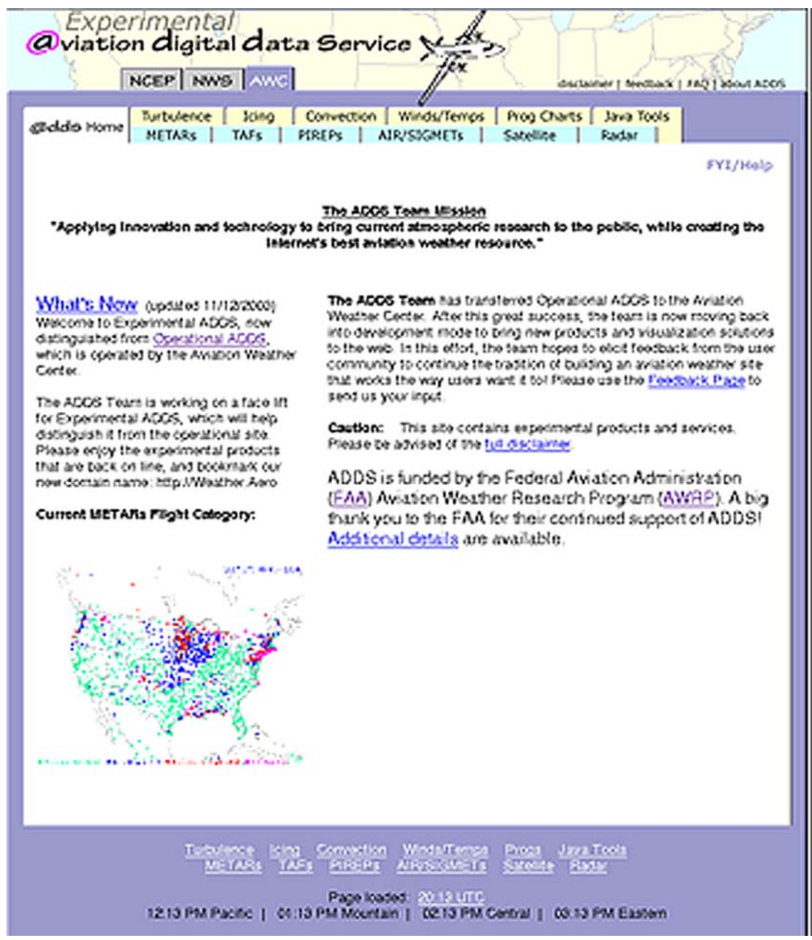

Figure 79. Experimental ADDS Website describing the new role of the ADDS team.

Traffic Management Unit Project

The team demonstrated and evaluated version 1.4 of the Tactical Convective Hazard Product (TCHP), which was available for operational use by the Dallas/Fort Worth traffic managers from their briefing terminal via an Internet connection to the Traffic Management Unit Website *(http://tmu.fsl.noaa.gov)*. This Website was enhanced to include a TCHP looping capability consisting of 7 graphical NCWF detection field images depicting past storm motion and ending with a graphical image (Figure 80) containing the current NCWF detection and 1-hour forecast fields with tops and movement information. While in looping mode, users can select to add or remove map backgrounds such as:

- State boundaries
- ARTCC areas
- Jet routes
- VOR (VHF Omni-directional Range) maps
- DFW and IAH TRACON areas

A Traffic Manager default static TCHP graphic was implemented for use during the 2003 convective season, as well. The default graphic (Figure 81) consists of the following TCHP maps and convective data products on the Dallas/Fort Worth ARTCC scale set to "auto-update" as new products are ingested on the server:

- State map
- ARTCC map
- VOR identifiers
- DFW TRACON
- IAH TRACON
- National Convective Detection Field
- National Convective Forecast Field
- National Convective Motion and Tops

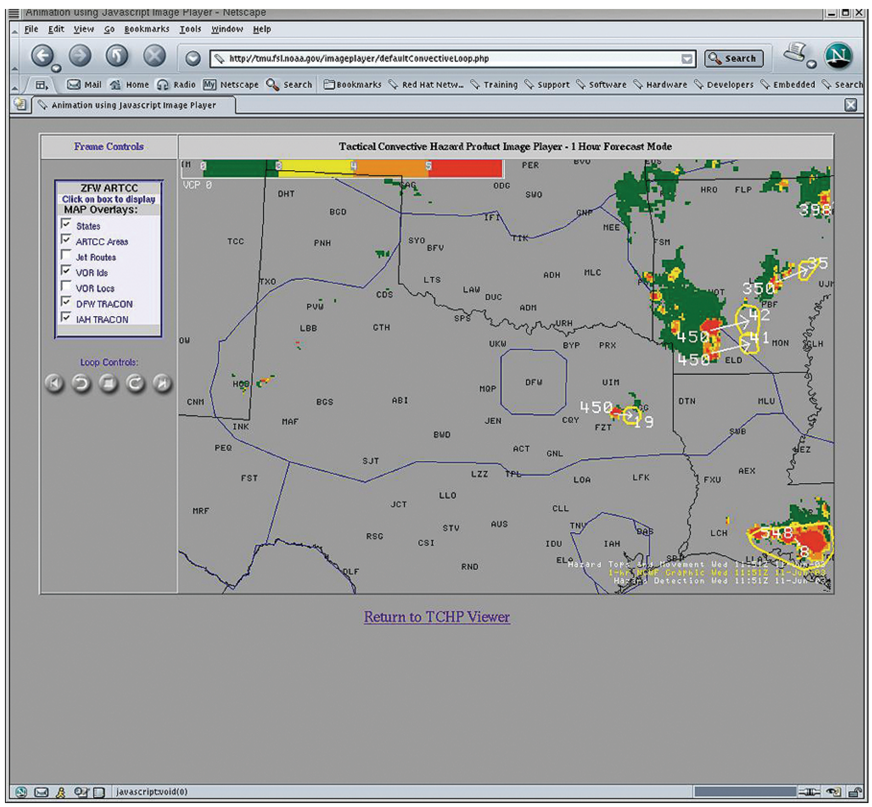

Figure 80. Graphical TCHP looping image showing current NCWF detection and 1-hour forecast fields.

Other convective datasets and an impacted high-use Jet Routes map were also available as enhancements to the TCHP graphic (Figure 82), and selectable by the Traffic Manager users on the TMU Website. The Traffic Managers' keystrokes were tracked to see when these products were invoked. These convective products include Impacted Jet Routes, Convective SIGMET Text, Convective SIGMET Forecast, and Convective SIGMET Nowcast.

All traffic managers at the Dallas/Fort Worth ARTCC were trained on the use of the new TCHP static and looping graphics capabilities of the TMU Website. A formal evaluation was conducted last summer, and a report was published in November 2003 on "Accessing the utility of an automated 0–1 hour Tactical Convective Hazard Product to FAA Air Traffic Managers Interim Report Submitted to FAA ARS-100 and AUA-430," by FSL in collaboration with the NWS Prototyping Aviation Collaboration Effort (PACE), in Fort Worth, TX. This report summarizes findings and recommends improvements, which are incorporated in TCHP enhancements for release during 2004.

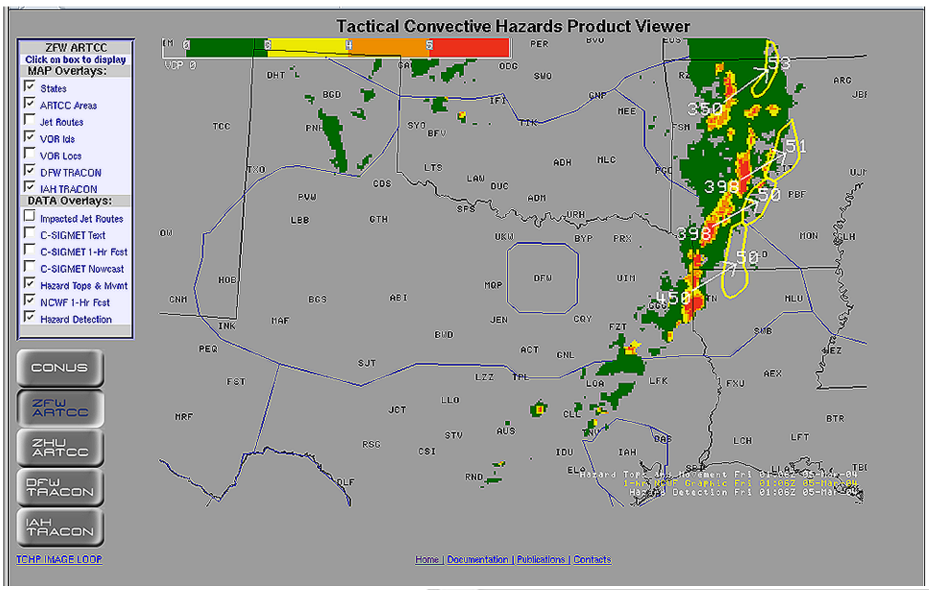

Figure 81. left, Default Static TCHP graphic.

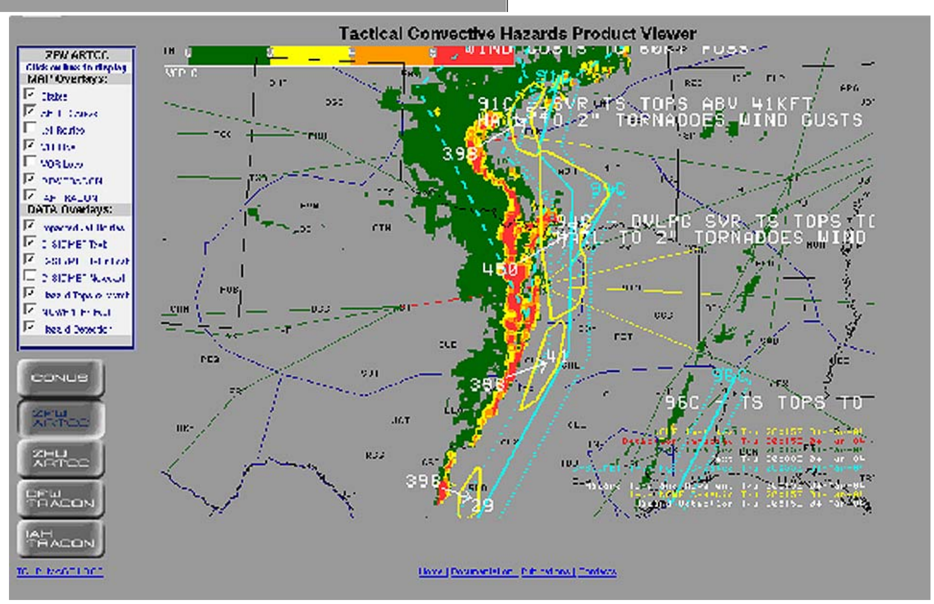

Figure 82. right. Status TCHP graphic showing selected convective products.

Volcanic Ash Coordination Tool Project

The VACT was initiated with a “requirements” meeting at the Alaska Region Headquarters on 30 April 2003. The participants agreed on the VACT client systems data and display needs and the order of importance for adding functionality to FX-Collaborate (FXC). The major data/display capabilities for FXC are listed below:

- Satellite Datasets – GOES, POES, DMSP, GMS, and China
- Dispersion Models – PUFF, VAFTAD, CANERM
- Radar – Alaskan, Washington Coast, Oregon Coast, and California Coast
- AVO Datasets – HDF and Seismic
- Cloud Tops
- Center Weather Advisory (CWA) and Volcanic Ash SIGMET creation tool
- Ability to generate and distribute products from a collaborative effort
- Ability to display the Oceanic Weather Product Development Team products
- Ability to upload VACT products to cockpit
- Ability to add local datasets from collaborators
- Satellite image enhancement capabilities
- Method for saving and recalling VACT sessions

Three VACT client systems were built and installed at the Anchorage CWSU, AAWU, and AVO in July 2003, and primary and backup servers were built and installed at FSL, as well. Version 0.0 of the VACT software was created from the FX-Collaborate base code, which included volcano map overlays of Alaska and Kamchatka, VOR locations for Alaska Air Space, split window displays (two satellite channels that are adjusted and enhanced to bring out volcanic ash) of Kamchatka and the Aleutian Islands. Training was provided for all users of the VACT client systems. Feedback from participants on release 0.0 of the VACT software was studied and incorporated, as appropriate, into release 1.0.

Version 1.0 of the VACT software was installed on all systems in October 2003. The enhancements to the VACT code included satellite datasets for Polar Orbiting Environmental Satellites (POES), Defense Meteorological Satellite Program (DMSP; Figure 83), Geostationary Orbiting Environmental Satellite (GOES)-9, and China. The radar products requested above were added, along with more map backgrounds and scales, based on user feedback from software version 0.0. User feedback was gathered from release 1.0 for incorporation in future software releases.

Data Link Dissemination Project

Development and operational testing systems were purchased and built for this project. A METAR decoder requirements specification document was derived from the “Federal Meteorological Handbook No. 1 Surface Weather Observations and Reports FCM-H1-1995,” Washington, D.C., December 1995, with a 5 November 1998 update. The FAA and private vendors agreed to the content of the document. The METAR decoder and test suite were built to this specification and released on April 2003 to the FISDL vendors, who have since verified and successfully implemented it. Pseudo-code and data flow diagrams describing the METAR decoder have also been developed. A data dictionary is being created that describes the METAR decoder. The operational system is being configured to acquire statistics on problems with the METAR datasets to initiate a feedback loop to the National Weather Service to help resolve METAR formatting problems. Development work will start on a pseudo-code, decoder, and test suite for the TAF delivery to FISDL vendors, pending funding.

Projections

Aviation Digital Data Service Project

Work on this project will continue through the Aviation Program Development Branch.

