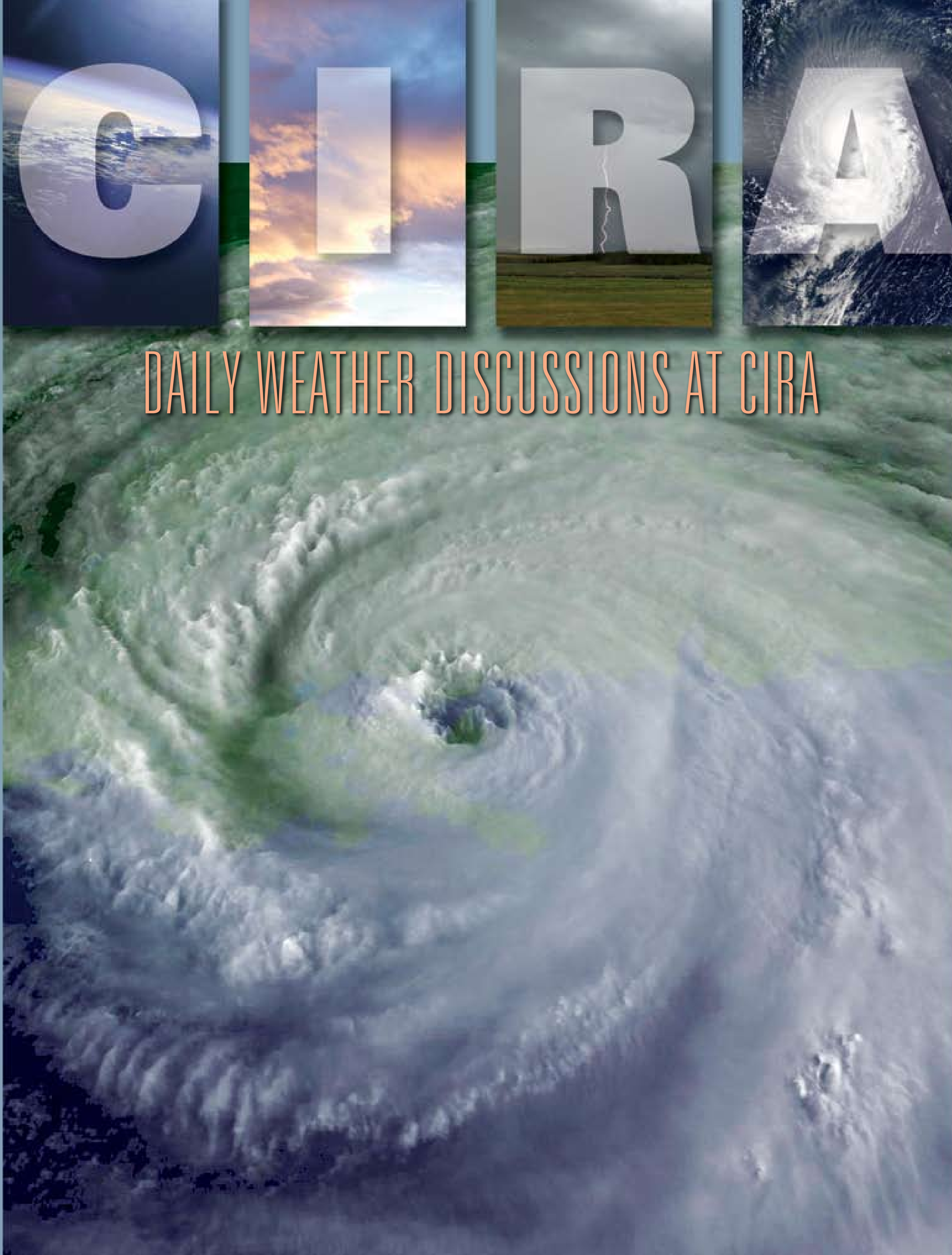
CIRA

DAILY WEATHER DISCUSSIONS AT CIRA



VOLUME 25, SPRING 2006

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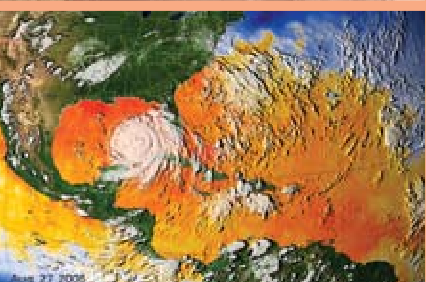

About the cover and above photos: Hurricane Katrina, August 2005. This storm was among the many topics discussed during the CIRA daily weather briefings held since CIRA's inception (see page 4).
Photos courtesy of NASA, www.nasa.gov.

CIRA
Cooperative Institute for Research in the Atmosphere

www.cira.colostate.edu

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GOES-R IS COMING

Preparing for GOES-R: Old Tools with New Perspectives

Bernie Connell and Don Hillger

GOES is coming.

The next generation Geostationary Operational Environmental Satellite (GOES), beginning with GOES-R, is expected to be launched in the 2012 timeframe. This new series of satellites will include instruments with improved spatial, temporal, spectral, and radiometric resolution. The last two characteristics are manifest by an increased number of spectral bands and increased precision for measurements from those bands. The current generation GOES Imager with 5 spectral bands will be replaced by an Advanced Baseline Imager (ABI) with 16 spectral bands. The current generation GOES Sounder with 19 spectral bands will be replaced by a Hyperspectral Environmental Suite (HES) with broader spatial coverage, higher spatial resolution, and over a thousand spectral bands.

Preparations are underway at CIRA to develop improved products for forecasting environmental and weather hazards from these instruments by looking at products available from instruments on current research satellites. Imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) and Atmospheric InfraRed Sounder (AIRS) are providing examples.

Table 1 shows the proposed ABI bands and the current GOES and MODIS bands. AIRS has over 2,000 spectral bands covering the 3.7 - 15.4 µm range.

Table 1. Proposed ABI bands and existing MODIS and GOES bands.

ABI Band (central wavelength)	Closest MODIS Band (central wavelength)	GOES-R Band (central wavelength)
1 (0.47 µm)	3 (0.4656 µm)	
2 (0.64 µm)	1 (0.6465 µm)	1 (0.7 µm)
3 (0.86 µm)	2 (0.8567 µm)	
4 (1.38 µm)	26 (1.382 µm)	
5 (1.61 µm)	6 (1.6291 µm)	
6 (2.26 µm)		
7 (3.90 µm)	22 (3.9719 µm)	2 (3.9 µm)
8 (6.185 µm)		
9 (6.95 µm)	27 (6.7654 µm)	3 (6.7 µm)
10 (7.34 µm)	28 (7.3367 µm)	
11 (8.5 µm)	29 (8.5288 µm)	
12 (9.61 µm)	30 (9.7344 µm)	
13 (10.35 µm)		
14 (11.2 µm)	31 (11.0186 µm)	4 (10.7 µm)
15 (12.3 µm)	32 (12.0325 µm)	5 (12.0 µm)
16 (13.3 µm)	33 (13.3651 µm)	6 (13.3 µm)

Fellowships in Atmospheric Science and Related Research

The 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 via electronic means only to: Professor Thomas H. Vonder Haar, Director, CIRA, Colorado State University, humanresources@cira.colostate.edu. Research Fellowships are available in the areas of: Air Quality, Cloud Physics, Mesoscale Studies and Forecasting, Satellite Applications, Climate Studies, Model Evaluation, and Economic and Societal Aspects of Weather and Climate. For more information, visit www.cira.colostate.edu.

GOES-R IS COMING

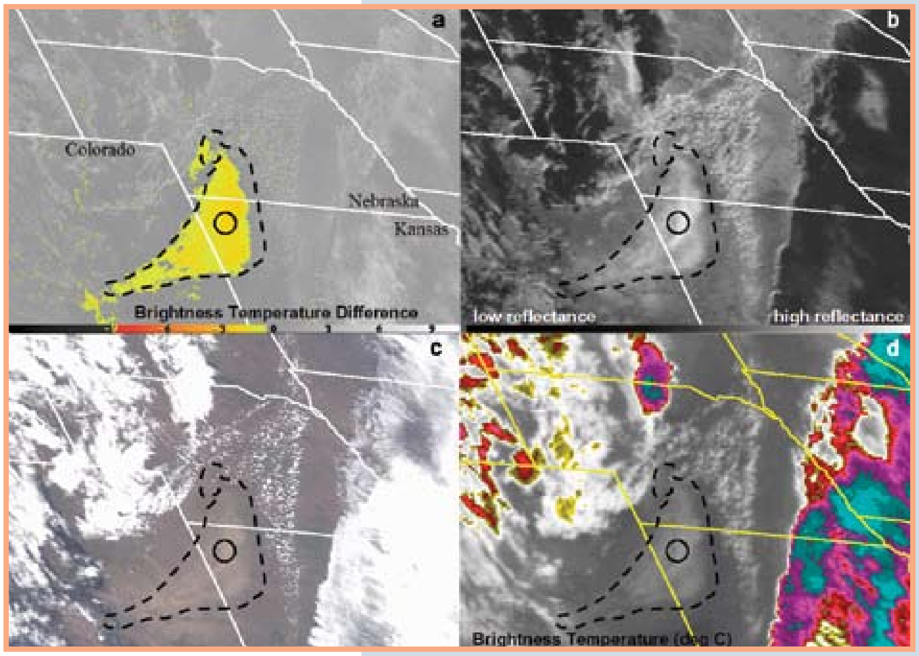


Figure 1. Satellite image products showing the dust plume extending from eastern Colorado into western Kansas and Nebraska on 18 April 2004 at 19:30 UTC. a) MODIS brightness temperature difference 11.0 µm - 12.0 µm, b) GOES-10 reflectivity product, c) MODIS true-color product and d) enhanced GOES-10 10.7 µm band. The dashed line indicates the plume outline and the circle indicates the location for the dust spectra in Figure 2. The dashed outline was determined by tracking the dust over time using GOES imagery.

Calculating brightness temperature differences between spectral bands is a common method used to detect and isolate spectral-specific features in satellite imagery. This is because the properties of features of interest will generally vary over the radiometric spectrum, and hence the brightness temperature will also vary. A PCI (Principal Component Image) tool developed at CIRA is a way to do multiple-differencing of spectral bands to find differences with the most explained variance.

Below is an example of the process of mining the available data in search of new and improved products for forecasting environmental and weather hazards. The example involves the detection of blowing dust.

What is the Spectral Signature?

In designing products some of the fundamental questions are: What are the spectral signatures of the feature of interest? How does the spectral signal vary for fog, thunderstorms, wave clouds, thin cirrus, ocean surfaces, land surfaces and dust?

For our example, to detect dust, the most-commonly-used product is the 10.7 µm brightness temperature minus the 12.0 µm brightness temperature. Generally, this difference is negative for blowing dust, and is positive for water and ice cloud. The negative difference that is sensed is usually only 1-2 degrees Celsius.

Figure 1a shows this brightness temperature difference product derived from MODIS data for a dust storm over the Central Plains on 19 April 2004. Another product to detect dust, derived from GOES-10 data for the same scene, is shown in Figure 1b. This product takes advantage of the higher reflectance of dust in the 3.9 µm region during the day. Clouds, particularly those with small water droplets, also have a high reflectance during the day, so the product cannot be used alone. For comparison, Figure 1c shows the true-color visible composite derived from MODIS bands 1, 3 and 4, and Figure 1d shows an enhanced GOES infrared image (band 4).

Are there any new ABI bands that can help detect blowing dust? Let's see what the AIRS data show for dust to determine which bands may help.

Using AIRS data, a spectral plot of the brightness temperature versus wavelength is shown in Figure 2 for a point within the circled region of the dust in Figure 1. Also shown for comparison is a spectral plot of the brightness temperature for a clear region to the east of the dust. In this plot, the focus is on the shortwave and longwave regions. Larger brightness temperature differences are seen for the dust in two regions: between 3.7 and 4.1 µm, and between 8.0 and 9.2 µm. Smaller brightness temperature differences occur between 10.4 and 12.2 µm. Based on these three gradient regions, a subset of eight AIRS bands were selected to run PCI analysis. The three best brightness temperature differences occurred between the 3.75, 4.05 and 8.15 µm bands. A resulting red-green-blue false-color composite combining three of the PCIs is shown in Figure 3.

Because of low spatial resolution (14 km), the AIRS pixels are replicated in this image. The bad news is not all of these spectral bands will be available with ABI on GOES-R instrumentation. The good news is that they may be available with HES on GOES-R.

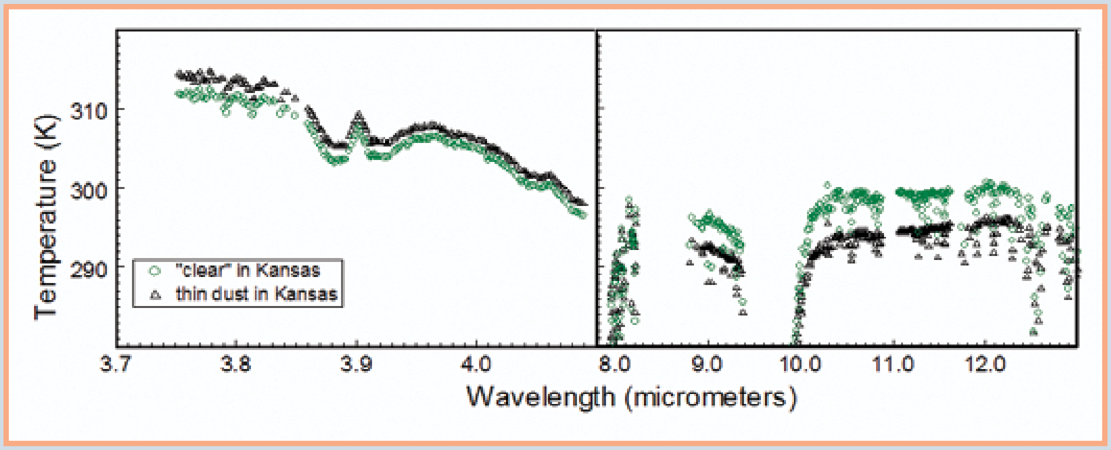


Figure 2. AIRS spectral plot of temperature versus wavelength for the shortwave and longwave regions for a point within the circle shown on Figure 1 representing thin dust, and a point farther to the east representing clear ground. Data are for 18 April 2004 at 19:30 UTC.

