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Message from the Acting Director

Forecast Systems Laboratory Director Alexander E. MacDonald has been on assignment at NOAA Research Headquarters for five of the first seven months of 2003, and so the pleasant duty of highlighting some of FSL's recent accomplishments falls to me as Acting Director.

FSL strives for excellence in four major areas: 1) bringing new atmospheric observing systems to maturity, 2) developing and improving regional mesoscale models for detailed weather predictions, 3) investigating parallel computer architectures as a vehicle for handling the huge computational demands of environmental models, and 4) developing environmental information systems for a variety of customers, within NOAA and outside.

In the past year, FSL continued to gather atmospheric observations from disparate sources in the service of local forecasting and regional modeling. For example, the number of Cooperative Agency Profilers, most of them sampling the boundary layer, has grown to over 60. The number of ground-based GPS sites estimating total column water vapor now exceeds 200. More than 5,000 new surface mesonet observations have been added to the FSL hourly collection. After performing quality control checks, FSL forwards all these data to the National Centers for Environmental Prediction (NCEP) for use in operational models.

FSL is developing plans for a global observing system with major in situ components that can settle the controversy about long-term tropospheric warming, monitor natural and anthropogenic atmospheric constituents, and sample the ocean depths. This system would meet requirements for climate monitoring and prediction and also provide much needed calibration of satellite observations in remote locations. The first phase of this program, called "Pacific Plus," would employ a combination of unpiloted aircraft, altitude-controlled balloons, and ocean buoys to sound the atmosphere and water across the length and breadth of the Pacific.

Gauging the contributions of various observing systems to forecast accuracy is an important activity. FSL recently completed the modeling and computing infrastructure for performing such impact tests. Because commercial airlines, which supply nearly 100,000 temperature and wind reports per day, are financially strapped, and the continuity of the NOAA Profiling Network is threatened, FSL conducted special impact tests, demonstrating that aircraft and profilers each contributes substantially to forecast accuracy and that these data are highly complementary.

Several FSL accomplishments in modeling are noteworthy. Three-dimensional variational analysis became operational in the 20-km version of the Rapid Update Cycle in May 2003. This opens the door to assimilation of many new sources of observations that were previously difficult to accommodate. A Developmental Test Center is being established in Boulder. FSL, NCAR, and NCEP will contribute staff and share computing resources. The initial focus of the Test Center will be on the development of the Weather Research and Forecasting Model, destined to become both an operational model and a research vehicle for the larger modeling community. The Federal Highway Administration supported a collaborative effort between FSL and NCAR to field test a model-based system for snow plow operators that helps them decide when to plow and what chemicals to spread on the road surface. This Maintenance and Decision Support System was successfully tested in Iowa in February and March 2003.

In November 2002, FSL accepted a major upgrade to its high-performance computing system,comprising 768 nodes with dual Intel Pentium processors rated at 2.2 Ghz. Also during that month, it was ranked #8 on the Top500 List of the World's Fastest Computers, and now serves more than two dozen external users representing most of the line offices within NOAA.

Capitalizing on major development work at FSL, the National Weather Service began installing two Linux-based workstations at each of its Weather Forecast Offices around the country in January 2002. Eventually these workstations will replace the Hewlett-Packard hardware which inaugurated the Advanced Weather Interactive Processing System (AWIPS) era. The highly robust Linux was developed in an open-source environment and runs on nonproprietary hardware.

FSL developed the FX-Net workstation as a low-cost alternative to AWIPS workstations. FX-Net can deliver fairly large datasets primarily because of wavelet compression techniques developed in-house. FX-Net has become the workstation of choice of the National Interagency Fire Center in Boise, Idaho, and at 11 Geographic Area Coordination Centers throughout the country. Meteorologists used FX-Net close to home last summer in fighting Colorado wildfires during an unprecedented drought.

NOAA Science On a Sphere (SOS)™ received major exposure during the past year. SOS is a powerful educational tool for projecting geophysical, other planetary, solar, or lunar data onto a sphere. The current prototypes are 5–6 feet in diameter. First field tested with hundreds of students and their parents at the Broomfield Heights Middle School last summer, SOS has since been an attraction at the annual meeting of the American Meteorological Society in Long Beach, California, the NOAA Science Center in Silver Spring, Maryland, and, most recently, at the National Cable and Telecommunication Association meeting in Chicago, Illinois.

For more information on the above items and many more, I hope you will browse through the following pages. We are eager to share with you our contributions toward NOAA research and technology transfer.

T. W. Schlatter

Thomas W. Schlatter
Acting Director

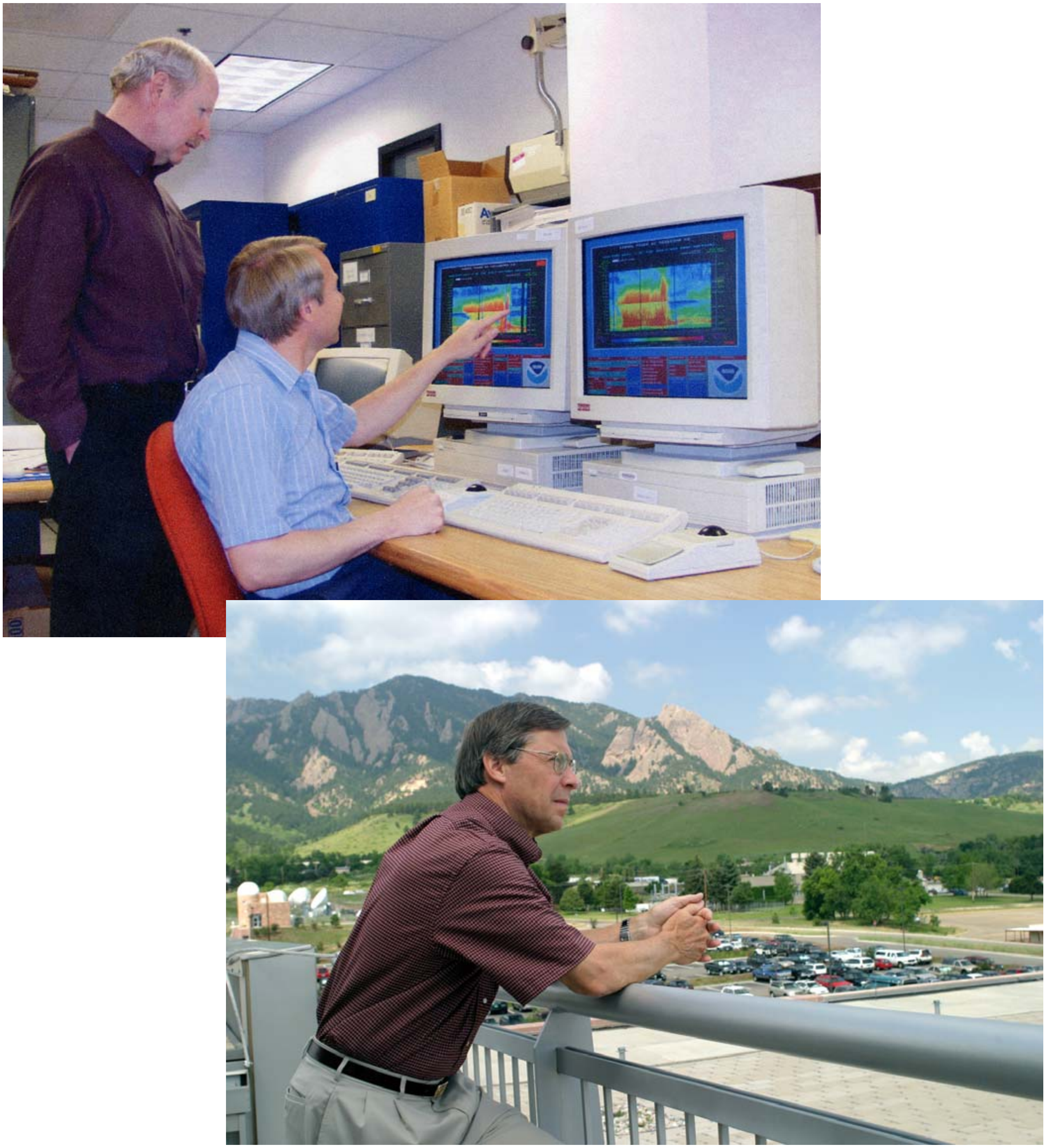

Figure 1. (above) Sandy MacDonald and Doug van de Kamp viewing output from the NOAA Profiler system and (below) Tom Schlatter checking out the weather at the FSL observatory. *(NOAA Photos by Will von Dauster, FSL.)*

NOAA Science On a Sphere™ Project

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Objectives

One of NOAA's goals is to establish an environmental literacy program for educating present and future generations about the changing Earth and its processes. Science On a Sphere™, a new concept by FSL Director Dr. Sandy MacDonald, is a NOAA program to develop a revolutionary system for educating the public on the holistic nature of Earth's ever-changing oceans, atmosphere, biology, and land. Science On a Sphere™ presents NOAA's global science in a new and exciting way by providing an engaging three-dimensional representation of our planet as if the viewer were looking at the Earth from outer space. The system uses a bank of computers coupled with video projectors to display animated geophysical and atmospheric information onto the outside of a large, opaque sphere (Figure 2). People move freely around the suspended sphere to view the scientific images as a speaker provides an interpretation of the images and the processes being observed. Some of the early and most popular images include a day-to-night rotation of the Earth, using high-resolution topography for the daylight side, and DMSP (Defense Meteorological Satellite Program) night light data on the dark side of the planet; global infrared weather images compiled from a series of geostationary meteorological satellites; weather prediction model output; climate change simulations; 600 million years of plate tectonics; the Sun as seen by the GOES X-Ray Imager; and the surfaces of the Moon and Mars.

Nearly any global data can be displayed on Science On a Sphere™, including the weather, climate, geology, images of solar system bodies, or any type of geographical information that covers a large portion of a planet's surface. NOAA's mission to understand and predict changes in the Earth's environment can derive special benefit from the ability to present its data with a geometry that corresponds to that chosen by nature. In many ways, Science On a Sphere™ 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.

Figure 2. Students at two different locations, Washington, D.C. (left) and Broomfield, CO (right), learning about Science On a Sphere™. *(NOAA photos by Will von Dauster, FSL.)*

Accomplishments

Development of Science On a Sphere™ has proceeded in phases at FSL for the past two years. Phase 0 was a proof of concept that demonstrated the idea of using computer technology, video projectors, and a large white sphere to create the illusion of a planet rotating in space. Phase 1 built on and improved the underlying concept to create striking, animated images of the Earth's atmosphere, land, and oceans. Phase 2 development of Science On a Sphere™ is proceeding and will produce a mature, robust visualization system that can be made commercially available for educational and scientific use across NOAA, K–12 schools, museums, science centers, and other public venues. A patent application for Science On a Sphere™ has been submitted on behalf of NOAA.

The initial Phase 0 prototype was developed in the summer and fall of 2001, using an Apple G4 with four video cards, low-end video projectors, and an acrylic sphere. The system had limitations in terms of resolution (400 x 400 pixel imagery) and a low video frame rate, along with deficiencies related to mapping and synchronization of the images on the sphere. However, even with these limitations, the visualizations and overall concept convinced other NOAA organizations to invest in the project. The Office of Oceanic and Atmospheric Research (OAR); National Weather Service (NWS); National Environmental Satellite, Data, and Information Service (NESDIS); and National Polar Orbiter Environmental Satellite System (NPOESS) provided resources to support the next development stage of Science On a Sphere™. NESDIS gave additional help and played an important role by providing a freestanding suspension structure for the sphere, significant support for dataset creation, and indispensable aid in planning and logistics for conferences and remote events.

The goals during Phase 1 development were to improve the system by 1) creating additional media sets to display on the sphere; 2) increasing the pixel resolution used by the display system; 3) improving the focus, convergence, and overall quality of the projected imagery; 4) creating a user interface to control the system; and 5) developing more portable and scalable construction techniques for the sphere itself. All of these goals were achieved to a large extent by December 2002.

Phase 1 development culminated in a series of presentations and remote events, starting with a week-long educational workshop at Broomfield Heights Middle School (near Boulder) in October 2002 to test the idea: "Can Science On a Sphere™ be used as a teaching tool?" The system was set up in a science classroom at the school, and for one week, nearly 500 students (some future scientists, no doubt) were led through exercises in atmospheric science, geography, and other earth science disciplines. The reactions from the students during the teaching exercises were fascinating to observe. They voiced their surprise to see the Earth and other planets at this scale and were very responsive in the classroom exercises. Some students were so influenced by the presentations and lessons that they were still discussing science at lunchtime in the cafeteria, a rare event according to one teacher. Parents attending parent/teacher conferences saw the sphere in the evening as enthusiastic students showed them what they were learning in science class.

In December 2002, Science On a Sphere™ was at the NOAA Science Center in Silver Spring, Maryland, for presentations to NOAA staff and management. Various NOAA groups participating in the program were excited with the prospect of displaying new NOAA data from their own group on the sphere. Science On a Sphere™ was exhibited at the Annual Meeting of the American Meteorological Society in Long Beach, California, where FSL hosted nearly 2,000 participants from the general public and the scientific community during the week-long conference. Overall comments and audience reactions were very positive, with the more common response that this is a dramatic way of looking at the geographic and atmospheric processes of our planet and conveying that information to the viewer.

Most recently, Science On a Sphere™ was shown at the Department of Commerce's Hoover Building in Washington, D.C., (Figure 3) as part of the national program, "Excellence in Science, Technology, and Mathematics Education Week."

Figure 3. NOAA Administrator Vice Admiral Lautenbacher (top) presenting NOAA's Science On a Sphere™ at the Herbert C. Hoover building in Washington, D.C., and Sandy MacDonald leading a demonstration.
NOAA Photos by Will von Dauster, FSL.

Projections

The next development phase during 2003 will involve creating an "industry-ready" system that can be made available commercially through a technology transfer mechanism. Two versions of Science On a Sphere™ will be created. The version suitable for use in schools will comprise a smaller sphere, lower-end computers, and less expensive display technology. The other version, a higher-end system, suitable for museums, conferences, and scientific institutions will have a corresponding increase in sophistication in terms of overall appearance, computing power, and projection technology. Additional features planned for implementation during Phase 2 development include:

- *Annotation* – Provide the ability to draw markers and place text over data being displayed on the sphere.

- *Simplified System Architecture* – Investigate and implement more compact computers and technology, along with a lighter and easier to assemble display structure, to facilitate setup and reduce the cost of transporting and assembling Science On a Sphere™ for conferences, workshops, and schools.

- *Documentation* – Create technical documentation and a user manual describing the operation and use of Science On a Sphere™.

- *Display Preparation Package* – Develop and provide a software package to convert scientific data to an SOS-ready format. Provide documentation on SOS data format.

- *Real-Time Data Ingest* – Provide for real-time data ingest for a limited set of NOAA satellite and model data products and develop an automatic way of distributing Science On a Sphere™ ready images from a central facility to remote Science On a Sphere™ sites.

- *Unattended Operational Mode* – Build the capability for Science On a Sphere™ to run in an unattended mode for public display, featuring automatic loading of data with synchronized audio narration.

- *Pole Rotation* – Add the ability to display the Earth or other planets at arbitrary angles of rotation. This feature includes the ability to rotate the Earth so that the poles can be displayed anywhere on the sphere for easier viewing and data exploration.

The continued success of NOAA Science On a Sphere™ is dependent on the support of NOAA and other government organizations, industry, and the private sector. Early and future development of the system is also supported by a very dedicated, capable team at FSL under the leadership of Sandy MacDonald.

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Figure 4. Sunset showing the transformation of a contrail in a cloudy sky. *(Photographer unknown)*

Background

FSL, established in October 1988, is one of 12 research laboratories under the Office of Oceanic and Atmospheric Research (OAR) of 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.

• *Exploratory System Development* – Anticipate requirements for NOAA's operational services and develop concepts in cooperation with operations specialists to meet these requirements. Test the utility of these concepts in environmental information and prediction systems for operations and data management.
• *Research Applications* – Conduct applied research toward improved forecasting capabilities. Capitalize on technological advances and improved understanding of the atmosphere-land-ocean environment to develop improved techniques for geophysical observations, more effective data assimilaton, and more accurate prediction models.
• *System Validation* – Use real-time and archived data to test and evaluate hardware and software systems and their diagnostic and predictive output.
• *Technology Transfer* – Work directly with users in expediting the transfer of new techniques and systems to operational use. Pursue goals toward effective dissemination of environmental information to foster highly informed decision-making.

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 (Figure 4).

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 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.

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 sites in Alaska), 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 NWS, Federal Aviation Administration (FAA), Department of Defense (DOD), and Department of Transportation (DOT), 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, the Aviation Division also ensures continued improvement of high-resolution numerical weather analysis and prediction systems.

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 **International Division** oversees internal development of systems intended primarily for global or international application. It is 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. The division also supports the GLOBE (Global Learning and Observations to Benefit the Environment) Program, which is widely recognized as one of the most successful international K–12 education and science programs of its kind. Since its inception 8 years ago, the Program has grown from an initial 450 U.S. GLOBE schools to more than 12,000 participating schools representing over half the countries of the world. GLOBE students conduct a large variety of scientific meausrements and use the Internet to send their findings to a central database. The GLOBE database contains more than 8 million records of atmospheric, soil, biologic, and hydrologic measurements that are used by researchers and students in numerous experiments. The International Division is also involved in the development of a real-time meteorological PC workstation called FX-Net. Based on a modified AWIPS D2D workstation, FX-Net makes AWIPS products available over the Internet via high and low bandwidth communication lines. The latest compression technologies are applied by FX-Net in order to reduce the product file sizes with minimal loss of information. Knowledge gained during research conducted in the area of wavelet compression technology is the underpinning of the FX-Net workstation. The International Division further expanded the research of wavelet compression into the domain of gridded model forecast fields. A method was developed to compress model grids with a prescribed maximum allowable error for each model parameter at all grid points. Wavelet compression studies conducted on the Eta 12-km forecast model delivered significantly better compression ratios than what conventional compression techniques can achieve for the same maximum error.

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 2002, FSL employees totaled 216 in the following categories: 92 Civil Service (including 1 NWS employee), 70 Joint Institutes (53 from CIRA and 17 from CIRES), 43 Commercial Affiliates, and 11 Visiting Scientists/Guest Workers (Figure 5).

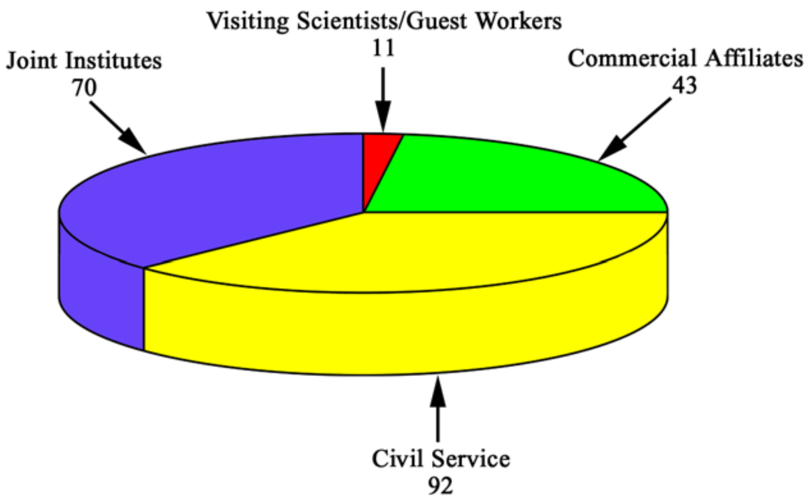


Figure 5. Categories of FSL's 216 employees as of October 2002.

Funding

Funding for FSL is received from a variety of sources. For Fiscal Year 2002, FSL received $27.9M from the following sources: $9.1M – NOAA's Office of Atmospheric Research (OAR) base funds, $12M – other NOAA funds, $5.4M – U.S. Government outside NOAA, and $1.4M – Non-Federal (Figure 6). The main components of "other NOAA funds" included $3.1M – NWS, $5.1M 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), and Lockheed Martin.

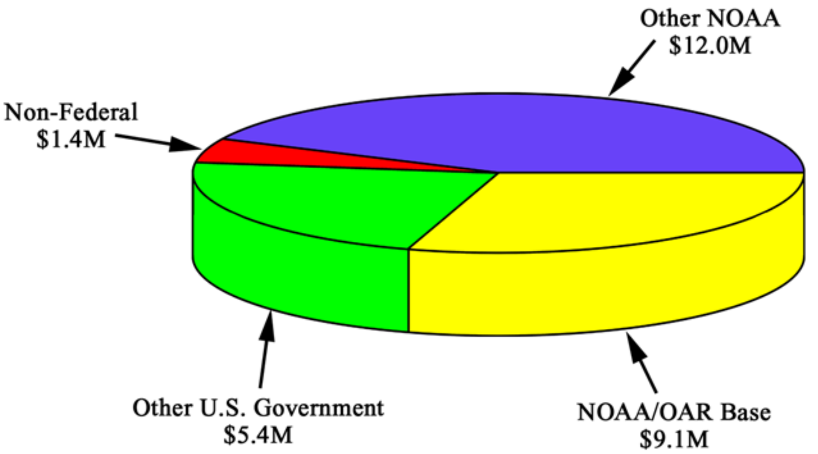


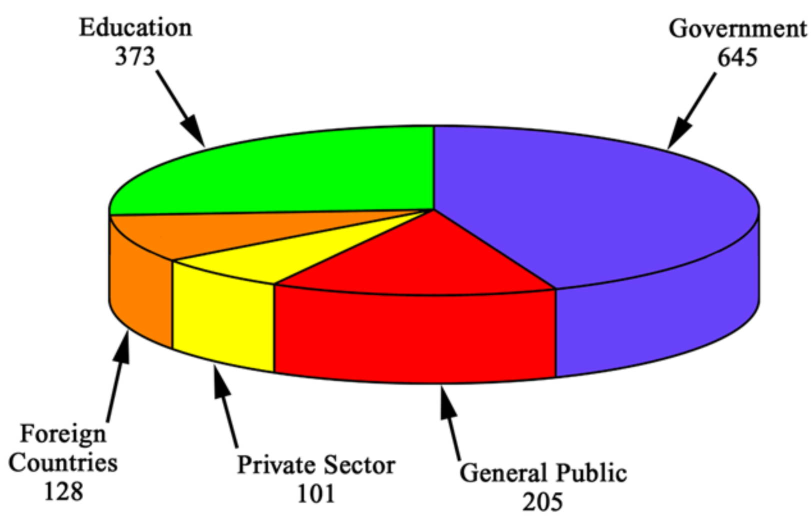
Figure 6. Funding sources totalling $27.9M for Fiscal Year 2002.

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 2002, the Office of Administration and Research accommodated at least 1,452 visitors (Figure 7), not including visits arranged directly with FSL staff outside this office. The largest category, 645 visitors came from the federal government. Other visitors included 373 from academia, (educators and students), 205 from the general public, 101 from the private sector, and 128 from foreign countries, including Taiwan, Singapore, Korea, China, Hong Kong, Columbia, New Zealand, Japan, and Australia.

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

Figure 7. Categories of the 1,452 recorded visitors during 2002.



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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 60 Sun Microsystems, Inc., Silicon Graphics, Inc. (SGI), Hewlett-Packard (HP), and Dell 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 500 Internet Protocol (IP)-capable hosts and network devices are connected to the FSL network. They include Unix 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 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 22 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 Computer System – During 2002, a 48-processor testbed system based upon the Intel Pentium IV-Xeon chip was deployed to evaluate the software and hardware issues associated with an Intel-based cluster for the final upgrade of the High-Performance Computing System (HPCS). The disk subsystem was upgraded to provide an additional 5.76 Terabytes of usable space. The Portable Batch System (PBS) was replaced with Sun's Grid Engine (SGE) to improve batch services on the HPCS. This change was necessary since FSL's job load had increased to thousands of jobs per day, and the PBS was not designed to handle such a heavy load. The computational core of the HPCS underwent a three-phased upgrade last year. Phase I involved the delivery of two 64-node clusters of dual-processor Pentium IV-Xeon systems (a total of 256 CPUs). During Phase II, the 256 single-processor Compaq Alpha systems (from the initial delivery) were decommissioned. Phase III involved the delivery of three more Intel-based clusters, one 128-node cluster, and two 256-node clusters, raising the HPCS to 280 Alpha CPUs and 1,536 Pentium IV-Xeon CPUs (Figure 8). Steps were taken to ensure the reliability of the HPCS, including the development of a sophisticated monitoring system with a screen that shows the status of the HPCS compute and file systems, chron servers, front-ends, and user activity (Figure 9).

Figure 8. An example of newly installed equipment (280 Alpha CPUs and 1536 Pentium IV-Xeon CPUs) in the Phase III upgrade of FSL's High-Performance Computing System.

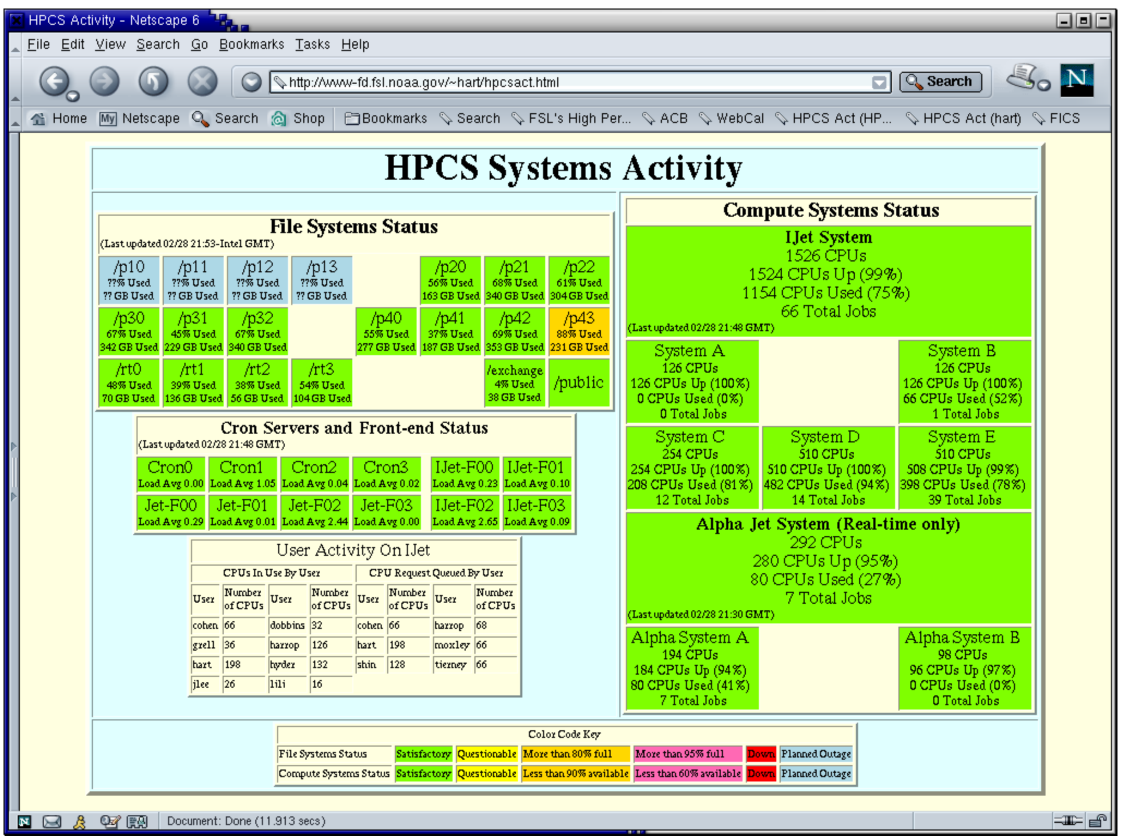

Figure 9. Monitoring screen showing the status of HPCS systems activity.

ITS continued its support of at least 40 projects on FSL's supercomputer Jet. The HPCS provides computational capability for numerous modeling efforts related to the atmosphere, ocean, climate, and air quality, which are carried out by FSL and non-FSL researchers. For example, several Joint Institutes, OAR (NOAA's Office of Atmospheric Research) laboratories including the Environmental Technology Laboratory (ETL), Aeronomy Laboratory (AL), National Severe Storms Laboratory (NSSL), and the NWS National Centers for Environmental Prediction (NCEP) all take advantage of the HPCS.

FSL Mass Store System (MSS) – Major upgrades were made to the Mass Store System to correct reliability and performance problems. This was necessary primarily because the large database maintained by Advanced Digital Information Corporations's (ADIC) FileServ Hierarchical Storage Management (HSM) software had compromised performance, and Sony's Advanced Intelligent AIT-2 drives and cassettes had become unreliable. First, steps were taken to stabilize the MSS by upgrading the ADIC FileServ/VolServ Hierarchical File System (HFS) software and server operating system. A major upgrade was implemented later that included installation of an additional, completely new HFS, which logically split the ADIC AML/J automated storage library robot into two virtual robots. The original FileServ/VolServ-based system continues to function in a read-only mode with 1,232 Sony AIT-2 tape slots and 4 AIT-3 tape drives. The new HFS, based on a Sun SunFire 480 server running ADIC's StoreNext software, features l,040 Linear Tape-Open (LTO) tape slots and 8 IBM LTO tape drives. Two 600-Gigabyte managed file systems (caches) were also provided, one dedicated to real-time data ingested by the Central Facility and the other available for user data. The new HFS has significantly increased speed and reliability. Major enhancements were also made to the FSL-developed tools for accessing the MSS.

Central Facility Systems Enhancements and Cost Savings – A major ongoing project in ITS involves defining ways to cut costs in the FSL Central Facility. Toward this end, ITS system administrators have decommissioned several older systems with high maintenance costs after moving to newer, less expensive systems. Central administration processes are being implemented for most Unix systems to cut system management costs. The printing systems have been reconfigured to increase reliability and offer better service to users. These activities allow system adminstrators more time to address other important issues.

System administrators became familiar with Sun's Solaris 9 operating system (OS) before moving systems to the newer OS. A used testbed system was procured and configured, and standard Solaris 9 installation procedures were defined and implemented. With the exception of systems running software that requires Solaris 8, new (replacement) Sun systems and rebuilds of current Sun systems have been placed on the more secure Solaris 9 platform, increasing security and decreasing system administrator time.

Another effective cost-cutting measure included developing more efficient use of existing resources. FSL's central data repository employing a Network Appliance, Inc. filer (NFS server) is a good example. This filer had become excessively overloaded, and often failed to respond to real-time data-access needs. An intensive mitigation project was implemented to reduce unnecessary load on this costly resource, avoiding (or at least postponing) the need to procure a new system.

FSL system administrators have been applying an unending stream of security related patches and upgrades. It is a major task to keep multiple versions of six different operating systems (Sun, Solaris, Linux, SGI IRIX, Microsoft Windows, etc.) patched and up to date.

The FSL mail lists were converted to NOAA Enterprise Messaging System (NEMS) groups. The names and descriptions of these groups are now visible in the NEMS directory, and conform to the NOAA enterprise mail strategy. Also, most of the laboratory was transferred to the main FSL mail server, eliminating miscellaneous mail servers and improving mail-handling reliability.

FSL PC Administration – The FSL Windows 2000 network was stabilized. Server logs containing errors and configuration problems related to Domain Name System (DNS) issues were corrected and updated. Prior to these upgrades, users were experiencing logon failures and connectivity outages. FSL's domain servers were rebuilt and patched with all known fixes and service packs, and are now running smoothly.

Network maintenance on the server level also included an upgrade to the antivirus software and a full rollout of the updated software to all PCs on the FSL network running the Windows operating system.

An additional 25 machines from the FSL International Division were transferred to the FSL PC Administrator. Network management software suites were evaluated to help manage the increasing number of PCs. The IBM Tivoli suite was chosen for its ability to control, update, and administer windows computers remotely.

PC security and systems patching remained a high priority throughout the year. Systems were kept up to date using Microsoft's Windows Update Utility. Also, the Microsoft Security Baseline Advisor was used to constantly monitor for security holes on all Windows networked machines.

The PC administrators' day-to-day tasks included support for various problems involving hardware and software, failed logons, password changing, disk problems, printing errors, drive failures, RAM issues, program errors, security updates, E-mail, OS reloads, backup configurations, dial-up accounts, data recovery, and network connectivity.

Systems Support and Computer Operations – The Systems Support Group (SSG) maintains a log (utilizing the FSLHelp System) that provides effective communication among the SSG staff, ITS Data Systems Group (DSG), system and network administrators, and other essential staff. The SSG log provides a higher level of service to FSL users in dealing with the numerous, varied issues responded to on a daily basis. This log also offers, among other things, a means for recording the history of events and tracking the procedures used to correct problems. During the year, about 2,170 log tickets were initiated and resolved. In addition, approximately 154 customer FSLHelp requests were processed for data compilations, file restoration, account management, video conferencing, and other requests requiring operator assistance.

The Web database used to document the procedures for maintaining the Central Facility has grown to 131 documents. New procedures and updated information require continual refinements, corrections, and updates to the documents. Good documentation, in turn, provides operators the means to troubleshoot and resolve issues involving real-time data, Central Facility equipment, and customer queries. The improved efficiency and consistency resulted in shorter downtimes and faster response to users.

SGG staff renewed efforts to provide assistance to system administrators, when feasible, in user account maintenance (such as adding/removing accounts) and other special projects on an as-needed basis.

The SSG weekly schedule was adjusted so that the lead operator could be more available during busier days. Also, overlap days, when three operators were on duty at once, were more spread out. This allows more time for special projects, facilitates flexibility in group training, and helps reduce overtime when operators take leave.

To accommodate 24-hour/7-day onsite support and augment staffing during emergencies, an emergency operator coverage plan was implemented which outlines the course of action to be taken when emergency coverage is required. Also, because of staff departures, and to ensure shift coverage, two full-time operators were hired and trained.

The SSG oversaw and monitored the daily laboratorywide computer system backups, with ~300 GB of information written each night for ~260 FSL client systems. Quarterly offsite backups were successfully completed on time. The tape rotation for quarterly offsite backups was increased to provide individual machine backups for up to one year.

In coordination with the Data Systems Group, numerous new products and critical systems (such as Fire Weather data servers, Temperature and Air Quality; TAQ systems, and RUC/RSAS (Rapid Update Cycle and the RUC Surface Assimilation System) backup were added to the Facility Information and Control System (FICS). To support these additions, several critical support documents and SSG Help documentation were updated so that the basic functions of the SSG (monitoring, troubleshooting, and discussing real-time data issues) are properly maintained.

A renewed emphasis placed on proper procedures for notifying data end-users (customers) resulted in updated documentation and other assistance tools (e.g., flow diagrams to ensure consistency within the SSG in this important area of customer service. The FSL Central Facility Data Availability Status Webpage was updated, and so was the tool that creates updates to this important customer information source.

A new feature was added to FICS that monitors product delivery to the NWS Telecommunications Gateway servers, in support of continued FSL backup of RUC/RSAS products for NWS/NCEP. The SSG online documentation was updated, and other assistance materials and tools were developed and implemented. These improvements ensured that SSG is more proactive and responsive in monitoring and communicating about FSL RUC/RSAS production and delivery to NCEP.

To keep well informed of computer security issues and maintain compliance with DOC, NOAA, and OAR security guidance, SSG staff took the NOAA IT online Security Awareness training, and also completed the online, in-depth SANS (SysAdmin, Audit, Network, Security) Institute Security training course. All SSG staff received ongoing, in-depth training on the main computer room VESDA Smoke Detection System and FM-200 Fire Suppression System.

Facility Infrastructure Upgrades – FSL underwent two substantial infrastructure upgrades to address the power, cooling, and space requirements of the final upgrade to the High-Performance Computing System. Every effort was made to implement the infrastructure upgrades with minimal downtime to existing equipment and FSL users.

The first infrastructure upgrade involved the expansion of the Central Facility Annex. An office and a storage room were relocated to add space for the computer room next door. The walls surrounding the new computer room required extensive sound mitigation work to meet the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) noise protection criteria for private offices. Surrounding walls were extended deck to deck, and an Uninterrruptible Power Supply (UPS, Figure 10) was installed to provide short-term backup power. A ramp was installed to raise the floor to 12 inches in support of a new dedicated CRAC (Computer Room Air Conditioner) unit.

To create space for the final upgrade, older racks and equipment were moved from the main computer room to the new annex. The finished Central Facility Annex (Figure 11) was then fully certified in accordance with National Fire Protection Association standards.

Figure 10. Uninterruptable Power Supply (cabinets to the left) and the GOES ground-station rack (tall, black unit toward the back) in the new Central Facility Annex.

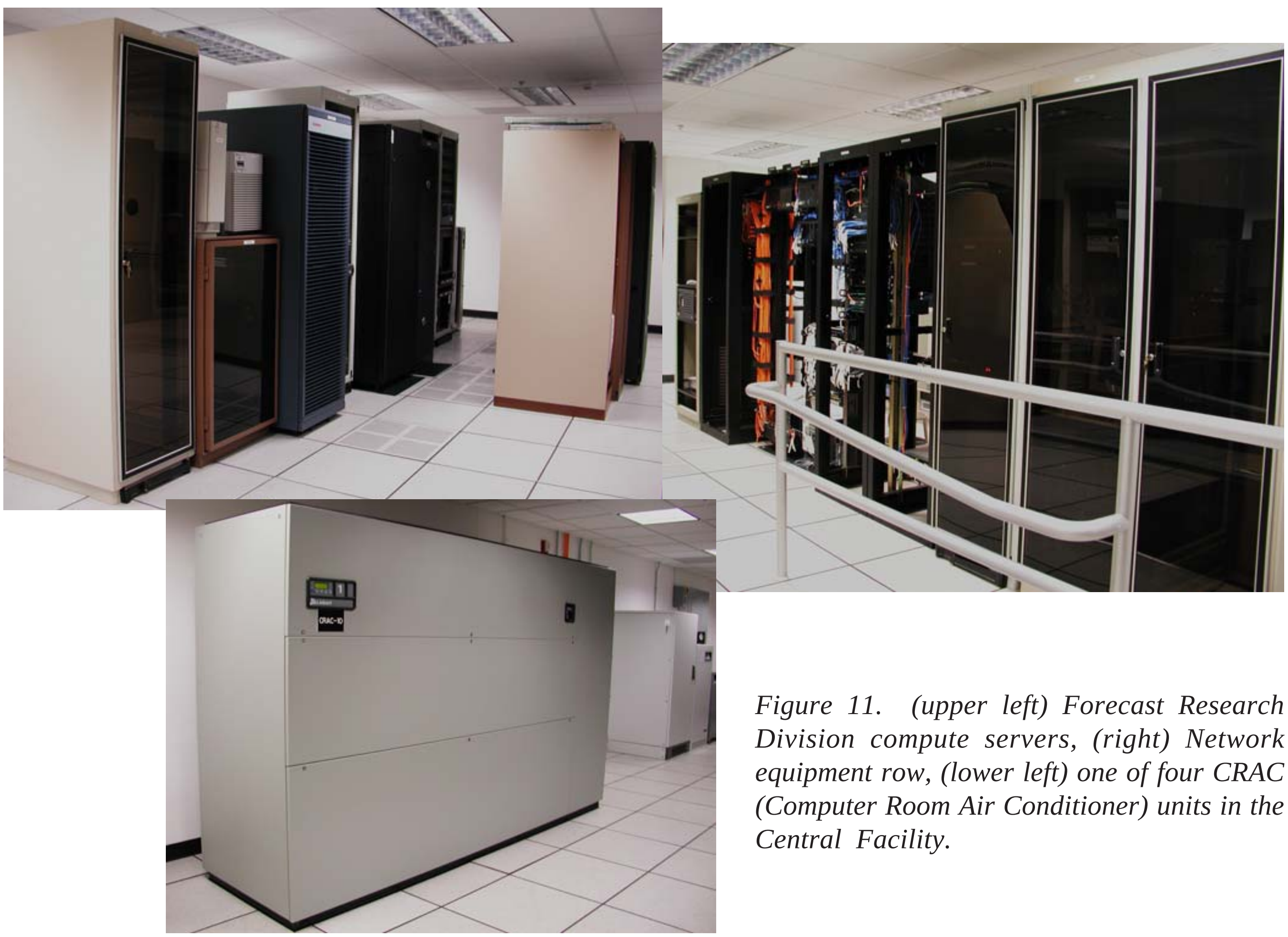

Figure 11. (upper left) Forecast Research Division compute servers, (right) Network equipment row, (lower left) one of four CRAC (Computer Room Air Conditioner) units in the Central Facility.

The second infrastructure upgrade brought the Central Computer Facility up to original specifications by increasing the cooling capacity to 120 tons and emergency UPS electric power to 300 kVA. Four 15-ton CRAC units were replaced with four 30-ton units. Chilled water piping modifications and leak detection upgrades were required as well as floor tile cutouts and stronger underfloor supports. Additional power distribution panels and larger power transformers were also installed to support the increased electrical requirements. The Emergency Power Off (EPO) bypass capability was separated from the FM-200 Fire Suppression bypass switch in order to perform functional FM-200 Fire Suppression testing and maintenance without powering down the entire computer room. Finally, 28 legacy HPCS computer racks were removed and 48 new HPCS final upgrade racks were installed. The implemented specifications for the main computer room and the annex are shown in Table 1.

FSL Network

Key enhancements were made to the FSL local area network (LAN) in 2002, with the integration of Gigabit Ethernet (GigE) and Asynchronous Transfer Mode (ATM) technologies and implementation of hardware-based routing. Two Cisco 6509 switch/routers were installed to make it possible to combine GigE and ATM, thus maintaining the fully meshed high-speed (622-Mbps) connections to core network devices and servers. The core network was also augmented with 1,000-Mbps GigE connections, and GigE links were provided to the FSL HPCS and new high-end servers. The Cisco 6509s increased switching performance in the two computer rooms from 20–32 Gbps. Other legacy switching devices (in the wiring closets) serving user workstations were replaced with 20-Gbps switches.

Table 1.
Specifications for Upgraded FSL Central Computer Facility and Annex

	Main Computer Room
Dimensions:	3,600 square feet; 12-inch Raised Floor; 8-foot, 6-inch Ceiling Height
Capacity:	142 Racks
Access:	Restricted
Power:	Utility with Emergency Generator Backup Transient Voltage Surge Suppressor (TVSS) Protected, Emergency Power Off (EPO) Switch Protected
UPS:	300 kVA (Useable), 8-minute Runtime (Full Load), and Semiannual Preventive Maintenance
Cooling Capacity:	90-tons Downdraft (De-rated for altitude)
Fire Protection:	FM-200 Fire Suppression System (Tied to EPO), VESDA Fire Detection System, Semiannual Preventive Maintenance, Semiannual Operational Training, Cerberus Smoke Detection System (GSA Notification), Sprinkler System (155^{o}F trigger point), CO_2 Portable Fire Extinguishers (Class B & C Fires)
Cleaning:	Semiannual Professional (Above and Below Floor)
	Annex Computer Room
Dimensions:	1,100 square feet; 12-inch Raised Floor, 8-foot; 6-inch Ceiling Height
Capacity:	46 Racks
Access:	Restricted
Power:	Utility with Emergency Generator Backup, Transient Voltage Surge Suppressor (TVSS) Protected Emergency Power Off (EPO) Switch Protected
UPS:	90 kVA (Useable), 8-minute Runtime (Full Load), and Semiannual Preventive Maintenance
Cooling Capacity:	23-ton Downdraft (De-rated for altitude) 5-ton Fan Coil (In Standby until Temp >78^{o}F)
Fire Protection:	Cerberus Smoke Detection System (Tied to EPO), Sprinkler System (155^{o}F trigger point), CO_2 Portable Fire Extinguisher (Class B & C Fires)
Cleaning:	Semiannual Professional (Above and Below Floor)

The ability of two Cisco 6509s to perform hardware-based routing represents a substantial improvement over the previous configuration of 5 Marconi PowerHub software-based routers for the 35 active networks at FSL. Figure 12 shows the upgraded network configuration.

The management of redundant path routing was also improved with implementation of the Virtual Router Redundancy Protocol (VRRP). Cisco's version of VRRP, the Hot Standby Router Protocol (HSRP) now provides one virtual default router address for each network, with automatic failover to the secondary router when needed. Redundant routes were previously managed at both the network and host level, which yielded an unnecessary burden on servers and workstations. The advent of HSRP at FSL has offloaded this burden from FSL hosts, freeing up valuable memory and CPU cycles, and placing the responsibility for network redundancy back in the network. The addition of one other protocol was also important for accomplishing the integrated ATM/GigE network at FSL. The Spanning Tree Protocol (STP) was enabled to help mitigate loops in the network. Because of the dual nature of our ATM/GigE network, there are loops present by design, and without STP, loops can quickly render Ethernet networks unusable.

During 2002, network services were provided for 207 FSL staff. The network utilized 532 total links, comprising 482 user (workstation and server) links and 51 network device links. The number of user links increased by 50 over the last year. The number of network device links decreased by 30 because routing services were consolidated and 14 small network switches were replaced with four better performing devices with a higher capability for user ports. Port capability available for network growth reached 18%, and 146 free ports were distributed across FSL computer rooms and wiring closets. All network routers and switches were running at an average CPU utilization of 13%, with the highest at 26% on the primary switch between FSL and the NOAA Boulder Network. A substantial improvement in routing efficiency was realized over last year. The PowerHub routers were exhibiting 100% utilization at times, resulting in poor routing performance until they were replaced with the Cisco 6509 routers, which now average just 1% utilization.

Link utilization in the core of the FSL network averaged 9.1% (57 Mbps on the 622-Mbps ATM segments), and 4.8% (48 Mbps) on the 1000-Mbps Gigabit Ethernet segment. In combination with all other NOAA Boulder network traffic, Wide-Area Network (WAN) utilization to commodity Internet and Abilene (Internet2) via the Front Range GigaPOP (FRGP) averaged 7%, with a maximum of 47% of the 155 Mbps available. WAN traffic over the secondary commodity Internet link provided by MCI/UUnet averaged 45%, with a maximum of 100% of the 12 Mbps available. WAN traffic via the FRGP stayed about the same as in 2002, while traffic via the MCI link increased by 11%, primarily for outbound traffic. FSL comprised 63% of the total NOAA Boulder WAN traffic, with the next nearest laboratory, the Climate Diagnostics Center (CDC) at 17%. While these figures are similar to 2002, the most recent month's statistics showed FSL at 84% of the total NOAA Boulder WAN traffic. The top protocols were once again FTP (43%), LDM (18%), and HTTP (16%).

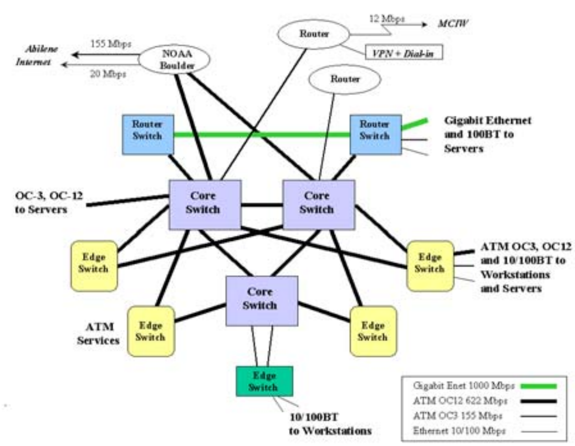

Figure 12. Diagram of the upgraded FSL Network as of September 2002.

As mentioned earlier, the computer room annex was converted into a fully operational computer room space housing network equipment and servers for six scientific divisions. In support of this task, FSL Networking staff installed all network cabling and patch systems. This included nearly a mile and a half of Ethernet, fiber optic, and console cables, underfloor power whips, and an ATM/Ethernet switch to connect 38 computer racks – all installed within one week. This computer room design and installation, and assistance provided for the relocation of servers, ensured minimal downtime for FSL users.

Enhanced network monitoring was implemented on all major FSL network devices and links. Webpage graphic displays of CPU and network link loads were implemented using public domain software Multi Router Traffic Grapher (MRTG). The resultant statistics were, and continue to be, valuable for resource management of network devices, and also improved the resolution of network problems. Web links to MRTG plots were made available for all direct-connected ATM hosts, primary FSL servers, and workstations upon request, allowing users to view network activity on the servers for which they are responsible. Access to the Web information is limited to FSL only.

