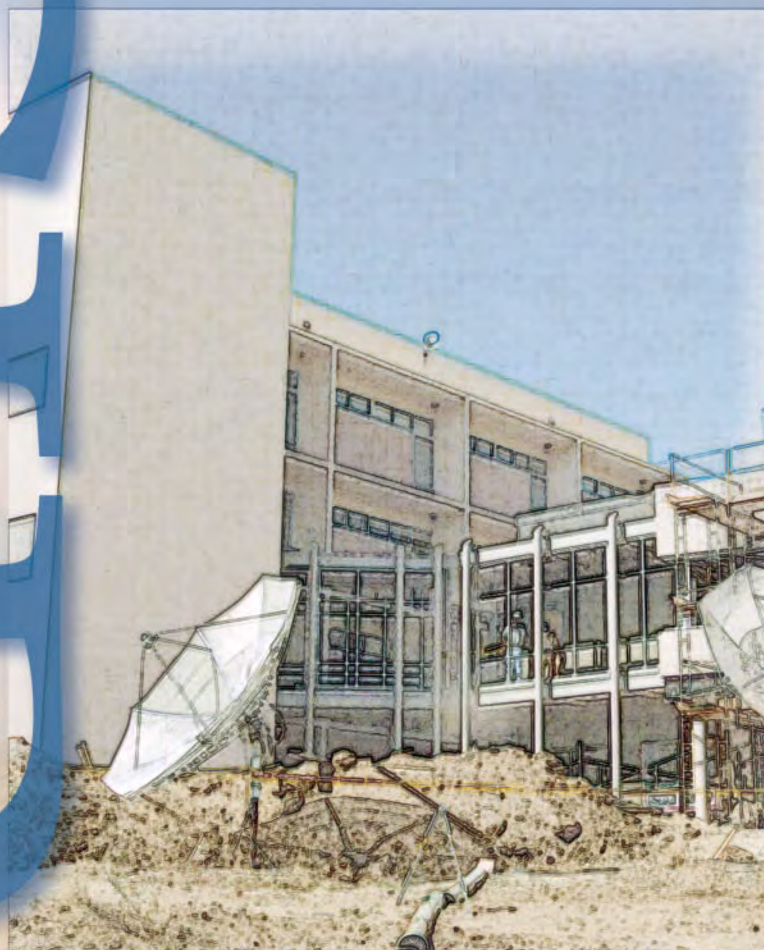
CIRA

ATS and CIRA Meet in the Middle: New Research Facility Underway



VOLUME 17, SPRING 2002

Colorado State University

Knowledge to Go Places

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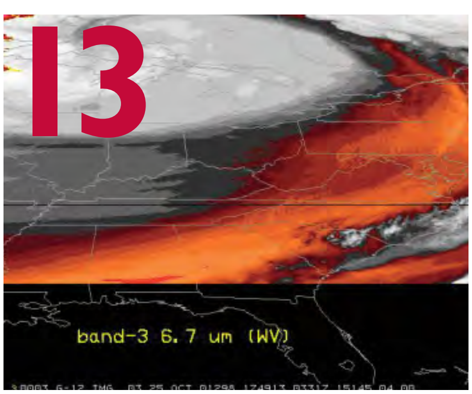

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ATS and CIRA Meet in the Middle: New Research Facility Underway

By Dave Cismoski and Mary McInnis

The trucks that seem to rumble constantly up and down the main drag of the Foothills Campus of Colorado State University are actually in support of a number of construction projects occurring both on the campus, as well as in the vicinity of it. While the big job of reinforcing the dams at Horsetooth Reservoir continues just west of the campus under the direction of the Army Corps of Engineers, the Department of Atmospheric Science (ATS) and the Cooperative Institute for Research in the Atmosphere (CIRA), are busy watching the construction of a new shared research facility.

ATS and CIRA have mutually agreed to construct an addition to the existing Atmospheric Science Building in support of their collaborative research programs. With added support from the Vice President for Research and Information Technology, the Provost, and the College of Engineering, the over 14,000-square-foot facility will provide the space needed for the continually expanding research programs in both departments, and will support the academic function through training and research opportunities. At a cost of $2.4 million, the project has been underway for several months now, and will include such features as a second-story bridge to the ATS building, and a covered walkway to the CIRA building.