A separate PCI analysis of this dust case is based on spectral bands used in a false-color dust product developed by Daniel Rosenfeld of Hebrew University for Meteosat Second Generation (MSG) data. That product uses the longwave (8.7, 10.8, and 12.0 µm) MODIS bands, bands that will be available with GOES-R, rather than the shorter wavelength bands found most useful with the AIRS analysis above.

Figure 4 shows the same dust plume as in Figures 1 and 3, this time in dark red, but at the higher 1 km spatial resolution of the MODIS infrared bands.

Getting There!

It is a challenge to figure out the best spectral combinations for detecting various environmental and weather hazards. Old tools, such as taking the time to look at the spectral signatures in the data and spectral differencing, can be carried to much higher levels than they could with the limited selection of bands on current GOES satellites. The spectral bands found to be of most use will of course be dependent on the features of interest, with focus on the spectral bands that will become available via the instrumentation on board the GOES-R series.

In designing products some of the fundamental questions are: What are the spectral signatures of the feature of interest? How does the spectral signal vary for fog, thunderstorms, wave clouds, thin cirrus, ocean surfaces, land surfaces and dust?

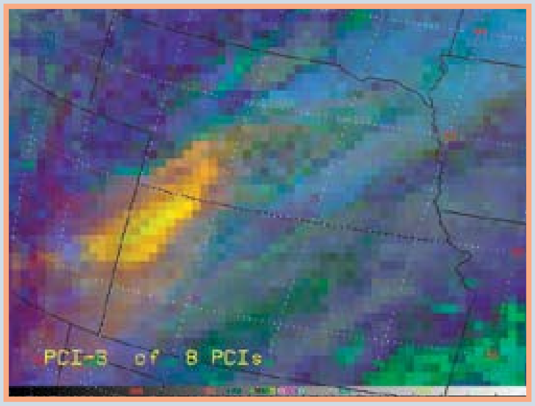


Figure 3. False-color dust product created from Principal Component Image (PCI) analysis of AIRS spectral bands for the same case as in Figure 1. The yellow region is the signature of airborne dust, with color intensity related to dust concentration.

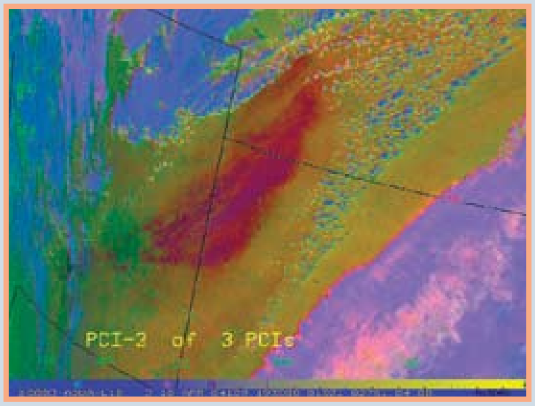
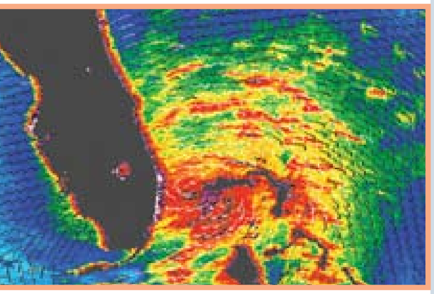


Figure 4. Same as Figure 3, but created from MODIS longwave spectral bands, and at much higher (1 km) spatial resolution

WEATHER DISCUSSION

The CIRA Daily Weather Discussion

Kathy Fryer
Mark DeMaria, NOAA/NESDIS



An important byproduct of the daily weather discussion (top) is the opportunity for individual meteorologists to share new and interesting developments in his or her area of expertise, and to interact with students.

Hurricane Katrina (bottom) has been one topic of the daily weather discussions. Photo courtesy of NASA, www.nasa.gov.

Promptly at 3:00 p.m., scientists and students gather in the dimly-lit CIRA lab for the daily weather discussion. The current-day forum came into being in the early 1990s with the advent of the RAMSDIS workstation. RAMSDIS (RAMM Advanced Meteorological Satellite Demonstration and Interpretation System), developed at CIRA, is a PC-based workstation for use in advanced satellite data display and analysis. Prior to deployment of the Advanced Weather Interactive Processing System (AWIPS), RAMSDIS was also used by some National Weather Service (NWS) offices for display and manipulation of satellite data. By 1998, weekly schedules were created for Regional and Mesoscale Branch (RAMMB) meteorologists to take their turn leading the daily discussions.

In the CIRA lab today, an array of colorful monitors displays the high quality animated images that are the foundation of the discussions. Seven computers, loaded with satellite data analysis applications, are connected to the "Jumbotron" plasma monitor. RAMSDIS remains the primary display system, in conjunction with web-based products and a research version of AWIPS that is being implemented at CIRA. They display surface and upper air observations, as well as radar, but primarily satellite data which is presented on monitors labeled Sounder, Imager (East-West GOES data), and RMTC/RSO (rapid scan operation). Tropical data is available through RAMSDIS as well as Meteosat (European geostationary satellites). The Polar system can show imagery over both the north and south poles, as well as globally. The computer systems can be switched back and forth onto the big screen, which is a great improvement from the days when participants crowded around the individual monitors.

With laser pointer in hand, the discussion leader begins with a brief view of current world and local weather. It is the prerogative of the leader to determine the focus of the discussion. An initial view of the jet stream gives information on weather conditions over a broad extent of the country. Discussions are not limited to weather. The power of the satellite imagery enables viewing of significant quasi weather events, such as, volcanic eruptions, fires, lightning, fog, and smoke.

Generally, the weather discussion narrows down to a weather event of current interest. In the spring, severe weather in the form of tornadoes, thunderstorms and floods takes center stage. Storms and lake effect snow events are examined throughout the winter months.

During the hurricane season, July through November, the weather discussion shifts to viewing digital imagery of evolving tropical storms. Students in the Colorado State University Department of Atmospheric Science volunteer to take a week each to guide the discussions. An active hurricane season can generate discussions lasting up to an hour, with space for standing room only. Examination of tropical cyclones is not limited to the months of activity in the Atlantic, but continues into the tropical cyclone events of the southern hemisphere.

An important byproduct of the daily weather discussion is the opportunity for individual meteorologists to share new and interesting developments in his or her area of expertise, and to interact with students. In the words of one scientist, the discussion becomes a mini-seminar. Through sharing these ideas, new products can emerge and be tested. A few intrepid souls examine the weather from the numerous resources, and actually forecast the weather.

The CIRA daily weather discussion, in its mode to reinforce, train, and generate interest in weather related topics, is a far cry from the days of the map discussions which were held in the Department of Atmospheric Science building. The paper maps of surface and upper air patterns have given way to an animated medium that is timely and infinitely more revealing of local and global weather events.

The emergence of the RAMDSIS and AWIPS systems has paved the way for "global" weather discussions and training. World wide, high profile training and discussions are about to take place with the World Meteorological Organization (WMO) focus groups through virtual laboratories in the Caribbean and Latin America. Web-based methods will be used to simultaneously connect participants from countries across the world.

WRF PORTAL

WRF Portal:
The Graphical Front End to WRF

Jeff S. Smith

What is WRF?

WRF is the mesoscale Weather Research and Forecasting model designed for both operational forecasters and atmospheric researchers. It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and an extensible software architecture that supports parallel computing. WRF is available on the web at http://www.wrf-model.org and is currently in operational use at NCEP (National Centers for Environmental Prediction).

What is WRF Portal?

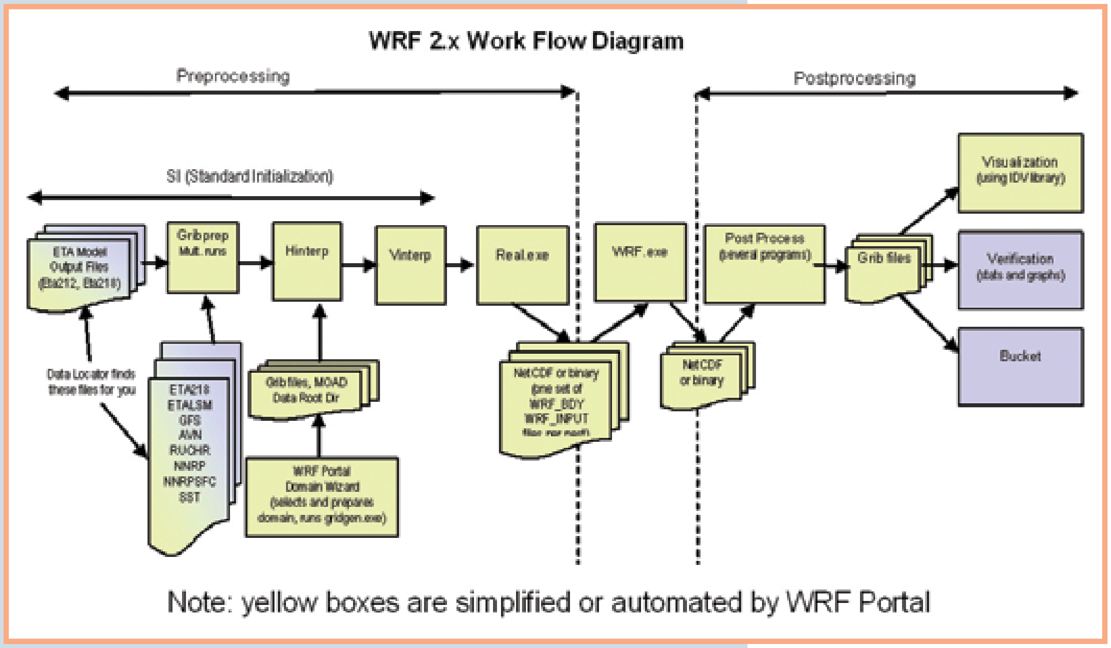
WRF portal is a NOAA/Earth System Research Laboratory/Global Systems Division (formerly FSL) funded project that is basically a Java webstart GUI (Graphical User Interface) front end for configuring and running both WRF cores: ARW (Advanced Research WRF (NCAR core)) and NMM (Nonhydrostatic Mesoscale Model (NCEP core)). It simplifies the configuring and running of WRF models, the selection/localization of your domain and the visualization of your model's output. WRF Portal runs on all platforms and can be accessed from a webpage. It also includes a data locator for finding your data, a job manager that manages and executes the jobs and a visualization tool for visualizing your WRF output. It does not include WRF itself – the WRF software must already be installed on a computer accessible by WRF Portal before you can use the GUI.

Why Would WRF Users Want To Use It?

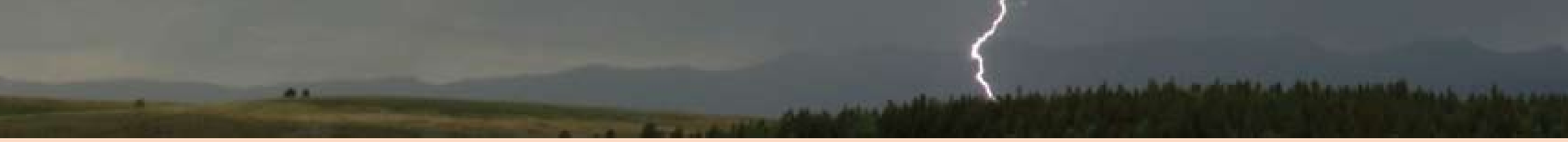
WRF Portal saves users' time by automating tedious tasks and providing time-saving features such as a domain wizard for the visual selection and preparation of a domain, a "diff" tool for comparing different model and run configurations, a data locator for finding your input data, a robust job manager for running various WRF tasks and a progress monitor for tracking the progress of your runs in a central monitor window. WRF Portal even allows you to graphically visualize your model output, and it stores all of its information in a database so you can easily search and retrieve your information without the tedium of hunting through a myriad of files in numerous disk directories.

Running WRF Without a GUI is Complicated

Configuring and running WRF is a very complicated process. The typical workflow entails editing multiple configuration files (namelists), setting environment variables, and running executables in the correct order. All of these files are scattered across many different directories. Moreover, editing the configuration files by hand in a text editor such as vi is tedious and mistake prone. Selecting a domain (geographic region) without visual feedback can be a frustrating exercise in trial and error. Here is a typical WRF work flow:



WRF Portal saves users' time by automating tedious tasks and providing time-saving features.



WRF PORTAL

A Few Workflow Comparisons

WRF from command line	WRF using WRF Portal
Lats/Lons are looked up in an atlas, grid points are computed with a calculator, user manually types all this data into namelist text filest.	User draws a box around a region of the Earth on the screen, grid points are automatically calculated with minimal user input, namelists are automatically written.
Namelists and scripts are scattered in multiple directories, manually edited in vi.	Namelists and scripts are stored in database and edited in WRF Portal visual editors.
New runs involve copying lots of files, editing them with vi, set environment vars, launching scripts manually.	New runs are launched from the New Run Config window. Most of the info is already filled out for you.
Runs are monitored by tailing certain log files in specific directories. Requires detailed knowledge of WRF.	Runs are monitored from a window which lists all tasks, how long they've been running and the est. time to finish.
Comparing two different models involves viewing multiple namelists files for each model and hunting for the differences.	Comparing two different models is done from a window that highlights all differences between the models.
Finding an old run involves hunting through directories on different computers.	Find an old run is done by typing in search criteria into a window.
Runs are cancelled by killing jobs from the command line.	Runs are cancelled with a mouse click.
Visualization is done with external tools.	Visualization is done within WRF Portal with a mouse click.