Traffic Management Unit Project

During 2004, the focus will be on enhancing the TCHP product, based on feedback gathered during the summer 2003 evaluation. The looping capabilities of the TMU Website will be enhanced to include the Convective SIGMET forecast product, the 2-hour Collaborative Convective Forecast Product (CCFP), and the Center Weather Advisory (CWA) product. The static displays will be updated to include the 2-, 4-, and 6-hour CCFP products, near real-time aircraft

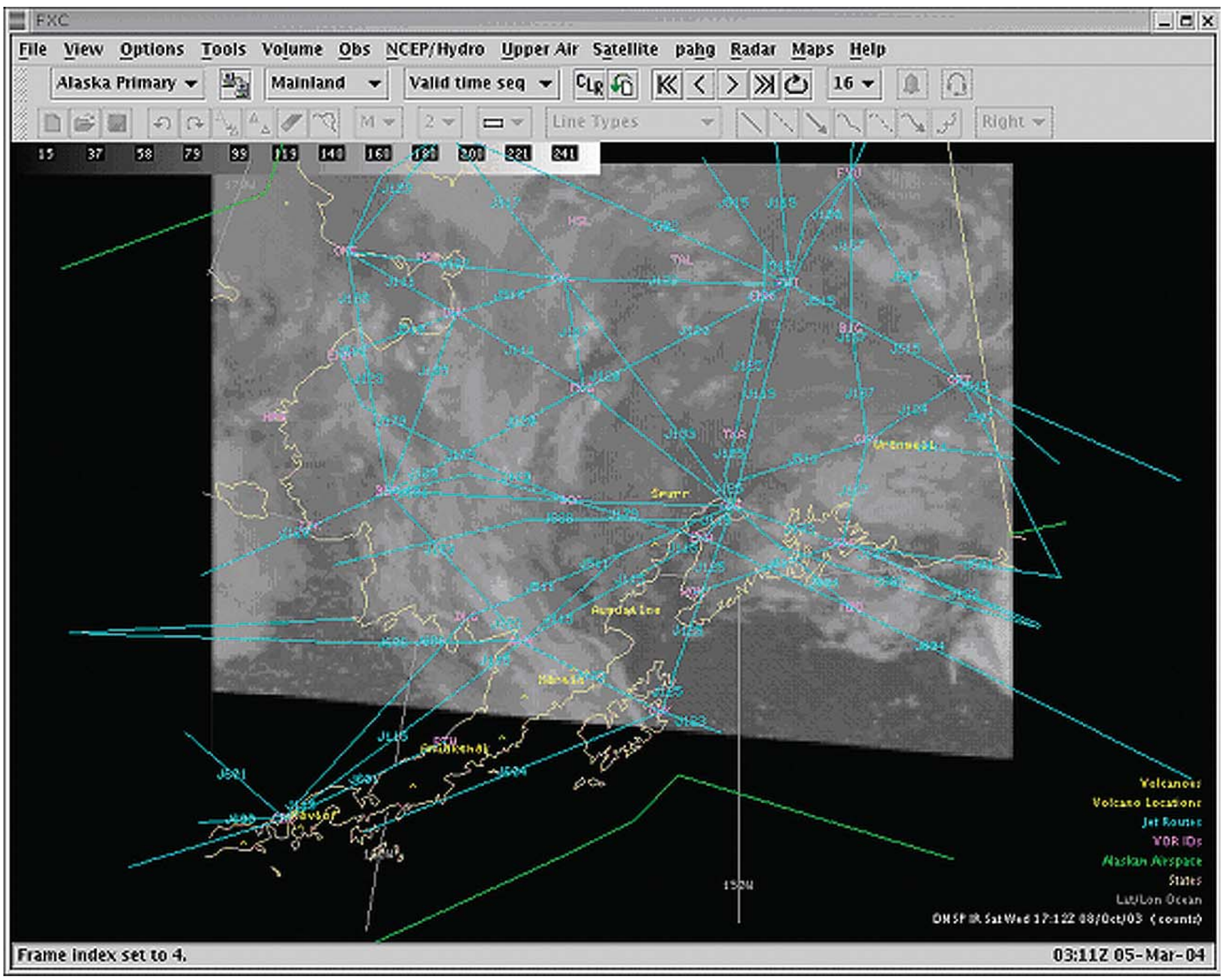

Figure 83. VACT (Volcanic Ash Coordination Tool) display of a satellite image from the DMSP (Defense Meteorological Satellite Program).

location data, and the CWA products. The FX-Collaborate system that is used by the forecasters at the Dallas/Fort Worth CWSU will also be updated to handle the above product suite. A CWA tool will be implemented to allow forecasters at the CWSU to create convective CWAs from the FX-Collaborate interface. Once the tool is in place, we will work with the forecasters at the CWSU to develop a methodology using the CWA tool to add value to the automated TCHP product. The TMU Website will be updated to include a crosswind product developed by the CWSU Forecast Team and to include placeholders for icing, turbulence, and ceiling and visibility products. Since TMU managers value the color-coded (based on type of impact) jet route displays, work will begin on creating impacted sector maps for the low, high, and ultra-high sectors for the Dallas/Fort Worth airspace. A new interface based on impact will be presented to the traffic managers for evaluation during the fall convective season.

Volcanic Ash Coordination Tool Project

Feedback from the VACT participants will continue to be incorporated into version 2.0 of the VACT software. This version will include the agreed upon scales, radar datasets, naming conventions for satellite products, and a subset of satellite images from each of the satellites: POES, GOES-9, GOES, DMSP, and China. The PUFF algorithm, selected as the first dispersion model to be made available for display on the system, will also be incorporated into version 2.0, which will be released in late spring 2004. Suggestions from feedback on version 2.0 will be included in Version 3.0, which will contain the VAFTAD dispersion model and the ability to display Volcanic Ash CWAs. Version 3.0 will be released in late summer of 2004. Subsequently, version 4.0 will contain suggestions from feedback acquired from the 3.0 build, the CANERM model, and the ability for CWSU forecasters in Anchorage to create and issue a CWA from the VACT interface. Version 4.0 will be delivered in late fall 2004.

Data Link Dissemination Project

The Aviation Systems: Development and Deployment Branch will continue creating a data dictionary for inclusion in the METAR decoder documentation. Statistics of METAR decoder failures will be analyzed to determine where corrections are needed in order to fix problems with the current design and implementation of the METAR decoder. Decoding of the “Remarks” section will be designed, documented, and the METAR decoder test suite will be updated to handle the remark section elements. The framework for all future development efforts on text-based decoding for the FAA is in place and will be used for the design, implementation, and testing of the TAF text product.

Advanced Computing Branch

Michael Kraus, Chief

Objectives

The traditional mission of the Advanced Computing Branch has been to enable new advancements in atmospheric and oceanic sciences by making modern high-performance computers easier to use. We continue to pursue that mission by supporting the Scalable Modeling System (SMS) and using it to parallelize numerical geophysical models. However, in the last year, the role of the branch has expanded to include grid computing at FSL, and in the wider context of NOAA, as another way to enable new advancements in atmospheric and oceanic sciences.

Grid computing is an emerging field in high-performance computing. With the availability of very high-speed networks, the backing of grid software by industry, and the potential to provide better utilization of IT resources, grid computing offers the potential to significantly benefit NOAA. Industry support for grid computing has coalesced around Globus, a software toolkit designed to handle resource sharing and discovery, data movement, security, access, and other operations required in distributed computing environments. With this support, the Globus software and the recent development of grid standards represent a roadmap to implement grid computing in the future.

We are currently engaged in several projects to explore the grid and how it can be utilized at NOAA. The branch is collaborating with two other NOAA laboratories in building a simple prototype NOAA grid. First, through this work, funded by the NOAA High-Performance Computing Systems (HPCS) office, we can explore our ability to construct a working grid, handle administrative and technical issues including resource allocation, security, and job scheduling, and run real scientific applications across wide-area networks.

Second, we are developing a grid portal for use in support of the development, test, and verification of the Weather Research and Forecast (WRF) model. WRF, a six-member ensemble model, is slated to become the operational model for the National Weather Service in October 2004. Prior to acceptance, extensive testing is required to ensure improved forecast accuracy over the existing operational model (Eta). These tests require significant computer and data storage resources. Further testing of new model variants, proposed as future candidates, is expected and will involve massive compute requirements and PetaBytes of data storage. Development of a grid portal is being explored as a way to simplify testing, share research results, and apportion compute and data resources with our collaborators at NCEP, the National Center for Atmospheric Research (NCAR), and the DoD.

Finally, we are studying longer term issues in developing a NOAA grid that spans the organization as a means to provide better integration of NOAA's growing data, compute, and network resources, and to meet the expected needs of these projects in the future. The availability of data is central to NOAA's mission, including 1) building and maintaining observational platforms including radars, satellite-based instruments, aircraft, profilers, weather balloons, ships, and buoys; 2) creating data products for weather and climate prediction and disseminating these products; and 3) archiving the data so they can be used by research laboratories to develop new prediction capabilities and forecast products. NOAA's IT investment directly relates to the volume of data it receives, processes, and disseminates. In the next 10 years, data volume is expected to grow by more than 100 times. To handle this expected enormous data growth, grid technologies are being explored as a means to 1) provide better utilization of NOAA's IT assets; 2) offer a more efficient way to ingest, disseminate and archive data to NOAA constituents and to the general public; 3) reduce costly duplication in data archival, product generation systems, and networks; 4) improve the usability of data handled by NOAA; and 5) provide more efficient access to compute facilities and storage facilities.

Accomplishments

The Advanced Computing Branch led the development of a rudimentary computational grid comprised of machines located at the Pacific Marine Environmental Laboratory (PMEL) and FSL. A computational grid provides a means for users to seamlessly execute jobs on resources spread across organizationally and/or geographically disparate resources. The grid is implemented with packages developed as part of the Globus grid toolkit. We demonstrated the feasibility of running the Regional Ocean Model System (ROMS) on a computer at PMEL, the WRF model on another computer at FSL, and exchanging surface boundary conditions in real-time across the Abilene network backbone. Our follow-on proposal to the NOAA CIO office was granted to extend this grid into a full prototype. The primary objective is to enable a grid user to submit jobs to a gridwide queue and have it run on any available platform.

The branch continued its collaborative efforts to support the development of the WRF model, and the related WRF Test Plan. We developed a Model Coupling Toolkit (MCT) implementation of the WRF I/O Application Programming Interface (API). The software provides the capability for the user to cleanly and efficiently interpolate gridded fields on parallel machines.

A concept paper was written describing a WRF portal (see *http://www.noaatech2004.noaa.gov/abstracts/ab29_govett.html*). The WRF Test Plan is a plan to test the WRF/masscor and the WRF/NMM, paving the way for an ensemble of the two models to become the next NCEP operational model. We ported the NCEP Verification software package and the NCEP Postprocessing software package from the IBM Power4 to the FSL HPCS, enabling FSL to honor its WRF Test Plan commitment to run 240 end-to-end tests of the WRF/masscor weather prediction package on the our supercomputer. The branch participated in WRF System Test Plan development within FSL and in the larger WRF community.

As part of the ITS Procurement Team, members of the branch engaged in procurement activities and produced the ROMS benchmark for the upcoming procurement. We developed a netCDF comparison program to facilitate the verification of ROMS results and the verification of other procurement benchmarks that use netCDF.

The RUC model was optimized for the IBM Power4 cluster, resulting in a 13% increase in speed. The RUC team has a fixed time allocation for running RUC on the power4, so the increase in speed not only assures that RUC will run in the allotted time, but also allows the RUC team to add more capability to the model.

The branch contracted with the Taiwan Central Weather Bureau (CWB) to provide recommendations on how to prepare for their upcoming supercomputer procurement. Recommendations were developed and presented to CWB at a meeting in Taipei last October. We were granted a contract from CWB to parallelize their Nonhydrostatic Forecast System (NFS) model using a two-dimensional data domain decomposition.

Continued development of SMS included increased Fortran90 support and extended PPP support for new application areas. SMS Version 2.7.0 was released.

Two papers were published: one titled, "The Scalable Modeling System: Directive-based Code Parallelization for Distributed and Shared Memory Computers" in the *Journal of Parallel Computing*, and another titled, "Performance Analysis of the Scalable Modeling System" in the *World Scientific Press*.

Projections

Plans for the Advanced Computing Branch during 2004 include:

- Construct a grid that includes multiple heterogeneous machines located at PMEL, FSL, and the Geophysical Fluid Dynamics Laboratory (GFDL).

- Continue to participate in the WRF System Test Plan and port the NCEP WRF/NMM forecast model to FSL High-Performance Computing System.
  - Parallelize the Standard Initialization (SI).
  - Work with ITS on WRF issues.

- Continue to support WRF.
  - Develop a requirements document for a WRF Portal.
  - Develop a prototype WRF Portal.
  - Document the WRF registry.

- Continue to support ITS procurement activities for acquisition of FSL's next High-Performance Computing System.

- Continue to support the RUC model.

- Use SMS to parallelize other atmospheric and oceanic models including the Taiwan Central Weather Bureau NFS model and help DTL parallelize the OMRT code using SMS.

- Continue to develop and enhance SMS.

- Continue to support users of SMS and FSL's High-Performance Computing System.

- Publish results in conference proceedings and journals.

Forecast Verification Branch

Jennifer Luppens Mahoney, Chief

Objectives

Verification is the key to providing reliable information for improving weather forecasts. As part of FSL's involvement with the Federal Aviation Administration (FAA) Aviation Weather Research Program (AWRP), the Forecast Verification Branch develops verification techniques, mainly focusing on aviation weather forecasts, and tools that allow forecasters, researchers, developers, and program leaders to generate and display statistical information in near real time using the Real-Time Verification System (RTVS).

In adhering to related goals in the FSL Strategic Plan, we strive to maintain a strong verification program by working closely with other agencies, such as the National Centers for Environmental Prediction (NCEP), National Weather Service (NWS) Headquarters, and the National Center for Atmospheric Research (NCAR). The technology developed through these close interactions can benefit all agencies by building and strengthening the verification programs.

The branch is involved in a variety of national programs: the International H_2O Project (IHOP), testing the accuracy of forecasts from weather models such as the Weather Research and Forecasting (WRF) model, and projects related to the development of collaborative convective forecast products for aviation. Another task involves development of verification techniques for evaluating precipitation forecasts, a capability that has been used to support local-scale numerical modeling efforts at FSL. Other activities include leading the AWRP Quality Assessment Product Development Team, and participating in the Collaborative Decision-Making Weather Applications Work Group.

Real-Time Verification System (RTVS)

In support of these verification efforts, scientists throughout FSL collaborate with colleagues at NCAR and the NWS Aviation Weather Center (AWC) to develop the RTVS as a tool for assessing the quality of weather forecasts. It is designed to provide a statistical baseline for weather forecasts and model-based guidance products, and support real-time forecast operations, model-based algorithm development, and case study assessments. To this end, the RTVS ingests weather forecasts and observations in near real time and stores the relevant information in a relational database management system (RDBMS). A flexible, easy-to-use Web-based graphical user interface allows users quick and easy access to the data stored in the RDBMS. Users can compare various forecast lengths and issue times over a user-defined time period and geographical area, for a variety of forecast models and algorithms.

The RTVS has become an integral part of the AWRP by providing a mechanism for monitoring and tracking the improvements of AWRP-sponsored forecast products. The RTVS provides displays and statistical information to forecasters and managers at the AWC, Air Traffic Control Systems Control Command Center (ATCSCC), and to the developers of the AWRP Weather Research Product Development Teams. The RTVS will run operationally at the NWS, providing feedback directly to forecasters and managers in near real time.

Verification Methods

The branch is an active participant, in collaboration with NCAR, in developing and testing state-of-the-art verification methods, with an emphasis mainly on aviation and precipitation forecast problems. New techniques have been developed for convection, icing, turbulence, ceiling and visibility, cloud-top heights, and precipitation. Many of these techniques are applied to aviation forecasts that have been deemed "unverifiable." Nevertheless, the development and implementation of these verification methods are leading to a better understanding of, and improvement in, the aviation forecasts.

Accomplishments

During 2003, we completed extensive verification activities supporting the transitions of the Current Icing Potential (CIP) forecast product for Alaska (CIP-AK), the CIP severity index, and the next-generation National Convective Weather Forecast Product (NCWF-2). The results were used in the FAA/NWS decision process to transfer the algorithms from a test phase to an experimental phase that will allow users to view these forecasts. Output from the CIP-AK, CIP severity, and NCWF-2 algorithms will be available to NWS Aviation Weather Center forecasters and others for use as a forecast product to evaluate where icing and convection may occur within the atmosphere.

