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WEATHERING HEIGHTS:
**FX-NET AT
THE 2002
WINTER GAMES**

Colorado State University

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FX-Net – Weather Support Platform for the Outdoor Venues at the 2002 Winter Olympics

Renate Brummer, Sean Madine and Ning Wang

A t this time of the year, why feature a snow scene on the cover of the spring edition of the CIRA newsletter? Although few of us are thinking about weather phenomena such as snow and ice, a group of researchers from the Boulder division of CIRA are looking forward to next winter. Their innovation, a network-based meteorological workstation called FX-Net, will be a key part of the Salt Lake City Winter Olympics in 2002. Such a high-profile assignment brings pride to our ranks, and is, therefore, the feature of this edition of the newsletter. What is FX-Net? It is a PC workstation that provides Internet access to basic meteorological analysis and forecast products. FX-Net leverages the Advanced Weather Interactive Processing System (AWIPS), the system used in all NWS weather forecast offices across the country. The AWIPS workstation user interface is emulated very closely.

Bandwidth limitations are addressed by using new data compression techniques along with multi-threaded, client-side processing and communication. Thus, forecasters can use a familiar tool at relatively low cost to monitor the weather during this prestigious event.

System Overview

The FX-Net project was established to develop a network-based meteorological workstation. Although designed primarily for Internet use, FX-Net will also accommodate local network, dial-up, and dedicated line use. The FX-Net system consists of a FX-Net HP

Figure 1: FX-Net System Schematic

Unix Server and a FX-Net PC client. The FX-Net server is a modified AWIPS workstation. It is locally mounted next to an AWIPS data server via a high-speed link. The FX-Net client sends parceled requests via the Internet to the FX-Net server, which responds by sending products to the client (Figure 1). The FX-Net client user interface closely resembles the AWIPS workstation but with reduced resolution and complexity to

Fellowships in Atmospheric Science and Related Research

T he Cooperative Institute for Research in the Atmosphere at Colorado State University (CIRA) offers a limited number of one-year Associate Fellowships to research scientists including those on sabbatical leave or recent Ph.D. recipients. Those receiving the awards will pursue their own research programs, collaborate with existing programs, and participate in Institute seminars and functions. Selection is based on the likelihood of an active exchange of ideas between the Fellows, the National Oceanic and Atmospheric Administration, Colorado State University, and CIRA scientists. Salary is negotiable based on experience, qualifications, and funding support. The program is open to scientists of all countries. Submitted applications should

include a curriculum vitae, publications list, brief outline of the intended research, a statement of estimated research support needs, and names and addresses of three professional references.

CIRA is jointly sponsored by Colorado State University and the National Oceanic and Atmospheric Administration. Colorado State University is an equal opportunity employer and complies with all Federal and Colorado State laws, regulations, and executive orders regarding affirmative action requirements. In order to assist Colorado State University in meeting its affirmative action responsibilities, ethnic minorities, women and other protected class members are encouraged to apply and to so identify themselves. The office of Equal Opportunity

is in Room 101, Student Services Building. Senior scientists and qualified scientists from foreign countries are encouraged to apply and to combine the CIRA stipend with support they receive from other sources. Applications for positions which begin January 1 are accepted until the prior October 31 and should be sent to: Professor Thomas H. Vonder Haar, Director CIRA, Colorado State University, Fort Collins, CO 80523, USA. Research Fellowships are available in the areas of: **Air Quality, Cloud Physics, Mesoscale Studies and Forecasting, Satellite Applications, Climate Studies, Model Evaluation, Economic and Societal Aspects of Weather and Climate.** For more information visit www.cira.colostate.edu

FX-Net *(continued from page 3)*

allow for rapid Internet response. Some of the FX-Net client functionality features are load, animation, overlay/toggle, zoom, and swap. The client Java application can be run on a number of standard PC platforms. The system performs best under Windows NT, Windows 2000, or a Linux operating system. The minimum client hardware configuration consists of a 400 MHz Processor with 256 MB memory. Internet bandwidth down to 56 kbits/second is considered sufficient for the FX-Net product transmission.

Product Representation and Processing Strategies

The appropriate representation of a given product is one of the most critical aspects of FX-Net. In order to transfer a product over the Internet, the size of the product is obviously an important factor. FX-Net products can be categorized into four groups: satellite imagery, model imagery, model graphics, and radar imagery (Figure 2). Of these, satellite imagery is the most difficult to handle because of its large size. Model imagery is also difficult not only because of its size but also because of the very large number of products that are available. Both of these

types of products are compressed through the use of a wavelet transform. For the purposes of FX-Net, it was determined that a small loss of fidelity would be tolerable in exchange for a high compression ratio. Model graphics are represented in a standard vector graphics format and radar imagery is encoded in a standard lossless image compression format.

Investigation of Different Compression Schemes:

Satellite and model images are grouped together because their size demands many common requirements related to compression. After decompression, these types of images continue to show meteorological detail even with the small loss of fidelity. The processing time associated with decompression must not offset the time that is saved during transmission. Furthermore, for processing reasons it is required that the decompression of a particular image frame is independent of adjacent image frames. In the context of the above requirements, a number of compression schemes were studied. The need for high compression ratios along with the tolerance for some loss of fidelity eliminated any lossless schemes. Tests with Joint

Photographic Experts Group (JPEG) format, the Moving Pictures Experts Group (MPEG) format, and the fractal (or attractor) coding method (which is a variant of the image vector quantization compression method) all resulted in the fidelity of the decoded images being unsatisfactory for meteorological use.