WRF Portal Architecture

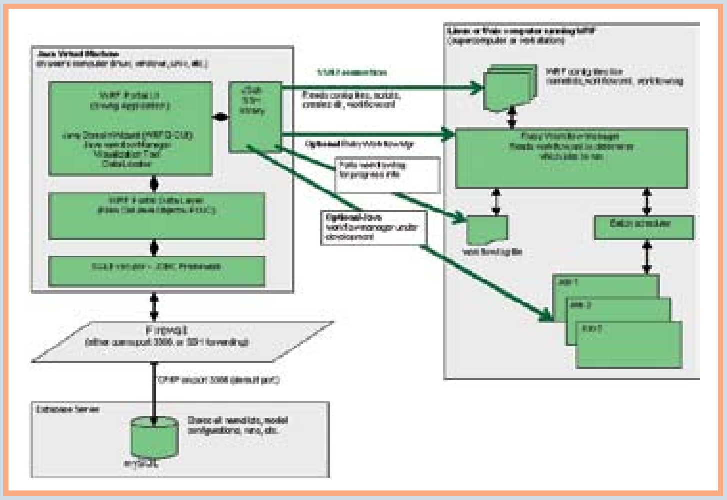
WRF Portal is written in Java so it runs on virtually all platforms (e.g. Linux, Windows, Unix) and can be launched from a webpage. It stores most of the user's work and information in a mySQL database. Each site can have its own database instance, or multiple sites can share a single mySQL database. For example, ESRL might have its own database for ESRL WRF users, while NCAR might have a separate database for its users. When the user first starts up WRF Portal, he/she is prompted for a username and password; these credentials establish the user's identity for the duration of their WRF Portal session. Any configurations the user creates or runs and executes are associated with the user's username in the database, so, for example, when the user looks up a previous WRF run, the user only sees his/her own runs, not the runs of every other user in the system. By storing his/her data in a database instead of in multiple disk files, we've made it easy to back up the data (archive it) and query it based on multiple criteria. Furthermore, we've eliminated the clutter and complication of the user maintaining many files in multiple directories on potentially multiple file systems, and we've enabled the user to run WRF Portal and access most of his/her data from any computer, mounted to any file system.

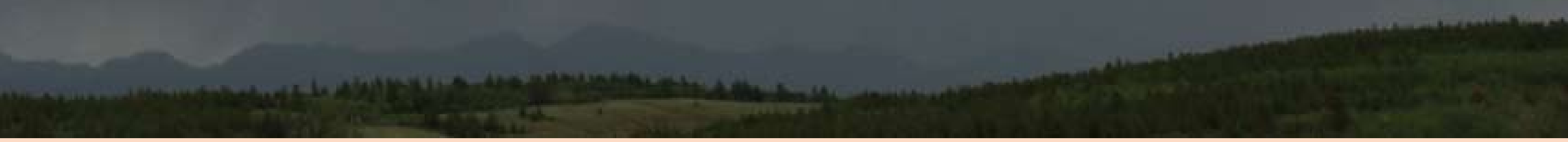
After creating a model configuration in WRF Portal, the user can choose to run it on any computer previously configured in the WRF Portal software (and database). He/she can run one or more tasks in any order he/she chooses. For example, a user may choose to run GRIBPREP and HINTERP. When he/she selects the RUN option in WRF Portal, one of two things happens. If he/she has chosen to run it on the local computer, WRF Portal executes the tasks on the local computer in the order the tasks appeared in the run configuration workflow. If he/she has chosen to run it on a remote computer (perhaps a supercomputer), he/she is prompted for his/her SSH (Secure Shell) credentials. WRF Portal then establishes an SSH2 connection to the remote computer and executes all the tasks via this connection. Users also have the option of running WRF Portal "locally" on a remote computer if they first SSH to the remote computer and then start up WRF Portal in an X Windows session.

The diagram below illustrates the architecture of the WRF Portal system.

WRF Portal Security

A WRF Portal user logs in with credentials that grants the limited database access required to run WRF Portal. The database does not store any sensitive information such as usernames or passwords to other computers. All database traffic is transmitted via TCP/IP to port 3306 (or another port designated by the administrator), and the password is encrypted during all transfers. We are also considering the possibility of further strengthening database security by using SSH Port forwarding to encrypt all incoming and outgoing data.





WRF Portal uses SSH2 for all connections to remote computers, providing the same high level of security a WRF user would have if he/she SSH'd to a remote computer and then ran WRF from the command line.

WRF Portal Job Management

There are two ways to execute jobs (such as GRIBPREP, REAL, or WRF) with WRF Portal. One way is to use the Ruby Workflow Manager developed by Chris Harrop. This workflow manager must be installed and runs independently on the remote computer. It provides robust job management including job restart on failure, job monitoring, and running multiple tasks simultaneously.

The other way to execute jobs is to use the somewhat simpler (and less robust) internal Java Workflow Manager. This workflow manager is built into WRF Portal and thus runs on your desktop computer and can only monitor jobs while WRF Portal itself is running. If you shut down WRF Portal, the workflow manager is also shut down and hence cannot monitor and restart jobs that fail. The next time you restart WRF Portal, however, the Java Workflow Manager resumes monitoring and starting jobs from wherever it left off.

Summary

In summary, WRF Portal simplifies the configuration of domains, models and runs, while providing many useful tools to make the WRF user's life easier. The software is still under development at ESRL and we are working with NCAR to make the software fully compatible with the upcoming release of WRF 3.0. We anticipate that WRF 3.0 will be released sometime in the latter part of this summer (2006), with WRF Portal's release following shortly thereafter. Please check our website at www.wrfportal.org for further information.

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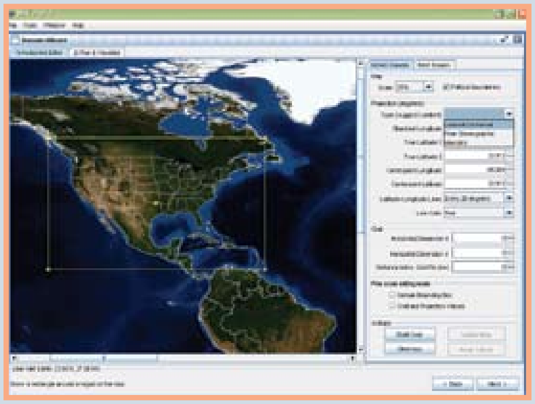
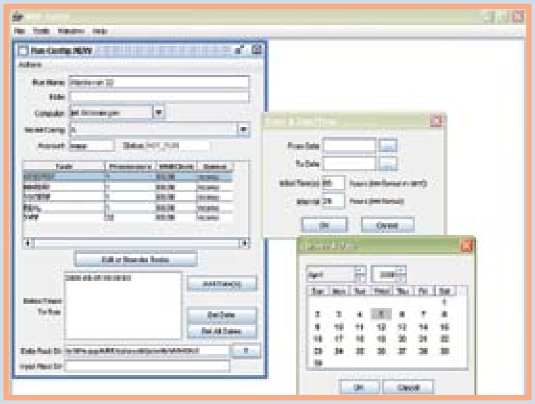
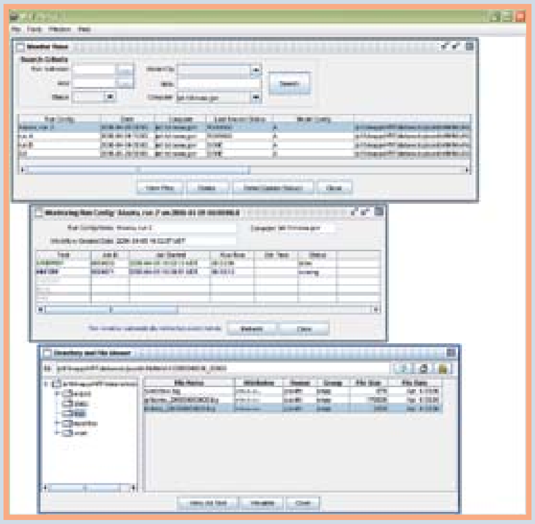
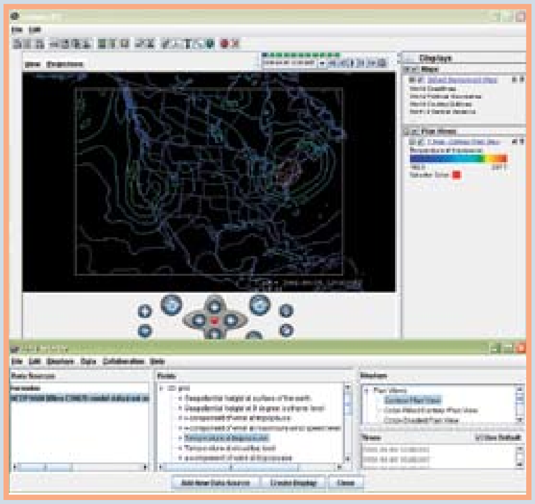








WRF Portal Screenshots

***Upper left:** This domain wizard enables a user to visually select and then localize a domain. The domain wizard currently supports the Lambert Conformal, Polar Stereographic, Mercator, and Long-Lat map projections, and will support nested domains.*

***Upper right:** This Run Configuration window is where a user selects the model, computer, tasks and dates to run their WRF model.*

***Lower left:** The Monitor Runs window enables a user to follow the progress of his/her runs. For example, the user can find out how much longer a job has to run or whether it has errored out. The user can also view the output files.*

***Lower right:** The integrated visualization tool (based on IDV – Integrated Data Viewer) enables users to visualize the output of their WRF runs. Users can also use this tool to visualize other meteorological data files.*

CIRA COMMUNIQUÉ

From top: Adam Carheden, Scott Longmore, and Nikki Prive

CIRA's Fellows

The Fellows of CIRA are the "Senior Faculty" of our institute. This honor is conveyed to those scientists from CSU and from our collaborating federal groups, who have contributed to the scientific, educational and outreach mission of CIRA for a number of years. Fellows comprise the Advisory Council of CIRA, which meets periodically to advise CIRA's Director and staff regarding matters important to the CIRA Mission. The Fellows also nominate and review applications for CIRA Fellowships and carry out other duties assigned to them from time to time.

As we enter CIRA's 26th year, the current Fellows of CIRA are:

Azimi, Mahmood, CSU/Electrical and Computer Engineering
Birkenheuer, Dan, NOAA
Cochrane, Hal, CSU/Economics
Collett, Jeff, CSU/Atmospheric Science
Cotton, William, CSU/Atmospheric Science
DeMaria, Mark, NOAA/NESDIS/RAMM
Feingold, Graham, NOAA
Fox, Doug, CSU/CIRA
Iyer, Hari, CSU/Statistics
Johnson, Richard, CSU/Atmospheric Science
Julien, Pierre, CSU/Civil Engineering
Kidder, Stan, CSU/CIRA
Koch, Steve, NOAA
Kreidenweis, Sonia, CSU/Atmospheric Science
Kummerow, Chris, CSU/Atmospheric Science
MacDonald, Sandy, NOAA/Global Systems
Pielke, Roger, CSU/Atmospheric Science
Purdom, James, CSU/CIRA
Rutledge, Stephen, CSU/Atmospheric Science
Stephens, Graeme, CSU/Atmospheric Science

Welcome CIRA's Newest Employees

Adam Carheden

Adam is a non-student hourly employee (Intern) who previously worked as an IT Auditor for Deloitte & Touche and as a writer for Windows IT Pro magazine. He joined CIRA in Fort Collins on September 26th to serve as the facility's Linux administrator. Adam works with CIRA's Linux users to maintain two high performance computing clusters as well as other Linux desktops and servers, and he holds a degree in Computer Science from Colorado State University. Michael Hiatt is his supervisor.

Scott Longmore

Scott is a Research Associate II and will join CIRA in Fort Collins on November 17th to assist with ongoing satellite data assimilation experiments. He will work closely with the CG/AR data assimilation team led by Tomi Vukicevic, and Andy Jones will serve as his supervisor. From 1998-2000 Scott worked at NOAA/FSL in Boulder as a CIRA employee (Senior Programmer/Analyst). Scott possesses an MS in Meteorology from Florida State University where he was advised by Dr. Henry Fuelburg, and he has substantial computer skills which he used most recently at NCAR to assist in the development and composition of documents related to the Intergovernmental Panel on Climate Change (IPCC) Working Group assessment reports. In addition to his background in satellite remote sensing, visualization software, and radar data compositing, Scott has experience with real-time weather numerical weather prediction, which he gained while working in the commercial sector.

Nikki Prive

Dr. Nikki Prive received her PhD from the Massachusetts Institute of Technology in June 2005 and joined the Office of the Director at FSL (now the Global Systems Division of Earth System Research Lab) at CIRA in Boulder on September 12th. She is a Research Associate II, and Cliff Matsumoto is her supervisor. Nikki participates in all aspects of program development for the NOAA Unmanned Aerial System program, including operations concepts, observing system simulation, and optimal aircraft observing strategies.

From left: Sean Madine, Missy Petty, Nick Matheson, and Dale Betterton

NOAA Global Systems Division (GSD) Team Members of the Month

The following nominations for GSD Team Members of the Month – March 2006 come from Aviation Branch Chief Mike Kraus: "I would like to recognize the Real Time Verification System – Next Generation Development Group for their outstanding work and incredible dedication to the turbulence verification module redesign for RTVS. In a very short time, the group re-engineered the turbulence verification portion of RTVS by restructuring the data ingest, relational database, and access to the results through the web. They worked as a team under very tight deadlines. Not only did they complete the entire redesign of a major RTVS component; they did it while also supporting a turbulence algorithm verification effort for the formal FAA/NWS Aviation Weather Technology Transfer process. This group's work will form the basis for the re-architecture of the entire Real Time Verification System."

CIRA employees who are involved with the RTVS include **Sean Madine, Missy Petty, Nick Matheson,** and **Dale Betterton.**

Correction

In the Outreach issue of the CIRA Newsletter ***(Vol. 24) it was stated that Evan Polster was the technical lead for the FX-Net program. While Evan is a valuable member of the project, Jebb Stewart is the technical lead for the FX-Net and W4 projects.***

NOAA 2005 ESRL/GSD Web Awards

Jeff Smith and **Glen Pankow** were recently recognized for their innovative achievements in web technology applications with the 2005 ESRL/GSD Web Awards:

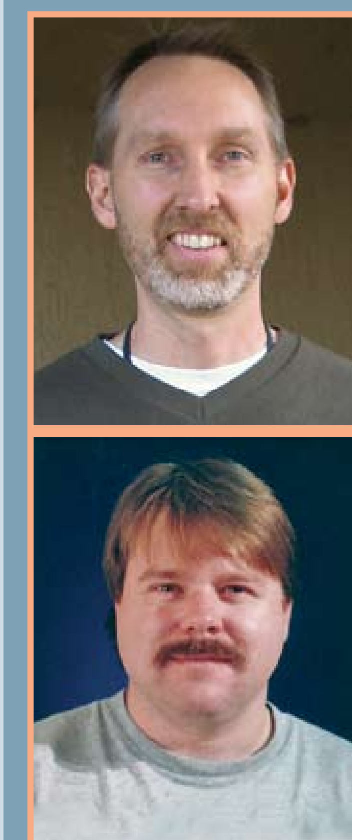
Jeff Smith *(Aviation Branch – Advanced Computing Section)*
Site: WRF Portal – Best New Site

WRF Portal is a Java GUI application that simplifies the configuring and running of WRF models. It includes the WRFSI GUI Tool that allows you to graphically select and define your domain. Additionally, WRF Portal allows you to see the differences between two different model configurations, it tracks the progress of the model run, and it searches your past configurations.

