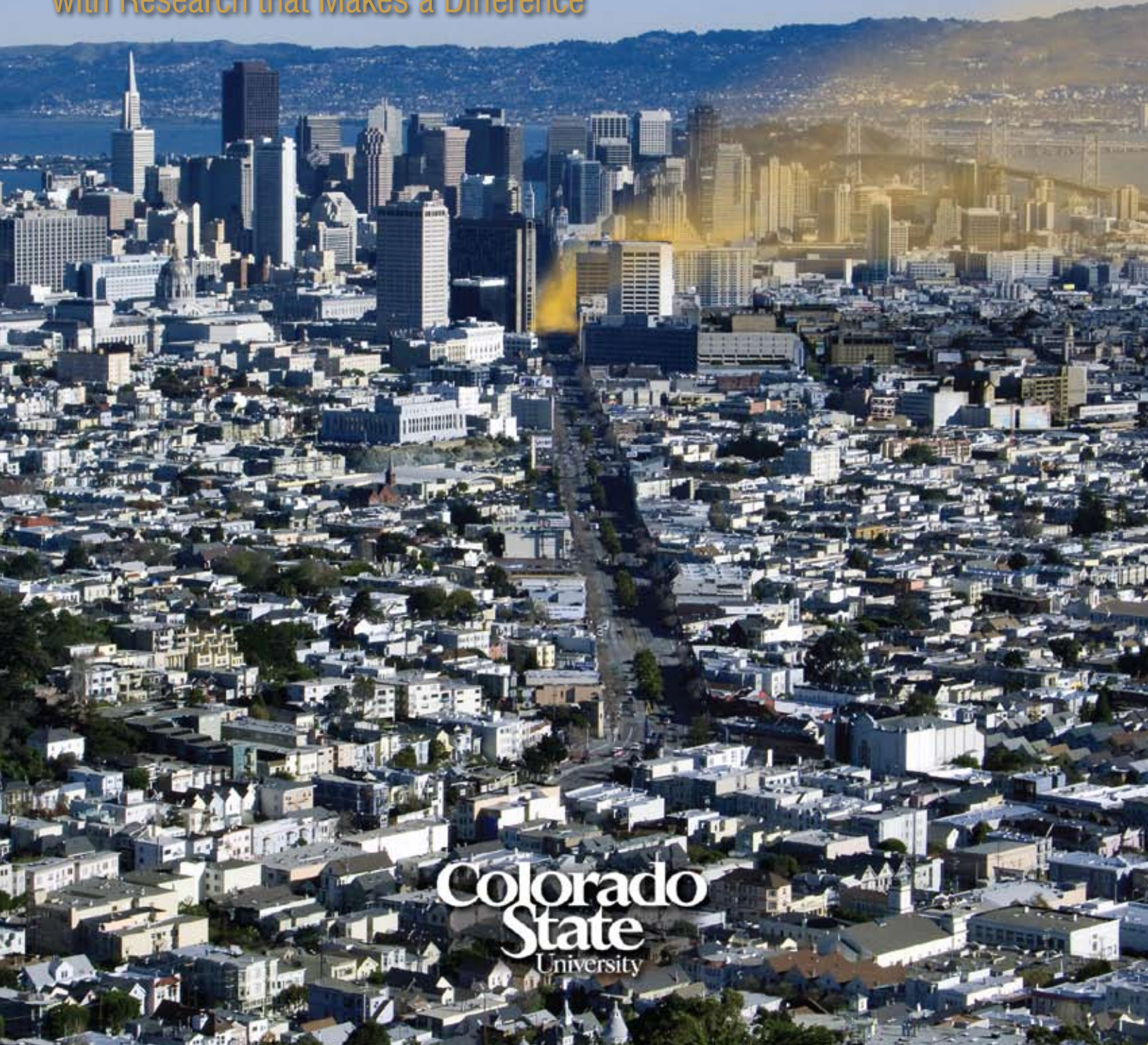


# CIRRA

VOLUME 29, SPRING 2008

Protecting Our Nation  
with Research that Makes a Difference



Colorado  
State  
University

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# GTAS

## Geo-Targeted Alerting System (GTAS)

*Herb Grote*

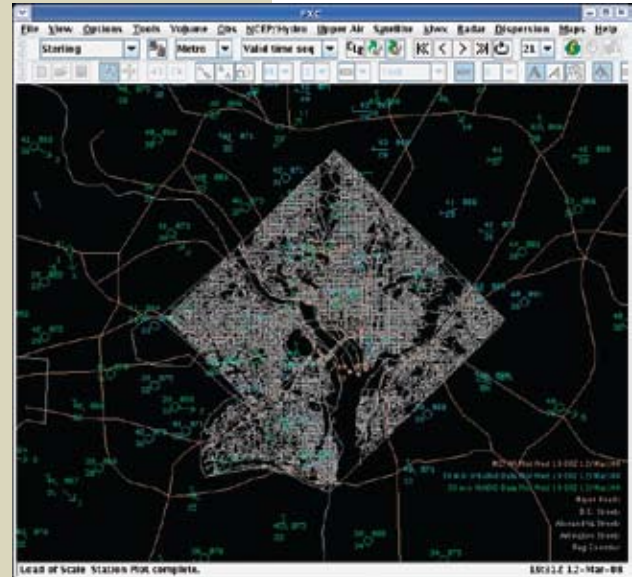
Since the events of September 11, 2001 in New York City, considerable focus has been placed on protecting the public from terrorist attacks and other man-made disasters that could jeopardize the lives of a large number of people. The release of biological, chemical, or radioactive material into the atmosphere in a heavily populated area could potentially kill thousands of people. The GTAS project is designed to develop an advanced warning system that can rapidly and precisely warn and provide safety information and instructions to the public in case of a life-threatening toxic release.

A key element of NOAA's current mission is to alert the public of potentially life-threatening weather events, such as blizzards, tornadoes, and flash-floods. The National Weather Service has the infrastructure in place to forecast the weather and to disseminate the forecasts, watches, and warnings to the public in an effective and timely manner. Weather offices exist in all fifty states and often are located near major population centers. Over the years, forecasters in these offices have established local contacts, developed procedures, and gained significant experience in supporting local governments during hazardous weather events. That same infrastructure can be leveraged to deal with terrorist attacks and other man-made disasters.

The NOAA infrastructure includes advanced new technologies that can generate high resolution weather data for use by Department of Homeland Security (DHS) operations. Some of the NOAA technologies designed to be used by GTAS are the Advanced Weather Information Processing System (AWIPS), the Meteorological Assimilation and Data Ingest System (MADIS), the Graphical Forecast Editor (GFE), the Hybrid Single Particle Lagrangian Integrated Trajectory (HySPLIT) model, and the 4-km Nonhydrostatic Mesoscale Model (NMM). The AWIPS system is in all of the NWS forecast offices and provides forecasters with a powerful tool to view and understand the past, present, and future state of

the atmosphere. AWIPS is currently being redesigned to use a Service Oriented Architecture (SOA) and is expected to be ready for initial deployment in fiscal year 2010. This presents an opportunity to incorporate essential new capabilities to support GTAS requirements.

The geo-targeted concept came from exploratory work using reverse-911 notifications to provide highly localized notifications of a hazardous weather event such as a tornado to affected individuals. To make geo-targeting feasible requires a telephone database that is current, complete, and contains very specific geographic location information in addition to just a street name and address. The initial vendor to support this exploratory work was Intrado, Inc. located in Longmont, Colorado. The FX Collaboration (FXC) system developed by the Global Systems Division at NOAA Earth System Research Lab was used to graphically generate a warning area and electronically transmit the geographic coordinates in latitude and longitude to the vendor. The vendor then accessed the telephone database and determined all of the phone numbers within the geographic area. After operator confirmation, the vendor's system dialed the designated phone numbers as quickly as possible according to a simple rule, e.g., from north to south. The purpose of the test was to determine the time it took to make the first phone call and the rate at which calls could be made thereafter. Obviously, if the vendor was unable to make the first call before the event entered the area or unable to call all of the numbers before the event traversed the area, the system was deemed of limited use.



*Figure 1. A sample GTAS screen showing some of the MADIS surface observations for the Washington, D.C. area.*

# GTAS

DHS' FEMA quickly became interested in developing a public warning concept for potential toxic release in the National Capital Region based on our reverse-911 geo-targeting work. The prototype system is based on FXC, which has many of the features of AWIPS. FXC is well suited for developing this prototype since it can be modified easily, unlike AWIPS which is under software configuration management by the NWS. It also has many of the features required by GTAS, such as weather data display and interaction, real-time collaboration, graphical annotation, and secure transmission of data to remote servers. The FXC capability allows participants at physically different locations to view identical weather data display and, through interactive tools, help in the discussion of the forecast. Also, since FXC is written in Java, the same programming language used by AWIPS II, it will make it easier to transfer code to the new AWIPS system. Some portions of the FXC graphic annotation code have already been ported to AWIPS II.

FXC needed some additional features in order to be used as a functional prototype for GTAS. The first and most significant feature to be added was the ability to run the HySPLIT dispersion model. The HySPLIT dispersion model calculates the dispersion assuming either puff or particle dispersion. The model's default configuration assumes a puff dispersion horizontally

and particle dispersion vertically. The model is initialized on the GTAS client using a dialog window that allows the user to specify various parameters such as duration of the run, maximum height, and the release point by entering the latitude and the longitude directly or selecting the location with the mouse cursor (see Figure 2). This information is then transmitted to the GTAS server where the

weather forecast models are available to initialize the dispersion model. Upon completion, the client is notified and the dispersion plume can be viewed as a vector graphic or image.

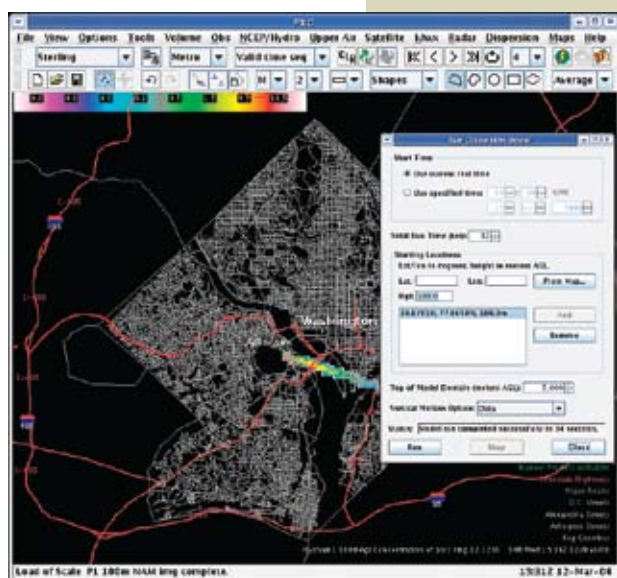
Another feature added to GTAS was the ability to send the warning area polygon to multiple reverse-911 vendors. GTAS needed the flexibility to communicate with different vendors according to their unique network and security requirements. The same message, in the form of a simple custom XML document, is sent to all of the vendors. In the final version, the XML message would comply with the OASIS Standard Common Alerting Protocol (CAP). The ability to notify several vendors can be used in areas where a single vendor does not have a complete telephone database for the area, or to selectively determine which of several vendors provides the best performance. GTAS supports encrypted https with security certificates and keys.

In order to accurately initialize the dispersion model and draw an accurate warning polygon, the map background information must be accurate and of high spatial resolution. The initial maps obtained from AWIPS had insufficient detail on the city scale. In order to meet the GTAS requirements, high resolution (ESRI) shapefiles were downloaded and mapped to the Washington, D.C. area. A utility to read shapefiles was partially implemented using the open source Java GIS toolkit GeoTools. Additional work is required to obtain greater benefit from the available shapefile information.

Additional enhancements were made to deal with firewalls and Network Address Translation (NAT). A message repeater, unique to FXC, routes all messages to and from the FXC server processes through a single port. This port was opened to the outside and used address translation to hide the internal network address from outside users. An address translation table implemented by FXC can now deal with traffic through NATs.

GTAS uses a client-server architecture with dedicated T1 communications links between the server and clients. The dedicated lines provide reliable performance and an acceptable degree of security for the prototype. The server has access

**Figure 2. View of the HySPLIT dispersion model dialog box superimposed on the dispersion plume generated by the model.**



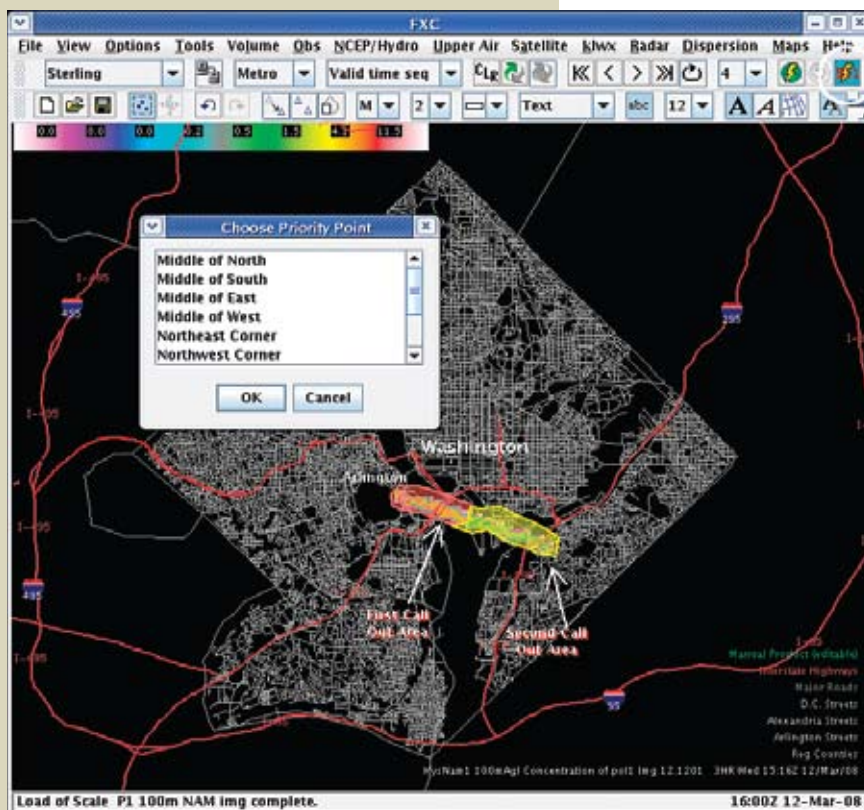
to the full AWIPS real-time meteorological data and can serve a number of clients who are either collaborating or working independently. Dual servers are implemented to provide the necessary redundancy. For the initial prototype, the servers reside at the NOAA/ESRL Global Systems Division (GSD) computer facility. The GTAS client software can be downloaded from a local server and installed on a remote client using a simple installation script. A single remote client was installed at the FEMA office in the Washington, D.C. area and several clients were configured at GSD in Boulder.