Ultimately, the wavelet transform was chosen as the approach to image compression for FX-Net. The wavelet transform was introduced in the early 1990s and has remained a cutting-edge technology in image compression research. Like the Fourier transform, the wavelet transform relies on a particular set of basis functions. However, the set of basis functions that the wavelet transform uses is localized in both space and frequency, whereas a Fourier transform only contains frequency information. It is the ability of the wavelet transform to retain some spatial information, in addition to the frequency information, that allows it to achieve excellent compression of meteorological images. Besides providing the necessary compression of images, the wavelet transform also fulfills the other representation requirements. The loss of fidelity is acceptable, the decompression processing is reasonable, and the image frames are individually compressed.

The three types of satellite imagery that are available through FX-Net are infrared, visible, and water vapor. Each of these has different characteristics in terms of the wavelet transform. One advantage of the wavelet transform is that it is possible to "tune" the compression with a judicious choice of basis functions. The table below compares compression ratios and PSNRs (Peak Signal to Noise Ratio) for infrared satellite images when compressed with different basis functions. The compression scheme follows the standard transform-quantization-entropy coding procedure.

Table 1.

Antonini (Antonini, 1992)	10:1, 41.01 20:1, 37.64 30:1, 36.00
Daubechies 6	10:1, 40.14 20:1, 37.04 30:1, 35.37
Quadratic Spline (Cohen, 1992)	10:1, 39.62 20:1, 35.41 30:1, 33.11

Compression ratio and PSNR for IR satellite image using wavelet compression.
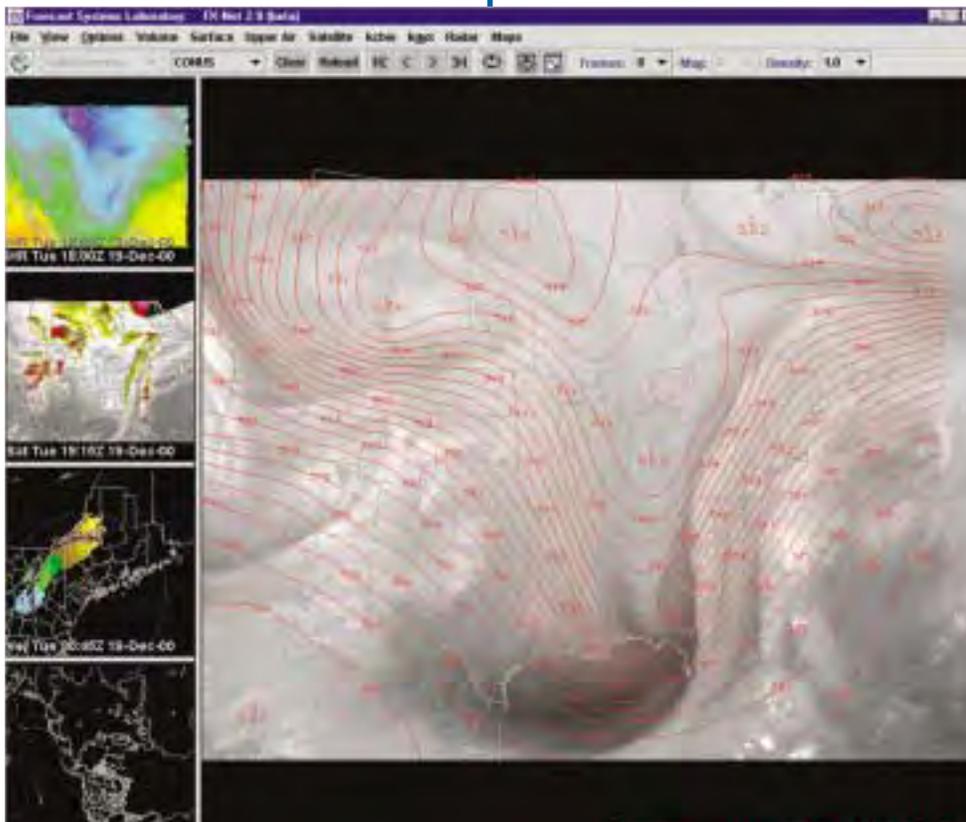

Figure 2: FX-Net User Interface

Figure 3: FX-Net in the PSC Meteorology Lab

The model image, which also lends itself well to wavelet compression, contains much less information than a satellite image. In comparison, the compression ratio for the model images is very high (about 100:1). The processing complications associated with the model images are discussed in the next section.

Wavelet Compression on the Server

Besides the actual wavelet transform, the compression routine on the server involves a dynamic search for the optimal set of basis function coefficients that are used to represent the image. This dynamic search greatly enhances the ability to compress the image at the cost of increased processing time, especially for satellite imagery, where the compression ratio is critical. The cost in time can be on the order of 20 seconds per image frame. For the set of available satellite imagery, frames are compressed immediately upon arrival from the data ingest system. Any subsequent requests for satellite imagery by a client can be fulfilled without performing the compression processing.

The production of model imagery is significantly different. Because there is a huge matrix of possible products, model image products cannot be generated before an actual request. However, the high compressibility of the model images allows the compression routine to bypass the dynamic search for coefficients. A best guess set of coefficients is used, and the processing time in this case is then reasonable for the necessary on-demand compression.

Wavelet Decompression on the Client

The decompression of the wavelet-compressed files on the client is also computationally expensive. The processing takes about 2-3 seconds per image frame when run on a 400MHz PC. The client takes advantage of the multi-threading offered by the Java programming language. By executing decompression and communication threads concurrently, the capabilities of the client hardware are optimally utilized. Each individual image frame is displayed for the user as the decompression completes, thus minimizing the perceived wait for the product arrival.

On the Job

FX-Net was developed with the meteorological workstation needs of research and teaching facilities, fire weather forecasters, and remote weather service offices in mind. Two years ago, FX-Net was installed at Plymouth State College (PSC) in New Hampshire (Figure 3) and a dedicated PSC server was set up at NOAA's Forecast Systems Laboratory. Since then, an operational real-time FX-Net system has been used to support the undergraduate meteorology curricula at this school.