Information Technology (IT) Security

Information Technology (IT) security is an integral part of the FSL design for all new network growth. Establishing a GigE backbone and GigE-capable routers was critical to the FSL IT security architecture. Redundant GigE network links from FSL to the NOAA Boulder network is the basis for a high-speed security perimeter. This security architecture includes a zone for public access servers that was logically implemented with the use of a dedicated subnet. This zone allows Network and Security staff to begin monitoring traffic flow into and out of the zone to appropriately set access policies for differentiated types of data and server access. Remote access (Dial-in and Virtual Private Networking (VPN)) to FSL resources was upgraded to utilize encrypted authentication via the Remote authentication Dial-In User Service (RADIUS). To assist with testing FSL IT security policies and methods, an AT&T small business Digital Subscriber Line (DSL) was installed at FSL. This DSL link is dedicated and physically separate from all FSL networks and address spaces. Network staff, System Administration staff, and users are able to utilize the DSL network from the Internet to view how FSL "looks" from the outside. This security tool is very effective for testing access control lists, verifying access to internal Webpages, and confirming patches on the host-based systems in FSL.

The FSL IT Security Officer (ITSO) developed and presented an IT security strategy to FSL managers, system administrators, FSL Technical Steering Committee, FSL IT Architecture Group, and FSL users. The security plan was approved and funded. In coordination with FSL network management and system administrators, the ITSO evaluated three firewall appliances in-house, and will recommend the one best suited to FSL's needs. Testing and implementation of the firewall and the associated Intrusion Detection System (IDS) and centralized logging will depend on completion and stabilization of the FSL and NOAA Boulder network backbone upgrades. Commercial and open-source vulnerability tools were evaluated, and the open-source tool Nessus was selected and implemented within FSL. Regular audits of FSL hosts were performed as required. A patch server was acquired and tested that mirrors local, secure copies of the latest vendor patches for all applicable FSL systems and applications. Centralized log servers were installed for secure logging of Unix host event entries; the old log server systems will be moved to the new infrastructure. System administrators and users were supported in several security responses, and appropriate input was submitted to the NOAA Computer Incident Response Team (N-CIRT). Newsgroups, mailing lists, and security sites are monitored for vulnerability alerts, potential threats are analyzed, and FSL security contacts are notified when applicable. Approximately 125 e-mail alerts were issued. The ITSO collaborated with N-CIRT personnel in Washington, D.C., to present their 16-hour "Essential Security Measures" training classes in Boulder (for the first time). This training was offered to all NOAA-Boulder and Western Region staff after all training requirements had been met.

Data Acquisition, Processing, and Distribution

The ITS Data Systems Group continued to design and develop real-time meteorological data acquisition and processing systems required by laboratory 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 (Figure 13) 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 –
  - – NCEP, including the Aviation Weather Center's (AWC) use of the Distributed Brokered Networking (DBNet) software
  - – WSR-88D narrowband and wideband Doppler radar data
- Aeronautical Radio Inc. (ARINC)
- Weather Services International Corporation (WSI) High-Capabity Satellite Network (HCSN) Data-Acquisition System that supplies WSI NOWrad and NEXRAD products
- FSL Demonstration Division
- Geostationary Operational Environmental Satellite (GOES-8 and GOES-10)
- National Center for Atmospheric Research (NCAR)
- Meteorological Assimilation Data Ingest System (MADIS) data providers

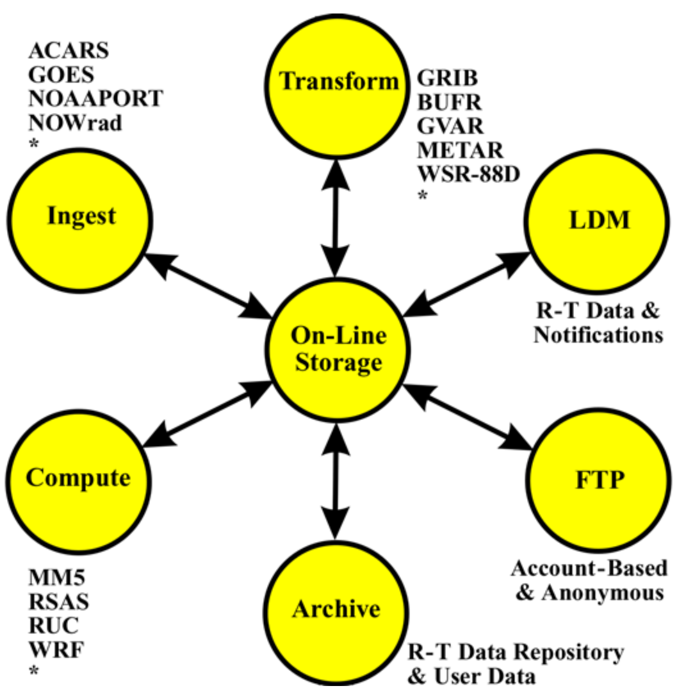

Figure 13. Data services currently provided by FSL.

Distributed datasets included:
• GOES imagery to the NOAA Environmental Technology Laboratory (ETL)
• Wind profiler data to University Corporation for Atmospheric Research (UCAR) Unidata program
• Quality controlled ACARS (Aircraft Communications Addressing and Reporting System) data to NCAR, government agencies, and universities
• RUC/RSAS data to NCEP for operational backup
• Real-time data were also distributed to several external organizations using the Unidata Local Data Manager (LDM) protocol

Data Acquisition Upgrades – An upgrade of the GOES data processing system was designed, developed, and completed. The local ground station system receives and ingests GOES Variable (GVAR) data (Figure 14) from the GOES-8 and -10 satellites. The system generates a suite of imager and sounder products in netCDF format.

The ACARS ingest hardware was replaced and processing software upgrades were completed. The new system was designed using IBM's MQ Server software, which replaced legacy hardware and software that acquired data using the outmoded X.25 protocol.

A new NOAAPORT Receive System (NRS) was evaluated, purchased, and integrated into production, resulting in much improved data reliability.

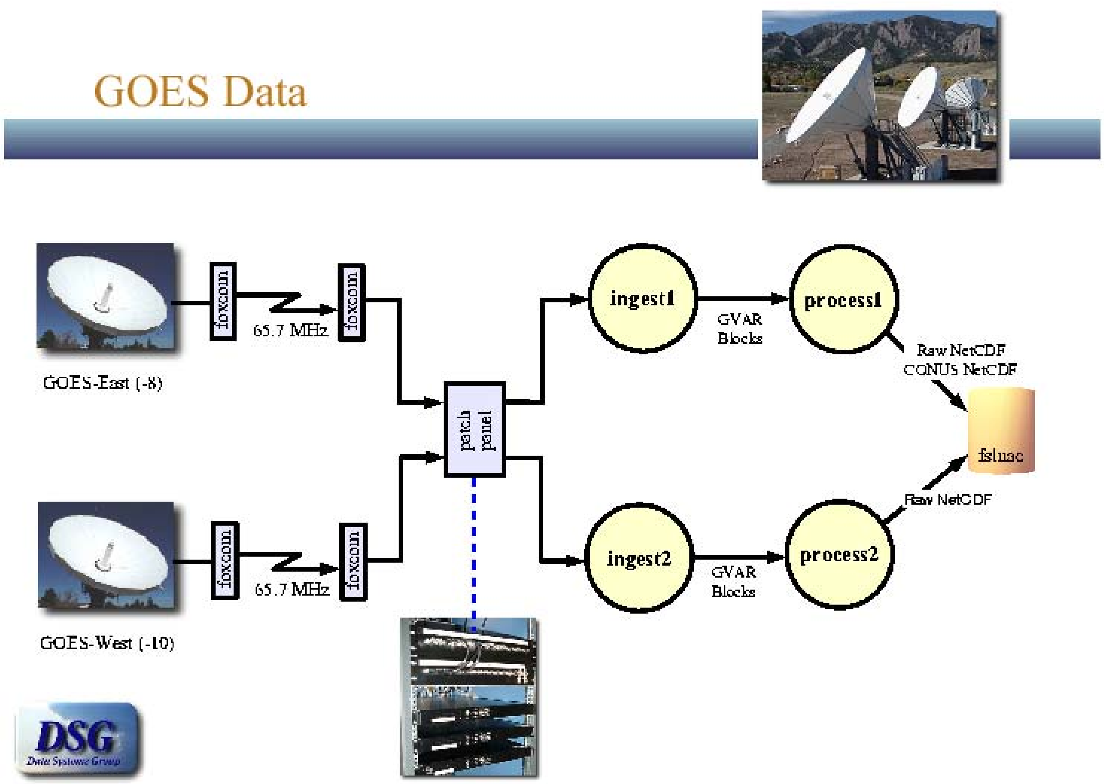

Figure 14. Schematic of GVAR (GOES variable) data processing at FSL.

Data Processing and Management Upgrades

Object Data Systems (ODS) – Software was designed and developed to streamline the acquisition and processing of point, radar, and satellite data. Advanced Object-Oriented (OO) techniques were used in creating the software to reduce required maintenance and to allow for generic, more efficient handling of various data types.

As part of the ODS improvements, the satellite GVAR processing was upgraded, as shown in Figure 14. In keeping with the ODS model of handling "raw" data for both the real-time and archive streams, a completely new scheme was developed which allows greater flexibility in the configuration and maintenance of GVAR datasets.

Facility Information and Control Systems (FICS) – FICS Monitor changes were implemented to account for the arrival of a variety of new datasets. Scripts were developed to monitor operation of the High-Performance Computing System and Mass Store System. A new, more flexible method of monitoring LDM servers also was developed. FICS monitoring of AWIPS Data Servers was upgraded. The new version includes an "AWIPS Data Servers" page which allows for more flexibility with the number of data servers being monitored, while keeping the main FICS page minimally cluttered.

Real-Time Advanced Weather Interactive Processing System (AWIPS) Data Processing – Several new Linux AWIPS data servers were implemented. Numerous Local Data Acquisition and Dissemination (LDAD) data providers were added as part of cooperative projects, including the International H_2O Project (IHOP) and the NOAA New England Forecasting Pilot Program: High Resolution Temperature and Air Quality Project (TAQ).

In collaboration with the FX-Net project, several AWIPS data servers were customized for displaying data for the TAQ, IHOP, and Fire Weather projects. Associated FICS monitoring and troubleshooting procedures were developed to monitor these systems. These tasks included customizing AWIPS data servers to process non-NOAAPORT model data, such as high-resolution MM5 and GPS-Met integrated precipitable water vapor (IPWV) data for display on FX-Net.

Data Storage and Access – The FSL Data Repository (FDR) and the Real-Time Data Saving (RTDS) systems were merged. Using ODS software to create a configurable and scalable system, the new FDR method reduces both the number of files (using Unix tar-tape archive) and the volume of data (using gzip compression) that is being stored using the MSS. As a result of the MSS upgrades described earlier and the improvements in data storage and access, users were able to store and retrieve data much faster and more reliably.

New Systems Architecture Development – Data ingest, processing, and distribution systems were developed to provide reliable, low-cost solutions for ftp, LDM, and other server applications using open source software. Since the new systems spread services among multiple commodity PC servers running on the Linux operating system, it is now easier to deploy additional servers to accommodate new services. An example of improved efficiency using these new systems is an ftp server (called eftp) which showed a steady increase of external users of FSL data, exceeding 150 by the end of 2002. To provide necessary backup, spare servers are now available that can be quickly imaged to assume the identity and function of any host that suffers a hardware failure. SystemImager software was used to clone appropriate server(s) from stored images and to duplicate and restore services as needed. File services for these systems were provided using low-cost RAIS devices with IDE disks. Refer to *http://www-fd-fsl.noaa.gov/dsg/* for additional information.

Laboratory Project, Research, and External Support

FSL's supercomputer provided computational capability for FSL modeling efforts, high-performance computing software development, and other NOAA organizations. The latter includes seven NOAA Research Laboratories: 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), Pacific Marine Environmental Laboratory (PMEL), and the National Geophysical Data Center. All projects were reviewed on the basis of scientific merit and their appropriateness for a commodity distributed-memory machine such as the FSL High Performance Computing System. The modeling projects involved the ocean, climate, atmosphere, and air quality.

ITS continued to distribute real-time and retrospective data and products to all internal FSL projects and numerous outside groups and users. External recipients included:

- ETL – Real-time GOES-8 and -10 extended-sector satellite data, and WSR-88D radar data.
- NWS Storm Prediction Center (SPC) in Norman, Oklahoma – Six-minute Profiler data.
- NWS Aviation Weather Center in Kansas City – Six-minute Profiler, ACARS, and RUC data.
- UCAR COMET© and Unidata Program Center – Six-minute Profiler, ACARS, MM5, RUC, and RASS data.
- NCAR RAP and Mesoscale and Microscale Meteorology Division – RUC and MM5 data.

Other data and product sets were provided to outside groups, including Doppler radar, ACARS, upper-air soundings, meteorological aviation reports (METARs), profiler, satellite imagery and soundings, MAPS and LAPS grids, and Meteorological Assimilation Data Ingest System (MADIS) datasets. As liaison for outside users, the Systems Support Group provided information on system status, modifications, and upgrades.

Staff continued development of the FSL Hardware Assets Management System (HAMS), whose database incorporates an accurate and detailed list of FSL's hardware and software holdings. HAMS produces reports that are invaluable in tracking FSL equipment and software and provide input for yearly maintenance contracts and updating government property lists.

The two Oracle servers for HAMS were upgraded to the latest releases of Oracle 9i, Oracle 9i Application Server, and Apache Web Server software. The HAMS application processed over 120,000 wireless and Web-based transactions during the year and tracked equipment and software resources within FSL. Version 3.0 of the HAMS application software was packed with new features and enhancements, including Support Contracts, Support Costs, Project and Task Hours, Dynamic Views, Software Parenting, Groups, Members, Room Contents, Rack Contents, Storage Contents, and hundreds of other enhancements. HAMS training courses were developed and classes were held for FSL system administrators, network administrators, operators, and property custodians. The HAMS Web-based application won the FSL Web Award for the "Best Internal Use" category this year.

Division staff advised FSL management on the optimal use of laboratory computing and network resources, and participated in cross-cutting activities that extended beyond FSL, as follows:

- Chaired the FSL Technical Steering Committee (FTSC), which reviewed all FSL equipment fund requests and provided the FSL director and senior staff with technical recommendations for equipment procurements.
- Served on the FSL Technical Review Committee.
- Served as Core Team and Advisory Team members for selecting upgrades to the FSL HPCS.

- Participated in the creation of OAR's (Office of Oceanic and Atmospheric Research) IT Architecture plan.
- Served as members of the Jet Allocation Committee, which reviews proposals for use of FSL's HPCS and provides recommendations to the FSL director for their acceptance.
- Served on the Boulder IT Council (BITC), including assuming the office of chair.
- Served as FSL representative and chair of the OAR Technical Committee for Computing Resources (TCCR).

ITS staff presented a well-received review of the FSL High Performance Computing System to the Commerce IT Review Board last September, and the program was given a green light to continue.

Projections

Computer Facility

FSL High-Performance Computer System and Mass Store System – The final upgrade and acceptance of the HPCS is planned for early 2003. The 48-CPU testbed system will be decommissioned as a cluster, and its nodes will be used within the HPCS and other areas of the Central Facility. A new RAID with file system software from IBM will be integrated into the HPCS. Associated software, the General Purpose File System (GPFS), will initially support highly critical usages of the HPCS such as real-time runs of forecast models. GPFS will be tested on the existing RAID system, with plans to make GPFS file systems available to more of the general user community. A cluster with 64-bit processors will be acquired and tested later in 2003 to ensure that critical software at FSL functions properly in such an environment. In collaboration with the Aviation Division, Grid Computing software (Globus, MPICH-G2) and Condor will be installed on a portion of the HPCS for initial development and testing of the Grid concept.

The MSS upgrade, also to be accomplished and accepted in early 2003, will involve moving to a new Hierarchical Storage Management System, a new host, and a more robust tape media, upgrading the HPCS RAID to be used as cache. FSL will survey its existing user base and other areas of OAR regarding requirements for future computational platforms to support NOAA research applications.

Central Facility Systems Enhancements and Cost Savings – With the implementation of the required firewalls during 2003, many Central Facility services will need to be rearchitected to work properly with the new firewalls and the resulting new network design. The DNS and e-mail gateways will be redesigned and rebuilt on new hardware that will be less expensive to maintain than the old systems. The new hardware will also have the advantage of allowing advanced testing of the rearchitected DNS and e-mail functions before switching FSL to the new systems. A new design for Web content delivery has already been drawn up to accommodate the firewalls and additional security without requiring the purchase of many new server systems.

A new version of FSLHelp will be developed and introduced that will fix bugs, increase security, provide an easier interface for users, and decrease response time of the system.

Cost saving efforts will continue through implementation of a much simpler computer environment. For example, testing will begin on a new, standard desktop system that will run either Red Hat Linux or Microsoft Windows , so that only two types of operating systems and one type of hardware will need to be supported in ITS desktops. This goes hand in hand with a steady move toward only running Red Hat Linux and Sun Solaris on server systems within ITS.

Systems Support and Computer Operations – Staff will continue to identify regularly failing client backups, track down the reasons for the failures, and implement proper corrective measures to reduce the number of client backups that fail daily. This will more effectively utilize system/network resources and provide a higher level of service for all FSL users.

Additional tools will be implemented to ensure task performance consistency. Links will be added to the FICS monitor that will allow quick and consistent generation of SSG Log tickets and Data Outage notifications. The Data Outage Notification Generator form Common Gateway Interface (CGI) script will be created and implemented. Additional new products, real-time machine loading, and systems will be added to the FICS monitor. To support these additions, several critical support documents and SSG Help documentation will be updated to maintain and enhance monitoring, troubleshooting, and communicating about real-time data issues with users and system developers. Staff also will continue to provide assistance to systems administrators.

A refresher training session for the VESDA Smoke Detection system and FM-200 Fire Suppression System will be provided for the SGG staff. Documentation will be updated, and other training devices and additional aids for quickly resolving issues with these systems will be developed.

Facility Infrastructure Upgrades – To improve emergency communications safety within the FSL's Central Computer Facility, wall-mounted telephones will be installed near each FM-200 Fire suppression abort switch. Electrical power surveys will be performed to more efficiently analyze power usage within the facility. Documentation will be prepared to better manage computer room growth with relation to space, cooling, and electrical power consumption.

FSL Network

The NOAA Boulder network plan to replace the ATM network backbone in the David Skaggs Research Center (DSRC) with a Gigabit Ethernet backbone will start in 2003. FSL will take advantage of the higher-speed GigE network by converting the link between FSL and NOAA Boulder from ATM to GigE, as shown in Figure 15. Internally, FSL will continue to maintain an integrated ATM and GigE network until funding becomes available, and the need is warranted technically to consolidate the two technologies into one (multiple) GigE core network. The GigE network within NOAA Boulder and FSL provides the topology needed to implement a high-speed redundant firewall security perimeter. This GigE topology will make it possible to physically separate the public access zone and internal network, which are currently only logically separated. Addess policies will be implemented to closely control all network traffic into and out of FSL public and internal (private) networks.

Remote access (Dial-in and VPN) to FSL will be upgraded to utilize a server with 56-Kbps modems, and a Cisco 300 VPN server to provide more secure authentication of users. The entry point for these remote access services will be relocated to the public access zone, as part of the IT Security Architecture implementation. A third form of remote access is planned by deploying wireless networking. The plan is to implement wireless networking access points throughout FSL office spaces in the DSRC, and provide a small number of wireless network interface cards for loan to laptop computer users. This will be very beneficial to a broad range of users, including visitors who need short-term network access, seminar presenters requiring live network access to materials or for demonstrations, systems administrators for quick on-the-spot troubleshooting and generating/updating systems inventories, and for roaming FSL internal users. The entry point for wireless networking will also be in the public access zone, and will require FSL-granted account access and encrypted user authentication.

The FSL WAN traffic increased significantly in 2002, and the secondary link to the commodity Internet, often fully utilized at 12 Mbps, will be upgraded to increase the bandwidth of this link to 18 Mbps. Additionally, more economical WAN services will be investigated to determine if higher bandwidths, such as GigE, may be available through WAN service providers located on the Boulder Research and Administrative Network (BRAN) path. FSL could benefit from a GigE, or direct optical service to national-scale networks for connecting to other major supercomputing centers.

IT Security

FSL will install a combined firewall and Intrusion Detection System (IDS) as a first step toward securing the network perimeter (see Figure 15). The firewall and IDS will be an integral part of the new Gigabit Ethernet network backbone, allowing FSL a modular, off-the-shelf upgrade path to accommodate configuration changes and future bandwidth growth. To achieve an economy of scale, the IDS will be implemented as an integral part of the NOAA Boulder Network Operations Center (NOC) building-wide system. The goal is for all NOAA Boulder Laboratories to eventually participate in a common IDS infrastructure, which will be managed by the NOAA Computer Incident Response Team (N-CIRT). For improved security, the earlier acquired and tested patch server wiill be placed into production. This server will mirror local, secure copies of the latest vendor patches for all applicable FSL systems and applications and will facilitate faster and more efficient systems patching.

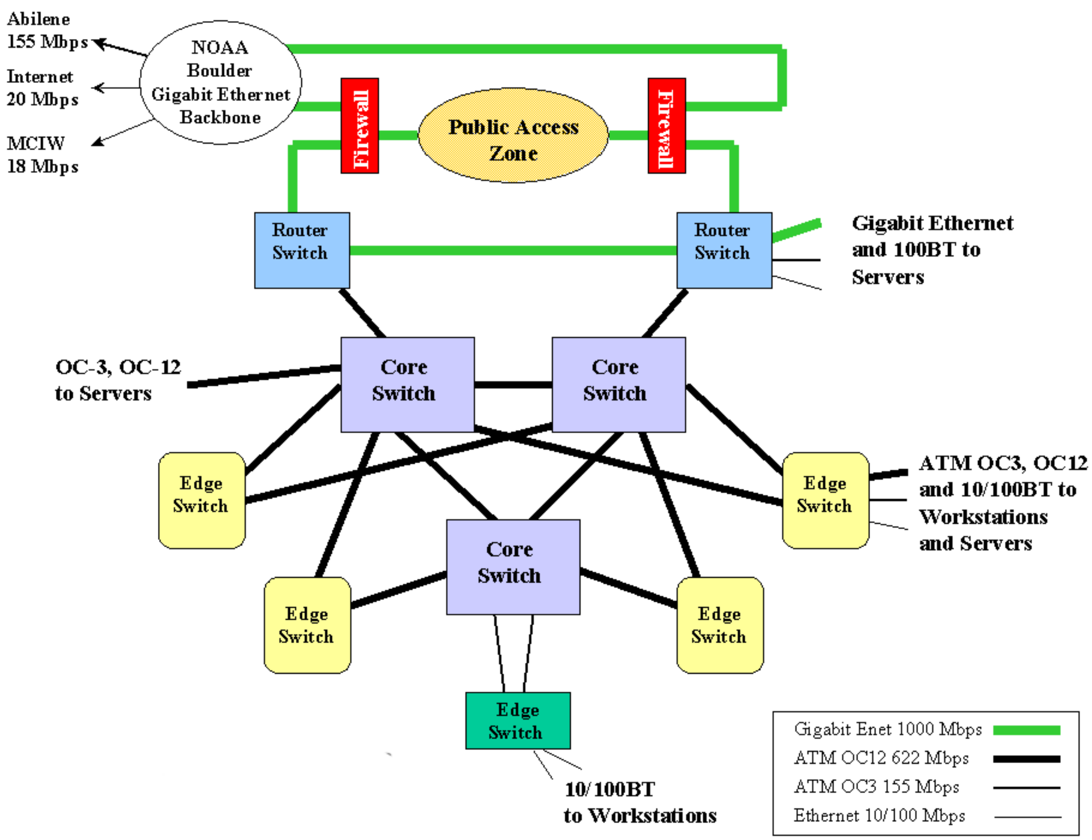

Figure 15. Diagram of upgraded FSL Network as of March 2003.

Additional IT security challenges require that a full-time assistant IT security officer be hired in order to keep abreast of the new policies, regulations, and actions from the Department of Commerce and NOAA, and to implement and maintain the firewall/IDS/central logging infrastructure. This additional help will ensure that FSL can respond quickly to the increasing security workload and stricter security directives. The N-CIRT also plans to hire a full-time security specialist for the Boulder campus.

Data Acquisition, Processing, and Distribution

Design and development for new and modified datasets will continue. Use of ODS applications and methods will expand as legacy translators and product-generation methods are replaced by the new techniques. Object Oriented software development for point data will continue.

Upgrades and enhancements to the AWIPS data servers will be performed in response to the continual addition of products to the NOAAPORT dataset. Design and development staff will continue to create an automated research system for generating AWIPS review cases form retrospective datasets.

Metadata handling techniques for use with GRIB datasets will be implemented for real-time data processing. An automated system for acquiring and incorporating digital metadata is part of this plan. Further work includes continued development of the interactive interface that allows for easy query and management of the metadata content, the addition of program interfaces to allow for secure controlled data access, and incorporation of retrospecive data processing and metadata mangement.

Laboratory Project, Research, and External Support

ITS will continue to support FSL users and projects as well as external FSL collaborators and data users. This support comprises real-time and retrospective FSL data, meteorological products, and technical data-handling expertise.

Efforts will continue toward providing HPCS support, assistance, and advice to both FSL users and numerous other NOAA and outside users.

To facilitate the management and tracking of the laboratory's multimillion dollar assets, more enhancements are planned for the FSL Hardware Assets Management System (HAMS). The new Electrical Power Management enhancement will accurately track and monitor computer equipment power requirements within FSL. HAMS will provide the FSL Central Facility managers with tools to monitor, balance, and plan electrical load and consumption within the laboratory.

Other planned enhancements include network connections, enhanced equipment searches, mass changes, vendor searches, credit card reconciliation, and automated excess property processing.

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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 comprises three branches:
Regional Analysis and Prediction Branch (RAPB)
Local Analysis and Prediction Branch (LAPB)
Meteorological Applications Branch (MAB)

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 (Figure 16) and the WRF/Air Chemistry model, continued collaboration with NCAR in the advancement of the science of modeling precipitation physics, participation in the development 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 start" 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 the National Weather Service (NWS), Federal Aviation Administration (FAA), Federal High Ways 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 Meteorological Applications Branch consist of the following:

GAINS Project – The Global Air-Ocean IN-situ System (GAINS) program is developing a proof of concept for routinely sounding the Earth's atmosphere, ocean, and in situ air chemistry over oceanic areas.

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, and the role of gravity waves in turbulence generation and convection initiation.

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 GAINS, the NOAA Chemical Weather Research and Development program (with information such as the MM5/Chem model domain in Figure 16), national precipitation data, ACARS data, interactive soundings, national mesonetwork data, and FSL publications.

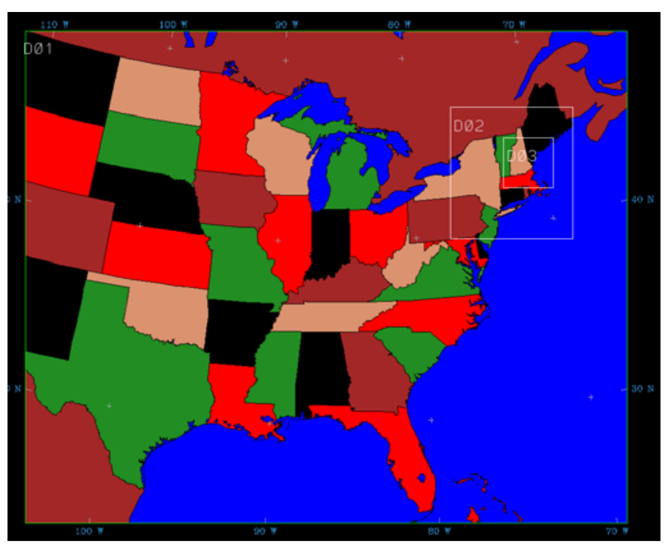


Figure 16. Domains over which air quality and weather forecasts were produced in real time – using the MM5/chem model – during the 2002 New England Temperature and Air Quality (TAQ) pilot experiment.

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 will be to develop a rapid update component to the WRF model by 2006.

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. 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 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 has been 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.

Accomplishments

Implementation and Enhancements to the 20-km RUC

NCEP Implementation – Culminating a four-year development and testing activity, a major revision to the RUC system including 20-km horizontal resolution was implemented at NCEP on 17 April 2002. This new version has four key aspects: finer (20-km) horizontal and vertical (50 levels) resolution (requiring about 10 times the computations of the 40-km version for the forecast model), an improved version of the RUC forecast model, assimilation of GOES-based cloud-top pressure to improve the initial RUC cloud and precipitation fields for each forecast, and use of an improved version of the RUC optimal interpolation analysis. Performance of the 20-km RUC has shown significant improvement over the previous 40-km RUC running at NCEP from 1998–2002. Verification against rawinsonde observations over a period of almost 4 months in late 2002 showed that the RUC is successful in producing shorter-range forecasts that are more accurate than those of longer durations. This is most true for wind forecasts, as shown in Figure 17, where improved skill is found all the way down to 1-hour forecasts. This same verification showed that RUC short-range forecasts generally improve on persistence forecasts. The RUC is also able to produce short-range forecasts at the surface that are more accurate than longer-range forecasts valid at the same time, and again, improve on persistence forecasts at 1- and 3-hour projections (Figure 18).

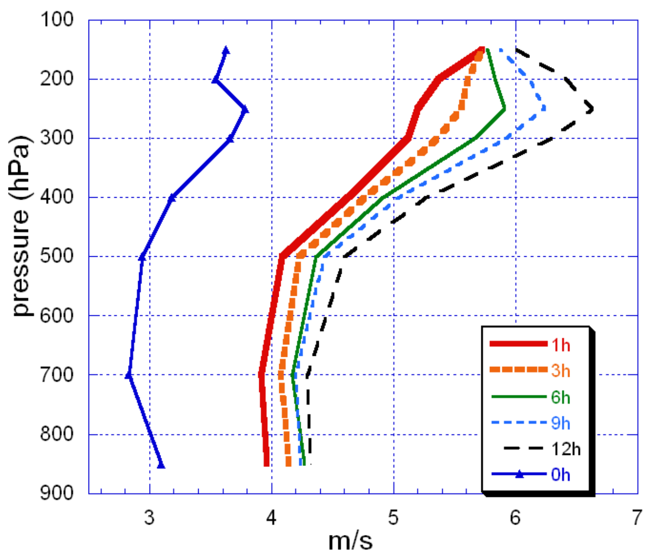


Figure 17. Verification of RUC wind forecasts against rawinsonde observations over entire RUC domain for 11 September–31 December 2002. RMS vector difference (m s^{-1}) between observations and forecasts is shown for forecasts of 1-, 3-, 6-, 9-, and 12-hour duration and for the analysis, all valid at rawinsonde observation times (0000 UTC and 1200 UTC).

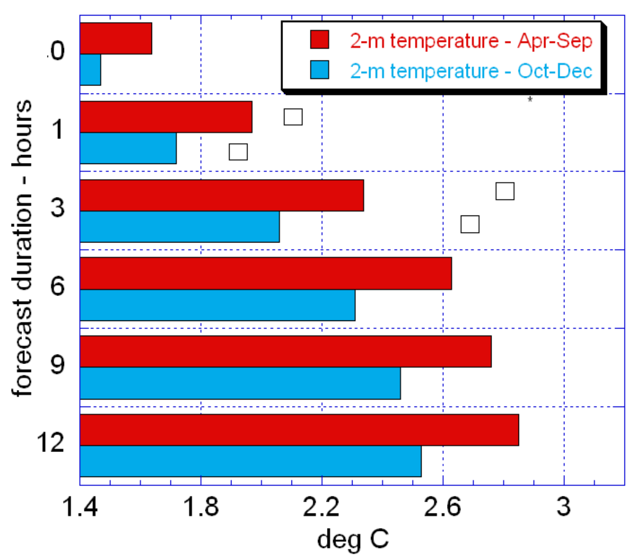


Figure 18. Verification of RUC 2-meter temperature forecasts against METAR (meteorological aviation report) observations over the full RUC domain. Value is standard deviation of observation-forecast difference in degrees C. Two seasons are shown: 17 April–27 September 2002 and 1 October–26 December 2002. Values are shown for RUC forecasts of 1-, 3-, 6-, 9-, and 12-hour duration. Open squares are RMS differences for 1-hour and 3-hour persistence forecasts using RUC analysis for each season.

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

3D Variational Analysis – A 3D variational (3DVAR) analysis has been developed for the 20-km RUC 1-hour cycle and is now being tested at NCEP for an implementation in 2003. The RUC 3DVAR analysis is configured in a generalized vertical coordinate set, which in this case is the RUC hybrid isentropic-sigma coordinate. The use of this coordinate provides an adaptive analysis space, with sloping of background error covariances in the proximity of baroclinic systems, and a stability-dependence for vertical error covariances. The RUC 3DVAR analysis has been shown to give equal or improved forecast skill to those from the current optimal interpolation analysis for forecast projections from 3–12 hours. The RUC 3DVAR analysis also assimilates the following new observational datasets:

- GPS ground-based precipitable water values (now over 180 in the United States)
- 915 MHz boundary-layer profilers (about 25 in the RUC domain)
- RASS temperature low-level virtual temperature profiles from selected 405-MHz and 915 MHz profilers
- Mesonet surface observations

Assimilation of Radar Reflectivity – An initial technique has been developed for assimilation of radar reflectivity and lightning data into the hydrometeor and water vapor fields in the RUC analysis to improve short-range precipitation and cloud forecasts. This technique can modify both rain and snow mixing ratios (Figure 19), accounting for the observed reflectivity in the column. National 2-km resolution reflectivity mosaic fields and 10-km Radar Coded Message fields are being inserted into the RUC20, since the former provides higher resolution but the latter provides beam blockage information to help differentiate "no echo" from "no coverage." Lightning data are used as an indication of convection. Verification of precipitation forecasts made in a parallel cycle using this technique have shown a significant improvement in skill.

Improved Version of the Grell-Devenyi Convective Parameterization – The RUC20 includes improved convective (subgrid-scale) precipitation from an ensemble closure/feedback convective parameterization by Grell and Devenyi. Additional research is being carried out to optimize the closure weighting and even to develop data assimilation techniques for probabilistic convective forecasts. An example of the difference in convective forecasts from the RUC is shown in Figure 20.

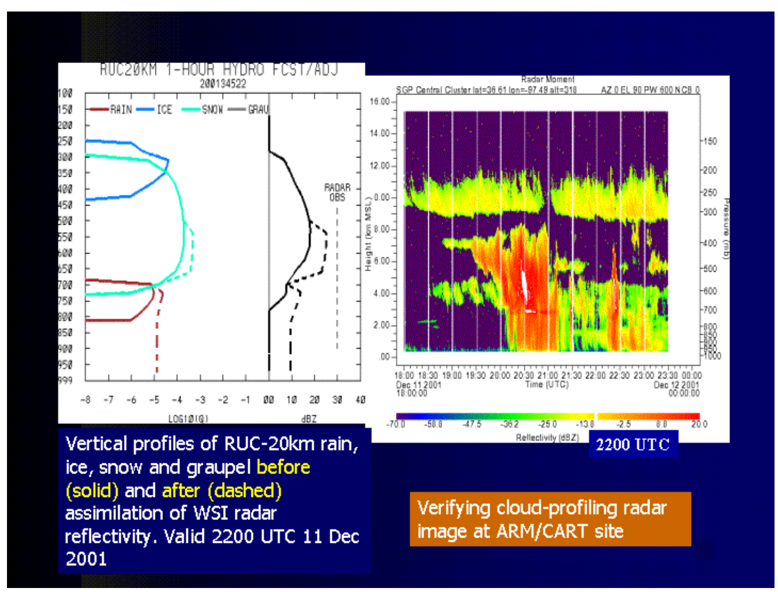


Figure 19. Vertical profiles of 20-km RUC rain and snow mixing ratio before and after assimilation of radar reflectivity for 2200 UTC 11 December 2001 at the ARM/CART site in Lamont, Oklahoma. Also a time series from a cloud-profiling radar at the same location around the same period shows the vertical profile of precipitation.

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.

Applications of the RUC

Development of Improved Atmospheric/Land-Surface Coupled Model Capability and Production of Integrated Datasets for GEWEX/GCIP/GAPP – FSL continues to participate in the multiyear GEWEX and the GEWEX American Prediction Project (GAPP) by providing data from the RUC/MAPS model/assimilation system to the GCIP (GEWEX Continental-scale International Project) archive of gridded datasets. The goal of GCIP is improved understanding of the continental scale hydrological cycle components, and ultimately, improved climate prediction capability. Ongoing improvements to all aspects of RUC/MAPS, especially to its land-surface component, contribute toward meeting this goal.

The RUC/MAPS system was the first regional model to cycle its multilevel soil moisture and soil temperature fields, and continues to be the only one to cycle snow water equivalent depth and multilevel snow temperature. This cycling of snow cover has proven beneficial in short-range surface forecasts in which there is change of snow cover over a 24-hour period, as shown in Figure 21, with snow melted over Wisconsin. In this case, the RUC was able to produce more accurate surface temperature forecasts than other models due to its cycling of snow variable in its 1-hour cycle. Paradoxically, although the RUC is used primarily as very short-range forecast guidance, the cycling of these surface

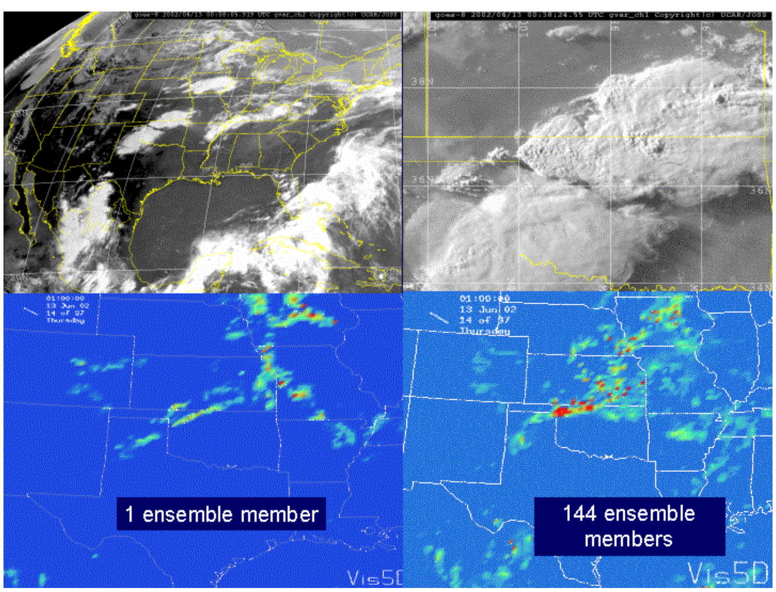


Figure 20. 13-hour forecasts of subgrid-scale precipitation from versions of the RUC using 1 ensemble closure and 144 closures in the Grell-Devenyi scheme, valid 0100 UTC 13 June 2002 (during the IHOP field program). Infrared and visible satellite images valid at the same time are also shown.

fields requires considerable robustness from the land-surface model for what is, in effect, a simulation spanning months to years. In turn, the cycling of soil moisture and snow water equivalent in the RUC leads to improved short-range forecasts. The RUC research for the GEWEX/GAPP project is aimed at using cycling of surface variables combined with data assimilation of radar reflectivity and other cloud/precipitation observations to provide improved land-surface fields which can result in improved seasonal and interannual climate forecasts.

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.

Special High-Resolution RUC Forecasts for NOAA Experiments (PACJET, IHOP, and TAQ) – FSL ran a special high-resolution version of the RUC model for three different special experiments over the last year (Figure 22). First, FSL distributed forecast fields to t he NWS Western Region Headquarters for real-time AWIPS display at local offices in support of the PACJET 2002 (Pacific Landfalling Jets) experiment. The special PACRUC configuration consisted of a 10-km grid covering all of the NWS Western Region, nested within the CONUS 20-km RUC domain. The 20-

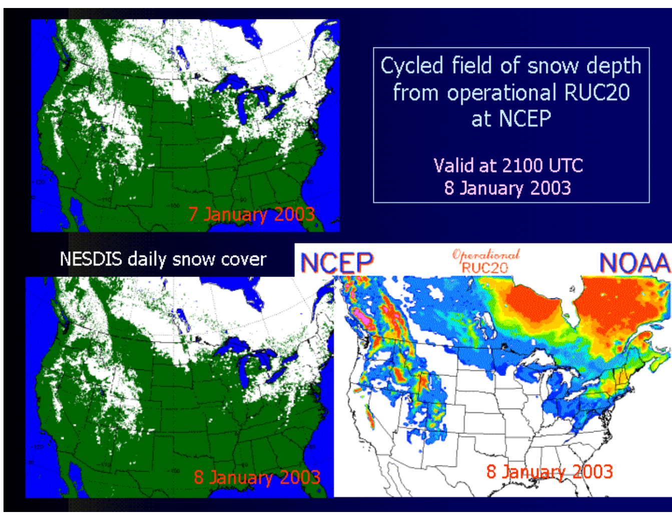


Figure 21. (left) Observed snow cover from 2200 UTC 7 and 8 January 2002 NESDIS analyses and RUC cycled snow cover valid at 2100 UTC 8 January.

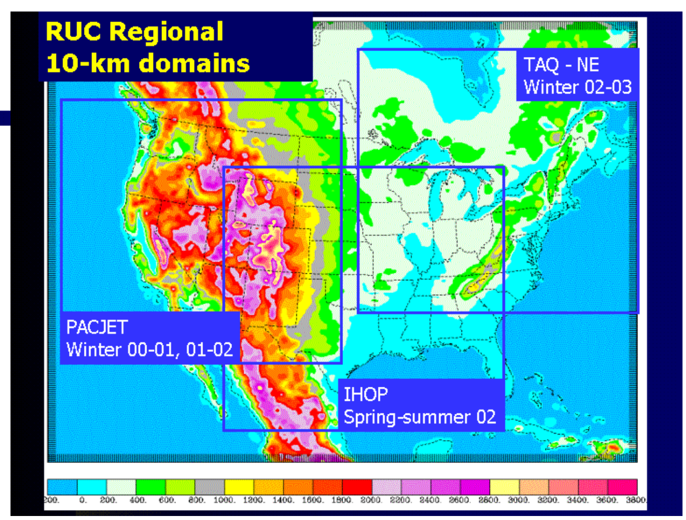


Figure 22. (right) Special 10-km RUC domains run in support of NOAA experiments for PACJET, IHOP, and TAQ programs during 2002.

km RUC utilized a 1-hour assimilation cycle to ingest all conventional observations. PACRUC 24-hour, 10-km forecasts were produced every 6 hours, and AWIPS files containing selected surface fields were transferred to NWS via automated LDM scripts. Additional RUC fields were provided to the forecasters through a Webpage, and a Web-based forecast evaluation form was used to obtain forecaster feedback. Special 10-km RUC forecasts were also produced for the May–June 2002 Central Plains International H_20 Project (IHOP-2002) to the NWS Storm Prediction Center in Norman, Oklahoma. Finally, the 10-km RUC was moved to a domain covering the northeastern United States in support of the Temperature and Air Quality (TAQ) experiment in summer 2002. Again, AWIPS-compatible NetCDF files were provided to the NWS, this time through the Eastern and Central Regions. The 10-km RUC TAQ runs were continued through the fall and into winter 2002–2003. An example of a lake effect snow band forecast from the 10-km TAQ RUC is shown in Figure 23.

Profiler Impact Experiments with RUC – An assessment of the value of data from the NOAA Profiler Network (NPN) on weather forecasting has been completed. A series of experiments were conducted using the RUC20 model in which various data sources were denied to assess the relative importance of the profiler data for short-range wind forecasts. Average verification statistics from a 13-day test period indicate that the profiler data have a positive impact on short-range (3–6 hour) forecasts over a central United States subdomain that includes most of the profiler sites as well as immediately downwind of the profiler observations (Figure 24). Averaged over time of day, the profiler data most strongly reduce the overall vector error in the troposphere below 300 hPa where there are relatively few auto-

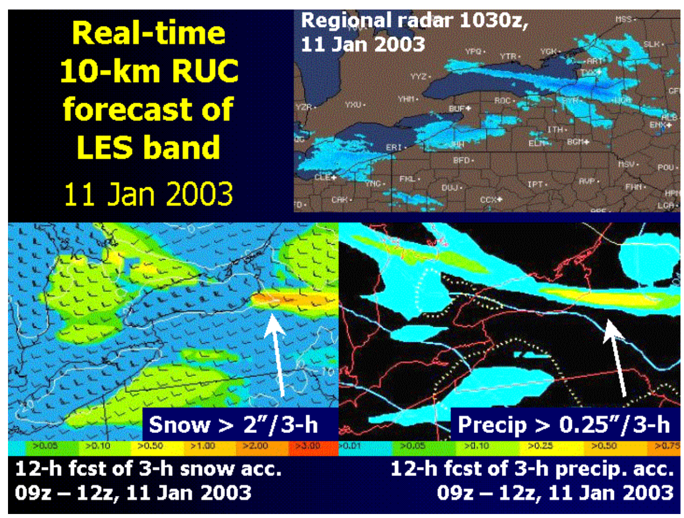


Figure 23. (right) 10-km RUC 12-hour forecast of lake-effect snow band from Lake Huron across Ontario and Lake Ontario into New York. Also shown is observed radar reflectivity at the valid time of 1030 UTC 11 January 2003.

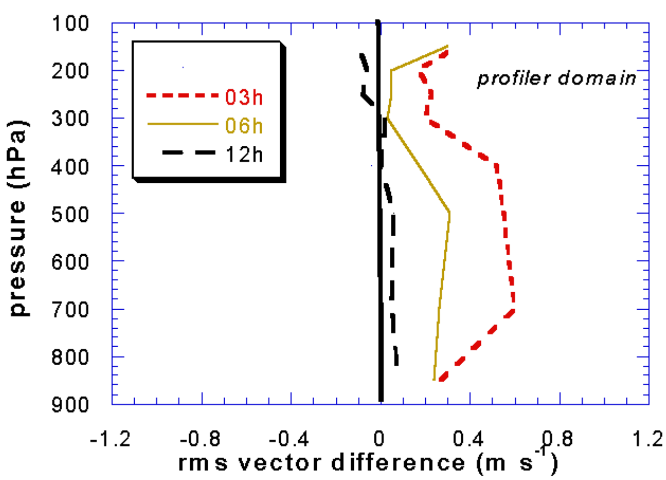


Figure 24. (left) Effects of profiler data denial (no profiler – control with profiler) on RUC wind forecasts. Average RMS vector errors against rawinsonde data for 4–16 February 2001 over an area in the central United States with 22 rawinsonde sites. Positive difference indicates that the control (cntl) experiment with profiler data had lower rms vector error than the no-profiler experiment.

mated aircraft observations. At night when fewer commercial aircraft are flying, profiler data also contribute strongly to more accurate 3-hour forecasts at jet levels. For the test period, the profiler data contributed 20–30% (at 70 hPa) of the overall reduction of 3-hour wind forecast error by all data sources combined.

Several case studies were examined in detail to illustrate the value of the profiler observations for improving weather forecasts. One of the case studies indicated that inclusion of profiler data in the RUC model runs for the 3 May 1999 Oklahoma tornado outbreak improved model guidance of convective available potential energy (CAPE), 850–300 hPa wind shear 0–3 km helicity, and precipitation in southwestern Oklahoma prior to the outbreak of the severe weather. In another case study, inclusion of profiler data improved RUC precipitation forecasts associated with a severe snow and ice storm that occurred over Kansas. Summaries of NWS forecaster use of profiler data in daily operations support the results from these case studies and the statistical forecast model impact study that profiler data contribute significantly to improved forecasts over the central United States, where these observations currently exist. The results of this profiler impact study have been submitted for publication.

Observation Sensitivity Experiments Using RUC to Examine the Impact of GPS Precipitable Water Observations – In collaboration with the Demonstration Division, the RAP Branch continued 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 relative humidity forecasts seen in earlier sensitivity experiments has continued to increase as more stations have been added to the network. Results from a new set of 2-week retrospective experiments for both cold and warm season periods with the 20-km version of the RUC show still greater impact from the addition of GPS precipitable water observations than with the 60-km RUC model.