Thus far, the system has only been used to demonstrate the basic GTAS concept. FEMA staff has been able to simulate a toxic release and initialize the dispersion model. Separate tests have been conducted to draw warning polygons and send the coordinates to two reverse-911 vendors – 21st Century and Intrado, Inc. Figure 3 illustrates a dispersion plume in the Washington, D.C. area using a simulated release point and agent. For the initial prototype, the HySPLIT model is initialized using the NAM-12 grids. Animated GIF images of the dispersion plume with time have also been made available on special websites using GTAS' capability to capture the screen and post the images to the web server.

The GTAS project is a joint endeavor between the National Oceanic and Atmospheric Administration (NOAA) and the Department of Homeland Security (DHS). The project was started nearly 3 years ago and is now awaiting a decision by DHS to continue with the development and evaluation.

## Acknowledgements

CIRA has the technical lead for the design and implementation of the GTAS system and also performs some of the development. Other groups have made significant contributions to the project. Chris Golden (SRG) performed much of the FXC software enhancement and Xiangbao Xing (CIRES) leads the installation of the HySPLIT model. The project manager is Richard Jesuroga (NOAA).



*Figure 3. Example of an annotated plume depicting the warning polygons that define the XML message sent to the vendors. The 911 icon in the upper right hand corner is used to transmit the polygon information.*

# DATA ASSIMILATION

## Data Assimilation: Extracting Maximum Information from the GOES-R Data

*Dusanka Zupanski, Milija Zupanski, Renate Brummer and Mark DeMaria (NOAA/NESDIS)*

### Next Generation Geostationary Satellites

The next generation GOES will begin with GOES-R, which is currently scheduled to launch in the year 2015. GOES-R will be equipped with the Advanced Baseline Imager (ABI), an imager that has significantly improved spectral, spatial, and temporal resolution relative to the current GOES I-M series satellites. These improvements will greatly enhance our ability to make mesoscale weather, climate, oceanographic, and environmental observations.

Because of the long lead-time required to design, build, and test new and complex satellite equipment, preparations for GOES-R applications are well underway. The approach for these “Risk Reduction” activities is to use data from existing operational and experimental satellites to create subsets of observations that resemble those we will eventually receive from GOES-R. These simulated GOES-R datasets will then be used for the development of algorithms for new satellite products or for the improvement of existing products, particularly for atmospheric and surface-related phenomena, using the additional GOES-R resolution capabilities that will be available.

The major objective of our specific data assimilation

research is to prepare algorithms to maximize the use of information from future GOES-R observations, especially in the area of operational severe weather forecasts.

### Challenges of Data Assimilation

*Data Assimilation* is the technique of blending data from very different sources in order to produce a new data set that is most consistent with the atmospheric state. Advanced data assimilation methods, which extract information about the true atmospheric state from observations and combine it with the information from a forecast model, have proven to be powerful tools in improving weather forecasts. New observations from GOES-R will pose new challenges to the data assimilation methods. A major issue that needs to be addressed is to estimate if, and how much, the GOES-R observations are expected to improve our knowledge about the true atmospheric state. In order to address this challenge, one needs to quantify (1) what is the amount of information provided by the currently available meteorological observations (e.g., conventional surface and upper-air observations) and (2) how much new information will be brought by the GOES-R data. Our goal is to

prepare methodologies capable of answering these questions before the GOES-R observations are available.

The answers to the questions posed above are not trivial, since the same observations could bring more or less information, depending on where and when the observations are taken, and on how accurate the forecast is for that place and that location. In other words, the information from observations is dependent on the number and quality of the observations and on the forecast uncertainty. Unlike the data assimilation methods currently used in operational weather centers (in the U.S. and worldwide), the next generation ensemble-based data assimilation methods are demonstrating a qualitatively new capability to address the above challenges. Of special importance is the new capability to estimate and use realistic forecast uncertainty, which depends on the atmospheric conditions. This forecast uncertainty is typically defined in terms of a covariance matrix measuring forecast errors, the so-called “flow-dependent” forecast error covariance. At CIRA, we are developing and exploring ensemble-based data assimilation methods for applications to the future GOES-R observations and to other current and

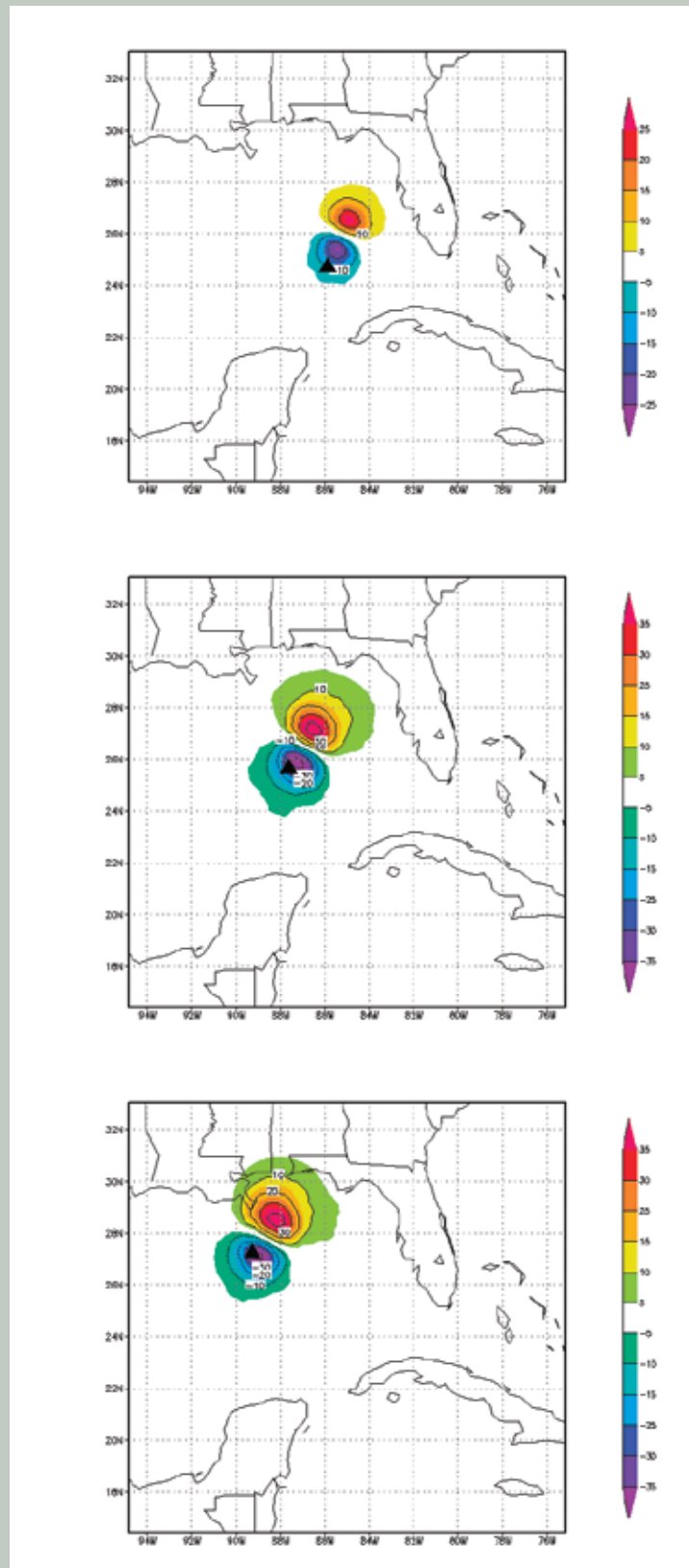
The major objective of our specific data assimilation research is to prepare algorithms to maximize the use of information from future GOES-R observations, especially in the area of operational severe weather forecasts.

upcoming satellite missions (e.g., CloudSat, Global Precipitation Mission-GPM and Orbiting Carbon Observatory-OCO).

### Ensemble Data Assimilation

Ensemble-based data assimilation methods employ ensembles of forecast model runs to estimate flow-dependent forecast uncertainty. Using flow-dependent forecast error covariance is essential for extracting maximum information from each observation because in the areas of high forecast uncertainty (where ensemble members differ among each other the most), the information given by the observations is more important. The opposite is true in the areas where the forecast uncertainty is low (i.e., all ensemble members are similar).

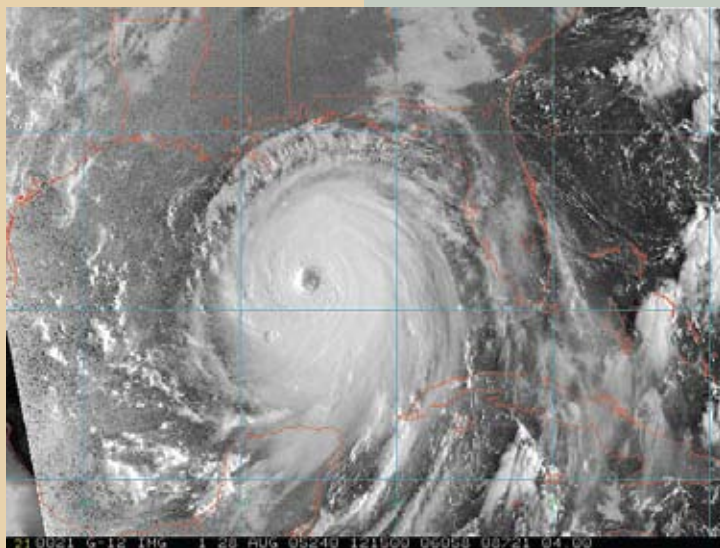
Under the GOES-R research project and various other research projects at CIRA, we are employing and further developing an ensemble-based data assimilation method, referred to as the Maximum Likelihood Ensemble Filter (MLEF). For the GOES-R application, we are focusing on the MLEF capability to extract maximum information from the future GOES-R observations. This is accomplished by evaluating information measures of assimilated observations. Information measure called *Degrees of Freedom for Signal* (DFS) is often used in meteorological applications. The DFS is a number, defined for a selected set of observa-



**Figure 1a-c.** Surface pressure forecast difference (hPa) between the experiments with and without data assimilation. In the experiment with data assimilation, a 6-hour forecast after data assimilation is used. In the experiment without data assimilation, a longer-term forecast is used, initialized at the beginning of the data assimilation experiment (first data assimilation cycle). Both experiments used the same boundary conditions. The triangle denotes the best position of Hurricane Katrina estimated by the NOAA/ National Hurricane Center report. The panels cover last 24 hours before the landfall: (a) Aug. 28, 2005 at 0000 UTC, which corresponds to 8th data assimilation cycle, (b) Aug. 28, 2005 at 1200 UTC, which corresponds to 10th data assimilation cycle, and (c) Aug. 29, 2005 at 0000 UTC, which corresponds to 12th data assimilation cycle. Negative values (blue and purple colors) indicate lower pressure, while positive values (yellow and red colors) indicate higher pressure in the experiment with data assimilation. Note that the data assimilation is moving the cyclone towards the observed location, since the triangle is located in the blue (lower pressure) area.

# DATA ASSIMILATION

tions, which counts how many pieces of independent information the observations are bringing into the data assimilation system. The DFS cannot be larger than the number of observations. In ensemble data assimilation methods, the DFS



**Figure 2. Visible satellite image of Hurricane Katrina on 28 Aug 2005 at 1215 UTC.**

is also limited by the ensemble size, thus appropriate ensemble size should be determined in such applications. This information measure, among others, is used in our GOES-R research.

In the first stage of this research, we applied the MLEF to quantify the information content of conventional observations. In the second stage, which is currently underway, we will examine and further develop this methodology in application to satellite observations with similar characteristics as the future GOES-R observations. We expect that the second stage should result

in a well-tested data assimilation algorithm capable of extracting maximum information from the GOES-R observations, before these observations become available.

We have recently applied the MLEF to improve forecast simulations of Hurricane Katrina by assimilating conventional surface and upper-air observations into the Weather Research and Forecasting (WRF) model. In the experiment presented, the model spatial resolution is 30 km with 28 vertical levels (totaling 75x70x28 grid points) and we employ 32 ensemble members. Observations are assimilated every 6 hours, during 12 consecutive data assimilation cycles. Figure 1a-c shows an example of the impact of data assimilation on improving the forecast of Hurricane Katrina. Most significant improvements are obtained by placing the cyclone center to the more correct location, as indicated in the figure by the dipole (positive-negative) pattern in the pressure difference field, while the improvements in the cyclone intensity were smaller. These improvements are quite substantial considering that only a relatively small number of observations are assimilated. For illustration, we also include a visible satellite image of Hurricane Katrina (Figure 2), valid approximately at the same time as the surface pressure difference field given in Figure 1b.

## Does More High Quality Data Mean More Information?

We expect that the GOES-R observations will be of excellent quality and will have high spectral, spatial, and temporal resolution. Can we automatically assume that more high quality data will result in improved data assimilation and forecast results? Classical data assimilation methods, which do not employ flow-dependent (but prescribed) forecast error covariance, would yield “yes” as an answer. This answer, even though desirable, may not be correct. Modern data assimilation methods, such as ensemble-based methods, could provide a different answer because of the use of the flow-dependent forecast error covariance.

We have calculated the DFS for the same case of Hurricane Katrina, given in Figure 1a-c. The DFS results are shown in Figure 3. The model integration domain was divided into nine equally sized areas (sub-domains) and the DFS are calculated for each sub-domain. The sizes of the sub-domains are selected by taking into account the spatial scale of the tropical cyclone. One can immediately notice that the highest amount of information is provided by the observations from the central sub-domain (pink color indicates that the DFS is equal or larger than 14). This is exactly the sub-domain where the cyclone center is located. Note that the number of observations (the number





of crosses) is not the highest in this sub-domain, thus the forecast uncertainty played a dominant role in defining the information content. Note also that there are more observations in the three sub-domains located in the northern part of the model domain, but these observations carry less information because the values of the DFS are smaller (colored in orange and green). These results demonstrate the ability of the MLEF to correctly take into account the characteristics of the atmospheric flow when extracting information from the available observations, thus maximizing the benefits of the assimilated observations.