Glen Pankow *(Information and Technology Services – Data Systems Section)*
Site: GRIB Data Viewer – Best Internal Use

Information and Technology Services (ITS) retrieves data in the World Meteorological Organization's GRIdded Binary (GRIB) format from a disparate set of providers, processes these and other GRIB data produced within ITS, and stores them short term on an NFS appliance and long term on the Mass Store System (MSS).

This gribviewer application provides an interface to browse the GRIB holdings currently stored on the NFS appliance. Near real-time data files may be browsed, and in addition, stub files of data no longer being actively retrieved may be browsed.



From top: Jeff Smith and Glen Pankow

CIRA COMMUNIQUÉ

From top: Gerald Browning, Mark DeMaria, Sonia Kreidenweis, and Graeme Stephens

CIRA's First Research Scientist Emeritus

In recognition of **Dr. Gerald Browning's** long and extremely high-quality research contributions to CIRA, the title of Research Scientist Emeritus was granted to Browning by Director Vonder Haar this past fall. This marks the first time CIRA has awarded this prestigious designation to one of its employees.

Since joining CIRA in 1991, Dr. Browning has successfully applied mathematical theories to solve many operational numerical weather and oceanic prediction problems. The results of his cutting-edge research are published in numerous peer-reviewed professional mathematical, atmospheric science, and oceanography journals. Presentation of the 1998 NOAA Environmental Research Laboratories' Outstanding Scientific Paper Award for Dr. Browning's (and Professor Heinz Kreiss') manuscript entitled "The Role of Gravity Waves in Slowly Varying in Time Mesoscale Motions" was one of the highlights of his 14-year collaboration with NOAA and FSL.

Notes of Note from the Department of Atmospheric Science

Dr. Sonia Kreidenweis, a CIRA Fellow and Professor of Atmospheric Science, received the Outstanding Professor Award for 2005 in the Department of Atmospheric Science, CSU. Her dedication to teaching, advising and research was recognized by the students and the staff and faculty of the Department.

Dr. Graeme Stephens, another CIRA Fellow and Professor of Atmospheric Science at CSU, was recently named a fellow by the American Association for the Advancement of Science, or AAAS, the world's largest scientific society. According to the announcement, Dr. Stephens was selected for "his numerous contributions to research in atmospheric radiation and the use of remote sensing in climate studies and for scientific leadership and service to the atmospheric sciences and global change research communities."

RAMM Branch Leader Wins Prestigious NOAA Award

Dr. Mark DeMaria, NESDIS/RAMM Branch leader at CIRA and CSU Department of Atmospheric Science graduate, has recently received the NOAA Silver Medal. This award is the second highest honorary award given by NOAA for exceptional performance. According to NOAA, "to warrant a Silver Medal, a contribution must focus on qualitative and quantitative performance measures reflected in the Department's Strategic Plan and be identified in one of the following areas: leadership, personal and professional excellence, scientific/engineering achievement, organizational development, customer service, administrative/technical support, heroism."

Dr. DeMaria was honored along with Dr. Michelle Mainelli of NOAA in their collaborative effort to improve the operational intensity forecast tool known as the Statistical Hurricane Intensity Prediction Scheme (SHIPS). This statistical model was significantly improved by the incorporation of input from the geostationary and polar orbiting satellites. Thanks to their efforts, SHIPS became operational after two years of testing and has become an important tool for the busy Atlantic hurricane season.

Colorado Senator Visits CSU

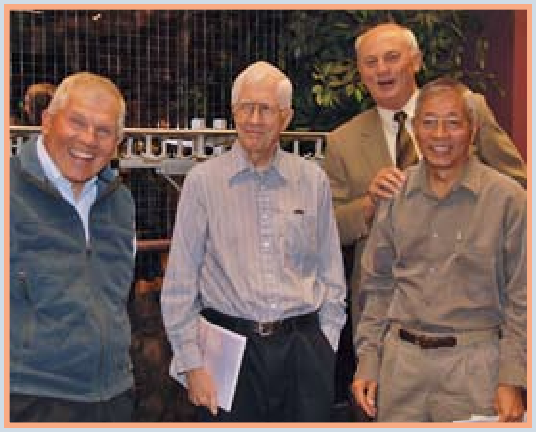
CIRA Deputy Director Ken Eis (left) was among a handful of CSU officials to brief Colorado Senator Ken Salazar (center) on atmospheric research at the university (both at CIRA and at the Department of Atmospheric Science).

CIRA Celebrates, Recollects Its 25-Year History

CIRA celebrated its 25th Anniversary on September 22, 2005. Invited guests included employees and esteemed colleagues who recalled their association with CIRA over the years and explained what CIRA has meant to both its supporters and to Colorado State University. Speakers at the celebration included Sandra Woods, Dean of the College of Engineering, CSU; John Cortinas, Cooperative Institute Program Manager for NOAA; Sandy MacDonald, Director, NOAA/Global Systems Division; Bret Schichtel, Affiliated Scientist with the National Park Service; Kathi Delehoy, CSU Associate Vice President for Research and Information Technology; and Steve Rutledge, Professor/Department Head, Department of Atmospheric Science/CSU.

CIRA was formally established on September 12, 1980 when the official Memorandum of Understanding with the National Oceanic and Atmospheric Administration (NOAA) was signed. The initial stated purposes for the institute were: 1) To improve the effectiveness of research and graduate-level teaching through close collaboration of the two parent organizations; 2) To serve as a focal point for cooperation in specified research programs by scientists from Colorado, the Nation, and other countries; and 3) To train personnel for research in the atmospheric sciences, and to accumulate experience with multifaceted research programs.

CIRA has certainly met, and far exceeded, its original goals. Involvement with research in such diverse areas as Global and Regional Climate Studies, Local and Mesoscale Area Weather Forecasting and Evaluation, Cloud Physics, Applications of Satellite Observations, Air Quality and Visibility and Numerical Modeling just to name a few, have contributed to the growth and continuity of CIRA over the years. The importance of partnerships has been demonstrated at CIRA through successful research with NOAA, the National Park Service, the EPA, NASA, NSF, the DoD Army Research Office, and the Office of Naval Research among other partners. With ongoing advances in science, CIRA readily looks forward to many years of research and exploration ahead.



From left, Drs. Bill Cotton, Paul Mielke, Tom Vonder Haar, and Cliff Matsumoto at the 25th anniversary celebration of CIRA's inception.

All of the invited guests enjoyed a catered luncheon at the Lincoln Center in Old Town Fort Collins. Speakers took their turn on the dais to offer their words at this important milestone in CIRA's history. Dr. Woods applauded CIRA's work and emphasized, "The College of Engineering values partnerships and excellence. The contributions of CIRA's faculty, staff, and students to our understanding of the atmosphere and the environment are extraordinary. This is reflected in the excellent scholarship that originates within CIRA. Thank you for the benefits that CIRA has provided to our students, but also the benefits to our faculty and staff."

Entertainment was provided by CIRA Research Associate, Don Reinke, who gave a witty presentation about the history and founding of the institute. Guests also enjoyed flipping through early photographs of CIRA personnel. The Director and founder of CIRA, Dr. Tom Vonder Haar, was also presented with an official CIRA branding iron to be passed on to future directors.

For more information on CIRA, please visit www.cira.colostate.edu.

Service Milestones

Please congratulate the following employees for reaching milestones of service to CIRA/CSU during FY 2005-2006:

Cynthia L. Combs, 15 years of service
Marilyn Watson, 15 years of service
Renate L. Brummer, 10 years of service
Young S. Chun, 10 years of service
David R. Cismoski, 10 years of service
Randall S. Collander, 10 years of service
John F. Dostalek, 10 years of service
Gracelyn J. Edwards, 10 years of service
James W. Fluke, 10 years of service
John M. Forsythe, 10 years of service
Jim T. Frimel, 10 years of service
Brian D. Jamison, 10 years of service
Joseph A. Kankiewicz, 10 years of service
Tom B. Kent, 10 years of service
Stanley Q. Kidder, 10 years of service
Sean Madine, 10 years of service
Scott O'Donnell, 10 years of service
Robin A. Paschall, 10 years of service
Mary Sue Schultz, 10 years of service
Edward J. Szoke, 10 years of service
Ning Wang, 10 years of service

NON-WEATHER HAZARDOUS INFORMATION

The HazCollect System

MarySue Schultz and Woody Roberts*

Introduction

In the 2004 Fiscal Year Budget, President Bush requested funds to develop an automated method of collecting and disseminating non-weather hazardous event information to the public. Seventeen different types of hazardous events would need to utilize the new system, including Earthquake and Avalanche Warnings, Hazardous Materials and Radiological Hazard Warnings, and Amber Alert messages.

The Department of Homeland Security sponsored a project to develop the HazCollect system, with the concept of combining existing Emergency Management (EM) technology with existing weather warning technology to accomplish the goal. The EM software selected for the project was the Disaster Management Interoperability Services (DMIS) tool kit, developed by Battelle Laboratories. The weather warning system selected was AWIPS, currently used for issuing weather warnings at the National Weather Service Forecast Offices (WFO). The DMIS tool kit was already in use for interaction and coordination within the emergency management community. AWIPS already had the capability of sending weather warnings to the public via NOAA Weather Radio and the NOAA Weather Wire Service.

A number of organizations were involved in developing the HazCollect system. Battelle Laboratories, a global technology and science enterprise, was responsible for adding HazCollect capabilities to the DMIS software. CIRA and the NOAA/ESRL Global Systems Division (GSD) were responsible for the design and implementation of the AWIPS enhancements; the NWS Systems Operations group was responsible for modifying the NOAA Weather Radio software, also part of AWIPS. Northrop Grumman Information Technology (NGIT) was responsible for developing the HazCollect Server, an important interface between DMIS and AWIPS. Battelle, CIRA, GSD, NGIT and Raytheon participated in the end-to-end testing that was performed to verify that all parts of the system worked correctly.

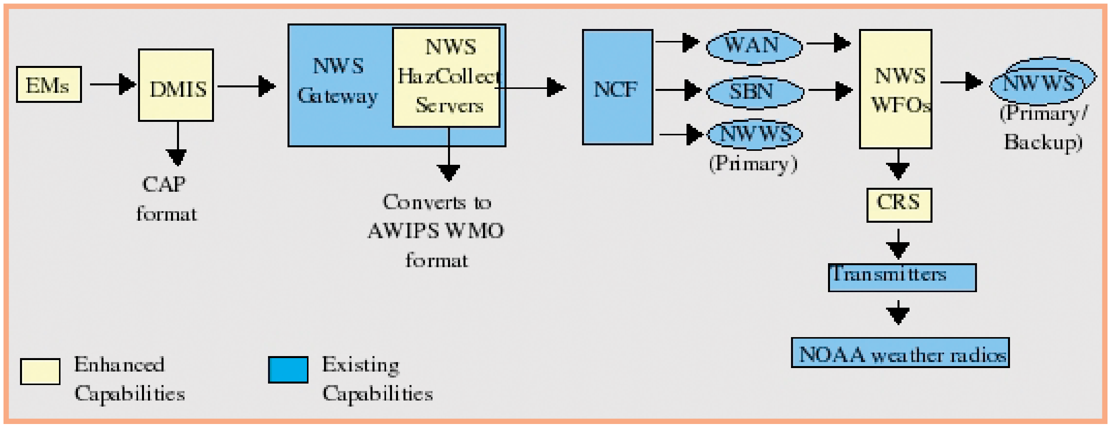
HazCollect System Design

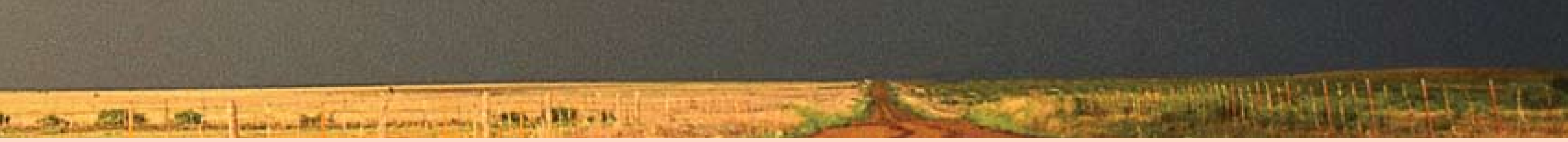
The HazCollect system has three components: the DMIS tool kit, the HazCollect Server, and the AWIPS software. The DMIS software will be installed on PCs at emergency management sites throughout the United States. The DMIS client provides emergency managers with a user interface for creating emergency messages and transmitting them to the HazCollect Server. The DMIS software also authenticates users to prevent invalid messages from being distributed. The HazCollect Server is located at the NWS Telecommunications Gateway in Silver Spring, MD. The Server routes the messages it receives from any DMIS site to the Network Control Facility (NCF) for distribution to the WFOs. The AWIPS software running at the WFOs stores HazCollect messages in a local database and forwards them to the site's primary and backup NWWS uplink sites. AWIPS also formats the messages for voice-simulated broadcast and sends them to the Console Replacement System (CRS) located at the WFO. The CRS determines which NOAA Weather Radio transmitters should receive the messages, and then sends the messages to the transmitters. Figure 1 shows a diagram of the HazCollect System components.

DMIS Interface

The DMIS user interface is designed to provide users with an intuitive and efficient mechanism to enter the necessary information for generating an emergency message. Figure 2 shows an example of the DMIS user interface. Whenever

Figure 1.
HazCollect System components





possible, pull-down menus are used to present predetermined lists of options. Space is provided for additional plain language alert detail.

Once a message is generated, a window appears, alerting the user that this message will be broadcast to the public. The alert window allows the user to review or modify the text before it is transmitted, or to cancel the message (Figure 3). As was previously noted, prior to the HazCollect development activity, the DMIS was used primarily for interaction within the emergency management community and not for broadcasting messages to the public. Thus, it was important to put safeguards in place so users would not inadvertently transmit warnings to the public.

The DMIS produces messages in Common Alert Protocol (CAP) format. The messages are sent to the HazCollect Server where they are converted to WMO format. This conversion represents an important functionality: it allows the CAP messages generated on DMIS or other vendor systems to be disseminated via NOAA/NWS systems. CAP is the emerging emergency management and public warning format, and WMO is the meteorological industry format.