In support of the Coastal Storms Initiative (CSI) project, the RTVS was modified to include verification of temperature, relative humidity, and wind forecasts. Meteorologists at the Jacksonville NWS Forecast Office and at Florida State University used these results to determine the usefulness of local-scale modeling on the accuracy of weather forecasts. For instance, wind and precipitation forecasts were of particular interest to the Jacksonville forecasters. Improvement in local precipitation forecasts as a result of locally run numerical models was evident in the statistical results.

The greatest improvement in the precipitation forecasts from the WRF-Hot Start was noted at short lead times and over 0.25 to 1.5 thresholds. Improvement was also noted at larger thresholds where the WRF-Hot continued to produce precipitation while the Eta model dramatically underpredicted the precipitation amounts. However, at 3 hours and at thresholds typically greater than 1.0 inch, little forecast skill was noted for all models. It should be noted that the summer precipitation regime in northern Florida during the evaluation was mainly dominated by an air mass of single convective cells, which may account for the low equitable threat scores (ETSs) for all models at all thresholds. Improvement in local wind forecasts produced by the WRF-Hot Start as compared to the Eta was evident in the results. Overall, the WRF models showed a statistically significant lower bias and statistical errors in the forecast wind speed than did the Eta at all forecast hours, though the greatest improvement occurred at 12 hours. The error in wind speed at 3 hours for the WRF-Hot Start was nearly 1 m s^{-1} less than for the Eta.

No improvement was noted in temperature for the local WRF as compared to Eta. The larger and negative temperature biases exhibited by the WRF-Hot during the evaluation period was the result of the WRF model generating too much low-level cloudiness related to a bias in the LAPS-provided 3D temperature analysis. The bias in the LAPS temperature analysis led to rapid cloud development in the WRF model and consequent shading, and thus cooling of afternoon temperatures. This mechanism is only partially responsible for the surface temperature forecast bias in the WRF-Hot Start forecasts. All of the models failed to accurately predict the full amplitude of the diurnal temperature curve. This was especially true in the WRF runs where the PBL schemes "flattened" the diurnal curve in the forecasts. These results were summarized in a report provided to the CSI leadership team. This groundbreaking work on the impact of local-scale modeling helped shape future NWS modeling activities.

Several verification exercises supporting the work of the AWRP Product Development Teams were conducted throughout the year. Specifically, a convective exercise was held from 1 March–31 October 2003, during which numerous high-resolution convective forecasts were evaluated over the United States. Automated forecasts for convection were compared to human-generated forecasts so that the strengths and weaknesses of each could be evaluated. Throughout the exercise period, feedback was provided by RTVS, through graphical displays (Figure 84) and statistics, to the algorithm developers and AWC forecasters.

The branch developed a new verification methodology for defining the observation fields used for evaluating convective forecasts that take into account the impact of convection on the flow of air traffic and specific forecast attributes. The technique for defining the observations for evaluating the convective forecasts was separated into parts: 1) developing a definition for the Convective Constrained Area (CCA) and 2) producing observed fields that reflect the size and coverage attributes of the forecasts. The CCA provides the basis for measuring the "scale" of convective activity that impacts the flow of enroute air traffic. To take this operational consideration into account, we defined the CCA as an area of intense convection plus a 10-nm radius surrounding the convection. Figure 85 shows the raw convective observations, with the green areas representing the grid boxes with intense convection. Once the 10-nm radius criterion is applied to the observations, the areas grow slightly (Figure 86) to represent the CCA area. When using the CCA area of interest, coverage is computed by evaluating the percentage of 4-km boxes meeting the CCA criterion within a larger 92 x 92-km search box. This search box represents the minimum forecast area for the convective forecasts issued by the NWS Aviation Weather Center (AWC). Figure 87 shows the CCA area and coverage for the example shown in Figure 85.

The development of RTVS has continued over the past year. The relational database management system (RDBMS) was extended to all aspects of RTVS and has become an integral part of the system data access and storage capability. The Web-based graphical user interface was also modified to allow easy and flexible access and manipulation of the

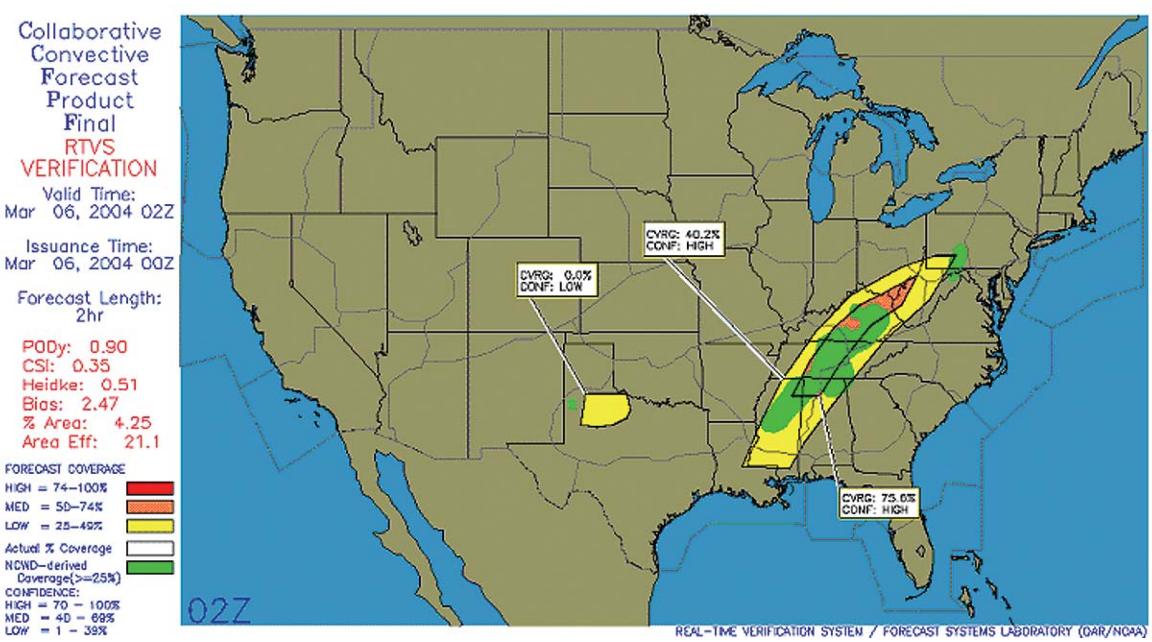

Figure 84. Example of an RTVS screen showing the Collaborative Convective Forecast Product (CCFP) for 6 March 2004.

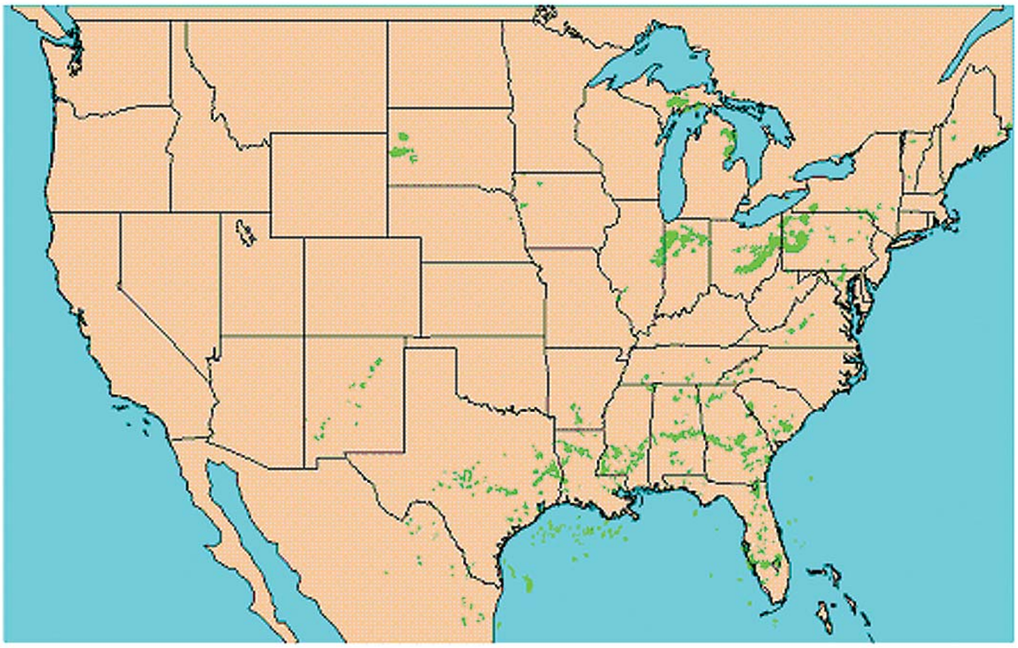

Figure 85. Raw NCWF (National Convective Weather Forecast) Hazard Product at 4-km resolution at 1900 UTC on 4 July 2003. Green areas indicate VIP values that are 3 and greater, and cloud tops are assumed to be 20,000 feet or greater.

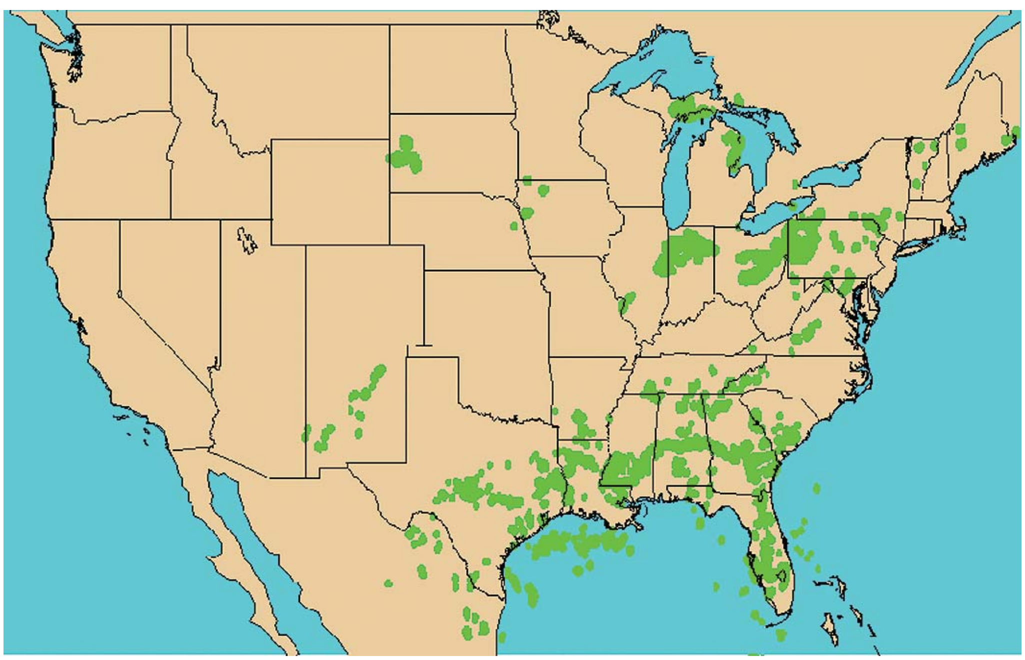

Figure 86. Map of convective activity that impacts enroute air traffic at 1900 UTC on 4 July 2003. Green areas indicate 4-km NCWF Hazard +10-nm radius.

data stored in the RDBMS. This flexibility allows users to compare various forecast lengths and issue times over a user-defined time period and geographical area, for a variety of forecast models and algorithms. The Web-based RTVS can be accessed at *http://www-ad.fsl.noaa.gov/fvb/rtvs/*.

Projections

The Forecast Verification Branch will continue with real-time objective intercomparison exercises for turbulence, icing, convection, and ceiling and visibility in support of the AWRP. New verification capabilities will be developed for aviation forecasts produced by the NWS. Support will continue for FAA and NWS activities such as providing input into the development of a national verification program, transition of RTVS to the NWS, and the WRF numerical modeling efforts. In addition, verification techniques will be explored to address questions pertaining to flight operations.

The RTVS will be enhanced to include advanced diagnostic verification approaches that will provide users with the ability to partition errors into errors that are associated with the phase, orientation, and displacement of the forecasts as compared to the observations. Extensive evaluations of the Forecast Icing Potential for Alaska (FIP-AK) algorithm and the Cloud-Top Height algorithm will be completed and provided to the FAA/NWS Aviation Weather Technology Transfer Board for its consideration to experimental status within the NWS. Finally, staff will continue to develop verification tools, through RTVS, that provide immediate and useful feedback to forecasters.

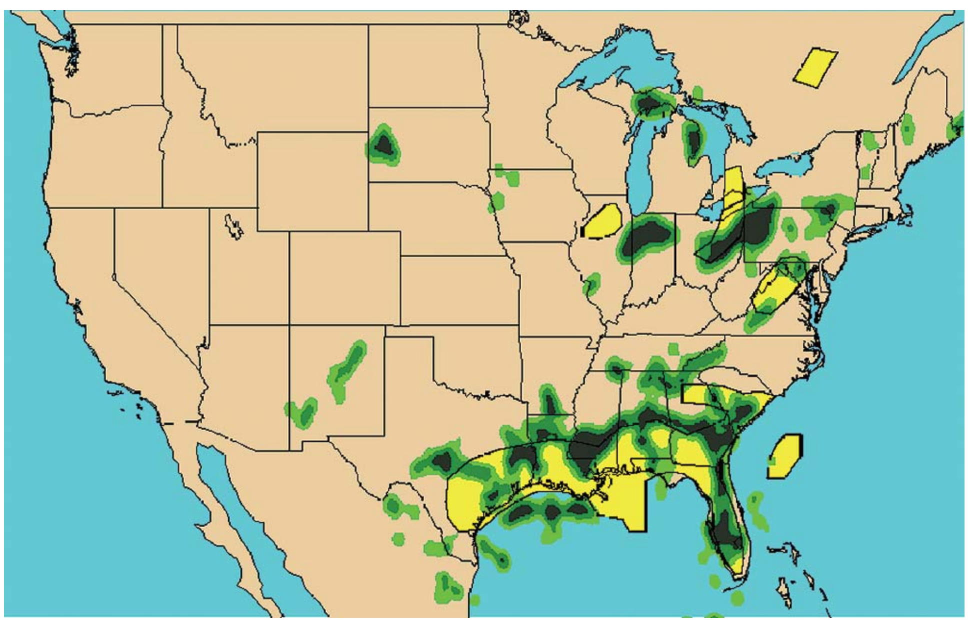

Figure 87. Map of convective constraint areas with coverage 3,000 mi^2 area that is 25–49% (light green), 50–74% (medium green) and 75% and greater (dark green), at 1900 UTC on 4 July 2003. Yellow areas indicate the CCFP.

Modernization Division

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Objectives

The Modernization Division produces functional designs, or working prototypes of techniques, workstations, and systems that may be implemented into the National Weather Service (NWS), or other agency operations up to a decade later. The process includes selecting, tailoring, and implementing advanced techniques and devices produced by the research and development community, industry, or elsewhere. Developments are state of the art and continually evolve along with new technological advances, such as the D2D (Display Two Dimensional) software.

The modernization of NWS operations involved the development of a new radar system, an automated surface observing system, a new series of geostationary satellites and products, and a communications and forecaster workstation system, the Advanced Weather Interactive Processing System (AWIPS). FSL participates in risk reduction activities to help the NWS meet its goals in the continued development of AWIPS.