Additional information can be found at [www.cira.colostate.edu/projects/ensemble/](http://www.cira.colostate.edu/projects/ensemble/)

### What is Next?

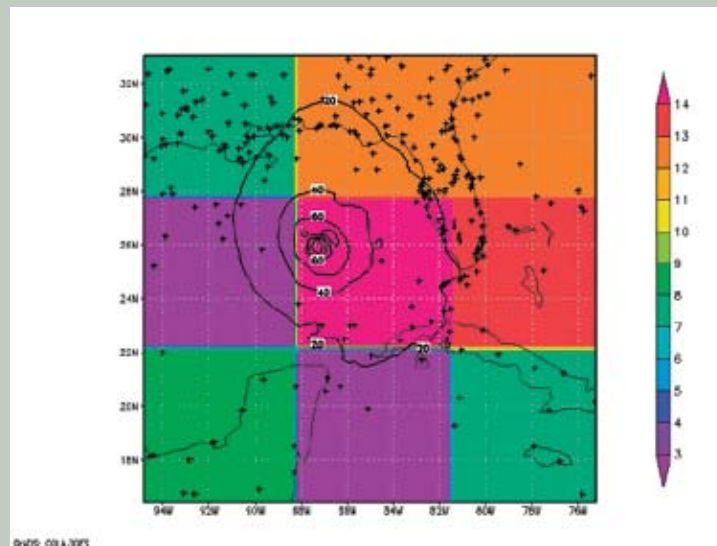
The experimental results with conventional upper-air and surface observations were quite encouraging. The next step of our research is to test the same methodology in application to satellite observations. We have already selected an interesting severe weather case (a very strong extra-tropical cyclone named Kyrill that occurred over Europe during January 18-19, 2007) and started collecting satellite data from the Meteosat Second Generation (MSG) satellite that resemble those we will receive from the future GOES-R instrument. In this case, the WRF model will be run in finer resolution (15 km/49 levels),

thus the data assimilation experiment will be computationally more demanding. It will be interesting to examine if the data assimilation algorithm will be able to correctly extract information from the satellite observations, while taking into account the flow-dependent forecast uncertainty.

### Acknowledgements

The research reported here was mainly funded by the NOAA/NESDIS/GOES-R Risk Reduction Program, under Grant No. NA17RJ1228. We also acknowledge research efforts under synergistic research projects at CIRA, funded by the NASA/Global Precipitation Mission (GPM) program, the NASA/North American Carbon Program (NACP) and the Department of

Defense (DoD) Center for Geosciences/Atmospheric Research (CG/AR). This research is a team effort including, besides the authors of this article, Louie Grasso of CIRA, Sara Q. Zhang of NASA/GMAO, Arthur Y. Hou of NASA/GMAO, Isidora Jankov of CIRA/NOAA/ESRL, Daniel Lindsey of NOAA/NESDIS, Managit Sengupta of CIRA, Thomas Vonder Haar of CIRA, Christian D. Kummerow of CSU/Department of Atmospheric Science and Scott Denning of CSU/Department of Atmospheric Science. The authors of this article would like to thank Ray Zehr of NOAA/NESDIS for preparing the satellite images of Katrina, and to Don Hillger of NOAA/NESDIS and Laura Leinen and Mary McInnis-Efaw of CIRA for the final editing.



**Figure 3.** The DFS calculated in data assimilation cycle 10 (valid at 12 UTC Aug. 28, 2005), shown, in shading, for each of the nine sub-domains covering the model domain. Also shown are the locations of the assimilated observations (crosses) and the location of the tropical cyclone, as defined by the isolines of the magnitude of the horizontal wind (in ms<sup>-1</sup>), obtained by the analysis at the model level corresponding to a height of 700 m.

# SERVING FORECASTER NEEDS

How can we make the powerful instruments onboard polar orbiting spacecraft show the time evolution of features which is so valuable to forecasters?

## CIRA's Multisensor Blended Total Precipitable Water Products Serve Forecaster Needs

*John Forsythe, Stan Kidder, Andy Jones; Sheldon Kusselson (NOAA/NESDIS Satellite Analysis Branch)*

Forecasters today are faced with many sources of data. What they need is meteorologically significant data fields blended from all available data sources, not numerous maps of observations from individual sources. Forecasters will use whatever products help them understand the current situation and make a better forecast, but if the product is not easily understandable within a few seconds it will not be used in a busy forecast office.

CIRA scientists Stan Kidder and Andy Jones have developed a technique to blend satellite retrievals of total precipitable water (TPW) to make a product which is easy to use by forecasters (Kidder and Jones, 2007). TPW is the amount of water vapor in a column from the surface of the earth to space (in kilograms per square meter or, equivalently, in millimeters of condensate). On a global average, the atmosphere contains 25 mm of TPW, with a range from near 0 mm (Antarctica) to extreme instances of 90 mm (strong tropical cyclones). It is this moisture that provides the fuel for many of the key elements of a forecast (clouds and precipitation). TPW integrated from radiosondes has historically been used by forecasters to predict heavy precipitation, especially in summertime flash flood situations. But radiosonde data is sparse compared to satellite data.

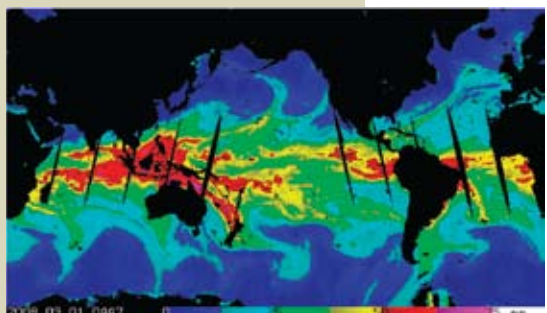
The idea behind this work, funded by the NOAA Product Systems Development and Implementation (PSDI) Program, is to present the forecaster with the best picture of TPW at a given time, and to insulate the forecaster from technical

concerns about which spacecraft or algorithm was used. There are many spacecraft in orbit which measure TPW and are candidates for blending. Passive microwave sensors are particularly well-suited for measuring TPW since they can retrieve TPW in the presence of clouds. Clouds block the retrieval of TPW from infrared sensors such as the GOES Sounder, which is unfortunate since often the most interesting forecast challenges are in cloudy areas where heavy precipitation might occur. But there is a catch – the only passive microwave sensors in space for weather measurements are on polar orbiting satellites. Polar-orbiting data are not as friendly to forecaster use as geostationary data. An area such as the west coast of the U.S. is observed at irregular times, so adding a regularly spaced time interval to examine the data, such as in the loops commonly used for GOES data, is not feasible. In addition, in midlatitudes there may be gaps in the geographic area observed between one overpass and the next. How can we make the powerful instruments onboard polar orbiting spacecraft show the time evolution of features which is so valuable to forecasters?

### Products

#### a) AMSU and SSM/I Blended TPW

Among the workhorse microwave instruments for measuring TPW are the AMSU onboard the NOAA and European METOP spacecraft series and the SSM/I and SSMIS onboard the DMSP spacecraft. For the past few years, there have been up to six of these spacecraft available from an orbital height of 860 km. All of these instruments are very capable of measuring TPW over ocean. Over land, retrieving TPW from passive microwave measurements is very challenging due to the variable emissivity of the land surface. CIRA is active in research to retrieve moisture over land as well, but at this time only micro-



*Figure 1. Example of the six polar orbiter microwave retrieved blended TPW product from March 1, 2008. Notice the plumes of moisture between the tropics and midlatitudes. TPW is not currently retrieved over land or in heavy precipitation.*

*Figure 2. The blended TPW AMSU and SSM/I product augmented with GPS data over the CONUS on March 4, 2008. Severe weather was occurring in the moisture plume over the eastern U.S.*



wave retrievals of TPW over water are performed routinely.

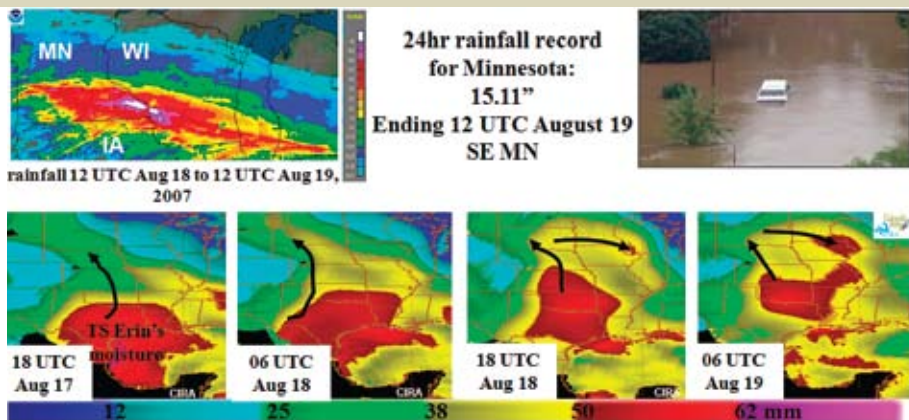
Figure 1 shows an example of the global TPW from six satellite instruments (AMSU and SSM/I). The powerful DPEAS data processing system (Jones and Vonder Haar, 2002), which was developed at CIRA, is used to manage the remapping and compositing of the data. All of the science code resides within DPEAS, allowing developers to have a common programming framework. The blended TPW product is updated every six hours and is available on [amsu.cira.colostate.edu/TPW](http://amsu.cira.colostate.edu/TPW). It is produced globally (except near the poles) on a 16 km resolution Mercator projection. The global product and sectors over various ocean basins are available on that site. The animations online capture the flow of moisture in a way not possible with other satellite products. The familiar geostationary water vapor channel animations are a complement of this product, but they only show upper level (above about 500 hPa) water vapor and provide no information when there are high clouds.

As detailed in Kidder and Jones (2007), a number of corrections need to be made to the AMSU and SSM/I products to make them useful for forecasters. Even though they use essentially the same spectral region to retrieve TPW, AMSU and SSM/I are quite different in their scanning geometry (cross-track vs. conical scan), and this can lead to artifacts and seams where they are merged together. Forecasters do not want to see artifacts of the sensor type in a blended product; they just want to see the meteorology! A correction factor is constantly updated to account for differences in the two sensors.

The blended TPW product has become a staple of the Daily Weather Discussion at CIRA (see CIRA Newsletter, Spring 2006).

### b) Addition of GPS and GOES Sounder over CONUS

The global TPW product shown in Figure 1 has proven its value for forecasters since its inception in 2003. The product is being generated operationally at NOAA/NESDIS. But the lack of information over land has hindered its usefulness



*Figure 3. The blended microwave / GPS product tracks the high TPW associated with the remnants of Tropical Storm Erin from August 17 – 19, 2007. The 24 hour rainfall record for Minnesota was broken when 15.11” of rain fell in the 24 hours ending 12 UTC August 19, 2007 in SE Minnesota.*

for weather analysis. While research on passive microwave retrievals over land should yield benefits in the future, they are not yet ready for operations. Fortunately, over the CONUS (Continental U.S.) there exists a rich dataset of very accurate TPW measurements. You might even use the same sensor yourself!

The signals transmitted from the 24 GPS satellites, while intended to provide earth location, suffer some signal degradation due to the temperature and moisture structure of Earth’s atmosphere. This variation in signal (called the wet delay) can be used to estimate TPW above a ground-based sensor with accuracy of greater than 2mm, in all weather conditions. A precise, collocated measurement of atmospheric pressure is also required. Various government programs, like NSF’s Suominet ([www.suominet.ucar.edu](http://www.suominet.ucar.edu)) and NOAA’s GPS-MET network ([www.gpsmet.noaa.gov/jsp/index.jsp](http://www.gpsmet.noaa.gov/jsp/index.jsp)) have placed these GPS sensors in the CONUS and adjacent regions – over 400 as of the spring of 2008. John Forsythe, Stan Kidder, and Andy Jones have been routinely bringing in the GPS TPW stations from NOAA/GSD in Boulder since 2006. Seth Gutman of NOAA/GSD has been of great assistance in obtaining this data. The data are overlaid on the CONUS and brought together with the satellite microwave retrievals to form a land/ocean satellite TPW product. An example is shown in Figure 2. Animations of the last three days of this product, updated every six hours, are available at [amsu.cira.colostate.edu/gpstpww](http://amsu.cira.colostate.edu/gpstpww). Finally, GOES sounder TPW from CIMSS at the University of Wisconsin is added when available in areas where

**CIRA has received a wide range of positive feedback and encouragement on the experimental products from NOAA offices such as the SPC, NWS Western Region, NHC, and HPC.**

# SERVING FORECASTER NEEDS

the GPS network is still sparse (for instance, parts of Montana and Mexico).

This experimental product with GPS and GOES Sounder went online as a near-realtime experimental website in 2006. Since then, McIDAS files are being generated and served to NOAA/NESDIS/SAB every six hours. Sheldon Kusselson of SAB, who recognized the value of the blended TPW product since he has forecast responsibility for heavy precipitation events, has been instrumental in popularizing the product with other NOAA offices and forecasters. CIRA has received a wide range of positive feedback and encouragement on the experimental product from NOAA offices such as the SPC, NWS Western Region, NHC, and HPC.

## Forecast Applications

The blended TPW product is invaluable for understanding the synoptic scale flow of moisture in the atmosphere. Applications where the product shines include:

- Atmospheric rivers striking the U.S. West Coast and causing floods.
- Return of Gulf moisture to the central U.S. for severe weather.

- Tracking tropical waves which might become hurricanes in the Atlantic, and also recognizing dry air that inhibits their formation.

A large injection of moisture associated with Tropical Storm Erin occurred in August 2007. The blended TPW field with the GPS input over CONUS allowed forecasters to track this tropical moisture as it traveled into the upper Midwest and caused severe flooding, as shown in Figure 3.