Collaborative Modeling Projects

Regional Lidar OSSE Experiments with RUC – FSL has completed a series of regional observing system simulation experiments (OSSEs) designed to test the potential impact of a space-based Doppler lidar wind profiling system on regional-scale numerical weather predictions. OSSEs utilize a numerical prediction model to mimic a typical atmospheric evolution, and provide a cost-effective method for evaluating the forecast improvement from potential new observing systems. As shown by Figure 25, the regional OSSE experiments were run in conjunction with a series of global OSSE experiments conducted by NCEP. Lateral boundary conditions needed for the regional OSSE

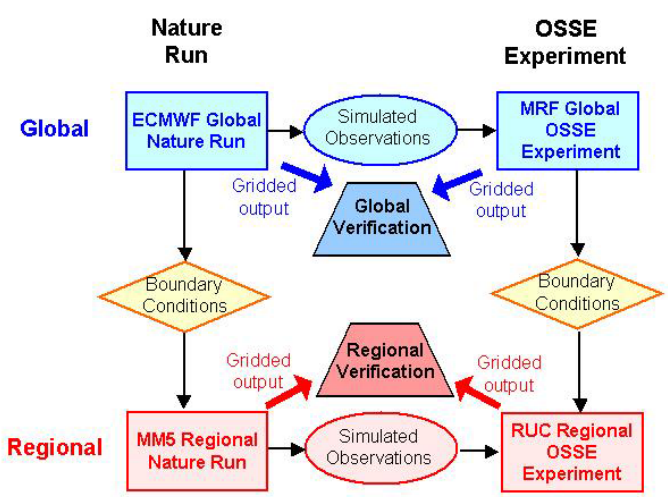


Figure 25. Flow-chart depicting the relationship between the regional and global lidar OSSE experiments. The global nature run (ECMWF model) supplies lateral boundary conditions to the regional nature run (MM5 model) and simulated observations to the global assimilation runs (MRF model). The regional assimilation runs (RUC model) receive boundary conditions from the global assimilation runs and simulated observations from the regional nature run.

experiments run with the RUC were obtained from matched global lidar OSSE experiments, while simulated observations, assimilated into the RUC, were obtained from the MM5 regional nature run completed by the Local Analysis and Prediction Branch. Conventional observations (rawinsonde, profiler, VAD, ACARS, METAR, buoy) and simulated lidar observations were computed directly from the regional nature run. The assumed characteristics of the lidar observations were produced by the NOAA Environmental Technology Laboratory. Calibration of the MM5 regional nature run was performed using the European Centre for Medium-Range Weather Forecasts global nature run, and coding of the regional verification software was completed by NCAR – thus a truly collaborative, multiyear effort.

Regional forecast improvements due to the lidar observations can come from three sources: 1) direct assimilation of the lidar observations on the regional domain 2) improved lateral boundary conditions due to the assimilation of lidar observations on the regional domain and 3) improved lateral boundary conditions due to the assimilation of lidar observations from the global model. As expected, results from this study indicate forecast improvement from all sources. Improvement from the direct assimilation of lidar observations is greatest at the analysis time, then slowly diminishes with forecast length, while improvements from the lateral boundary conditions increase with forecast length. Initial OSSE experiments focused on a best-case scenario, in which no lidar observations were lost due to cloud attenuation and no errors were added to the lidar observations. In these experiments, lidar wind observations produce modest short-range (0–12-hour) forecast improvements over the data-rich RUC domain. Midlevel wind forecasts benefit the most, with 6-hour forecast error reductions of up to 10% (Figure 26) from the assimilation of lidar observations. Other experiments which accounted for the loss of lidar observations due to clouds and the existence of random errors in the lidar observations, have shown only a slight reduction in the forecast improvement compared to the best-case experiments. As part of this project, the formulation of the RUC 3DVAR was modified to facilitate the direct assimilation of lidar line-of-site wind observations. This modification also allows for the future direct assimilation of Doppler radar radial velocity observations, in accordance with planned RUC analysis enhancements.

Air quality Forecasts from a Coupled Weather/Air Chemistry Prediction Model – FSL is developing and applying a next-generation coupled weather/air quality numerical prediction system. This system is capable of forecasting ambient ozone concentrations over regional to urban scales and includes the MM5 meteorological model with "online" chemical capability. In this system the chemical kinetic mechansm is embedded within the meteorological model structure, and thus the integration of the chemistry is performed as part of MM5 (MM5/Chem). Biogenic emissions

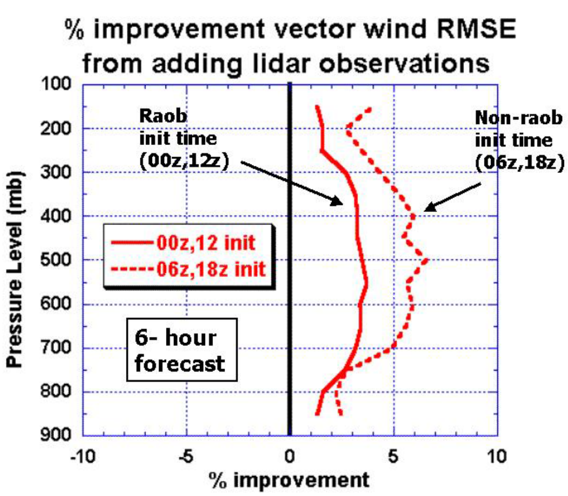


Figure 26. Vertical profile of the percent improvement (reduction in error) in vector wind root mean square error for 6-hour RUC forecasts due to the assimilation of idealized simulated lidar observations. The impact for forecasts initialized at the rawinsonde observation times (0000, 1200 UTC) is less than that for forecasts initialized at nonrawinsonde observation times (0600, 1800 UTC).

are also integrated online since they are strongly modulated by meteorology. A second coupled modeling system, led by FSL, is based on the Weather Research and Forecasting (WRF) numerical model and uses the same chemical modules as MM5/Chem.

During the summer of 2002, MM5/chem was run in real time at FSL in support of the New England Temperature and Air Quality (TAQ) pilot experiment. The domains for which forecasts were produced were shown in Figure 16, and Table 1 summarizes each of the runs. In addition, during 5 July–30 August 2002, data from the model forecasts were provided in real time to several OAR laboratories via the Web. NOAA/ETL received data from the numerical forecasts for verification with meteorological observations at profiler locations, and with surface observations at special high energy usage sites. (Figure 27 shows an example of a meteorological comparison that was displayed in real time.) Scientists at the National Severe Storms Laboratory (NSSL) received meteorological data on a common three-dimensional grid for ensemble predictions. Special three-dimensional chemical and meteorological datasets were also provided to the NOAA Aeronomy Laboratory (AL) for verification as well as for real-time forecasting aboard the *Ron Brow*n. An example of a comparison of ozone forecasts with measurements from the *Ron Brown* as seen in real time on 24 July is shown in Figure 28. Note that for this particular case the model did exceptionally well in predicting the ozone concentrations, especially for the highest resolution forecasts. Finally, the Air Resources Laboratory (ARL) received surface chemistry and meteorology datasets for verification. The completion rate of the model forecast run on the Jet supercomputer at FSL was greater than 95%.

In addition, data from July and August 2002 have since been rerun to create a complete testbed dataset. A statistical comparison with observations over this time period was performed by AL and is now available as a baseline dataset to compare against. (See Figure 29 for an example of a comparison of ozone forecasts and observations at one particular station.) Development of this type of testbed dataset is a powerful tool in model development to aid the assesment and

Table 1
Real-time Model Runs at NOAA/FSL

Domain/ Horizontal Resolution	Meteorological Input Boundary Conditions	Simulation Length	How Often	Initial Chemistry Fields	Chemistry Boundary Conditions	Anthropogenic Emissions Input
DO1/ 21 km	RUC20/Eta	60 Hours (12 Hours (FDDA + 48-Hour Forecasts)	Twice Daily	FDDA	Background Soundings	EPA NET 95
DO2/ 9 km	MM5/Chem – DO1	24 Hours	Twice Daily	12-Hour Forecasts	M5/Chem – DO1	EPA NET95
DO3/ 3 km	MM5/Chem – DO2	24 Hours	Twice Daily	12-Hour Forecasts	MM5/Chem – DO2	EPA NET95

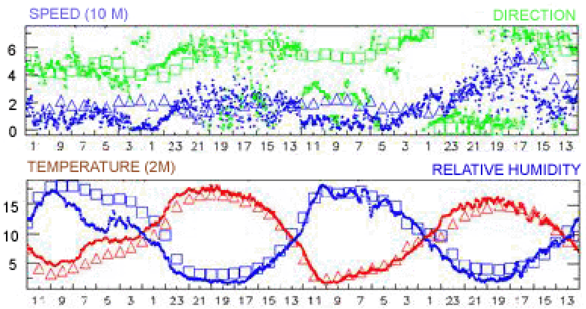


Figure 27. (left) Time series of predicted (symbols) versus observed (dots) wind speed (a, blue) and wind direction (a, green), 2-m temperature (b, red), and relative humidity (b, blue) for the Schenectady profiler site as seen at 1200 UTC 10 August. Time starts on the right side of the graph 1200 UTC 8 August.

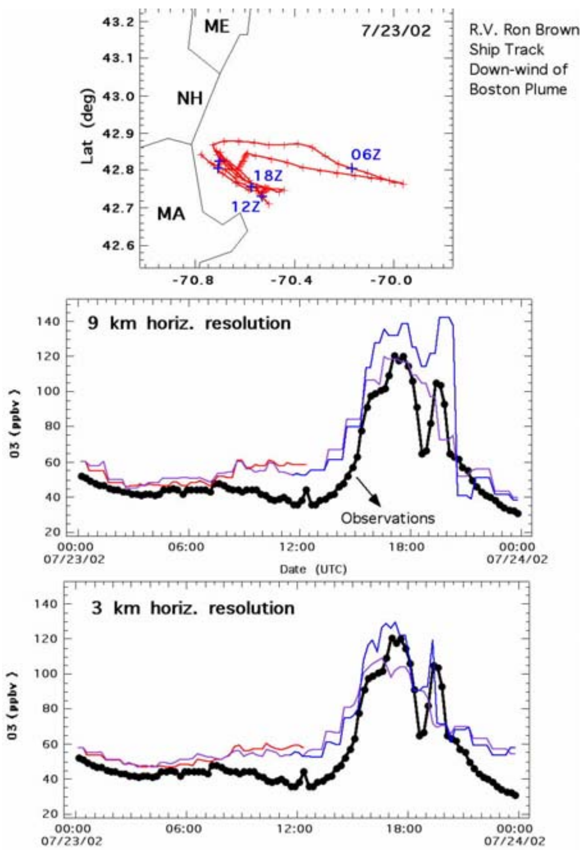


Figure 28. (left) Observed (thick black line) and predicted (color lines) ozone concentrations as measured on the Ron Brown for predictions using MM5 9-km horizontal resolution (middle panel) and 3-km horizontal resolution (bottom panel). Displayed are results from model runs starting at 1200 UTC 22 July (red lines), 0000 UTC 23 July (purple lines), and 1200 UTC 23 July (blue lines).

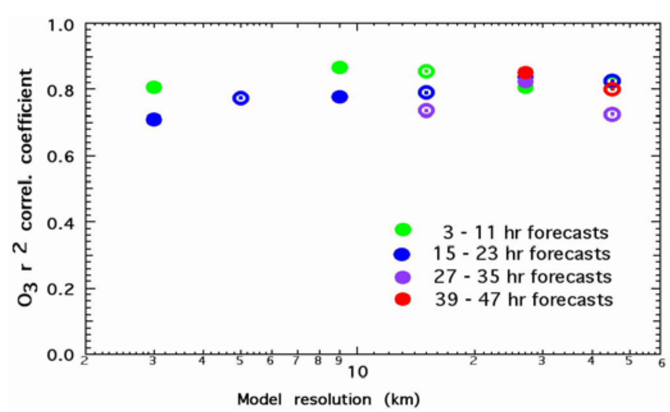


Figure 29. (right) Correlation coefficients of observed versus predicted ozone concentrations at Harvard Forest, averaged over 120 runs (July and August 2002). Displayed are the r^2 for different model resolutions and different forecast times for the day times.

understanding of currently available atmospheric numerical modeling systems, and point to areas where further development is needed as we work toward production of reliable air quality forecasts.

In addition, FSL is taking the lead in developing the next-generation air quality forecast model, WRF/chem. The first version of this model already exists and includes all chemical modules that are a part of MM5/Chem (grid-scale and subgrid-scale transport, biogenic emissions, deposition, photolysis, and the RADM2 chemical mechanism). Evaluation of this model is currently in progress, and it will probably be run in realtime during the summer of 2003.

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.

In collaboration with NCAR, FSL has worked on the development of physics packages and a three-dimensional (3DVAR) analysis system. FSL has contributed two physics components to the WRF forecast model – an alternative land-surface model based on the RUC land-surface model and the Grell-Devenyi ensemble convective parameterization. Both of these schemes have been fully implemented and tested in the WRF model. FSL has also developed the standard initialization package for the WRF model, and has worked with the University of Miami on development of a quasi-isentropic variant of the WRF nonhydrostatic model.

The WRF model is being tested with RUC initial conditions for two different domains, the 20-km CONUS RUC domain; and the 10-km TAQ New England domain. The WRF standard initialization (SI) procedure was modified to fully use RUC native-coordinate initial conditions, including hydrometeor and land-surface fields. In addition, a post-processor was developed from the WRF model to produce RUC-like GRIB output files, facilitating comparisons with RUC model forecasts. FSL will adapt WRF assimilation and model systems over the next several years to include an advanced rapid update capability for operational implementation at NCEP. It is planned that the WRF model will supplant the current RUC forecast model in the Rapid Update Cycle by 2006.

Projections

The Regional Analysis and Prediction Branch will continue to work with scientists 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.

Implementation of Three-Dimensional Variational (3DVAR) Analysis in the 20-kilometer RUC – With tuning to ensure sufficient accuracy for short-range wind forecasts, the RUC 3DVAR analysis will be added to the 20-km RUC running at NCEP. The 3DVAR implementation will provide smoother analyses, more accurate forecasts, and a framework for assimilation of radial wind observations from radar in the future. Development and real-time testing will continue on the 3DVAR analysis, both for incorporation into the RUC and toward the development of the 3DVAR analysis for the WRF model.

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.

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, which 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.

High-Resolution Experiments Using RUC for the New England Temperature Air Quality Experiments – RUC forecasts will continue to be made at 10-km resolution in support of this experiment. In addition, the WRF model will be run over the same domain, also at 10-km resolution, initialized from the RUC. This will allow initial intercomparisons between the current RUC hydrostatic model and the WRF nonhydrostatic model including RUC physical parameterizations, the RUC land-surface model, and the Grell/Devenyi ensemble-closure cumulus parameterization. Objective verification of the model forecasts will be performed as part of these studies.

Participation in GEWEX – Collaboration will continue on the GEWEX/GAPP program, with the focus on development of a coupled atmospheric/land-surface assimilation system that uses an optimal combination of radar and satellite observations to modify clouds and precipitation along with model forecasts in regions where observations are unavailable.

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 – Future work will first involve 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.

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. The branch carries out the research and development of the Local Analysis and Prediction System (LAPS) and the implementation of mesoscale forecast models. The primary objective is to provide real-time, three-dimensional, local-scale analyses and short-range forecasts (0–24 hours) for operational weather offices, facilities, or field operations. Activities cover four broad areas:

Data Acquisition – Includes identifying, collecting, and quality-controlling any kind of atmospheric or earth surface measurement, such as those provided by satellites, radars, mesonets, aircraft, GPS, balloons, 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, which stores portable applications that retrieve and render AWIPS weather data into images and graphical displays for dissemination.

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 National Ocean Service for Chesapeake and Naragansett Bays, for the U.S. Forest Service (USFS) in support of fire mitigation and firefighting, and for the U.S. Army in support of precision parachute airdrop activities.

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, Aviation, and the U.S. Navy Operational Global Atmospheric Prediction System). Implementation of the LAPS system at some NWS forecast offices has demonstrated the portability and effectiveness of running models locally. One such demonstration, sponsored by NWS, tests the feasibility of local modeling in NWS WFOs. The collocation of FSL with the Denver-Boulder NWS Forecast Office has demonstrated the effectiveness of locally run models during the past few years, as LAPS-initialized mesoscale models have been run on their local AWIPS hardware 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. A unique ensemble of mesoscale models (RAMS, MM5, and WRF) is currently supporting the weather forecast input to a road maintenance decision support system demonstration for the Federal Highway Administration.

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 such as those mentioned later. LAPS fields are compatible with AWIPS file formats and appear in a number of dedicated Webpages for specified customers. 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.

LAPS can be displayed in three dimensions using the experimental D3D (Display Three-Dimensional) add-on to AWIPS. Figure 30 illustrates an end product of the LAPS effort, namely to completely define the local meteorological environment using this D3D display (in the form of isosurfaces). 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 as well as within other operational environments.

Accomplishments

Basic Analysis System Development

Three-Dimensional Variational 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.

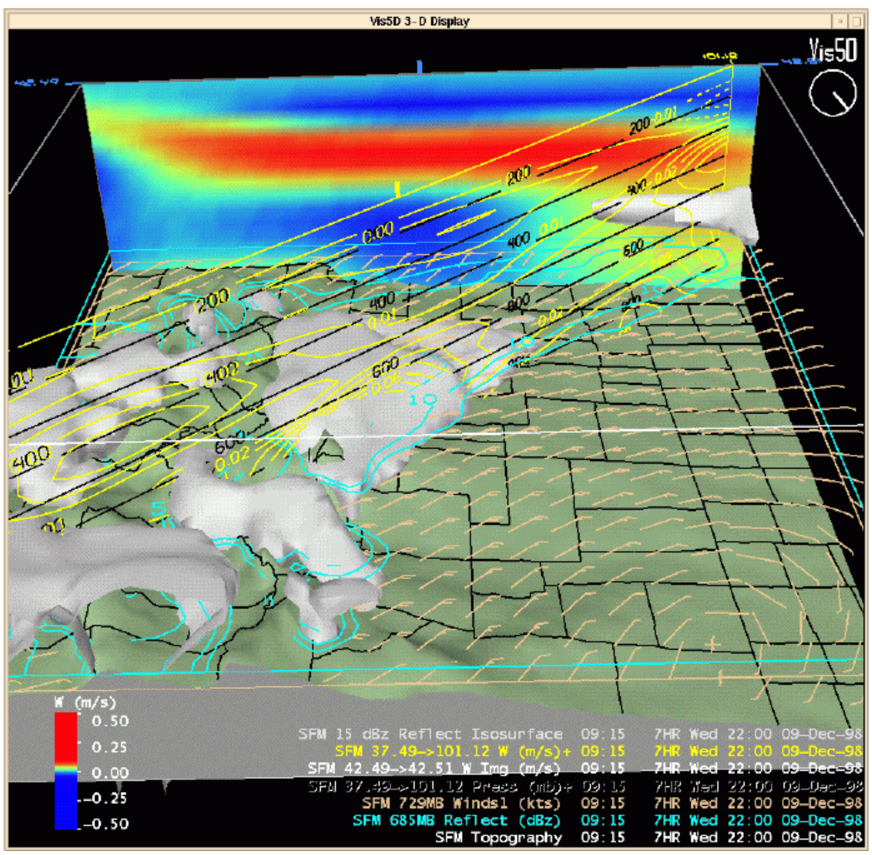


Figure 30. Three-dimensional Vis 5-D image of forecast LAPS fields including clouds (white/grey material surfaces), horizontal reflectivity at 675 meters (blue lines), vertical cross section of reflectivity (yellow lines), pressure (millibars, black lines in diagonal cross-section plane). Back graphic plane shows vertical motion (blue upward; red downward).

In LAPS the variational step was previously used only with GOES sounder radiances. The variational adjustment using GOES radiances includes 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 are 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 has been used to improve model initialization. This analysis 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 substance. Variational methods are used to impose dynamic balance and continuity on the first-stage analyzed fields to accommodate the "Hot Start" analysis described below.

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 LAPS support of a three-dimensional 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. Since the Kalman scheme still requires more computer storage than is currently available in the local weather office, it has not been widely used.

LAPS "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 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. This system depends greatly on the accuracy of the background modeling system, currently the NCEP versions of the RUC and Eta models. 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.

Verification with MM5 during the 6-week International H_2O Project showed that the Hot Start outperforms other initialization techniques in the 0–6-hour time frame in forecasts of precipitation, most state variables, and 3-D cloud and radar fields. Figure 31 shows equitable threat scores for precipitation for the entire experiment. Note that the bias for the LAPS Hot Start 3-hour forecasts is nearly 1.0 across all precipitation categories (i.e. it is nearly unbiased), whereas the other models characteristically overforecast very light precipitation amounts and display a large dry bias for precipitation amounts >0.25 inch. The Hot Start method is used to initialize MM5 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

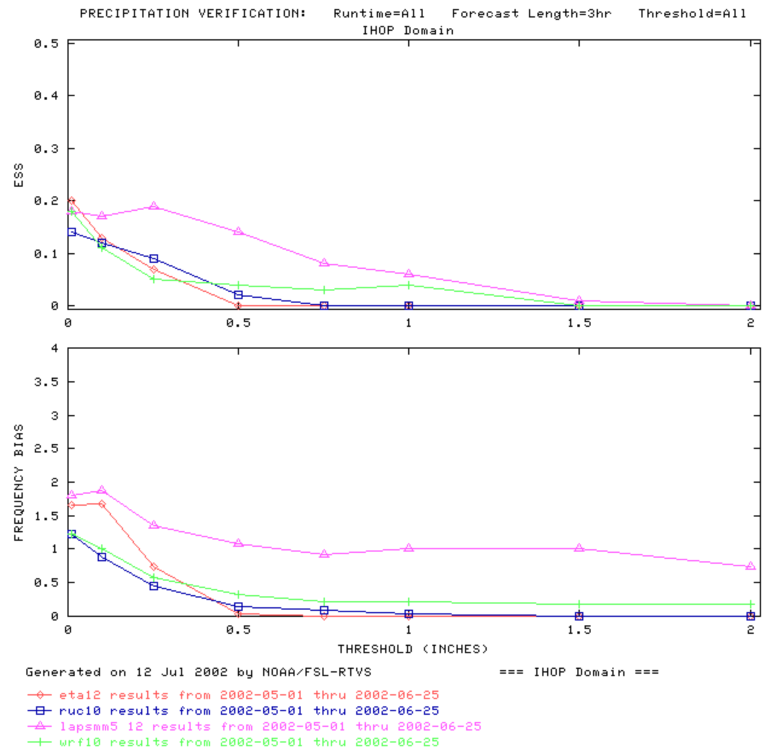
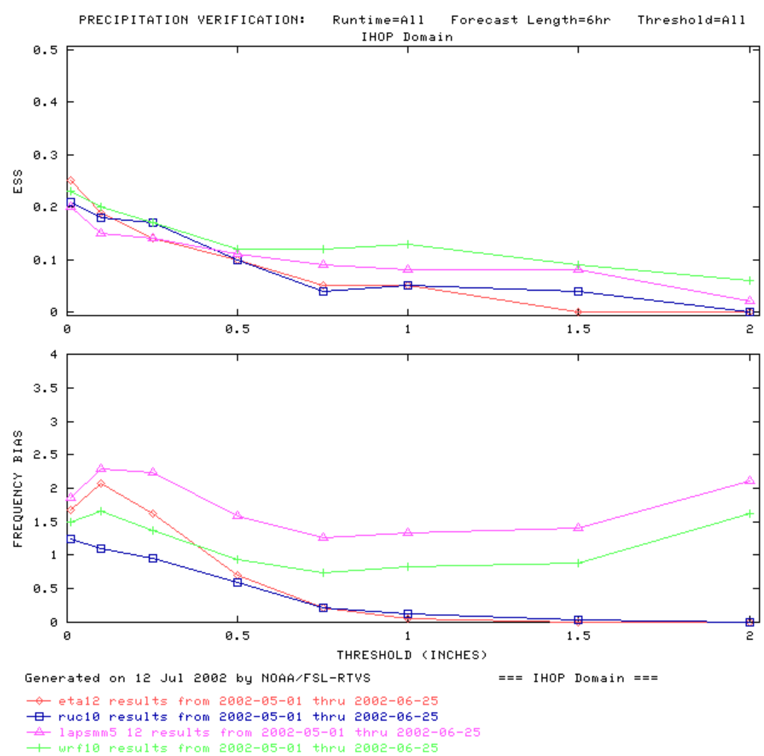


Figure 31. (a, above) Equitable threat score (ETS) and frequency bias for various precipitation categories (x-axis) for 3-hour precipitation forecasts from the 12-km LAPS Hot Start MM5 (pink), the 10-km WRF (green), the 12-km Eta (orange), and the 10-km RUC (blue) models; (b, below) Same results for the 6-hour forecast period.



at Vandenberg Air Force Base as part of the Range Standardization and Automation (RSA) implementation discussed below, and IHOP field operational 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 National Weather Service and National Ocean Service. It is also under evaluation as part of the MM5 modeling system at the Central Weather Bureau of Taiwan.

GOES Improved Measurements and Product Assurance Plan – The GOES Improved Measurements and Product Assurance Plan (GIMPAP) project has been a key part of the LAPS 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 total precipitable water analysis over the IHOP domain as generated by the LAPS analysis system incorporated real-time NESDIS product data with greatly reduced latency (a 30-minute cycle instead of the customary 60-minute cycle) and experimental GOES-11 single field-of-view (unsmoothed) radiance data. It also used indirect NESDIS cloud-top product data via the LAPS cloud analysis. The IHOP product stream was accurate and timely throughout the 6-week field project.

Joint Center for Satellite Data Assimilation (JCSDA) – The latest OPTRAN code was obtained from NCEP, compiled and tested, and made to run under IBM AIX, Linux Dec Alpha and Linux PC, and Sun OS. Current work involves writing the interface between OPTRAN and LAPS, and exploring the mesoscale nature of the background and observed error covariances for moisture analyses.

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 serves the LDAD system operating outside the AWIPS network. The independent LAPS quality control system will supplement the LDAD quality control system to ensure that local data are monitored and properly employed. The LAPS group continues to support new AWIPS builds and updates the software as needed.

The WFO-Advanced workstation in Boulder receives 10-km resolution MM5 model output from twice daily model runs on exactly the same grid and projection as the LAPS analysis. This permits 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. The model is running experimentally in the Denver-Boulder NWS Forecast Office on a system within the AWIPS application hardware suite. The model runs in automated mode with little intervention required, and is diabatically initialized using the Hot Start procedure discussed above. Another onsite model implementation is now in progress for the Jacksonville, Florida, WFO under the Coastal Storms Initiative. This model is being established to test short-term forecast capabililty and application of high-resolution wind forecasts to improve estuarine water flow for harbor operations.

U.S. Army Precision Air Drop Project – In 2002, the LAP Branch became involved with a U.S. Army-sponsored development to improve the accuracy of middle-level 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 channeling terrain, computed air drop release points (CARP) were often inaccurate, resulting in cargo being substantially off target. In regions of Bosnia, for example, the errors were often whole valleys off target, resulting in long excursions to recover the needed material. In conjunction with Planning Systems Inc., of Reston, Virginia, the LAPS group was asked to port the LAPS analysis onto a laptop that would be 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, process and assimilate the dropsonde with model background fields, and create a high-resolution profile that accommodates time and space displacements from the dropsonde to cargo release time, while accounting for flow channeling over rugged terrain. The laptop computes an updated CARP, within minutes, reducing the threat period for the aircraft. LAPS was ported into the PADS and is now undergoing testing at an Arizona drop range. LAPS is able to ingest the data quickly and provide the wind data to recompute the CARP in less than 3 minutes. Tests so far have been good for mid-level drops, but less so for high-level drops.

Participation in IHOP – FSL participated in the International H_2O project (IHOP) in May and June 2002. Different versions of mesoscale models – run in real time – were used to aid in the nowcasting and forecasting effort to support IHOP operations. Formal real-time evaluation and documentation of the model forecasts were part of the IHOP effort, using online forms to record forecaster assessment of the quality and usefulness of the models. A more formal evaluation is taking place after the end of the IHOP field phase, in coordination with researchers at NCAR and at the Storm Prediction Center (SPC). Figure 32 shows example forecasts from three of the models for a rather subtle dryline situation during a very dynamic convective event and a comparison of the composite radar imagery over the IHOP region to a forecast from the 4-km MM5 model showing a pronounced bow echo forming along a developing squall line.

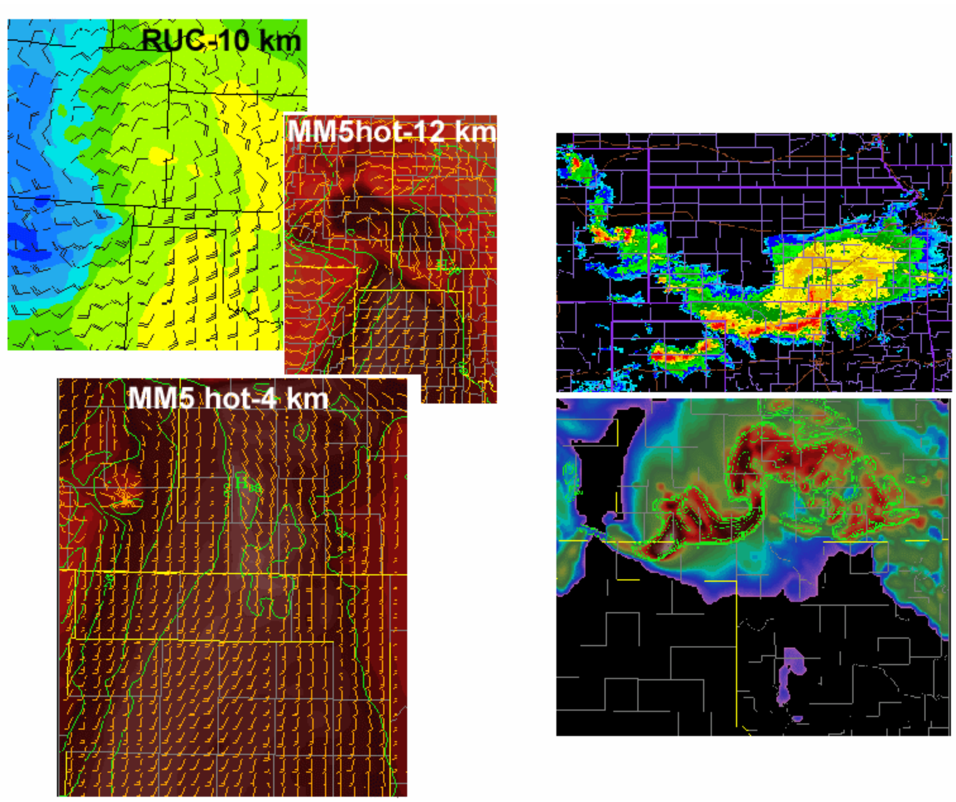


Figure 32: (a, left side) 6-hour surface temperature and wind forecasts valid at 2100 UTC 15 June 2002 from three experimental mesoscale models run by FSL during IHOP for a rather subtle dryline situation during a very dynamic convective event and (b, right side) composite radar imagery over the IHOP region at 0000 UTC 16 June and a 6-hour forecast from the 4-km MM5 model.

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, 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 first version of the RSA Data Assimilation and Forecast System, based on LAPS coupled with the NCAR fifth-generation Mesoscale Model (MM5), is in testing mode. 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 14, 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 33 shows an example of a product on the interior (1-km mesh) of forecast surface wind and temperature, verifying surface plots, and comparative wind forecasts from the MesoEta model over the local area surrounding Vandenberg AFB.

The RSA and projects spurred numerous improvements to the LAPS/MM5 prediction system. First, the cloud analysis was adapted to ingest and use narrowband radar reflectivity from multiple WSR-88D sites, available via the Satellite Broadcast Network (SBN) feed into AWIPS. This provides better coverage over the entire domain of the grid used for the RSA, which is spatially larger than a typical NWS Forecast Office domain. Second, the cloud analysis was modified to use a climatological albedo field to increase the utility of the visible satellite imagery. This, combined with the recent integration of the GOES 3.9 micron channel, has greatly improved the system's ability to detect low stratus clouds over the ocean surrounding the Western Range. Third, for the purposes of initializing a numerical weather prediction model, the final three-dimensional concentrations of the hydrometeor species are scaled as a function of horizontal grid spacing. Finally, to ensure compatibility with current numerical weather prediction model microphysics schemes, any grid box volume containing cloud liquid or ice is raised to its saturation level with respect to the phase of the cloud species. This prevents rapid evaporation of the cloud and the concomitant spurious generation of cool downdrafts within the first few time steps of model integration.

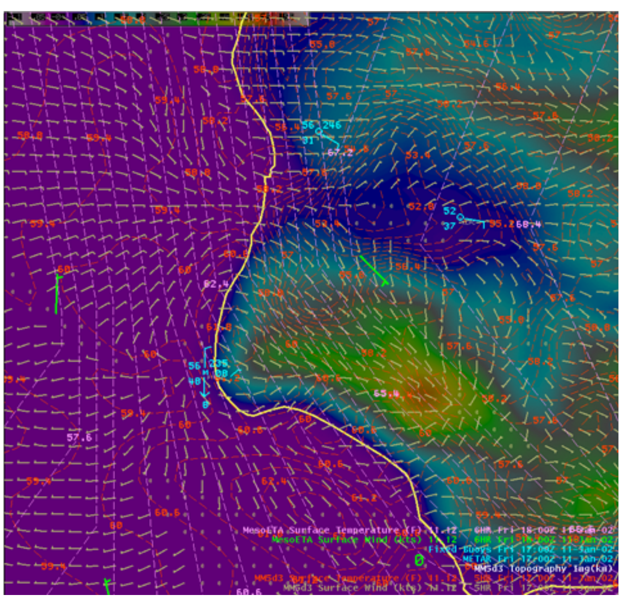


Figure 33. 5-hour surface forecast for 1700 UTC 11 January 2002 from LAPS/MM5 of isotherms (red contours), wind barbs (tan), and 6-hour MesoEta wind forecasts (green), all valid at 1800 UTC, and verifying surface observations (cyan).

These RSA capabilities together represent 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 FSL work includes ingesting and optimizing the use of all 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

International Collaborations **–** 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. 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. 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.

The CWB-LAPS products feed into CWB's Weather Information and Nowcasting System workstation. The onsite and "shadow systems" (running at FSL) were improved to completely mimic the CWB system. The surface analyses were upgraded to handle analysis of variables in the coastal zones by increasing correlation over similar earth surface characteristics. Use of model backgrounds into LAPS was improved and coupled to bogussing techniques for tropical cyclone positioning. Satellite imagery for infrared and visible bands are ingested in the cloud analysis scheme.

The CWB MM5 modeling effort was the focus of a visiting scientist at FSL who worked with the group to configure a multinested modeling domain, a LAPS Hot Start initialization capabililty, inclusion of bogussing, and a precipitation verification system. Results indicated that the Hot Start scheme helped to better define tropical rainbands leading to improved 0–9 hour forecasts. As an example, Figure 34 shows forecasts of Typhoon Rammasun, which skirted the islands to the northeast of Taiwan. Experiments were run with cold start, hot start only, and hot start with bogussing. Three 6-hour forecasts are shown along with comparative track forecasts out to 24 hours for each realization. The Taiwan MM5 system is being implemented at the CWB.

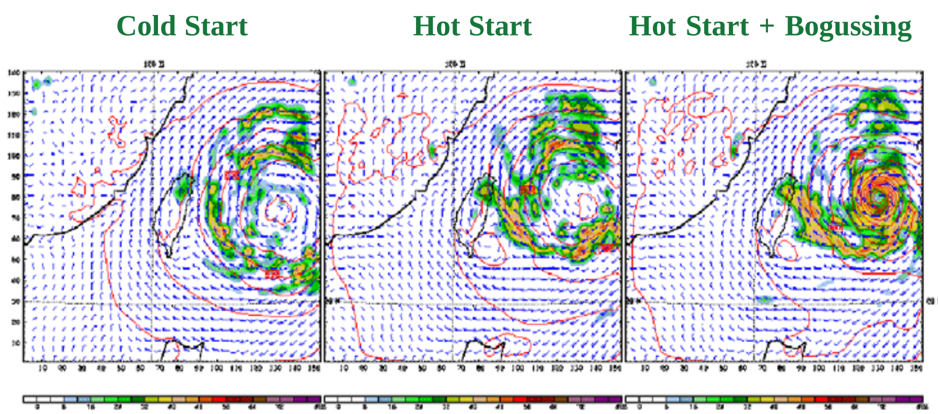
Branch staff visited with Central Weather Bureau forecasters and researchers in Taipei to conduct training on the potential use of LAPS in operational forecasting and discuss ideas for nowcasting. A Webpage *(http://laps.fsl.noaa.gov/szoke/taiwan/taiwan_lapstrainingpage.html)* was created to display the training sessions online and provide a subjective evaluation of the LAPS performance at the Taiwan CWB.

Additional collaboration with the Korean Meteorological Agency (KMA) and Hong Kong Observatory (HKO) has been less formal but ongoing. Both agencies are interested in developing a 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.

Ensemble Modeling of Winter Road Conditions – In collaboration with NCAR, LAP Branch scientists began designing an ensemble of mesoscale models to support a Federal Highways Administration (FHWA) road weather project. The ensemble includes multiple models (MM5, RAMS, and WRF) with lateral boundaries provided by multiple large-scale models (AVN, Eta, and RUC) that run at relatively high spatial resolution. Although ensemble techniques have been applied before on grids with approximately 25-km resolution, runs for this experiment were performed on 12-km grids and were used to make site-specific (road) probabilistic forecasts. The need for quantitative precipitation forecasts early (0–3 hours) in the forecast cycle necessitated the use of the LAPS hot start for all model runs. Cold started model runs were attempted, but these were of little value. Grids from the 9-member ensemble were fed into the NCAR Maintenance Decision Support system where the weather probabilities were used to make road maintenance decisions (mobilization of trucks, routes, types of chemicals, duration, etc). The system has been tested during the 2003 winter. Figure 35 shows four ensemble members and forecasts centered over the Iowa test area.

Developments for the Weather Research and Forecast Model – The branch is involved in three key areas of the WRF modeling system. The Standard Initialization (SI) software creates model start-up grids from the NCEP national AVN, RUC, or Eta models. The land-surface module (LSM) of WRF uses "static" fields (such as vegetation greenness,

Typhoon Rammasun



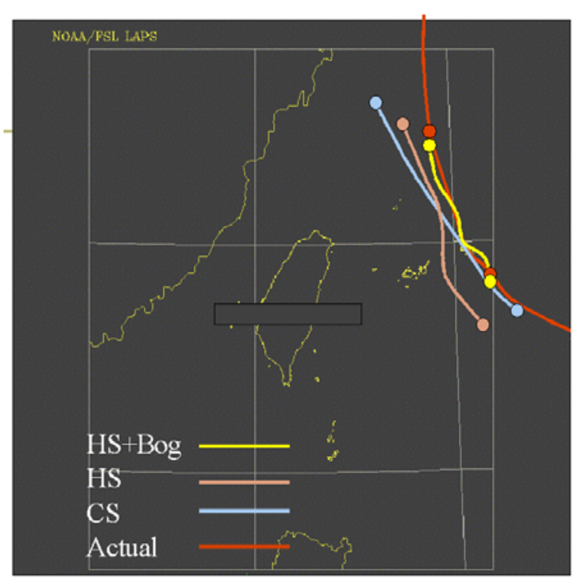


Figure 34. MM5 simulated radar 6-hour forecasts for three scenarios: (a, top panels, left) cold start (model initialized with background only), (center) LAPS Hot Start with data and background, and (right) LAPS Hot Start using a background bogussed position of storm in the background fields. The latter method produces the best analysis, although rainbands are more mature in the hot start versus the cold start. (b, left) shows the comparative track forecasts: red is actual track with southern dots showing initial positions and northern dots showing forecast position at 24 hours; blue is cold start forecast; brown is hot start; yellow is hot start with bogussed initial position.

albedo, land use, terrain height, land fraction) that have been assembled and reformatted, along with efficient interface software. The third area is a graphical user interface (GUI) for the localization of the WRF to be used by the WRF community. The initial version of the GUI was released to the WRF user community in early 2003. These software components – developed by the LAP Branch and sponsored jointly by the Air Force Weather Agency, FHWA, and FAA – are released routinely with the WRF model itself.

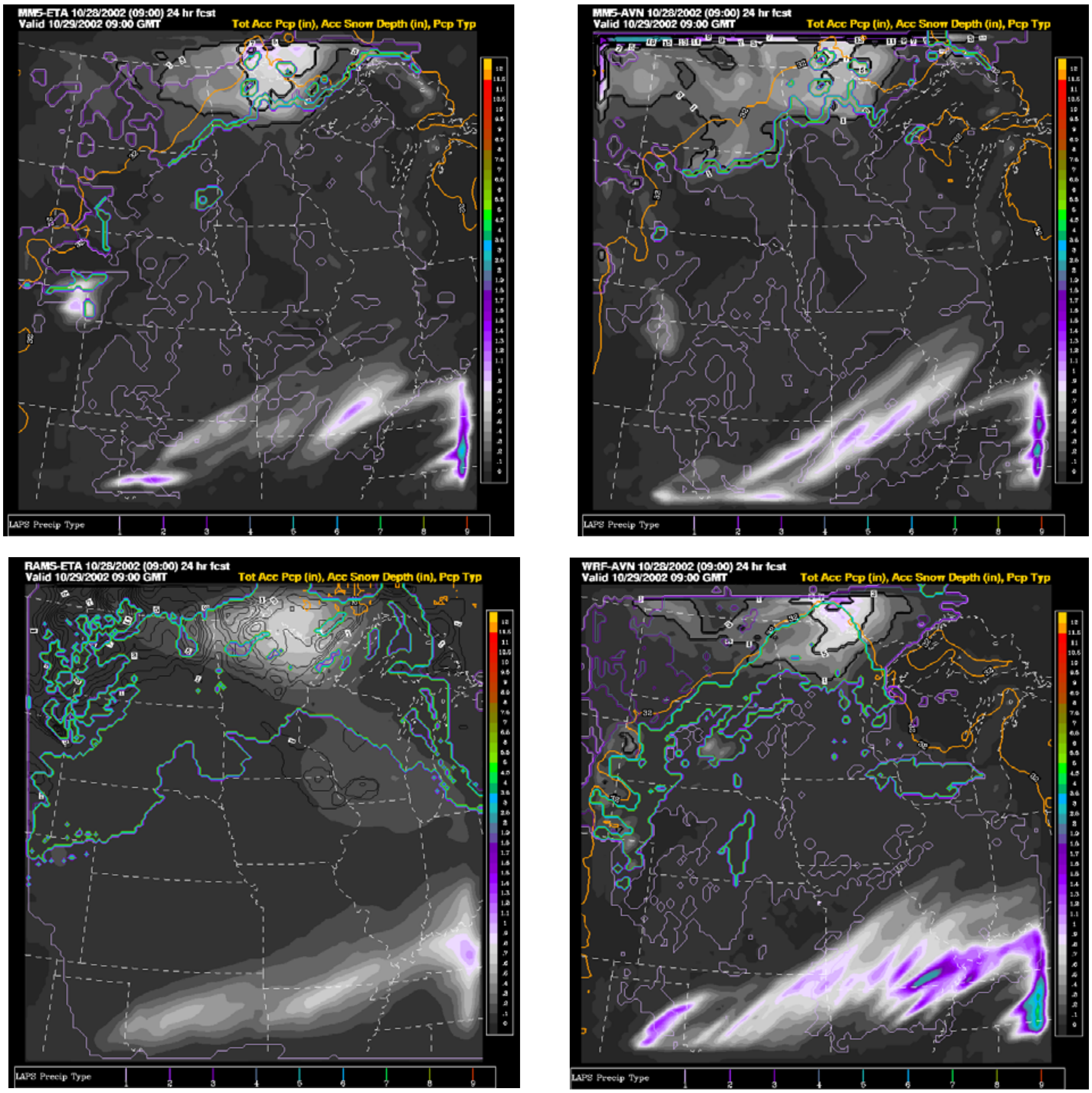


Figure 35. 24-hour forecasts on 29 October 2002 showing precipitation accumulation for the upper Midwest (centered over Iowa). (a, upper left) MM5 with Eta boundary condition; (b, upper right) MM5 with the AVN boundary conditions; (c, lower left) RAMS with Eta boundary conditions; and (d, lower right) WRF with AVN boundary conditions using models initialized with LAPS/Hot Start.

Lidar OSSE Studies – A strong interest has evolved over the last 20 years in the possibility of inferring atmospheric winds from Doppler lidar measurements aboard a polar orbiting satellite. Two satellites in appropriate orbits could provide daily global wind coverage, at least where the pulses of energy from the lidar are not blocked by clouds. Cost is not the only issue with this observing system. The technology for obtaining radial wind velocities with good signal-to-noise ratio is still being perfected, and more than one lidar has been proposed to do the job. For this reason, FSL cooperated with the Environmental Technology Laboratory (ETL), NCEP, and NCAR to study the impact of Doppler wind lidar data on numerical models. FSL was responsible for studying the impact of the data on forecasts over the U.S. using a regional observing systems simulation experiment (OSSE).

For the case study, a long-duration, pure forecast from February 1993 was generated using the global model developed at the European Center for Medium-Range Weather Forecasts (ECMWF). LAP Branch ran the Regional Nature Run (RNR) using the PSU/NCAR mesoscale model (MM5) initialized from the ECMWF Nature Run to simulate onboard lidar data (clouds, winds, vertical velocity). The huge MM5 domain of the RNR covered most of North America with a 10-km horizontal (740 x 520) grid spacing and 43 vertical levels. This domain was tailored to include the present domain of the RUC model. Simulated observations were extracted from the RNR over an 11-day period for inclusion into the RUC data assimilation system. The simulated data included the entire suite of operational and future lidar observations; thus, synthesized rawinsonde, ACARS/MDCRS, surface, METAR, wind profiler, and VAD winds were all extracted from the RNR fields with appropriate error characteristics. The lidar line-of-sight winds from the satellite positions in four-dimensional space were determined by ETL from the Cartesian winds and cloud hydrometeor fields provided from the RNR. The last remaining task was to conduct a variety of sensitivity experiments with the mesoscale data assimilation system (RUC) with and without the lidar data, with various combinations of boundary conditions, and with and without liquid and/or ice clouds present. Results from this experiment can be found in the section on the Regional Analysis and Prediction Branch.

NOAA Coastal Storms Initiative – With the cooperation of the NOAA National Ocean Service, the NWS embarked on a project to test and evaluate locally produced, high-resolution grids derived from an onsite, high-resolution mesoscale model, driving an estuary flow model that predicts harbor and river depths for safe navigation. A secondary purpose is to test the model for forecasting marine hazards like thunderstorms, winds, and heavy precipitation events. LAP Branch's role in this is to bring to bear the experience gained from other deployments (such as RSA), link the LAPS analysis to the new WRF model, and set up the system at the Jacksonville, Florida WFO. Jacksonville is uniquely qualified for the test with a busy harbor, two major estuaries (St. Mary and St. John rivers), and frequent occurrence of thunderstorms and tropical weather. The sea and river breezes make for a complex land/water interaction and justifies the high-resolution modeling approach. The system runs on a 9 dual processor linux cluster and ingests all local data. The 24-hour forecasts (4 times a day, both cold and hot start) run in about 3 hours. The grid is a single nest of 5-km resolution and uses the Eta model as background and boundary conditions. The need for short range quantitative precipitation forecasts necessitates the use of the LAPS diabatic initialization scheme. Adjusting the scheme for the sub-tropics will be a major challenge. This demonstration will be an important consideration for the NWS in the decision to support local modeling in weather offices.

U.S. Forest Service Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) – In 2002 the LAP Branch became involved in a project to develop 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 newsworthy 2002 fire season. Products were disseminated using a Webpage. 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 test product was generated with weather for the next 24 hours. Development is continuing to add new products, increase resolution, and improve existing products and the appearance and utility of the Webpage. Once the initial capability is completed, new members of the consortium will be sought. State and federal agencies with a need for high resolution weather support are likely candidates.

Projections

During 2003, 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, and improved estimates of model error and variance.
- 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. Help with expanding the customer base for RSA-like systems. Investigate whether improvements to the background error term specifications and new methods to deal with spurious convection in the model forecast can result in replacement of the current system with a fully cycled, rapidly updated four-dimensional data assimilation system.
- 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 (QPFs). Strive for further improvements in short-range QPFs using an optimized diabatic initialization technique applied to the MM5, WRF, and RUC models. 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 Hot Start techniques, and perform an assessment on the use of 3DVAR for local analysis in the context of the WRF model.
- Continue development of the multimodel ensemble methodology; 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 for a mesoscale model approach.
- Complete the WRF Standard Initialization and graphical user interface and distribute the model to the community. Complete range of land surface fields for ingest into the land-surface model subsystem.
- Support the U.S. Forest Service FCAMMS project by improving the local model runs and analyses, and improving dissemination via the Web. Provide training to USFS personnel on model configuration and management.
- Set up, install, and tune 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.