AWIPS Interface

The AWIPS software at the WFOs receives HazCollect messages from the NCF over the existing NWS transmission networks that deliver weather products to the WFOs: the Satellite Broadcast Network (SBN) and the Wide Area Network (WAN). Once a message has been received and stored in the AWIPS database, the message header is checked to determine whether the local office should broadcast the message. If so, the HazCollect transmission software executes automatically, sending the message to the NWWS, formatting it for broadcast on NOAA Weather Radio, and sending it to the appropriate NWR transmitters. No manual interaction with the system is necessary.

Forecasters at the WFOs are notified of HazCollect transmissions by means of red banner boxes displayed on the AWIPS workstations (Figure 4), along with audible alarms. The text displayed in each box identifies the product, and notes that it will be sent to the NWWS and NWR. When this notification occurs, forecasters can display the warning message on their AWIPS workstations to see what type of warning has been issued for their area. If errors are encountered during transmission, another red banner box is displayed, alerting WFO staff that there has been a problem, and allowing them to notify the appropriate emergency management site. This is an important capability, because there is no

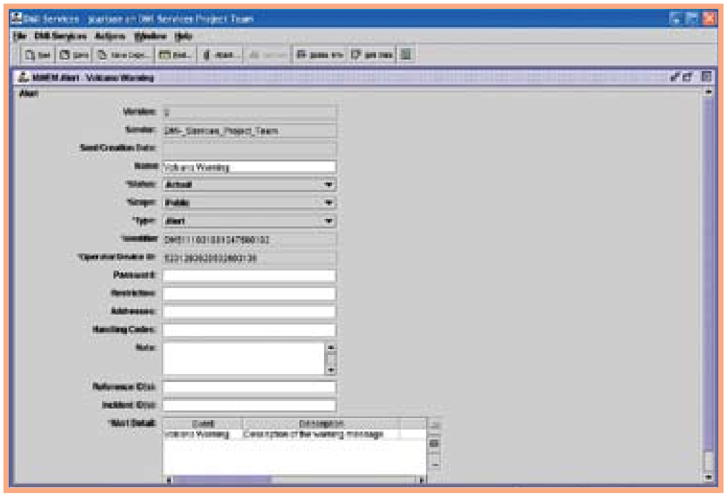


Figure 2. DMIS User Interface

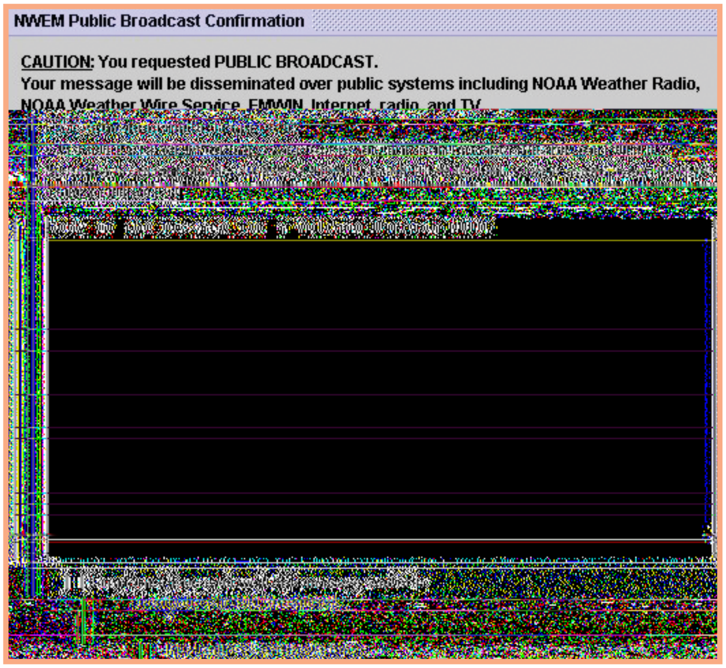


Figure 3. DMIS Alert Window

** Woody Roberts is a NOAA researcher with the Global Systems Division of the Earth System Research Laboratory, Boulder, Colo.*

NON-WEATHER HAZARDOUS INFORMATION

Table 1. Non-Weather Emergency

911 Telephone Outage Emergency
Avalanche Warning
Avalanche Watch
Child Abduction Emergency
Civil Danger Warning
Civil Emergency Warning
Earthquake Warning
Fire Warning
Hazardous Material Warning
Evacuation Immediate Warning
Law Enforcement Warning
Local Area Emergency
Nuclear Power Plant Warning
Radiological Hazard Warning
Shelter In Place Warning
Volcano Warning
Administrative Message / Follow-up Statement

mechanism for sending automated acknowledgements from AWIPS to the issuing EM site, verifying that AWIPS has received and transmitted a particular message.

HazCollect Development and Testing

The HazCollect project used a phased approach for development and testing. Phase I involved developing a proof of concept system. The software allowed one message to be composed on a DMIS client and sent through the rest of the system. The Phase I testing involved generating a message on the DMIS client, transmitting it to the HazCollect Server and NCF, sending it to an AWIPS test site, and distributing it to NWWS and NWR test sites. This test verified that CAP format could be translated successfully to WMO format, demonstrated that a single message type could be handled automatically within the required amount of time, and demonstrated that the hardware configuration was viable.

Phase II involved developing the full capability for all message types, which are listed in Table 1. Phase II testing was more extensive; it verified that all of the HazCollect message types could be generated and distributed to the NWWS and NWR successfully. AWIPS systems located at six of the NWS Regional Headquarters were involved, in addition to several AWIPS test systems. Numerous procedural functions and operational scenarios were tested, including message updates, cancellations, and corrections. Tests were performed to assure that messages could be sent to multiple sites and that messages would only trigger at the appropriate sites. During the testing, great care was taken to assure that no messages would be sent out inadvertently by operational systems, since these test warnings could cause alarm if broadcast to the general public.

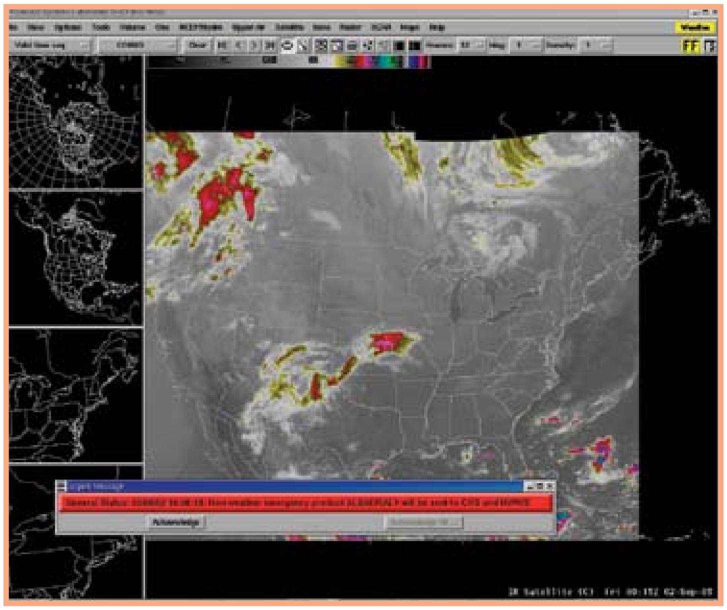


Figure 4. Red Banner Box

Event Types

Phase I and II development and testing have been completed. The next phase involves Operational Acceptance Testing (OAT), which will be conducted by the NWS during May and June 2006. After OAT is finished, a team composed of NWS, emergency management and Battelle personnel will begin the installation phase, which will involve training emergency managers in the use of the DMIS user interface and conducting end-to-end tests between the emergency management sites and their local WFOs.

Future Plans

There are plans to extend the HazCollect capability in the next few years to disseminate national messages to all parts of the country in case of a national emergency. There are also plans to incorporate additional EM toolkits, to give emergency managers a choice of user interfaces for composing their emergency messages. CIRA, GSD, NWS and Battelle will be involved in implementing these future plans.

Summary

The HazCollect system will provide a new and efficient capability for broadcasting critical non-weather event messages to the public using enhancements to current operational systems. Emergency management and weather warning technology were successfully used together to disseminate non-weather emergency warnings to the public. The overall system design worked well; communications between components were stable and reliable, messages in CAP format were converted to WMO format, and were then processed by the AWIPS systems. This development activity successfully brought together talented development organizations to complete this task. Once deployment and training have been completed, critical non-weather messages should be available to the public as quickly as critical weather messages are today.

In Search of Above-Surface Humidity Measurements: The Potential of TAMDAR

Ed Szoke

Forecasts from both numerical models and humans are often hindered by a lack of knowledge of the moisture details above the surface, so critical to many types of weather forecasts. Satellite measurements have improved over the years, but still cannot resolve the details of the vertical distribution of moisture to match what is measured by the rawinsonde launches (hereafter RAOBs) twice per day at selected sites around the world-the standard for detailed moisture measurements above the surface. Very accurate measurements of the total water vapor above the surface are provided through GPS measurements (see http://gpsmet.noaa.gov/jsp/index.jsp), but not its distribution in the vertical. Although still the standard for moisture measurements in the vertical, the limitations of the sounding network include the significant variations that can occur horizontally between the widely-spaced RAOBs, and the changes that can occur over the 12-h period between balloon launches. A lot can happen in this 12-h period that can make a forecast go awry! Recently developed humidity sensors being tested on selected regional commercial airlines give new hope to filling this important void. This article reviews evaluation activities of this new data by CIRA and Government researchers at the Global Systems Division (GSD) of NOAA's Earth System Research Laboratory (ESRL) in Boulder.

The new sensors are called TAMDAR, for Tropospheric AMDAR (Aircraft Meteorological Data Relay). AMDAR is the international name for aircraft data that have been called ACARS (for Aircraft Communication and Reporting System) in the United States (see the overview article by Moninger et al., 2003), the automated wind and temperature reports from commercial aircraft that have been available now for a number of years. Generally, AMDAR is concentrated at commercial jet cruising altitudes above 30,000 feet AGL, with extensive coverage over the Continental United States (CONUS). There is considerably less data below 20,000 feet, generally in descents into and ascents from major airports. Two major differences between the AMDAR observations that are currently available and the TAMDAR observations that have been available on an experimental basis since late 2004 are: 1) humidity measurements are made (in addition to temperature and wind), and 2) data are available at lower altitudes and with greater ascent/descent coverage than AMDAR, since the experiment uses regional aircraft that both cruise at lower altitudes and fly into smaller airports. The TAMDAR demonstration targeted aircraft in the Great Lakes area, and was called the Great Lakes Fleet Experiment (GFLE), rather than the full CONUS, with major hubs at Minneapolis, Detroit, and Nashville.

TADMAR is a self-contained unit and so does not rely on the equipment of the aircraft carrying the TAMDAR unit for pressure, temperature, and position information. See Daniels et al. (2004) for a full description of the TAMDAR sensor and the testing it was subjected to before deployment. The sensor is capable of measuring temperature, relative humidity, pressure and icing. It can compute pressure altitude, indicated air speed, true air speed, turbulence (eddy dissipation rate) and winds. The National Aeronautics and Space Administration (NASA) Aviation Safety Program funded the development of the TAMDAR sensor by AirDat, LLC of Raleigh, North Carolina (Daniels et al., 2006).

Over the past year or so, there has been an intensive effort by a number of groups to examine many aspects of the TAMDAR data, including an assessment of its overall quality, use by National Weather Service (NWS) forecasters, and impact on numerical weather prediction (NWP) models. At the recent AMS Annual Meeting in Atlanta (January 2006), much of this research was discussed in sessions devoted to TAMDAR at the 10th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS) and at the 12th Conference on Aviation Range and Aerospace Meteorology. CIRA researchers involved in the TAMDAR collaboration at ESRL/GSD include Ed Szoke, Tracy Smith, Brian Jamison and Randy Collander. In October 2005 at a NASA Aviation Weather Accident Prevention Project Review meeting in Virginia, Bill Moninger, lead scientist for ESRL/GSD's TAMDAR efforts, received an award and GSD/CIRA team members received certificates for "outstanding contributions to aviation weather safety research and development." In this paper, some of this work which continues into FY06 will be described.

Assessment of TAMDAR Quality

Initial efforts were focused on assessing the overall quality of the TAMDAR data under funding by the Federal Aviation Administration (FAA) and NASA. Thanks to the efforts of Bill Moninger of ESRL/GSD, TAMDAR from the GLFE began arriving in real-time at GSD in late September 2004. The data can be plotted in plain view mode as well as sounding mode (for comparison with

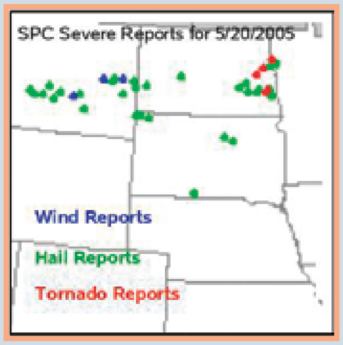


Fig. 1. Severe reports for 20 May 2005 from the Storm Prediction Center (SPC).

TADMAR is a self-contained unit and so does not rely on the equipment of the aircraft carrying the TAMDAR unit for pressure, temperature, and position information.

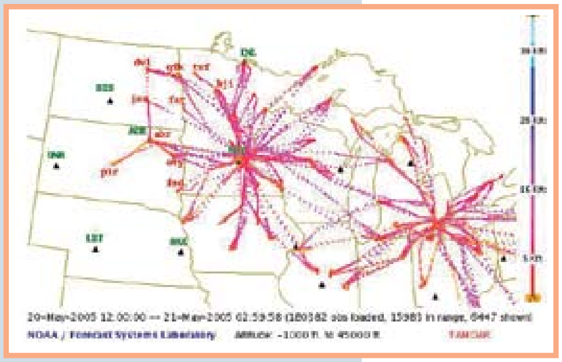


Fig. 2. Plan view of available TAMDAR data for 20 May 2005. Triangles indicate RAOB locations, labeled with upper case green letters, while airports within the study area are labeled with lower-case red letters. TAMDAR flight data shown is from 1200 UTC 20 May through 0300 UTC 21 May.