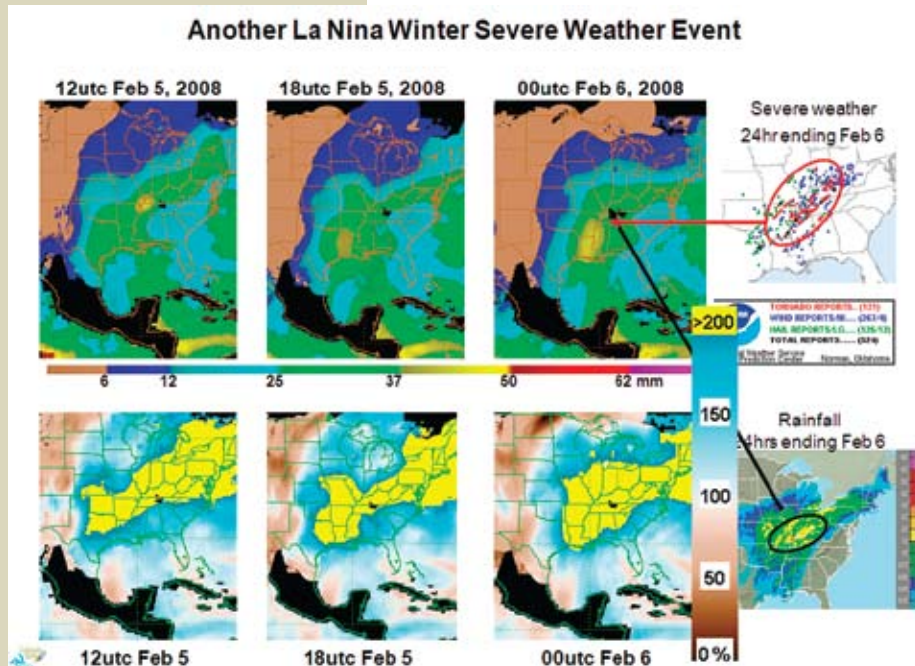
## The Future

Along with the development of the blended TPW product, an experimental TPW anomaly product has been developed at CIRA. The anomaly is the percent of the weekly normal TPW derived from the global NASA Water Vapor (NVAP) dataset (Randel et al. 1996) for 1988 – 1999.

The progression of a large positive TPW anomaly (> 200% of normal shaded as yellow) is shown in Figure 4. Blue shades are more moist than normal, and brown shades are drier than normal. In this case from February 2008, severe weather occurred over Mississippi and Georgia as the intense midlatitude cyclone tracked towards the northeast. The TPW anomaly, and the companion GOES water vapor imagery, captures the location of clouds and precipitation very well, and the drying in the wake of the system is also well-articulated. Forecaster experience at NESDIS SAB indicates that the TPW anomaly field is a useful tool for forecasters to diagnose heavy precipitation events. John Forsythe and Stan Kidder at CIRA are currently exploring the utility of the TPW anomaly for forecasting.

An exciting technology transfer effort is now underway to install the blended satellite/GPS/GOES Sounder TPW product into AWIPS Operational Build 9 in 2009. Stan Kidder is leading this effort for CIRA, and Limin Zhao and John Paquette are the technical leads for NOAA/OSDPD. Work is also underway on adding the European METOP TPW data into the blended product. As the NPOESS era approaches with the scheduled launch of NPP in the 2010 timeframe, the system needs to be agile to accept the ever-changing cast of satellite and ground-based TPW

*Figure 4. TPW anomaly product and GOES water vapor imagery for an intense midlatitude cyclone on February 16 and 17, 2008. Yellow color in the TPW anomaly is > 200% of normal and is indicative of heavy clouds and precipitation.*



sensors. The blended TPW project has served as a good example of a NOAA Cooperative Institute performing research relevant to the NOAA mission and implementing that research into operations. It also illustrates the need for a successful technology transfer to have a recipient (NESDIS SAB in this case) willing to make the effort to try out an experimental product and provide valuable feedback. CIRA and NESDIS are excited about future collaborations which will continue to give NOAA forecasters the benefit of the latest university research.

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AMSU	Advanced Microwave Sounding Unit
AWIPS	Advanced Weather Interactive Processing System
DPEAS	Data Processing and Error Analysis System
HPC	Hydrometeorological Prediction Center
MetOp	Meteorological Operational Satellite
NHC	National Hurricane Center
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
OSDPD	Office of Satellite Data Processing and Distribution
SPC	Storm Prediction Center
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager/Sounder

The production code is being ported to NOAA/NESDIS so that the blended TPW product will be available in Operational Build 9 of AWIPS.

## 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](mailto: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](http://www.cira.colostate.edu).

# REGIONAL IMPACTS

## Regional Impacts of Oil and Gas Development in the Western United States

Marco A. Rodriguez<sup>1</sup>, Michael G. Barna<sup>2</sup>, Tom Moore<sup>3</sup>, Kristi Gebhart<sup>2</sup>, Bret Schichtel<sup>2</sup>, Bill Malm<sup>2</sup>

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<sup>3</sup> Western Regional Air Partnership, Western Governors' Association, Fort Collins, CO 80523-1375

High ozone levels at the earth's surface, such as the photochemical smog that frequently envelopes Los Angeles in the summer, have typically been regarded as an urban air quality problem. A disturbing trend in recent years, however, has been the rise of tropospheric ozone in remote regions of the western U.S. Ozone ( $O_3$ ) is a strong oxidant that can harm human health at relatively low concentrations. Recently, the U.S. Environmental Protection Agency (EPA) tightened existing National

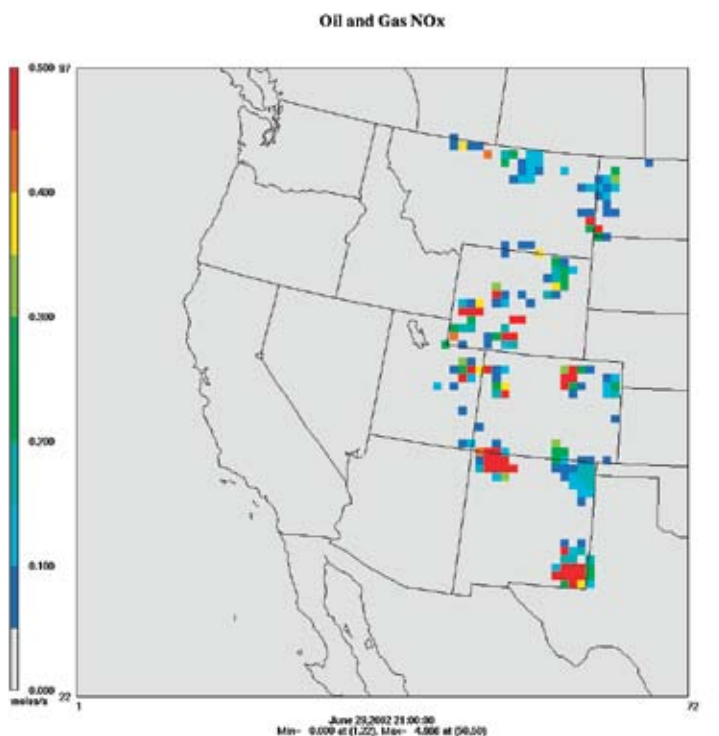
Ambient Air Quality Standards (NAAQS) for ozone to 75 ppb (assessed as the 4th highest monitored ozone concentration value over a running average eight hour period, over 3 continuous years) from the previous 80 ppb, effectively reducing the compliance level of the ozone NAAQS by 9 ppb. Many medical experts assert, however, that an ozone standard between 60 and 70 ppb is required to protect human health.

Ozone is formed through a complex series of chemical reactions involving nitrogen oxides ( $NO_x$ ) and volatile organic compounds (VOC) in the presence of sunlight. To combat rising ozone levels, these precursors must be reduced. As oil and gas development in the western U.S. continues to accelerate, however, there is significant potential that emissions from these sources will exacerbate the existing ozone problem. Although emissions from oil and gas development may appear small as compared to other emission categories such as coal-fired power plants and automobiles, they typically occur in remote regions of the country, far removed from urban areas, and can have a disproportionate effect

on air quality in rural regions. For example,  $NO_x$  emissions from an internal combustion engine at a gas well may react with terpenes (a reactive VOC) emitted from pine forests and form ozone in an area where, previously, the right mix of precursors was not available for this reaction to take place. This is especially worrisome since recent observations indicate that many remote wilderness areas and national parks, such as Mesa Verde National Park in southwestern Colorado, are confronted with ozone concentrations that are trending towards the EPA's acceptable limits. Very near Mesa Verde National Park are rapidly growing oil and gas extraction operations in northwestern New Mexico. As this type of development continues throughout the West, it is essential to understand its potential negative impact on air quality in some of our nation's most cherished protected areas.

To investigate this issue, CIRA and National Park Service (NPS) scientists are using sophisticated meteorological and air pollution models to simulate air quality in the western U.S., and determining which emission sources (e.g., oil and gas development, power

Figure 1. Typical  $NO_x$  emissions [moles  $NO_x$  s<sup>-1</sup>] from oil and gas development in the western United States from the 2002 WRAP emission inventory.



plants, automobiles) contribute to the pollution burden in our national parks and wilderness areas. This understanding is crucial to developing effective strategies that reduce regional air pollution. Although this article focuses on the impact of ozone pollution, the concept of “one-atmosphere” computer modeling is being employed by CIRA and NPS researchers, and collaboratively by the Western Regional Air Partnership (WRAP) in their air quality analyses and planning efforts<sup>1</sup>. This approach is being used to investigate several issues related to regional formation and transport of air pollutants such as the primary and secondary NAAQS for ozone and particulate matter, visibility protection, and mitigating health and ecosystem effects due to excessive nitrogen deposition and toxic air pollutants such as mercury.

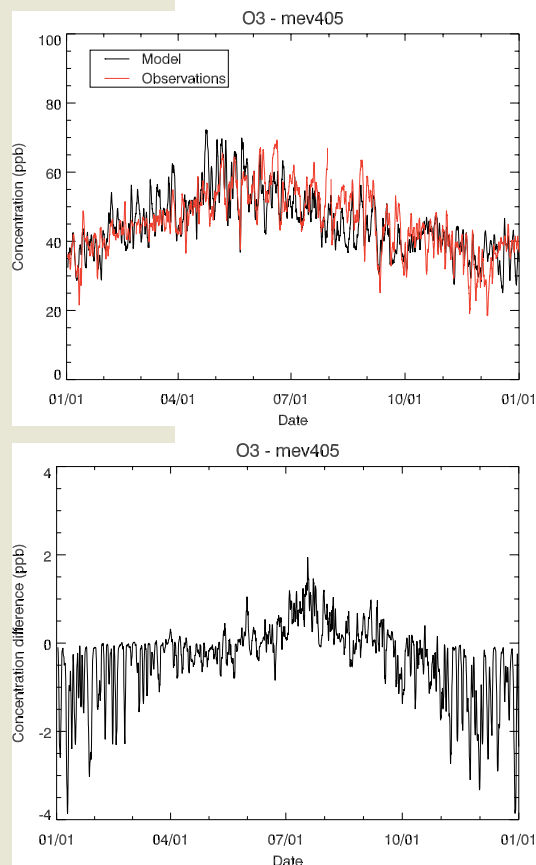
Three major components comprise the modeling system: MM5 (Mesoscale Model 5), a regional weather model, CAMx (Comprehensive Air Quality Model with Extensions), a chemical transport model, and an inventory of pollutant emissions. CAMx simulates the emissions, dispersion, chemical reactions, and removal of pollutants in the troposphere by solving the pollutant continuity equation for each chemical species on a system of nested three-dimensional grids. Although computationally expensive, this type of simulation accounts for the complex physical and

chemical processes that govern the fate of pollutants. MM5 provides the wind fields that CAMx needs to determine the transport of chemical species, as well as other meteorological variables such as temperature and mixing height. A detailed emission inventory focused on pollutants important for regional haze and visibility that covers the model domain, which includes the contiguous U.S., southern Canada, and northern Mexico, specifies the hourly flux of emissions from numerous area and point pollutant sources. The inventory consists of 22 emission categories (e.g., automobiles, powerplants, forest fires, oil and gas development) and was developed for the WRAP. Figure 1 shows example NO<sub>x</sub> emissions associated with oil and gas development in the western U.S. Note the significant emissions that occur throughout the Intermountain West, and in particular the Four Corners region of northwestern New Mexico.

The oil and gas emission inventory used in this study was initially compiled for the WRAP’s regional haze simulations, with a focus on NO<sub>x</sub> and oxidized sulfur (SO<sub>x</sub>) emissions, which are precursors to fine particulate nitrate and sulfate, respectively. However, subsequent versions of this inventory have been developed and improved, and emissions of some species, such as VOC, have been substantially revised. Although this study uses the

earlier version of the WRAP oil and gas emission inventory, it is anticipated that the general trends presented here give a gross indication of the impact of this source category on regional ozone formation. Future simulations will incorporate the updated oil and gas emission inventory from WRAP.

CAMx was used to simulate the entire year of 2002, which corresponds to the “base modeling year” being investigated by the WRAP, and the latest year in which detailed emissions were readily available. The first step in this evaluation is the comparison between predicted ozone concentrations with available observations. Once the performance of this “base case” simulation is deemed adequate, a second simulation that evaluates the impact of oil and gas emissions is performed. Ground-level ozone concentrations predicted by CAMx were compared to surface measurements at 22 sites within the Clean Air Status and Trends Network (CASTNET) monitoring network. The sites  
(continued on page 28)



**Figure 2a-b. Ozone time series for (a) simulated (black) and observed (red) ozone [ppb, 24 hour average] at Mesa Verde National Park during the 2002 base case simulation, and (b) the change in ozone concentration [ppb, 24 hour average] at this site due solely to VOC and NO<sub>x</sub> emissions from oil and gas development.**

# CIRA COMMUNIQUÉ

## Correction to Fall 2007 Communiqué

In June of 2007, the CloudSat SDPC Team received a NASA Honor Award (Group Achievement Award) for exceptional contributions to the CloudSat mission in the design, development and implementation of the CloudSat Data Processing System.

**Michael Hiatt** was also in the list of team members awarded. Michael developed the CloudSat hardware platform and DVD writing system. Thank you for your dedication, and congratulations Michael!

## Future Plans for CIRA

I am pleased to announce that Graeme Stephens has accepted our offer to serve as the next director of CIRA. He will serve as CIRA director - select beginning February 1, 2008. He will become CIRA director on August 1, 2008. Therefore, Tom Vonder Haar will remain CIRA Director through July 31, 2008 to allow for a transition as we develop our proposal to recompete for CIRA.

Please join me in congratulating Graeme and thanking Tom for many years of strong leadership. We truly are fortunate to have two such individuals within our college.

*Sandra Woods, Dean  
College of Engineering  
Colorado State University*

## Congratulations to NOAA's 2007 Presidential Rank Award Winners

Each year the President recognizes a distinct group of career senior executives with the President's Rank Award for exceptional long-term accomplishments. High-performing senior career employees are strong scientific leaders who achieve results and consistently demonstrate strength, integrity, industry, and a relentless commitment to excellence in public service. This year Dr. Alexander E. MacDonald was one of two Presidential Rank Award winners. Congratulations, Sandy!