Meteorological Applications Branch

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Objectives

The Meteorological Applications Branch performs diagnostic studies of weather-related phenomena, including mesoscale convective systems 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 branch 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

Global Air-ocean IN-situ System (GAINS)

The Global Air-ocean IN-situ System (GAINS) is an Earth observing system of 400 regularly spaced platforms from which in-situ sounding of the atmosphere and ocean, and in-situ collection of air chemistry samples can be performed. It is anticipated that several kinds of vehicles, operating between 18 and 23 km, will make up the GAINS low-Earth-orbit constellation. Superpressurized, shear-directed balloons and remotely operated aircraft (ROA) are presently under consideration. GAINS vehicle development currently emphasizes the superpressure balloon and appropriate altitude control mechanisms. A number of forecast tools have been refined for planning and support of GAINS field tests. Execution of a major milestone in the development of the GAINS brought the concept one step closer to fruition.

GAINS PIII Flight – The maiden flight of the 60-ft diameter GAINS Prototype III (PIII) balloon occurred on 21 June 2002. This flight met several development objectives, including launching the PIII balloon, floating it at altitude for more than eight hours, transforming the balloon envelope into a deceleration device, achieving a safe descent rate, tracking the balloon from an aircraft; forecasting balloon trajectory before launch, updating balloon landing position during flight, and recovering the balloon and payload.

Manufactured by GSSL, Inc., of Hillsboro, Oregon, and launched from their Small Balloon Facility at Tillamook, Oregon, the 500-pound balloon carried a 325-pound payload containing packages from four organizations. The FSL payload included GPS for locating the system, two independent radio- and software-controlled termination methods, and environmental sensors to monitor balloon performance. The payload also contained a GPS reflection experiment from NASA/Langley, redundant locating capability based on a design adapted from the Edge of Space Science (EOSS) of Denver, Colorado, and backup location and termination units from the Physical Science Laboratory of New Mexico State University and from GSSL.

Nominal float altitude of 54,000 ft was achieved after reaching a maximum altitude of 57,000 ft. A tracking aircraft kept the balloon within radio line of sight at all times during the 225-mile flight, and personnel on board coordinated the flight with FAA Air Traffic Control. Two additional vehicles tracked the balloon from the ground and recovered the payload. The balloon's descent was slowed by the GSSL BERS™ (Balloon Envelope Recovery System), in which the balloon envelope transformed to a parachute and the system descended at about 500 ft per minute. The soft landing caused no damage to the payload capsule, and minimal damage to the wheat field south of The Dalles, Oregon, where it landed. The entire system was removed from the landing site and returned to Tillamook within 24 hours of landing. Figure 36 shows the actual flight path and the path predicted using winds from the global AVN numerical model.

GAINS Pump Test Flight – On 17 August 2002 a flight was launched from Meadow Lake Airport, northeast of Colorado Springs in a cooperative effort between the GAINS and EOSS groups. The main objective of the flight was to test the operation of the turbine developed by Advanced Engineering at GAINS operational altitudes. Results from laboratory experiments indicated that the turbine met the requirements for flow rate, power needs, and weight; this experimental flight was intended to affirm these results under true atmospheric conditions. Turbine electronics and control software algorithms were also tested. A 19,000 cubic-ft polyethylene balloon was used for lift, and a 500-gram latex balloon in a GAINS P-I 8-ft nylon shell used as a ballast balloon. The plan was for the turbine to pump ambient air into the ballast balloon until the desired super pressure was achieved. For this experiment, the turbine was to be tested at 50,000, 60,000, and 70,000 ft, with inflation continuing until a super pressure of ambient plus 15% was achieved. The payload, consisting of all control and communication electronics, was located in an insulated ring that encircled the turbine on a lightweight disc with three supporting legs, known as the "lander" (Figure 37).

The gusty nature of the surface winds prior to launch made for complications, the most significant being the introduction of small holes in the polyethylene lift balloon from contact with the ground. Most, but not all, of these were repaired prior to launch, resulting in a flight duration shorter than expected. The balloon reached a maximum altitude of 32,000 ft before descending back to earth. Unfortunately, this altitude was not sufficient to allow testing of the GAINS pump. Although the pump performance could not be tested, the setup and launch procedures as well as tracking and recovery were successful. This will enhance the ability to achieve the goals when the test is repeated later.

Evaluation of Balloon Trajectory Forecast Routines – Software has been developed that uses observations and model wind data for prediction of balloon trajectories for GAINS. A fifth version of the software, utilizing output from the U.S. Navy NOGAPS model, was added to the four other versions that currently use rawinsonde data, global

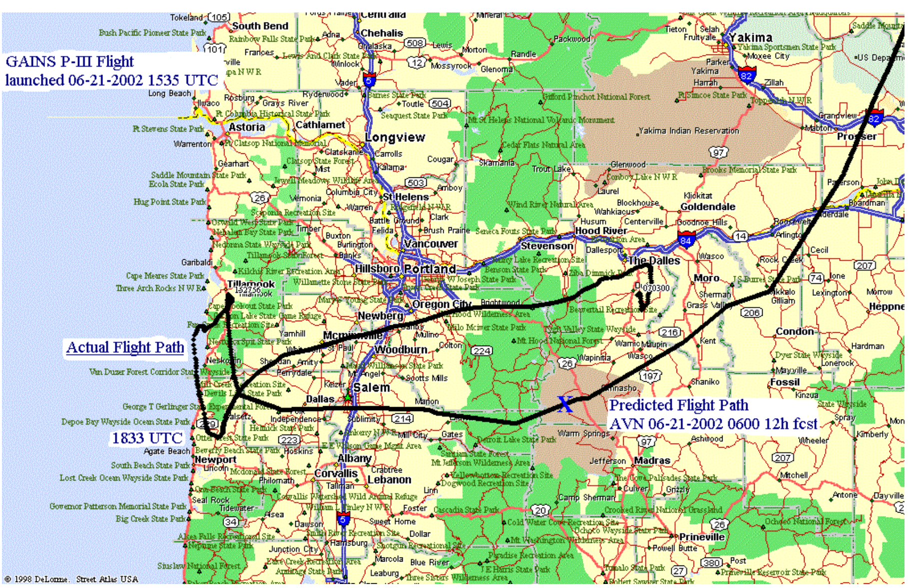

Figure 36. Flight path taken by the GAINS PIII balloon and the path predicted using winds from the global aviation (AVN) numerical weather prediction model.

AVN model winds and RUC-2 model winds. Each version produces predicted balloon positions in 1-minute increments, and these are available to FSL personnel and collaborators in textual and graphical form at the GAINS Website, *http://www-frd.fsl.noaa.gov/mab/sdb/overview.htm*.

A verification study was performed on the predictions made for the period 1 March 2001–31 August 2001, building upon a 1-month study performed in 2001. Prior to that initial study, comparisons were limited to examination of experimental flight data on a case-by-case basis. Since resource constraints have not permitted twice daily balloon launches (from which actual balloon trajectories can be obtained), a verification system was developed using predictions from hourly analyses from the MAPS RUC-2 model as a baseline to examine differences between baseline and predicted trajectories from the rawinsonde and AVN model-based predicted trajectories. When segregated by season (spring and summer), the comparisons show a significant decrease in correlation of longitudinal errors from spring to summer. Median values appear to indicate stronger zonal winds in the RUC data in comparison to the values obtained from the AVN-based predictions. Further study is planned, including comparison with GAINS and other actual balloon flights.

Support of NCAR Dropsonde Experimental Flight – The InterContinental Radiosonde Sounding System (ICARUSS), also called Driftsonde, is a proposed new atmospheric sounding system for use during the upcoming THORpex (THe Observing-system Research and predictability experiment) field projects in 2003 or 2004. The ICARUSS concept uses a thin polyethylene balloon (0.35 mm) with a volume of 268 cubic meters to lift a payload (up to 40 kg) of 24 dropsondes or modified radiosondes to an altitude of about 100–75 mb (53,000–60,000 ft) and maintain that altitude for 5 or 6 days. The altitude of the balloon can be adjusted over a limited range to take advantage of the most favorable upper-level westerly wind flow.

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

A 2-hour experimental flight was launched from Tillamook, Oregon, on 28 February 2002. Software written for GAINS balloon trajectory prediction was modified to use flight parameters appropriate for the Dropsonde flight, and these changes were provided to NCAR personnel at Tillamook. Through use of these predictions, NCAR was able to make a prelaunch assessment of the expected flight path, and recovery personnel were positioned in the proper area.

Figure 37. The GAINS payload lander package prior to launch.

Station-keeping Balloon Concept – A cursory examination of the technical feasibility/capabilities of a self-propelled Aerodynamic Canopied Balloon Cluster (ACBC) was prepared, and a rudimentary model was constructed and demonstrated. This concept evaluation was toward a buoyant craft that could float (rather than fly) to high altitudes where the air is thin enough so that aerodynamic streamlining and solar powered turbines could allow the craft to fly against the prevailing wind with enough speed to remain fixed in space at altitudes exceeding 70,000 ft. As envisioned, the systems onboard an ACBC craft might include:

- Standard lifting balloons
- GBP-033 altitude ballast control pumps (GAINS pump)
- Aerodynamic canopy structure
- Solar cell panels with manipulators
- Propulsion pods with ducted fan units/motors controllers
- Battery charging system with lithium ion polymer batteries
- Programmed module for GPS location capability
- Radio communications module
- Cargo gondola and load lines

The overall ACBC concept suggested here is radical, but the various components exist and in some cases are "off the shelf." The net payloads may be substantial, as balloon technologies allow for payloads into the thousands of kilograms at relatively low cost.

Forecasting Clear-Air Turbulence

Field Studies – Funded in part by the FAA's Aviation Weather Research Program and operating in the Pacific Ocean in collaboration with NOAA's Winter Storms Reconnaissance Program, the SCATCAT (Severe Clear-Air Turbulence Colliding with Aircraft Traffic) experiment was conducted in 2001. Scientists in the Meteorological Applications Branch collaborated with NCAR, the Aeronomy Laboratory, and NASA to test the performance of RUC model predictors of turbulence and to better understand turbulence generation mechanisms. These forecasts are used to construct the Integrated Turbulence Forecast Algorithm (ITFA) appearing on the Aviation Digital Data Service (ADDS), *http://adds.awc-kc.noaa.gov*, at the Aviation Weather Center.

FSL scientists have analyzed data collected by the NOAA Gulfstream-IV (G-IV) aircraft from one of the SCATCAT missions. In-flight observations were made at several altitudes and dropsondes were launched from the 41,000-ft level along a track perpendicular to the core of an upper-level jet streak. The aircraft encountered moderate-or-greater (MOG) turbulence on three legs of the stack, highlighted in yellow in Figure 38. This figure is a cross-section analysis of wind speed, potential temperature, and DTF3-diagnosed Turbulent Kinetic Energy (TKE) fields computed from the dropsonde data. Regions of strong vertical wind shear are evident above and below the level of the jet core. There is also a strong suggestion of vertically propagating gravity waves above the jet core and to its cyclonic side in the lower stratosphere (in the 260–176-mb layer). Coherent streaks of MOG turbulence are predicted by the DTF3 (Diagnostic Turbulence Flux Algorithm) field primarily in the layers of strong shear just above and below the jet core and within the warm front stable layer. These layers of high DTF3 correspond well to the observed in-flight turbulent regions.

The RUC20 model was run for this SCATCAT case, representing the first time that the RUC had ever been positioned to run entirely over the Pacific Ocean. The AVN model was also used for the first time instead of the Eta model for specification of the RUC boundary conditions. Figure 39 shows a cross section of isentropes and isopleths of isentropic potential vorticity taken perpendicular to the jet core but over a longer length than the dropsonde cross section in Figure

38. These model predictions were compared to fields of winds, potential temperature, and ozone (potential vorticity is taken as a surrogate for ozone) measured by the aircraft. This comparison revealed very similar features, including the warm frontal zone, the upper-tropospheric front/jet system zone, and regions of strong vertical wind shear and associated large DTF within these zones. A deep tropopause fold is present along the warm frontal zone down to almost 700 hPa, but of greater interest are multiple tropopause "undulations" in the upper-level front of the model. Also of interest are mesoscale gravity waves in the lower stratosphere directly above the jet core, with vertically varying horizontal wavelengths of ~100–160 km. Similar waves in the dropsonde analyses in the lower stratosphere directly above the jet core displayed wavelengths of ~80 km. A higher-resolution version of the RUC, of course, might have produced shorter wavelength features.

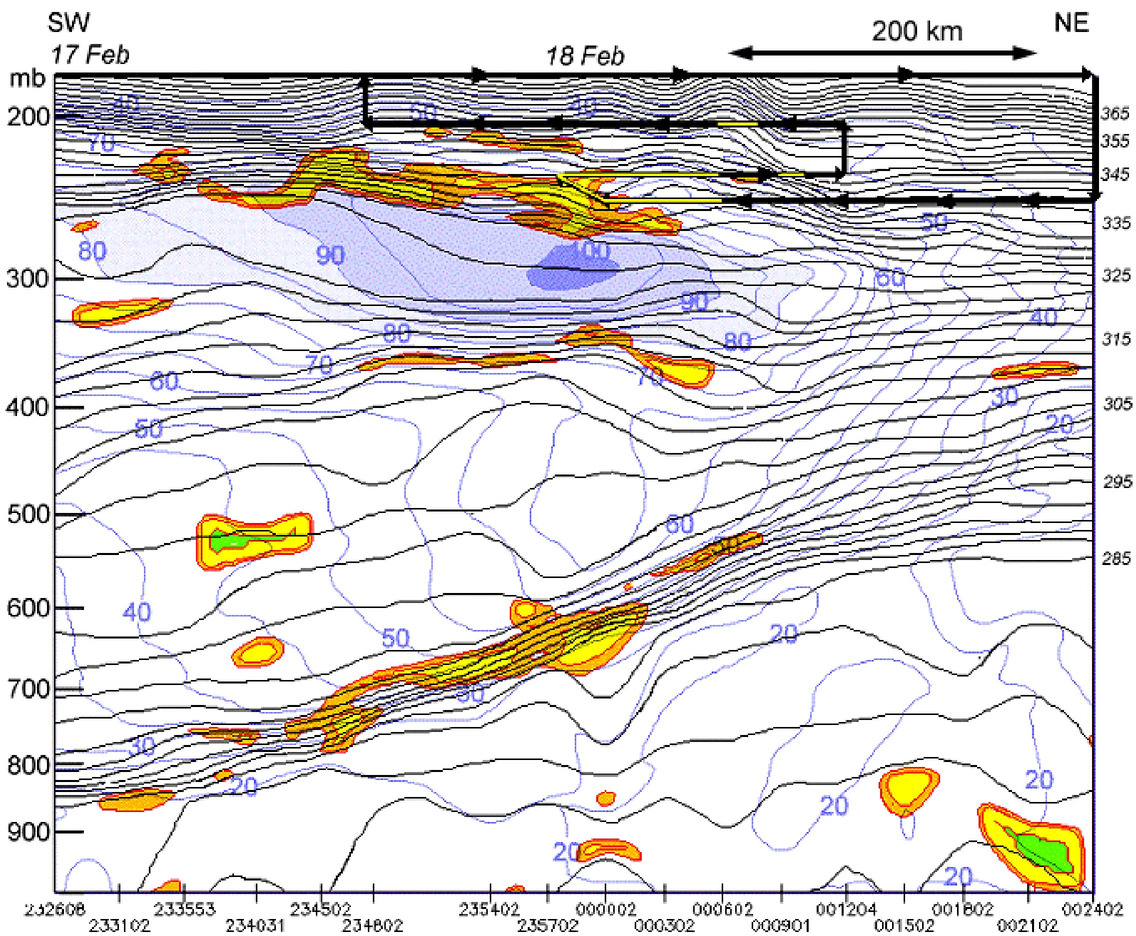

Figure 38. Vertical cross section of wind magnitude (blue lines, 5 m s^{-1} isotachs), potential temperature (black lines, 2K isentropes), and DTF3 turbulence diagnostic computed from dropsondes (note release times at bottom of display) from 2300, 2600, and 0600 UTC 17 February through 0000, 2400, 0200 UTC 18 February 2001. Jet core is highlighted by winds in excess of 80 m s^{-1} (maximum of 100 m s^{-1}), and DTF3 values are contoured at 0.6 and 1.0 m^2 s^{-3} (yellow and red areas, respectively). Also shown are the stacked legs of the G-IV tracks (black lines with arrows depicting sense of aircraft travel), and those segments of the legs (yellow highlighting) for which moderate-or-greater turbulence was diagnosed in the flight-level data (see text). Note distance scale at top of display.

Wild fluctuations in ozone measurements from the NOAA/ARL experimental instrument were measured at the 41,000-ft level, but fluctuations in the potential temperature and wind in-flight observations did not correlate highly with the ozone data, nor was much turbulence reported on this flight leg. It was concluded that these rapid fluctuations in ozone at this level represented "fossil turbulence" or remnants of earlier stratosphere-troposphere turbulent exchange processes. By contrast, the correlation between the ozone and in-flight variables, as well as with the RUC model potential vorticity variations, was very high at the 33,000-ft altitude. Also, moderate turbulence was reported at this flight altitude, as the G-IV was penetrating a rather pronounced gravity wave within the upper-tropospheric frontal zone. Thus, active turbulence was occurring in association with gravity wave activity at this altitude, but not at the higher level.

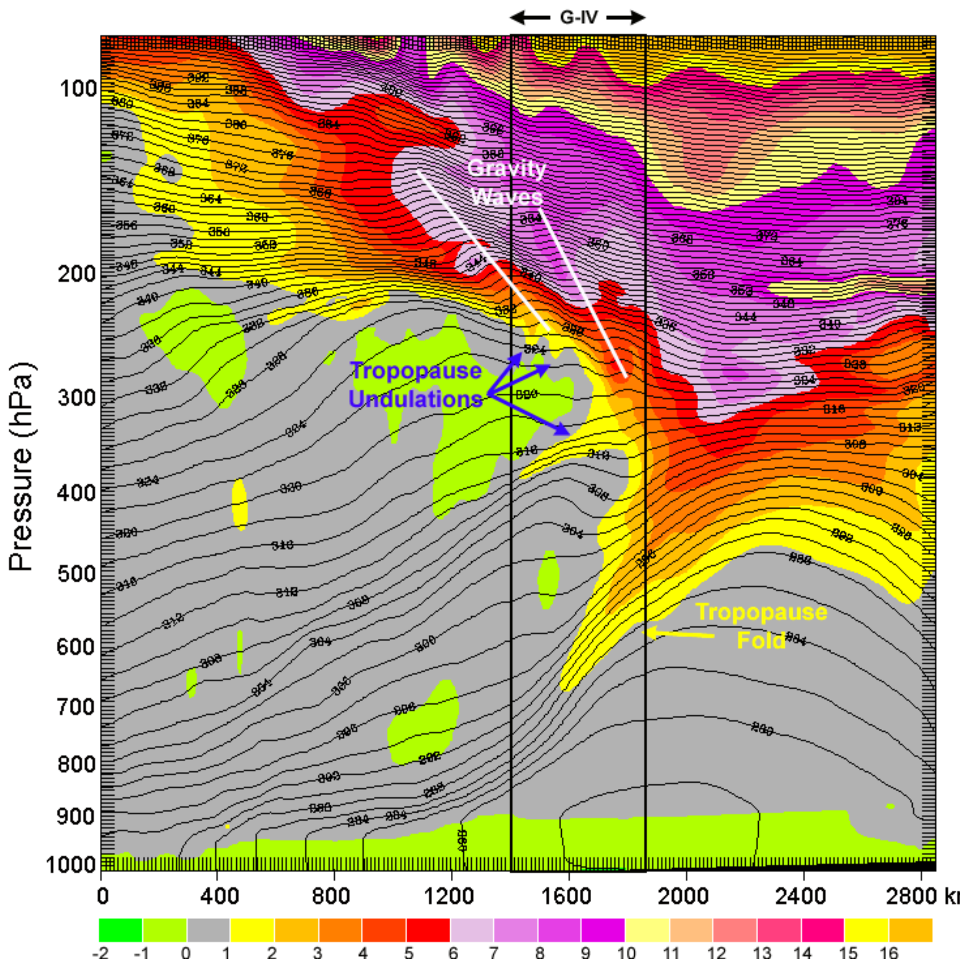

Figure 39. Vertical cross section of potential temperature (black lines, 2K isentropes) and isentropic potential vorticity (colored shading, in units of PVU) produced from a 6-hour forecast by the RUC20 model valid at 0300 UTC 18 February. A pronounced tropopause fold is shown at the upper reaches of the warm front, which is marked by strong static stability from 500 hPa to 900 hPa in the center of the domain. The upper-level jet core occurs in the vicinity of several "tropopause undulations." Notice the presence of mesoscale gravity waves in the lower stratosphere above the jet core. Also shown is that part of the cross section sampled by the G-IV aircraft (black vertical lines). Distance scale appears at bottom of display.

Time series and spectral analyses were performed for each of these flight legs in an attempt to relate the appearance of turbulence to mesoscale gravity wave activity. Potential temperature and longitudinal wind exhibited a high degree of cross correlation, as did the potential temperature and ozone data at the 33,000-ft level. Such a strong "in-phase covariance" is expected of either deep propagating gravity waves or, more likely, decaying (evanescent) waves.

The SCATCAT research revealed that MOG turbulence occurred in conjunction with gravity waves shed within an upper-level fractured front on the cyclonic shear side of the jet core. Besides this major finding, it was concluded that RUC-forecast DTF is a useful diagnostic of turbulence, whereas ozone is not, and that both the MOG turbulence and the high DTF regions occurred in the vicinity of the strongest mesoscale gravity wave activity in both the model forecasts and the aircraft observations.

Diagnostic Algorithm Development – The forecast skill of Integrated Turbulence Forecasting Algorithm (ITFA) and its component algorithms has been evaluated both objectively and by forecasters. These studies show that the best of the algorithms display similar probability of detection (POD) curves, and that there is considerable room for improvement. Research conducted at FSL indicates that these algorithms also typically predict patterns that are similar to one another, and that MOG pilot reports (PIREPs) of turbulence often fall in the margins of the predicted ITFA regions. The best of these algorithms are fundamentally based on the destabilizing dynamics of vertical wind shear.

FSL developed an experimental turbulence prediction scheme based on a radically different dynamical concept, namely that turbulence is generated as mesoscale gravity waves are shed when an unbalanced jet streak propagates toward an inflection axis in the upper-level height field (the SCATCAT analyses discussed above lend additional support to this contention). Diagnosed gravity waves and model flow imbalance have been shown in detailed case studies by Forecast Research Division scientists to relate strongly, not only to each other, but also to MOG turbulence reports. The flow is considered to be unbalanced when there is a pronounced residual in the computed sum of the terms in the nonlinear balance equation from the RUC model. Imbalance typically occurs in essentially the same region as where mesoscale gravity waves develop and upstream of where the turbulence is reported, as demonstrated in one case shown in Figure 40. Note in this example that the imbalance is occurring precisely at the tip of the dry air stream associated with subsidence within a pronounced jet streak (or "potential vorticity streamer," discussed below). The conventional turbulence diagnostic DTF3, which is a major contributor to the ITFA, fails to predict the swath of turbulence reports in the Ohio River Valley region, whereas the imbalance indicator field successfully captures this event. On the other hand, DTF3 does a credible job at delineating the other swath of turbulence reports in the Great Lakes region, not captured by the imbalance field. This complementary nature of the imbalance indicator fields and DTF/ITFA is typically observed to occur.

A Webpage was created this past year to examine the relationships between diagnosed flow imbalance from the RUC20 model and MOG turbulence reports on a daily basis. This more thorough investigation has shown that mountain waves generated by strong flow over rough terrain like the Rocky Mountains are even more highly correlated with turbulence and flow imbalance than are the imbalances associated with the jet stream and cyclonic storm systems. While mesoscale models like RUC can be useful for diagnosing the flow imbalance regions and where generally gravity waves are likely to form, they do not reliably predict the details of the gravity waves themselves, such as their wavelength, phase speeds, and so forth. The new predictive scheme being developed at FSL not only produces patterns systematically different from the current ITFA algorithms but also predicts turbulence regions missed by those methods. Further refinement of forecast turbulence regions might be obtained by adding the requirement that an efficient wave duct must be present downstream of the region of diagnosed flow imbalance to retard the vertical leakage of wave energy, thus allowing coherent waves to persist. The optimum amount of smoothing of the imbalance fields, the proper thresholds, and other numerical issues must all be resolved, before the new imbalance indicator field can be incorporated into ITFA to increase its utility.

Mesoscale Diagnostic Studies

Moisture Transport by the Low-level Jet (LLJ) – 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. Unfortunately, the existing observational network is not well designed to describe the LLJ. The radiosonde network, for instance, often misses the period of maximum jet intensity in very early morning (to say nothing of its spatial dimensions or substructures), and wind profilers often cannot observe low enough to capture the LLJ core. Perhaps even more critically, neither radiosondes nor profilers can adequately observe the detailed boundary layer moisture distribution. As a result, numerical initialization fields do not accurately represent transport of moisture by the LLJ, with inevitable negative implications for quantitative precipitation forecasting.

The IHOP project offered a unique opportunity to carry out two aircraft missions (led by the Forecast Research Division Chief) 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

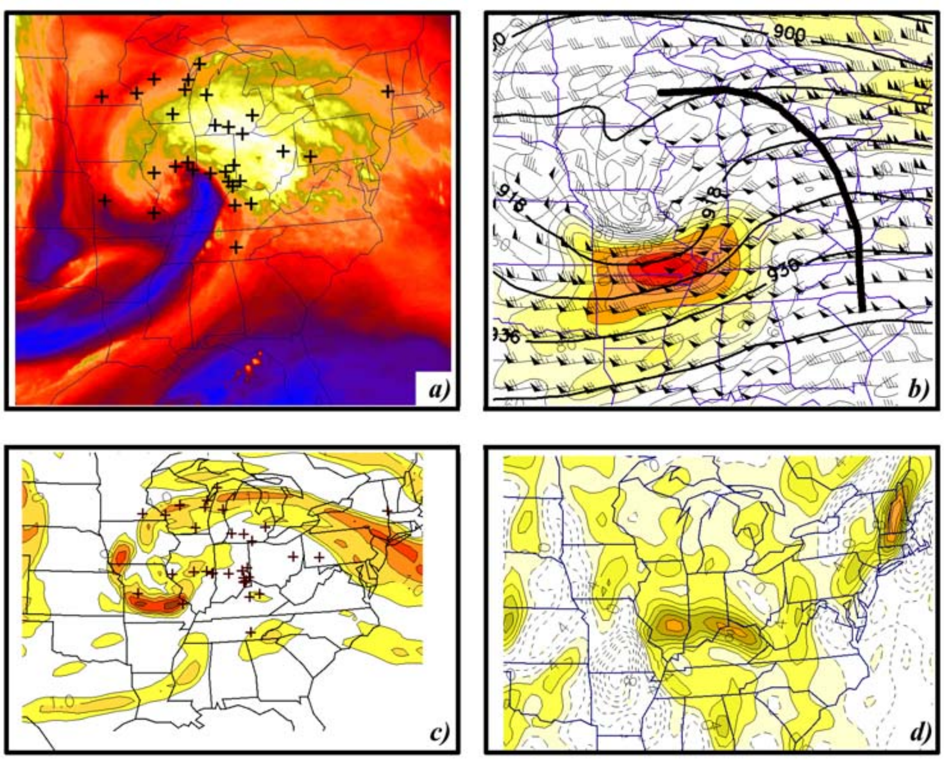

Figure 40. Analyses and 3-hour RUC forecast diagnostics valid at 1200 UTC 7 February 1999: (a) enhanced water vapor imagery and time-space converted MOG PIREPs over a ±2-hour interval, (b) heights and wind at 300 hPa, ridge axis (thick curve), and jet isotachs (kt), (c) DTF3 prediction of turbulence and MOG PIREPs overlay, and (d) unit streamwise advection of the residual of the nonlinear balance equation (the imbalance indicator field).

(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.

Structure and Dynamics of Gravity Currents and Undular Bores – The IHOP field phase collected a surprisingly large number of events in which either a thunderstorm outflow boundary or cold front, acting as an atmospheric gravity current, intruded into a stably-stratified boundary layer and generated an undular bore (a kind of hydraulic jump) on the top of the inversion. In some cases, deep convection appeared to have been generated by the vertical motions attending this phenomenon, which are quite strong (updrafts of several meters per second magnitude). An unprecedented number of ground-based and airborne remote sensing systems observed the passage and evolution of bores in IHOP, including FM-CW radar, the NCAR Multiple Antenna Profiler (MAPR), Raman lidar, the NASA GLOW and HARLIE aerosol backscatter lidars, refractivity fields obtained from the NCAR S-POL radar, an Atmospheric Emitted Radiance Interferometer (AERI) system, the French Leandre-II DIAL system aboard the NRL P-3 aircraft, and the University of Wyoming *King Air* aircraft. FSL is collaborating with a team of international scientists to analyze these data. Also, very high-resolution numerical simulations of two bore events are underway to better understand the origin, dynamics, entrainment mechanisms, and influence on convection initiation by undular bores. Much more will be reported on these studies in the next issue of *FSL in Review*.

Potential Vorticity Streamers – Researchers in Europe and the United States have noted the frequent occurrence on water vapor satellite imagery (GOES and METEOSAT) of pronounced dark filaments, which are mesoscale in width and varying in length up to the largest scales of atmospheric motion (see Figure 41). The most pronounced of these dry filaments have a parallel jet stream immediately to the south, and according to recent studies conducted at FSL, a similarly shaped band of collocated, enhanced potential vorticity (a "PV streamer"). Another satellite-observed feature – enhanced ozone – suggests that a PV streamer is a downward intrusion of stratospheric air along an upper-level front.

Monitoring PV streamers has prognostic value. In Europe, PV streamers have been identified as precursors to flooding along the Mediterranean slopes of the Alpine piedmont. In the United States a number of case studies have documented MCS development near a preexisting PV streamer. Some of these MCSs were accompanied by severe weather and flash flooding, as was the case with one occurring 28 June 1999 over Kansas (described in the 2002 *FSL In Review*). This storm was one in a series of four MCSs that occurred along a PV streamer that persisted six days over the central and southeastern United States. The total precipitation from these four MCSs produced a significant fraction of the area's annual precipitation.

In addition to being a valuable forecasting ingredient to organized convection and heavy precipitation, the PV streamer is a fascinating phenomenon, rich in dynamical and thermodynamic implications deserving of serious scientific study. It combines upper-level jet stream dynamics with the flow of midtropospheric, dry, potentially cold air having a low static stability. Some researchers have suggested that the exit region of an upper-level jet streak enhances a transverse low-level jet as a result of mass balance. Others have suggested that upper-level PV passing over a low-level front can organize a developing cyclonic circulation. With the addition of moisture to the low-level jet, the mechanisms for producing organized convection are all present. The details of how the ingredients combine to shape an MCS await results of field experiments (such as BAMEX) and those of mesoscale modeling at FSL.

Research Quality Datasets

Climate Station Monitoring Project – As part of the USWRP- (U.S. Weather Research Program) funded Health of the Network Project at the National Climate Data Center, a system to assure precipitation observation homogeneity in the climate data record has been devised and partially tested. Magnitude, frequency bias, and Equitable Threat Score have been chosen as measures of correlation between measurement sites because they implicitly compensate for the highly variable and binary (on-off) character of precipitation. In this application, scores are computed between sets of observation pairs made at individual target stations and a set of their neighbors. Comparison of results between winter and spring in Iowa illustrate that seasonal variability caused by instrumentation response to frozen precipitation may not be as significant a problem as feared. Computations of longer-term precipitation totals (3–7 days) have revealed no advantage to homogeneity tests performed over periods longer than one day.

NCEP Gauge Quality Control Project – A system for the automated screening of hourly gage precipitation observations has been designed to find failing gauges in the Hydrometeorological Automated Data System (HADS). Funded by the USWRP, this system was solicited by National Centers for Environmental Prediction (NCEP) to provide

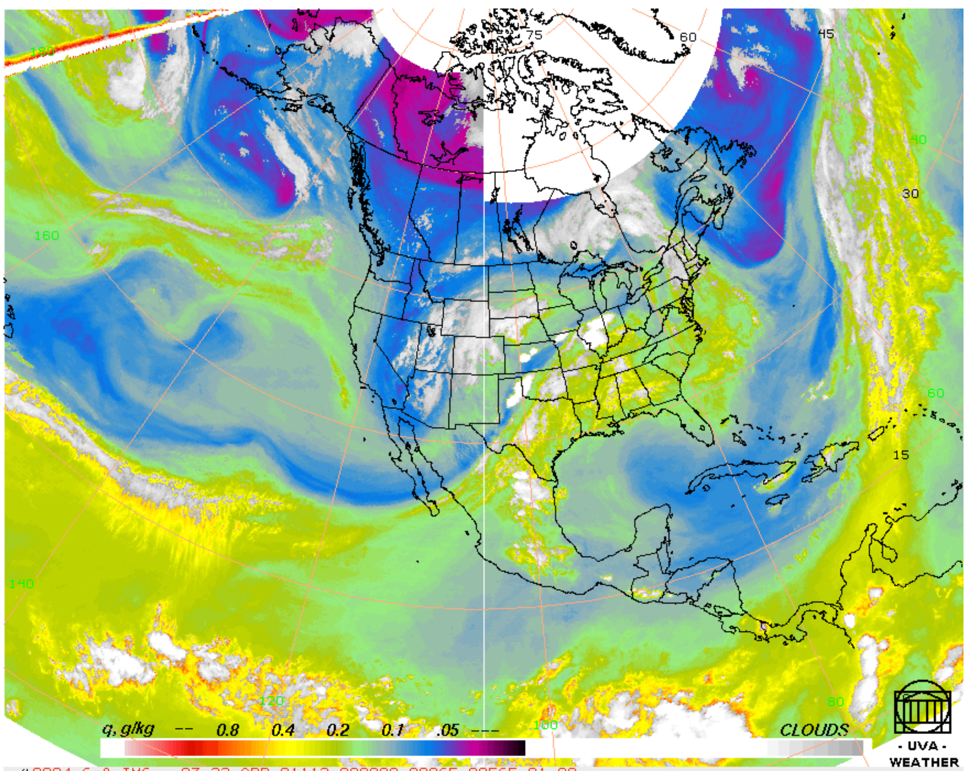

Figure 41. Mid-to-upper tropospheric specific humidity at 0000 UTC 22 April 2001 displayed using an altered water vapor product. Note that the dry filament in the CentralU.S. is an extension of a much larger feature of the large-scale flow pattern.

more timely gauge quality indicators to prevent the use of faulty gauges in analyses used to initialize model runs. Following the identification of several characteristic failure types (e.g., gauges that jam on or off for long periods), tests for these failures on individual gage have been devised. Several of these tests are based on the most recent 30-day distributions of precipitation characteristics such as daily and hourly rainfall frequency. Gauges that fail these tests can then be entered on a reject list to eliminate them from precipitation analyses and model verification. Because old or inaccurate station metadata have often been a weak link, procedures to automatically update relevant station lists have been introduced. An automated procedure for gauge quality control and rejection will be completed during 2003 and delivered to NCEP for implementation.

Assessing the Quality of Real-Time Precipitation Gauge Observations – An ongoing collaboration with the Real-Time Verification System project group seeks to improve verification procedures for model-based precipitation forecasts. Over the past year, this verification effort concentrated on the use of hourly point precipitation observations at sites to which model fields were interpolated. Of major concern was the determination of the quality of hourly observations in order to screen out unsatisfactory observing sites and to reincorporate sites with good observations that in the past have not been included in the set of stations presented in near real time by River Forecast Centers.

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. The quality control system uses temporal and spatial consistency checks along each flight track and altitude-adjusted climatological consistency checks to discover errors. It also interpolates locations and times for high-resolution observations taken during ascent and descent enabling these data to be used in numerical weather prediction model research and weather forecasting. The quality control system was upgraded to ingest and display data from the MDCRS (Meteorological Data Collection and Reporting System) data stream, produced by Aeronautical Radio, Inc. MDCRS data are largely the same as data provided by airlines directly to FSL, and decoded here, but have some differences. Because MDCRS feeds numerical weather prediction models run by NCEP, it is important to understand these differences. The QC system attempts to match each MDCRS observation with one decoded directly by FSL, and report the differences. The QC system was also upgraded to process experimental icing data from Delta Airlines, in support of a research effort led by the National Center for Atmospheric Research and funded by the FAA.

ACARS-RUC Intercomparison Database – A database has been developed that compares ACARS data with 1-hour RUC forecasts. RUC data are interpolated to the location of each ACARS observation. This database, with 9 months accumulated data, is used to develop error statistics for longitudinal and transverse winds, and for other RUC and aircraft error analyses.

North American Radiosonde Dataset – For years FSL has been providing a CD-ROM archive of quality-controlled radiosonde data for use by the research community. During 2002, updates were made to the global and North American station history files to reflect changes in the network sites, including moves, station identification changes, and addition of new stations. The Website was modified to correct problems in the generation of duplicate skew-T plots for different stations, and software was incorporated to handle the change to a new year without interrupting service.

FSL Websites

GAINS Website (http://www-frd.noaa.gov/mab/sdb/) – This GAINS field briefing Webpage is accessible to crews in the field wherever a phone line exists. Updated hourly, this page contains the current surface observation and upper-air winds for Tillamook, Oregon, the location of annual test flights, as well as links to satellite, radar, numerical model, and surface and upper-air charts and other data. Upper-air charts for mandatory pressure levels above the height of 100 mb covering the continental U.S., Pacific Northwest, and Colorado regions are generated in-house and added to the briefing Webpage.

Chemical Weather Research and Development Website (http://www-frd.noaa.gov/aq) – In support of a major NOAA initiative to improve temperature and air quality forecasting, a Website was developed that that will present real-time and retrospective results from air quality models. The region of interest is primarily New England, the location of the Temperature and Air Quality (TAQ) project conducted in 2002. A related site on high-resolution temperature forecasting may be found at *http://www.temp-aq.org*.

National Hourly/Daily Precipitation Website (http://precip.fsl.noaa.gov/hourly_precip.html) – Development work continued on a Website that displays hourly and daily precipitation data from NCEP. Data are displayed on a national map that optionally shows rivers and county boundaries. Moving the cursor across the map reveals the available data, and a mouse click provides a daily time series of the data. Users can zoom and roam on the map for detailed local structure of precipitation events. Years of precipitation observations are available at the site. Significant improvements have been made to this Website as part of a USWRP-funded project with NCEP to improve screening of the operational network of real-time hourly precipitation observations. Included in the set of new features are a utility to locate individual stations on the display, extension of the geographical display to a global domain, incorporation of standardized Java code from several FSL Websites to simplify site maintenance, and improved ability to distinguish stations that are in very close geographical proximity.

ACARS/AMDAR Website (http://acweb.fsl.noaa.gov/) – Many upgrades were made to this site, which displays weather data from automated sensors on commercial aircraft. Air Route Traffic Control Center boundaries were added to aid users working at Center Weather Service Units (CUSUs). Additional North American VOR stations were added, primarily at the request of users at CWSUs. Experimental icing data from Delta airlines can now be displayed. Data can be selectively displayed based on data source: either ACARS (decoded at FSL), MDCRS (decoded at ARINC and ingested into NCEP models), or AMDAR (non-U.S. data). Observations with missing or bad wind and temperature data can be excluded from the display. Additional statistics (such as number of observations in a particular geographic region) are displayed. Data reporting wind speeds in excess of 200 kts are now displayed. Data downloads may now be restricted to specific types of data (such as ACARS or AMDAR) and data in specific geographic regions, thereby potentially speeding up data loading. Java code was upgraded to be consistent with the latest versions of Java, such as those used by Netscape version. Several audiovisual tutorials were created and made available on the Web; these show in detail how to use the various options available on the Web display.

Recently, 86 sites (such as participating airlines, United States and foreign forecast offices, and research institutions) accessed the site, which is restricted to specific users at the request of the airlines providing the data. These sites requested more than 2,500 data loads and looked at more than 4,100 soundings. Figure 42 shows the upgraded display.

Interactive Soundings Website (http://www-frd.fsl.noaa.gov/mab/soundings/java/) – This Website interactively displays past and forecasted soundings from two versions of the RUC model, as well as from wind profilers, radiosondes, and aircraft. This page is becoming increasingly popular, with more than 56,000 accesses from over 450 major domains (such as "noaa.gov" or "delta.com") – nearly twice as many as in January 2002. 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 worldwide radiosonde data. Also, the latest available data from any radiosonde site are listed, to save users the trouble of seeking data from sites that have not reported recently.

National Mesonet Website (http://www-frd.fsl.noaa.gov/mesonet/) – Using Java, a national mesonet Website was developed to interactively display observations from 22 mesonetworks (up from 17 a year ago), maritime buoys, and the METAR network, with typically more than 7,000 stations from around the world (up from 3,200 a year ago). The site displays weather data and quality control information from FSL's Meteorological Assimilation Data Ingest System (MADIS). The Java code has been modularized into packages, which are shared with other FSL Websites to allow easier code maintenance, and upgraded to be consistent with the latest versions of Java, while remaining compatible with earlier versions. Recently, North American highways were added as an overlay, thereby helping to put site locations in perspective, particularly when the map is zoomed in to a local region. The site, previously restricted, is now publicly available. During January 2003 it was accessed more than 2,900 times from 525 unique domains. Figure 43 shows mesonet data for a region centered on Washington, D.C.

RUC-ACARS Website (http://acweb.fsl.noaa.gov/ruc_acars/) – This page is similar to the ACARS/AMDAR Website (above), and similarly 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 selectively be displayed, along with ACARS-RUC differences in vector wind, wind speed,

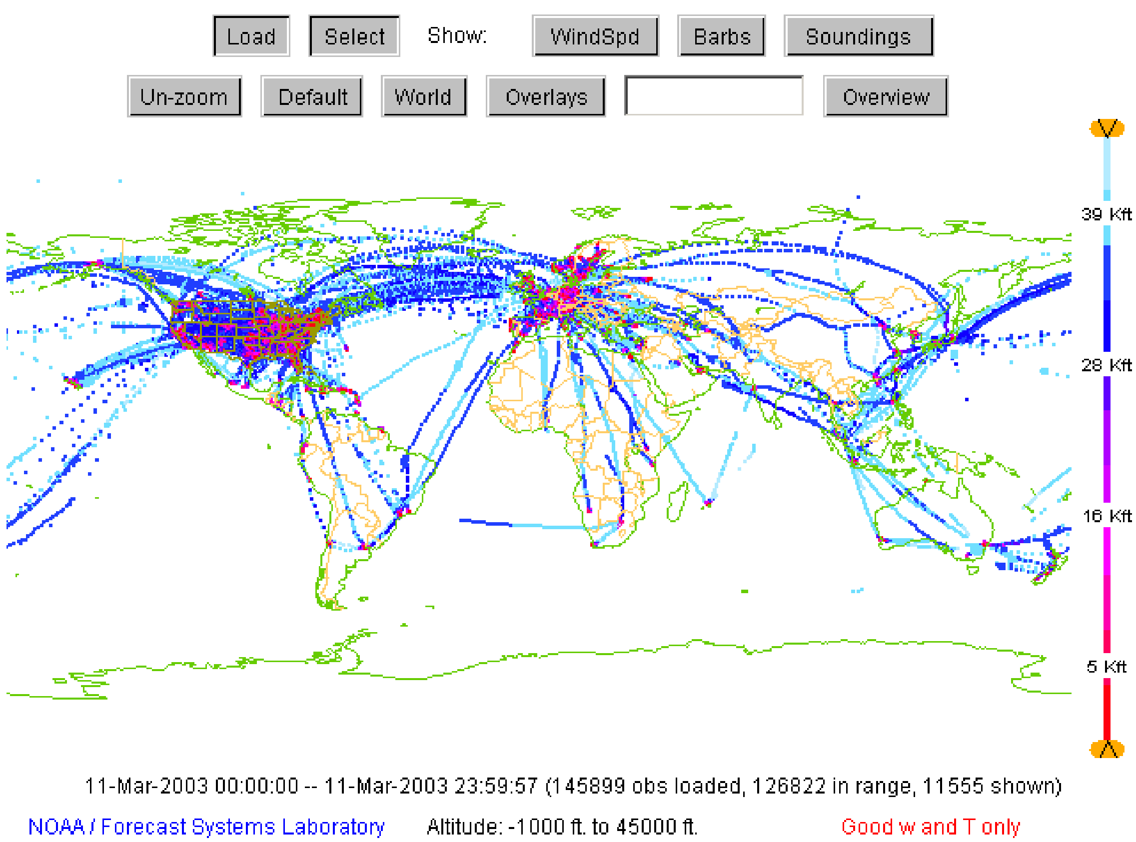

Figure 42. ACARS/AMDAR Website display of aircraft tracks worldwide for a 1-h period on 11 March 2003.

and temperature. The site is used primarily within FSL, and is useful for identifying aircraft wind and temperature biases, and RUC errors. The page displays data from the ACARS-RUC intercomparison database, and as of this writing, 9 months of data are available for display.

PIREPs-AIRMETs Website (*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 PIREPs 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, 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 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.

North American Radiosonde Database Website (*http://raob.fsl.noaa.gov*) – This site provides access to the most recent years of global radiosonde data. Upgrades last year included updates to the global station history and provisions to accommodate the change over to the most recent year without service interruption or loss of data. The FSL format was slightly changed to show north or south latitudes and east or west longitudes to avoid confusion. Problems with duplicate skew-T images being generated for different stations were resolved.

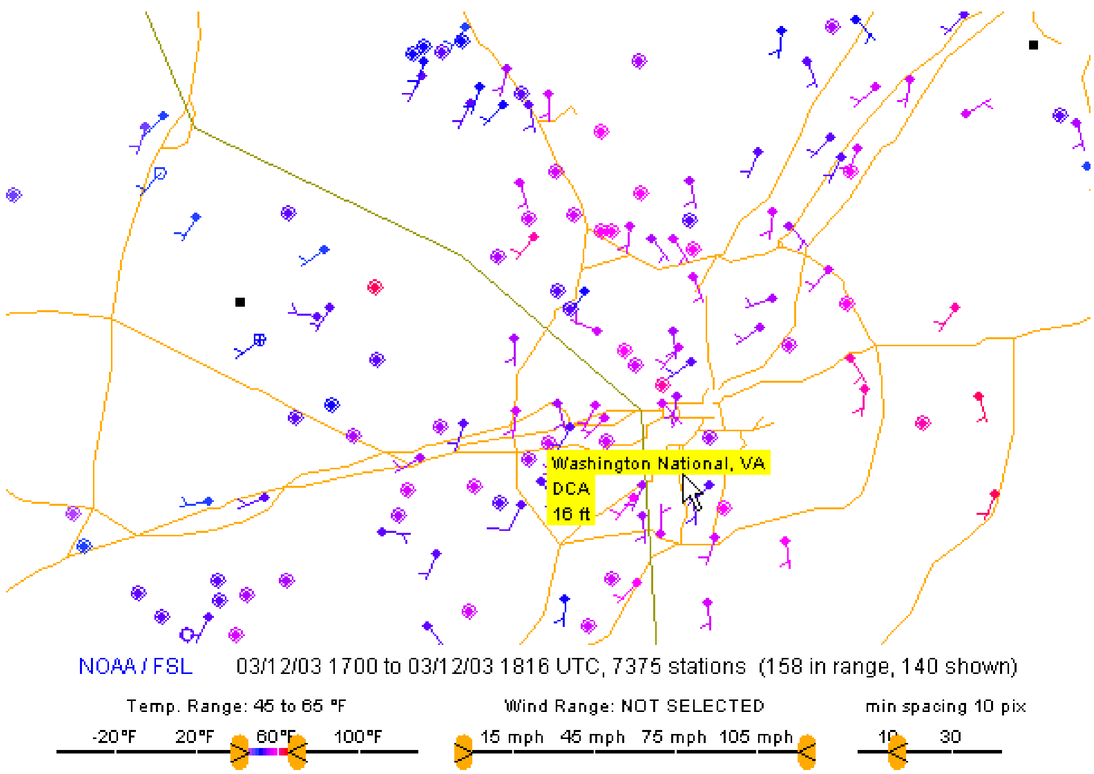

Figure 43. Surface mesonet data for a small region centered on Washington, D.C., for a 76-minute period on 12 March 2003. The temperature coding range has been adjusted so the cooler stations, toward the west, are shown in blue, and the warmer stations, in the east, are shown in red. Washington National Airport is shown at the cursor location. The beltway and other highways are shown in brown.