RAOBs) through a web interface at http://acweb.fsl.noaa.gov/java/. Through this web interface at GSD beginning in October 2004, we started to assess the overall quality of the data, especially by making comparison with nearby RAOBs. Assessment activities were also done within some NWS Weather Forecast Offices (WFOs) in the experiment area. Another assessment activity led by the University of Wisconsin-Madison focused on launching CLASS soundings coordinated with TAMDAR flights out of Nashville, Tennessee. Generally, the focus of these studies was on the quality of the relative humidity measurements, but temperature and wind were also assessed. Other evaluation efforts at NCAR in Boulder focused on the turbulence measurements.

Some overview articles on initial efforts were presented at the AMS 11th Conference on Aviation, Range and Aerospace Meteorology held in Hyannis, Massachusetts in October 2004 (see, for example, Moninger et al., 2004). The following spring (April 2005), a workshop was held in Boulder where the various groups got together to discuss the assessments to that point. Feedback to the sensor developers at such workshops as well as other frequent interactions with AirDat have been critical in improving the quality of the data from TAMDAR. The quality was sufficient to begin a TAMDAR impact study in January 2005 using parallel versions of the Rapid Update Cycle (RUC) model at 20 km horizontal grid resolution, run with and without TAMDAR. Before discussing some results of this assessment, we will examine the use of TAMDAR by NWS forecasters.

At GSD one of our tasks was to put together some examples of how TAMDAR might be used to aid the forecaster as additional potential training aids for NWS forecasters.

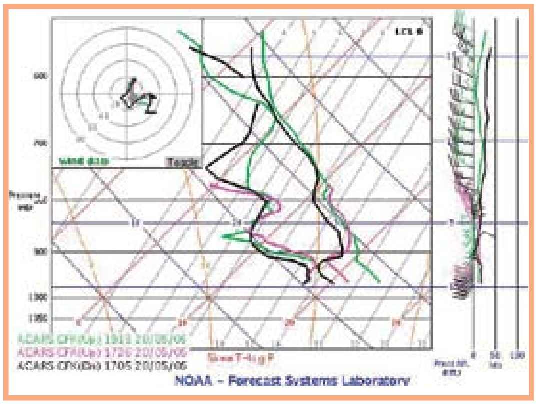
Use of TAMDAR by Forecasters

The Green Bay, Wisconsin WFO has taken the lead in promoting awareness of the GLFE and TAMDAR to forecasters at offices where the data could be of use. The Central Region of the NWS organized training materials, a user survey, and access to TAMDAR can be found at http://www.crh.noaa.gov/tamdar/index.php. On this site are a number of examples of how the data can be used to better forecast weather for both aviation and public concerns, from severe weather potential, to precipitation, fog and general cloudiness. In addition to some case study examples, the site lists instances where the forecaster noted the use of TAMDAR in their Area Forecast Discussion (AFD), which is a narrative issued at least twice per day by every NWS WFO to explain forecast reasoning and other forecast concerns. Mention of use in an AFD is considered a good way to document that certain data is being used, particularly if it is new to the forecaster, though, of course, if something is not mentioned, the corollary is not necessarily true.

At GSD one of our tasks was to put together some examples of how TAMDAR might be used to aid the forecaster as additional potential training aids for NWS forecasters. A number of cases were assembled, mostly for convective weather, and a particularly interesting case from 20 May 2005 is illustrated here. The 20 May case illustrates how rapidly the environment can change from that measured by the standard 1200 UTC RAOB, especially in the springtime environment of the High Plains. Fig. 1 shows the severe weather reports for 20 May (partial map courtesy of NOAA's Storm Prediction Center (SPC) in Norman, Oklahoma). As shown in Fig. 2, the eastern Dakotas were at the western edge of the TAMDAR flights. Storms began developing across Montana by late morning into early afternoon, with quite a number of wind and hail reports mainly during the afternoon. The strongest storms were found in eastern North Dakota later in the afternoon with at least one supercell storm and several tornadoes produced from 2100 through 2230 UTC (Fig. 3).

A series of TAMDAR soundings (Fig. 4) from Grand Forks (gfk in Fig. 2), North Dakota illustrates how rapidly the environment was changing as strong southerly flow advected moisture northward. Over a period of a little over an hour, the temperatures in the lower levels warmed considerably, as might be expected, reducing the inhibiting inversion. But at the same time, the depth of the surface-based moisture increases while maintaining the same mixing ratio. This results in much more Convective Available Potential Energy (CAPE) by 1913 UTC, while at the same time, the Convective INhibition (CIN) is much less. These changes, coupled with increas-

Fig. 3. Regional low-level radar reflectivity at 2200 UTC.



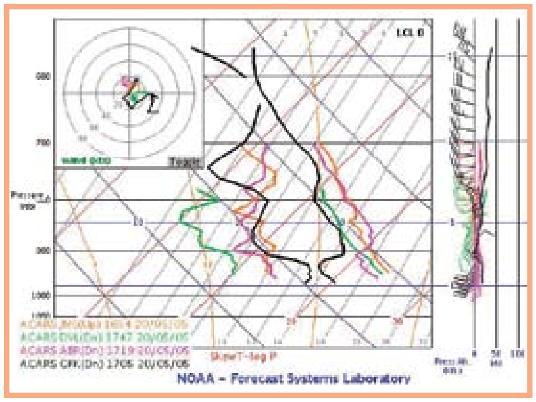


Fig. 4 (left). Series of TAMDAR soundings from Grand Forks, North Dakota on 20 May.

Fig. 5 (right). Sounding comparison for several TAMDAR soundings around 1700 UTC in the area of interest.

ing low-level vertical wind shear, set up a tornadic environment in eastern South Dakota where one did not exist at morning RAOB time. One would not have been able to know that the moisture depth was actually increasing, rather than the typical mixing out of low-level moisture, without the TAMDAR data.

In addition to the value added by having more above-surface temperature and humidity measurements over time is the value of observations at greater density than the sparse RAOB network. The variability that can exist in relatively small areas within the spacing of upper-air soundings is illustrated by the set of TAMDAR soundings near the same time in Fig. 5. A huge variation in both temperature and moisture exists over portions of North and South Dakota, creating a range of conditions, even just over the eastern half of North Dakota, from supportive of tornadic storms to not supporting storms at all (at DVL, for example).

The NWS website noted earlier lists other examples of the value of TAMDAR soundings noted by different WFOs. The soundings have also attracted the interest of the SPC (Storm Prediction Center), where they often need to call for special soundings to be launched during severe weather outbreaks (for example, 3-h soundings were launched at Springfield, Missouri during the recent 12 March 2006 tornado outbreak). NOAA's Aviation Weather Center (AWC) in Kansas City, Missouri, responsible for aviation related forecasts on the CONUS scale, also use TAMDAR (see Paper 9.6 by Fischer in the TAMDAR session of the 10th IOAS-AOLS Conference at the 2006 AMS Annual Meeting).

TAMDAR Impact on NWP

It has been fairly straightforward to find examples of the usefulness of TAMDAR for forecast situations based on a subjective look at different cases. An important question, often in the eyes of funding agencies, is whether the data adds value to objective forecasts from numerical models. In order to address this question, CIRA and federal researchers at GSD have been running two versions of the RUC model at 20-km horizontal grid resolution out to 12 h since January 2005, with the only difference being that one has TAMDAR while the other does not. An interactive webpage maintained by Bill Moninger of GSD allows for easy comparison of standard scores for verification of analyses and forecasts against RAOBs for the eastern half of the CONUS region and a subset encompassing the area where TAMDAR is available (see http://ruc.fsl.noaa.gov/stats/inter.html).

A summary of the first year of statistics was presented by Stan Benjamin of ESRL/GSD in Paper 9.8 in the TAMDAR session of the 10th IOAS-AOLS Conference at the 2006 AMS Annual Meeting (Benjamin et al., 2006). While at times some of the scores have varied and the improvement using TAMDAR can be marginal, the objective scores indicate

- greatest improvement in short-range forecasts (out to 3-h)
- improvement in wind forecasts from low levels (850 mb) up through 500 mb
- temperature and relative humidity improvement most consistently only at 850 mb
- less impact or even somewhat negative impact at 700 and 500 mb
- more impact for the Great Lakes area domain than for the larger domain.

Monitoring the scores has been valuable in identifying problem sensors or other instrument issues with ascent versus descent that have been passed back to AirDat, resulting in an overall improvement in reliability of the sensors during the past year. In addition to the real-time runs, we have also been involved in retrospective runs where different impact studies can be done.

While objective scoring of model forecasts is valuable for determining impact, it can be useful and enlightening to examine subjectively individual forecasts,

In addition to the value added by having more above-surface temperature and humidity measurements over time is the value of observations at greater density than the sparse RAOB network.

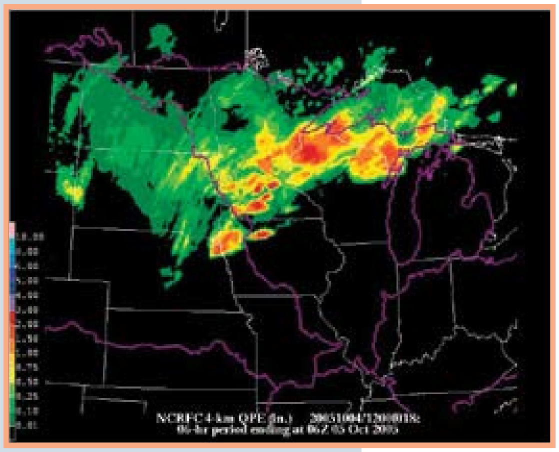


Fig. 6. NPVU precipitation analysis for the 6-h period ending 0600 UTC 5 October, in inches.

concentrating on specific weather events moving through the TAMDAR area where one would expect that the data should add value to the model forecast. Such subjective case studies have been part of my more recent work with TAMDAR and were presented at the AMS 10th IOAS-AOLS Conference (Szoke et al., 2006, Paper 9.9), as well as at another TAMDAR workshop held in Boulder in August 2006. (Presentations from this workshop are available at http://acweb.fsl.noaa.gov/TAMDAR/2005_08_24_mtg/.)

Cases were sought where systems producing precipitation were moving across TAMDAR area, focusing on 6-h forecasts of precipitation ending at either 0000 UTC or 0600 UTC, since these forecasts would incorporate the most TAMDAR data, which generally maximized from about 1200 UTC to 0200 UTC. The forecasts ending at 0000 UTC (from the 1800 UTC runs) were especially attractive as one could then make direct comparisons between the 0000 UTC RAOBs and the forecast soundings.

One such case is a convective event from the Upper Midwest in early October 2005, with heavy rains falling near a stalled front lying across Minnesota and northern Wisconsin. Precipitation estimates from the National Precipitation Verification Unit (NPVU) for the 6-h period ending at 0600 UTC on 5 October 2005 are shown in Fig. 6. Of particular note are the very heavy rains across northwest Wisconsin (over 2 inches in 6 h) and the sharp southern cutoff to the precipitation. A comparison of the 6-h precipitation forecasts from the RUC runs with and without TAMDAR is shown in Fig. 7. The forecast for the RUC run that uses TAMDAR does a much better job predicting the heavy precipitation in northern Wisconsin, and also captures the very sharp southern edge to the precipitation.

Forecasts from the 1800 UTC also were superior for the RUC run that used TAMDAR, and two sounding forecasts compared to 0000 UTC RAOBs are shown in Fig. 8. The forecast sounding for Peoria, Illinois (ILX) from the run using TAMDAR is much closer to the observed RAOB at lower levels, and quite a bit moister than the run without TAMDAR that failed to forecast enough heavy precipitation. The sounding comparison at Detroit, Michigan (Fig. 8b) is even more dramatic, with an erroneous dry layer from the run without TAMDAR.

Other convective and rain cases are shown in the workshop presentation and conference paper. Winter cases were also gathered (though it was difficult to find very many) and a couple of these are shown in the conference presentation, which can be downloaded from the AMS site for the Annual Meeting at http://ams.confex.com/ams/Annual2006/techprogram/programexpanded_316.htm. A similar improvement was seen in one of the winter cases, with distinct sounding differences noted, as in the early October 2005 case. Some other winter cases failed to show much difference in the forecasts, and, consistent with this, sounding comparisons for these cases generally failed to find any dramatic differences between the forecast soundings from the RUC runs that used TAMDAR and those that did not. In general, an examination of objective scores for the individual cases was consistent with the subjective results, although some of the cases with the most dramatic improvements in the forecast of precipitation noted subjectively, such as the October case illustrated here, did not stand out in the objective scores against RAOBs. This suggests the value in doing both subjective and objective verification.

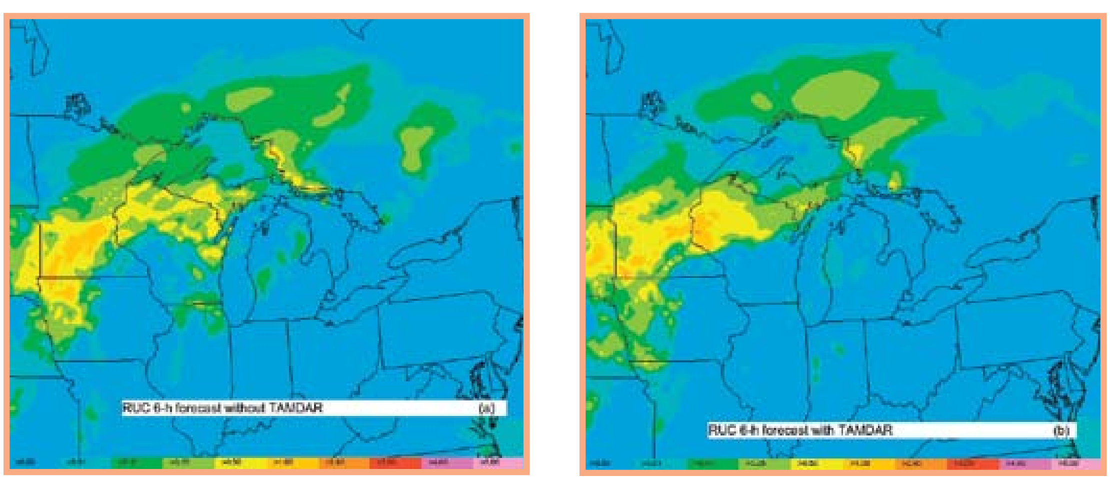
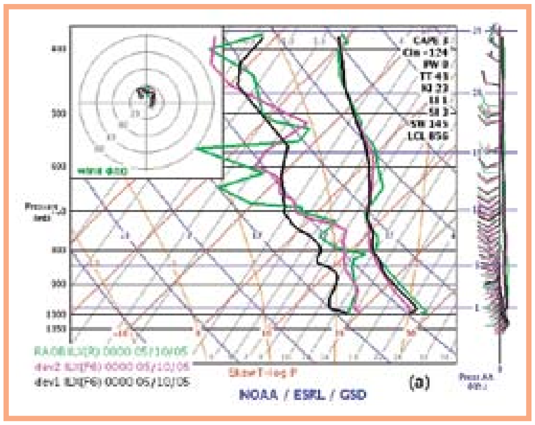


Fig. 7. RUC 6-h forecasts, ending 0600 UTC 5 October, of accumulated precipitation (in) (a) without TAMDAR; and (b) with TAMDAR.