The Modernization Division comprises two branches:

Risk Reduction Branch – AWIPS support and evaluation

Enhanced Forecaster Tools Branch – AWIPS Forecast Preparation System

Risk Reduction Branch

Carl S. Bullock, Chief

Objectives

Work in the Risk Reduction Branch is directed toward helping the National Weather Service (NWS) evolve. The two focus areas include operation and evaluation of risk reduction activities and the continued development of AWIPS. Since NWS announced in 1996 that the FSL-developed WFO-Advanced system would form the core of the AWIPS software to run at all Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs), the development and evolution of AWIPS has been our primary activity.

Accomplishments

AWIPS Software

During 2003, AWIPS Operational Builds (OBs) 1 and 2 were deployed, and the development for OB3 was completed. The upgrades included the introduction of new radar data and products in each of these software builds. High-resolution wind data, derived from Doppler velocity data, are now availability in AWIPS in real time. Before this upgrade, a graphic plot of these winds were only available every 5 to 10 minutes. Typically covering the lowest few thousand feet of the atmosphere, these winds can be displayed in a variety of ways: as wind barbs on a vertical staff, as wind reports on a time versus height graph, or on a wind speed versus height plot. Another addition was a high spatial resolution (.25 km) storm-relative velocity display, which is key in diagnosing the motion of the atmosphere relative to fast moving storm cells. A graphical user interface allows the forecaster to easily enter storm direction and speed in the forecast, or the default value calculated by the radar can also be automatically invoked.

The manner in which AWIPS handles WSR-88D radar products has been thoroughly revised in OB3 to accommodate new volume scan strategies to be introduced in 2004. For example, radar products will be handled in a generic fashion with a narrow range of tilts assigned to a group. Rather than displaying each tilt separately, radar tilts within a few tenths of a degree can be displayed together. Thus, the changing of volume scans will not interrupt the time continuity of radar loops. AWIPS will also display radar products of different resolutions with a single selector which simplifies the user interface.

A rapid update radar algorithm product was introduced in OB2. Algorithm products used to be generated at the end of a radar volume scan, which meant that these products were several minutes behind the latest radar data. The new rapid update scheme now used to generate these products allows algorithm outputs such as mesocyclone and tornado vortex detection to update after each tilt. AWIPS can now handle these new rapid update radar products.

NWS changed the AWIPS ingest of WSR-88D radar data from proprietary hardware (X25 protocol) to a TCP/IP-based approach during the past year. FSL revamped the radar request software to use the AWIPS wide-area network (WAN). These requests to noncollocated radars used to be made via a dedicated phone network. The new WAN-based approach is much faster and more flexible, and will allow decommissioning of the dedicated phone network, which costs of over $1 million each year.

Substantial enhancements have been made to the warning generation (WarnGen) application in AWIPS. The NWS is implementing a new code (Valid Time and Event Code, or VTEC) in watch, warning, and advisory products. Outside users can track weather events via a code string which is added to these products. The FSL application used to generate warnings will automatically add the appropriate VTEC code. Forecasters can also issue followup statements, via the Warngen application, that automatically refer to the original warning. In addition, a number of quality control checks are performed by the software to ensure that these products are internally consistent and properly formatted before they are transmitted to the public.

A number of new datasets were added to AWIPS last year, such as high density winds derived from each of the GOES satellite imager channels. These winds cover many atmospheric levels and represent high spatial resolution where there are targets that can be tracked by the automated routines generating these estimates. Also added to AWIPS were QuickSCAT ocean surface winds, which are derived from a specially instrumented polar orbiter satellite. These data are very valuable to offices with marine responsibility in providing information over a large area that is otherwise devoid of data. Temperature and precipitation anomaly grids were added. They are generated by experts at the Climate Prediction Center at the National Centers for Environmental Prediction (NCEP). They depict departures from normal conditions for many months into the future. Many new fields can now be generated from model grids thanks to additional equations that were added to the grid volume browser. The user interface was modified in OB3 to show the resolution of the various grids from numerical weather prediction models.

Projections

During 2004, we will continue to work on updating AWIPS software with two major Operational Builds: OB4 and OB5. These implementations will involve porting of the remaining decoders to Linux so that the Hewlett-Packard application servers can be decommissioned. Acquisition of the NOAAPORT data stream will undergo a significant upgrade with the introduction of digital video broadcast technology. A new GRIB decoder will be installed, enabling transmission of compressed grids in GRIB 2 format. We anticipate a 100-fold increase in the amount of grid data that can be sent as a result of these changes. In addition, a number of maintenance releases are planned; maintenance release OB 3.1 will be deployed by summer 2004 to enable testing of the new VTEC text messages.

We plan to start work on a new prototype system which will represent the completed evolution of AWIPS to a Linux-based system, including exploration of software and hardware architecture changes. The goal is to improve performance and investigate the possibility of integrating separate applications into a single system, for example, combining the drawing and editing capabilities. The new prototype is a major interest, and we will look ahead to some of the planned improvements in other areas of NWS and NOAA, such as the proposed NOAANet and enterprise architecture.

Enhanced Forecaster Tools Branch

Mark A. Mathewson, Chief

Objectives

The focus of the Enhanced Forecaster Tools Branch is the development of the Interactive Forecast Preparation System (IFPS). In consultation with a working group of National Weather Service (NWS) forecasters and partners in the NWS Meteorological Development Laboratory, we are designing and building the graphical forecast support system for AWIPS. A basic NWS concept driving the design of the IFPS is that NWS forecasts are now based on a suite of grid-based digital data. The forecaster is responsible for the creation and maintenance of a digital database containing all forecast elements over a 7-day forecast period. IFPS permits forecasters to spend the bulk of their forecast shift focusing on meteorology rather than typing text products. At each office, a team of forecasters interact with the database by applying tools that manipulate the gridded data in meteorologically meaningful ways. Once the forecast is complete, this weather forecast information can be communicated in a variety of ways, ranging from automatically formatted text products to simple images that represent a particular weather forecast element to a highly interactive user interface in which customers query the forecast database to get precise information.

Accomplishments

During 2003, we focused on three development tasks of the advanced IFPS: enhancing the capabilities of the Graphical Forecast Editor (GFE), developing field customizable text products, and providing IFPS field consultation and support.

Enhancing the Graphical Forecast Editor – The GFE provides tools for the forecaster to view and edit grid fields that capture the essential information needed to generate a variety of forecast products. Productive interactions between field forecasters and developers prompted numerous enhancements of the GFE graphical user interface (Figure 88), GFE Inter-Site Coordination (ISC) capabilities for coordinating forecasts between NWS offices, and extending the IFPS database for new data types. Smart tool infrastucture was improved to provide forecasters with more powerful tools to compare and edit their forecast grids. Three versions of the GFE were delivered to the NWS for inclusion in the AWIPS Rapid Alpha Process (RAP), IFPS13, 14, and 16. In addition, three major and numerous minor revisions of the Rapid Prototype Process (RPP) software were provided to RPP field sites for focused testing on particular areas of the GFESuite, such as text product formatting.

A major milestone was reached for the NWS on 1 October 2003 when IFPS and GFE reached their Initial Operating Capabilities (IOCs). This marked the transition to the gridded forecast paradigm, with the emphasis on quality gridded forecasts that have been collaborated and coordinated with adjacent offices.

Developing Field Customizable GFE Text Products – During 2003, the NWS asked us to develop a set of locally customizable text formatters of operational quality for IFPS. This development continued throughout the year. The first version of the 10 core products required for the IFPS Initial Operating Capabilities was completed for IFPS14 last summer. The products range from tabular summaries and coded tables to narratives, and cover the public, marine, and fire weather services in the NWS. We continued working with the field offices via the RPP software process, and provided multiple software releases to the field for testing the new infrastructure. Another focus involved improving the phrase structuring of the worded forecasts for local effect areas. The NWS field offices began replacing the older technology IFPS product formatters with new GFE field customizable formatters.

Providing IFPS Field Support – The NWS maintains three IFPS-related listservers for the field to discuss issues, find solutions, and interact with the developers. We make good use of the listservers to the benefit of the forecasters and focal points by providing quick turnaround to questions, tips on better use of the software, and field troubleshooting as well as focal point consultations. In a typical month, we interact with half (approximately 60) of the NWS offices via the listservers.

Projections

During 2004, we will continue to improve the GFE, improve the field customizable GFE text products, and provide field support. Development focus on the GFE is shifting from "knobology" to science. Additional data types will be added to the GFE, such as satellite, radar, and climatology. Improved Smart Tool infrastructure and interpolation techniques will be tested and deployed. The GFE Text Products will undergo transition as we implement the NWS Valid Time Event Code (VTEC) into the appropriate products, and as we improve the word phrasing in times of complex weather situations.

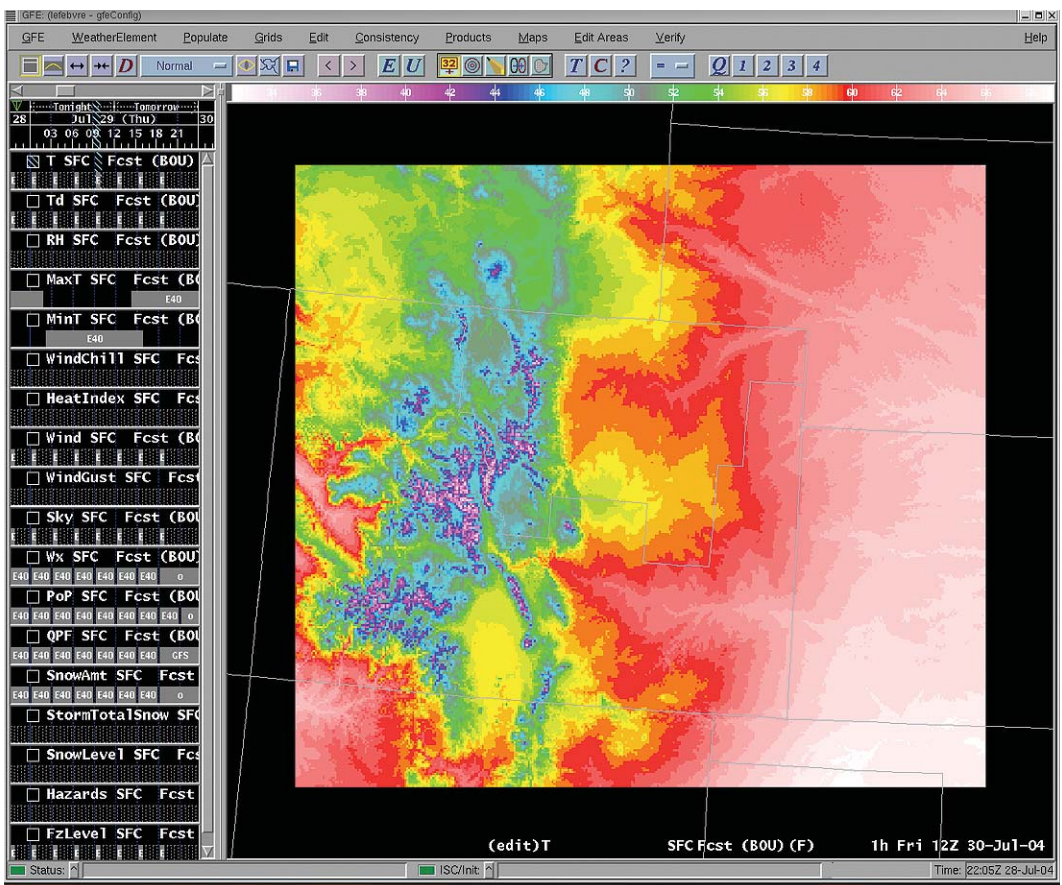

Figure 88. Screen from the Graphical Forecast Editor showing a highly detailed forecast surface temperature field. A meteorologist has edited this field in preparation for dissemination to users.

Technology Outreach Division

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Objectives

The Technology Outreach Division, previously named the International Division, develops and promotes new FSL project opportunities and emerging technologies to NOAA and other government organizations and the private sector. It facilitates international technology transfer programs through cooperative agreements. Support is provided for the following major activities:

- *Science On a Sphere™* – Conceived by FSL Director Dr. Sandy MacDonald, Science On a Sphere™ (SOS) is a NOAA program to develop a revolutionary system for educating the public on the holistic nature of Earth's ever-changing oceans, atmosphere, and land. SOS presents an engaging three-dimensional representation of our planet as if the viewer were looking at the Earth from space, offering a new and exciting way to learn about NOAA's global science programs.

- *CWB Technology Transfer Project* – The Technology Transfer Project at the Central Weather Bureau (CWB) of Taiwan is FSL's longest standing cooperative project. The 14-year CWB-FSL partnership has resulted in mutual benefits and cooperation in the areas of information systems, data assimilation and modeling, high-performance computing, and observing systems.

- *Korea Meteorological Administration (KMA) Project* – Working under agreement, FSL is collaborating with the Meteorological Research Institute (METRI) of the Korea Meteorological Administration (KMA) to design a nowcasting system based on FSL's WFO-advanced meteorological system, support startup and operation, and implement a training program for forecaster systems and operations staff.

- *Hong Kong Observatory LAPS Training Program* – In support of nowcasting systems and numerical weather prediction models at the Hong Kong Observatory (HKO), FSL is under contract to provide in-depth training on the design and implementation of the Local Analysis and Prediction System. This frequently updated local-scale analysis scheme will be set up to run operationally at the HKO to improve weather prediction in the area.

- *FX-Net Program* – FX-Net is designed as 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. FX-Net makes AWIPS products accessible over the Internet via high and low bandwidth communication lines.

- *Wavelet Data Compression Project* – Integral to the FX-Net technology is a wavelet compression technique that can reduce and transmit product file sizes with minimal loss of resolution.

NOAA Science On a Sphere™ Project

David Himes, Senior Software Engineer/Team Leader
(303-497-5447)

Web Homepage: *http://www.fsl.noaa.gov/sos*

Objectives

The success of every aspect of NOAA's mission depends on public understanding of science and the environment. Science On a Sphere™ is the centerpiece of a NOAA program for educating the public on the dynamic forces of nature that impact our oceans, atmosphere, and land. Using computers coupled with video projectors, the system presents NOAA's global science in an engaging three-dimensional representation of the Earth's features as if they were viewed from space. Unlimited global scientific datasets can be displayed on the surface of a large opaque sphere, including the weather, climate, and geology, as well as images of the solar system. At exhibition centers featuring NOAA's Science On a Sphere™ (Figure 89), audiences enter a display area and move freely around the vibrant, suspended "Earth" and listen to a narrative describing, for example, how warm water signaling an El Niño travels across the Pacific Ocean. Hurricanes, as viewed from weather satellites, can be observed forming off the coast of Africa and moving across the Atlantic Ocean toward the United States. Data from military satellites show the spectacular lights of our planet at night. Other popular displays include massive, churning solar flares of the Sun, geological objects on the surface of Mars, and the cloudy atmosphere of Jupiter. Science On a Sphere™ technology provides an ideal way to educate the public on many important issues, both environmental and economical, and enhances NOAA's capacity to advance science and environmental literacy in partnership with public and private organizations.

Figure 89. David Himes (right) discussing Science On a Sphere™ at a conference.