**Dr. Alexander E. "Sandy" MacDonald's** leadership and success in technology development and transition to operations has helped make NOAA a leader in its operational systems. He is widely regarded as a visionary, who is able to both predict where science and technology are going, and to lead the way in important programs. In the last five years, Dr. MacDonald has made some extraordinary contributions to NOAA and the Nation. He invented a new display technology, Science On a Sphere, (SOS) that visually displays global data in a truly spectacular way. His new SOS display technology was awarded a patent to the government in 2004. These popular educational systems are now in multiple museums, resulting in the education of hundreds of thousands of people on the

workings of the global ocean and atmosphere. In 2003, when OAR was without an assistant administrator, he led and organized a group of laboratory directors to serve as acting assistant administrator (AA) and deputy assistant administrator (DAA), and he served for two months as acting AA, and another two months as acting DAA. Dr. MacDonald chaired the Physical and Social Sciences Task Team (PSTT) group that looked at the entire organizational and geographic structure of NOAA's research, and made recommendations that were unanimously accepted by NOAA's highest level of leadership. In August of 2006, he became OAR's deputy assistant administrator for laboratories and cooperative institutes, and the first director of Earth System Research Laboratory (ESRL).

## Nobel Peace Prize Shared by CIRA Researchers

University Distinguished Professor **Tom Vonder Haar** and Senior Research Scientist Emeritus **Doug Fox** worked with the Intergovernmental Panel on Climate Change, which shared the Nobel Peace Prize announced Oct. 12, 2007. Thousands of scientists from across the globe were involved in the IPCC. Vonder Haar made contributions to several chapters, while Doug Fox was the coordinating lead author for the "Impacts of Climate Change on Mountain Ecosystems Chapter" in the IPCC

1995 Assessment. Graeme Stephens (CIRA director-select) was another important contributor.

## 2007 Bronze Award Winners

Message From the Under Secretary of Commerce for Oceans and Atmosphere –

NOAA is pleased to announce the winners of the 2007 Bronze Medal Awards. Please join me in congratulating the following individuals, groups and organizations for their dedicated service to NOAA:

### **National Environmental Satellite, Data and Information Service Ken Knapp**

For analyzing terabytes of data from 18 different satellites from more than 20 years of observations in order to create climate data records on hurricane trends and improve the understanding of climate variability and change.

**Mark DeMaria, Antonio Irving, Nancy Merckle, John A. Knaff (Andrea Schumacher and Bernadette Connell** were also contributors).

For the development and operational implementation of the Tropical Cyclone Formation product that quantitatively predicts storm formation probability.

*Conrad C. Lautenbacher, Jr.  
Vice Admiral, U.S. Navy (Ret.)  
Under Secretary of Commerce  
for Oceans and Atmosphere  
and NOAA Administrator*



## CIRA Scientist Among Authors of Book Celebrating 50 Years of Earth Observations from Space

**Stan Kidder** has contributed to a new book celebrating 50 years of Earth observations from space. He is one of a dozen scientists from around the country who have written chapters in the book *Earth Observations from Space: The First 50 Years of Scientific Achievements*. The book was sponsored by The National Academies in honor of NASA's 50-year anniversary in 2008.

**Dr. Tom Vonder Haar** helped manage the book project as a member of the Board on Atmospheric Sciences and Climate. Vonder Haar also serves as the chairman of the interdisciplinary section of the National Academy of Engineering.

"The report sponsored by the National Academies at the request of NASA is timely as we plan the next segment of our space missions to monitor Planet Earth," Vonder Haar said. "Our past accomplishments and lessons learned will assist with the design of future Earth climate and science missions."

Kidder talked about his chapter on the contributions satellites make to weather forecasting on February 17 at the American Association for the Advancement of Science annual meeting in Boston.

"People have been interested in weather for hundreds of years, but you can't forecast

when you don't know what the weather is in lots of places," Kidder said. "You've got to see the big area to make the forecast. Satellites provide us with that capability - looking at temperature and humidity all over the Earth."

Before satellites, severe weather surprised people, often resulting in thousands of deaths. Kidder points to the hurricane that hit Galveston, Texas, with no warning in 1900 and killed 8,000 people. "Now, there are no surprise tropical storms anywhere on Earth," he said.

Kidder's research at CIRA focuses on using satellite data to study meteorological problems such as the amount of water vapor in the atmosphere, which is useful for forecasting rain. He takes satellite information and builds products for the scientific community including forecasters.

A sample of Kidder's and CIRA's work:

- CIRA local-scale products: [amsu.cira.colostate.edu/GOES](http://amsu.cira.colostate.edu/GOES)
- Water vapor imagery, including GPS data: [amsu.cira.colostate.edu/GPSTPW](http://amsu.cira.colostate.edu/GPSTPW)
- Oceanic water vapor imagery around the world: [amsu.cira.colostate.edu/TPW](http://amsu.cira.colostate.edu/TPW)

## November 2007 GSD Team Member of the Month: Leigh Cheatwood-Harris

The following nomination for GSD Team Member of the Month for November

2007 comes from Information Systems Branch Chief Carl Bullock.

"I am nominating Leigh Cheatwood-Harris for GSD's November 2007 Team Member of the Month. Leigh has supported a number of important evaluation and training activities in ISB over the past several months. Two of particular note were her work with the AWIPS II development and GFE training for River Forecast Center forecasters.

For AWIPS II, Leigh was persistent in working with the version 1.0 despite many problems typical of a first release of software. She became the de-facto expert on this system helping others learn and use AWIPS II. She also developed test metrics which will be used to evaluate the new AWIPS II system. This development included compiling and evaluating usage logs, interacting with NWS staff at the Boulder forecast office, and running and documenting performance tests. These metrics will form the basis of comparing the performance of the new AWIPS II system.

She has also played a key role for developing and testing training material for initial GFE training conducted with River Forecast Center forecasters from across the nation. She meticulously went through training material before training began and suggested changes to the material in order to make it more meaningful to

participants during training. She also assisted during training and answered questions during lab exercises. These contributions helped lead to a successful training experience for the participants, most of whom had little prior experience with the GFE."

## December 2007 GSD Team Member of the Month: Sean Madine

The following nomination for GSD Team Member of the Month for December 2007 comes from Aviation Branch Chief Mike Kraus.

"Sean Madine is GSD's Team Member of the Month for December. We in the Aviation Branch would like to recognize Sean's significant contributions to the Forecast Verification Program. Sean is a key contributor to the success of the Verification Program. He provides programmatic coherence, project leadership and vision, and has infused innovative scientific concepts into the verification and evaluation process. For instance, Sean is leading the design of the next generation RTVS, is developing a significant cutting edge project with Boeing Corporation to understand the economic value of weather forecasts, and is working to extend verification concepts and information for automated decision support."

"Thanks Sean for all you do and congratulations!"

# CIRA COMMUNIQUÉ

## **Announcing the 2007 GSD Web Award Winners – The “Webbies!”**

### **Best New Site Jeff Smith**

“Data Locator” Site

This new site provides a search engine for finding GRIB and NetCDF meteorological data here at GSD. Employing a web coverage service (WCS) to return subsets of desired data in NetCDF format, the Data Locator web application can either return this data as a downloaded NetCDF file (.nc), or it can generate web pages for viewing the data in a web browser or from within Google Earth. A web service is also available for other applications to invoke in order to find and retrieve this data.

### **Best Product/Internal Use Patrick Hildreth**

“FIDO” – Short for FICS Docs

The GSD ITS Operations staff have long relied upon FICS to assist them in monitoring the various systems in support of the research projects here at GSD/ESRL. “Fido,” short for FICS Docs, is an add-on to FICS used to store and manage the detailed information pages associated with these systems. With Fido, operators are now able to edit, add, and delete information pages as well as view an archive of previous versions. The primary users of the system like it so well that they have expressed a desire to move all of their documentation to this new system.

## **Please congratulate the following employees on their recent promotions:**

### **Christopher Anderson**

Chris was promoted to research associate III in January 2008. He has been a researcher at CIRA in Boulder for several years and has applied his atmospheric modeling expertise in a wide variety of endeavors that the ESRL/GSD/FAB (Forecast Applications Branch) has been involved in. Chris’ Hydrometeorological testbed (HMT) work has numerous components with the real time model forecasts/ensembles, and he coordinates his efforts together with those of two other FAB researchers in HMT-related ensemble post-processing. Chris’ other area of climate-related work takes the form of WRF downscaling with LAPS analyses for the ESRL Carbon Cycle group, as well as interactions with the NOAA Western Water Assessment.

### **Daniel Bikos**

Dan works with the RAMM Branch at CIRA in Fort Collins and was promoted to a research associate III in July 2007. Within the RAMM Branch, Dan has worked with the Virtual Institute for Satellite Integration Training (VISIT) program since its inception in 1998 and has helped VISIT become established as a premier virtual training program for the NWS. He collaborates with colleagues from CIRA, CIMSS, and the NOAA/NWS Training Branch to research

topics and develop and deliver teletraining to students – primarily to NWS forecasters as well as other NOAA and DOD personnel.

### **Robert DeMaria**

On July 1, Robert began a half-time research associate I assignment at CIRA in Fort Collins, a promotion from his former assignment as a coordinator (non-student hourly). He is a familiar face here at CIRA, as he has worked part time with the RAMM Branch for the past seven years – first as a high school PACE student and then while he completed an undergraduate degree in Computer Science at CSU. In his new position, Robert will work with database formatting and conversion, development of graphical display programs, algorithm verification programs, management of remote sensing databases, and code optimization. In his off-time, Robert enjoys the challenge of programming computer games. Bernie Connell is Robert’s supervisor.

### **Joanne Edwards**

Joanne was promoted to research associate IV in July 2007. She has been a researcher at CIRA in Boulder since February 1996 and a research associate III since the AP career ladder was implemented in 2002. She received the CIRA Research Initiative Award in 2000 as a key member of the Department of Commerce Gold Medal-winning AWIPS development team. Over the

past few years, she has assumed increased technical leadership roles and played a significant part in several collaborative projects with ESRL/GSD and NWS.

### **Kathy Fryer**

In recognition of Kathy’s evolving role within the RAMM Branch at CIRA in Fort Collins, she was promoted to a research coordinator position in November 2007. The promotion recognizes the broad range of assignments for which she is responsible and her independence in carrying out most of those duties. Congratulations to Kathy!

### **Hiro Gosden**

Hiro was promoted to research associate III in August 2007. He is responsible for computer support to the NOAA RAMM Branch at CIRA in Fort Collins. This includes Windows and Linux system administration, hardware repairs, network support, and student hourly supervision. He also serves as backup administrator for the RAMMB AWIPS system. In addition, Hiro maintains various meteorological workstations utilized by NOAA and CIRA researchers to ingest global satellite data and develop research products. Hiro serves as manager for several projects, including a current project to streamline the process for research product development, evaluation and transition to operations.

### **Robert Hale**

Dr. Hale (located in New Mexico) was promoted to research scientist I on December 1st, having served CIRA as postdoctoral fellow for three years. Dr. Hale's research focuses upon changes in observed temperatures associated with changes in land cover at climate station locations throughout the conterminous USA. His supervisor is Tom Vonder Haar.

### **Paul Hamer**

Paul was promoted to research associate IV in July 2007. Paul has been a researcher at CIRA in Boulder since 1998 and a research associate III since the AP career ladder was implemented in 2002. During this time, Paul has been responsible for the redevelopment of the Central Facility's data acquisition and processing system. The implementation of the Object Data System he totally designed and developed has permitted GSD's Information and Technology Services to more easily acquire, process, store, and access a greater amount of data. Paul also completely developed the long-term archiving of data using Facility Data Repository. Paul takes the initiative to explore new ideas and concepts to solve GSD's data acquisition and processing challenges and to implement novel approaches to maintain the Lab on the forefront of IT technological advances.

### **Isidora Jankov**

Dr. Jankov joined ESRL/GSD's CIRA staff in Boulder as a research scientist on December 1st. Isidora first joined GSD's Forecast Applications Branch at CIRA in Boulder in February of 2006 as a postdoctoral fellow working on ensemble modeling and rainfall forecasting efforts. Isidora has her Bachelor of Science in meteorology from Belgrade University in Serbia and Montenegro, and her Master of Science and Ph.D. in meteorology from Iowa State University in Ames, Iowa. She remains with the Forecast Applications Branch – Development Section involved in research activities that span improvement of the diabatic analysis methodology, evaluation of model error and error covariances, assessment and implementation of 3-dimensional variational methods, ensemble design and optimization for specific problems, ensemble post-processing using advanced statistical approaches, and configuration of probabilistic products for operational use. The culmination of her effort will be an experimental system aimed at supporting field efforts of the Hydrometeorological and Hazardous Weather Testbeds.

### **Hongli Jiang**

Hongli, a CIRA research scientist II at CIRA in Boulder for over two years and a research scientist with the CSU Department of Atmospheric Science for over 10 years, was promoted to research scien-

tist III in January 2008. Over the past 2 years, Dr. Jiang has become an indispensable member of a research collaboration involving the Chemical Sciences Division at NOAA/ESRL. Among her accomplishments are her conversion of the RAMS model to run on NOAA's parallel processing supercomputer which has permitted the group to simulate their very detailed microphysical models in 3-D and over significant simulation times. She has also played a very significant role in expansion of their coupled model to include an aerosol model that interacts with the dynamical, microphysical, and land-surface modules. This allows the group to see aerosol effects on clouds as part of a coupled system with multiple feedbacks. She has also been responsible for the huge task of simulating case studies from NOAA's TEXAQS/GoMACCS (2006) field program in Houston.

### **Kevin Micke**

Kevin was promoted to research associate II in January 2008. He is responsible for RAMMB web page development and maintenance at CIRA in Fort Collins and works closely with research staff to transition real-time research products to the web. The RAMMB web page plays an increasingly important role in experimental product dissemination and evaluation. Kevin has also developed template scripts that allow researchers to more easily develop their

own web pages in an efficient manner. He coordinates every aspect of the development, maintenance, and administration of the RAMMB website and research databases. Kevin works closely with NOAA web development staff to ensure that all NOAA security issues and standards are addressed. In addition to his web master responsibilities, Kevin provides a wide variety of Windows hardware and software support to research staff. Additional responsibilities include system configuration, repair, and new hardware and software research, evaluation, and implementation. Kevin also supervises two student hourlies assisting with web page development.