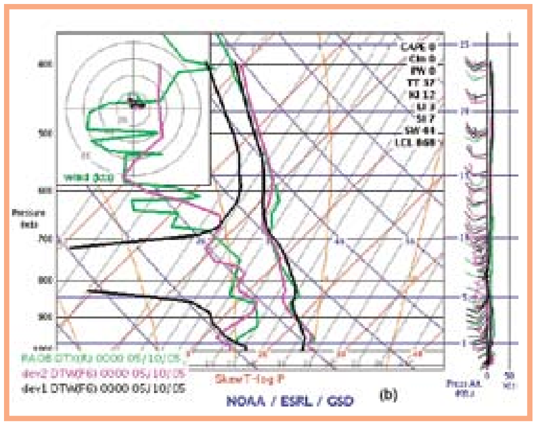


Fig. 8. Comparison of 6-h forecast soundings from the RUC 1800 UTC runs with (magenta, labeled dev2) and without (black, labeled dev1) TAMDAR, compared to observed soundings at 0000 UTC on 5 October 2005 (green, labeled RAOB) at Lincoln, Illinois (ILX, (a)), and Detroit, Michigan (DTW, (b)).

The Future of TAMDAR

What happens next with TAMDAR? At ESRL/GSD, we continue to run the parallel RUC versions, do retrospective studies, and look for particularly interesting cases to examine in more detail. The official test period for the GLFE ended as of January 2006, but the data continues to be made available by the participating airlines and is available through the GSD website. If future funding for the program continues, then the next experimental area added will be across the western states over the next two years, with the most dense area of coverage from the Central Rockies to the West Coast, but some coverage as far east as Denver. The eventual hope would be to have sensors on regional carriers across the entire CONUS, which can be achieved with about 600 aircraft. Should the sensors prove to be reliable and the data valuable, it is hoped that someday, relative humidity measurements will be taken by aircraft worldwide.

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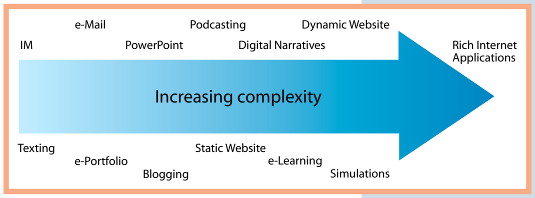
Should the sensors prove to be reliable and the data valuable, it is hoped that someday, relative humidity measurements will be taken by aircraft worldwide.

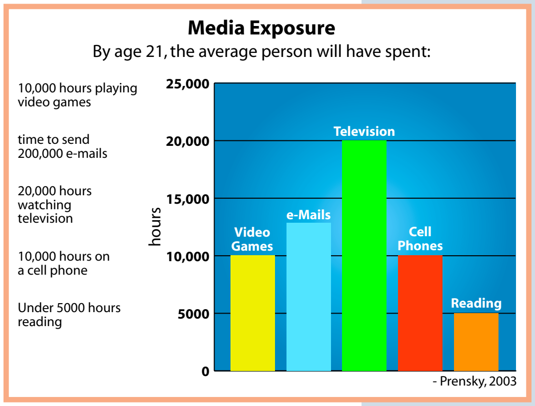
COMMUNITY OUTREACH

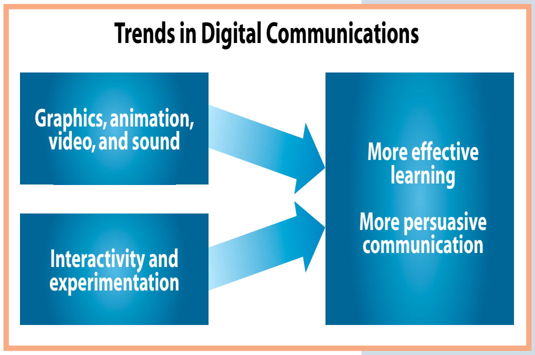
Emerging Technology and Learning Spaces

Julie Winchester

Emerging technologies are challenging communicators in business, industry, and education to create engaging, rich, and interactive content to be delivered remotely through the web, in classrooms, and in specialized on-site learning environments.







In modern life we are constantly connected to some form of technology-based media via the Internet, e-mail, cell phones, and television, in car GPS systems, and through satellite radio. Digital technology provides an unprecedented level of choice and control.

Young people today are growing up digital. They have excellent IT skills and live with an abundance of technology and networks that are incorporated into their academic and social lives. The ability to process massive amounts of information quickly and a learning style that demands entertainment are forcing communicators to rethink how they package information.

As a digital culture, we are no longer passive consumers of information. We demand to be engaged and active participants in learning activities. The digital experience comes with expectations of individualized services and tools, with open and immediate access to media and information. We crave instant feedback and lots of interactivity and collaboration. In a time when the 30-second commercial has lost its power, presentations must be filled with sophisticated, creative, and rich media content to capture and hold our attention. Learning activities that invite experimentation and interaction facilitate a better understanding of ideas and better retention of information.

With these parameters in mind, the National Park Service media group at CIRA set out to design a visitor education program about air quality issues at Sequoia and Kings Canyon National Parks.

Case Study: Air Quality Exhibit Sequoia and Kings Canyon National Parks

The Challenge

The goal is to create an interactive presentation to make visitors aware of a growing air pollution problem in the parks and its effects on people and resources. Because the "learning space" is out-of-doors in the park environment, the content chosen is relative to the parks and surrounding area. As visitors pursue various activities in the parks, they will carry a new awareness of the air quality issues and look for visual evidence of the problems.

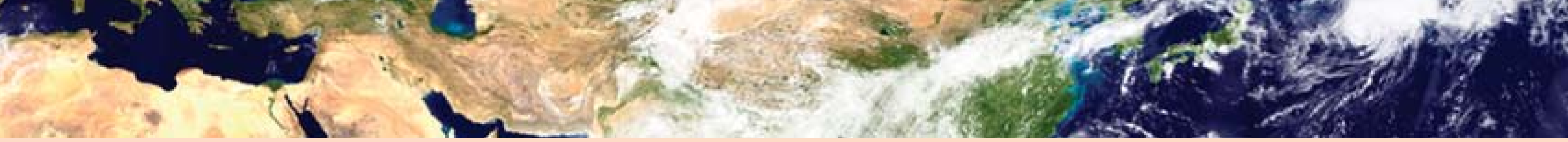
Concepts and ideas are presented in an engaging and entertaining format. Extensive use of rich media (graphics, animation, and video), a user interface that is interactive and allows users to randomly explore a variety of topics, and activities that challenge users to test their knowledge of energy conservation practices are features that will capture and keep the attention of visitors who span a range of age and education levels. In order to appeal to a growing population of Spanish-speaking visitors, there are English and Spanish versions of the program.

The visitor center at Grant's Grove in Kings Canyon National Park is newly remodeled and hosts state-of-the-art presentation technology. The presentation was designed for two touch-screen-enabled computers slaved to two large format LCD flat screen displays. It loads automatically each morning and runs without intervention during the day.

The design team at CIRA is collaborating with park resource management and interpretive staff, using the Internet to share ideas and draft content. Modular design provides an avenue for easy upgrades with technical support from a remote location.

Project Details

Macromedia's Flash MX Professional 2004 software was the perfect solution for this project. Content developed in individual modules is easily updated and can be repurposed for other presentation platforms at a later time. Flash provides a powerful library of pre-scripted tools that facilitates building animations, integrating video, incorporating timers, and adding user interaction, and uses a Unicode text for conversion to several different languages. Flash projects are also easily published to the Internet.



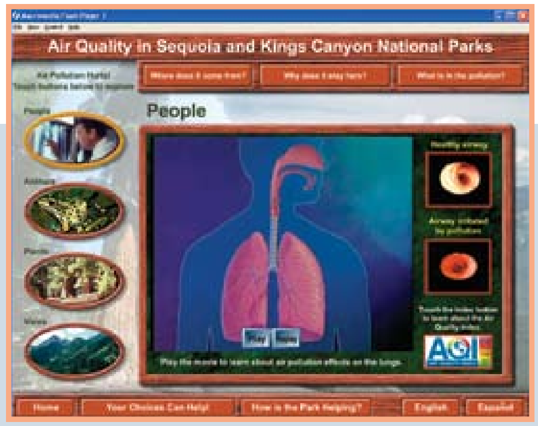


Fig. 1. Home Page

Fig. 2. Air Pollution Hurts – People

Fig. 3. Air Pollution Hurts – Views

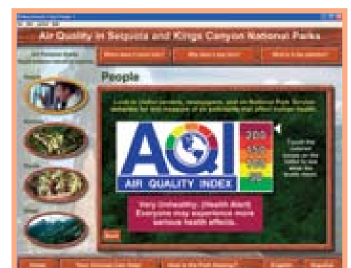


Fig. 4. Air Quality Index

Fig. 5. Research and Monitoring

Giving the user maximum flexibility in choosing topics requires an interface with many ways to access multiple layers of information.

The home page (Fig. 1) allows users to explore how air pollution impacts various resources, look at what the park is doing to solve problems, or choose a fun activity to learn what they can do to lessen pollution in their daily life. Options allow in-depth looks at any subject; however, the interface allows users to easily navigate to other topics from all pages (Fig. 2). An option to change the language of the program is always available.

In the "views" section, visitors can click on a slide show that shows how landmarks disappear as pollution builds up in the San Joaquin valley. As visitors drive to various view points, they should recognize how air pollution limits the distance at which landscape features can be seen and how pollution impairs their inherent scenic beauty.

Another section explores the air quality index by having the user touch the boxes to get definitions of pollutant levels. In areas where photographs are used (Fig. 5), users can get more information by touching any photo icon.

A cartoon segment (Fig. 6) provides a fun learning activity for all ages. In "Our Town", visitors select an area to test their knowledge of energy conservation practices at home, in the car, and in the yard. They answer multiple-choice questions and get immediate feedback. Right answers get green leaves and a positive message, while wrong answers get brown leaves going up in smoke and a negative message. A feedback page for each question has clickable icons for more explanation of conservation practices. The number of green or brown leaves at the end tells visitors how energy conscious they are! There is also a "Recycle Challenge" allowing the user to drag symbols of items we use every day to either the trash or recycle bin.

Animation is used throughout the program to illustrate concepts. In the ozone section (Fig. 7), animation is used to illustrate the differences between the beneficial effects of "good" ozone in the stratosphere and the harmful effects of "bad" or ground-level ozone. Clickable windows show animations of the chemistry taking place in each case. In a discussion about climate change (Fig. 8), animation is used to illustrate how the earth warms as greenhouse gases accumulate. The section describing pollutant transport and wind flow in the central valley (Fig. 9) illustrates how pollutants are trapped, then get washed back and forth between mountain ranges for days before they mix into the upper atmosphere and disseminate. A digital flyover of the central valley in this section gives visitors a better sense of the geography facilitating pollutant buildup.

Summary

The Sequoia and Kings Canyon project is scheduled to open in the new park visitor center in April of 2006. The benefits of modular design are already becoming apparent.

As changes are made to various modules, executable files are created and made available to the park from the CIRA-NPS ftp site. These relatively small upgrades require the park to overwrite only older files. No modification of the larger program is needed.

The program is self paced and the layered nature of the presentation allows visitors to tailor exploration to the amount of time available. This facilitates exploration at either an introductory level or an in-depth look at any topics of interest.

Reviewers looking at draft material have already identified modules that could be repurposed for other applications. By creating a different interface, general information can be given a new look and feel and can be published on the CIRA-NPS or Air Resources Division websites.

Some modules lend themselves to further development as stand-alone projects. For instance, the "What You Can Do" section could be developed with more user activities and extracted as a stand-alone project. This might be a good demonstration project for Earth Day presentations in the community at large.

In an effort to see how effective the presentation is and to gauge user interest areas for future projects, it would be useful to incorporate some tracking variables to see which modules attract users and what depth (or layer) of information is pursued.

See Figures 6-9 on pages 20-21.

COMMUNITY OUTREACH

Emerging Technology and Learning Spaces, continued

Fig. 6. Our Town

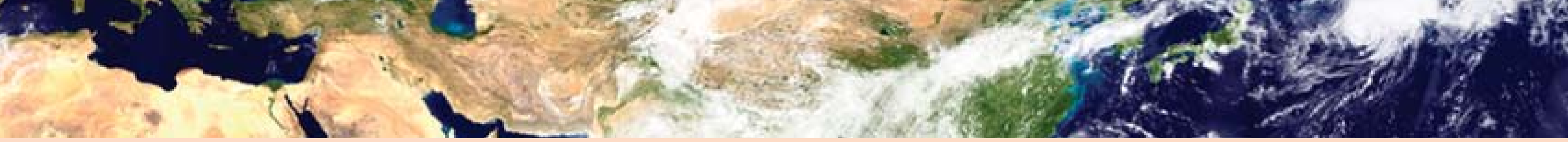
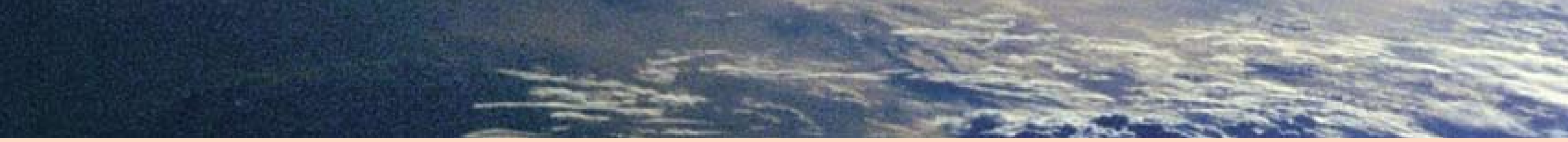


Fig. 7. Ozone

Fig. 8. Climate Change

Fig. 9. Transport



AEROSOL EFFECTS

The Effect of Aerosol on Warm Convective Clouds Simulated in a Large Eddy Model

Hongli Jiang and Graham Feingold

The aerosol-cloud-climate system is a complex one, comprising a myriad of feedbacks that challenge our ability to predict the radiative response of clouds to changes in aerosol. In addition to the direct effect of aerosol on radiation, a host of "aerosol indirect effects" have been proposed. The "first indirect effect" [Twomey, 1974] considers the response of cloud drop size and reflectance to a change in aerosol with reference to a constant liquid water content.