Accomplishments

Under development at FSL since 2001, Science On a Sphere™ has been shown to thousands of viewers, children and adults, at its home location at NOAA's David Skaggs Research Center in Boulder. Since its 2002 public viewing at the NOAA Science Center, it has been exhibited at numerous scientific and educational conferences around the United States. Major exhibits during 2003 included the National Association of Broadcasters/Cable Conference in Chicago, the Association of Science-Technology Centers Conference in Minnesota, and the Earth Observation Conference in Colorado Springs. Development of the system during the past year involved increasing interaction with outside organizations through a partner program and creating new system features, as described below.

Partnerships – NOAA and FSL developed a partner program that enables Science On a Sphere™ to be permanently installed at a small number of science centers and museums around the world. The partnership is structured on a cost-recovery basis, in which the participating organization purchases all of the parts (hardware and software) needed to build Science On a Sphere™ and then provides NOAA with a budget to install, configure, and support the system. The negotiations so far have resulted in agreements with two sites to participate in the program, and several other sites under negotiation. In conjunction with the partner program, NOAA is actively soliciting licensing agreement proposals that would enable the transfer of all or part of the technology supporting Science On a Sphere™ to a private organization for marketing and commercial distribution. NOAA is also awaiting delivery of a patent for Science On a Sphere™.

New System Features – The visualization system of Science On a Sphere™ includes video projectors, computers, and custom display software. Four computers run the video projectors (Figure 90) that shine separate images (from

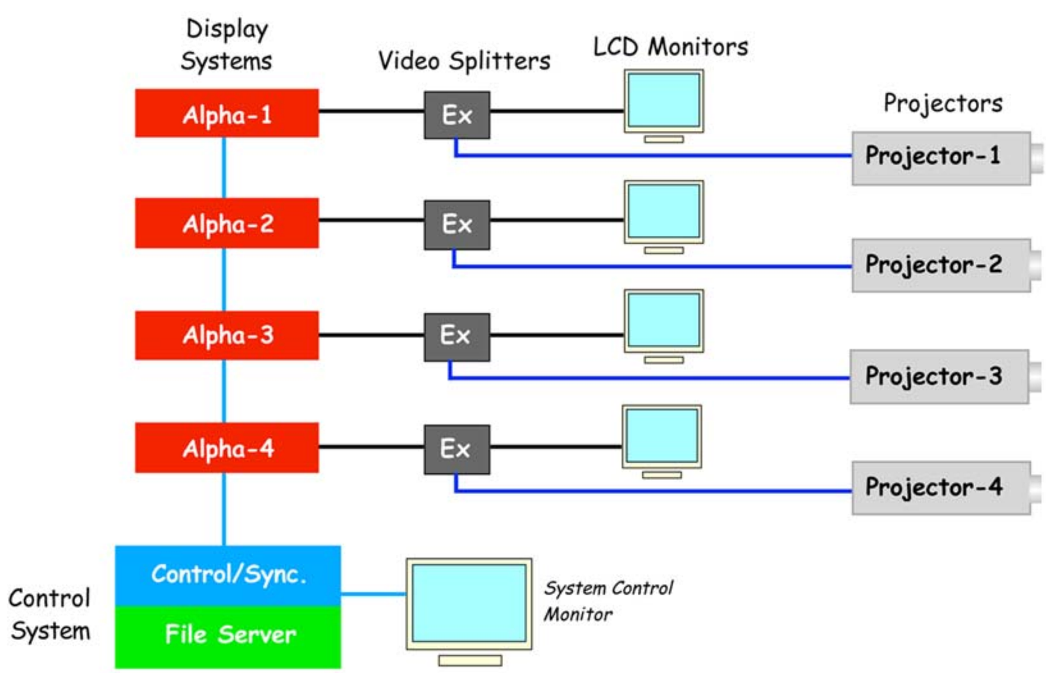


Figure 90. Schematic showing the connection between the computers that run the video projectors and the control system for Science On a Sphere™.

data) onto each quadrant of the sphere, and a separate computer controls the whole system. This fifth computer synchronizes the four displays and runs the user interface and automation controls. The general development goal was to make Science On a Sphere™ a robust visualization system to present a museum-quality exhibit for deployment in museums and science centers. The three top priorities established to reach this goal are to 1) create a partner program to give Science On a Sphere™ broader public exposure; 2) build an automatic, unattended mode of operation, synchronized sound, and application programming interfaces for automation control; and 3) develop the capability to prompt external audio-visual displays and streaming media.

Science On a Sphere™ was traditionally controlled through a user interface, and display products were selected by a mouse click. The SOS team investigated and developed a method for running the system unattended for long periods of time. The concept of "playlists" (a collection of visual displays) was employed to create an automatic play capability. After being loaded into the system, the playlist can automatically sequence through a specified number of visual displays to create an entire Science On a Sphere™ presentation. The system can be programmed to stop at the end of the playlist or loop through it forever. Combined with an automatic mode of operation, the playlist function allows Science On a Sphere™ to work well in a museum setting, where the system is started at the beginning of the day, run all day long, and shut down at the end of the day.

Audio Enhancements – Another important new feature is the ability to play audio streams that are coordinated and frame-synchronized to the media being shown on the sphere. Through part of the system, an audio file, such as an MP3 or WAV file, can be created independently and associated with display data to be shown on Science On a Sphere™. The playlist associates the audio file with a specific visual presentation, thus enabling the system to run soundtracks along with the visuals.

Automation Controls – Automation control systems, generally purchased from commercial vendors, are used by many museums and organizations to operate exhibits for public viewing. Sometimes called "show floor control systems," this technology is ideally used to automatically control functions such as turning lights on and off, opening doors, or starting video presentations. The show floor control system connects to the device to be controlled across a network, or through a serial line, and then sends commands to control a particular function, such as showing a new satellite display; however, many devices are generally controlled simultaneously by one system. Science On a Sphere™ now supports the standard protocols used by most commercial show floor control systems. This major advancement allows it to be operated with various remote control devices, such as touch screens, hand-held remotes, and other software applications.

External Triggers – The ability to display PowerPoint-created slides on external display devices was also added to Science On a Sphere™. The slides for a presentation are associated with media being shown on the sphere through the playlist. As the visualization is shown on the sphere, the system advances through the slides that are then displayed on a separate display device, such as a large plasma monitor or a series of LCD screens. This feature adds flexibility to the system and enables the enrichment of any particular presentation with additional, perhaps more detailed information about what is being displayed on the sphere.

Projections

As Science On a Sphere™ continues to evolve and mature, new partnerships will be formed through negotiations with museums, science centers, and other organizations. It is anticipated that FSL will contribute significant effort toward the support of Science On a Sphere™ at remote locations as more institutions sign on for the partner program. Planning and organization activities will continue in support of exhibitions of the system at scientific, educational, and other special venues.

New system development is proceeding toward software robustness, ease of use, increased sophistication in the treatment of audio, 3D graphics, and investigation of new technology. Future enhancements will include capabilities that make the system more useful for museums, for example, running the system nonstop in an unattended mode for 10–12 hours every day of the week. A kiosk-style or touch-screen interface will be investigated to provide public access to the interactive features of the system. The audio subsystem will be enhanced to provide tighter synchronization between the visualizations and the soundtracks. Increases in the power of 3D graphics hardware will enable new levels of interaction with the system. Another task is to determine if an MPEG-based video system can provide a viable, low-cost alternative to the data-driven version of Science On a Sphere™. High-definition video formats will be explored as an alternative to using the standard MPEG format.

Among the planned exhibitions in 2004, NOAA's Science On a Sphere™ is invited to participate at the G8 Summit Conference (8–10 June 2004, Sea Island, Georgia) to help demonstrate some of NOAA's Earth systems science at work.

NOAA and FSL will continue to cooperate in finding ways to maximize the usefulness of this powerful visualization system, and to enhance the partnership program to provide broader public exposure of NOAA's accomplishments and goals.

Central Weather Bureau of Taiwan Technology Transfer

Fanthune Moeng, Program Manager

Objectives

FSL's collaboration with the Central Weather Bureau (CWB) of Taiwan is a 14-year success story in technology transfer of weather forecasting applications. Since the approval of formal cooperative agreements in June 1990, the CWB-FSL partnership has grown to include major initiatives for improving CWB forecasting capabilities. Together they have developed a series of PC-based forecast workstations, the latest one – operational at the CWB Forecast Center – is the Weather Information and Nowcasting System (WINS II). Now incorporated into the CWB central facility, this system includes data sources, communication, preprocessing, and product generation. WINS II provides data and products to outside users such as the Civil Aeronautics Administration (CAA), universities, the Environmental Protection Agency (EPA), and the Taiwan Hydrology Bureau.

The strong forecasting infrastructure that has been built at CWB includes greater data collection, improved observation systems, high-performance computing, and management capabilities – all combining to empower CWB with new and more useful forecast products. CWB is positioned to take advantage of this infrastructure in new ways as more powerful techniques are developed within FSL and other NOAA laboratories. The effectiveness of the CWB-FSL cooperation is based in large part on CWB's willingness and ability to develop and use customized products with associated technical support. FSL's mandate to provide useful technologies fits with CWB's real-world forecasting needs.

Accomplishments

The goals to improve forecasting capabilities at CWB during 2003 involved three major areas:

- Local Analysis and Prediction System (LAPS)
- Forecast Assistant System (FAS)
- Continuing interaction on earlier cooperative projects.

Local Analysis and Prediction System – The latest LAPS software code for the MM5 Hot Start model was delivered to CWB's visiting scientist at FSL in late September 2003. This software, to be run on Linux PCs, will include the cloud and precipitation analysis package along with the MM5 model and Hot Start to focus on 0–12-hour forecasting. New datasets included visible and IR data from the GOES-9 satellite; more complete, consistent, and better quality surface data; and composite radar data with improved reflectivity quality control and velocity dealiasing. FSL staff continued to improve the real-time LAPS running on the CWB system in Taiwan, and provide support for the staff there on the daily running of the LAPS system.

Members of the LAPS group trained CWB visiting scientists, including two outstanding scientists who worked at FSL for almost six months in 2003 to help define Taiwan's radar quality control issues and diabatic heating from radar reflectivity. Significant contributions were made in defining cloud vertical motions and precipitation fall velocity and concentration, which improved LAPS cloud and precipitation analysis. This collaborative work (CWB-FSL) was published in the *Terrestrial Atmospheric and Oceanic Sciences Journal* in September 2003, titled "Precipitation simulation with Typhoon Sinlaku (2002) in Taiwan area using LAPS diabatic initialization for MM5." Figure 104 shows the latest LAPS product displayed on the CWB WINS II system. More detailed LAPS analysis information and online training materials can be found on Webpage *http://laps.fsl.noaa.gov/szoke/taiwan_lapstrainingpage.html.*

Forecast Assistant System – During 2003, FSL continued its general support of CWB's WINS II forecast system, and helped enhance its severe weather warning and forecast capabilities. In collaboration with the National Weather Service Meteorological Development Laboratory (MDL), FSL provided support in porting the System for Convection Analysis and Nowcasting (SCAN) to WINS II with an upgraded AWIPS Operational Build 2 (OB2). SCAN is an integrated suite of multisensor applications that detect, analyze, and monitor convection, and generates short-term probability forecasts and warning guidance for severe weather. The initial SCAN component includes a series of severe weather detection and prediction algorithms such as a 0–1-hour quantitative precipitation forecast (QPF) product. A scientist from Taiwan visited FSL for a half year to support the integration and configuration of the SCAN source code with AWIPS OB2. FSL and MDL also provided test data and scripts necessary to provide localization for use at CWB. Figure 91 shows preliminary SCAN products used on WINS II. The first display shows CZ radar data with overlays of three SCAN products. The second image shows a cell table in real time that forecasters use to review particular attributes of the identified storm cells. By clicking on a particular cell identifier, SCAN zooms in to the storm cell of interest so the forecaster can inspect details. The cell table attributes are ranked (color-coded and ordered) with respect to user-defined categories for each attribute. The time trend plots (small 2D plots) of the storm attributes are obtained by clicking on the table entry.

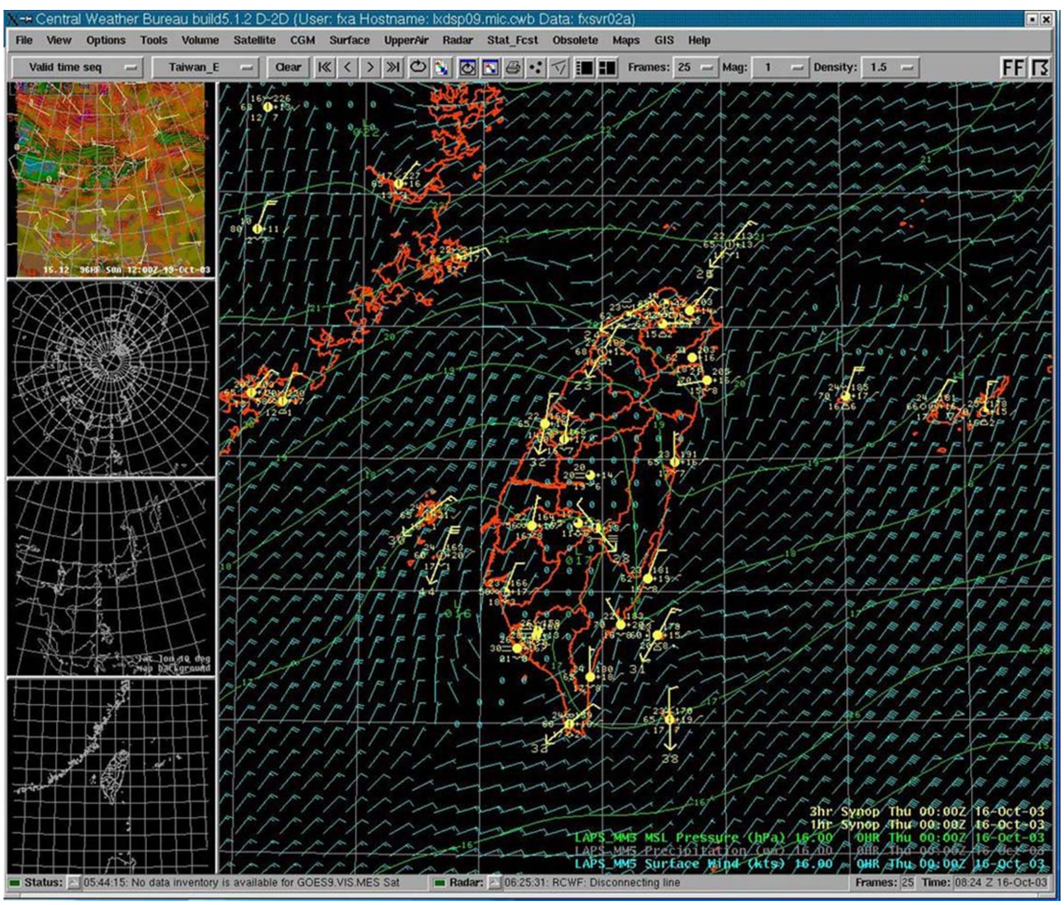
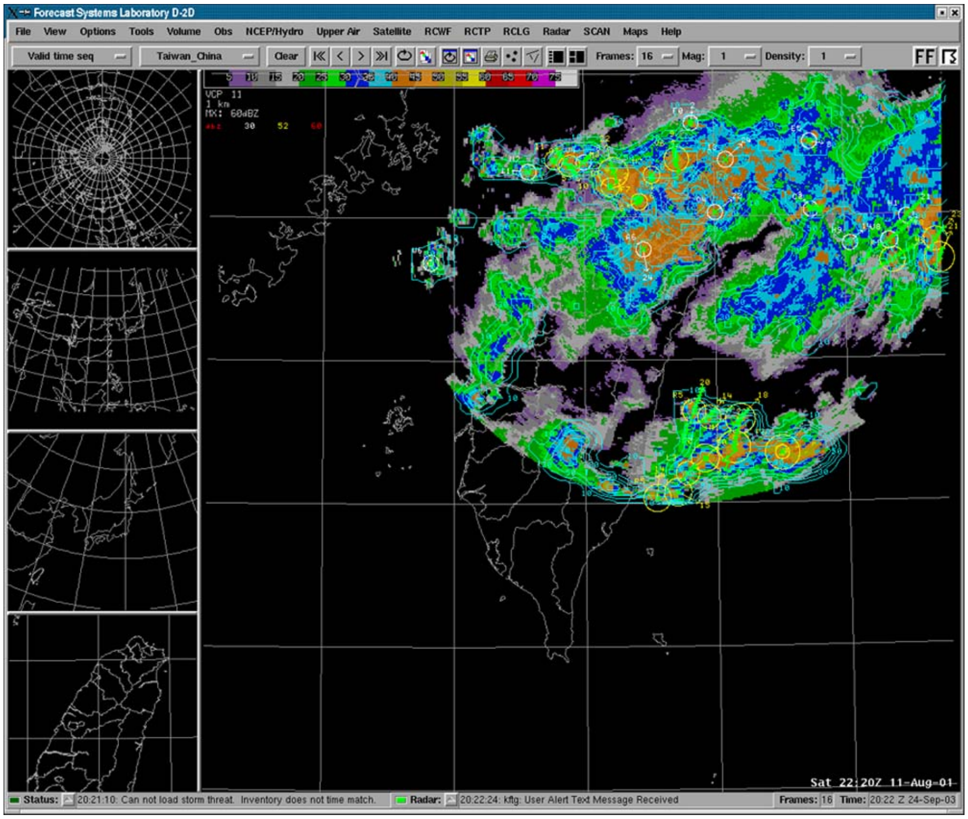