Projections

During 2003, the Meteorological Applications Branch 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 10-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 ITFA in the next year. 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 (LLJ) – The aircraft data will be processed and analyzed to determine the impact of fine-scale moisture observations on the numerical prediction of precipitation. The combined datasets obtained from the two aircraft missions will be used to compute moisture budgets and diagnostic and numerical modeling studies of these cases will be performed in order 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.

Structure and Dynamics of Gravity Currents and Undular Bores – The remote sensing data observing bores in IHOP will be analyzed in collaboration with a team of international scientists. Very high-resolution numerical simulations of two bore events, possibly to include Large-Eddy Simulation (LES) studies with specialized treatment of the boundary layer, will be conducted to increase understanding of the origin, dynamics, entrainment mechanisms, and influence on convection initiation by undular bores.

Potential Vorticity Streamers – FSL plans to participate in the BAMEX field experiment and complete its mesoscale modeling of PV streamer interactions with mesoscale convective systems, and to publish the results within the year.

Research Quality Datasets

NCDC Climate Station Monitoring – A prototype monitoring system utilizing algorithms based on precipitation verification scores will be completed and forwarded to NCDC for installation and testing. Prior to project completion, the scheme will be tested on selected states and on stations with identified historical inhomogeneities. The results of statistical simulations done at NCAR intended to determine the required duration of precipitation analysis periods for different regions of the United States will be applied to the system when completed.

NCEP Gauge Quality Control Project – Software to apply a set of retrospective checks on distributions of key precipitation characteristics (e.g., frequency of hourly and daily precipitation intended to determine, respectively, gauges that stick on or off and observing sites that report only non-zero precipitation amounts) will be completed and forwarded to the Environmental Modeling Center of NCEP for installation. A period of monitoring system performance at FSL (via the RTVS, where the system will also be installed) and at EMC will be instigated prior to final application at EMC. Also during this period, a daily automated procedure to update and collate daily and hourly reporting stations and produce a reduced station list will be written and installed. There are no firm plans for additional improvements to the Real-Time Precipitation Website.

ACARS/AMDAR Quality Control – This system will be fully documented and passed on to a group of programmers at FSL so that there is no single point of failure for the system. Data from additional airlines, will be integrated into the system, and the error characteristics of these data will be investigated.

ACARS-RUC Intercomparison Database – Once an entire year of data have been accumulated, detailed ACARS-RUC statistics will be generated and stratified by season.

North American Radiosonde Dataset – Plans to continue with upgrades to this dataset are pending sufficient funding.

FSL Websites

Chemical Weather Research and Development Website – Development of this Website depends upon new directions taken in the NOAA Chemical Weather program.

National Hourly Precipitation Website – The collaborative project with NCEP to improve rain gauge QC and assess the Stage IV precipitation product involves further improvements to this Website, to be completed over the next year.

ACARS/AMDAR Website – This system will be fully documented and passed on to a group of programmers for several points of failure for the system. Data from additional airlines and additional sensors will be integrated into the system.

Interactive Soundings – This site will continue to be maintained and data flow into it monitored, but it will probably not be upgraded, because the early version Java code used in it is useable on a wider variety of computers that cannot run newer versions of Java. Pending identification of resources, scripts will be written to ease the reloading of past data cases upon request.

National METAR Website – New mesonets will be added as they become available, and data loading will be speeded up. Pending identification of additional resources, wind gust and precipitation amounts will be shown for those sites that support them.

RUC-ACARS Website – 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 Website – This page is designed primarily to provide feedback for forecasters at the Aviation Weather Center. Feedback will be gathered, and future upgrades will be tailored to the forecasters' 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 demonstrations 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, the division uses new upper-air observing techniques to create and disseminate reliable assessments of weather, climate, space environment, and geodetic phenomena. The data and techniques developed and implemented by the division also support seasonal to interannual climate forecasts as well as the prediction and assessment of decadal to centennial climate change. Due to a largely unanticipated synergy between the requirements for atmospheric remote sensing and the more traditional applications of the Global Positioning System (GPS; i.e., positioning, navigation, and time transfer), the GPS-Met Observing Systems Branch within the Demonstration Division also promotes safe navigation by providing 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 are an investment in scientific research, the development of new technologies to improve current operations, and in 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 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/technologies to improve NOAA's ability to serve its customers and forge stronger ties with its partners, especially NOAA's National Weather Service (NWS), DOT, and Department of Defense (DOD).

During 12 years of operation, the NPN has been providing important upper-air data to a variety of customers. The NWS uses data from the NPN, CAP, and GPS networks routinely in computer-generated forecasts, and its field forecasters tailor model guidance to local conditions. The data are also available for interested users via the Global Telecommunication System and for the public via the Internet. Data are used by many other federal, state, and local organizations for support in weather forecasting, aviation, and monitoring climate and air quality. One of the NPN customers, the Lawrence Livermore National Laboratory, uses NPN data as critical input to its dispersion model. The model supports work under contract to DOD and the Department of Energy (DOE) for Homeland Security. At the request of NASA and the National Transportation Safety Board (NTSB), all NPN, CAP, and GPS-Met data taken during the break up of the space shuttle Columbia were provided to them for important forensic analysis in determining the root cause. In particular, the Palestine, Texas, and Winnfield, Louisiana, profiler data captured the time and horizontal and vertical positions of some of the falling fragments.

Currently the division is engaged in the following major projects:

- Operation, maintenance, and enhancement of the 35-station NOAA Profiler Network (NPN), which includes three systems in Alaska and the CAP sites (Figures 44 and 45).

- Collection, correction, and distribution of wind and temperature data from the CAP sites.

• Planning and support activities for a Fiscal Year 2006 initiative for a national upper-air mesoscale observing system which will include profilers and GPS-Met systems.

• Development, deployment, and evaluation of an all weather integrated precipitable water vapor (IPW) observing system using radio signals from the satellite GPS.

• Evaluation of three GOES high data rate communication systems for network deployment.

• Assessment of alternative network data communication technologies.

• Upgrade of the surface meteorological sensor package at NPN sites to include winds and precipitation measurement capability.

The division comprises five branches organizationally; however, the branches work in a fully integrated team mode in supporting the overall objectives of the division.

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

Figure 44. Location of all 35 NOAA Profiler Network sites and Cooperative Agency Profiler (CAP) sites providing data via the Profiler Website.

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, develops new software and database systems as needed, provides Web support of the division's extensive Web activities, and designs software to support a national deployment of profilers.

GPS-Met Observing Systems Branch – Supports development and deployment of the GPS-IPWV 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.

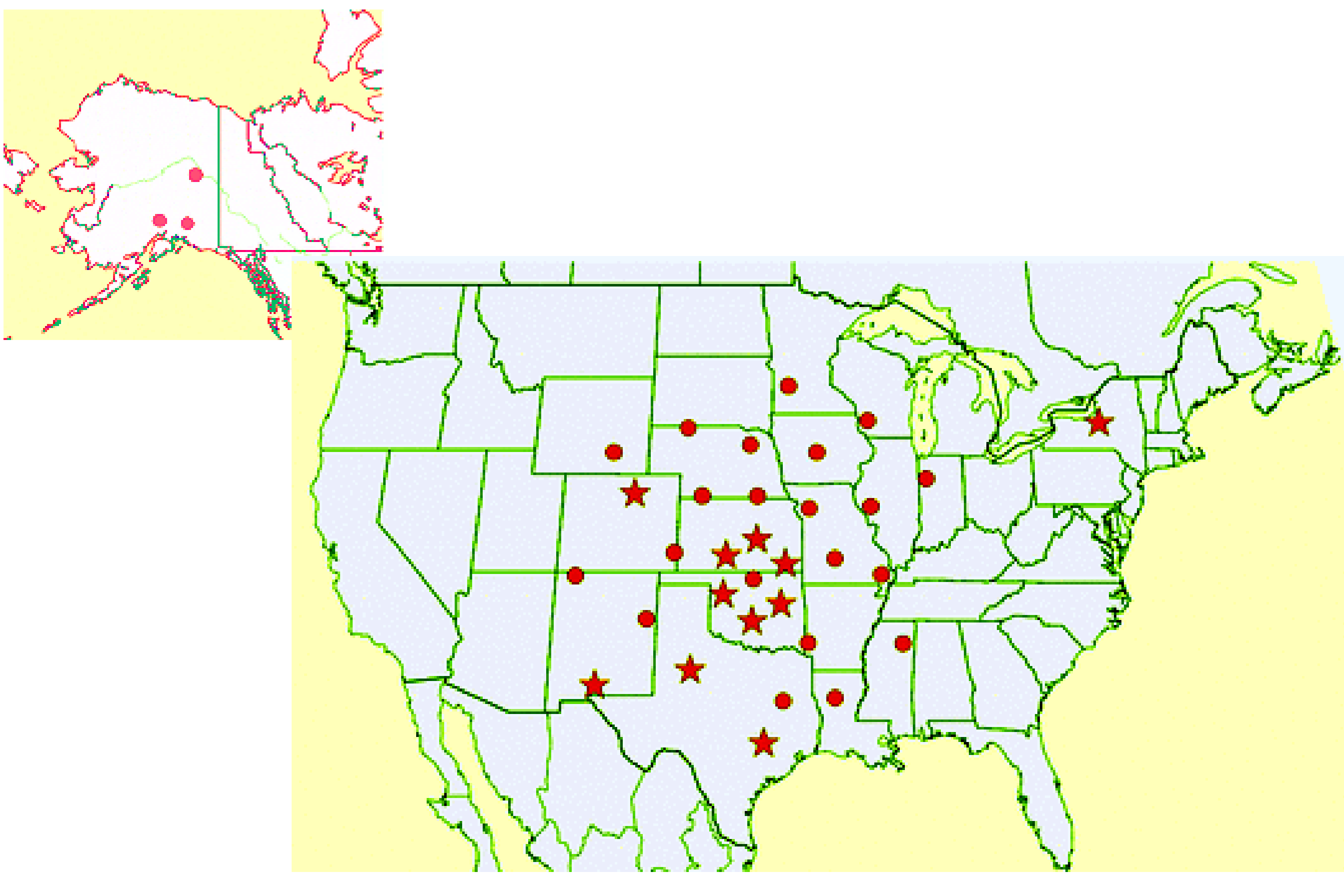

Figure 45. All NOAA Profiler Network sites, including Alaska (upper left), with radars and surface instruments. Circles show location of NPN sites without RASS; stars show location of NPN sites with RASS.

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 vapor (GPS-IPWV) systems for moisture measurements at all NPN sites. In addition to the 35 NPN sites, another 200+ NOAA and other-agency sites are monitored for timely GPS positions and surface observations to produce real-time IPWV measurements. Additional wind and RASS data have been acquired from a growing number of independently operated profiler sites, now totalling about 80. These Cooperative Agency Profilers (CAPs) include many lower tropospheric boundary layer profiler sites plus a few higher power profilers similar to NPN sites. The data from these CAP sites are now available to the meteorological community in real time via the division's Webpage. Along with the four other branches within the division, this branch maintains and improves the NPN and CAP real-time data availability to the National Weather Service (NWS) and other worldwide users. The Network Operations Branch directly supports NOAA's mission of improving 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

The availability of hourly NPN winds to the NWS remained high through 2002, averaging about 95%. A summary of the overall performance of the network for the past 12 years is presented in Figure 46. This and other tracking

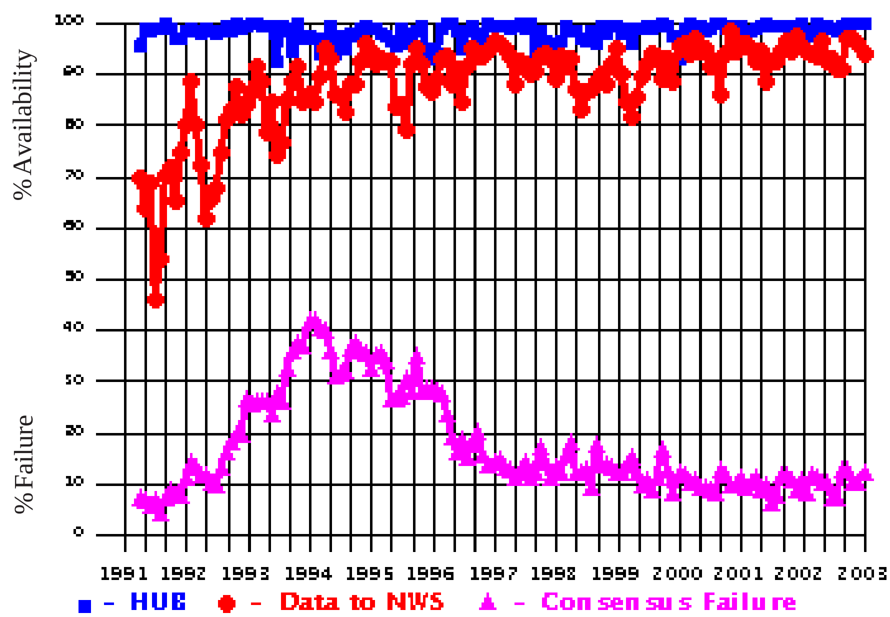

Figure 46. NOAA Profiler Network 404-MHz profiler data availability from January 1991–January 2003.

mechanisms are used to assess the strengths and weaknesses of the NPN. During the past year, the NPN data never fell below 90%, compared to all previous years. 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. This pattern has been analyzed and is attributed to increased lightning activity and severe weather during the convective season (cause of more commercial power failures and lightning induced profiler site hardware damage) and air conditioner failures during the summer. From this trend analysis, additional lightning suppression and communications equipment protection were added to the profiler sites.

The mean time between failure (MTBF) for individual NPN sites and the total number of failures resulting in a data loss of 24 hours or greater are presented in Figure 47. The more reliable sites are listed to the right, and the less reliable sites to the left. These MTBF statistics include any communication and commercial power outages (with duration of 24 or more hours) and any profiler site hardware failures. The profiler site hardware was designed for an MTBF of 6 months, and at least 6 NPN sites are exceeding this. Typical NWS commissioned systems such as NEXRAD, ASOS, and radiosondes have a data availability of 97% or better. Figure 47 shows that the NPN is comparable in data availability, but is currently less than the target of 97%. Also plotted here is the maximum time between failure for each NPN site. It is interesting to note that many sites have operated without a failure for 1–2 years, and 5 sites without a failure for over 2.5 years during the total 7-year period of this study.

A significant portion of personnel time involves the day-to-day operations and monitoring tasks related to the hardware, communications, and meteorological data quality aspects of the NPN. Constantly attending these tasks has resulted in high data availability rates for the past few years. Other tasks include initial diagnosis of equipment failures, coordination of all field repairs and maintenance activities, and maintenance of logs of all significant faults that cause an outage of profiler data. Figure 48 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 seven fiscal years. The duration of each data outage is broken down into many different states, 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

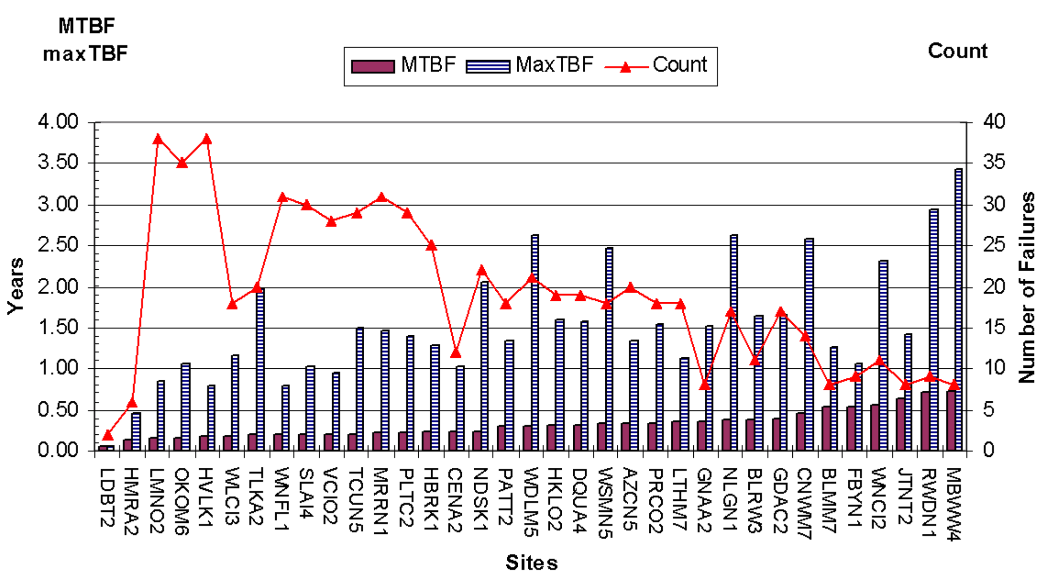

Figure 47. Seven-year analysis (January 1996–January 2003) of mean time between failure (MTBF) and the total number of failures, based on data outages for more than 24 hours.

power or communications, and document when and how the fault was ultimately repaired. Figure 49 shows the distribution of these categories of downtime (normalized over the past 6 years). Analysis of all these states reveals important information regarding the operation of the network. In addition to the data monitoring tasks, there are 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, currently noncommissioned 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

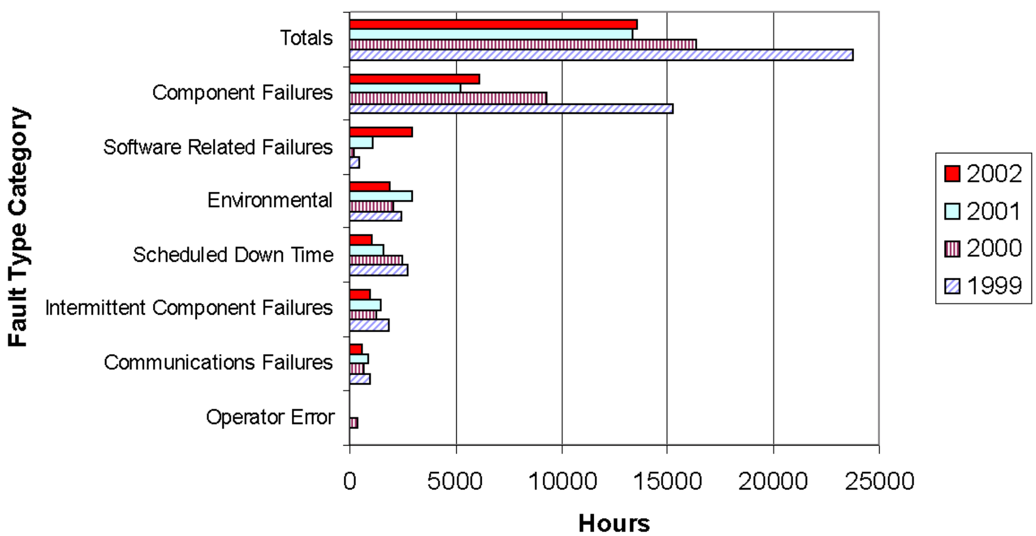

Figure 48. Hourly NOAA Profiler Network data lost by fault type for the past four fiscal years, from 1999–2002.

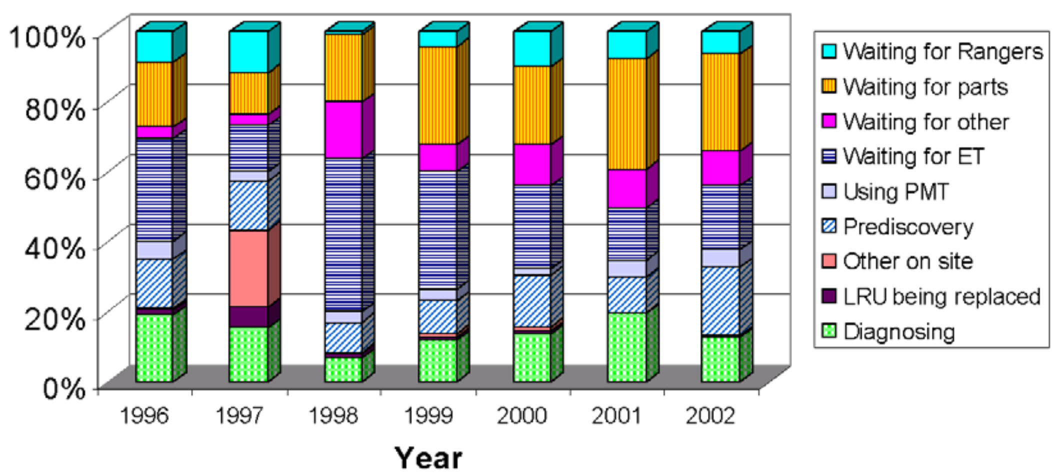

Figure 49. Distribution of NOAA Profiler Network downtime by categories (normalized over six years) from 1996–2002.

of the time, the profilers, dedicated communication lines, and Profiler Hub computer system operate unattended. The division has made significant improvements in its ability to remotely monitor activity within the NPN, Hub processing, and data communications via displays available on the Web and other tools. Activities that are now routinely monitored 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). Using 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 caused by lightning related power surges. Simply resetting the breaker would restore operation, but still required a site visit, typically by an NWS technician of the local landowner. From this analysis, the Engineering and Field Support Branch designed and installed a device to remotely reset the main breaker via a phone call to the site. The Network Operations Branch routinely uses this method to restore profiler operations, as well as "power cycling" a site in an attempt to clear software "hangs" and other problems. Last year the breaker reset capability was attempted 226 times outside of normal work hours to restore operations. It was successful 180 times (80%), resulting in an additional 4,700+ hours of profiler and GPS-IPWV data availability to our customers. These resets performed outside normal work hours alone increased data availability by 1.5%. This is quite impressive when our data availability is already routinely >90%.

The Network Operations Branch provided support for all aspects of planning, installation, activation, and evaluation of two relocated NPN profilers. The original 404-MHz profiler located near Platteville, Colorado, was disassembled, transported, and reassembled at a site near Ledbetter, Texas, in cooperation with the NWS Southern Region and the Lower Colorado River Authority in Texas. The 449-MHz profiler originally located at the Vandenberg Air Force Base in California was disassembled, transported, and reassembled at the Platteville site to replace the original 404-MHz profiler. Compared with the 404-MHz system, the 449-MHz system is much more versatile. It is a hybrid system that uses transmitter and antenna hardware similar to that originally installed in the NPN, but with different receiver, data processing, and beam steering capabilities.

Eleven NPN sites have RASS capabilities, typically providing measurements up to 2.5–4 km above the ground. In general, the velocity of the lower tropospheric wind limits the maximum height coverage of RASS by advecting 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 being 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 500–1000 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. They primarily support air quality measurements and meteorological forecasting and research programs, and typically operate independently or in small groups. Approximately 80 CAP sites are currently operating and providing data to the Profiler Control Center in Boulder. The division is working in cooperation with other agencies to acquire CAP wind and temperature data that are processed into hourly and subhourly quality-controlled products, and are ultimately distributed along with products from the NPN. 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 gain a better understanding of how and when NPN data are used by the NWS field offices, this branch started monitoring their Area Forecast Discussions (AFDs). Each day NWS offices typically write two AFDs, 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. All AFDs are searched for the term "profiler." During a 45-day period (1 December 2002–14 January 2003), 51 NWS offices (out of a possible 114) mentioned the use of profiler data in at least one of their AFDs. Figure 50 displays the geographical location of these offices. Note that the spatial distribution is very similar to that of all the profiler sites shown in Figure 44. The NWS offices located in the central U.S. are of course primarily using NPN data, while those offices near the East and West Coasts are all using CAP data. Of the 51 offices indicating the use of profiler data, a total of 220 AFDs (~5 per day) mentioned the use of profiler data in their decisionmaking process.

Projections

The Bird Contamination Check algorithm will be examined for possible additional improvements. The original algorithm analyzed only the hourly averaged north and east beams to detect the broader spectral widths caused by migrating birds. Recently the spectral width from the vertical beam was incorporated into the algorithm. The next significant im-

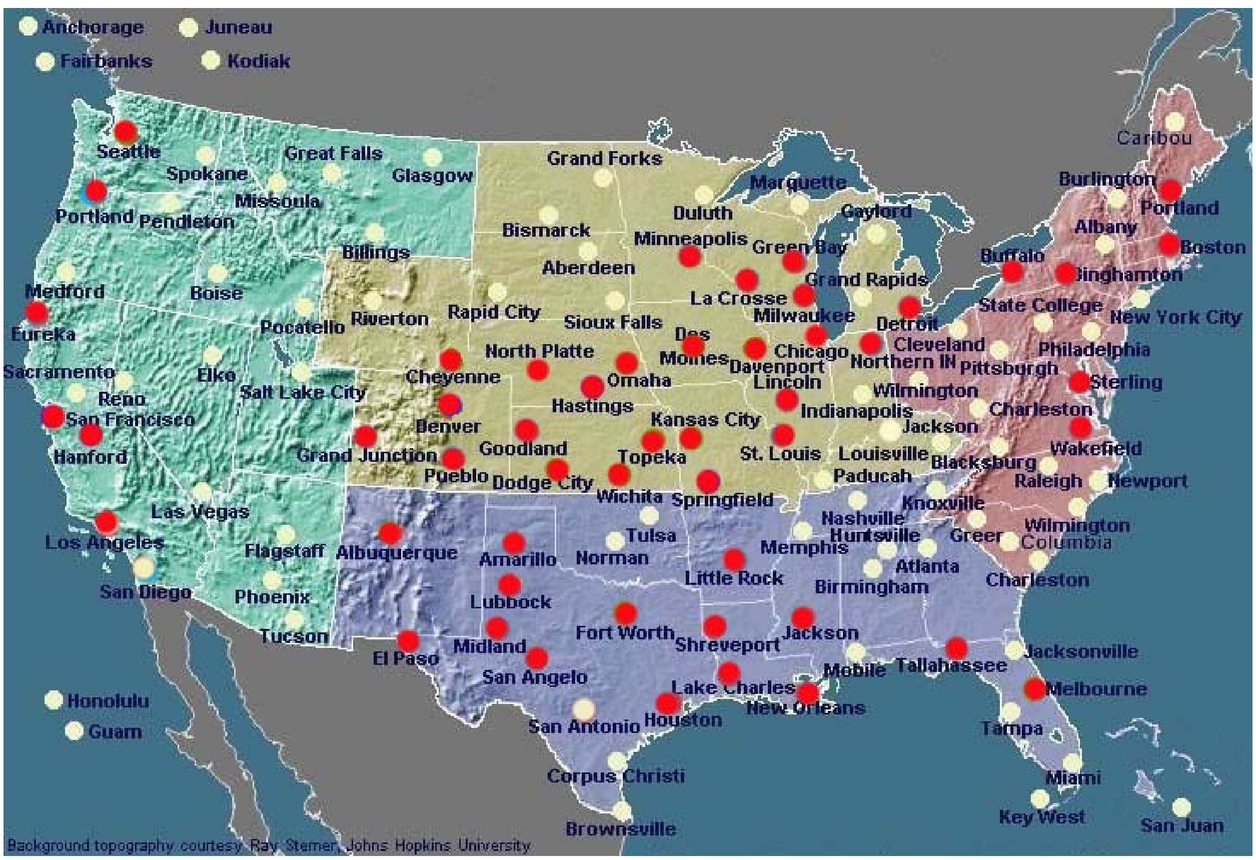

Figure 50. Location of National Weather Service offices (in red) identifying the use of profiler data in their Area Forecast Discussions (AFDs) during a 45-day period, from 1 December 2002–14 January 2003.

provement is likely to involve more sophisticated processing of the 6-minute moment data. Since the current Profiler Hub cannot incorporate any more processing, additional QC development work is limited at this time.

The division will continue to operate and maintain the 11 RASS-equipped profiler sites. Experiments will continue at Platteville and Purcell 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.

The operations of the CAP Hub will continue and will be used to acquire additional tropospheric profiler data from targets of opportunity, provide quality control for these data, and distribute that data to users via the Web and the NWSTG. 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 449-MHz profiler at Platteville will be investigated. This will include data quality and height coverage of two 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. These are all issues 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 each evening during weekdays, and (typically) 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.

Continued collaboration within the division to support the operation and maintenance of the NPN will 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 35-site NPN network is monitored 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 the remote diagnostics 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

In collaboration with the the Lower Colorado River Authority (LCRA) and NWS, this branch installed a 404-MHz profiler – complete with the Radio Acoustic Sounding System (RASS), GPS Surface Observing System (GSOS), and GPS instruments – at Ledbetter, Texas (Figure 51). This profiler, located at the Natural Science Laboratory (75 miles east of Austin at Cooper Farm), will support the NWS Southern Region and the growing Texas Mesonet.

Figure 51. The 404-MHz profiler at the Lower Colorado River Authority's Natural Science Laboratory in Ledbetter, Texas. *(Photo courtesy of Brian Phillips, SRG, Inc.)*

The 449-MHz profiler at Vandenberg Air Force Base was relocated to Platteville, Colorado, and will be used as an operational testbed for the conversion of the 404-MHz systems to 449-MHz. The Platteville profiler (Figure 52) is a hybrid system consisting of Vaisala and Lockheed Martin components.

The grounding systems at 30 profiler sites were tested and upgraded to meet current electrical specifications. To ensure that each site is more reliable during severe weather events, lightning and current surge protection devices were installed to protect the electronics and communications equipment.

Eleven data processors were acquired and installed at profiler sites to replace obsolete ones that can no longer be purchased or repaired.

Projections

An all-digital surface meteorological sensor package, the Profiler Surface Observing System (PSOS-II), will be installed 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 will bring equipment availability at the 35 profiler sites into uniformity and provide additional meteorological data.

New signal processing techniques will be tested at the Platteville profiler to determine the best method for acquiring quality data. The new techniques will help alleviate the problems associated with ground and sea clutter and bird contamination.

The Engineering and Field Support Branch will provide operations and maintenance support to the 10 quarter-scale profilers to be installed for the Air Force Tethered Aerostat Radar System (TARS).

Figure 52. The 449-MHz profiler at Platteville, Colorado, planned as a testbed site for a national 449-MHz profiler network. *(Photo courtesy of Brian Koonsvitsky, SRG Inc.)*

Software Development and Web Services Branch

Alan E. Pihlak, Chief

Objectives

The responsibilities of the Software Development and Web Services Branch are to provide software support for existing systems, develop new software and database systems as needed, provide Web support for the division's extensive Web activities, and design 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. The Profiler Website provides historical archives of wind, temperature, and other profiler information beneficial to researchers for forecasting and modeling both long-term and short-term climate change. A constant goal is to improve the timeliness of profiler data delivery and distribution through work on existing software systems and development of new software.

Branch resources are used in the operation of the Cooperative Agency Profiler (CAP) network, a non-NPN network of profiler sites. FSL, in cooperation with other agencies, ingests profiler data in near real time from different sources ranging from the Environmental Protection Agency to the Japanese Meteorological Agency. Unlike the radars used in the NPN, the CAP sites are operated in many different ways, are owned by about 30 different agencies, and are optimized for different applications. 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 where the NPN does not operate tropospheric profilers.

Accomplishments

In 2002, this branch began delivery of single-station, single-time-period messages to the National Weather Service Telecommunications Gateway (NWSTG). The message format is a simplified subset of the COST-76 standard BUFR format for profiler data. These changes are steps toward future use of alternate communications solutions. FSL's Modernization Division received a grant for modifying the AWIPS workstation to accept and process data in these new formats, which allow data to be processed closer to their time of arrival. These data now arrive at the NWSTG an average of 6 minutes faster every hour. Before changing the formats, data would occasionally arrive too late to be used in the NCEP (National Centers for Environmental Prediction) numerical weather models. Also, GPS precipitable water vapor measurements are now delivered to the NWSTG twice each hour.

The number of profilers in the CAP project more than doubled during the last two years, from approximately 50 in 2001 to over 100 currently. Division resources were shifted to accommodate this explosive growth. Data from CAP are routinely used by NWS forecasters from California to Virginia.

Work on other subsystems required to eliminate the aging NPN Hub is estimated to be 50% complete. Progress on this goal was affected by the growth of the CAP network.

The Wind Profiler Processing Platform (WPPP) is progressing, with decisions made regarding the standard hardware and software configuration.

Low-level, reusable software components based on a station-instrument model have been completed. In this model, station objects own instrument objects capable of producing different types of meteorological data in various composites. Now every station, whether CAP or NPN, can be treated in a similar fashion without writing new software every time a new station is added, removed, or relocated. These components can reside on any Java-enabled processor on the system, as long as it is connected to the Internet, regardless of operating system. Many of these components are currently in use in the production environment.

New, reusable graphics software for displaying winds, temperatures, and moments from the Web and local or remote datasets was completed and is being used on the Demonstration Division Website.

Projections

As we enter the third generation of wireless technology, organizations have been sponsored by the National Science Foundation to create, demonstrate, and evaluate a noncommercial prototype high-performance wide-area wireless network for research and education. Wireless technology is in daily use by millions of consumers, and an evolution in observing systems communications must progress in the same direction. It is expected that at least four NPN sites will be converted to use satellite Internet in place of direct phone line connections in 2003. Staff will explore the results of last year's COMET project grant for JINI/TINI technology using packet radio communications, as well as other technologies such as cellular and point-to-multipoint IP.

In 2003, completion of the Phase 1 transition will include retirement of the obsolete NPN Hub and supporting 1980s era peripherals, and completion of a general-purpose serial data client-server component, the basis for several subsystems such as a new Web-based PMT control system.

Improvements and updates will be made to the Demonstration Division Website.

Final work will be completed related to the National Climatic Data Center's (NCDC) profiler data archive. These data, covering the last 11 years, have been reprocessed into a modern storage format and will be sent back to NCDC within the year.

Archived NPN and CAP data will be placed online (*http://profiler.noaa.gov*) and available for downloading or viewing. At least one year of data will be available online, and requests for older historical data will be processed as received.

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. The activities of the branch primarily support NOAA's environmental assessment and prediction mission. It creates and disseminates reliable assessments of weather, climate, the space environment and geodetic phenomena using a new upper-air observing system technique in support of advance short-term warning and forecast services. The data and techniques developed and implemented by the branch also support seasonal to interannual climate forecasts as well as the prediction and assessment of decadal to centennial climate change. Due to a largely unanticipated synergy between the requirements for atmospheric remote sensing and the more traditional applications of the Global Positioning System (i.e., positioning, navigation, and time transfer), the branch's activities also promote safe navigation 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 of the GPS-Met Observing Systems Branch are to define and demonstrate the major aspects of an operational ground-based Global Positioning System (GPS) integrated precipitable water vapor (IPWV) monitoring system, facilitate assessments of the impact of GPS meteorological data on weather forecasts, assist in the transition of GPS-Met data acquisition and data processing techniques to operational use, and encourage the use of GPS in atmospheric research and other applications. The work utilizes the resources and infrastructure established to operate and maintain the NOAA Profiler Network (NPN) in achieving these objectives at low cost and risk. The branch collaborates with other FSL divisions (especially the Forecast Research Division, Aviation Division, International Division, Systems Development Division, and the Director's Office which includes the Information and Technology Services group) to achieve objectives of mutual interest and benefit the laboratory, its customers and partners.

This work represents an investment in scientific research, the development of new technologies to improve current operations, and assistance in helping NOAA prepare for the future. 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 partnerships. 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), DOT, and Department of Defense (DOD).

Accomplishments

The focus of the GPS-Met project during 2002 was on expanding the demonstration network to facilitate assessment of these observations on weather forecast accuracy, investigating other uses for GPS data and meteorological models assimilating GPS observations, and making NOAA and other agencies more aware of these research and development activities. In this regard, the branch completed its second technical review (available at *http://gpsmet.fsl.noaa.gov/jsp/review2002.jsp*), published four peer-reviewed papers, presented two papers at the annual meeting of the American Meteorological Society, and presented briefings to numerous organizations, including the ASOS Program

Management Committee, CORS User Conference, the NOAA Space Environment Center, U.S. Air Force Space Command, and Purdue University. Support, information, and materials were also provided to schools and other institutions, federal agencies, foreign countries, and private companies.

Impact of GPS Water Vapor Data on Weather Forecast Accuracy

The GPS-Met Observing Systems Branch assisted the Regional Analysis and Prediction Branch in performing the fifth consecutive assessment of the impact of GPS integrated precipitable water vapor (IPW) retrievals on weather forecast accuracy. The annual assessments are actually data denial experiments using the 60-km 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. (Figure 53). 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 5 pressure levels (850 hPa, 700 hPa, 500 hPa, 400 hPa, and 300 hPa). The results are summarized in Table 1, which compares GPS-Met impact assessments over the past 5 years. Table 2 presents the results of Table 1 in terms of percent improvement in 3-hour relative humidity (RH) forecast skill for the lowest two levels evaluated, 850 hPa and 700 hPa. From a weather forecast perspective, these are the two most important levels, since most of the moisture in the atmosphere resides at or below these levels. Figure 54 shows the reduction (increase) in forecast error as a function of the number of GPS stations used in the data denial experiments: 18 in 1998 and 1999, 55 in 2000, 74 in 2001, and 100 in 2002. Figure 55 is the improvement in 3-hour RH forecast skill in 2002 as a function of month of the year. Although RH forecast skill was again greatest during the cold months, improvements during the warm months appear to be larger than previously observed. This is probably related to the increasing size of the GPS network as discussed below.

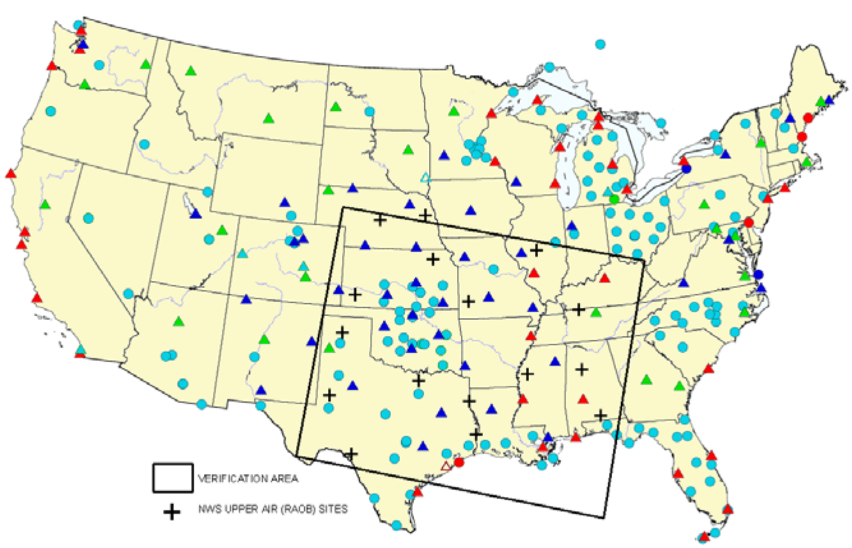

Figure 53. Verification area for GPS-Met impact assessments using the 60-km MAPS model.

Table 1.

Comparison of five years of GPS impact on RH forecasts in the 60-km RUC. Numbers in the columns labeled "Control 2002" and "with GPS" are (forecast–RAOB in % RH) without and with GPS IPW, respectively.

Level	1998–1999	2000	2001	2002	Control 2002	With GPS
850	.15	.38	.39	.50	14.26	13.76
700	.11	.41	.63	.65	16.43	15.78
500	.07	.21	.20	.24	18.07	17.83
400	.03	.01	-.04	-.05	18.54	18.59
300	.01	.01	-.12	-.25	17.84	18.09

Table 2.

Results for 850 hPa and 700 hPa, binned by whether they were better, worse, or the same with GPS.

850 mb	1998	1999	2000	2001	2002	(Number of Cases in 2002)
Better	25%	28%	37%	38%	45%	(266)
Worse	21%	19%	23%	24%	26%	(152)
Same	54%	53%	40%	38%	29%	(174)
						(74% same/better)

700 mb	1998	1999	2000	2001	2002	(Number of Cases in 2002)
Better	23%	27%	39%	49%	52%	(310)
Worse	21%	21%	21%	18%	20%	(119)
Same	56%	52%	40%	33%	28%	(163)
						(80% same/better)

The magnitude of the improvement shown in Table 1 is relatively small in absolute terms, (0.5% at 850 hPa in 2002), primarily because the evaluation includes days when the addition of GPS has little or no impact on the forecast, or the addition of GPS makes the forecast slightly worse. In fact, the former constitutes the majority of the cases. This occurs when the moisture field is not changing rapidly and is well described by the model using the current suite of operational observing systems. However, a major goal of modern weather prediction is to improve forecasts of severe weather, and this is precisely when GPS appears to be making its greatest contribution. With this in mind, we present the following points.

- The NWP model is assimilating an integrated quantity (IPW), comparing the difference between the model-predicted values and observed moisture in the vertical column, and distributing the difference to the model as a percent correction. Obviously this is a simplistic approach to distributing the errors, since it has absolutely no physical basis. Nonetheless, we see more or less continuous improvement below 500 hPa, and the improvement diminishes with altitude becoming (on average) slightly negative above 500 hPa. From a pragmatic standpoint, it is better to have an improvement in moisture forecast accuracy where the moisture is, rather then where it is not (i.e., above 500 hPa).
- A major problem in estimating an initial state for a numerical forecast comes from spatial and temporal aliasing when interpolating discrete observations into an "analysis increment" field. This is especially true for a vertically integrated quantity, because the forecast background error at discrete vertical levels must be estimated from the

difference between observed and forecast integrated quantities.

• The assessment is being carried out in one of the best observed regions on Earth. Considering the number of observations going into modern mesoscale models such as the RUC2, it is surprising that we see any positive impact at all from the assimilation of GPS-IPW. For example, the number GOES PW estimates under cloud free conditions is nearly an order of magnitude greater than the number of GPS sites.

• Other areas in the western United States, the Caribbean, Mexico, and Canada are not as well observed, however. As a consequence, the potential contribution of GPS-Met to improved forecasts downstream of these regions is probably much greater than it is from the central United States.

• After 5 years, it is clear that the impact on 3-hour forecasts steadily grows as the network expands, and it seems that there is no reason to doubt that this trend will continue. This is not so much an expression of having a large number of sites per se, but of having a sufficient number of observations when and where they are needed to better define the initial conditions for the model.

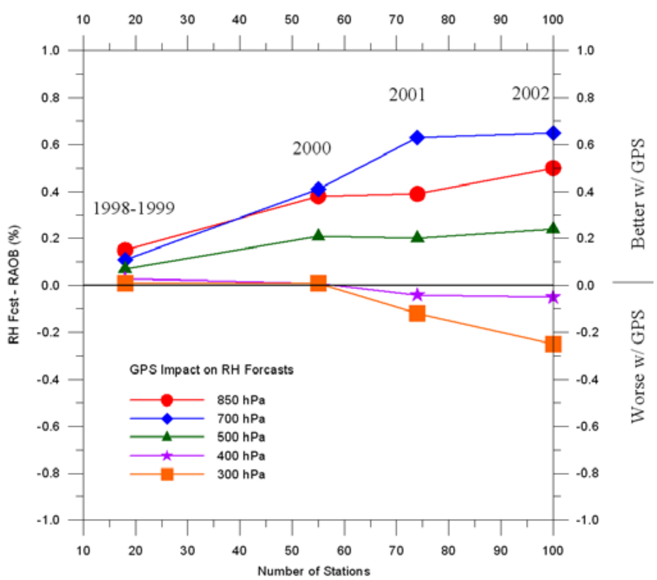

Figure 54. 3-hour RH forecast improvement as a function of the number of GPS stations used in the data denial experiments: 18 in 1988 and 1999, 55 in 2000, 74 in 2001, and 100 in 2002.

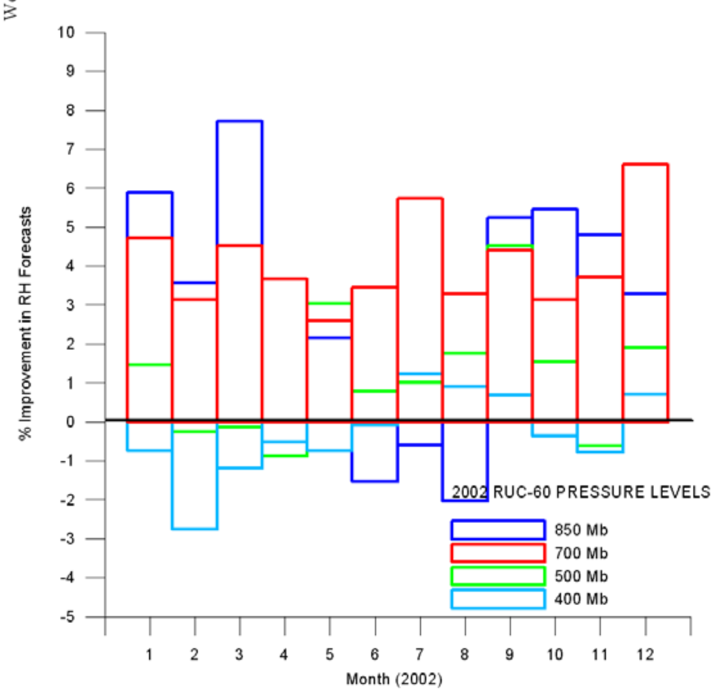

*Figure 55. Improvement in 3-hour RH forecast skill in 2002 as a function of month of the year. Percent improvement in RH is defined as 1-*100 (3-hour forecast error with GPS and 3-hour forecast error without GPS).*

- The relationship between an improvement in RH forecast skill and an improvement in precipitation forecast skill is not straight forward since a large number of other factors besides the amount of moisture in the atmosphere are involved in determining if, when, where, and how much precipitation will occur.

Expansion of the GPS-Met Network

GPS Surface Observing System (GSOS) packages were installed at 5 Nationwide Differential GPS sites and at 25 U.S. Coast Guard and U.S. Army Corps of Engineers Maritime Differential GPS sites. This brings the number of "backbone" sites in the network to 110, with a goal of 200 sites nationwide by 2005.

The GPS-Met team collaborated with NGS in a Center for Operational Oceanographic Products and Services (CO-OPS) program to use GPS to monitor the levels of the Great Lakes and its tributaries. Other participants include the Ohio State University, NOS Office of Ocean and Coastal Resource Management, NOS Office of the Coast Survey, OAR Great Lakes Environmental Research Laboratory, Canadian Hydrographic Service, and the National Resources Canada Geodetic Survey Division. Ultimately eight new sites were added to the network.

To facilitate the expansion of the GPS-Met network, the branch worked on techniques to ingest data from a growing number of GPS continuously operating reference stations (CORS) in the United States. These CORS sites are established by state and local government agencies to improve local high accuracy positioning and navigation services (including surveying, 911 response, and intelligent transportation system applications), and by universities for teaching and research. Most state and local government CORS do not have collocated surface meteorological sensors that permit the GPS data to be used directly for GPS meteorology. However, since these agencies have graciously provided NOAA with access to their observations at no cost, it is worthwhile to see if they could still be used for operational weather forecasting. The branch investigated how water vapor retrieval accuracy degraded as the distance between the GPS antenna and the pressure and temperature sensors increased. Results showed that if an automated surface observing system such as ASOS was within a reasonably short distance (less than 50 km horizontally and 100 meters vertically), then the water vapor retrieval error could be kept to less than 1 mm IPW through a process called "bias fixing." This was done using products generated by the Mesoscale Analysis and Prediction System/Rapid Update Cycle (RUC) Surface Assimilation Systems (MSAS/RSAS), at *http://www-sdd.fsl.noaa.gov/MSAS/msas.html*, developed by the FSL Systems Development Division. While this technique is not deemed suitable for climate monitoring applications, the level of accuracy is more than sufficient for current mesoscale weather forecasting applications. As seen in Figure 56, the implementation of this technique in 2002 more than doubled the number of GPS-Met stations available in the conterminous United States at virtually no direct cost to the government. Figure 57 shows the configuration of the GPS-Met network, including "backbone sites" operated by United States federal agencies (identified by triangles) and "infill sites" operated by other government agencies, universities, and the private sector (identified by circles).