The unique location of the CIRA/ATS complex has presented some construction challenges over the course of the building. As the facilities are situated on the knob of a hill overlooking the city of Fort Collins,

The east-facing side of the new ATS/CIRA Research Facility. A second-story catwalk connects the ATS building with the new addition.

severe and strong winds are not uncommon. As a result, the cost of a fully enclosed walkway between the new building and CIRA was cost prohibitive. However, landscape elements such as trees and bushes will be strategically located around the area to temper the force of the winds. In addition, concrete caissons which extend below the building and several yards into the ground will provide extra structural support against high winds.

Currently scheduled for occupancy in mid to late April 2002, the new facility will provide research space for atmospheric scientists, postdocs, graduate students, support staff, and visiting scientists from all regions

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ATS and CIRA Meet in the Middle *(continued from page 3)*

of the globe. Among the agencies whose support allows the many research projects to continue to flourish are the National Oceanic and Atmospheric Administration (NOAA), the Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA). Some of the research teams planning to occupy the facility upon its completion include CEAS and CloudSat, both headed by Dr. Graeme Stephens (ATS); the Cloud Sat Data Processing Laboratory, headed by Dr. Thomas Vonder Haar (CIRA); the Global Precipitation Mission (GPM), headed by Dr. Chris Kummerow (ATS); and the Center for Geosciences and Atmospheric Research (CG/AR), headed by Dr. Vonder Haar.

The CIRA satellite farm had to be moved slightly to make room for the new facility.

The hilltop location of the building has presented some design challenges.

Special capabilities within the new addition include an integrated classroom/lab with the capacity for lidar observations, a dedicated multi-circuit computer room for Cloud Sat data processing, a temperature and humidity controlled underground tape storage room, and high band width Internet computer connections throughout the facility. Designed by Aller-Lingle Architects P.C., the new facility is scheduled to be dedicated in early July 2002 to coincide with the 50th anniversary celebration of the Atmospheric Science Department.

Fellowships in Atmospheric Science and Related Research

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

CIRA is jointly sponsored by Colorado State University and the National Oceanic and Atmospheric Administration. Colorado State University is an equal opportunity employer and complies with all Federal and Colorado State laws, regulations, and executive orders regarding affirmative action requirements. In order to assist Colorado State University in meeting its affirmative action responsibilities, ethnic minorities, women and other protected class members are encouraged to apply and to so identify themselves. The office of Equal Opportunity is in Room 101, Student Services Building. Senior scientists and qualified scientists from foreign countries are encouraged to apply and to combine the CIRA stipend with support they receive from other sources. Applications for positions which begin January 1 are accepted until the prior October 31 and should be sent via **electronic** means only to: Professor Thomas H. Vonder Haar, Director CIRA, Colorado State University, humanresources@cira.colostate.edu. Research Fellowships are available in the areas of: **Air Quality, Cloud Physics, Mesoscale Studies and Forecasting, Satellite Applications, Climate Studies, Model Evaluation, Economic and Societal Aspects of Weather and Climate.** For more information visit www.cira.colostate.edu

Regional Air Quality in the United States: Here Come the Models

By Doug Fox & Mike Barna

Air quality simulation models have been used for the past fifty years in the United States for many different applications ranging from strategic and tactical planning to operations and forecasting. Recently for the National Park Service, the U.S. Forest Service and the EPA, CIRA's air quality team has started to evaluate selected regional air quality models for their use in support of new national regulations to reduce regional haze and improve visibility. This short article will address the requirements that regulatory programs have for air quality simulation models, and very briefly review the state of science in regional air quality modeling and outline aspects of the new CIRA program.

Regulatory Air Quality Modeling

The breadth of applications for air quality simulation modeling has encouraged a wide diversity of scientific approaches to be applied over the past 50 years. In part this has been driven by the complexity of atmospheric turbulence and dispersion along with the added complications of chemical reactions occurring on these same scales. Some problems are best approached using a lagrangian framework employing simplified dispersion parameterizations passively following the flow field. Others have lent themselves to a eulerian approach sacrificing sub-grid scale physics in return for a spatial field distribution. While some applications have clearly favored one approach over the other, others have been more general having aspects best suited to one or the other approach. This has all been helpful for generating new concepts and advancing air quality modeling science.