Figure 91. Central Weather Bureau's WINS II workstation user interface showing LAPS products.



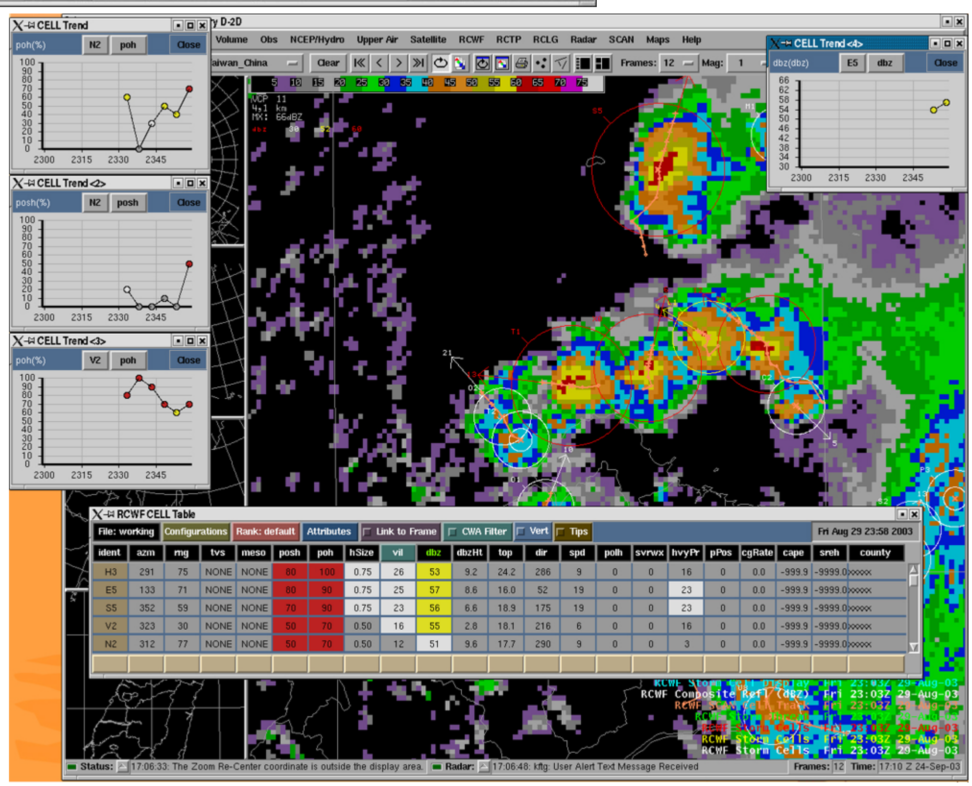


Figure 92. Central Weather Bureau's WINS II user interface showing: a, above) CZ radar data with overlays of three SCAN products: detected storm cells color-coded by intensity (red, yellow, and white circles); storm cell velocity vectors (green arrows, barely visible in this graphic); and 0–1 hour rainfall forecast, probability of rain exceeding 0.5 inch (light blue lines). b) a SCAN display of a storm cell table for forecaster inspection (see text on previous page).

FSL also provided FXC (FX-Collaborate) and D3D (Display 3D) software to the Central Weather Bureau for further evaluation and customization. Using the common AWIPS database, FXC provides collaborative features such as drawing tools, briefing tools, and Web access. Two FXC and D3D experts from FSL visited Taiwan last October to provide technical support to CWB forecast staff, including talks about design details and demonstrations for potential FXC users.

Interaction on Earlier Cooperative Projects – Several earlier projects between CWB and FSL involve continuing interaction. For example, last year the U.S. Government decided to move the GOES-9 satellite so it could cover the Asian area in support of weather service operations. In response, FSL provided satellite receiving hardware configuration information to CWB's Satellite Center. FSL also modified the GOES variable (GVAR) data system to provide CWB with the capability to ingest and process GOES-9 data prior to the critical typhoon season in 2003.

Projections

During 2004, the FSL-CWB team will focus on three ongoing tasks:

- Local Analysis and Prediction System (LAPS), which performs high-resolution analyses and provides short-range forecasts of the weather using both locally and centrally available meteorological observations.

- Continuation of enhancements to CWB's current forecast workstation, WINS II, including SCAN, which will provide short-range forecasts of precipitation from remote-sensor observations.

- Interactions on earlier cooperative projects.

LAPS – FSL will add additional background models as options for the LAPS analysis and the Hot Start MM5 run. Candidates for the background models are CWB's Global Forecast System (GFS), Typhoon Forecast System (TFS), and NFS with different resolutions. FSL and CWB will implement the existing LAPS Real-Time Verification System (LRTVS) to accommodate variables for the Hot Start MM5. The two MM5 groups will add a precipitation verification component, continue to improve the cloud analysis scheme, and provide support on ingesting new data sources such as GOES and GPS-IPW. FSL will establish a shadowing system of CWB's Hot Start MM5 at FSL. LAPS training and technical support will be provided when the LAPS Hot Start is running at CWB.

Enhancements to WINS II – Using statistical extrapolative techniques, FSL and CWB will collaborate to port an existing quantitative precipitation forecast system of short-range precipitation forecasts from remote-sensor observations. CWB technical support will be trained on the use of SCAN, Interactive Forecast Preparation System (IFPS), D3D, and FXC software customization, so that CWB can include these components as part of the WINS II system.

Interactions on Earlier Cooperative Projects – Technology continues to be transferred successfully from FSL to the Central Weather Bureau as a result of close interaction between the two organizations. FSL will continue to keep CWB staff updated on current developments, which will allow continued interaction at an appropriate level. Ongoing activities involve new software releases of the forecast information system, including the Internet-based forecast workstation, data assimilation, forecaster training, visitor exchanges, published papers/progress reports, and frequent e-mail interaction.

Korea Meteorological Administration Forecaster's Analysis System

Fanthune Moeng, Project Manager

Objectives

The Technology Outreach Division is under agreement with the Meteorological Research Institute (METRI) of the Korea Meteorological Administration (KMA) to design a nowcasting system based on FSL's WFO-Advanced meteorological system. The development of an integrated workstation, the Forecaster's Analysis System (FAS), is the capstone of years of modernization at the KMA to provide better weather information to its citizens. The cooperative effort will be carried out by researchers and engineers from both organizations.

Accomplishments

In meeting the goals to improve forecasting capabilities at KMA during 2003, four major tasks were completed:

- Development of nowcasting techniques
- Quality control and standardization of domestic remote sensing data
- Enhancement of the Forecaster's Analysis System (FAS)
- Automation of the Forecast Preparation System (AFPS)

Nowcasting Techniques – Initial nowcasting techniques are being developed for the Forecaster's Analysis System at KMA. These nowcasting techniques are based on the AWIPS System for the SCAN (Convection Analysis and Nowcasting) application with the ORPG (Open systems Radar Product Generator) algorithms, such as Storm Cell Identification and Tracking (SCIT), Composite Reflectivity (CZ), and Vertically Integrated Liquid (VIL). These algorithms are based on the centroid identification and a tracking technique that detects, analyzes, and monitors convection, and generates short-term forecasts and warnings for severe weather and flash floods. During 2003, FSL and the Meteorological Development Laboratory (MDL) delivered the AWIPS Operational Build 2 (OB2) to KMA visiting scientists. FSL, MDL, and the National Severe Storms Laboratory (NSSL) also provided KMA with the ORPG code and data simulator software applications, along with support for their installation. NSSL also provided a radar format conversion application for converting KMA's UF radar format to the NEXRAD format.

Data were ingested from the KMA radar (at Jindo, Korea) in UF format and run through ORPG to generate the radar products (mentioned above). These products are necessary to manually use the radar cell-tracking algorithms and port them to FAS. Visiting scientists from KMA worked with MDL and FSL staff to set up a proper working environment with the latest AWIPS OB2, and receive training and/or demonstrations on basic radar meteorology, FAS, SCAN, and ORPG. Staff from the National Weather Service and MDL also helped them to improve their programming skills related to the project.

Quality Control and Standardization of Domestic Remote Sensing Data – Another goal was to analyze and evaluate prospective radar quality control algorithms and develop a proposed scheme to resolve quality control problems at the KMA. This work, led by NSSL, involved examining quality control algorithms within ORPG and other NSSL-developed radar quality control algorithms. The QC-related ORPEG algorithms currently include Velocity Dealiasing, Radar Echo Classifier, and Data Quality Analysis, all of which are used operationally at each NEXRAD radar site. Other NSSL quality control components reviewed included ground clutter, AP removal, sea clutter, velocity dealiasing, point echoes, clear air echoes, line echo, and ring and disc-shaped echoes. When these analyses were completed, NSSL provided a comprehensive report that recommended a plan for KMA to implement its Data Quality System for 2004–2005 and address its radar quality control problems.

A visiting scientist from KMA studied the basic NEXRAD components (radar data application, radar product generator, and principal user processor), as well as numerous radar meteorology and conference proceedings from a recent American Meteorological Society Radar Meteorology Conference. This scientist visited NSSL for two weeks in May and again in November to learn the whole suite of quality control algorithms at NSSL. FSL received other software from NSSL, including the ORPG quality control algorithms, ORPG data simulator, UF format decorder, and additional software scripts and instruction. The visitor applied this evaluation software to analyze KMA radar. The proposed ORPG platform could integrate additional quality control algorithms, including others from NSSL.

FAS Enhancement – FSL provided KMA with periodic upgrades to the Forecaster's Analysis System along with new AWIPS OB releases, products, capabilities, and software. FSL released AWIPS OB2 to KMA to enhance FAS operational capability. Currently, a modified version of the 5.2.2 version of AWIPS is running on the system. FSL also provided technical support to KMA on localization and configuration, and other specific areas such as latitude and longitude lines on the map background, and a new GOES data display. FSL staff supported KMA in the installation and configuration of new AWIPS OB2 software for FAS enhancement work.

FSL hosted a training session for eight KMA senior forecasters at FSL in October 2003, which included an overview of FSL and an introduction and/or demonstration of the Graphical Forecast Editor, MSAS (Mesoscale Surface Assimilation System) quality control, LAPS, SCAN, Flash Flood Monitoring and Prediction (FFMP), Wind Profiler, Doppler radar meteorology, GPS network, hydrological applications, and satellite meteorology. The trainees also toured the National Center for Atmospheric Research (NCAR) and the Space Environment Center (SEC), and participated in FSL's daily weather briefings.

Automation of the Forecast Preparation System – KMA will benefit from incorporation of the Automation of Forecast Preparation System (AFPS), based on the AWIPS Graphical Forecast Editor (GFE) application, which is used by NWS forecasters to improve the efficiency of generating gridded forecasts. AFPS will minimize forecast preparation time and maximize the forecaster’s ability to interact with the digital forecast database. A KMA visiting scientist installed and configured the GFESuite for evaluation on a local development workstation, and participated in the GFE user training. This visitor also studied the GFE software documentation and training guide, and investigated a proposed Korean menu for GFE and facsimile capability (within GFE or FAS), and Python software for GFE smart tool algorithms. Other KMA senior managers also visited FSL for coordination purposes. An important aspect of this project is publishing articles related to the KMA-FSL project. Two KMA visitors published papers for the 2003 Annual American Meteorological Society Meeting. One presented a paper titled "FAS: An International Version of AWIPS" detailing the successful implementation of the Forecaster's Analysis System at KMA, and the other presented a paper titled "Application of the SCIT Algorithms to South Korea Storm Data." Figure 93 shows one storm case observed by Jindo, Korea, radar and Figure 94 is the SCIT tracking results from the case study presented in this paper.

Projections

During 2004, FSL will collaborate with the KMA project team on three tasks:

- Development of nowcasting technique
- QC and standardization of domestic remote sensing data
- Further enhancement of the Forecaster’s Analysis System (FAS).