Using Meteorological Models to Improve GPS Positioning Accuracy

During average (quiet) geomagnetic and tropospheric conditions, the gradients in total electron content in the ionosphere over the continental United States, and temperature, pressure, and moisture in the lower atmosphere are usually small. Under these circumstances, existing methods to correct for excess signal delays caused by the ionosphere and troposphere over short to moderately long baselines work reasonably well for many but not all (e.g., rapid static and real-time kinematic, or RTK) positioning and navigation requirements. During significant space and tropospheric weather events, however, the constituents of both the ionosphere and troposphere can vary greatly in

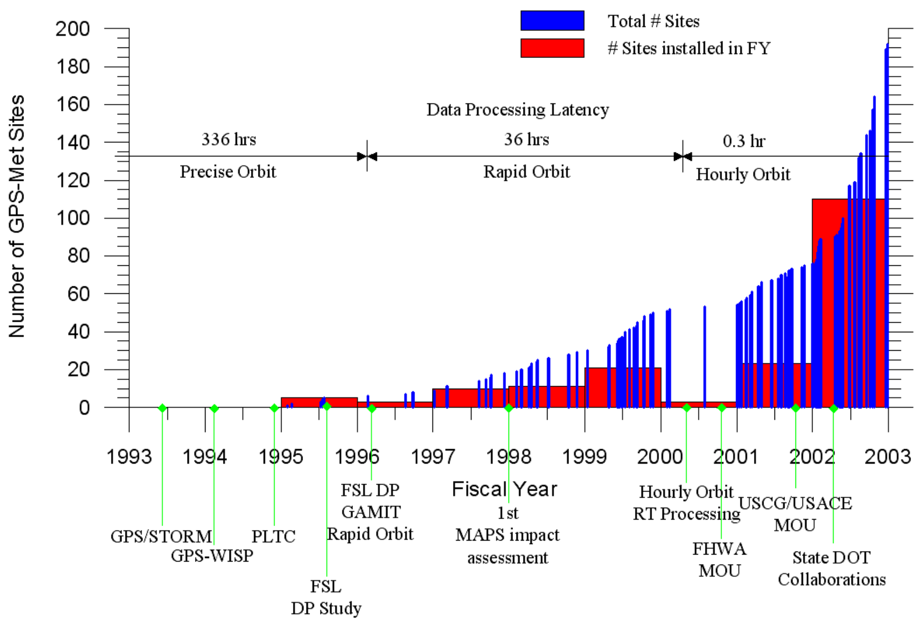

Figure 56. Growth of the GPS-Met network and major milestones.

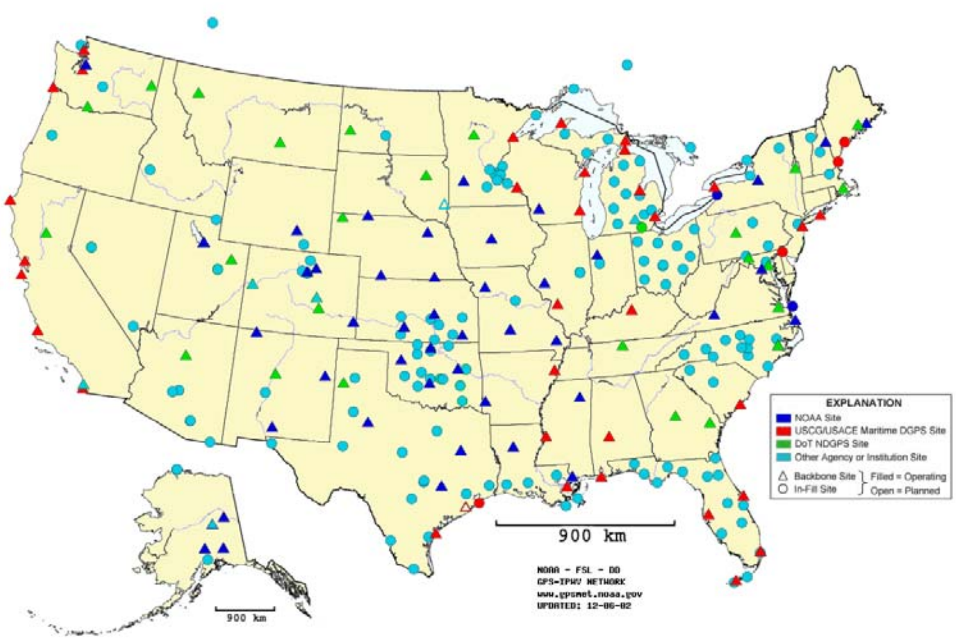

Figure 57. GPS-Met Network at the end of 2002. Triangles identify "backbone sites" owned and operated primarily by U.S. federal agencies. These provide the highest quality GPS IPW retrievals and are maintained as operational systems. Circles identify "infill sites" used for network densification. The quality of retrievals from infill sites vary from site-to site, but all are suitable for use in weather forecasting. Since infill sites are not operated or maintained as operational systems, they have (in general) lower reliability than backbone sites.

time and space, leading to rapid changes and large errors in GPS accuracy. During geomagnetic storms, for example, gradients in the electron plasma density of the ionosphere increase considerably, and transients are expected to propagate from high latitudes. At these disturbed times the steep gradients associated with the equatorial ionization anomaly begin to penetrate into midlatitude regions. In similar fashion, strong gradients in pressure, temperature, and moisture commonly associated with severe weather in the lower atmosphere also affect GPS accuracy. While the magnitude of the impact of the lower atmosphere on positioning accuracy is less than the ionosphere, the need for higher accuracy dynamic positioning and navigation requires significant improvements in both areas.

GPS observations can be used to improve weather forecast accuracy, especially during active weather. The observations improve the NWP model's initial description of the moisture field, which, under most circumstances, leads to improved short-term forecasts of atmospheric moisture and precipitation. The parameter being assimilated, integrated precipitable water vapor, is retrieved from the GPS tropospheric signal delay. The tropospheric signal delay is estimated as a free parameter in the solution of the double-difference equation that is used to measure changes in the position of the GPS antenna over time. The NWP model assimilates GPS IPW and other thermodynamic quantities (or proxies thereof) and provides a three-dimensional analysis of the mass and momentum fields. From this, a prediction of the future state of the atmosphere comes from a finite difference or spectral representation to the equations describing geophysical fluid dynamic flow on an unevenly heated rotating sphere. This is an initial value problem (and also a lateral boundary problem for a non-global, limited-area model of a closed set of non-linear partial differential equations) that describes the physical laws governing change of atmospheric parameters including temperature, moisture, wind, and pressure. These parameters can be inverted to provide an estimate of the tropospheric signal delays over the model domain. In similar fashion, improved space weather models will soon be able to do this for the ionosphere using an analogous procedure applied to different physical parameters. These delays can be used to constrain two of the five elements of the GPS error budget: namely the ionospheric and tropospheric signal delay to each satellite in view, thus improving the GPS estimate of position.

The U.S. DOT Federal Highway Administration (FHWA) received funding in 2002 from the Interagency GPS Executive Board (*http://www.igeb.gov/org/execsec.shtml*) to determine the feasibility of developing more robust atmospheric (ionospheric and tropospheric) corrections using space and tropospheric weather models. In this project, FSL is collaborating with the NOAA Space Environment Center (SEC) and the NOAA National Geodetic Survey (NGS) to investigate how the improved ionosphere and troposphere models could be used to improve GPS data processing, especially the integer-fixing problem for mobile GPS observations and rapid-static GPS surveying.

FSL has already demonstrated that it is possible to use the 20-km RUC model assimilating GPS IPW data to characterize and make short-term predictions (nowcasts) of the signal delays caused by the lower atmosphere with an accuracy about 5 times better then the best available techniques currently used in the FAA Wide Area Augmentation System. Techniques to characterize and predict the total electron content of the ionosphere are under evaluation, with a goal of improving these delays by a factor of about 3.

Atmospheric Infrared Sounder (AIRS) Calibration and Validation

NASA selected the FSL GPS-Met group to collaborate as co-principal investigator with the NOAA NESDIS Office of Research and Applications on a project to evaluate the AIRS (Atmospheric Infrared Sounder) radiometer and other moisture sensing systems aboard the Aqua spacecraft using ground-based GPS water vapor observations. GPS-IPW is now recognized internationally as a base level, climate-quality observation, in part because of the collaborative work conducted by FSL between 1994 and 2002.

The Aqua/AIRS mission provides observations that contain information about the state of the Earth's surface and atmosphere. These observations should be sufficient in quality, quantity, and timeliness of delivery to advance the state of the art of numerical weather prediction and the characterization and understanding of atmospheric and climate processes. To help meet these broad objectives, the Aqua/AIRS project will provide more accurate and higher resolution measurements of atmospheric water vapor profiles than has been available from satellite sensors previously. This investigation is intended to provide accurate measurements that are closely matched in time and space of the column integrated precipitable water vapor (IPWV) product from AIRS. In addition, it is being used to identify the best radiosonde data to use as the basis for AIRS water vapor profile retrievals. The AIRS validation process has been designed to establish in sequence the reliability of Level 0 data – EDRs (eddy dissipation rates); Level 1 data – radiances; Level 2 data – temperature retrievals; and Level 2 data – trace gases, such as H20, CO, and CO2.

The validation of AIRS radiances is a necessary prerequisite to the validation of derived products (Level 2), since high quality, well-characterized radiance measurements are needed as input to the Level 2 retrieval algorithms. Nine months after the launch of Aqua in May 2002, the high radiometric quality of AIRS observations has been established by other members of the validation team, and derived temperature profiles have been assigned a high degree of confidence. The AIRS science and validation teams have begun producing initial AIRS water vapor profiles and IPWV data. Preliminary comparisons of those data with the NOAA GPS IPWV are now underway. Definitive GPS-to-AIRS IPWV comparisons await the optimization of AIRS water vapor retrieval algorithms. Careful has been taken for data exchange and rapid analysis once the water vapor product stream is ready for full-scale validation.

IPW measurements at 30-minute temporal resolution from the GPS-Met network continue to be archived on an operational basis, and are available as images or data via the Web. Moreover, sample GPS IPWV datasets have been transmitted to NASA/JPL and to individual AIRS validation team members upon request in designated formats, typically netCDF or ASCII. Finally, the fixed locations of the GPS receivers (latitude, longitude, and altitude) have been provided to the AIRS science and validation team so that relevant members can select portions of their datasets (both AIRS and alternate validation measurements) that match the GPS data in time and space.

Outreach

An outreach effort was funded to inform federal, state, and local government agencies about the NOAA Profiler Network, GPS Meteorology, and the advantages of joint use and sharing of GPS and surface meteorological data in near real time. The Aviation Division assisted in providing booth displays and presentations at major meetings, including the American Meteorological Society, World Space Congress, and the Intelligent Transporation Society of America.

Projections

During 2003, GSOS packages will be installed at approximately 20 new backbone sites: 6 new NDGPS sites; 10 Maritime DGPS sites in the conterminous U.S., Puerto Rico, and Hawaii; and about 6 other backbone sites to be selected in collaboration with other NOAA organizations. Tools to incorporate and display GPS-Met data on operational AWIPS workstations will be prototyped and evaluated. The GPS-Met network will continue to expand through the incorporation of infill sites operated by State Departments of Transportation, universities via SuomiNet, and other organizations. Assessment of GPS-Met on weather forecast accuracy will be facilitated. The branch will work with other organizations to assess the utility of meteorological models assimilating GPS observations to improve real-time GPS positioning accuracy. It will also become more involved in multiagency efforts to utilize ground-based GPS observations for satellite calibration and validation.

Facilities and Systems Administration Branch

Bobby R. Kelley, Chief

Objectives

The objectives of the Facilities and Systems Administration Branch are to manage and support the Demonstration Division communications and computer requirements. Duties include performing systems operations, systems maintenance, systems administration, network administration, NOAA Profiler Network (NPN) telecommunications administration, and support of the Global Positioning System Integrated Precipitable Water Vapor (GPS-IPWV) demonstration project.

Accomplishments

While NPN processing is in the process of being converted to a network of off-the-shelf PCs running Linux, the original two clusters of 13 micro-VAXs are still operating as primary and backup data processing and distribution systems. Components of the new modernized NPN processing system are currently running in parallel with the original NPN processing and distribution system. Work is ongoing to replace the NPN VAXs and NPN Hub software with robust production, backup, and development environments, using low-cost off-the-shelf equipment. Backup communications for NPN data acquisition are being converted to a newer PC running Linux to acquire data as necessary from a DOMSAT receiver. A PC-based server running the Linux operating system has replaced Sun Microsystems equipment for data processing and Webpage hosting. Two remaining Sun systems that are still in modest use will be decommissioned by April 2003. Support for the GPS-IPWV demonstration project has grown from 18 PCs running Linux to a total of 34.

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. 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-IPWV data acquisition, processing, and distribution. Full-time (24/7) operations coverage is provided during normal workdays through the Profiler Control Center in Boulder 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. When Unisys elected to discontinue providing telecommunications services in 2002, it became necessary to obtain an alternate provider. AT&T provided telecommunications services directly on an interim basis at approximately the same cost as the original services through Unisys. With the establishment of a Memorandum of Understanding (pursuant to the Economy Act) between FSL and the Department of the Interior's Minerals Management Service (DOI/MMS), an interagency fund transfer was accomplished to obtain telecommunications services at reasonable cost and without requiring replacement of $130,000 of existing NOAA equipment. The DOI/MMS contract can provide services through Fiscal Year 2005. Meanwhile, investigation is ongoing to determine the viability and cost effectiveness of alternatives such as wireless technologies and satellite-based communications to provide future communications services, meeting potentially expanding requirements for additional circuits and greater bandwidth while reducing communications costs.

A stand-alone computer room air conditioning unit was installed in the NPN computer facility. This has served to further stabilize the computer room temperature and provides redundancy for the building air conditioning system which was originally the only source of cooling. The installation was successfully accomplished without interrupting NPN operations. The investment serves to further improve NPN processing reliability.

Projections

The branch will maintain current operations and ensure continuous and dependable NPN acquisition, processing, and distribution of NPN and GPS-IPWV data (Figure 58) to all customers. Further development, testing, and implementation of the modernized NPN processing system will continue. To expand earlier successes, a low-cost approach of using off-the-shelf PCs running the Linux operating system will continue. Computer network equipment in the NPN computer facility will be replaced to maintain pace with building network upgrades, enable easier maintenance of the NPN network, and support expansion of the NPN network. Investigation of alternative communications options will be undertaken to provide increased bandwidth for NPN data acquisition and remote system control, and reduce future communications costs.

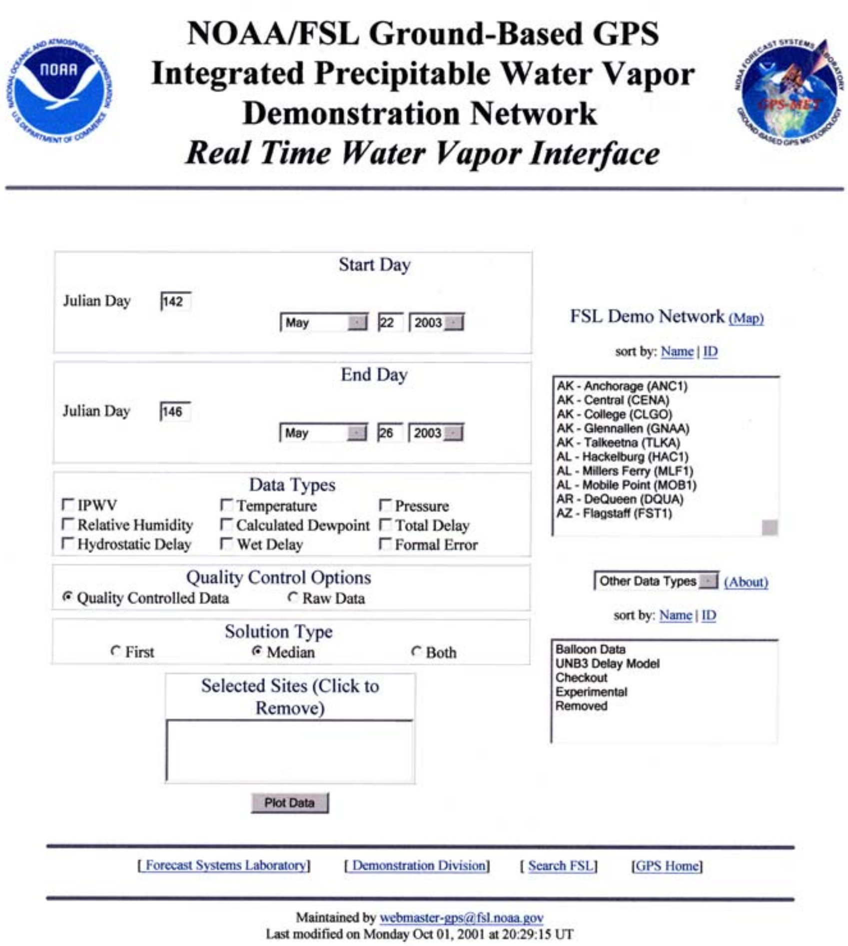

Figure 58. GPS-Met Network Webpage screen showing the Real-Time Water Vapor Interface.

Systems Development Division

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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 2002, work continued, in cooperation with the NWS, on the D2D meteorological display and text components of the AWIPS Weather Forecast Office (WFO) system. AWIPS Builds 5.2.1 and 5.2.2 and Operational Build 1 (OB1) were all addressed, as follows.

Build 5.2.1 was installed at most NWS field offices in the summer. Key new features developed by FSL include:

- High-resolution soundings from NWS forecast models are available to support forecast operations. Dynamic maps show the location of available soundings.
- A window-capture feature allows users to save images of AWIPS displays for use in publications or on Webpages.
- Some higher-resolution radar imagery is now available.

The general field deployment of Build 5.2.2 was underway at the end of 2002, with the following new features:

- Pilot report plots are available, categorized by hazard (e.g., icing) and level (e.g., 18,000–26,000 ft).
- GOES soundings, similar to model soundings in Build 5.2.1, are processed and made available for display.
- Dynamic analysis and contouring of observations makes it easier to visualize mesonet or other point data.
- Location, size, and resolution of the MSAS domain are under site control; sites include Alaska and Puerto Rico.
- Units conversion and sunrise/sunset tools are available.
- Ensemble grid forecasts can be viewed on AWIPS.
- A new Variable versus Height mode is available for examining model data.

The bulk of FSL's work on OB1 was also completed, with the following new features:

- Local profilers and rawinsondes can be processed by the LDAD function.
- POES (polar orbiting environmental satellite) soundings are added to the list of soundings available for display.
- MDCRS (automated aircraft reports) are processed, offering availability/plan-view plots and ascent/descent soundings.
- The radar product generator for NEXRAD data is upgraded and offers several new radar products.
- A new meteogram feature allows viewing of common surface weather parameters in a stacked time series form.

Range Standarization 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. Initial work included the addition of several local datasets to the system. This work, based on AWIPS Build 5.1.2, was delivered to Lockheed Martin in early 2002 and they performed an acceptance test with the Air Force at the Western Range (Vandenberg AFB) in June. The system was delivered to the Eastern Range (Cape Canaveral) in July. Development work on an AWIPS Build 5.2.2-based upgrade was nearly complete at the end of the year. Enhancements include the addition of a text subsystem, additional datasets, and a tabular text display that allows users to set thresholds on various parameters with colored highlights of observations exceeding the limits.

A proof-of-concept version of the RSA 3D lightning display application was demonstrated at the AMS annual meeting and at the Range Operations Control Center at Cape Canaveral. The specifications and requirements for the application were developed at a later meeting with Lockheed Martin, NASA, and FSL. The prototype includes a modified and enhanced Vis5D to display LDAR (Lightning Detection and Ranging) and CGLSS (Cloud-to-Ground Lightning Surveillance System) data, and development of a Tcl/Tk graphical user interface to control the application.

Other Projects

Linux – FSL continues to develop low-cost meteorological workstation capabilities. A Unix PC workstation developed over a decade ago is still being used by the Taiwan Central Weather Bureau (CWB) to support their daily forecast operations. NWS fully embraces the use of Linux on low-cost computers as its next generation of AWIPS processors. FSL continues to support this transition by exploring architectural improvements to accommodate changes in technology and user requirements. Software was developed for the transition of field systems from Hewlett-Packard workstations and servers to Linux PCs. Exploratory work includes the use of RAM disks and multicast technology for distributing data to workstations and making the system more responsive in servicing user requests.

D3D – A high point was reached for D3D when six papers were presented at the annual American Meteorological Society's AWIPS session, "Visualization: D3D Overview and Operational Use." These articles are available at *http://d3d.fsl.noaa.gov*. As a proof-of-concept, a basic netCDF ingest method was added to the D3D version of Vis5D. This method was applied to high resolution mosaicked radar data and demonstrated to the Taiwan Central Weather Bureau. With this project terminated in October 2002, only minimal support for existing users is now provided.

Projections

FX-Advanced/AWIPS – Continuing support will be provided to the NWS during the fielding of AWIPS Build 5.2.2 and OB1, and development and testing of Build OB2, targeted for field release beginning August 2003. Key development tasks will include accommodation of additional datasets (high-density winds derived from GOES and several radar items), and quality control of text warning products released by forecasters. System performance issues will continue to be addressed.

RSA – Software based on AWIPS Build 5.2.2 will be installed at the Ranges, and the branch will assist Lockheed Martin with installation and testing. Development of additional datasets (notably, lightning/field mills and radar) will continue, and user training and documentation will be provided. A prototype of the 3D lightning display application will be delivered in June 2003 and the operational version will be delivered in late September or October 2003.

Linux – FSL will continue to work toward the complete transition of AWIPS to the Linux/PC platform. During 2003, NWS hopes to replace all remaining Hewlett Packard workstations at field sites, and also augment data processing with the installation of two Linux data processors. FSL will continue to assist with testing, develop software components, and explore architecture improvements.

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 National Centers for Environmental Prediction (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 packages 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. The resulting functions help to take into account physical blocking by mountainous terrain, and improve the representation of surface gradients.

Data typically ingested by MSAS and RSAS include standard METARs, 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 any 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

During 2002, the Scientific Applications Branch continued to support the operational MSAS and RSAS versions on AWIPS and at NCEP.

MSAS – The major MSAS accomplishment in 2002 involved the initial development of software upgrades necessary to increase grid resolution and vary domain boundaries for MSAS on the AWIPS system. These upgrades were delivered with AWIPS Build 5.2.2, and include the incorporation of a customization script that allows each NWS WFO to specify the domain and resolution of their local MSAS systems, and also to specify the analysis grids desired by their forecasters.

Although the domain and resolution parameters for MSAS are flexible, in previous AWIPS builds they have always been preset to cover the continental United States (CONUS) with a 60-km analysis grid. Starting in AWIPS Build 5.2.2, however, each forecast office is able to modify the location, size, and resolution of its local MSAS domain, and also to specify the model background utilized in the MSAS analyses, the level of the MSAS pressure reduction (for example, 1500 m or sea level), and the time interval used in the MSAS pressure change analysis (for example, 1-hour or 3-hour pressure change). (Figure 59 shows an MSAS sea-level pressure analysis on AWIPS.) Changes in the domain size are linked to changes in the grid resolution in such a way as to minimize AWIPS impacts and guarantee that overall MSAS computational demands remain the same. For example, forecast offices can choose a 15-km, regional-scale domain, or a 60-km CONUS domain, but not a 15-km CONUS domain. Starting in Build 5.2.2, MSAS will also, for the first time, supports domains outside the continental U.S., such as Alaska and Puerto Rico.

Initial development was also completed on a new AWIPS software package to display observation QC results produced by MSAS for the AWIPS QCMS. In addition to gridded surface analyses, MSAS regularly produces QC information for surface observations ingested into the AWIPS database. The information includes the results of various QC checks applied to each individual observation as well as the hourly, daily, weekly, and monthly percentage of failure for observations at each surface station, along with the errors associated with those failures. The current AWIPS system, however, provides no efficient or easy access to this information. The new software package, called the QCMS Browser, will allow the MSAS QC information and statistics to be easily accessed by NWS personnel for the purposes of 1) monitoring station performance, 2) locating persistent biases or failures in surface observations, 3) evaluating observation/QC accuracy, and 4) subjectively overriding QC values.

RSAS – Significant upgrades to the RSAS system at NCEP were also completed. The new system both increases the RSAS horizontal resolution to 15 km and extends its domain boundaries from Alaska in the north to Central America in the south, and also covers significantly more oceanic areas. Additional RSAS upgrades include a new topography grid which has been improved to better match observation elevations and provide better treatment of the model backgrounds. The system continues to provide hourly surface analyses, updated twice per hour (currently at 5 and 21 minutes past the hour), for RSAS sea-level pressure, NWS sea-level pressure, altimeter, potential temperature, dew point temperature, dew point depression, 3-hour pressure change, and surface winds. In addition, temperature, specific humidity, and equivalent potential temperature are provided as derived grids.

Operational implementation of the new RSAS version at NCEP was completed in 2002, along with the objective and subjective evaluations required for that implementation. Subjective evaluations were conducted by the NWS Reno, Nevada, WFO and the NCEP Aviation Weather Center (AWC) with good results. Forecasters at both NWS offices reported a significant improvement in the new 15-km system, stating, for example, that it "...provided detail not observable in the previous 60-km system" and it was a "huge improvement" over the previous system. Objective evaluations also showed significant improvement, specifically in the statistical fit of the grids to surface observations. The new RSAS also has the advantage of providing surface analyses over Alaska, Canada, Mexico, and Central America.

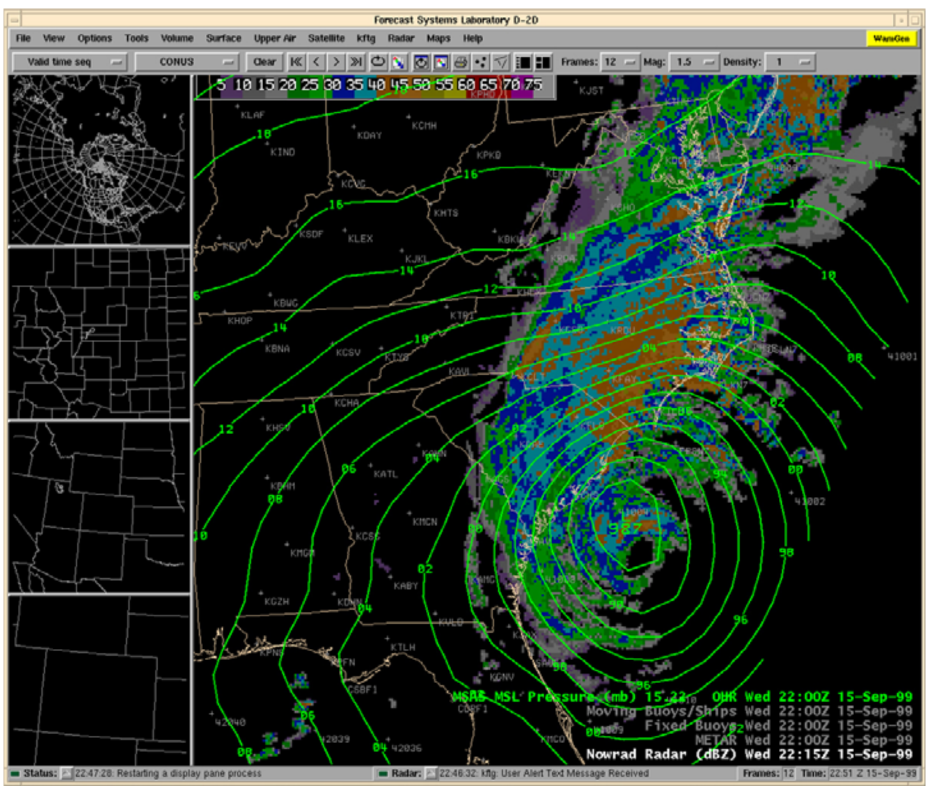

Figure 59. An AWIPS D2D screen showing an MSAS sea-level pressure analysis overlaid on NOWRAD radar data.

Another accomplishment was the initial development of a Korean configuration of MSAS for the Korean Meteorological Administration (KMA) Forecaster's Analysis System (FAS). Figure 60 shows an MSAS wind analysis over Korea.

For more information on the customization options offered in the AWIPS Build 5.2.2 MSAS, refer to *http://www-sdd.fsl.noaa.gov/MSAS/localization.html*. For more information on the new RSAS version, see the Technical Procedures Bulletin at *http://www-sdd.fsl.noaa.gov/MSAS/rsas_tpb.html*. For general information on both MSAS and RSAS, see *http://www-sdd.fsl.noaa.gov/MSAS/msas.html*.

MADIS

MADIS now supports observation distributions to many government, research, and education institutions, as well as private companies. Organizations already receiving MADIS datafeeds include NWS forecast offices, NCEP, the National Center for Atmospheric Research, the National Ocean Service, the National Aeronautics and Space Administration's Marshall and Kennedy Space Flight Centers, the Massachusetts Institute of Technology Lincoln Laboratory, and several 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 Local Data Manager (LDM) software. Nearly 50 subscribers were added in 2002 alone.

Datasets supported by MADIS include standard maritime and land surface observations, including Meteorological Aviation Reports (METARs) and Surface Aviation Observations (SAOs), along with surface mesonet observations from over 5000 stations provided by local, state, and federal agencies and private firms. Upper-air observations include radiosonde observations, automated aircraft reports, wind profiler data from the NOAA Profiler Network (NPN), and

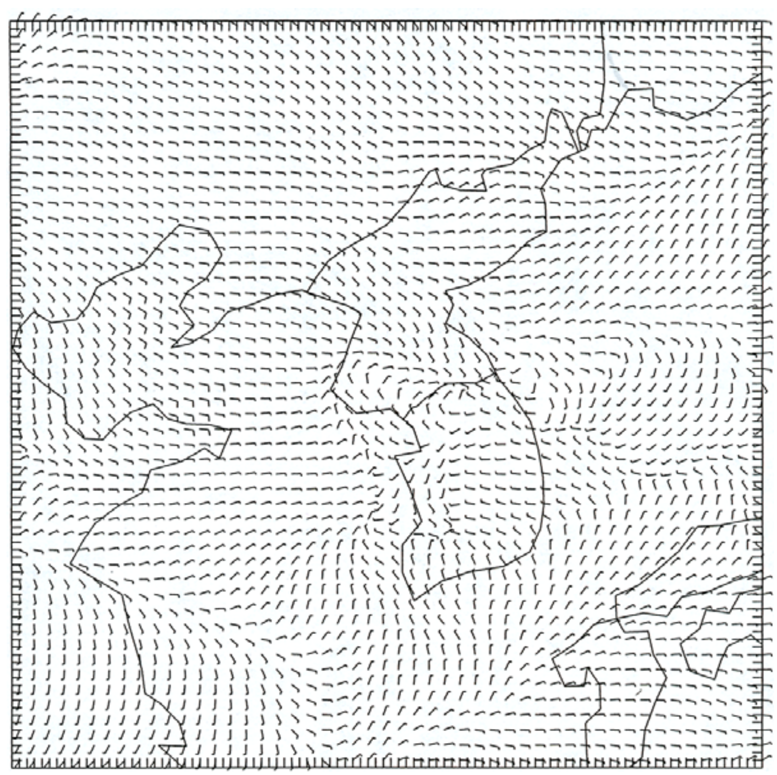

Figure 60. A 15-km MSAS wind analysis over Korea.

also non-NPN profiler data contributed by a number of different organizations including the Environmental Protection Agency, NOAA research laboratories, and several major universities. The observations are acquired by the FSL Central Facility from a variety of sources including NOAAPORT, Aeronautical Radio INCorporated (ARINC), and FSL's Demonstration Division NPN and ground-based Global Positioning System (GPS) data hubs. Mesonet data is decoded and stored with software originally developed for the NWS Local Data Acquisition and Dissemination (LDAD) system. Major contributors to the mesonet data stream are the NOAA Cooperative Institute for Regional Prediction at the University of Utah, which provides "MesoWest" data from the Cooperative Mesonets in the Western United States, and 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. The mesonet dataset also includes observations from volunteer citizen weather observers. Wherever possible, FSL uses redundant sources to maximize data availability. Although most of the MADIS data is available without restrictions, aircraft and mesonet observations are proprietary to the data providers, and are subject to review and restriction by those providers. Observations added in 2002 include over 2100 surface stations from 13 new mesonet providers and 60 profiler stations from about 30 multiagency providers. The latter dataset was added in cooperation with the Cooperating Agency Profiler (CAP) project in FSL's Demonstration Division, and consists largely of 915-MHz boundary layer profilers. Figure 61 shows MADIS surface stations in and around the state of Iowa.

Observations from the NWS Cooperative Observer Program (CO-OP) network were also added to the MADIS database. NWS modernization efforts for the CO-OP network 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. To support the NWS CO-OP modernization, a new CO-OP data hub was installed in the FSL Central Facility to accept observations from the newly automated stations. Another addition to MADIS is an online archive that allows MADIS users to easily access not only real-time observations but also saved observations. The archive is updated daily, and currently supports observations from 1 July 2001 to the present.

In 2002, MADIS also provided observation ingest, QC, and distribution support for the NOAA New England High-Resolution Temperature and Air Quality (TAQ) Forecasting Pilot Project and for the International H_2O Project (IHOP). MADIS observations were also provided to FSL's FX-Net and Real-Time Verification System projects, and

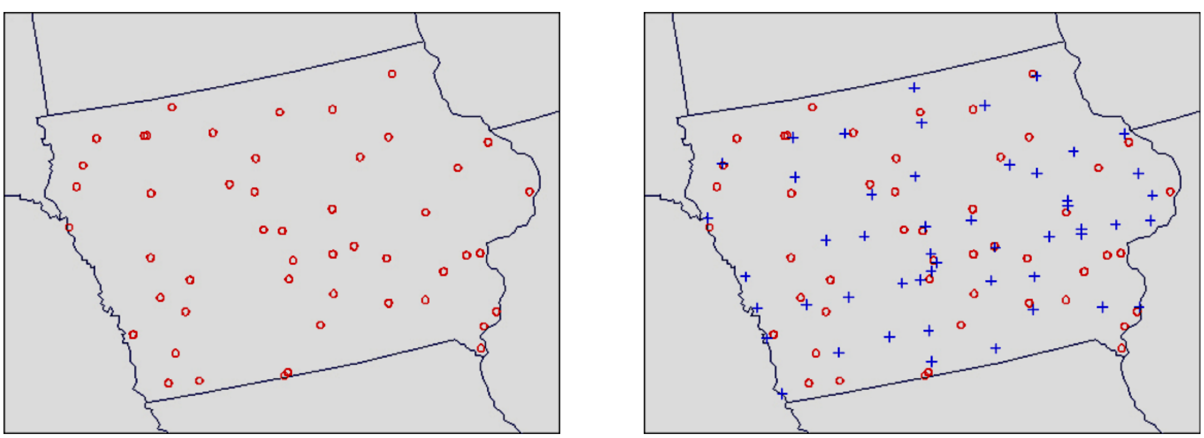

Figure 61. MADIS surface stations in and around the state of Iowa. a, left) METAR surface stations; b) METAR surface stations plotted with mesonet stations. Circles indicate the METAR stations; crosses the mesonet sites. Adding mesonet stations to the MADIS database nearly triples the surface observations available.

initial work was done to support the data assimilation system for the Weather Research and Forecasting (WRF) model being developed by the operational and research meteorological communities.

The MADIS API was also updated in 2002 to provide support for the new observations in the MADIS database, and to improve processing capability and speed. The API is easy to use, and is designed so that the underlying format of the database is completely invisible to the user, a design that also allows it to be easily extended to other databases. In the current version of the API, support is provided for the FSL MADIS database, and also for the database used in the AWIPS systems deployed at all NWS weather forecast offices.

The FSL MADIS database and API are freely available to interested parties in the meteorological community. MADIS data files are currently compatible with AWIPS, and with the analysis software provided by the FSL Local Analysis and Prediction System (LAPS). For more information on MADIS, or to apply for a MADIS datafeed, refer to *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 62 shows MADIS mesonet data as displayed on the Web.

Projections

During 2003, the Scientific Applications Branch will continue to support NWS in the operational implementation of the MSAS and RSAS systems. Development of new capabilities, including a port of MSAS to a Korean domain, will also be completed.

New observations and capabilities will continue to be added 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 also completing a MADIS software interface for the data ingest system of the community-developed Weather Research and Forecasting (WRF) model. 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.

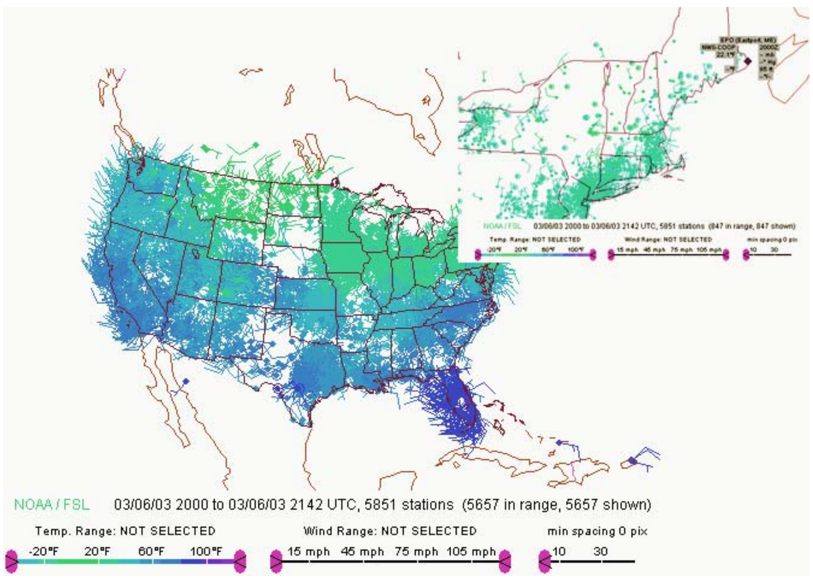

Figure 62. MADIS mesonet data as displayed on the Mesonet Webpage developed by the Meteorological Applications Branch in the Forecast Research Division.

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 2002, development versions of AWIPS Builds 5.2.1, 5.2.2, and OB1 (Operational Build 1) 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 iterface 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 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.

Similar support activities were carried out in 2002 for the RSA program and a customized AWIPS setup for the Johnson Spaceflight Center.

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, 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 serves as FSL's liaison to NGIT/NWS; his duties include tracking problems discovered during AWIPS testing, maintaining our local software development environment, and keeping file versions synchronized between FSL and NGIT/NWS software repositories. Figure 63 illustrates the relation between FSL's local directories and the official AWIPS repository, which is managed by PVCS.

As in past years, a branch member designed the layout of FSL's exhibit space at the 2002 American Meteorological Society's annual meeting. In addition to coordinating the collection, shipping, and setup of all FSL equipment and furnishings, this enormous job included working with AMS and Orlando 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 Division and the Modernization Division. Most user machines in these two divisions were upgraded to Red Hat Linux v7.2. In addition, new communications processors received from NGIT were installed in the FSL computer room to replace older machines. The configuration files for these machines were maintained 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 2003, new software repositories will be created for AWIPS Operational Builds 2 and 3 (OB2 and OB3) development. Branch staff will support the development, testing, and documentation of these Builds as described above, with OB2 testing occupying the first half of the year, and OB3 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.

The Red Hat 7.2 upgrade will be completed, and some exploratory work will be done with version 8.0; however, a general upgrade will be postponed until the National Weather Service decides to move forward.

The AWIPS OB2 release will be tested early in the year, with OB3 testing planned to commence in the summer.

Some new hardware is expected from NWS to be added to FSL's field-release system, and the branch will upgrade the software as new AWIPS releases are made available by NWS.

The usual coordination and planning will be performed to support FSL's exhibits at the American Meteorological Society annual meeting.

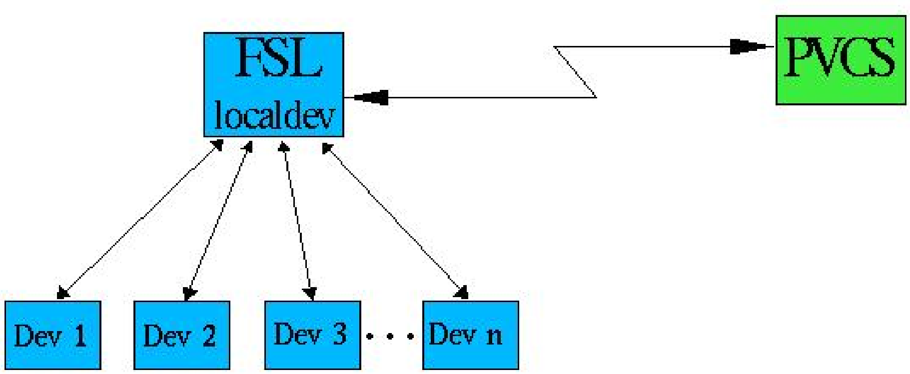

Figure 63. The official AWIPS software repository is managed by PVCS. Since direct access to PVCS is slow, FSL maintains a local copy of the PVCS database, known as localdev. The code is built daily (both HP and Linux versions) at FSL during the development cycle. Developers (Dev) access the files via soft links, locking a copy when needed for editing, then checking the revisions back into localdev. Daily changes made at FSL are uploaded to PVCS and changes made by NWS or NGIT developers are downloaded to localdev. Since development responsibilities are well segregated, only rarely is there a merge issue, where changes have been made in both locations.

NWS Projects Group

Richard T. Jesuroga, Lead

Objectives

The NWS Projects Group conducts research and develops technology for the exchange of critical weather information between the National Weather Service (NWS) offices and between the NWS and the community. A major area of focus is the FX-Collaborate (FXC), a Java application that supports collaboration among users, distributed processing, and distributed databases. As an interactive meteorological display system, FXC provides users access to a variety of meteorological data stored in remote AWIPS databases and on Web servers and 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. During collaborative sessions, each user interactively performs hand analyses, drawing meteorological features that instantaneously appear on other users' remote FXC systems.

Accomplishments

Several additional users chose FXC to meet their data display and coordination needs. These users include the USAF launch facilities at Vandenberg AFB and Cape Canaveral Air Force Station/Kennedy Space Center, National Weather Service (NWS) Weather Forecast Offices (WFOs), and the NWS Southeast River Forecast Center (RFC).

RSA – The RSA program was initiated by the Air Force 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. FSL released a new version of FXC, also known as the Briefing Tool, to Lockheed Martin Mission Systems (the USAF contractor for RSA) for installation at the Western Range, Vandenberg AFB, California. This RSA version includes several new features, such as the ability to export the AWIPS D2D screen, a totally revised slide show user interface, and a large selection of slide templates. The system will be used at Vandenberg to give launch weather briefings. FSL also provided user documentation and onsite training to forecasters.

NASA - FSL customized the FXC system for use at NASA in Houston, Texas. The requirement for worldwide coverage led to the addition of new scales (geographic areas of interest) and more datasets. A number of minor enhancements to the drawing tool were made based on user feedback prior to delivery. The system will be used to give weather briefings prior to Space Shuttle landings. Figure 64 shows an example of FXC use.

National Digital Forecast Database (NDFD) – The FXC software was installed on over 30 workstations at WFOs in the NWS Central and Eastern Regions to support intersite coordination of gridded forecast fields generated by the Graphical Forecast Editor (GFE). Dedicated FXC servers were installed at Tulsa and Norman, Oklahoma to support two NDFD test clusters. FSL extended FXC's text chat capability to include audible alert, time stamp, chat history, alert on text string(s) within message, selective disabling of alert, and color coding of messages. The system was successfully tested for several months. The test helped to define NDFD collaboration requirements.

NWS/SERFC – A new version of FXC was installed at the Southeast RFC in Peachtree City, Georgia, and at Emergency Operations Centers in several southeastern states. The system was used successfully during several potential flooding situations in the area last year, including Hurricane Lili, to exchange crucial weather information with emergency operations officials.

NWS/WFO – Some support was given to forecast offices desiring to use FXC's extensive drawing capability to generate graphical products of weather hazards for the offices' Webpages.

Projections

The focus of FXC work in 2003 is expected to cover the following areas:

- *Alaska* – As a result of a demonstration of FXC last year to attendees at the Volcanic Ash Workshop in Anchorage, Alaska, it is anticipated that FXC will be used in some capacity to collaborate on volcanic ash dispersion assessment and forecasting between staff members at the FAA Center Weather Service Unit (CWSU) and WFO.

- *Flight Service Stations* – FXC's capabilities are well suited for pilot weather briefings by Flight Service Stations. It is anticipated that a test of this capability will be conducted to evaluate its potential use as a pilot briefing tool.

- *RFC* – FSL will continue its evaluation of FXC in the NWS Southern Region to support flood coordination between the RFCs and emergency operations personnel. Additional offices are also expected to use FXC to help prepare graphical weather products for inclusion in their Webpages.

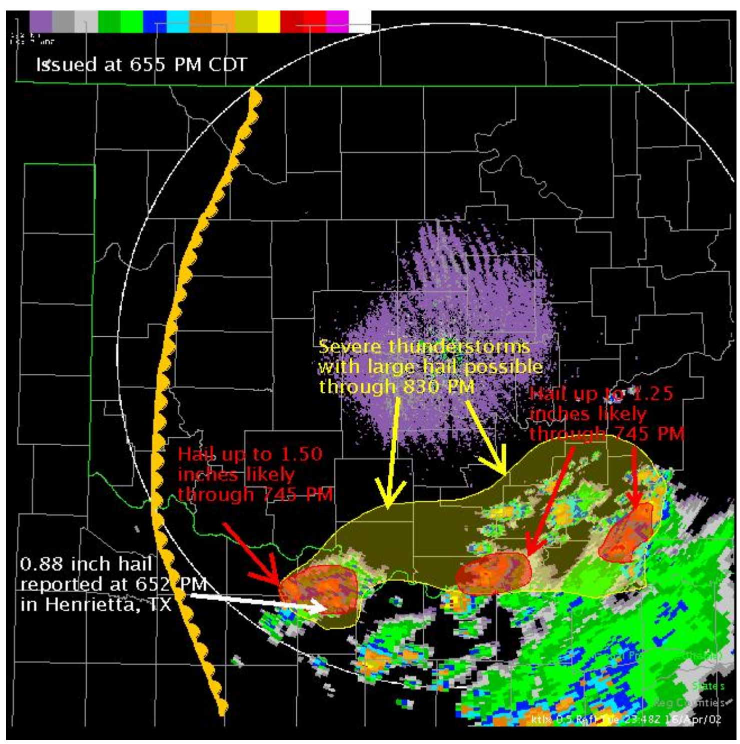

Figure 64. Example of how FXC can be used to annotate weather data displays. Pictures such as this can be posted on WFO's Webpage for public information.
(Courtesy of NWS/WFO Norman, Oklahoma.)

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Boulder, CO 80305-3328

Objectives

The Aviation Division collaborates with the Federal Aviation Administration (FAA), the National Weather Service (NWS), and the Departments of Defense and Transportation. The product of these collaborations is an improved weather forecasting and visualization capability for use by military and civilian 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); develops Aviation Digital Data Service (ADDS) Web 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 (Figure 65) in near real time using the Real-Time Verification System (RTVS).

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

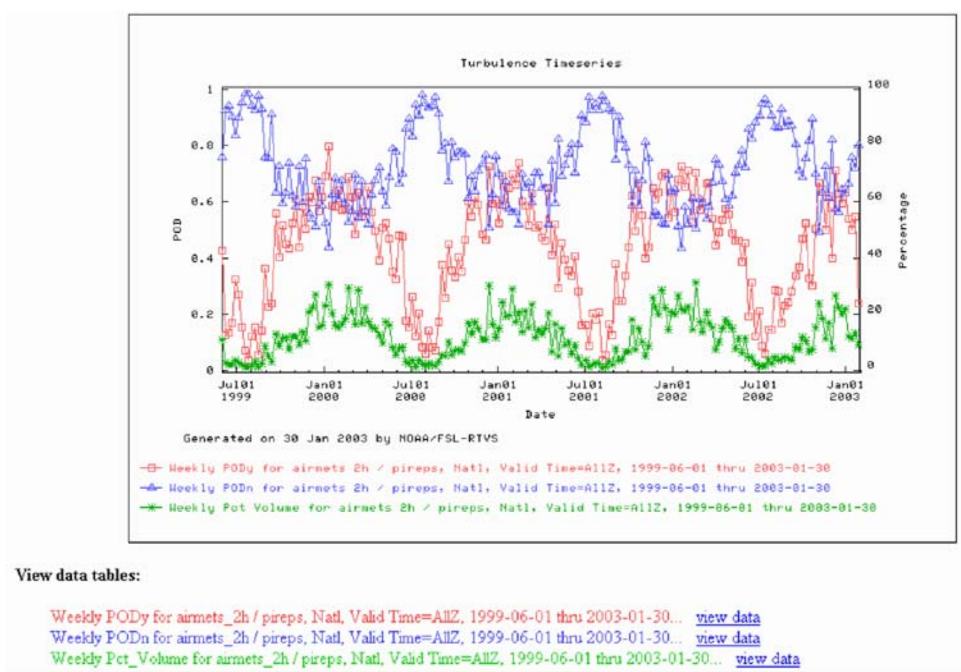


Figure 65. RTVS time series of the turbulence forecast verification using the Aviation Weather Center's AIRMETs and PIREPs of observed turbulence. The plotted values include the probability of detection of turbulence (PODy) in red, the probability of detection of no turbulence (PODn) in blue, and the percent volume of the total airspace impacted by the forecast volume (Pct Volume) in green. The X-axis shows time (weekly) increments, the left side Y-axis is the POD values, and the right side Y-axis is the Pct Volume values.