### **Karen Milberger**

Karen was promoted to research associate III in July 2007. Karen has been a researcher at CIRA in Boulder since 2003. She received the CIRA Research Initiative Award in 2004 as a key member of the GLOBE Program. In 2006, Karen was handpicked by the GLOBE Director to lead an across-the board redesign of their entire website. As the new Tech Lead for Web Support, she has been responsible for a major long-term effort to overhaul the software architecture to improve student-friendly visualization and to support easier navigation and interactive content.

*(continued on page 29)*

# CIRA'S NEW FACE

**We have now completed a renovation project that has pulled everything together into one unified color scheme and given us a clean, fresh background upon which to mount our scientific canvas.**

## CIRA Has a Brand New Look

*Marilyn Watson*

CIRA has had a face lift! The final of seven phases of renovation are now complete. Over 50 staff members have been jostled around as the building has been worked on piece by piece. Along with staff moves, all furniture has been moved; computers have been powered down, moved, and powered up again. Phase after phase it has gone on, and thus CIRA has gained a great new start.

The CIRA building is a unique building on the foothills campus of CSU. The first wing was built in 1981, the second and third phases added in 1987, phase four was completed in 1998, and then came the main entry remodel of 1999. Because the building was constructed in several phases, the carpet and paint were different in each wing. Design and color choices are constantly changing, making it difficult to match new to old. We have now completed a renovation project that has pulled everything together into one unified color scheme and given us a clean, fresh background upon which to mount our scientific canvas.

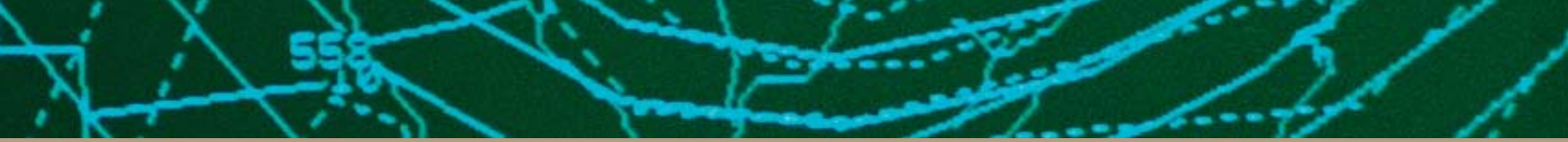
The CIRA Renovation has been an interesting challenge for our department. Dr. Thomas

Vonder Haar, our department director, had the idea last summer to renovate the CIRA building to give us a fresh look as we face the recompetition for NOAA funds that is coming up this year. Mary McInnis-Efaw, our CIRA manager and assistant director, asked Walt Naylor and me to assist with the remodel along with two hourly workers, James Ubillos and Chris Musgrave. James and Chris were the backbone of all the preparation and facilitating that went into packing up staff offices, settling folks into temporary quarters and finally moving them back into their freshly renewed office spaces.

The extensive remodel plan included new paint inside and out as well as new carpet throughout the building; new floor tile in the restrooms and break room and new ceiling tile in the older sections of the building. Also included were new half-light doors at upper and lower exits, replacing dark solid doors to give the building more light and open up the space a bit.

We began the facelift mid-October of 2007. As the project progressed, more ideas for updates emerged. For example, over the years, computer LAN lines were added in a constantly changing configuration as technology advanced and our research staff was moved about to accommodate project group changes. Because of the fluid needs





of this ever-changing connection landscape, lines were originally run in the ceilings and dropped down into whichever area needed at the time. This proved to be an efficient if unsightly solution. Now we have afforded ourselves the luxury of permanent LAN line jacks to allow connectivity from most areas in each office.

In addition, broken seals were revealed on a great number of exterior windows which will have to be replaced. This will occur in the spring of 2008 after the worst of the winter cold has given way to warmer weather.

The renovation also gave us the opportunity to clean blinds and windows inside and out as well as clearing the dust from behind furniture that had not been dislodged for some time. We took this opportunity to clean the air ducts to rid the building of allergens lurking in the ceiling and wall cavities. Other changes include new handicap openers on our entry doors, new sinks and cabinets in the restrooms, a new chaise lounge in one restroom, new entry floor mats, and most conspicuous of all, a new counter top, all new conference tables and chairs, and a new wireless conference phone in our Director's Conference Room. All of this has enhanced our building and our outlook.

During this project it has been necessary for occupants of the CIRA building to be moved in phases to temporary locations either in our building or in adjacent buildings. The cooperation of the staff has been phenomenal! Complaints were few and morale was high as everyone got into the spirit of the updated look. Kudos to CIRA staff for tolerating amazing inconveniences and continuing to produce their fantastic scientific products in spite of the chaos of the remodel!



## Vonder Haar Celebrates 100th Student

Since his arrival at Colorado State University in 1970, Dr. Tom Vonder Haar has enjoyed advising and mentoring more than 100 students to receive more than 100 degrees, including 76 M.S. and 27 Ph.D.s.

Of course, some students obtain both the M.S. and Ph.D. in atmospheric science at CSU, so the question in the hallway has always been "Who will be Professor Vonder Haar's 100th student to graduate?"

The counting began easily with Tom's first M.S. student (Capt. Gerry Sikula, 1971) and Ph.D. (Dr. Jim Ellis, 1975). Then, with co-advising of some and a few M.S. students taking the non-thesis option, the counting became a bit fuzzy. By combining the department records provided by Jen Weingardt, the Vonder Haar research group records compiled by Holli Knutson and Tom's own count, it has been determined that his 100th student graduate ( $\pm 1$  or 2) is among a group of four M.S. advisees that completed their degrees in Fall-Winter 2006. They are: Kate Maclay, Becca Mazur, Kevin Donofrio, and Dustin Rapp.

Tom hosted a good sized group at his "100th student/graduate" lunch!

# EDUCATION AND OUTREACH

## Environmental Education and Public Outreach

Julie Winchester

*Acts of conservation without the requisite desire and skills are futile. To create desire and skill, and the 'community motive,' is the task of education. – Aldo Leopold 1944*

According to a National Environmental Education and Training Foundation (NEETF) report, "Understanding Environmental Literacy in America and Making it a Reality," 95 percent of American adults think environmental education should be taught in schools and 90 percent believe that adults in the workplace should also receive some kind of environmental education. Ten years of survey results show that while American adults value the environment, their comprehension of complex environmental issues is limited. About 80 percent of Americans are influenced by incorrect or outdated environmental information and just 12 percent of those surveyed can pass a basic quiz on awareness of energy topics. At a time when we are confronted with increasingly complex environmental choices, our "EQ" (environmental intelligence quotient) is extremely low and most of us are ill-prepared to understand and address the environmental

issues that will arise in the next 15-25 years. We have yet to make the link between environmental health and welfare and the impacts of cumulative individual actions.

The NEEFT, in collaboration with Roper Research, has conducted surveys to better understand what Americans know about the environment and how they view emerging environmental problems. Figure 1 displays topics posed in a 2000 survey that addressed subjects ranging from energy, water, and air pollution, to habitat loss and more. Figure 2 displays topics posed in a follow up study in 2001 that tested knowledge of energy topics. In both charts, the numbers in the far right column represent the percentage of the sampled population who answered the question correctly. There were some surprising results.

Two thirds of the American public says they know a fair amount about the environment but statistics tell a different story. Surveys show that 80 percent of the public are heavily influenced by incorrect information and it seems that we are stuck in the environmental mindset of 30 years ago. For example:

- Only 27 percent of Americans know that 60 percent of our electricity is produced by burning coal and other flammable materials. 40 percent of people believe that hydroelectric power is America's top source of energy (only 10 percent of the total)
- Add up hydropower, nuclear, and solar sources, and the majority of Americans think our electricity is generated in ways that have little or no impact on air quality
- Just 22 percent of Americans know that runoff from farm fields, roads, parking lots, and lawns is the leading cause of water pollution in America today. 47 percent think the most common form is waste dumped by factories
- 120 million Americans believe spray cans still have CFCs in them even though CFCs were banned in 1978

**Figure 1.**  
Percentage of sampled population who answered these basic environmental knowledge questions correctly.

Source: NEETF & Roper, 2001[1]

Content of Environmental Knowledge Question	2000
The most common source of water pollution	28
How most electricity in the United States is generated	33
Definition of biodiversity	41
The primary benefit of wetlands	53
Protection provided by ozone in the upper atmosphere	54
Disposal of nuclear waste in the United States	57
Recognition of a renewable resource	65
The largest source of carbon monoxide (air pollution) in the United States	65
Knowledge about materials considered hazardous waste	67
Name of the primary federal agency that works to protect the environment	72
The most common reason for extinction of animal and plant species	74
Where most household garbage ends up	85



- 45 million Americans think the ocean is a source of fresh water
- One in four Americans (23 percent) knows that paper products are the number one source of landfill material in America. 29 percent still think that disposable diapers are the greatest cause of over-stuffed landfills
- Two-thirds of Americans fail to recognize that the transportation sector is the largest petroleum user in the U.S.

These facts and figures point to the need for comprehensive environmental education. While the American public continues to engage in basic activities (recycling, conserving electricity, and saving water) to benefit the environment, they are not embracing the fact that the lion's share of our pollutants is generated by individuals and small entities. The environmental impact of small point sources is complex and is largely beyond the reach of environmental regulation programs, yet our environmental future depends on personal knowledge and action. An informed and knowledgeable public can play a larger role in evaluating proposed environmental laws and determining new policies. Awareness of environmental systems and an understanding of emerging environmental issues will spur the public to action in making long-lasting behavioral changes.

## Scientists and Researchers – Bridge to the Future

As we move into the 21st century, it is essential that each of us has a sound knowledge of scientific concepts, processes, and technologies in order to make informed decisions and take an active role in advancing our society. With a wealth of information available over the internet and through the media, our skills in information management, critical thinking, and problem-solving techniques will be sorely tested. The communication of sound research is increasingly important as we make choices about energy providers, support new sources of power generation, choose health care providers, vote to support stem cell research, or make behavioral changes that will lessen our impact on the environment. The vital

Content of Energy Knowledge Question	2001
Source of most energy usage in the home	66
Percentage of oil imported from foreign sources	52
Percentage of world's energy consumed by the United States	50
Disposal of nuclear waste in the United States	47
Fastest and most cost-effective way to address energy needs	39
United States industry increased energy demands most in past 10 years	39
Fuel used to generate most energy in the United States	36
How most electricity in the United States is generated	36
Sector of United States economy consuming greatest percentage of petroleum	33
Average miles per gallon achieved by vehicles in past 10 years	17
Average number of correct answers	4.1

role of the scientist and researchers in education and public outreach should not be ignored.

Many research and funding agencies now require the integration of science and education with mandates for greater involvement in public outreach. The role of the scientist in education and public outreach has evolved to more than just the K-12 school visit or the occasional public lecture. One can advocate, be a resource, or join in a partnership with educators and public outreach specialists.

Working in tandem with education and public outreach specialists, scientists, and researchers brings:

- strong content knowledge,
- access to resources,
- critical and analytical thinking,
- scientific literacy,
- technical support for outreach products.

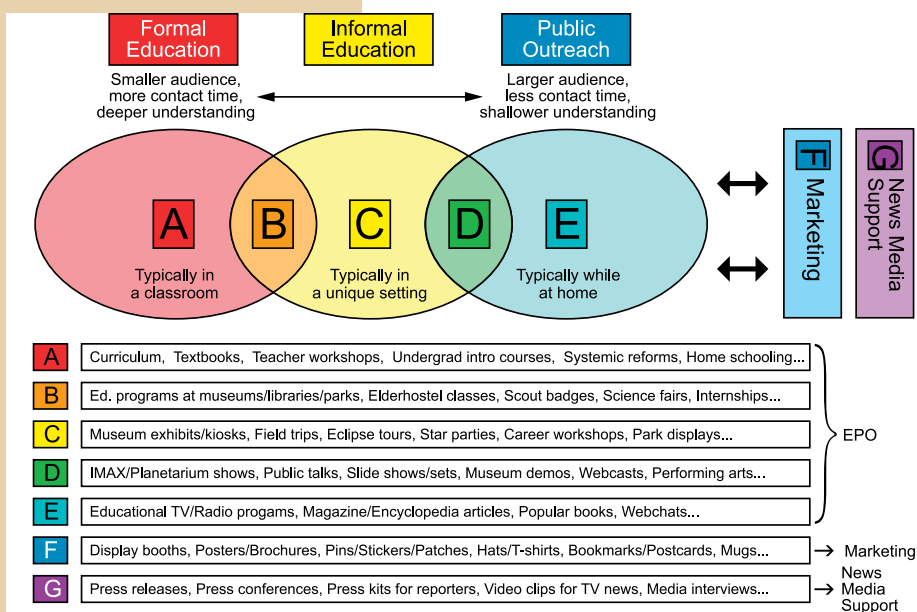
The following Venn diagram, conceptualized by Cherilynn Morrow of the Space Science Insti-

**Figure 2.**  
*Percentage of sampled population who answered these basic energy knowledge questions correctly.*  
Source: NEETF & Roper, 2001 [2]

**Figure 3.**  
*Roles for scientists and researchers.*  
Source: Cherilynn Morrow, Space Science Institute, May 2000

Roles for Scientists and Researchers	
Advocate	Inspires, encourages, gives permission, empowers
Resource	Helps when called upon; makes resources available
Partner	Works as a team member with education and public outreach specialists to create new products and educational opportunities

# EDUCATION AND OUTREACH



**Figure 4.** Three circle Venn diagram offering a framework for planning education and public outreach and programs associated with scientific research programs.

Source: Cherilynn Morrow Space Science Institute, May 2000

tute, presents a framework for planning education and public outreach programs associated with scientific research programs (Figure 4). As one moves from formal education, through informal education, and into public outreach, the capacity to reach larger audiences greatly increases. However, the potential to communicate in-depth knowledge of the topic is greatly reduced. At all levels there is ample opportunity to reach out to

all age and education levels with shared knowledge that will perhaps inspire curiosity and further exploration of the topics. Many of the outreach products created by the CIRA-NPS air quality research group at Colorado State University fit into the education and public outreach sections of this framework. Under formal education, the "VIEWS" website provides real-time access to monitoring data with software tools, allowing users to create summaries on demand. Undergraduate and graduate students work

directly with researchers conducting field monitoring and data analysis for special focus research studies. Informal education encompasses field training guides on CD-ROM, web-based presen-

tations of scientific concepts behind air quality research, and interactive displays relating to air quality issues in national park visitor centers. In the public outreach arena, scientists reach out to the general public, policy makers, fellow scientists, and educators with presentations of their work.