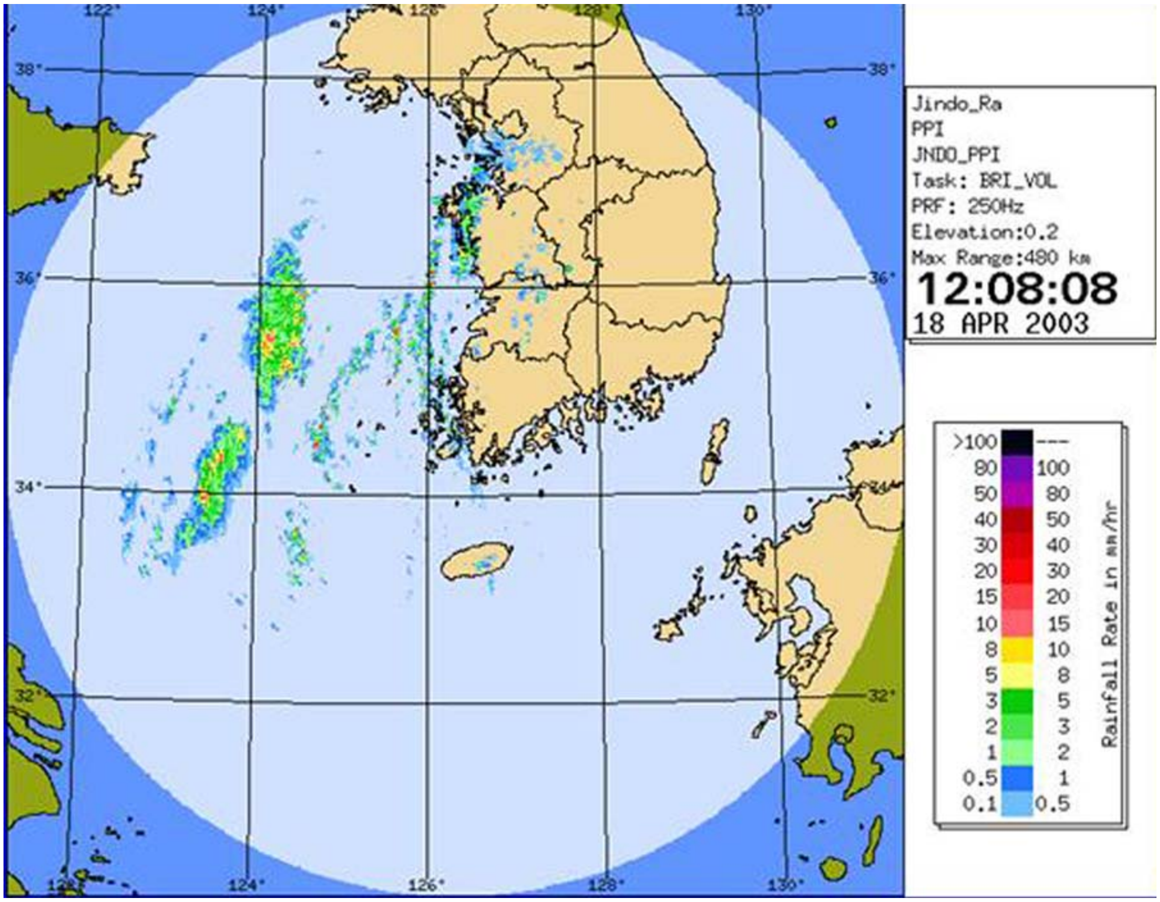


Figure 93. Storm data observation by radar at Jindo, Korea, used in a case for applying SCIT algorithms to Korea storm data (collected once every hour).

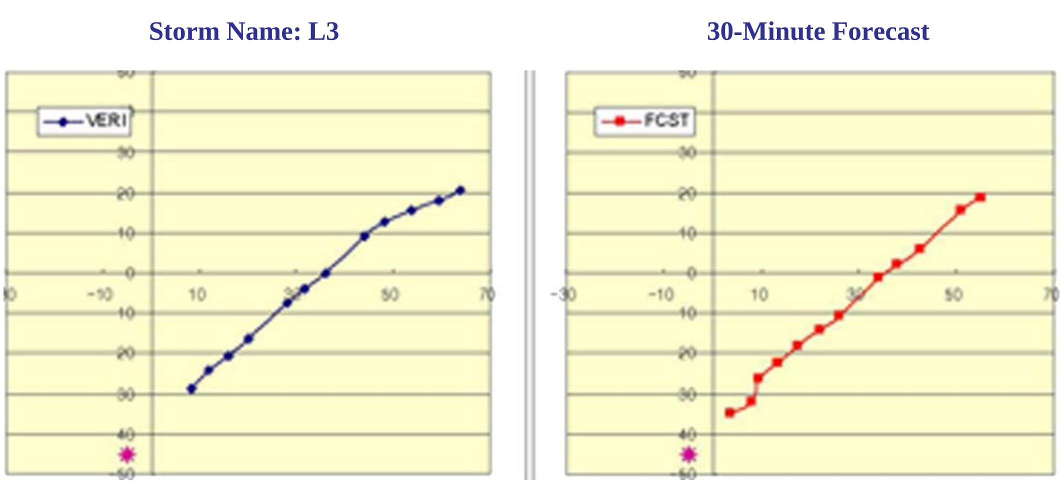


Figure 94. Storm tracking information computed from ORPG algorithms.

Development of Nowcasting Technique – FSL and KMA will port SCAN code into FAS and get ready for a trial operation test. The SCAN components will have a series of operations including storm detection and prediction algorithms plus data integration techniques for KMA forecasters to use during severe weather warning operations. FSL and the Meteorological Development Laboratory will also provide SCAN training and technical support on the testing and validation of SCAN.

Quality Control and Standardization of Domestic Remote Sensing Data – FSL, NSSL, and KMA will begin to design and develop the initial KMA Data Quality System. Candidate algorithms will maintain the components and coding from ORPG, NSSL radar quality control algorithms, and other algorithms that will best address KMA's quality control needs. FSL and NSSL will make available a preliminary KMA Data Quality System based on sample data and QC software that will undergo initial testing at FSL and NSSL, and provide it to KMA personnel to test on KMA's operational radar.

FAS Enhancement – FSL will continue to provide technical support on FAS evaluation and improvement, periodic upgrades to AWIPS Operational Build 3 or 4 (with new product display tools for cold and warm fronts), and system modification to meet KMA's forecast system requirements.

Hong Kong Observatory LAPS Training Program

Fanthune Moeng, Project Manager

Objectives

FSL is under agreement to collaborate with the Hong Kong Observatory (HKO) to provide it with specific weather services:

- In-depth training on the design and implementation of FSL's Local Analysis and Prediction System (LAPS). A frequently updated local-scale analysis scheme will be set up to run operationally at HKO in support of nowcasting systems and NWP models.

- Advance the scientific knowledge and skills of the HKO forecast system developers in data assimilation.

- Enhance analysis and forecast systems management at the HKO.

Accomplishments

During 2003, FSL provided a visiting scientist from HKO with a 10-week training program at FSL that emphasized:

- *Data Ingestion* – Details about the ingestion of various observations into LAPS, especially the satellite (geostationary and polar orbiting) data.

- *Data Analysis* – Details of the analysis methods used in LAPS including successive correction and variational analysis. Implementation of these methods in LAPS, in particular the cloud forward model and balance scheme.

- *WIAP Analysis* – Details of the "Water In All Phases" (WIAP) analysis for initializing model forecast in a "Hot Start" mode.

- *Model Interface* – Details on ways to develop interfaces to connect LAPS analyses with nonhydrostatic models, such as WRF.

Projections

This project was completed in 2003.

FX-Net Program

Sher Schranz, Project Manager

Objectives

The FX-Net program 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, dialup, and dedicated line use. The system consists of an AWIPS data server, an FX-Net computer file server, and a PC client. In the case of a completely redundant system, a load balancer is also part of the system. The FX-Net server, a modified AWIPS workstation, is locally mounted next to the AWIPS data server via a high-speed link. The FX-Net client sends 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 features related to functionality 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 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.

Data are received by the FX-Net data server through the AWIPS NOAAPORT broadcast, FTP servers, and LDM data feeds. The available FX-Net products are categorized into four groups: satellite imagery, model graphics and observations, radar imagery, and model imagery. A wavelet transform technique 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 is further minimized by pregenerating and compressing all satellite data on the FX-Net server. 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.

Accomplishments

The FX-Net team worked very hard during 2003 to continue to improve the FX-Net system through the addition of new data and features. Though this was a year of significant changes in management and technical personnel, we were still able to maintain system reliability and add new tools and data to FX-Net on schedule. Exciting new datasets were added such as GPS integrated precipitable water vapor (GPS-IPW), Cooperative Agency Profilers (CAPs), and air quality datasets. One of these new datasets, GPS-IPW, overlaid on a GOES-IR in a water vapor image, is shown in Figure 95. New tools were also added to enhance the forecasters' presentation capability.

Air Quality Programs – FX-Net has supported the AIRMAP (Atmospheric Investigations, Regional Monitoring, Analysis, and Prediction) program for the last few years. As a newly established Cooperative Institute between the University of New Hampshire (UNH) and NOAA, this program focuses on the long-term monitoring and forecasting of air quality parameters such as 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. Research has found that 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 workstation such as FX-Net is 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.

Additional air quality observation data were added to the FX-Net system in 2003. The FX-Net Air Quality (FX-Net/AQ) datasets include six parameters (O_3, CO, NO, NO_y, SO_2, and condensation particles), which are continuously measured at three UNH sites (Mount Washington, Castle in the Clouds, and Thompson Farm) located in New Hampshire. FX-Net/AQ users also have access to all of the CAP data from wind profilers installed around the U.S. by many organizations such as the Environmental Protection Agency (EPA) and state and local air quality agencies. FX-Net ingests data from the EPA's AIRNOW program, including 1-hour averages of ozone, Particulate Matter-Fine (PM 2.5), and Particulate Matter-Coarse (PM 10). (An FX-Net display of a WRF/Chem ozone forecast and air quality surface observations is shown in Figure 96.) In addition, the rich MADIS (Meteorological Assimilation and Data Ingest System) dataset is also ingested. MADIS contains observations not offered through the AWIPS NOAAPORT

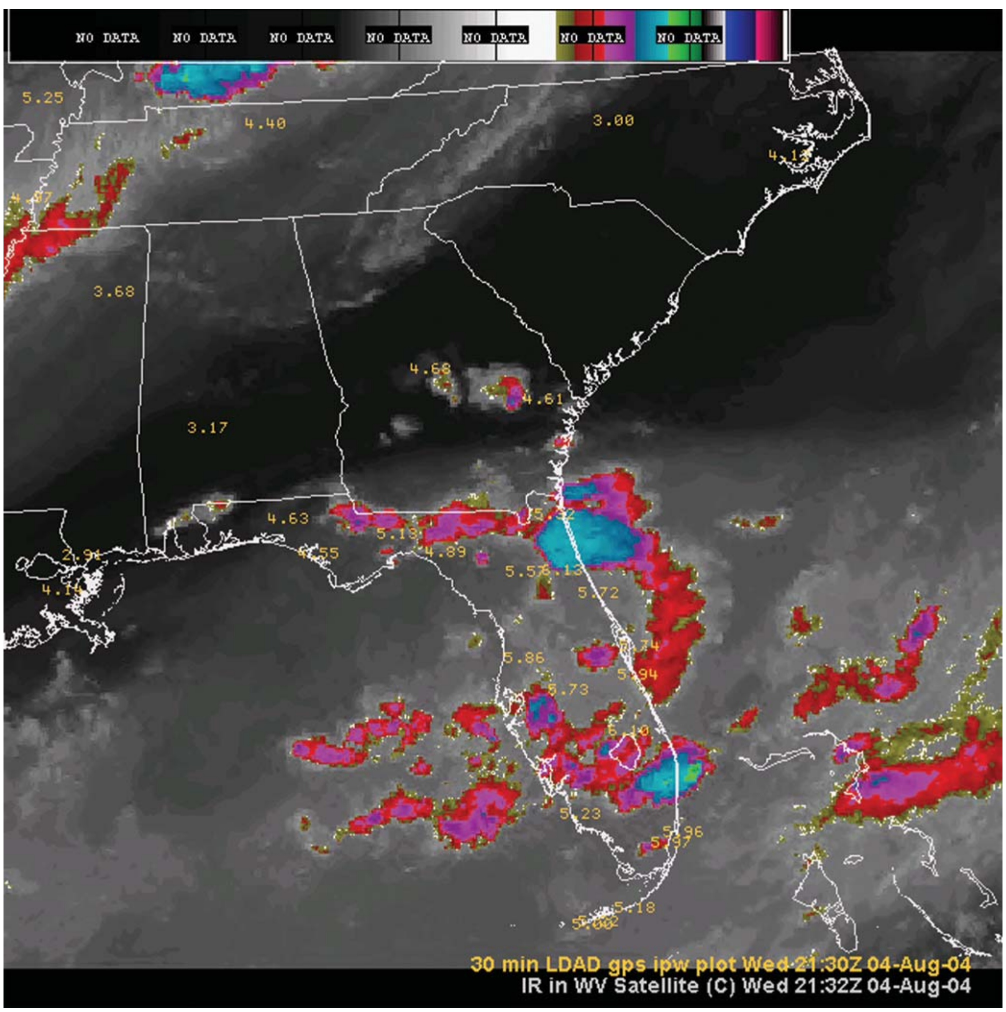


Figure 95. GOES IR in Water Vapor image overlaid with a convective outlook graphic and local data plot.

broadcast (such as MesoWest and GPS-IPW data). Air quality forecasters in the Mid-Atlantic Regional Air Quality Management Association area began an assessment of FX-Net as a complete real-time air quality forecasting workstation.

Fire Weather Projects – The National Interagency Fire Center (NIFC) requested that FX-Net be modified for its use as the primary real-time meteorological workstation by fire weather forecasters at NIFC and at the Geographic Area Coordination Centers (GACC). The 2001 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 FSL. This experimental use of FX-Net led to its operational use during the 2003 season during which the system performed very reliably with no data or system outages.In addition to providing critical support to the NIFC and GACC forecasters, the FX-Net team delivered a new and improved FX-Net client. One of the important services that these forecasters provide to coordinators at the fire control centers is a daily weather briefing. To enhance their presentation capabilities, a selective density function was added to control the displayed density of observations and model contours. Users can now select the line thickness for individual model contours, along with the existing capability to change contour colors.

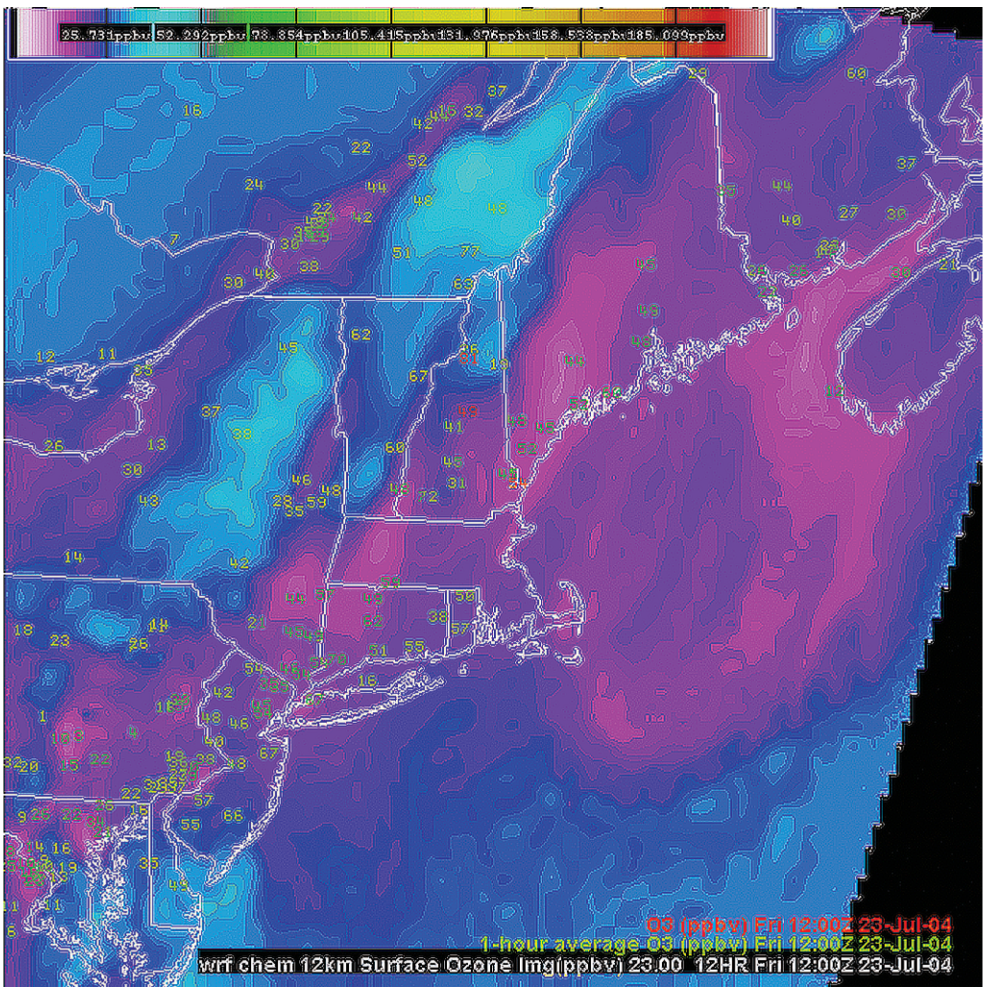


Figure 96. FX-Net display of a WRF/Chem ozone forecast and air quality surface observations.