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. The software includes flight planning tools for pilots, air traffic controllers and managers, and airline dispatchers, as well as 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 U.S. Air Force Weather Agency (AFWA), organizations which fund the development efforts. Two other functions involve leading the AWRP Product Development Team for Aviation Forecasts and Quality Assessment (AF&QA), and facilitating projects that provide the Air Force with globally relocatable, high-resolution atmospheric analyses (using the Air Force's global datasets).

Flight Planning Tools

Development of the Aviation Digital Data Service (ADDS) continues, in collaboration with the National Center for Atmospheric Research (NCAR) and the NWS Aviation Weather Center (AWC). Aviation decision-makers can use this Internet-based system to access text, graphics, grids and images of up-to-the-minute observations, and forecasts of high-resolution aviation impact variables (AIVs) tailored to specific flight routes. The ADDS Website (Figure 66) is available at *http://adds.aviationweather.gov*.

Product Generation Tools

The branch is serving as the focal point for developing and evaluating the utility of advanced weather display products for FAA Traffic Management Units (TMUs), which are tasked with managing air traffic in enroute and terminal environments. This effort includes developing and evaluating the utility of software that enables NWS Center Weather Service Unit (CWSU) forecasters to collaborate in real-time to generate products for TMUs.

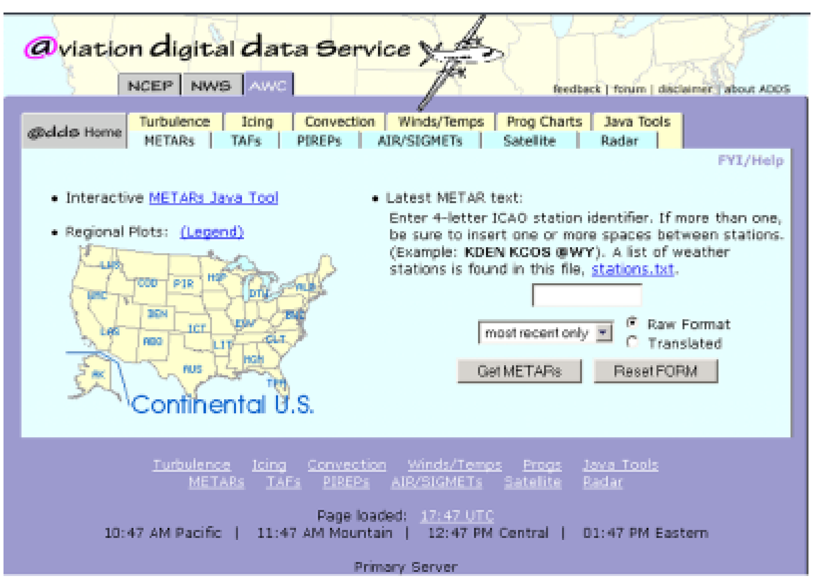


Figure 66. Screen showing a Java tool available at the ADDS Website, http://adds.aviation weather.gov.

Volcanic Ash Coordination Tool

Responding to the need for better coordination among the operational organizations that make forecasts for volcanic ash, the branch is seeking support to develop a Volcanic Ash Coordination Tool (VACT) that will benefit from FSL's FXC (FX-Collaborate) workstation. (To learn more about how volcanic ash threatens aviation and the organizations that must respond, refer to Simpson et. al., *Wea. Forecasting*, August 2002.)

Program Development and Technology Transfer Project

The goal of the Program Development and Technology Transfer project is to expand FSL's opportunities to develop new collaborative activities with domestic and foreign research and operational groups within government, educational institutions, and the private sector. The project leaders will build on FSL's expertise in numerical weather prediction, data assimilation, high-performance computing, and observing systems. Advances in weather warning support, dissemination, and graphical forecast editing are among the technologies planned for infusion into operational weather services during the coming years.

Accomplishments

Flight Planning Tools

During 2002, along with NCAR, the branch focused on preparing to implement ADDS operationally at the NWS Aviation Weather Center with the primary goal of ensuring that the software runs very reliably. Tasks included enabling all ADDS products to be generated at AWC instead of at development laboratories, and to run on the operating system that AWC supports. NCAR and FSL now have identical development and testing environments, thereby ensuring that all ADDS Java tools have a standard code base and identical "look and feel." This will make it easier for AWC to maintain the Java tools when ADDS becomes operational.

The branch participated in a joint FAA/NWS working group to identify weather information requirements for FAA Traffic Management Units. Assistance was provided the FAA in preparing a detailed research plan for rapid prototyping of weather products for TMUs and methods for collaboratively generating those products. In coordination with the NWS Southern Region, a Test and Evaluation facility was set up at the Fort Worth, Texas, Air Route Traffic Control Center (ARTCC), which will initially focus on convective forecasts for FAA traffic managers.

Key tasks included 1) setting up FXC product generation, server systems, and communication links; 2) implementing a Website that will enable traffic managers to view prototype products; and 3) developing a prototype of graphical convective forecasts for FAA traffic managers that combines into a single graphic key with attributes of Convective SIGMETs (generated each hour by forecasters at NWS/AWC) and the National Convective Weather Forecast (an automated product based on NEXRAD observations and lightning observations that is generated every five minutes).

Besides generating and disseminating products, FXC enables forecasters at various locations and on various computer platforms to view concurrently and in real time basic AWIPS weather displays, invoke basic workstation functions (such as animating, zooming, and overlaying), and collaboratively generate (in real time) free-hand and icon-based graphical products. This system can be readily adapted to ingest local data and display output generated by advanced algorithms and forecast models. It is also ideal for rapid prototyping because it resides outside of the AWIPS firewall, thus providing the flexibility to make rapid enhancements.

Volcanic Ash Coordination Tool

The initial concepts for the Volcanic Ash Coordination tool were developed and presented to the FAA and NWS, and funding opportunities are being pursued.

Program Development and Technology Transfer Project

In keeping with FSL's mission to transfer new technology and research findings to other NOAA offices and other users of environmental information, many new program development activities are underway. The cooperative agreement between FSL and the Colorado State University's Cooperative Institute for Research in the Atmosphere (CIRA) is utilized to support collaborative research between FSL, CIRA, and other agencies such as NASA and NCAR. This agreement provides a defined cooperative relationship with scientists at CIRA and FSL who work to solve operational weather problems. It provides a unique opportunity for applied researchers from the public sector to transfer proven scientific advances and technologies to operational agencies to benefit their respective weather observing and forecasting systems.

A major task last year was management and execution of the 2002 FSL Technology Day, which showcased real-time demonstrations of FSL research projects. All activities required extensive planning and coordination to inaugurate the exhibition of research results that were considered mature enough to demonstrate to the government and public sector. The participants strongly encouraged further collaboration with FSL in continued research and development of these results. New collaborations were identified as a result of the 2002 FSL Technology Day, held at the Skaggs Research Center, involving the Real-Time Verification System (RTVS), Graphical Forecast Editor (GFESuite), and the FX-Collaborate (FXC) and FX-Net workstation projects. Ongoing technology transfer activities include continued collaboration with the Air Force Launch Ranges regarding the RSA program and the Air Force Weather Agency regarding the development of data assimilation for the Weather Research and Forecasting (WRF) model.

Another important collaboration involved outreach with the FSL Director's Office to develop materials and provide outreach for the Global Universal Profiling System (GUPS) initiative. Contacts were developed with international, private sector, university, and other government agencies, such as the Department of Defense, to participate in scientific collaboration, concept feedback, and planning activities. A proof of concept plan and a detailed briefing were prepared for use as outreach tools when contacting potential supporters and collaborators. Scientific and program planning meetings were held with researchers from other NOAA Office of Atmospheric Research laboratories, such as the Climate Monitoring and Diagnostics Laboratory, Aeronomy Laboratory, and the Environmental Technology Laboratory.

New research collaborations were initiated with support from the GPS-Met Observing Systems Branch in the Demonstration Division. Activities included outreach and education efforts and development of research partnerships, as follows:

- Coordinated a program funded through the Federal Highways Administration for a partnership with the National Geodetic Survey and the Space Environment Center to research the use of meteorological and ionospheric models to improve GPS positioning accuracy.
- Seminar and poster presentations at local AMS Chapter meetings, the annual AMS meeting, regional meetings of NWS Science Operations Officers, the National Transportation Board annual meeting, the World Space Congress, and CORETech. Three papers were co-authored for these activities.
- Identification of user requirements for the Federal Highways, Air Force, and Army program development efforts.

Projections

Flight Planning Tools

The primary focus is to continue collaboration with NCAR and AWC to make ADDS fully operational at AWC by July 2003. Following operational implementation, AWC (with support from FSL and NCAR) will undertake the key task of enabling ADDS to conform to criteria for reliability, accessibility, security, and archiving set forth by the FAA to qualify as an approved provider of weather information over the Internet. The criterion for archiving requires reproducing the specific data requested by each user for 15 days following the request. To meet this recommendation, all products will be archived and each product request and ADDS response will be recorded. It will not be feasible for ADDS (and other Internet-based aviation weather systems) to ascertain if users receive or look at the products.

Operational and software documentation will be prepared to familiarize the Aviation Weather Center with ADDS software and hardware. Plans are to implement the same development environment at AWC that NCAR and FSL use, thereby ensuring that any software "fixes" made by AWC have a path to future versions.

Another expected task is to develop an "application" version of the ADDS Flight Path Tool. Benefits of the new version, which is based on Java Developer's Kit 1.4, include a common "look and feel" across platforms, faster printing and saving preferred configurations, and an "environment" to build custom graphics for specific flight routes.

Product Generation Tools

A major task will be to assess the utility of the prototype convective forecast, Convective SIGMET and NCWF combination, that was developed in 2002. Software will be developed to display prototype inflight icing products. The initial focus will be on the automated Current Icing Potential (CIP) and Forecast Icing Potential (FIP) in context with conventional AIRMETs and SIGMETs for icing.

Volcanic Ash Coordination Tool

Development of the VACT will begin in 2003, with initial implementation at the Alaska Aviation Weather Unit (AAWU) and the Anchorage Center Weather Service Unit (CWSU). The AAWU generates SIGMETs for volcanic ash and the CWSU generates Center Weather Advisories (CWAs) for volcanic ash. Enabling both entities to view identical data and collaborate in real time will help ensure that warnings and forecasts are consistent.

Program Development and Technology Transfer Project

The Program Development and Technology Transfer Project will continue to expand efforts to create new collaborations with domestic and international research and operational groups in the private sector, government, and academia. Operational user requirements will be developed and documented for the GPS-Met project to be used as an outreach tool to create new research and technology transfer opportunities with the DOD, Federal Highways Administration, and the NPOESS program. Activities to expand collaboration with FSL and CIRA will focus on GPS-Met, data assimilation, and satellite calibration/validation. Other outreach plans in support of program development include finding additional venues for systems demonstrations and technical presentations and developing a Website that highlights collaborative project opportunities at FSL. Finally, activities are ongoing related to planning and coordinating the 2003 FSL Technology Day.

Aviation Systems: Development and Deployment Branch
Greg Pratt, Chief

Objectives

The Aviation Systems: Development and Deployment Branch works with other groups within FSL and outside agencies in an effort to rapidly prototype new or enhance existing meteorological information systems for use by the aviation community. Goals are to improve safety and use of the National Air Space (NAS) by improving the tools used by aviation forecasters, creating temporally and spatially seamless aviation weather forecasts through forecaster collaboration, and delivering the best aviation weather products available to air route traffic controllers, dispatchers, and pilots in easily understood formats. Current activities involve four projects: Aviation Digital Data Service (ADDS), the Enhanced Traffic Management System (ETMS), Traffic Management Unit (TMU), and Data Link Dissemination (DLD).

Aviation Digital Data Service Project

ADDS is a Web-based real-time aviation weather dissemination system (*http://adds.aviationweather.noaa.gov*) with a primary objective to facilitate a safer and more efficient NAS. To accomplish this goal, the ADDS 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 in a variety of formats that they can tailor to fit their individual needs. The user can view and print text products and pregenerated graphics products, or interactively query the ADDS site by running Java applets.

A secondary goal of the ADDS is to rapidly release new and improved aviation weather products to the aviation community. The ADDS meets this goal by involving the user at an early stage in the development cycle. User feedback from the ADDS Advanced User Group, the ADDS Forum, and e-mail determines design decisions and product usability. This means that end-users are involved in the requirements phase and determine whether a product is useful by accessing it during the experimental portion of the development cycle. The end-user determines the needs and when they have been met.

The branch continues to work jointly with the National Center for Atmospheric Research (NCAR) and the Aviation Weather Center (AWC) to add functionality and support the ADDS Website. The ADDS is funded through the FAA Aviation Weather Research Program (AWRP).

Enhanced Traffic Management System Project

The ETMS is a real-time aircraft tracking system being used operationally by all FAA air traffic control personnel to direct aircraft flow in the United States NAS. Goals of the ETMS are to maintain safe airways, help minimize delays, and conserve energy. Weather plays a key role in all three of these areas. The branch has developed and operationally deployed the Aviation Weather Network, designed to add real-time weather information to the ETMS for display on the Traffic Situation Display and provide automation support for strategic planning of the National Airspace System.

Work continues with the Volpe National Transportation Systems Center (the Volpe Center) in integrating new aviation-tailored weather products on the Aircraft Situation Display and upgrading the Aviation Weather Network to handle the latest improvements to the Rapid Update Cycle (RUC) gridded datasets. The RUC grids are used to create displays for the Traffic Situation Display and provide automation support for strategic planning of the National Airspace System.

Traffic Management Unit Project

The TMU project is currently in the initial phase of a four-phase project designed to address unmet or newly identified weather information needs of the TMU 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 ARTCC airspace. All phases will be subjected to the iterative process of defining, developing, demonstrating, and evaluating the weather related hazard graphic and its presentation to Traffic Manager users.

The project is sponsored by FAA's Air Traffic System Requirements (ARS-100), AWRP (AUA-430), and Southwest Regional Headquarters, as well as the National Weather Service Southern Region Headquarters. The purpose of the project is to address 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 (TMU) and the Center Weather Service Unit (CWSU) on Phase 1, the Tactical Convective Hazard Product (TCHP) graphic.

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

Data Link Dissemination

The Flight Information Services Data link (FISDL) is a partnership between the government and private industry to get affordable, near real-time weather data to the cockpit of general aviators. In an agreement signed by private vendors and the FAA, it was 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. In an effort to make these products usable in the cockpit, the FAA has sponsored FSL and NCAR to work jointly on creating decoders for the above weather products. This effort is called the Data Link Dissemination (DLD) project.

Accomplishments

Aviation Digital Data Service Project

During 2002, work continued on moving the operational support and maintenance of ADDS to Aviation Weather Center developers and technicians. Satellite data ingest/image creation has been fully transitioned to AWC. A TAF (Terminal Aerodrome Forecast) decoder was built that stores TAF messages in a relational database (MySql). The PIREP (pilot report) applet was upgraded to conform with new ADDS applet standards. The time selector bar widget was enhanced on the PIREP applet to allow for viewing of a composite of six hours of PIREP data or allow for looping 6 hours of PIREP data on hourly time steps. A new concept for flight service station briefings using FXC has been explored and demonstrations have been given to the ADDS advance user group, Flight Service Station personnel, and our FAA sponsors. (Figure 67 shows a new tool for ADDS that will benefit pilots during preflight planning.)

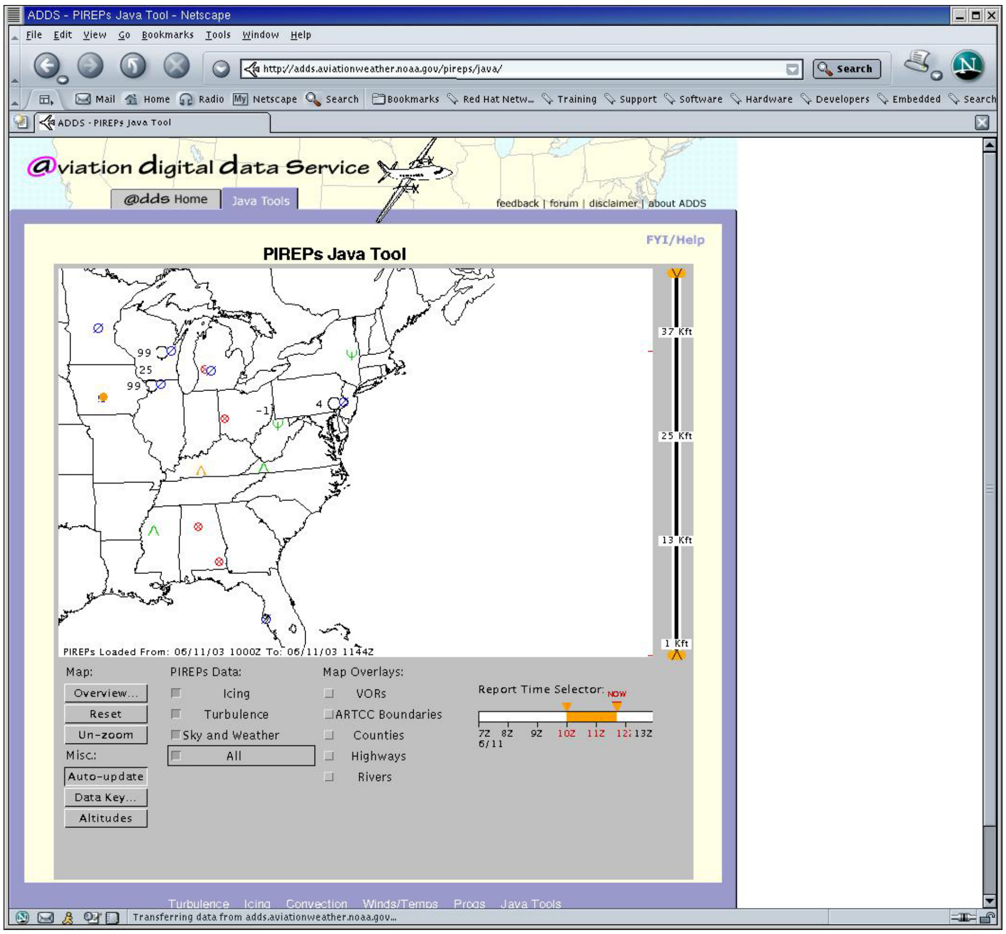


Figure 67. Web screen showing a new PIREP Java tool for ADDS, developed to provide pilots with preflight planning information regarding the current status in the National Airspace.

Enhanced Traffic Management System Project

The focus of ETMS work was to help Volpe Center transition software development to their facility. Training and software source documentation was given to Volpe software developers. Volpe developers are currently extending the Northern Hemisphere Winds Aloft and Jet Stream products to the Southern Hemisphere.

Traffic Management Unit Project

The team demonstrated and evaluated the initial version of the Tactical Convective Hazard Product (TCHP) on the Traffic Management Unit (TMU) Website (*http://tmu.fsl.noaa.gov*) to the Dallas/Fort Worth traffic managers. The Website was enhanced based on feed back from the traffic managers from static displays of the TCHP to allow the traffic manager user to toggle on/off map backgrounds and convective products that comprise the TCHP (Figure 68). The convective SIGMET portion of the TCHP was enhanced to include convective SIGMET nowcast, convective SIGMET forecast, and convective SIGMET text. The convective SIGMET forecast is created by advecting the convective SIGMET nowcast using the motion information so that it is time matched with the National Convective Weather Forecast. A new impacted jet route map background was created using the convective products that comprise the TCHP for color-coding jet route segments. Testing, training, and evaluation plans have been created and added to the Website. The following convective products and map backgrounds make up the TCHP:

- Convective SIGMET Nowcast
- Convective SIGMET Forecast
- Convective SIGMET Text
- National Convective Weather Forecast
- National Convective Detection Product
- National Convective Detection Motion Vectors and Cloud heights
- VOR (VHF Omnidirectional Range) maps
- Jet Route maps
- DFW TRACON scale and map background
- ZFW ARTCC scale
- IAH TRACON scale and map background
- ZHU ARTCC scale
- Impacted Jet Routes

The traffic manager will be able to toggle on/off the other TCHP map backgrounds and convective data. The TCHP viewer is also being enhanced to allow for looping. The traffic managers will be trained how to use the TCHP in April 2003, and the evaluation of the TCHP will begin shortly thereafter. Feedback will be gathered during the evaluation period and used to make further improvements to the TCHP. Work will begin on acquiring and displaying icing products in an effort to create a Tactical Icing Hazard Product (TIHP).

Data Link Dissemination

Involvement with the DLD project began by searching for a no-assumption robust decoder that could be used by the private sector for their FISDL systems. FISDL is a VHF-based radio link to a special aircraft receiver. Land-based transmitters placed across the U.S. send weather and other important flight information to these airborne receivers. A separate cockpit display formats and shows stored information to the pilot. Textual weather information is transmitted at no cost, but the vendors charge a monthly fee for graphics, such as NEXRAD and graphical METARs.

Data linked flight information helps pilots make better and earlier decisions when facing potentially hazardous conditions.

FSL and NCAR presented findings to the FAA and private vendors on METAR decoders that are available. It was recommended that the METAR decoder developed at FSL's Information Technology Services (ITS) be used as a starting point for developing a robust no-assumption decoder. FSL procured and configured a real-time ingest system in this process. The ITS decoder has been reimplemented and is being reconfigured to meet FISDL vendor requirements. Work has begun to develop a test suite so that the vendor implementation of the decoder can be verified against the FAA-funded implementation. FSL and NCAR are also developing a psuedo code for describing the decoder, and delivery to the FISDL vendor will include the decoder, test suite, and psuedo code.

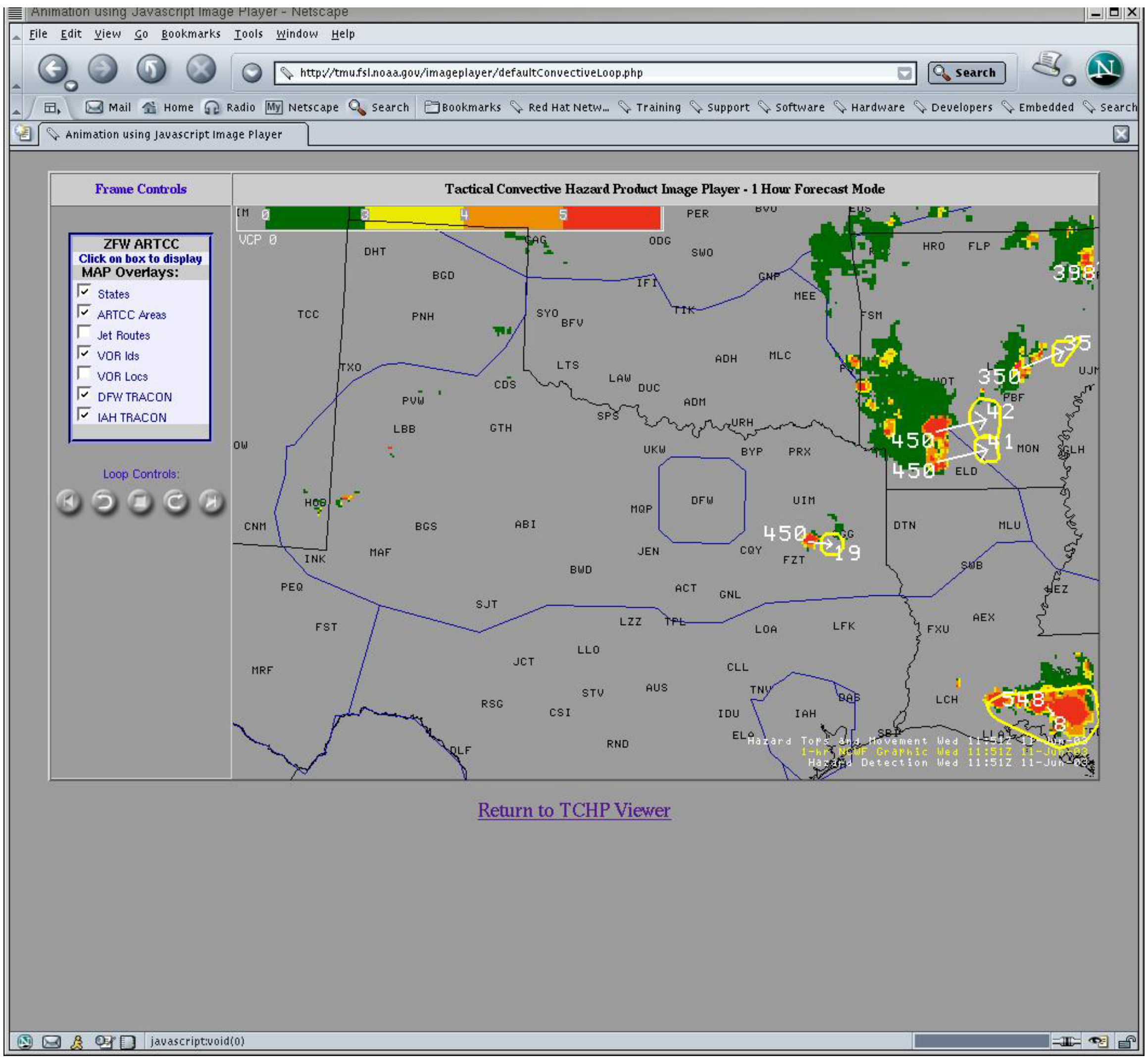


Figure 68. A Web screen showing a 1-hour forecast of the Tactical Convective Hazard Product, developed to show aviation traffic managers at the Dallas/Fort Worth Air Traffic Control Center the 1-hour projected movement of a severe thunderstorm in their airspace.

Projections

Aviation Digital Data Service

An operational version of the ADDS will be implemented at the Aviation Weather Center, where it will be tested to ensure that implementation and support of the ADDS system passes FAA's Qualified Internet Communications Provider policy. An ADDS development and support environment will be configured and installed at the Aviation Weather Center, and developers there will be trained on all aspects of the ADDS code. The TAF decoder and MySql implementation will be enhanced to work in the new ADDS data server architecture. The TAF applet will be enhanced to take advantage of the TAF in decoded form.

Enhanced Traffic Management System Project

No new work at this time.

Traffic Management Unit Project

A Traffic Manager default TCHP display version is being implemented for use during the 2003 convective season. The default display will bring up the following TCHP maps and convective data products on the Dallas/Fort Worth ARTCC scale in auto-update mode:

- State and ARTCC Maps
- VOR Identifiers
- DFW TRACON
- IAH TRACON
- National Convective Detection Product
- National Convective Forecast Product
- National Convective Motion and Tops

Data Link Dissemination

Plans are to deliver the psuedo code, decoder, and test suite to the FISDL vendors in April 2003. FSL and NCAR will help the FISDL vendors get a METAR decoder running and verified in their workstation environment. Tasks include gathering statistics on problems with the METAR datasets and creating a feedback loop to the National Weather Service to help resolve METAR formatting problems. The branch will begin work on development of psuedo-code, decoder, and a test suite for the TAF delivery to FISDL vendors.

Advanced Computing Branch

Michael Kraus, Acting Chief

Objectives

The mission of the Advanced Computing Branch is to enable new advancements in atmospheric and oceanic sciences by making modern high-performance computers easier to use and by exploiting high-speed networks and Web technologies to utilize distributed data management and distributed computing. Modern parallel supercomputers, typically composed of commodity off-the-shelf components, offer a less costly alternative to traditional vector supercomputers for the fast, efficient production of numerical forecasts. However, they are more difficult to use. The branch has developed software that simplifies the porting of numerical geophysical models from FSL, other NOAA/OAR laboratories, the National Centers for Environmental Prediction (NCEP), and other organizations to modern parallel computing architectures. The culmination of this development is the Scalable Modeling System (SMS).

Using SMS, parallelism is added to a Fortran program by inserting directives in the form of Fortran comments. SMS then automatically translates this source code into parallel source code, inserting calls to SMS subroutines that perform interprocess communication and other parallel operations as needed. Since the directives are comments, a single source code can be maintained for both serial and parallel machines. Also, automatic source code translation allows complexity to be hidden from users to a greater degree than more traditional subroutine-based approaches.

The SMS subroutines form a software layer between the prediction model's source code and Message Passing Interface (MPI), the industry standard for interprocessor communication. This layered approach provides SMS users with ease of use, minimal impact to their source code, portability, and high performance. Source codes that include SMS directives are fully portable to most high-performance computers, Unix workstations, and symmetric multiprocessors (SMPs). SMS subroutines provide high-performance scalable I/O supporting both native and portable file formats. Also, data ordering in files is independent of the number of processors used. Further, since parallel operations are implemented as a layered set of routines, machine-dependent optimizations have been made inside SMS without impacting the model source code. SMS also supports many user-specified optimizations. For example, the execution of redundant computations to avoid time-consuming interprocessor communication will reduce run times in some cases. SMS also provides tools to assist in testing and debugging of parallel programs.

The following atmospheric and oceanic analysis and prediction models have been parallelized using SMS: Quasi-nonhydrostatic (FSL), Rapid Update Cycle (FSL), Local Analysis and Prediction System (FSL), Regional Ocean Modeling System (Rutgers University/UCLA, Pacific Marine Environment Laboratory), Global Forecast System (Central Weather Bureau, Taiwan), Typhoon Forecast System (Central Weather Bureau, Taiwan), NALROM (Aeronomy Laboratory), Princeton Ocean Model (Environmental Technology Laboratory), Hybrid Coordinate Ocean Model (Los Alamos National Laboratory/University of Miami), Eta (NCEP), and a coupled POM-ice model (NASA Goddard Space Flight Center). Computer architectures supported by the SMS include the IBM SP2 and IBM Power4 Cluster, Cray T3E, SGI Origin 3000, Sun E10000, Linux clusters (Intel OA32 and IA64 and Compaq Alpha), and other Unix workstations and SMPs.

Accomplishments

During 2002, the branch continued development and enhancement of the functionality and portability of SMS, and updated documentation with each new release. The most significant newly developed features are additional runtime debugging tools, support for more flexible decompositions, and support for most Fortran90 syntax. Training on SMS was provided for scientists from NOAA and other organizations including CIRA and NASA.

SMS was used to parallelize a convection code supporting a grant for air quality, a coupled POM-ice model for NASA's Goddard Space Flight Center, and the Large-Eddy Simulation (LES) cloud model for the Pacific Northwest National Laboratory (PNNL).

The branch continued its collaborative efforts to support the development of the Weather Research and Forecast (WRF) model, and became involved in related efforts such as the Joint Modeling Testbed (JMT). The JMT, a plan to provide a testbed for weather models which would span weather laboratories, is superseded by the Developmental Test Center (DTC), which is being replaced by the WRF System Test Plan. The design and implementation of the WRF model's I/O API was completed. The Standard Initialization was modified to provide the capability of performing output in the WRF I/O API. The WRF regression test was ported to Jet and IJet, and the compile time of WRF on IJet was cut in half.

Support continued to be provided, as needed, for the parallel RUC and Quasi-Nonhydrostatic (QNH) models, for users of the High-Performance Computing System (HPCS) at FSL and for the HPCS management team, regarding hardware and software upgrades.

The TeraGrid was studied and a proposal was written for NOAA HPCC grant funding to explore the feasibility of running an ocean model and an atmosphere model on different machines coupled over the TeraGrid. The proposal was funded.

A paper on "The Scalable Modeling System: Directive-based Code Parallelization for Distributed and Shared Memory Computers" was written and accepted for publication by the *Journal of Parallel Computing*.

Projections

Plans for the Advanced Computing Branch during 2003 include:

· Use SMS to parallelize other atmospheric and oceanic models as needed. Continue to develop and enhance SMS and to port it to new computer architectures. Continue to support users of SMS and of FSL's HPCS. Provide SMS user training as needed.

· Continue to participate in the WRF System Test Plan, which will include the porting of the NCEP Verification and Post Processing software to an FSL computer. In collaboration with the WRF community, develop a requirements document for a WRF Portal. Publish results in conference proceedings and journals.

· Optimize the RUC code for the IBM Power4 Cluster.

· Support ITS procurement activities, beginning this spring, for acquisition of FSL's next HPCS. Benchmark suites will be created for the procurement. The feasibility of running a coupled model over the TeraGrid for the HPCC will be demonstrated by developing a prototype coupled model and running it at FSL and PNNL, coupled over the Teragrid. The branch will produce a report documenting what we accomplished and the lessons learned, both about how to use the TeraGrid as well as possible shortcomings of the TeraGrid itself.

• In collaboration with the International Division, support the Taiwan Central Weather Bureau in their upcoming procurement of an HPCS.

• Help NOAA/ETL parallelize a RAMS model using SMS, and help NASA Goddard parallelize its Ocean/Ice Ecosystem model using SMS.

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, the branch strives 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), and the National Center for Atmospheric Research (NCAR) Research Applications Program. 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 such as the International H_2O Project, the Coastal Storms Initiative (CSI) program, and projects relating to fire weather. 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 important activities include serving as co-lead of the AWRP’s Quality Assessment Product Development Team and lead of the Collaborative Decision-Making Weather Applications Verification Subcommittee.

Real-Time Verification System (RTVS)

In support of these verification efforts, scientists throughout FSL collaborate with scientists at NCAR and the NWS Aviation Weather Center (AWC) to develop the RTVS as a tool for assessing the quality of weather forecasts. RTVS is designed to provide a statistical baseline for weather forecasts and model-based guidance products, support real-time forecast operations, model-based algorithm development, and case study assessments. To this end, RTVS was designed to ingest weather forecasts and observations in near real time and store 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. RTVS will run operationally at the AWC 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, 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 and improvement in the aviation forecasts.

Accomplishments

This year extensive verification activities supporting the transition of the Integrated Turbulence Forecasting Algorithm (ITFA) were completed. The results were used in the FAA/NWS decision process to transfer the algorithm from an experimental phase to fully operational weather product that will be supported by NWS. The ITFA algorithm (known as the Graphical Turbulence Guidance Product) will be available to NWS Aviation Weather Center forecasters and others to be used as a forecast guidance product for evaluating where turbulence may occur within the atmosphere.

From 30 July–1 August 2002, a workshop entitled "Making Verification More Meaningful," cosponsored by FSL and NCAR and funded by the AWRP program, brought together an international group of researchers and operational meteorologists and hydrologists. The workshop focused on the development of advanced diagnostic verification approaches, operational and user issues, observational concerns, and verification of ensemble forecasts. The workshop included 9 invited presentations, 20 contributed presentations, and 10 poster presentations. Access to the presentations can be obtained at *http://www.rap.ucar.edu/research/verification/ver_wkshp1.html*. Some of the main conclusions presented include 1) measures of forecast quality are not equivalent to measures of forecast value; 2) there is a large loss of information – and consequently, economic value – associated with use of nonprobabilistic forecasts; 3) pilots and other aviation personnel are in need of clearly defined weather information; 4) scaling issues need to be taken into account in verification studies; 5) new object- or field-based verification approaches show promise for providing more useful information than the traditional verification methods; observational uncertainty limits how well quality can be measured; and 6) additional educational opportunities regarding statistics and verification should be made available through atmospheric science curricula, short courses, and Web-based material.

In support of the CSI project, 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 will be using these results to determine the usefulness of local-scale modeling on the accuracy of weather forecasts. This ground-breaking work on the impact of local-scale modeling will help shape the NWS modeling activities in the future.

During the IHOP project, statistical results were produced by RTVS for four high-resolution models. The impact of the LAPS Hot-Start technique was clearly indicated in the standard statistics produced by RTVS. In addition to the standard approaches, an object-oriented approach for diagnosing errors in precipitation forecasts was implemented into RTVS (Figure 69). The results generated using this diagnostic approach brought new insights into the accuracy of precipitation forecasts produced by a variety of high-resolution numerical models. For instance, the phase and orientation errors produced in the forecasts could be clearly identified.

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 2002, during which numerous high-resolution convective forecasts were evaluated over the northeastern United States. Automated forecasts for convection were compared to human generated forecasts so that the strengths and weakness of each could be evaluated. Throughout the exercise period, feedback was provided on RTVS through graphical displays and statistics to the algorithm developers and AWC forecasters.

In meeting the needs of the AWC forecasters, graphical displays depicting forecasts of turbulence, observations, and statistics were developed and implemented on RTVS for evaluation. Examples of the turbulence displays are shown in Figure 70; a plan and vertical view of the turbulence forecasts, PIREPs, and lightning data are shown on the graphic. The graphic is updated in near real time so that the information can be used during the forecast MetWatch activity.

Figure 70a shows the AWC human-generated forecasts (e.g., AIRMET) and Figure 70b shows the automated Integrated Turbulence Forecasting Algorithm (ITFA). Forecasters can use these graphics to distinguish differences that may occur between the two types of forecasts. For instance, the depth of turbulence produced by the two forecasts is quite different, as indicated by the heights of the solid bars shown on the vertical panels of Figure 70a/b. The graphic is updated in near real time and made available to AWC forecasters so that the information provided on the graphic can be used to update the forecasts as needed.

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 Center Weather Service Units, and support is ongoing for FAA and NWS activities such as providing input into the development of a national verification program and the WRF numerical modeling efforts. In addition, the branch will explore verification techniques that address questions pertaining to flight operations, and participate in developing a verification program for the Graphical Area Forecast; an advanced graphically produced weather forecast that would be used directly by airline pilots. 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 (FIP) algorithm and the Current Icing Potential (CIP) algorithm will be completed and provided to the FAA/NWS Aviation Weather Technology Transfer Board for its consideration to operational status within the NWS. Finally, staff will continue to develop verification tools, through RTVS, that provide immediate and useful feedback to forecasters.

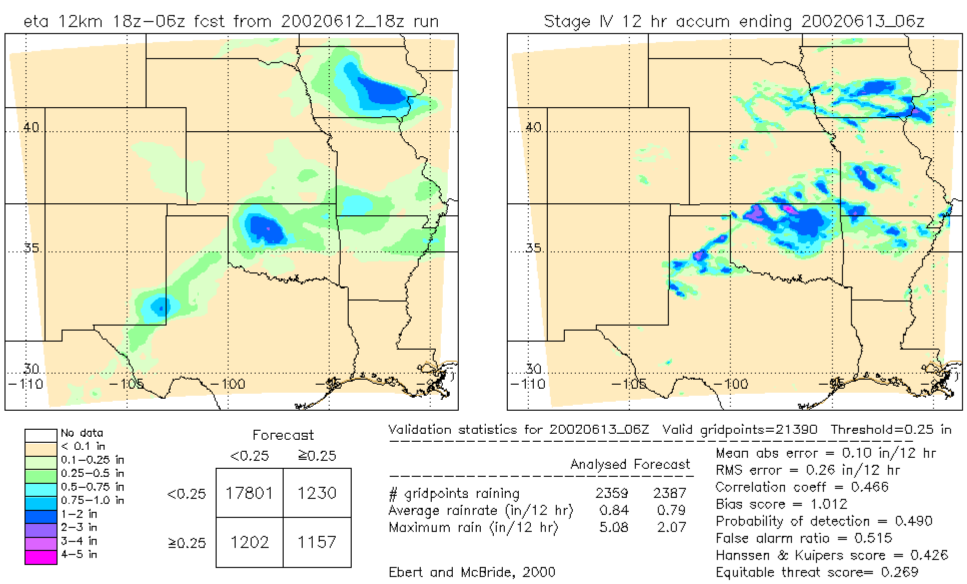
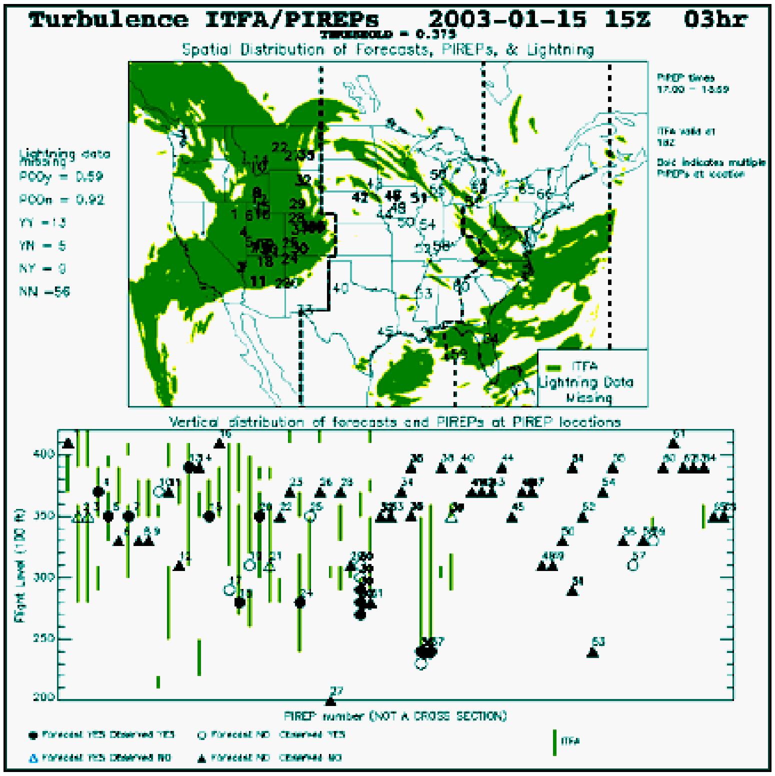


Figure 69. An example of an object-oriented approach to diagnosing errors in precipitation forecasts (Ebert and McBride 2000). Verification of Eta 12-hour QPF for a precipitation accumulation threshold of 0.25 inches. The left image is an Eta 12-hour QPF issued at 1800 UTC 12 June 2002 and valid at 0600 UTC 13 June. The right image is the NWS Stage IV precipitation analysis for the 12-hour period ending 0600 UTC 13 June. Statistical scores are given below.



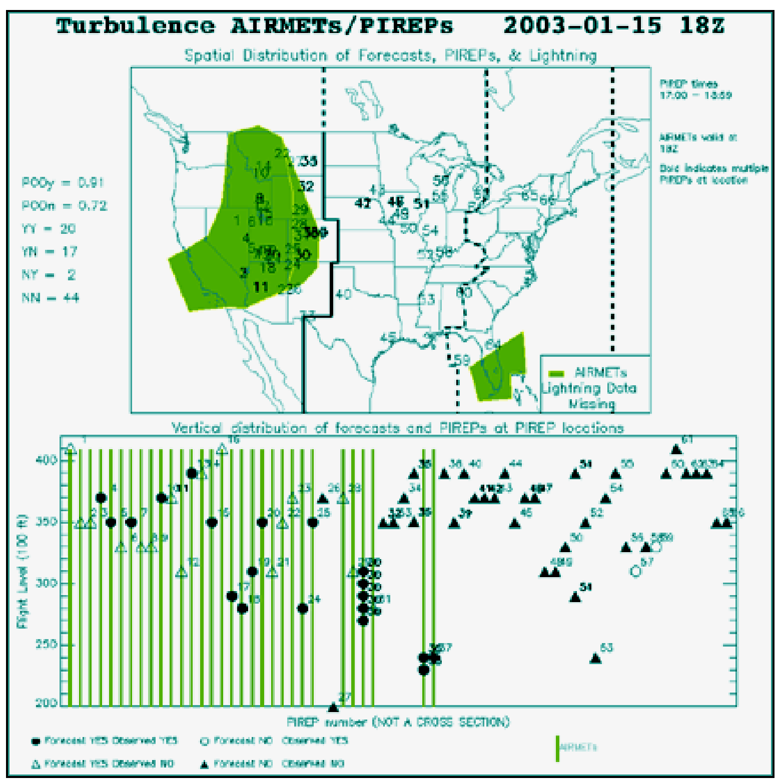


Figure 70. a, above) Plan view and vertical depiction of the Aviation Weather Center turbulence forecast and the verifying observations. The plan view shows the active turbulence forecasts, lightning, and voice pilot reports (PIREPs) at the PIREP locations. The PIREP number corresponds to the numbers shown in the plan view. The "X" axis is simply the PIREP index allowing forecasters the ability to investigate and interrogate the raw forecasts and observations. b, right) Same as above except for ITFA (Integrated Turbulence Forecasting Algorithm).

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 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 commensurate with new technological advances, such as D2D (Display Two Dimensional) shown in Figure 71.

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 has been participating for years in risk reduction activities to help the NWS meet its goals in the development and deployment of AWIPS.

The Modernization Division comprises three branches:

Risk Reduction Branch – AWIPS support and evaluation

Enhanced Forecaster Tools Branch – AWIPS Forecast Preparation System

Advanced Development Branch – AWIPS system evaluation and enhancement.

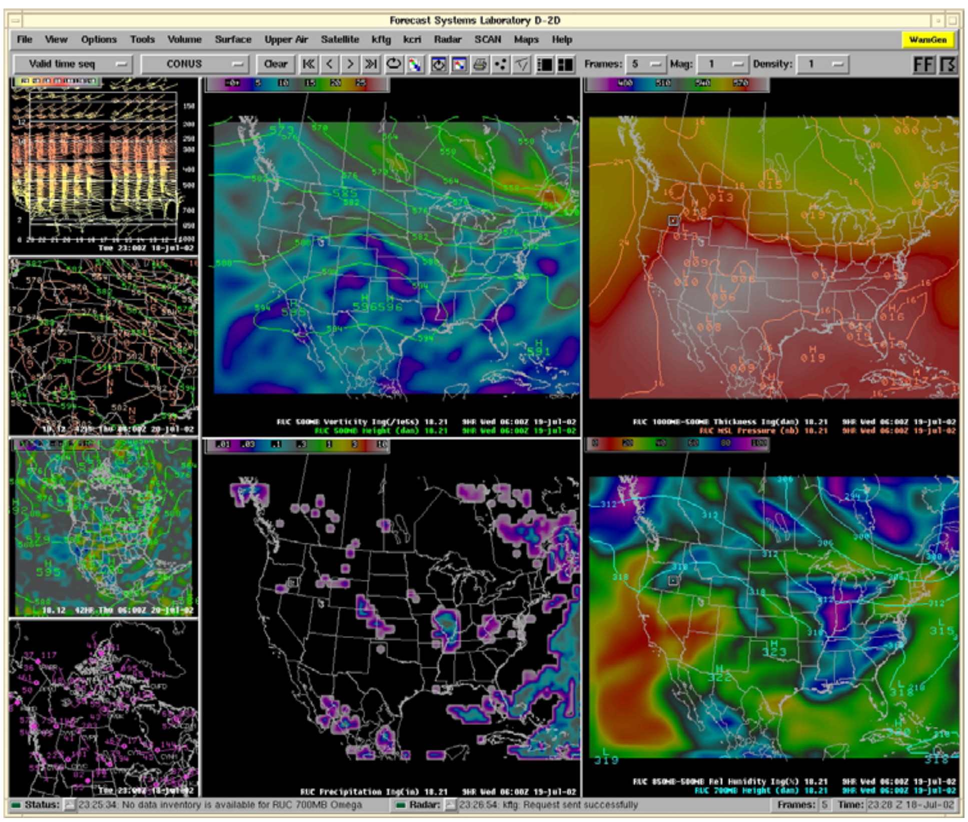

Figure 71. D2D screen showing meteorological information from the RUC model in 2002.

Risk Reduction Branch

Carl S. Bullock, Chief

Objectives

Work in the Risk Reduction Branch is directed toward helping the National Weather Service (NWS) prepare for operations in the AWIPS era. The two focus areas include operation and evaluation of risk reduction activities and the 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 the primary activity.

Accomplishments

AWIPS Software

The final development of Build 5.2.2 was completed, tested, and installed during 2002. This work concludes the mandate by Congress to complete the initial AWIPS system capabilities including interactive forecast preparation, severe weather reporting, service backup, and radar display functions that replace the WSR-88D Principal User Position (PUP) displays. The first operational build, OB1, was developed and tested as well.

New datasets were added in both of these builds. Aircraft reports can now be decoded and displayed; these messages report turbulence, icing, cloud layers, winds, temperature, and other parameters important to air navigation. In some cases, detailed temperature and humidity profiles are obtained from aircraft that are arriving or departing major airports. With FSL's implementation of a decoder for synoptic observations, many more reports of surface weather conditions are available, particularly from other countries. Atmospheric soundings retrieved by geostationary and polar orbiting satellites have been added as well. These provide much greater horizontal and temporal coverage than is obtained from radiosonde balloons. Numerical weather prediction grids for the Great Lakes, Atlantic, and Gulf Coast have been added in support of marine forecasting and navigation.