The "second indirect effect" [Albrecht, 1989] proposes that an increase in aerosol will reduce the ability of a cloud to precipitate, increase cloud liquid water, and extend cloud coverage and lifetime. A number of modeling studies have pointed out that even the sign of these responses is unclear [Stevens et al., 1998; Jiang et al., 2002; Feingold and Kreidenweis, 2002] and dependent among others, on temperature, humidity and stability parameters, both in the boundary layer and above [Ackerman et al., 2004; Lu and Seinfeld, 2005].

The "semi direct effect" introduces added feedbacks due to the radiative properties of the aerosol. During the daytime, absorbing aerosol heats the atmosphere locally and reduces the amount of solar radiation reaching the surface [Hansen et al., 1997; Ackerman et al., 2000; Koren et al., 2004], although there is some dependence on the vertical distribution of the aerosol [Johnson et al., 2004]. Over land, the reduction in downwelling solar radiation, and associated decrease in surface latent and sensible heat fluxes, result in further, significant reductions in cloud fraction and LWP, regardless of the vertical distribution of the absorbing aerosol [Feingold et al., 2005].

Table 1. Description of simulations. Na is aerosol concentration; τ_a aerosol optical depth (dry); $\tau_{a,rh}$ is optical depth associated with the hydrated aerosol on the initial RH profile.

EXP	N_a cm^{-3}	τ_a	$\tau_{a,rh}$	Aerosol heating
S1-100	100	0.04	0.05	No
S1-500	500	0.20	0.26	No
S1-1000	1000	0.40	0.53	No
S1-2000	2000	0.80	1.05	No
S2-100	100			Yes
S2-500	500			Yes
S2-1000	1000			Yes
S2-2000	2000			Yes

Model and Case Description

The model is a large eddy model based on the Regional Atmospheric Modeling System [RAMS, version 4.3, Cotton et al., 2003] coupled to a microphysical model described by Feingold et al., [2005]. For a detailed description of the various elements of the model, readers are referred to Jiang and Feingold [2006]. Simulations are based on a sounding on 26 September 2002 at 7:38 LT (11:38 UTC) from a continental site in Brazil (Fazenda) during the Smoke Aerosols, Clouds, Rainfall and Climate (SMOCC) experiment [Andreae et al. 2004]. The simulations are performed for 500 min. The domain size is 6 km x 6 km x 5 km with $\Delta x = \Delta y = 100$ m and $\Delta z = 50$ m. The time step is 2 s. Two sets of three-dimensional simulations were performed, as summarized in Table 1. Set 1 (S1) treats the aerosol as cloud condensation nuclei CCN only. Set 2 (S2) also includes the direct coupling of aerosol heating with the dynamical model.

Simulation Results

S1: No Direct Effects

Time series of the various fields for S1 simulations are shown in Fig. 1. The time series of LWP (averaged only over columns that have LWP > 20 g m^{-2}) shows no clear dependence on Na over the range 100 cm^{-3} < N_a < 2000 cm^{-3} although the increase in aerosol does change the frequency and duration of cloud events. The time series has a number of distinct maxima that are

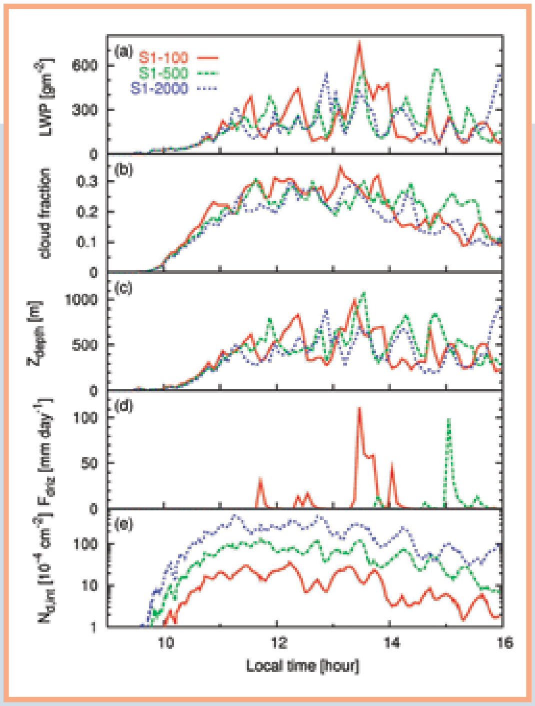


Fig.1. Time series of (a) LWP, (b) cloud fraction, (c) cloud layer depth, (d) surface drizzle rate, and (e) vertically integrated number concentration of droplets.

correlated with higher cloud fraction (Fig. 1b) and a deeper cloud layer (Fig. 1c). The increase in N_a results in higher $N_{d,int}$ (vertically integrated number concentration of droplets). Surface drizzle (Fig. 1d) events occur only when clouds grow deep enough (~700 m), LWP exceeds about 400 g m^{-2}, and then only for the cleaner cases (N_a = 100, 500 cm^{-3}). Surface rain is suppressed for the polluted cases (N_a = 2000 cm^{-3}) because of a reduction in the growth of drops via collision coalescence.

S2: Aerosol-Radiative Coupling

Time series of the various fields for S2 simulations are shown in Fig. 2. Here, LWP, cloud fraction, and cloud depth show distinct decreases with increasing aerosol amounts (Fig. 2a-c), particularly when comparing results for N_a = 100 cm^{-3} and N_a = 2000 cm^{-3}. Precipitation is now suppressed at N_a > 500 cm^{-3}. The domain-maximum w'w' (averaged over the horizontal plane), a measure of the strength of convection, is plotted since $N_{d,int}$ variability is similar to that in S1. Fig. 2f shows total surface heat flux ($F_{sen+lat}$, the sum of the surface sensible and latent heat fluxes). It is noted that the increase in N_a tends to decrease convective activity and surface fluxes.

Time-Averaged Fields for Both S1 and S2

A sample of fields presented in Fig.1 and 2 are now time-averaged over the last 5 h (11 h to 16 h LT) and plotted as a function of N_a (Fig. 3).

The general tendencies with respect to increases in Na are quite different in S2 from those in S1. In S2, when N_a increases from 100 cm^{-3} to 2000 cm^{-3}, the cloud-averaged LWP decreases by 64% (Fig. 3a); cloud fraction decreases by 58% (Fig. 3b); and cloud depth decreases by 62% (Fig. 3d) (all calculations relative to S2-100), although there is still a great deal of dynamical variability at any given N_a. The increase in N_a leads to a smaller increase in the vertically integrated $N_{d,int}$ than in S1 due to reduced convective activity associated with the suppressed surface fluxes (Fig. 2f). The smaller increase in $N_{d,int}$ and larger decrease in LWP result in an increase in cloud optical depth from S2-100 to S2-500, and then a decrease back to roughly the same value as S2-100. The clouds become optically thinner above N_a = 500 cm^{-3}, largely because of the decreasing cloud depth and LWP. The solid square in Fig. 3a shows that LWP does increase with increasing Na when the precipitating drops (r > 25 µm) are removed from the LWP calculations.

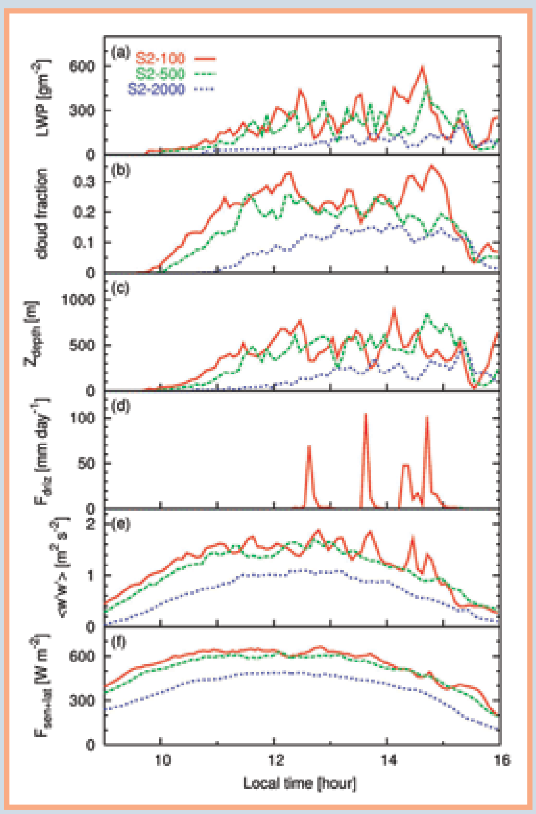


Fig. 2. As in Fig. 1, but for time series of S2 simulations; (e) maximum domain averaged <w'w'> which is a measure of convective activity and (f) sum of sensible and latent heat fluxes.

The aerosol-cloud-climate system is a complex one, comprising a myriad of feedbacks that challenge our ability to predict the radiative response of clouds to changes in aerosol.

Fig. 3. A sample of fields averaged over the last 5h (11 to 16 local time) of the time series shown in Fig. 1 and 2 as a function of aerosol concentrations for both S1 and S2 simulations. Vertical lines represent the standard deviation. (a) LWP averaged over cloudy columns. The solid squares in Fig. 3a are calculations of the LWP for cloud droplets with radius <25 µm. (e) Cloud optical depth, (f) surface temperature, (g) net surface radiation, and (h) sum of sensible and latent heat fluxes. S1 results (without standard deviations) are superimposed for comparison.

In the S1 simulations, as N_a increases from 100 cm^{-3} to 2000 cm^{-3} the surface air temperature is unchanged (values are within 0.04°C of each other; Fig. 3f); the net radiative flux at the surface decreases by only 2.2% (Fig. 3g); changes in surface total heat flux are almost the same (Fig. 3h) to balance the decrease in Rnet. In these S1 simulations, the R_{net} and $F_{sen+lat}$ are reduced only slightly by the increase in N_a over the 5 h time period because the aerosol is not coupled to the dynamical model.

Decreases in R_{net} (Fig. 3g) relative to S1 range from 8% for the clean (S2-100) to a maximum of 31% for the polluted (S2-2000) case. The commensurate reduction in the surface total heat flux (Fig. 3h) leads to a maximum of 1.32°C surface cooling relative to the S1 simulation for the most polluted conditions (Fig. 3f).

Discussion

Effect of N_a on LWP and Precipitation

The results for the S1 simulations show some subtle but important differences from the hypothesis that an increase in N_d (numbers of droplet) results in clouds with higher LWP and cloud fraction as a consequence of reduced precipitation (the second indirect effect). Although some weak trends appear to be due to aerosol, the dynamical variability in LWP and cloud fraction at any given N_a is much greater than the aerosol-induced change in LWP. The suppression of precipitation does not lead to a distinct increase in LWP if all drop sizes are included in the LWP calculation (Fig. 3a). There is even some suggestion of a decrease in cloud fraction with increasing N_a which runs counter to the accepted hypothesis, possibly due to the fact that under polluted conditions, the more numerous, smaller droplets evaporate more efficiently (Xue and Feingold, 2006).

For S2 simulations, there are two competing factors at work: first, convective activity tends to increase with increasing N_a as stabilization due to precipitation progressively diminishes; second, convective activity decreases with increasing N_a as surface fluxes are reduced. On average, the cleaner clouds do tend to be characterized by stronger convection.

N_a, N_d, and τ_c

The correlations between N_a, N_d, and τ_c (S1) are clear and robust after time averaging (Fig. 3) even though LWP is not necessarily constant. The effect of increasing N_a on the net radiative flux and the heat flux at the surface is small for the S1 simulations (Fig. 3h), in spite of the doubling in τ_c from clean to polluted cases, because of the small cloud fractions.

In contrast, an increase in N_a causes a significant reduction in surface fluxes in the S2 simulations, primarily due to the increase in τ_a, whose effects are felt over the entire surface. The reduction in LWP and cloud fraction with increasing N_a does little to reverse this trend because of the small cloud fractions. When the aerosol particles are allowed to contribute to heating, the 26.5% reduction in the downwelling radiative flux at the surface between S2-2000 and S2-100 is balanced by the reduction in the surface heat flux, which in turn results in further reduction in LWP, cloud fraction, cloud depth, and τ_c. These include the changes caused by increasing N_a that were visible in S1.

Summary

S1 Simulations

- Increases in N_a in these warm cumulus clouds do not cause statistically significant changes in cloud fraction, LWP and cloud depth. Aerosol effects are well within the dynamical variability in LWP and cloud fraction at any given N_a.
- Increases in N_a result in increases in N_d and cloud optical depth τ_c.

- Increases in N_a are associated with reductions in surface precipitation.

S2 Simulations (including aerosol direct effect-dynamical coupling)

- Strong decreases in LWP, cloud fraction, and cloud depth are shown with increasing Na associated with weaker convection.
- The direct effect included in the S2 simulations blocks up to 26.5 % of incoming solar radiative flux from reaching the surface (for the most polluted case). The reduction in the surface radiative flux leads to a reduction in the surface heat flux and consequently weaker convection, much shallower clouds and lower cloud cover than in S1 simulations.
- Cloud optical depth shows non-monotonic behavior as aerosol loadings increase due to the opposing effects of a decreasing drop size (which increases τ_c) and a decreasing LWP (which decreases τ_c). With progressively higher N_a, a point is reached where the decrease in LWP dominates. In these simulations, this point occurs at N_a approx 500 cm^{-3}.

This study has challenged us to look at some fundamental issues regarding aerosol-cloud-radiative-surface flux feedbacks in the cumulus cloud regime over land. In particular, the sign of the change of aerosol induced effects on LWP and cloud fraction is called into question. This study has also pointed to the importance of coupling aerosol radiative properties and a surface soil and vegetation model to the microphysical-dynamical model. As shown here, under polluted conditions (associated, e.g., with biomass burning smoke), the surface flux response to the aerosol may be the single most important factor in cloud reduction.

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