In its most prominent assignment to date, FX-Net has become the official forecaster workstation for the Salt Lake City Winter Olympic outdoor venues. This is the first time that a FX-Net server has been installed at a NWS location – in this scenario, at the NWS Western Region Headquarters in Salt Lake City. Small forecast offices at each of five different Winter Olympic outdoor venues were equipped with FX-Net PC clients. Private forecaster teams working for the local Salt Lake City television station, KSL, were trained by CIRA's FX-Net developers on the use of the FX-Net client (Figure 4). These training sessions were very

successful. The first real-time tests using the FX-Net system in Salt Lake City were conducted during international pre-Olympic winter games, which started in November 2000 and were completed in April 2001.

Beyond the athletes themselves, it's difficult to imagine a more essential element of the Winter Games than the weather. A tool like FX-Net will help forecasters to provide good meteorological information to event organizers, the athletes, and spectators alike. In this way, all can enhance their involvement in the Olympics, be it by anticipating conditions at their outdoor venue, in preparing a certain way for the competition, or simply by dressing more or less warmly to watch. CIRA is particularly proud of this assignment, thus, as spring descends on our Colorado side of the Rockies, many of us are thinking ahead to the cold and snows that will herald the start of the Winter Games on the Utah side of the Rockies.

Additional information on the FX-Net project can be obtained by clicking on FX-Net at the following web site: www-id.fsl.noaa.gov

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Cohen, A., I. Daubechies, and J. Feauveau. 1992: Bi-orthogonal bases of compactly supported wavelets. Communications on Pure and Applied Mathematics, 45, 485-560.
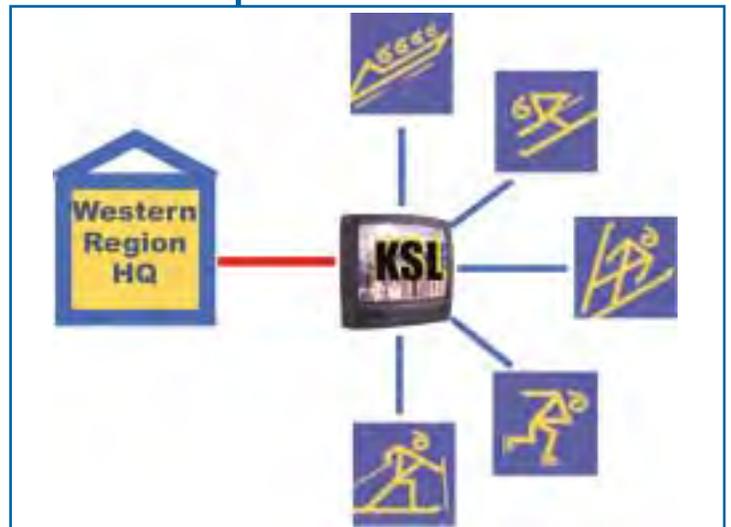
Figure 4: FX-Net Support of the Outdoor Venues

Improving Short-Range Forecasts of Clouds and Precipitation in LAPS

Brent L. Shaw and Steven C. Albers

One of the greatest deficiencies of numerical weather prediction models is their lack of skill in predicting clouds and precipitation in the early portions (0-6 hours) of their forecast period. The Local Analysis and Prediction Branch within the Forecast Research Division of NOAA's Forecast Systems Laboratory is attempting to address this issue for local scale modeling using a new version of their Local Analysis and Prediction System (LAPS, Albers et al., 1996) to directly initialize the cloud and precipitation fields of a local forecast model.

Although LAPS was developed over a decade ago, it has undergone nearly continuous improvement during that period. It has a wide variety of private and government users around the world and has demonstrated a robust capacity to combine nearly all available sources of meteorological information into a single, coherent three-dimensional view of the atmosphere for real-time "nowcasting" and short-range prediction. Throughout its history, the LAPS analyses have been coupled with a variety of mesoscale forecast models, including RAMS, MM5, Eta, and ARPS. Its capacity to ingest a multitude of data types, combined with its portability and computational efficiency, has made it ideal for such applications.

In the past year, a project was undertaken to develop a national, high-resolution, real-time analysis of water in all phases (McGinley et al., 2000) using LAPS. As part of this project, two significant improvements were implemented which ultimately made it possible to perform a diabatic initialization of a mesoscale model with analyzed hydrometeor species.

First, the LAPS cloud analysis was modified to improve the diagnosis of hydrometeor concentrations in all phases. The initial cloud analysis is performed by combining a variety of data sources, including a model first guess of cloud liquid and ice (or relative humidity), observed satellite brightness temperatures, surface and aircraft observations, radar reflectivity, visible satellite imagery, and other LAPS state variables. From this step, a three-dimensional distribution of clouds is created. This cloud field is then partitioned into concentrations of the various water species using temperature, moisture, stability, and radar reflectivity. During this step, other parameters are derived, including heights of the bases and tops and the cloud type. From the cloud type and depth analysis, an appropriate vertical motion profile is determined for each vertical column containing clouds.

The second major improvement is the LAPS dynamical balance package. The balance package is run after the initial analyses of the atmospheric state variables and the clouds are completed. The purpose of the balance package is to ensure that the final mass and momentum fields are consistent with the cloud and precipitation field. This is the crucial component of the analysis, as attempts by others in the past to directly initialize clouds usually resulted in a rapid dissipation of the clouds within the first few time steps of model integration due to lack of such balance. The scheme employs several dynamical constraints as well as a diabatic term within a three-dimensional, variational formulation to adjust the wind, temperature, and height fields based on the background vertical velocity field and the diagnosed cloud motions from the cloud analysis. During the minimization of the variational cost function in this step, the time tendencies of the u and v wind components are also minimized, which results in a very stable initial condition such that the numerical forecast model is not "shocked" at the initial time and the cloud field is properly maintained.