An important addition in Build 5.2.2 is the introduction of ensemble numerical weather prediction model grids. These data provide an objective method of dealing with the uncertainty inherent in weather prediction by generating multiple solutions based on different initial conditions. Algorithms to calculate the mean and standard deviations of these fields have been added to the volume browser menu, which is used to access gridded model data. To accommodate the volume of data anticipated with ensembles, a compression algorithm has been included for storing and retrieving these data.

New radar capabilities include detailed inventories, high-resolution storm relative velocity, and the rotational velocity (Vr) shear function that works in four-panel mode. Detailed inventories allow the user to differentiate between multiple request products such as cross sections or storm relative motions. The system will automatically load a loop of the particular cross section selected by the user. Now that high-resolution velocity data are available, a capability has been added to the AWIPS workstation to calculate storm relative velocity using user input for storm motion. This is an important tool for diagnosing severe weather. The Vr shear function is another tool used to diagnose severe convective storms. It can now function on four different radar tilts simultaneously so the user can measure how shear in a storm changes with height.

The volume browser has been enhanced with the addition of two new methods for displaying data. To view some high resolution vertical data, a new viewing option that plots a variable versus height was added. Users can now plot any variable (such as wind speed) versus height. The user can also zoom in on one axis to display the additional detail for high resolution data sets. Time-series plots were enhanced to allow multiple plots stacked vertically. This is a widely used method of displaying parameters in a display arrangement known as a meteogram. Typically this is done with METAR (meteorological aviation report) observations, but in AWIPS point forecast data from the various models can also be displayed in this manner.

During 2002, progress was made on the transition of AWIPS to the Linux operating system. The main task was to port certain decoders to Linux in an attempt to offload the HP data servers. The two decoders chosen represent the greatest volume of data sent over the Satellite Broadcast Network (SBN), the grib decoder, and the satellite decoder. These decoders will run on a new preprocessor Linux system where cpu and storage capabilities greatly exceed the existing HP servers. Another accomplishment involved porting of the Product Maker to the Linux workstation. This is a general purpose utility that allows the user to define computations to be performed on gridded or image data with the results displayed on AWIPS.

Collaboration with the Korean Meteorological Agency (KMA) continued. KMA has modified an AWIPS workstation to use the data generated by their ingest systems. These data include radar, surface and upper air observations, satellite imagery, and numerical weather prediction grids. The menu interface to use Korean characters was also modified. The Korean forecasters visiting FSL received two training sessions on how to use AWIPS in forecasting various weather phenomena.

Projections

Although the main development of AWIPS concluded with Build 5.2.2, there is a continuing stream of additions and enhancements that are needed by the operational forecasting community. AWIPS must respond to changes in the data that it ingests. For example, the WSR-88D radar is undergoing a series of upgrades and is able to produce more detailed products and new products. These developments will be coordinated with new AWIPS builds allowing forecasters to take advantage of new data as they become available. An example is the new radar scan strategies planned for implementation in 2003. The WSR-88D radar can now connect to AWIPS over a local area network. This will remove some of the current limitations and makes it possible to replace the existing dialup network, eliminating substantial telecommunications expense. NESDIS continues to generate new products from satellites. GOES high density winds and QuikScat wind retrievals will be added into AWIPS during the next year. The National Centers for Environmental Prediction (NCEP) continues to produce more detailed numerical weather forecasts. The Eta model currently outputs information at 12-km resolution, which will require modifications in AWIPS to accommodate these more detailed fields.

During 2003, continued collaboration with the Korea Meteorological Administration and the Taiwan Central Weather Bureau will focus on nowcasting tools, particularly those that use radar data.

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) weather forecasters and partnership with the NWS Meteorological Development Laboratory, staff 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 will no longer be text-based, but instead will be based on a suite of grid-based digital data. The forecaster will be 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

The branch concentrated on four development tasks of the advanced IFPS: enhancing the capabilities of the Graphical Forecast Editor (GFE), developing field customizable text products, developing the Daily Forecast Critique (DFC), providing forecaster training, and providing IFPS field consultations 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, GFE Inter-Site Coordination (ISC) capabilities for coordinating forecasts between NWS offices, and scripting and other capabilities. Smart tools were written to aid the forecaster in comparing differences between their forecasts and their adjacent site's forecasts. The ISC facility (Figure 72) has been enhanced so that the forecaster can now use tools that take into account data from neighboring forecast offices. These tools enhance the forecaster's ability to maintain spatial consistency between adjacent offices. An enhanced Temporal Editor now displays the range of values, giving forecasters more information about how the values vary over any region they specify. The new interactive query interface provides a much more flexible way to define areas of interest based on forecast data values. This will help forecasters create forecasts that are better coordinated among physically related weather elements. Three versions of the GFE were delivered to the NWS for inclusion in the new AWIPS Rapid Alpha Process (RAP), IFPS10, 11, and 12. Seven major and five 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.

Developing Field Customizable GFE Text Products – During 2002, the NWS asked the branch to develop a set of locally customizable text formatters of operational quality. The branch created the initial infrastructure and "first-look" versions of the 10 products required for the IFPS Initial Operating Capabilities. The products range from tabular summaries and coded tables to narratives, and cover the public, marine, and fire weather services in the NWS. Using the RPP software approach, the branch worked with 15 field offices and provided 7 software releases to these offices for the express purpose of arriving at an initial text formatting infrastructure, which was completed by spring 2003.

Developing the Daily Forecast Critique – Last summer, the EFT branch released the initial version of the Daily Forecast Critique (DFC, Figure 73), a data visualization package that, for the first time, allows forecasters to compare their digital forecasts to observations measured at the surface. DFC includes a data archiving facility that permits each site to archive surface observations as far back as several months, greatly extending the current AWIPS limitation of 36 hours. The system archives previous forecasts as well, both model-based and human generated, providing a rich data set with which forecasters can determine where their forecasts deviate from observed conditions. Forecasters view these point-based datasets with the DFC Viewer, which plots these data in time-series format. The flexible way in which the data can be plotted allow forecasters to investigate many attributes of forecasts such as direct comparison between various models, determining trends over subsequent model runs (dProg/dt), and examining error as a function of forecast lead time. Future work includes providing the capability to compare grids to grids rather than points, routinely generating statistics to determine model and official forecast bias, and tools to apply these statistics to the new forecast to remove these biases, thus improving the forecast.

Providing Forecaster Training – The branch held three hands-on workshops and reached virtually every NWS office. Approximately 140 NWS forecasters and IFPS focal points attended the workshops. The intensive 3-day workshops covered advanced concepts of GFESuite (such as writing smart tools), creating smart initialization algorithms for model processing, and writing text formatters. The format of these workshop sessions ranged from lecture to interactive hands-on sessions, where forecasters performed exercises to familiarize themselves with technical aspects of GFESuite. Open discussion sessions provided a chance for forecasters to share ideas, suggest improvements, and discuss particular forecast problems. Forecaster feedback about these workshops was very favorable.

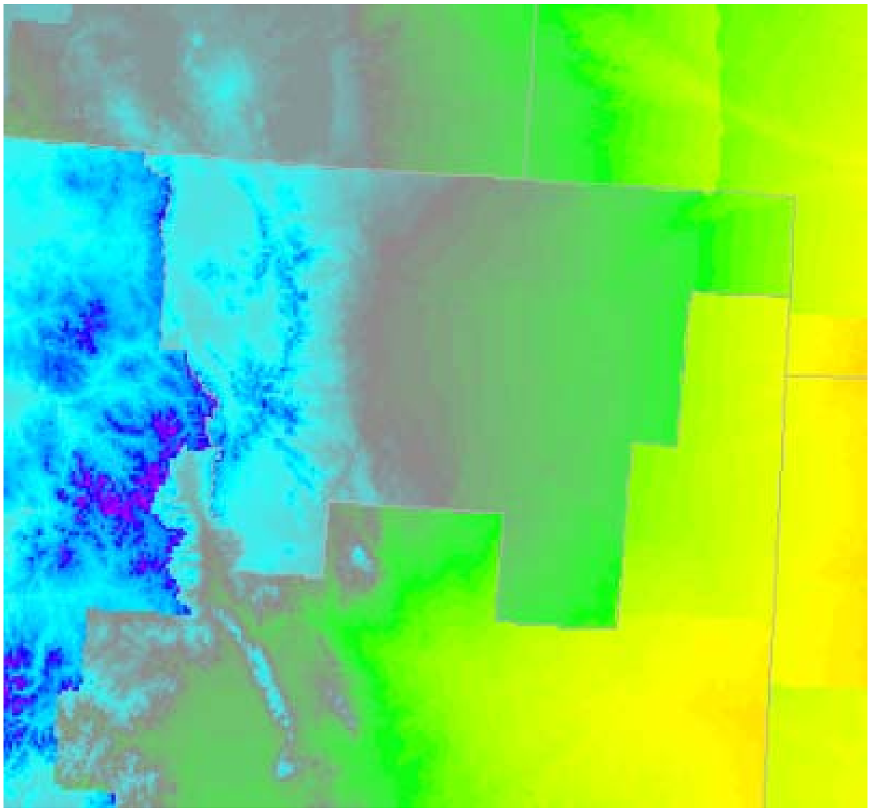

Figure 72. Forecasters utilize displays like this one to compare and reconcile spatial differences between their forecast and those of adjacent sites.

Providing IFPS Field Support – The NWS maintains three IFPS-related listservers for the field to discuss issues, find solutions, and interact with the developers. The branch makes 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 both field troubleshooting as well as focal point consultations. During 2002, every forecast office spun up GFE operations.

Projections

During 2003, NWS offices will complete the transition to GFE and IFPS operations. This is a major milestone that could only have been achieved through collaborative efforts between FSL and the NWS Meteorological Development Laboratory, and many person-years of development time.

All of the support, enhancements, and training are in preparation for the IFPS Operational Readiness Demonstration, planned for June 2003, and the IFPS Initial Operating Capabilities (IOC), planned for September 2003.

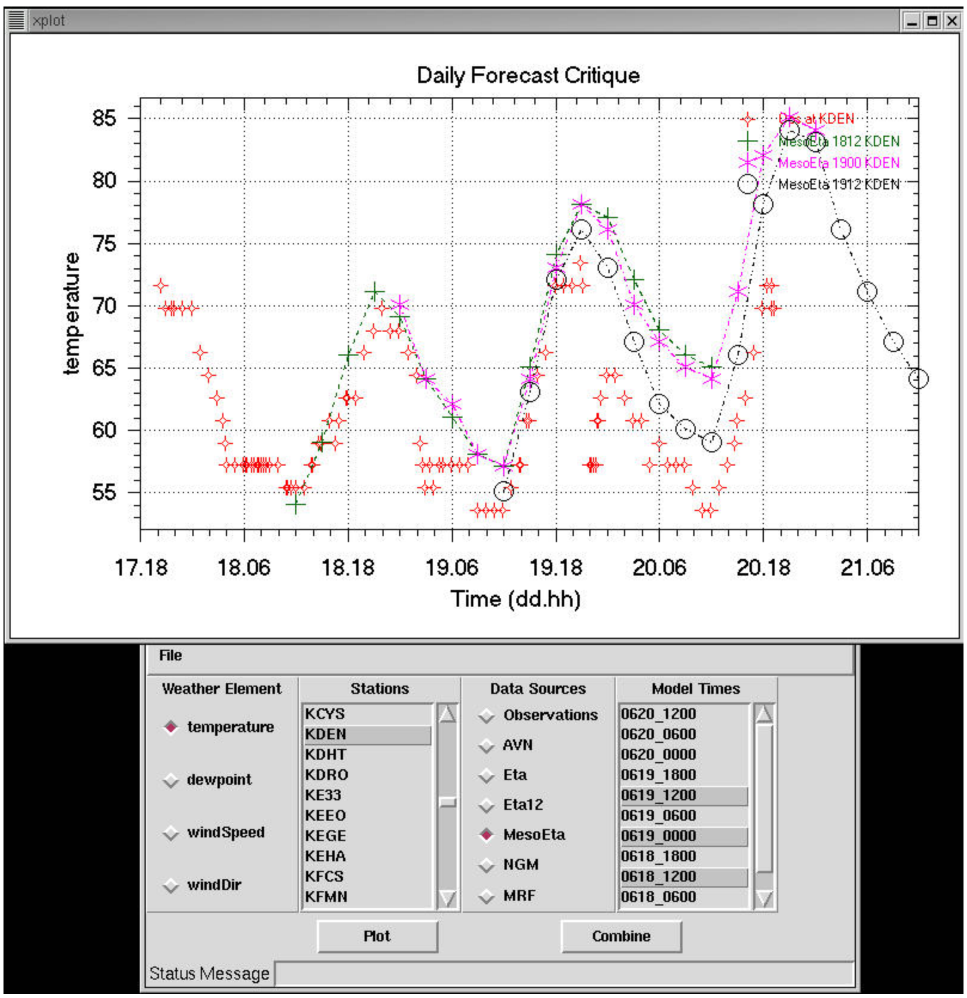

Figure 73. A screen showing the Daily Forecast Critique, which allows forecasters to compare their digital forecasts to observations measured at the surface.

Advanced Development Branch

Carl S. Bullock, Acting Chief

Objectives

The Advanced Development Branch endeavors to keep the National Weather Service abreast of advanced technology, particularly with regard to how it can be effectively utilized in forecasting systems related to the operational AWIPS.

Accomplishments

Considerable effort was spent investigating alternative approaches to the Configuration Management system used in AWIPS. The current system has many drawbacks and is not well suited to a rapid development cycle. AWIPS program managers had expressed a desire to follow a much shorter development cycle, on the order of 2 months versus the current 6 month paradigm. In surveying the market for potential tools, Extraview and PerForce appeared to have the right combination of flexibility, support for multiple source trees, and other required features. We worked with these packages to put together a demonstration system for a new configuration management approach. Unfortunately there wasn’t enough time to complete the demonstration.

Projections

Lack of funding necessitated reassignment of staff in this branch to other divisions within the laboratory for Fiscal Year 2003.

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Objectives

The International Division's mission is to oversee internal development of systems intended primarily for global or international application and to facilitate international cooperative agreements and technology transfer programs. Support is provided for the following major activities:

• *The Global Learning and Observations to Benefit the Environment (GLOBE) Program* – GLOBE is an international environmental research program that links the efforts of students, teachers, and scientists. Students at schools around the world monitor a wide variety of environmental parameters that are regularly posted on the GLOBE Website. This provides a unique global database of atmospheric, soil, biologic, and hydrologic measurements available to researchers for a multitude of experiments.

• *The CWB Technology Transfer Project* – FSL's longest standing cooperative project is the Technology Transfer Project at the Central Weather Bureau (CWB) of Taiwan. Since 1990, CWB-FSL activities have created joint mutual benefits, especially cooperation in the areas of information systems, data assimilation and modeling, high-performance computing, and observing systems.

• *The Korean Meteorological Administration (KMA) Project* – The International Division is under agreement with the Meteorological Research Institute (METRI) of the Korean 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.

• *The 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.

• *The Wavelet Data Compression Initiative* – The Wavelet Data Compression initiative was established to further investigate the possibility of using the technology for other meteorological datasets. Compared to imagery datasets, model datasets usually have higher numbers of dimensions, but each dimension is of much smaller size. Therefore, special treatments are needed to exploit the correlation among all dimensions.

The GLOBE Program

Michael Turpin, Project Manager

Objectives

Established in 1994, GLOBE is implemented through bilateral agreements between the U.S. Government and governments of partner nations. The goals of this education and research program are to increase environmental awareness of people throughout the world, contribute a better understanding of the earth, and help all students reach higher levels of achievement in science and mathematics. Under the guidance of their teachers, students worldwide collect environmental data around their schools and post these findings on the Internet. GLOBE scientists design protocols for measurements (Figure 74) that are simple enough for K-12 students to perform, and are also useful in scientific research. As scientists respond to the major environmental issues of today, laboratory and classroom collaboration will help unravel how complex interconnected processes affect the global environment. Years of student data collection have resulted in a significant contribution to science. GLOBE's unique global database holds more than 9 million student measurements of atmospheric, soil, land cover, biological, hydrological, and phenological data, all of which are universally accessible on the Web for research. Since it was initiated, the GLOBE Program has grown from 500 U.S. schools in 1995 to more than 12,000 participating GLOBE schools located in 101 partner countries today.

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

Figure 74. GLOBE students conducting hydrology measurements.

Accomplishments

Use of the GLOBE Website continues to grow in number, location, and human diversity. This is the primary site where science students go to enter their data and collaborate on a variety of projects, where the public goes to learn more about the program, and where users go to access the GLOBE database. Keeping the interests of the users in mind, the Web developers redesigned this site (incorporating constructive input from GLOBE Headquarters) to make the homepage cleaner and the overall site easier to navigate. Students and teachers are guided through introductory information by clicking on the "GLOBE Schools Log-in" link. Those being introduced to the concepts of GLOBE can quickly find more information via the "Learn About GLOBE" link, and repeat users, such as scientists and others in the general community, simply "Enter the Site." The overall appearance of the site was changed to blend consistently with the homepage.

In looking at ways to improve site performance and keep abreast of recent technology, the GLOBE team explored implementation of J2EE components (Java Servlets and Java Server Pages) into the site. As a case study, all of the content-rich pages of the site were imported into the database, code was developed that dynamically requested content, and then the Webpage was built through the Tomcat Servlet Container. The Oracle large object (LOB) support was examined to see how more content could be added into the central database. The GLOBE student investigation reports are now stored in CLOB columns (character large objects, ideal for large text strings) in the database.

The GLOBE data acquisition code base is contantly growing so that students, teachers, and researchers can continue to collect new datasets. GLOBE students can send their data via Web forms on the very interactive site or via an email message (typically used by schools wishing to report a lot of data at once). In 2002, tasks involved developing code for acquisition, processing, and storage of data from a digital multiple-day or single-day maximum/minimum thermometer, hummingbird observations (the first protocol to study animals), and phenological gardens.

In view of GLOBE's strong international roots, the GLOBE team is committed to having the Website translated into the six United Nations languages, and with interest shown in non-UN languages, these are being accommodated as well. In addition to Dutch and German translation accomplishments, a Japanese coordinator has begun translating the GLOBE site into Japanese – the first Asian language. It is rewarding to participate in tasks related to displaying the first data entry pages in Japanese and foresee their completion in the coming year.

A separate, nonpublic Website allows GLOBE Headquarters staff in Washington, D.C., GLOBE partner groups, and country coordinators to track GLOBE workshop participation, school contact information, school reporting rates, etc. New interfaces were designed so that GLOBE partners can select and specify trainers for their own workshops based on the prospective trainer's experience and qualifications (for specific protocols), availability, and location. This information on the trainers is maintained at Headquarters along with another set of interfaces. The FSL GLOBE team enhanced and released a Web-enabled database query tool that allows Headquarters to look at any of the data stored in the central database without needing to know any database query languages such as SQL.

When running an operational system, the back-end systems require constant maintenance and upgrades to help ensure that they stay highly available and are kept current with the latest software technologies. Another accomplishment involved moving a significant fraction of our software and database files to a NetApp filer to centralize data storage and to improve I/O performance. Taking advantage of the "snapshotting" capability of the filer, we increased the uptime of the database for backups, and shifted from cold to hot backups so that the database does not need to be shut down as often as was required in the past. The Oracle database was upgraded from version 8i to 9i to enable the addition of more new features to the Website.

The Web servers also needed attention since all of our nonvisualization Web servers now operate on Linux platforms. Furthermore, the GLOBE training server that accommodates teachers at workshops uses a database that also runs on Linux. The German GLOBE Program was fully supported by helping them move their legacy GLOBE mirror server to a new platform. This operational mirror server can now run the entire Website, including the current visualization system. Though schools in Germany and the contiguous countries predominantly use the mirror, they may decide to convert this mirror to a failover for the mirrors located in the United States (FSL and NASA/Goddard Space Flight Center).

Projections

During 2003, the development tasks will continue commensurate with the evolution and growth of the GLOBE Program, as follows.

When the GLOBE science and education releases a GLOBE 2003 Teacher's Guide in the spring, many new protocols will be added. These include contrail observations, fire fuel ecology, ground surface temperature, freshwater macroinvertebrates, bird and seaweed phenology, and various modifications to the hydrology and land cover measurements. GLOBE staff will also continue encouraging schools to use automated data logging devices from providers such as HOBO, Davis, and AWS/WeatherNet. With a potential for the daily data ingest to grow by as much as a factor of 100 due to the 15-minute increment reports, steps will be taken to ensure proper storage handling for the additional data. A primary undertaking will be to complete the work to accommodate the new protocols which will allow entry of these new datasets.

The GLOBE Website will continue to be improved and made more user-friendly. Randomized "smart info" (e.g., "A GLOBE school in Sydney, Australia, reported the same temperature and humidity you reported on this day.") will be added to data entry verification pages to help ensure data quality while making the data entry process less repetitive to students. Another plan is to develop an interface whereby schools can upload images (such as data graphs and site photos) directly to the Website, at which time they could be approved before they are posted. Now is an appropriate time to redesign the "administrative" Website from the ground up. Years ago this site was designed for two or three users, but today its use is much more widespread – about 300 users in the large GLOBE partner community.

The mission-critical GLOBE database will continue to be modified and maintained as more data (quantity and type) are ingested from additional participating schools. With the upgrade to Oracle 9i software, spatial queries will be developed that help to improve visualizations by making them more GIS-capable. Also, with more complete XML support in Oracle 9i, GLOBE developers will need to familiarize themselves with the new version. Building on successful tests of migrating Website content to the database, the content will be placed into the operational database to centralize content management and make authoring and editing easier.

Central Weather Bureau of Taiwan Technology Transfer

F*anthune Moeng, Program Manager*

Objectives

FSL's collaboration with the Central Weather Bureau (CWB) of Taiwan has been a 13-year success story in technology transfer of weather forecasting applications. The CWB and FSL partnership has grown to include major initiatives for improving CWB forecasting capabilities. Together they have developed a series of PC-based forecast workstations, and the latest one – the Weather Information and Nowcasting System (WINS) – is now operational at the CWB Forecast Center. The system was incorporated into the CWB central facility including data sources, communication, preprocessing, and product generation. WINS provides data and products to outside users, including two 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 efficient management capabilities. CWB is positioned to generate new and more useful forecast products and take advantage of the more powerful techniques under development at 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

In meeting the goals to improve forecasting capabilities at CWB during 2002, three major tasks involved:
- 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, run on Linux PCs, was delivered to CWB in December 2002. This software includes an improved cloud and precipitation analysis package as well as the MM5 model with the Hot Start code. The new data include visible data from the GMS satellite and multiple radar data (both Level II and Level III) from all four CWB Doppler radars at Wu-Fen-Shan, Haulien, Chi-Ku, and Kenting. FSL continued to improve the real-time LAPS running on systems at CWB and to provide support to CWB on the daily running of Taiwan's LAPS system. Last December, FSL also provided LAPS training at the CWB Forecast Center, working with forecasters there to define the CWB nowcasting procedure and use of the LAPS analysis field as well as the forecast fields. A scientist from Taiwan visited FSL for most of 2002 to help define the Taiwan Hot-Start MM5 domain. This visitor worked to stabilize the Hot Start scheme with improved cloud analysis for Taiwan, and to test its application under tropical cyclone cases with a bogus typhoon position. More detail on the LAPS analysis (example shown in Figure 75) and training materials can be found at Webpage *http://laps.fsl.noaa.gov*.

Forecast Assistant System – Through this project, support continued toward upgrading CWB's WINS II system. FSL provided an upgraded AWIPS Build 5.1.2 with the upgraded GFESuite (Graphical Forecast Editor) software. FSL also provided D3D software to CWB for further evaluation and customization. Last October, FSL's Technical Lead for GFESuite visited CWB to provide extensive training to four forecasters on the use of GFESuite, including the spatial and temporal editors, grid manager, and the necessary steps required to create and execute smart tools. They worked with two developers from CWB, answered questions about GFESuite software, including the latest verion (RPP18), and provided training on the use of Python for developing smart tools. A less technical seminar was presented to the CWB general audience on the functions and use of GFESuite.

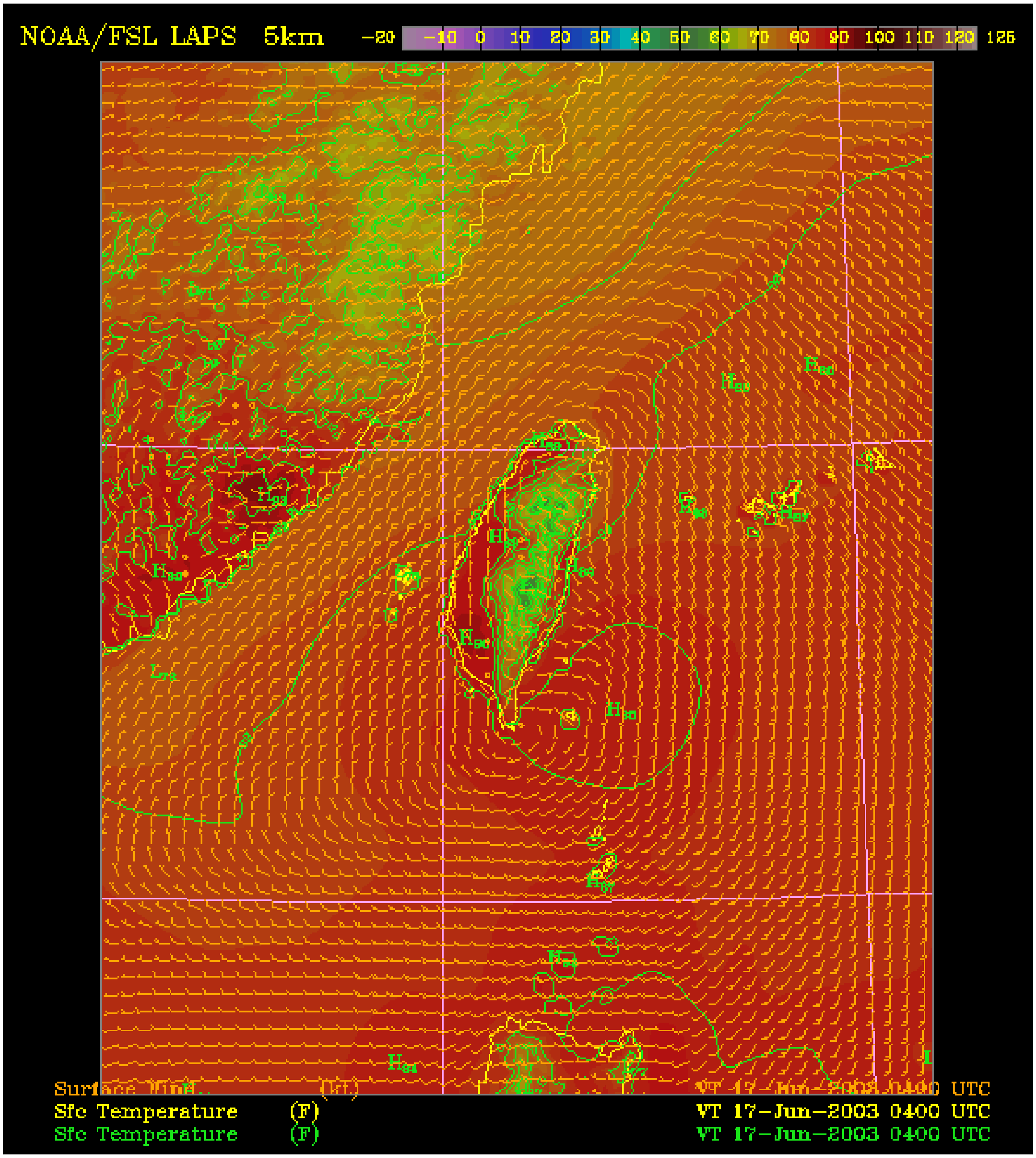


Figure 75. A LAPS analysis of surface wind and temperature at 0400 UTC on 17 June 2003 over the Taiwan Central Weather Bureau domain.

Continuing Interaction on Earlier Cooperative Projects – Interactions continued between CWB and FSL on earlier cooperative projects. FSL provided relevant documents on the following topics: 3DVAR (three-dimensional variational data assimilation), RUC20 (the 20-km version of the Rapid Update Cycle model), FX-Net component, and FX-Connect (FXC) software and user guide. (For more information on FXC, refer to *http://www-sdd.fsl.noaa.gov/FXC UG/FXC UG TC.html*.)

Projections

During 2003, the FSL-CWB joint team will focus on four ongoing tasks, as follows:

- Activities related to the Local Analysis and Prediction System (LAPS)
- Development of a Warning Decision Support System (WDSS)
- Enhancement of CWB's current forecast workstation, WINS, including a new system called SCAN (System for Convective Analysis and Nowcasting), which will provide short-range forecasts of precipitation from remote-sensor observations
- Interactions on earlier cooperative projects.

LAPS – FSL will focus on the 0–12 hour forecast, using the Hot Start implementation as part of CWB operations to ensure good cloud analysis with full radar coverage. The Hot Start technique will be applied using the balanced LAPS analysis on a forecast model for the Taiwan LAPS domain. LAPS training and technical support will be provided during the LAPS Hot Start runs at CWB.

WDSS – NOAA/NSSL will lead the effort of the development of a warning decision support system for CWB. NSSL will focus on refining the Vflo model, enhancement of QPE-SUMS, and radar data communication assistance. NSSL will also continue to assess and perform field testing to identify real-time simulation issues and further operational needs. Refinements will be made to the Vflo model, including improvements in the model physics and product display, the addition of new parameters, and the incorporation of improved GIS reference data.

WINS II/SCAN – FSL and CWB will collaborate to develop a strategy for the short-range forecasts of precipitation from remote-sensor observations using statistical extrapolative techniques. FSL will also support CWB in the porting of SCAN code to WINS II. The initial SCAN component will have a series of severe weather detection and prediction algorithms plus data integration techniques for CWB forecasters to use during severe weather warning operations.

Interaction on Earlier Cooperative Projects – FSL will provide technical support to CWB on GFESuite, D3D, and FX-Collaborate (FXC) software customization, so that CWB can include these components as part of WINS II.

Korean Meteorological Administration Forecaster's Analysis System

Fanthune Moeng, Project Manager

Objectives

The International Division is under agreement with the Meteorological Research Institute (METRI) of the Korean 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 2002, four major tasks were completed:

- Upgrade of the FAS nowcasting system
- Implementation of the Local Analysis and Prediction System (LAPS)
- Implementation of the Mesoscale Analysis and Prediction System (MAPS) Surface Analysis System (MSAS) quality control and monitoring system
- Provision for forecast training and risk reduction.

Upgrade of the KMA Nowcasting System – The FAS became operational at KMA and was also deployed at six Regional Offices in July 2002. A KMA visiting scientist worked with FSL staff to upgrade the FAS to the AWIPS 5.2.2 Build, and incorporated Korean menu changes (Figure 76) and necessary unit conversion changes to MKS units. FSL provided KMA with the AWIPS 5.2.2 Build, which is the latest and the last development version. This version has many new features and improvements, such as the ability to customize the AWIPS MSAS analysis to different localizations.

Implementation of the Local Analysis and Prediction System – Over the past five years, KMA scientists have adopted three-dimensional analysis software developed from LAPS. The goal of this task was to implement the latest FSL/LAPS II analysis as an integral part of the KMA nowcasting system (FAS) so that forecasters could access LAPS II products through a single display system provided by FAS. The diabatic initialization capability (Hot Start) has been incorporated into LAPS to perform dynamic balance adjustment.

Regarding the Korean LAPS (LKAPS), the latest LAPS II software is running every hour, and the FAS development team is testing the integration of KLAPS with FAS. (More detailed LAPS analysis information and training materials can be found on Website *http://laps.fsl.noaa.gov/*.)

MAPS Surface Analysis System Quality Control and Monitoring System – MSAS provides accurate quality control (QC) for surface observations, plus timely and detailed gridded fields of surface variables. The AWIPS 5.2.2 version of MSAS has the latest implementation, including configuration files so that KMA can implement this QC software using KMA's surface observation data. With the assistance of FSL staff, a KMA visiting scientist was able to build and correctly install all of the AWIPS software including MSAS software at FSL. FSL staff also verified the test data from KMA, properly ran the MSAS with these data, and produced the correct outputs.

Forecast Training and Risk Reduction – During 2002, FSL hosted a training session for six KMA senior forecasters. Extensive training was provided on AWIPS, including case studies; demonstration and introduction of the Graphical

Forecast Editor (GFESuite), MSAS QC, LAPS, FX-Collaborate (FXC), D3D, NOAA Profiler Network (NPN), and the GPS network; supercomputer, hydrological applications, and WRF introduction. They also visited a wind profiler at Platteville, Colorado, and the Boulder Weather Forecast Office (WFO), and participated in FSL daily weather briefings. One of the KMA visiting scientists wrote a paper titled "FAS: An International Version of AWIPS" and presented it at the Annual Meeting of the American Meteorological Society (AMS).

Projections

During 2003, the FSL/PG-NOW team will focus on four tasks: development of nowcasting techniques, QC and standardization of domestic remote sensing data, enhancement of the FAS, and implementation of the Automation of Forecast Preparation System (AFPS).

FSL staff will continue to train KMA forecasters on using the FAS, evaluate the proficiency of these forecasters, and identify areas for further training. FSL will work closely with KMA forecasters in developing their workstation skills and understanding of workstation use during various meteorological events. In particular, case studies will be reviewed in order to determine which meteorological fields enhance forecaster understanding for nowcasting and forecast purposes.

FSL and KMA will develop an Automation of Forecast Preparation System (AFPS) based on the AWIPS GFESuite software application. GFE is a graphical forecast support system used by NWS forecasters to improve the efficiency of generating forecasts. A goal of the AFPS is to minimize forecast preparation time and to maximize the forecasters' ability to interact with the data, thus allowing more time to focus on the science of forecasting.

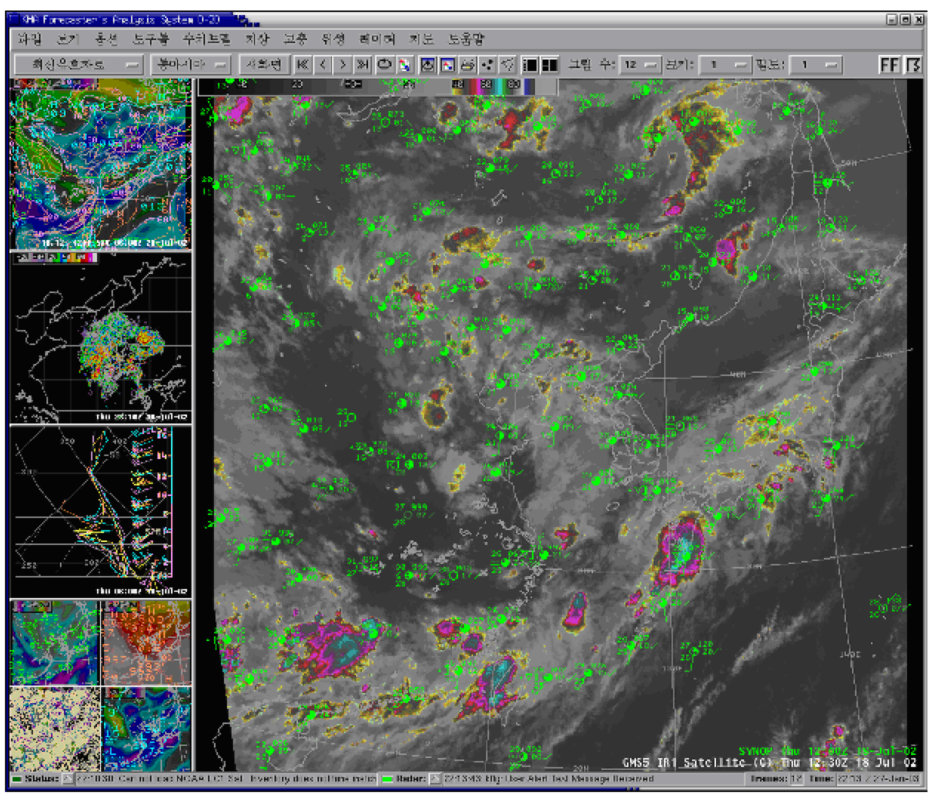


Figure 76. Example of an FAS display with the Korean menu user interface.

FX-Net Program

Renate Brümmer, 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, dial-up, and dedicated line use. The system consists of an AWIPS data server, an FX-Net server, and a PC client. The FX-Net server is a modified AWIPS workstation. The server is locally mounted next to the AWIPS data server via a high-speed link. The FX-Net client sends requests for small-sized product requests via the Internet to the FX-Net server, which responds by sending the products to the client. The user interface of the FX-Net client closely resembles the AWIPS workstation user interface, except for reduced resolution and complexity to allow for rapid Internet response. Some of the FX-Net client functionality features include load, animation, overlay, toggle, zoom, and swap. Although the client Java application can be run on a number of standard PC platforms, the system performs best under Windows NT, Windows 2000, or Windows XP. The minimum client hardware configuration consists of a 500-MHz processor with 256-MB memory. Internet bandwidth down to 56 kbps is considered sufficient to transmit FX-Net products.

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

Accomplishments

For the last few years, FX-Net had been supporting the AIRMAP (Atmospheric Investigations, Regional Monitoring, Analysis, and Prediction) Program. As a newly established Cooperative Institute between the University of New Hampshire (UNH) and NOAA, AIRMAP 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. 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 like 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. A new FX-Net/AQ client was successfully released in July 2002, just in time to support the real-time forecasters who participated in the NOAA New England Forecasting Pilot Program: High-Resolution Temperature and Air Quality (TAQ) field experiment during the summer of 2002. AIRMAP was part of the TAQ field project.

The new FX-Net/AQ datasets include six parameters (O_3, CO, NO, NO_y, SO_2, and condensation particles) that are continuously measured at three UNH sites (Mount Washington, Castle in the Clouds, and Thompson Farm) located in the state of New Hampshire (Figure 77). The FX-Net/AQ user also has access to the data from 13 wind profilers recently installed across the New England states. In addition, hundreds of new meteorological surface observation data, fixed buoy records, and ship measurements are available on the latest FX-Net menu. On the continental U.S. scale (CONUS), FX-Net displays the hourly average of the national EPA low-level ozone data. The FX-Net team is still working on the ingest and display of the MM5 air quality model, and once this task is completed FX-Net can truly be called a "real-time air quality workstation."

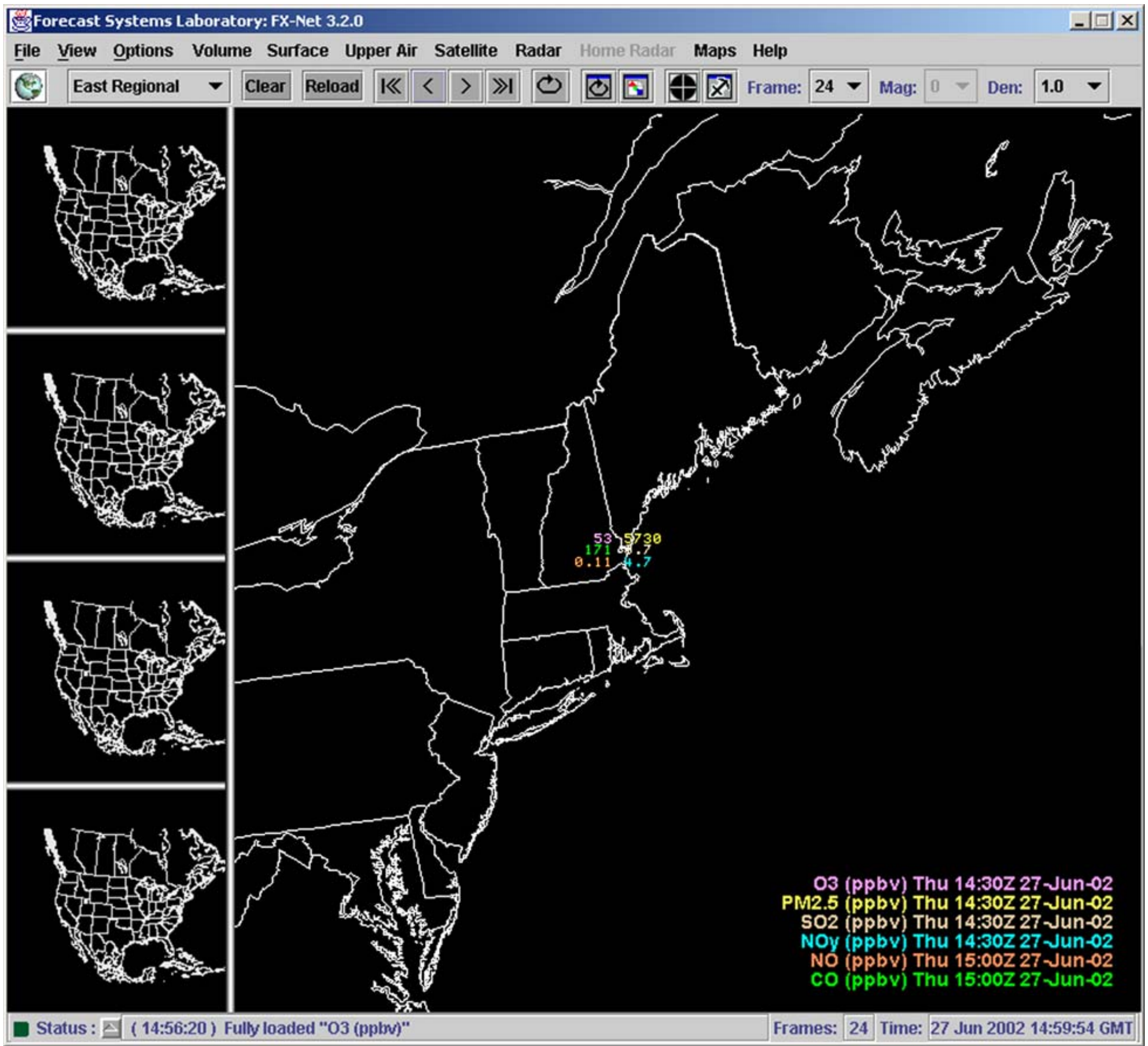


Figure 77. University of New Hampshire air quality measurements (lower right) using FX-Net.

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

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

Figure 78. FX-Net display in the GACC map room at Lakewood, Colorado.

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

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

Projections

University and Research – During 2003, the FX-Net team will continue to operate and maintain a system to support university meteorology classes and meteorological research at Plymouth State College in New Hampshire, University of New Hampshire, University of Northern Iowa, and Colorado State University.

Real-time Air Quality Forecast Workstation – FX-Net will increasingly focus on adding products to support real-time air quality forecasting.

Fire Weather Forecasting – Since FX-Net has become the primary meteorological workstation to support the fire weather forecasters in all national GACC offices and the NIFC headquarters in Boise, Idaho, many special products and functions will be added to the system as part of ID's continued support.

NWS: Western, Southern, Alaska, and Pacific Region – Early in 2003, four complete FX-Net systems will be installed at four NWS Regional Headquarters to support Incident Meteorologists (IMETs) in the field as well as to provide remote data collection offices with AWIPS-like products.

Additional information on the above FX-Net activities is available on the International Division homepage (*http://www-id.fsl.noaa.gov*).

The Wavelet Data Compression Initiative

Renate Brümmer, Project Manager

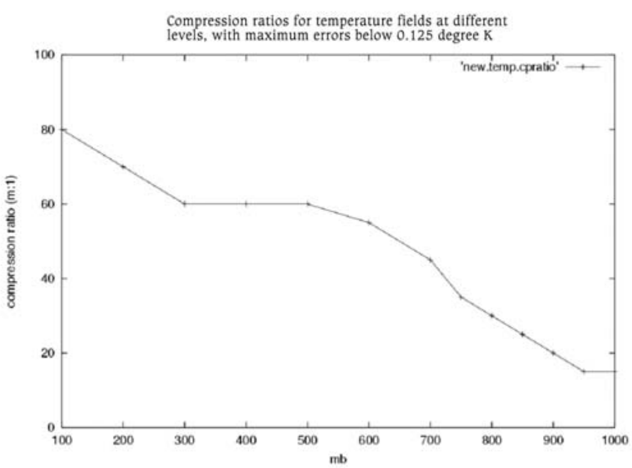
Objectives

After successfully applying the wavelet data compression technique to satellite imagery, the Wavelet Data Compression initiative was established to further investigate the possibility of using the technology for other meteorological datasets. Compared to imagery datasets, model datasets usually have higher numbers of dimensions, but each dimension is of much smaller size. Therefore, special treatments are needed to exploit the correlation among all dimensions. A multidimensional data arrangement and transform scheme 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 waves and different posttransform compression algorithms.

Accomplishments

During 2002, much effort was dedicated to improving the existing wavelet compression code with the goal to achieve even higher compression ratios. The routine was also rewritten to improve its run time, an important aspect for all operational applications. A major milestone was achieved with the introduction of the so-called "precision-control," which allows users to define the acceptable maximum or average error for the compressed and reconstructed dataset. Extensive studies were conducted using the original Eta-12 forecast model (14 May 2002 1200 UTC run). For a predefined maximum temperature error of less than 0.125^{o} K, this compression scheme achieved compression ratios from 17:1 (for the 1000-mb level) up to 80:1 (for the 100-mb level). The average compression ratio for this dataset was 50:1 (Figure 79).

The average error reflects the overall quality of the reconstructed data. In this example, the average error was nearly an order of magnitude smaller than the predefined maximum error. This large difference between the maximum and the average error means that most of the grid points in the reconstructed field show an error much smaller than the defined maximum error.



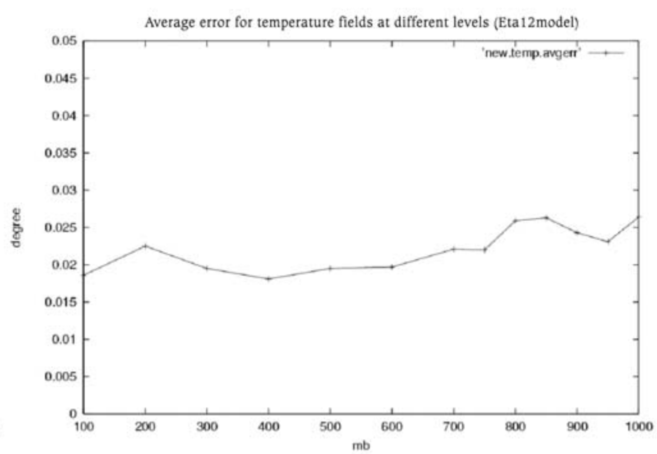


Figure 79. a, left) The compression ratios for the Eta-12 temperature field at different pressure levels with controlled precision (maximum error <0.125 K). b, right) Average errors for the temperature field at different pressure levels for the same compression ratios.

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

Compared to typical lossless codecs with the same precision requirements, this codec achieves 2–6 times higher compression ratios. It implies that for a typical model output sized at 1 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.

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

Projections

In 2003, continued development on the data compression scheme will focus on the following.

The approach to control the maximum round off error is computationally simple, or somewhat ad hoc. It is feasible with our current operational environment; however, an ideal algorithm should be able to find the best bits allocation that minimizes the maximum error. An efficient algorithm that can carry this out would be very useful both in theory and in practice. The vertically and timely adjacent frames are highly correlated. Current results only reflect the compression performance of this scheme on the two-dimensional field (in the horizontal plane). Three- or four-dimensional separable wavelet transforms can be applied to the volume data. To meet the robust (error propagation control) requirement, each partitioned group of coefficients can possibly be encoded individually into an independent bitstream to build a more error-resilient codec.

The above technology will feed directly into the project's workstation developments. Compression ratios of the above magnitude now allow for sending high-resolution forecast models (with typical model outputs sized at 1 GB and larger) via low bandwidth to an FX-Net or WorldWide Weather Workstation (W^4) client in very reasonable amounts of time. This will make satellite broadcasting mechanisms (with a bandwidth of 128 kbs or less) for meteorological datasets feasible.

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-dd.fsl.noaa.gov/FIR_01_02 AcroTerms. html*.

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This document is available online at the FSL Website, *http://www.fsl.noaa.gov*, click on "Publications" and "*FSL in Review*." If you no longer wish to receive a hard copy of this report, please e-mail the editor at *Nita.Fullerton@noaa.gov*.

Figures

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