## CIRA-NPS Web Presentation Nitrogen Emissions, Atmospheric Processes and Deposition

Education and outreach programs at CIRA build on the expertise of scientists involved in the study of severe weather, weather forecasting, climate change, and air quality-related issues including visibility and acid deposition. The air quality research group depends heavily on local and national partnerships to carry out its goal to preserve, protect, enhance, and understand air quality and the relationship to sensitive resources in national park systems (Figure 5).

In an ongoing effort to develop outreach materials that reflect current research activities within the NPS air quality group, we are launching a web-based presentation that seeks to convey an understanding of the sources and effects of reactive nitrogen (both naturally occurring and human caused) in the environment. (The term reactive nitrogen refers to all biologically active, photochemically reactive, and radiatively active nitrogen compounds in the atmosphere and biosphere of the earth). It focuses on the formation of reactive nitrogen in the atmosphere and how it is transported and deposited in remote national parks and wilderness areas. Finally, it explores a range of negative environmental effects caused when there is too little or too much reactive nitrogen introduced into sensitive ecosystems. The goal is to provide a resource for the environmentally concerned community including public officials, students, teachers, and the general public. We focus on optimizing the link between education and research, taking care to present facts and concepts, not opinions or advocacy. The following highlights the web presentation on nitrogen deposition:

The most abundant gas in the atmosphere is nitrogen (N<sub>2</sub>). Today, human activities associ-



**Figure 5** A Conceptual diagram of the partners involved in CIRA-NPS air quality research and the available public outreach products.

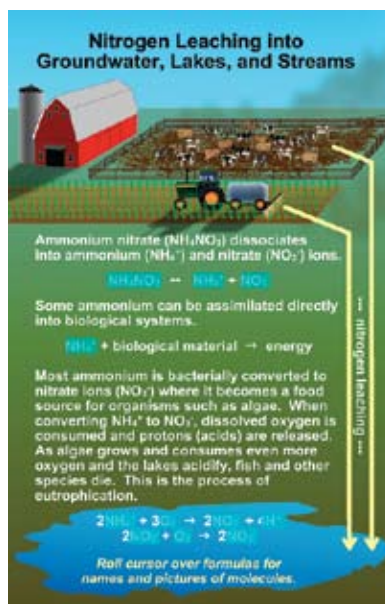




ated with food production and fossil fuel combustion are increasing the amount of nitrogen cycling between the atmosphere, soils, and water resources. Reactive nitrogen is found both in its oxidized and reduced forms. Combustion sources, such as power plants and automobiles, produce nitrogen oxide (NO) and nitrogen dioxide (NO<sub>2</sub>), while fertilizing activities and feedlots produce ammonia (NH<sub>3</sub>), a reduced form of nitrogen.



In its molecular form, nitrogen is unusable by most living organisms. It must be transformed into reactive nitrogen before plants and animals can make use of it. The application of reactive nitrogen, in the form of synthetic fertilizers, allows for increased food production but increases the release of nitrogen into the environment through agricultural runoff and sewage.



While nitrogen compounds are important to the nature and diversity of plant life; excessive amounts have deleterious effects on sensitive remote ecosystems including:

- an increase in global concentrations of nitrous oxide (N<sub>2</sub>O) a potent greenhouse gas;
- increasing concentrations of nitric oxide (NO) which drives the formation of photochemical smog;
- acidification of soils and the loss of nutrients such as calcium and potassium necessary for soil fertility;
- acidification of lakes and streams including transport of nitrogen into sensitive coastal waters and estuaries;
- loss of biological diversity in plants and microbes which impact the aquatic and animal species dependant on them to survive;
- lower numbers of nitrogen-fixing organisms (algae and bacteria) that convert gaseous nitrogen to plant-usable forms;
- reduced visibility.

Public education about reactive nitrogen as an environmental problem is an essential first step towards making informed decisions to mitigate it. This presentation communicates in nontechnical, understandable language: 1) the sources and storage mechanisms of reactive nitrogen; 2) the chemistry and flow paths it follows in the environment; and 3) the consequences for people and ecosystems as reactive nitrogen deposits in the environment.

[1] Kevin Coyle, Report: "Environmental Literacy in America," 2005 The National Environmental Education & Training foundation, Washington, D.C.  
 [2] Dr. Cherylann A. Morrow, "A Framework for Planning Education and Public Outreach Activities Associated with Scientific Research Programs," Space Science Institute, Boulder, Colorado www.spacescience.org/ click on "Papers on EPO."

# DPC HARDWARE

## Cloudsat DPC Hardware

*Michael Hiatt*

When CIRA started discussing a plan to build and operate the CloudSat Data Processing Center (DPC) with NASA/JPL, the Institute was already well established at data collection, processing, distribution, and archive techniques and technologies. CIRA has been operating a satellite earth station since 1978. During this time, CIRA has designed many unique hardware and software solutions using mainstream technologies to improve and streamline its earth station. These improvements have significantly reduced costs and manpower needed to operate an earth station thus allowing CIRA to be very competitive when bidding for data processing projects. Some of CIRA's earth station design topologies were used in the Cloudsat DPC to take advantage of this efficient low-cost architecture. These mainstream technologies and their impact on the Cloudsat DPC are discussed here.

**Limiting Physical Building Space Requirements.** The first consideration of any DPC is the physical building space requirements. A dedicated computer room is a primary requirement and has significant impact on the budget. The size, number, power requirements, and heat dissipation of the computers dictate how the room will be designed. CIRA has successfully used Small Form Factor (SFF) Intel quad-core PCs with heat pipe technology in areas where space and cooling were limited and noise could be a factor. Computer racks using 19" rack PCs also offer high density solutions but double heat, power, and cooling requirements. CIRA's unique computer solution allows rooms to be used with less power and cooling, which keeps construction costs low.

**Low-Cost Targeted Hardware Configuration.** The SFF PCs are purchased as bare bone systems that only contain the chassis, power supply, and main board. These are mainstream systems sold in mass quantity at competitive prices. CIRA installs whichever Intel processor currently meets the best performance vs. cost. Memory is installed using the amount needed for the task. CIRA

assembles these systems onsite. System design and spare parts are kept in CIRA's control, greatly simplifying configuration changes and maintenance. Furthermore, CIRA can perform in-place upgrades should the need arise. These systems can accommodate two SATA hard drives, which are typically configured in a redundant array of inexpensive disks (RAID) configuration for redundancy. Although the drives can store data, they are configured primarily for the Operating System (OS). These systems perform all data collection and processing.

**Meeting Internal and External Distribution Requirements.** Data storage and distribution is handled by hardware dedicated systems called Network Attached Storage (NAS). Since a NAS device has the single purpose of data storage, it is well optimized, using high density hot swappable RAID bays, proper drive cooling, a high speed Ethernet port, embedded OS, and a web interface with email notification for issues. NAS devices are simpler to build and maintain since a general purpose PC and OS are not required. Today, using 1TB drives, CIRA's NAS provides 3.6TB of RAID storage for about \$2,000. Heat dissipation, power requirements, and footprint are similar to the SFF PCs above. Performance is roughly equal to a dedicated PC performing the same task.

**Robust Data Archive.** Data archiving is the last step in the process. In many DPCs, tape drives are the primary archive media. In 2001, CIRA developed a DVD archive system that addressed the many shortfalls of tapes. These include lower media cost, random access, reduced storage room requirements, less expensive hardware to read and write, no special software to access, ability to verify without media degradation, and easy duplication. An article in the Fall 2003 *CIRA Magazine* discusses this further. Since the system was deployed, CIRA's archive has performed at a 99.9 percent storage and retrieval rate. Due to the success of the DVD archive system, CIRA is able to archive more data than ever before. Today,

CIRA's unique computer solution allows rooms to be used with less power and cooling, which keeps construction costs low

about 100GB of data is written and verified each day as a part-time task for one person. Room storage requirements have actually reduced as old tapes have been converted to DVD.

In summary, use of mainstream technologies customized for CIRA's tasks has provided fast,

easy to maintain, inexpensive systems which are now well proven. CIRA continues to research and develop new technologies that fit this model as they become available. CIRA is well positioned for future DPC missions.

## International Polar Year Expedition to the South Pole, Antarctica

*Dr. Glen E. Liston and Dr. Jan-Gunnar Winther*

### Diary Excerpt (Glen), 1 December 2007

As I lie in my small tent at  $-48\text{ }^{\circ}\text{C}$  ( $-54\text{ }^{\circ}\text{F}$ ) near the center of Antarctica, I try to mentally force my near-frozen toes back to life. The temperatures I am experiencing now are just about equal to the mean annual Antarctic air temperature in this area; something that typically changes only slowly over the decades and centuries. I also note that one month ago I was flying, uncontrolled, 15 meters (50 feet) through the air in response to a  $52\text{ m/s}$  (132 mph) wind gust during a storm near the Antarctic coast. I am part of a scientific research expedition traversing from the Antarctic coast to the South Pole, and this is exactly what we are here to study and understand: weather and climate variability and change on time scales of 1000 seconds (like my wind-borne flight) to 1000 years (like my cold, cold night).

*Editor's Note:* Glen received a College of Engineering Outstanding Administrative Professional Staff Award on April 10, 2008. It was presented at the College of Engineering awards ceremony held at the Edna Griffin Concert Hall, Center for the Fine Arts, Colorado State University. Remarks were made by Steven Miller, deputy director of CIRA, including excerpts from Glen's journal entries. Glen was unable to be there due to his travels.



*"The story of this CIRA-sponsored International Polar Year (IPY) expedition will be featured in the Fall 2008 issue of the CIRA Magazine. In the article Dr. Liston will describe what it is like to work in wind-chill factors as low as  $-69\text{ }^{\circ}\text{C}$  ( $-92\text{ }^{\circ}\text{F}$ ), and to go 89 days without a shower!"*

# NEW GLOBAL MODEL

## ESRL's New Global Model and Its Implementation

Jacques Middlecoff and Ning Wang

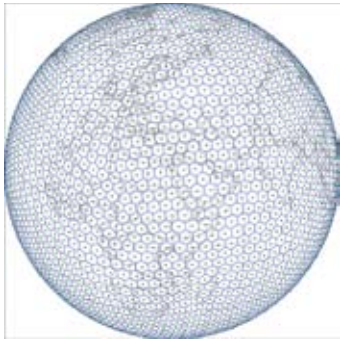
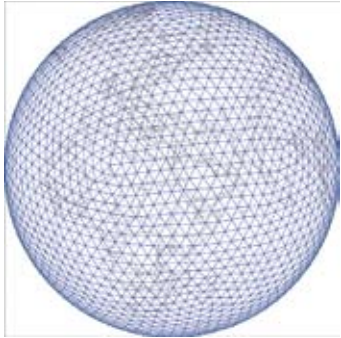


Figure 1. Icosahedral hexagonal grid and its Voronoi cell boundary.

A new global weather prediction model has been developed at the NOAA Earth System Research Laboratory (ESRL) in Boulder called the Flow-following Finite-Volume Icosahedral Model (FIM) [1]. FIM is a hydrostatic model with a flow-following vertical coordinate whose surfaces may deform freely according to air flow. Aloft, the flow-following coordinate is isentropic, while near the surface, the coordinate surfaces are terrain-following [2]. The horizontal grid consists of hexagons that cover the world like the hexagons on a soccer ball (see Figure 1).

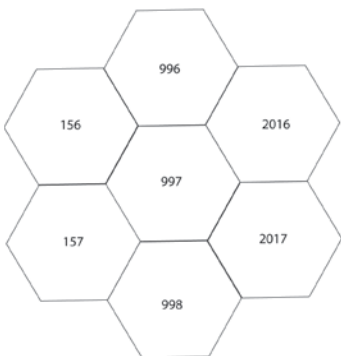
For more information on FIM, see <http://fim.noaa.gov/>.

### Icosahedral hexagonal grid

The horizontal grid mesh is created from a set of 12 evenly spaced grid points on the sphere. Each of the 12 grid points is connected to five neighbors to create 30 great circle edges and 20 spherical equilateral triangles. The resulting polyhedron is called an Icosahedron.

From each of these equilateral triangles, the following operations were performed recursively: find the middle points of each great circle of the spherical triangle and connect them with a great circle to make 4 sub triangles [3]. The resolution of the grid mesh is determined by the recursive level specified (Table 1).

Figure 2. Example of hexagonal nearest neighbors with not near indexes.



Grid level	Number of grid point	Grid resolution (km)
6	40962	120.5854
7	163842	60.1623
8	655362	30.0806
9	2621442	15.0408

Table 1. Grid statistics for recursion levels 6 through 9.

For each grid point on the sphere, a Voronoi cell is constructed around it. The Voronoi cell of a grid point is a point set whose elements are closer to the grid point than any other grid points. Except for those cells around the 12 starting grid points which have five edges, all other cells have six edges to form a hexagon. The numerical computations are carried out based on these cells (Figure 1).

In general, it is a rather uniform grid mesh. The ratio of the greatest grid point distance to the smallest one is less than 1.19512. The ratio of the greatest Voronoi edge to the smallest one is about 1.9. The relatively larger triangles appear around the center of these 20 starting triangles and smaller ones close to the corners of these triangles. Table 1 lists some statistics for the icosahedral grid for recursion levels 6 through 9.

A rather interesting aspect of this construction is its simplicity and regularity. It is easy to analyze the geometric properties of the generated grid. On the other hand, depending on our aim or the metric we wish to optimize, there could

be many variations to this basic construction. It is possible to create different variations of the grid to meet the needs of different numerical discretization schemes or numerical computations of the dynamic operators.

### Grid Structure and Parallelization

Since FIM has an icosahedral horizontal grid, a conventional rectangular grid structure was not used. Instead, the grid points are laid out in a one-dimensional vector that traverses the globe and adjacent points are referenced by indirect addressing (see Figure 2). Indirect addressing has implications for the parallelization of the code. To distribute the vector onto N processors, the vector is simply divided into N sections, one section per processor. Thus, adjacent points may be on another vector section or another processor and this affects how data is optimally communicated between processors. FIM is parallelized using the Scalable Modeling System (SMS) developed at ESRL's Global Systems Division (GSD). SMS is a directive-based system for parallelizing weather

and climate codes for distributed memory machines. For more information on SMS, see CIRA Magazine Vol. 17, Spring 2002 and <http://www-ad.fsl.noaa.gov/ac/sms.html>.