For several months beginning in the fall of 2000, we have been using the improved LAPS analyses to diabatically initialize the NCAR/PSU MM5 forecast model for a domain centered over Colorado and Wyoming with a grid spacing of 10 km. These simulations are run four times per day in real-time on FSL's massively parallel High Performance Computing System (HPCS). Products from these runs are posted on our web site (http://laps.fsl.noaa.gov). The gridded fields are also being provided to the Denver-Boulder National Weather Service Forecast Office (WFO) for display on their Advanced Weather Interactive Processing System (AWIPS) and have proven to be a valuable source of information during the preparation of operational public forecasts for their area of responsibility.

We used this initialization technique as part of a case study of a severe weather
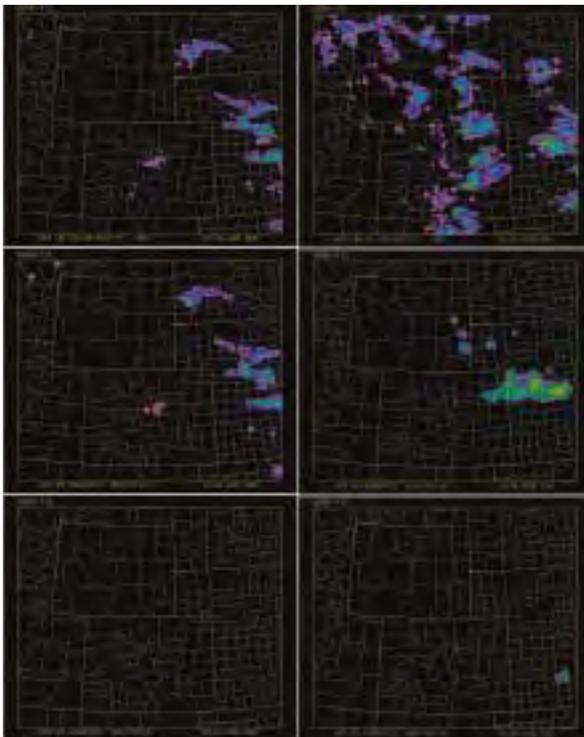

Figure 1. Top panel: LAPS analyzed low-level reflectivity valid at 1800 UTC (left) and 2100 UTC (right), 20 July 2000. Middle panel: MM5HOT diagnosed reflectivity for the initial condition (1800 UTC) and the 4-hour forecast (2200 UTC). Bottom panel: MM5ETA diagnosed reflectivity for same times as MM5HOT and LAPS analyses.

event which occurred in eastern Colorado on 20 July 2000. Figure 1 shows a comparison between observed low-level reflectivity and simulated reflectivity from two different MM5 forecasts valid at the initial time (1800 UTC) and four hours into the simulation (2200 UTC). One of the simulations ("MM5HOT") was initialized using the technique described above (middle two panels) and the other ("MM5ETA") was initialized using the 00 hour forecast from the 1800 UTC cycle of the NCEP Eta model. The 1800 UTC cycle of the Eta provided lateral boundary conditions for both simulations. Since the MM5HOT simulation had the hydrometeor fields provided by LAPS, the diagnosed reflectivity pattern matches the observed reflectivity almost identically. Furthermore, by 2200 UTC, the major area of convection initially in southern Nebraska at 1800 UTC was generally maintained and moved southward into eastern Colorado and western Kansas, where numerous reports of hail and tornadoes occurred during the next few hours. Additionally, new convection developed in eastern Wyoming consistent with the observed reflectivity. In contrast, the MM5ETA simulation had not yet fully developed the cloud and precipitation fields by this point. The MM5ETA method of initialization, which does not include any hydrometeor fields or the addition of any new observation data, is the typical configuration used by many real-time users of mesoscale models.

Although these types of anecdotal cases (including feedback from the Denver-Boulder WFO) are very encouraging, we endeavored to assess the skill quantitatively, as well as determine the benefits gained (if any) of initializing the model with this technique compared to other more traditional techniques. To address these issues, we have also been producing real-time forecasts using the same domain but different initialization techniques. One of the additional runs ("MM5WARM") employs a three-hour analysis nudging period, whereby the model is initialized with a LAPS analysis (state variables only) valid three hours prior to the desired 00HR forecast and integrated for three hours with three-dimensional nudging applied to the state variables from subsequent LAPS analyses. At the end of the three-hour dynamic initialization period, the model is allowed to run normally without any further nudging to produce the forecast fields. This dynamic initialization method allows the model to spin up its own clouds and precipitation with a weak constraint toward the analyzed state variables. The third configuration is identical to MM5ETA described above, except that the initial conditions come from the Eta 6-hour forecast. This same Eta cycle provides lateral boundary conditions for all three of the simulations.
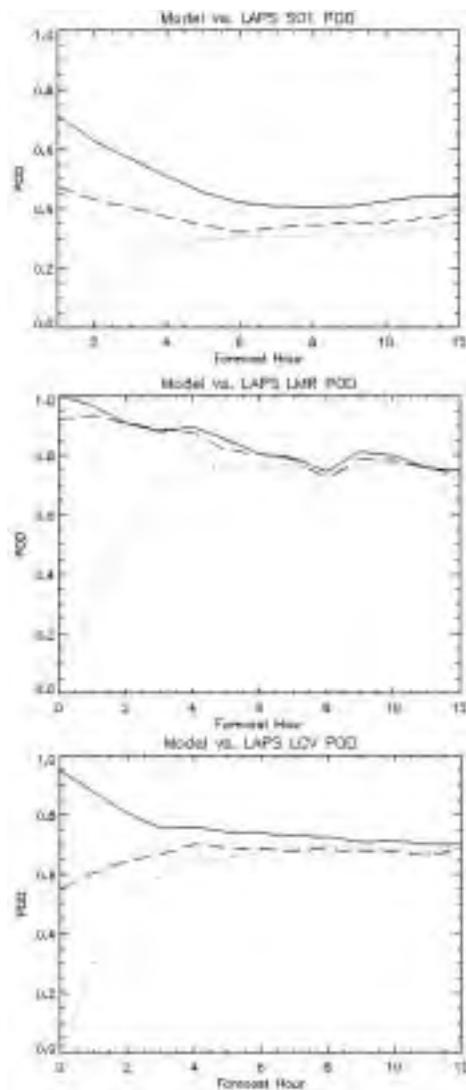

Figure 2. Probability of detection of hourly snowfall accumulation in excess of 1 mm (top), radar reflectivity in excess of 20 dBZ (middle), and total cloud cover greater than 50% (bottom) by forecast hour for MM5HOT (solid lines), MM5WARM (dashed lines), and MM5COLD (dotted lines). A perfect score is 1.0.