During the 2003 fire season, another very important project was completed: FX-Net server systems were installed in four of the National Weather Service Regional Headquarters. Incident Meteorologists (IMETS) and remote area forecasters in the Western, Southern, Alaska, and Pacific regions became real-time FX-Net users. During a very active wildfire season, the Western Region deployed IMETS (Figure 97) to fire sites across the United States. At one point there were 32 IMETS in the field using FX-Net as their primary forecasting system. FX-Net was used over a variety of communications systems ranging from two-way satellite phones to low-bandwidth dial-up lines. The requirement that the system support any type of communication link at any speed was validated during its rigorous use in this fire season**.**

FX-Net proved to be a critical component for the fire management team struggling to save lives and control the fires in California last fall. The Chief of the Meteorological Services Division at the NWS Western Region Headquarters in Salt Lake City, Utah, and others gave FX-Net high marks for improving firefighter safety. For example, the MSD Chief stated that the real-time wind and radar data display capability was incredibly critical to the fire management team's efforts to get fire fighters in the right position on the fire line and in moving people out of harm's way.

Projections

University and Research – During 2004, the FX-Net team will continue to operate and maintain a system to support university meteorology classes and meteorological research at Plymouth State University in New Hampshire, University of New Hampshire, and the University of Northern Iowa. FX-Net will support the summer 2004 New England Air Quality Study (NEAQS) field experiment, with the WRF/Chem model added to the system.

Real-time Air Quality Forecast Workstation – The FX-Net team will focus more on adding products, such as NWS operational air quality model grids (CMAQ), and more datasets from the EPA AIRNOW program to support real-time air quality forecasting.

Fire Weather Forecasting – The FX-Net team will continue to support NIFC and 11 GACC offices while using the system as their primary meteorological workstation to support fire weather forecasters. A new FX-Net client will be delivered to all these offices in late 2004.

NWS: Western, Southern, Alaska, and Pacific Regions – FSL will deliver upgraded data servers, new security software, NOAAPORT broadcast changes, and an upgraded FX-Net client to the offices of these NWS regional headquarters that already have FX-Net. The FX-Net team will improve the interface tools, datasets, and reliability.

Figure 97. NWS Incident Meteorologist briefing a Fire Coordinator using FX-Net during the 2003 California fires.

Wavelet Data Compression Project

Sher Schranz, Project Manager

Objectives

The Wavelet Data Compression Project was established after an experimental wavelet data compression technique was successfully applied to satellite imagery. Compared to imagery datasets, gridded numerical weather prediction datasets usually have higher numbers of dimensions, but each dimension is much smaller in size. Therefore, special treatments are needed to exploit the correlation to all dimensions. A multidimensional data arrangement and transform scheme have 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 wavelets and different post transform compression algorithms.

Accomplishments

A primary objective in 2003 was to test the wavelet compression technology as applied to gridded meteorological datasets. The the existing wavelet compression code was optimized to achieve higher compression ratios and faster code execution. The wavelet data compression technique is used in the Internet-based FX-Net meteorological workstation and in a project with the Cooperative Institute for Research in the Atmosphere (CIRA); National Environmental Satellite, Data, and Information Service (NESDIS); and the Office of Oceanic and Atmospheric Research (OAR) Hurricane Research Division (HRD) to transmit real-time satellite data to NOAA WP-3 aircraft.

Image Compression for NOAA/NESDIS – NOAA's two WP-3 aircraft are the primary tools for the annual hurricane field program conducted by the NOAA HRD. The WP-3s do not have the capability to display or animate current satellite imagery because of their limited bandwidth communication systems. Since this capability would significantly aid many of the WP-3 research and operational missions, a demonstration project was undertaken during the 2002 and 2003 hurricane seasons to display and animate real-time GOES satellite data aboard the aircraft. (Figure 98a shows an original GOES VIS image and then the same image (98b) compressed at 20:1 Wavelet Compression.) The demonstration sought to take advantage of cell-phone and Internet communication technologies coupled with advances in FSL's wavelet data compression technique. The available bandwidth aboard the aircraft was increased to 2400 baud for the experiment. The compression technique used was evaluated on the basis of the need for high compression ratios and image quality. Though the JPEG format is a commonly available image compression technique, it achieves the compression needed for this project, but the fidelity of the decoded image is less than satisfactory for this application. The images decoded from the wavelet data compression technique show an ever-decreasing degree of higher frequency detail with an increasing compression ratio. However, the resulting images are still superior to the JPEG image, consisting of a larger file size.

Gridded Data Compression Comparisons – Tests compared precision controlled wavelet compression to several other compression techniques. The goal of the comparisons was to determine the percentage of bandwidth used by each technique. As shown in Table 1, the wavelet compression reduced the size of the gridded files enough to shrink bandwidth usage 8–15% of that used by gridded datasets compressed using the GRIB1 technique. This implies that for a typical model output sized at 12 GB, if transmitted over a 1-Mbps communication channel, the transmission time can be reduced from about 2.8 hours to about half an hour. Figure 99 shows an original psuedo color image of an Eta-12 temperature field, and then shows the same temperature field wavelet compressed at a 50:1 ratio. For comparison, look in the circle placed in the same location on both images.

Table 1. Bandwidth Usage

CompressionTechnique	Bandwidth Usage (% of GRIB1)
GRIB1	100%
2D/Round/Difference/BZIP2	31%
Wavelet ("lossless,"*quantization, error grid)	8% to 15%

* "lossless" is lossless with respect to GRIB1's current rounding level

Projections

During 2004, the focus of the Wavelet Data Compression project will cover two areas of research. First, data transmission techniques will be developed to utilize an imbedded wavelet compression that is applied to images and gridded datasets. A new file- sharing and distribution system based on this technique will be proposed to facilitate the efficient dissemination of model output data to a large number of remote users. Second, spline wavelet functions will be applied over a localized, very dense observing area to improve data analysis. With improved aviation forecasts as the goal, better analysis of these dense data corridors may allow for enhanced numerical model data assimilation. Additional improvements to the aviation forecasts will be investigated by applying continuous wavelet analysis to the airborne observations to better understand the interaction between gravity waves and turbulence.

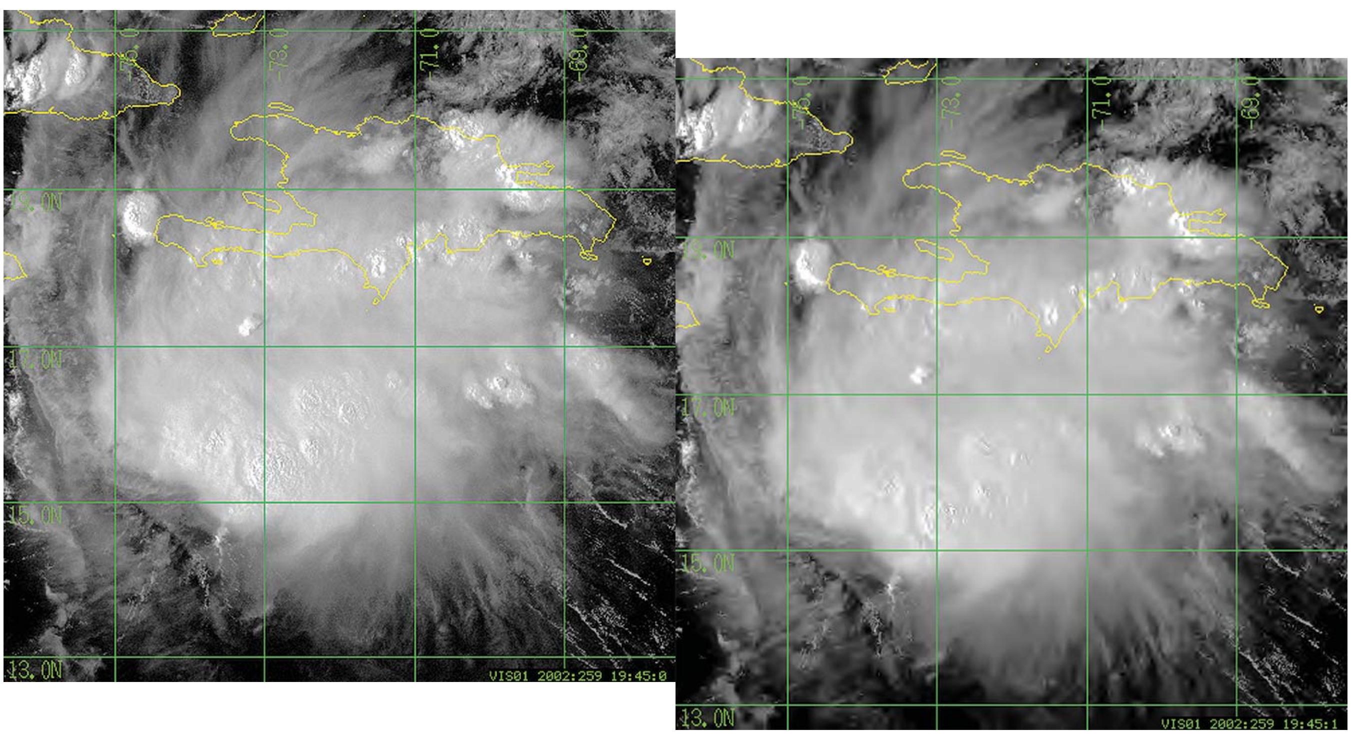


Figure 98. a, left) Original GOES VIS image, b, right) same image compressed at 20.1 using Wavelet Compression.

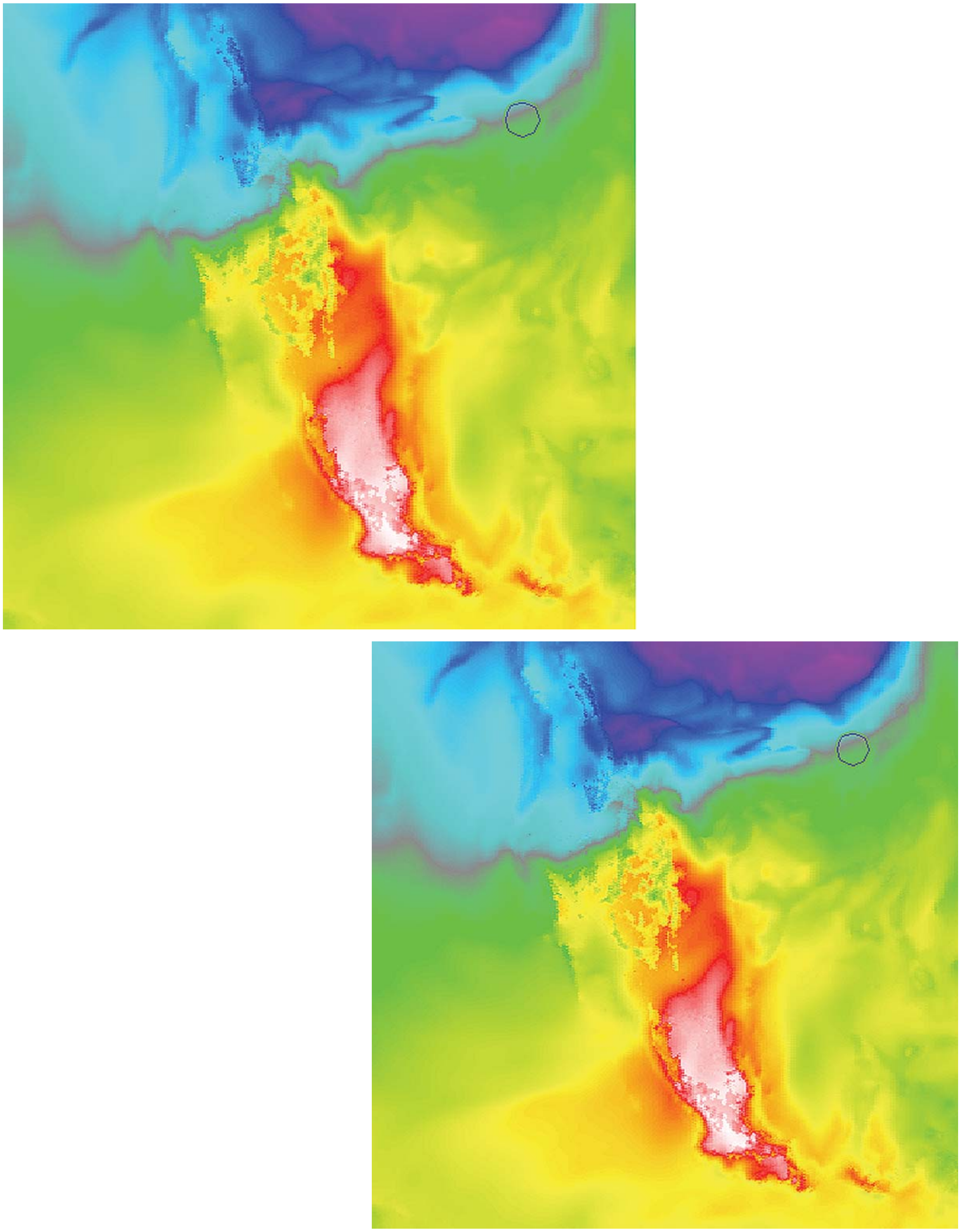


Figure 99. Eta-12 temperature field a) at 850 mb, original; b) same temperature field with 50:1 compression.

Nita Fullerton, Writer-Editor/Publications Coordinator

Special Notices

Publications

As the number of projects at FSL increases, so does the length of this report. To keep publishing costs at a minimum, individual bibliographies of published articles during the past year are no longer printed in this document. A current list of FSL publications is available at the main FSL Website, *http://www.fsl.noaa.gov;* click on "Publications" and then "Research Articles."

Acronyms

A current list of acronyms and terms related to projects and programs at FSL is available at Webpage *http://www.fsl.noaa.gov;* click on "Publications" and then "*FSL in Review, 2003-2004*."

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Figures

One last measure to limit the length of this report is to discontinue listing figures at the back.