To accommodate the indirect addressing of FIM, SMS was generalized to include general, indirect addressed, unstructured grids. We consider 2500 points per processor to be the “sweet spot” for FIM and, for 30 km resolution, 240 processors results in 2731 points per process. Very good scaling (1.96X) is obtained from 120 processors to 240 processors.

### Grid Layout Optimization

The path the vector actually takes as it traces out all the points on the globe was not specified above because the path is optional. Currently, a Hilbert curve is used to trace out the path because, theoretically, a Hilbert curve traces the points in such a way as to maximize locality. Locality is good for cache utilization, but caches are very complicated. Depending on the machine, there can be up to three levels of cache, each level having arbitrary size, bandwidth, latency, and replacement strategy. Additionally, the cache performance depends on the number and size of the arrays being used and on the data reference patterns. It’s clear that figuring out the best curve for cache optimization is a daunting task, further complicated by the fact that changing the curve also affects inter-processor

communication optimization. Fortunately, an advantage of indirect addressing is that the code is independent of the data layout so the data layout can be varied to see which data layout is optimal. We have developed tools for automatically varying the data layout and are just now beginning experiments to see which layouts are optimal. The first two layouts that will be tested are the Hilbert curve and a layout that mimics a Cartesian coordinate layout.

### Some Results

In late February 2008, FIM began producing daily global forecasts at 30-km resolution running on 240 processors. Thanks to extensive collaboration throughout GSD, we were able to treat Mary Glackin, NOAA’s Deputy Undersecretary for Oceans and Atmosphere, to a spectacular global weather forecast produced by FIM and displayed on Science on a Sphere (SOS) during her visit to GSD in early March. Figures 3 and 4 are two examples of what was shown to Ms. Glackin.

For more information on SOS, see CIRA Magazine Vol. 23, Spring 2005 and <http://sos.noaa.gov/>.

### Future Plans

FIM has now moved into a testing phase under the leadership of Stan Benjamin. After successfully completing testing, FIM will become part of the NCEP production ensemble.

Jin Lee will lead Jian-Wen Bao, Ning Wang, and

Jacques Middlecoff, with Sandy MacDonald and Steve Koch advising, in the development of a non-hydrostatic version of FIM called the Non-hydrostatic Icosahedral Model (NIM). NIM will use a horizontal grid similar to FIM’s horizontal grid, but will use the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) AM2 model’s vertical Lagrangian coordinate system for the vertical grid. NIM will also use a modified version of AM2 physics with the aim of doing climate prediction as well as weather prediction. Our 2-year goal is to run NIM at 3.5 km resolution requiring about 31,000 processors. At that resolution, we hope to be able to perform a 2-month forecast and predict the Madden-Julian Oscillation (MJO).

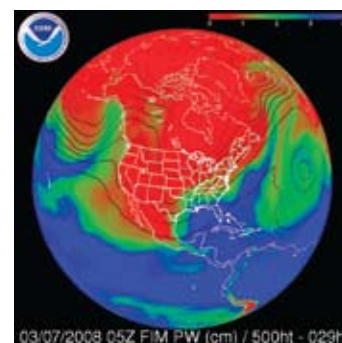
### Acknowledgements

The other members of the FIM development team were Jin Lee (NOAA/ESRL/GSD), Rainer Bleck (CIRES), Jian-Wen Bao (NOAA/ESRL/PSD), and Stan Benjamin (NOAA/ESRL/GSD), with Sandy MacDonald (NOAA/ESRL) and John Brown (NOAA/ESRL/GSD) in an advisory role.

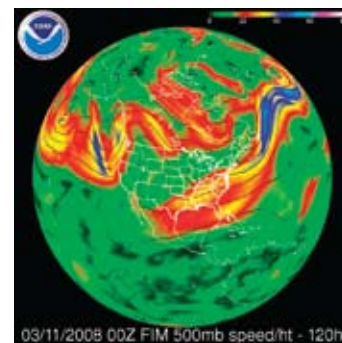
[1] Lee, J.L., R. Bleck, A.E. MacDonald, J.W. Bao, S. Benjamin, J. Middlecoff, N. Wang, and J. Brown, 2007: FIM: A vertically flow-following, finite-volume icosahedral model. Preprints, *22nd Conference on Wea. Analysis and Forecasting / 18th Conference on Num. Wea. Pred.*, 24-29 June 2007, Park City, UT, Amer. Meteor. Soc.

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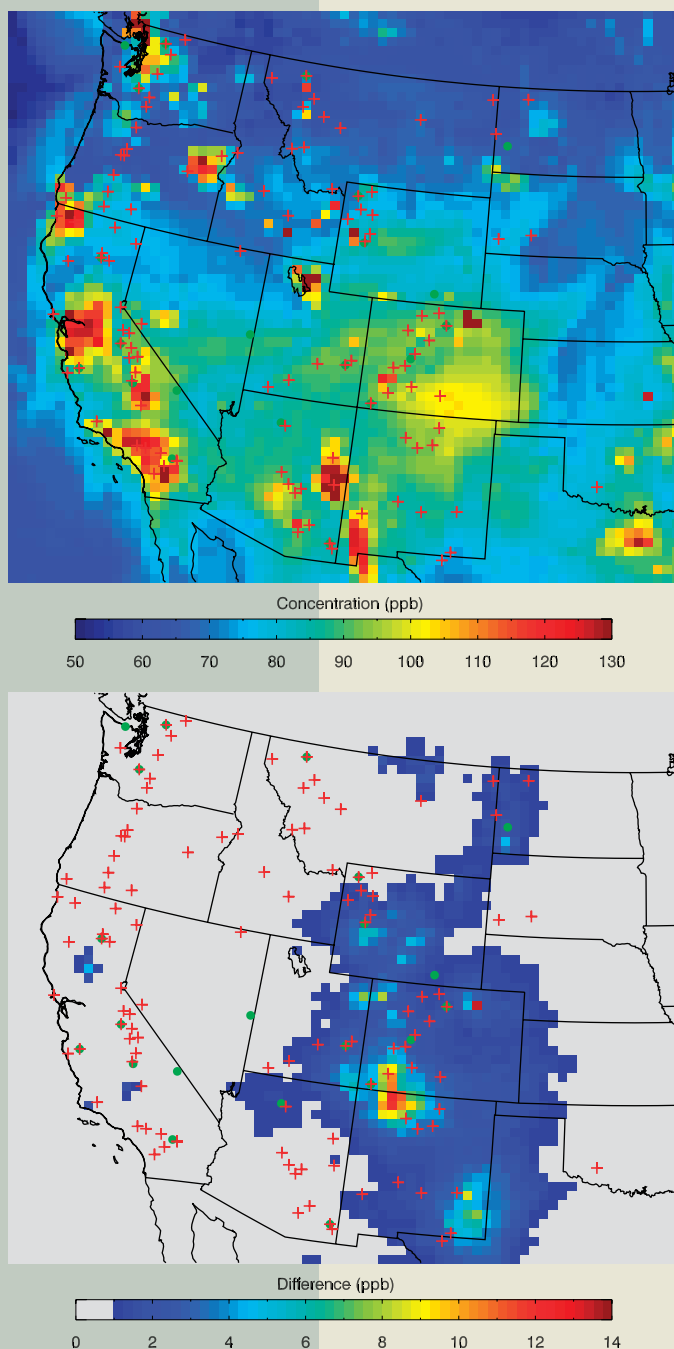


**Figure 3. Precipitable water (cm) overlaid with geopotential height at 500mb.**



**Figure 4. Wind speed (meter/sec.) at 500mb and geopotential height at 500mb.**

# REGIONAL IMPACTS CONTINUED FROM PAGE 13



**Figure 3a-b.** Peak predicted annual ozone maxima [ppb, 1 hour average] in the western U.S. from (a) the 2002 base case simulation and (b) the enhancement from VOC and NO<sub>x</sub> emissions from oil and gas development.

chosen fall within the western region of the United States. An evaluation of CAMx's skill in predicting ozone is done in accordance with the EPA's suggested performance guidelines for ozone modeling. In general, within the western U.S. (the

focus of this study) CAMx is able to consistently predict the general annual trends for ozone concentrations, with an annual normalized error and normalized bias of 22.7% and -1.6%, respectively, falling well within the EPA's guidelines for acceptable model performance.

For this study, the largest impacts from oil and gas emissions on regional ozone were seen near Mesa Verde National Park. This is not surprising, given its proximity to the extensive development that is occurring in northwestern New Mexico as shown in Figure 1. Figure 2a shows the predicted (black) and observed (red) ozone concentrations for Mesa Verde National Park, and Figure 2b illustrates the change in ozone concentration at this site attributed to oil and gas emissions. As expected in Figure 2a, the general trend of both predicted and observed ozone is low concentrations during the colder winter months, when limited photochemistry will occur, and higher concentrations during the warmer late spring and summer months, when meteorological conditions are more favorable to ozone production. In addition, it is anticipated that enhanced biogenic VOC emissions occurring during the spring and summer will further influence ozone formation in this region. Figure 2b shows the resulting change in predicted ozone concentrations that are attributed solely to emissions from oil and gas development.

This estimate was calculated by evaluating two CAMx simulations: the base case simulation, in which all emission categories are accounted, and a "no oil and gas" simulation, which is similar to the base case, except that oil and gas emissions are removed. The difference between these two predictions represents the contribution of oil and gas emissions on regional ozone. Notable in Figure 2b is the fact that oil and gas emissions can actually decrease ozone concentrations at Mesa Verde National Park through the process of "NO<sub>x</sub> scavenging", where available ozone is consumed by reacting with nitric oxide (NO). This effect is most prevalent in the winter, when ozone concentrations are lower (at approximately 40 ppb), which is near the global background concentration. However, in the summer, the situation is reversed, and warm, stagnant conditions yield an increase in ozone from oil and gas emissions. Although these impacts appear relatively small (e.g., an increase of a few ppb in the summer), it should be remembered that this period corresponds with seasonally-high ozone concentrations, and that the results presented here represent a 24 hour average; on an hourly basis, the impacts at Mesa Verde National Park can be much more significant, approaching 10 ppb.

A regional perspective of ozone formation is illustrated in Figure 3. Figure 3a shows



the peak estimated ozone concentration at each model grid cell that occurred during the 2002 base case simulation. As expected, there are high concentrations, exceeding 120 ppb, downwind of major urban areas such as Los Angeles, San Francisco, Salt Lake City, and Denver. There are also large ozone peaks in the more remote regions of Nevada, Wyoming, Utah, Arizona, New Mexico, and Colorado. These maxima occur during hot

days with light winds in the summer, when the meteorology is most favorable for ozone production. These periods also typically correspond to peak VOC emissions from biogenic and anthropogenic sources. The role of NO<sub>x</sub> and VOC emissions from oil and gas development on ozone in the western U.S. is shown in Figure 3b. Similar to Figure 3a, the peak simulated ozone for each grid cell during 2002 is shown, but in this case, the

ozone concentration is due solely to emissions from oil and gas development. Although the peak ozone maxima throughout the West are typically quite small, there is a strong signature of a 2-3 ppb of ozone throughout New Mexico, Colorado, and Wyoming, with a pattern that approximates the emissions shown in Figure 1. In addition, significant ozone concentrations, exceeding 10 ppb, are evident in southwestern Colorado and northwestern

New Mexico. Class I areas in this region that are likely to be impacted by increased ozone include Mesa Verde National Park and Weminuche Wilderness Area in Colorado, and San Pedro Parks Wilderness Area, Bandelier Wilderness Area, Pecos Wilderness Area, and Wheeler Peak Wilderness Area in New Mexico.

This study, although not exhaustive, does indicate a clear potential for oil and gas development to negatively impact regional ozone concentrations in the western U.S., including several treasured national parks and wilderness areas in the Four Corners region. It is likely that accelerated energy development in this part of the country will worsen the existing problem. The formation of ozone pollution examined here represents a complex phenomenon involving non-linear physicochemical processes, uncertain emission inventories, and fine-scale transport in mountainous terrain. These simulations will be refined with the updated emission inventories available from the WRAP. Although a daunting technical problem, regional air quality modeling remains the only feasible option for developing emission control strategies that have the potential to reduce ozone concentrations and protect air quality.

[1] Western Regional Air Partnership 2008-12 Strategic Plan; March 2008; [www.wrapair.org/WRAP/documents/WRAP\\_2008-12\\_Strategic\\_Plan3\\_08final.pdf](http://www.wrapair.org/WRAP/documents/WRAP_2008-12_Strategic_Plan3_08final.pdf)

## CIRA COMMUNIQUÉ CONTINUED FROM PAGE 17

### **Yoo-Jeong Noh**

Dr. Noh was promoted in February 2008 to research scientist II. Having served CIRA in Fort Collins for two years as a postdoctoral fellow, she has achieved significant research results relevant to snowfall retrievals over land utilizing high-frequency satellite microwave measurements. Recently, Dr. Noh's study of remote sensing of snowfall has expanded to incorporate microwave and radar radiative model system developments and soon she will interface with the CIRA/CSU clouds/radiation/precipitation research group and collaborate with CIRA/CSU's Center for Geosciences/ Atmospheric Research, Army Research Laboratory, and CloudSat scientists.

### **Melissa Petty**

Missy Petty, a researcher for CIRA in Boulder since

2005, was promoted to research associate III in January 2008. Primarily working on verification of meteorological products for use in aviation, she made significant contributions to the Real-Time Verification System (RTVS), which currently serves the needs of the NWS, the FAA, and the research community. Missy has also worked on the team tasked with designing and demonstrating a verification service for use in the nation's future air traffic management system. The verification software, called the Network-Enabled Verification Service (NEVS), will allow integration of verification data with other information necessary to support air traffic flow algorithms. Missy's role has involved design and proof-of-concept implementation for the management

of verification metadata, a component critical to the success of the project.

### **Tong Zhu**

Dr. Zhu was promoted to research scientist II on September 1st. Having served CIRA for three and a half years as a postdoctoral fellow located in Camp Springs, Maryland, he has helped to develop a unique hurricane model initialization scheme that allows important assimilation of satellite microwave data into mesoscale models. Currently, Dr. Zhu participates actively in a GOES-R AWG project and JCSDS OSSE study.

### **Harold Gibson**

Harold Gibson, Research Scientist Emeritus, passed away January 5, 2008.



## **CIRA Mission**

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

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

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