Using LAPS analyses as truth, we computed various statistics for the first 12 hours of the forecast period for each of the runs above during a two-month period covering December 2000 through January 2001. Computed probabilities of detection for hourly snowfall accumulation in excess of 1 mm, radar reflectivity in excess of 20 dBZ, and cloud cover in excess of 50% are shown in

figure 2. The MM5HOT runs clearly demonstrated the best skill in detecting these events, particularly in the 0-6 hour forecast period. The MM5WARM method showed comparable skill, but at the cost of additional computation time due to the three-hour nudging period. The MM5ETA had far less skill than either of the other two during the first portion of the forecast, thereby demonstrating the value added by initializing the model with recent observation data. The convergence of skill scores for the three configurations between the 6 and 12 hour point is likely due to the error sources being dominated by the lateral boundary conditions combined with the inherent unpredictability of small scale features with time. We speculate that the period of time before this occurs could be lengthened through the use of a larger nest. Additionally, the use of a coupled land surface model (which was not implemented in our runs) could lead to more accurate long term forecasts due to improved prediction of accumulated precipitation (and thus enhanced soil moistening) during the early hours of the simulation.

This work has promising implications for short-range NWP forecasts. Testing with our real-time runs continues, and it will be interesting to see how the system performs during the convective weather season. Thus far, the experimental runs are having a positive impact on the operations at the Denver-Boulder WFO, and such a system will be ported to three NWS WFOs located in the southern region later this year, as well as at the two USAF space launch facilities at Patrick AFB, Florida and Vandenberg AFB, California. Future work will consist of continued enhancements to the balance package and cloud analysis, improved verification methods, coupling to other forecast models, and the use of higher resolution grids.

References

Albers, S., J. McGinley, D. Birkenheuer, and J. Smart, 1996: The Local Analysis and Prediction System (LAPS): analyses of clouds, precipitation and temperature. *Weather and Forecasting*, 11, 273-287.

McGinley, J., S. Albers, D. Birkenheuer, B. Shaw, and P. Schultz, 2000: The LAPS water in all phases analysis: the approach and impacts on numerical prediction. Conference paper at the *5th International Symposium on Tropospheric Profiling.*

Vision

By Mary McInnis with Cliff Matsumoto

"Vision: the art of seeing things that are invisible." Jonathan Swift describes to some degree the task of a researcher in that quote – in perpetual search of the invisible, be it a better solution or a more satisfactory explanation of a phenomenon in nature. Research is the life-blood of CIRA, it is what we're all about, and as such, the standards for quality are high. Research activity nourishes not only the infra-structure with grant funding, but more impor-tantly the imagination and knowledge of the scientists at work. In recognition of this, in the year 2000 the directors sought ways to both encourage and acknowledge its research staff by establishing a new award to bring attention to the particularly innovative and creative work being done here. Hence the CIRA Research Initiative Awards were launched.

The inaugural CIRA Research Initiative Awards were presented at the 20th Anniver-sary celebration in October 2000. The annual award was designed to recognize outstanding research initiative or achievement by CIRA Research Scientists, Associates, or Coordina-tors – individuals or groups – over the past three years. The award is based on the follow-ing selection criteria:

1. Demonstrates initiative, resourcefulness and/or creativity by the use of innovative techniques and/or technology in daily research activities.
2. Provides team leadership and/or mentor-ing capability to fellow workers.
3. Performs "cutting-edge research" that is reflected in publications, reports, and deliverables.
4. Responsible for noteworthy accomplish-ment that results in substantial impact on CIRA, CSU, or sponsoring agency research mission.
5. Demonstrates successful proposal writing skills in attracting program funds.
6. Responsible for extraordinary achieve-ment relative to the employee's normal job responsibilities.

The recipients of the first annual award were:

Dr. Andy Jones, Jim Ramer, and the team of MarySue Schultz, Joanne Edwards, and Gerry Murray.

Andy Jones began with CIRA as an Atmospheric Science graduate student under Professor Vonder Haar in 1986. Andy's groundbreaking innovation was the develop-ment of a system called DPEAS (Data Pro-cessing and Error Analysis System). It is a parallel data processing system that per-forms cross-sensor satellite research and frees researchers to focus on algorithm develop-ment rather than on implementation and scal-ing issues. DPEAS is currently being used for cross-sensor research associated with both CG/AR research initiatives and with Stan Kidder's AMSU project. In the near future, CIRA will be participating in the CloudSat Data Processing Center (DPC) which will be the first 95 GHz CPR to fly in a sun-syn-chronous orbit, and will provide a unique look at the vertical distribution of clouds. The DPEAS system will allow researchers to pro-cess the entire CloudSat data stream at the CIRA DPC for a fraction of the cost at exist-ing large data centers.

Jim Ramer joined CIRA in December 1989 as a Research Associate supporting the Systems Development Division of NOAA/Forecast Systems Lab. He has been an invalu-able contributor over the years as both a meteorologist and a computer scientist. The breadth and significance of his contributions were recognized for his design and develop-ment of some of the most important and heav-ily used components of AWIPS (Advanced Weather Interactive Processing System) – tools and techniques to display numerical model fields and compose warning genera-tion.

MarySue Schultz joined CIRA in Feb-ruary 1996 as a Research Coordinator and supervisor of the CIRA staff in the Modern-ization Division of FSL. She was responsible for the design, development, implementation, and testing of the AWIPS "Message Handling System" software. This critical AWIPS com-ponent handles intersite and network dis-tribution of all text messages and locally generated forecasts and warnings, and was a key requirement for AWIPS commissioning.

Joanne Edwards also joined CIRA in February 1996 as a Research Coordinator in the Modernization Division of FSL. She is now the Data Group manager in the Division and plays a key role in providing leadership for the group and interfaces with the lab management on project issues. Joanne was

> "Last year, NWS completed its $4.5 billion national modernization effort with the commissioning of AWIPS (Advanced Weather Interactive Pro-cessing System) playing a key role. AWIPS has won many national engi-neering, scientific, and technology awards including the "ComputerWorld Smithsonian Award for the most inno-vative use of technology" and the Department of Commerce Gold Medal. The core software for AWIPS was designed and developed by the NOAA Forecast Systems Lab and several CIRA employees were key members of this design and development team."

responsible for the development of the com-munications interface between AWIPS and all local and remote Doppler radars – key to the severe weather watches and warning mission of NWS.

Gerry Murray joined CIRA in February 1996 as a Research Coordinator in the Sys-tems Development Division of FSL. He was responsible for the design and development of the interactive and visualization software for the AWIPS workstation. The exceptional software he developed has been lauded for its reliability, efficiency, and ease of use. Gerry had also been on the forefront in leading-edge design of Linux applications for the AWIPS follow-on (prior to his recent departure).

IMPROVE and WRAP Launch New Websites

By Bret Schichtel and Doug Fox

The National Parks and Wilderness Areas throughout the U.S. are pristine reserves of nature in its full glory, free from the sprawling reach of humans. Unfortunately, air pollution has found its way into these Class I areas. Haze causing discoloration, loss of texture and visual range is diminishing the natural beauty. Recognizing the importance of visual air quality, Congress included legislation in the 1977 Clean Air Act to prevent future and remedy existing visibility impairment in Class I areas. To aid the implementation of this legislation, the IMPROVE program was initiated in 1985. This program launched an extensive long term monitoring program to establish the current visibility conditions, track changes in visibility and determine causal mechanism for the visibility impairment in the National Parks and Wilderness Areas. In the 1990 Clean Air Act, a Grand Canyon Visibility Transport Commission (GCVTC) was established to identify causes and develop strategies to improve visibility degradation in the Grand Canyon and nearby Class I areas. In 1997 the western states, tribal governments and federal agencies formed the Western Regional Air Partnership (WRAP) to implement the recommendations from the GCVTC and other regional air quality issues. In 1999, the EPA issued regional haze regulations that require states and tribes to develop and implement strategies to improve visibility in Class I areas, based on IMPROVE program data.

These recent developments imply a need for new approaches for disseminating IMPROVE information. First, the regional haze rule has expanded the focus of IMPROVE from its original purpose as a scientific database to that of assuming added regulatory responsibilities. To support regional haze rules, the IMPROVE monitoring network needs to have openly documented QA/QC procedures and results, and the data needs to be as *widely* and *easily* available as possible. In addition, states and tribes new to the issue of regional haze need background information about visibility science, history and regulations. Secondly, WRAP has determined there is a need for air quality and related information to be made readily available to all of their partners through a web-based, interactive database.

To support these needs, two new websites are under development by CIRA staff. The IMPROVE website is focused on delivering IMPROVE data and general information about visibility science and regulations. The WRAP website, being developed for WRAP's Ambient Monitoring and Reporting Forum, is focused on providing visibility, air quality and meteorological data to WRAP partners in an online database. The IMPROVE data are central to both websites. Therefore, the co-development of the websites is mutually beneficial with WRAP benefiting from the database development for the delivery of the IMPROVE data, and the IMPROVE website benefiting from the integrated WRAP database and data visualization tools to be developed.

Both of these sites are in development and, as such, are not complete. However, they contain sufficient content to open them up to interested users. All users are encouraged to provide comment and feedback concerning these sites.

➢ The IMPROVE site can be accessed at http://vista.cira.colostate.edu/improve/

➢ The WRAP/AMRF site can be accessed at http://vista.cira.colostate.edu/wrap/

Figure 1

Current and Future Content and Capabilities

IMPROVE website

The primary objective of the IMPROVE website is to provide federal, state, and local air quality regulatory agencies, as well as the general public, access to IMPROVE data, data products and metadata fully describing the IMPROVE database, including characteristics and history of all network sites. Secondary objectives include providing

- access to data analysis tools and algorithms to facilitate analysis of IMPROVE data;

- access to educational material on visibility issues, science, and regulations;

- a user-supported discussion forum;

- feedback mechanisms for users to report QA/QC issues.

To accomplish these objectives, the IMPROVE website is presented in a hierarchical structure with five main sections: Data, Tools, Publications, Special Studies
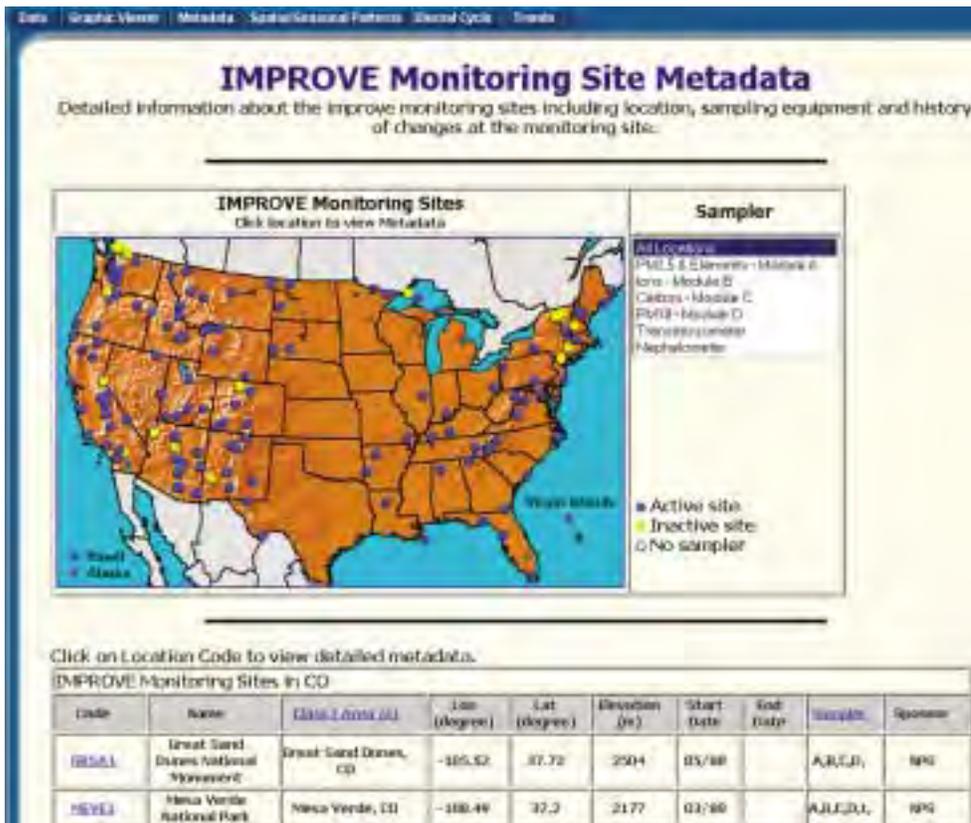
Figure 2

and Education (Figure 1). Other features of the website include a user-supported discussion forum and separate sections presenting an overview of the website, information on IMPROVE activities and related web links.

Data section. The central part of the website is the availability of IMPROVE data, its metadata, and high quality processed data products. A number of tools have been created enabling a user to browse and access these data resources. The exploration of the content of the IMPROVE aerosol, optical and scene data sets is accomplished via the metadata browser (Figure 2). This is an interactive tool allowing the retrieval of detailed information about all IMPROVE monitoring sites. This information includes the monitoring site's location, topography, the air quality species measured, changes over time to the sampling and filter analyses, and pictures of the site and surroundings.

The raw data are currently accessible as ASCII (text) files for each site as well as the entire database. In addition, location and variable tables are provided describing the monitoring site locations and species sampled. In the coming months, facilities will be implemented to allow ad hoc queries of the data based upon the location, variable and time range. Also, photographs documenting the spectrum of visibility conditions at each IMPROVE monitoring site, developed by Air Resources Specialists, Inc., will be provided. The CIRA/NPS group continually produces routine and novel data analyses of the IMPROVE datasets including spatial and temporal patterns of major aerosol types and reconstructed visibility. These analyses are summarized every three years in the IMPROVE reports. In order to make these results more accessible, an interactive graphic viewer has been constructed. This viewer consists of a series of linked views allowing the user to browse the spatial patterns of the data in a Map View, temporal cycles including, diurnal, seasonal, and long-term trends in a Time View and the frequency distributions of the data (Figure 3). In addition, the data used to generate these plots are available as ASCII data files and the algorithms used to process the raw IMPROVE data are also available.

Tools section. A goal of this website is to empower data analysts with tools to examine the IMPROVE database and perform routine analyses required for the regional haze regulations. To accomplish this, a tools section has been created. The tools section contains standard algorithms for aggregating and deriving new variables, such as the aerosol types and reconstructed light extinction from the IMPROVE speciated aerosol data. In addition, other tools are available such as Win Haze for estimating the impact of various air quality levels on the visual environment.

In the future, tools will be added to allow online analytical processing which would enable users to perform such tasks as calculating reconstructed visibility for selected monitoring sites and time periods. Also, simple visualization tools for plotting the data, such as time series and scatter plots will be added. These tools will be linked directly to the IMPROVE air quality database.

Publications section. The publication section of the website is where all documents important to the IMPROVE program and products of the IMPROVE program are made available. This includes the IMPROVE reports, network standard operating proce-
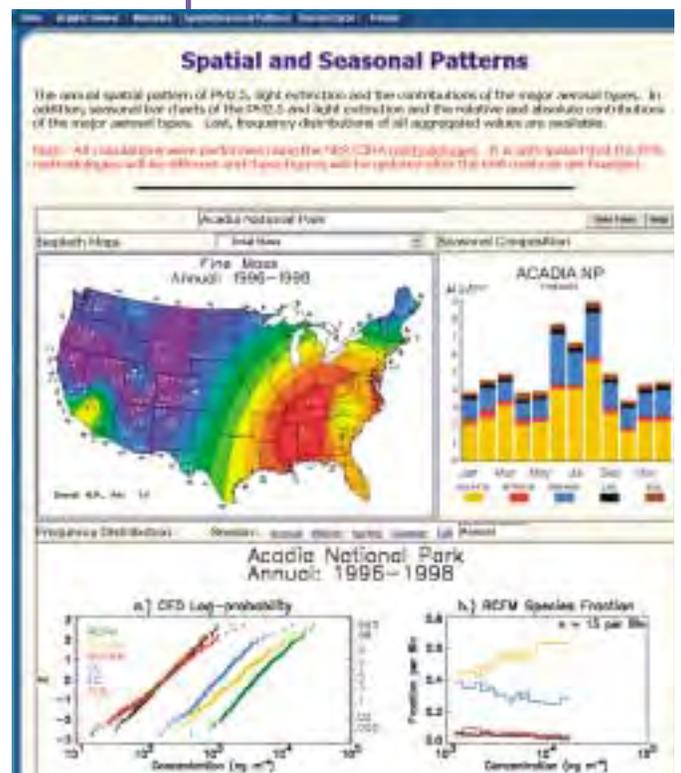

Figure 3

dures and IMPROVE newsletters. In addition, principle visibility documents such as the NAPAP State of the Science report are provided. A searchable reference database is also included containing all articles and abstracts from the CIRA/NPS reference database. The documents are a basic resource of the website containing detailed information on the IMPROVE network and visibility science. This information allows context sensitive links throughout the website for added information.

IMPROVE Special studies. The IMPROVE program conducts special studies periodically. These studies are designed to collect air quality, meteorological and emission data helpful in identifying sources contributing to impaired visibility. The website section provides background information and findings from these studies. It focuses on the resources generated by the CIRA/NPS group. These resources include the measured aerosol, optical and meteorological data, data reports and papers, and links to related websites.

Education section. The education section of the website will guide people though the basic visibility science and regulatory information at their own pace. Currently it is under development and contains only links to several basic visibility documents such as Bill Malm's "Introduction to Visibility," a glossary and EPA documents on the Regional Haze rule. However, a multi-media presentation using animations, voice, and still images to convey the basic concepts of visibility science, air quality data analysis and haze regulations is under development. The multimedia document will draw extensively on the "Introduction to Visibility" report, and a new regional haze regulations video produced by Julie Winchester at CIRA.

WRAP Website

The primary objective of the WRAP Ambient Monitoring & Reporting Forum website is to provide WRAP partners - western State and local air agencies, western Indian tribes, and federal land managers – data and information resources to help identify common regional air management issues; develop and implement strategies to address these common regional issues; and formulate advance western regional policy positions on air quality. The WRAP AMRF website is designed to:

- create a living inventory of distributed air quality, meteorological and emission data resources for the western U.S.,

- provide a uniform interface to these organized and described data resources,

- enable searching, querying, analyzing and visualizing a subset of the datasets.

The WRAP website (Figure 4) is a data resource tool consisting of an integrated database of raw data and data products from multiple networks, as well as catalogs of other online air quality data resources. All catalog entries have a description of the data resource, a list of keywords to facilitate searching with future tools and links to its metadata description file. These online data resources include links to measured and modeled air quality, meteorological, and emission datasets, as well as satellite imagery. Currently, the WRAP website contains the same data and data products, such as the graphic viewer, as the IMPROVE website. In addition, we have begun to add entries to online resources in the data catalogs, such as to EPA's AIRS database and the RAWS data archive at DRI's Western Regional Climate Center. Catalog entries will be continually added as new resources are found.

In the future, the WRAP website will distinguish itself from the IMPROVE website by including additional aerosol, optical, and meteorological data. The site will invite public and private data sources to submit data to be included, providing it meets posted metadata standards and other criteria. New graphics will be created from these additional data resources and will be added to the graphic viewer. The WRAP website will also have additional data analysis tools, most of which will be subsequently applied to the IMPROVE website. Some of these tools will include integra-

tion of meteorological and air quality data (e.g. trajectory analysis), and calculations of extinction from aerosol speciation data using the EPA-approved approach and other selected methods. The WRAP database web is likely to be the principal means for publishing and distributing WRAP annual data reports.

Implementation

To leverage the development of both websites, they are being developed simultaneously following a three-tier process. The first tier release represents the current capability of both websites. The second tier release, within the next 6 months, will include IMPROVE data added to a multi-dimensional database allowing ad hoc queries of the database and some simple data aggregation and manipulation tools. The design of this database and the metadata, to describe the data, will follow the recent developments of EPA's Supersite Data Management workgroup that is creating a metadata standard for describing all data collected by the Supersite program. The final tier release for the websites, anticipated within the year, will enhance the online querying and manipulation tools and add some online data visualization tools.

Details of the data included, and the state of completion of the website, can be assessed by visiting the site. We invite you to browse and we welcome your feedback on the site. For more information, contact either Bret Schichtel or Doug Fox.

Figure 4

CIRA Mission

The Cooperative Institute for Research in the Atmosphere (CIRA), originally established under the Graduate School, was formed in 1980 by a Memorandum of Understanding between Colorado State University (CSU) and the National Oceanic and Atmospheric Administration (NOAA). In February 1994, the Institute changed affiliation from the Graduate School to the College of Engineering as part of a CSU reorganizational plan.

The purpose or mission of the Institute is to increase the effectiveness of atmospheric research of mutual interest to NOAA, the University, the State and the Nation. Objectives of the Institute are to provide a center for cooperation in specified research programs by scientists from Colorado, the Nation and other countries, and to enhance the training of atmospheric scientists. Multidisciplinary research programs are given special emphasis, and all university and NOAA organizational elements are invited to participate in CIRA's atmospheric research programs. Participation by NOAA has been primarily through the Oceanic and Atmospheric Research (OAR) Laboratories and the National Environmental Satellite, Data, and Information Service (NESDIS). At the University, the Departments of Anthropology, Atmospheric Science, Biology, Civil Engineering, Computer Science, Earth Resources, Economics, Electrical Engineering, Environmental Health, Forest Sciences, Mathematics, Physics, Psychology, Range Science, Recreation Resources and Landscape Architecture, and Statistics are, or have been involved in, CIRA activities.

The Institute's research concentrates on global climate dynamics, local-area weather forecasting, cloud physics, the application of satellite observations to climate studies, regional and local numerical modeling of weather features, and the economic and social aspects of improved weather and climate knowledge and forecasting. CIRA and the National Park Service also have an ongoing cooperation in air quality and visibility research that involves scientists from numerous disciplines. CIRA is also playing a major role on the NOAA-coordinated U.S. participation in the International Satellite Cloud Climatology Program (part of the World Climate Research Programme).

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If you know of someone who would also like to receive the CIRA Newsletter, or if there are corrections to your address, please notify us.