However, one unique set of extremely important applications are regulatory. Regulatory applications have tended to reduce diversity and limit scientific innovation. Regulatory air quality models are more than packages of scientific algorithms; they include a mix of science, engineering and politics. The politics are involved because high-stakes decisions are aided by these model applications. In many applications, there are at least two opposing sides: one seeking a decision in support and the other seeking a decision in opposition to, for example, construction of a new pollution source, implementation of a new pollution reducing strategy, etc. These decisions are public and generally involve litigation. Hence, it must be more than science that informs the decision process and the modeling used in its support. More than science in that all parties need to be comfortable that the model displays no particular bias, other than a tendency to be conservative, that is, to over predict concentration (a requirement of the Clean Air Act), that the model treats all sources equitably, and that the model can be understood and applied by all the parties to the decision making. These requirements have led to the formation by the EPA of specific modeling guidance and a formalized protocol of testing and evaluation before a model can be used for regulatory applications.

Figure 1. Regional Planning Organizations (RPOs); multi-state organizations formed to look at regional haze issues.

At the same time air quality applications have grown steadily more complex. The impacts from pollutants directly emitted from isolated individual sources have, by in large, been regulated. Today's regulatory environment involves controlling photo-chemically active precursor emissions to both gaseous (ozone) and aerosol (fine particles, acid deposition and visibility impaired regional haze) pollutants. These issues involve not only multiple sources but also multiple categories of sources, ranging from power plants to restaurants, dry cleaners, unpaved roads, forest fires and agricultural burning. The scale of simulation needed has also grown from local to citywide to regional. Toward this end, models have become regional simulations of air quality including meteorological simulations of the wind, temperature, humidity and precipitation fields. Input emissions data are spatially and temporally complex. Output files are similar in size to regional meteorological model outputs. Evaluating model performance is not easily accomplished and can be effectively achieved only within the context of a large-scale experiment for a limited period of time.

In response to the complexity of these models and the environment in which they are applied, the regulatory community has had to organize itself into Regional Planning Organizations (RPOs). The RPOs (Figure 1) are better able to organize multi-state regions for gathering emission data and developing regional simulations. The EPA and those associated with air pollution regulation have

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Regional Air Quality *(continued from page 5)*

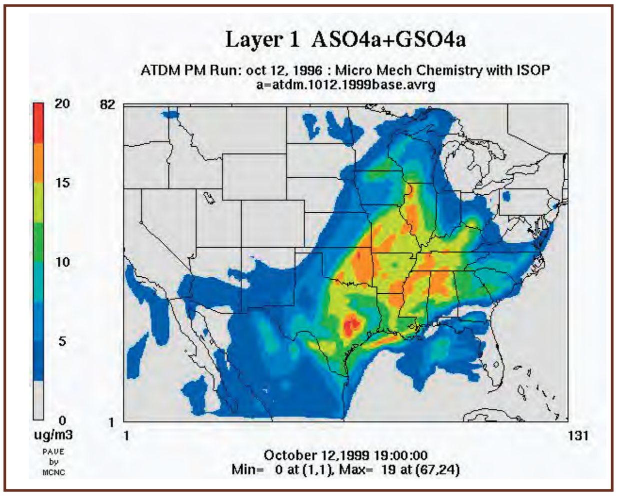

Figure 2. Surface sulfate concentrations predicted by the REMSAD air quality model for the BRAVO study. Total sulfate concentrations are the sum of gas-pathway sulfate (GSO4) and aqueous-pathway sulfate (ASO4). Sulfate particles are a major cause of reduced visibility in many regions of the U.S.

also begun developing comprehensive models to support the work of the RPOs.

Models Used to Support Regional Haze Regulations

CIRA's air quality group has been deeply involved in the regulation of regional haze. The metrics against which regional haze is evaluated are based largely on aerosol data collected by the IMPROVE (Interagency Monitoring of Protected Visual Environments) program. These data are evaluated and analyzed by the NPS-funded air quality team at CIRA. The CIRA group continues to be involved in helping EPA to determine appropriate algorithms for evaluating regional haze and determining such important characteristics as the concept of natural background. Of course, ultimately the NPS group is concerned with developing and implementing tools and technologies to protect the visibility at Class I areas, National Parks and Wilderness Areas within the United States.

A growing responsibility for the CIRA team has been the design, development and implementation of online data delivery and analysis systems for regional haze. Currently the group is developing this for IMPROVE and for the Western Regional Air Partnership (WRAP), the western RPO.

The IMPROVE data are essential to the evaluation and application of regional air quality models. While the CIRA group has been involved in a number of studies over the past 20 years that have advanced the development and evaluation of these models, CIRA has not specifically done any of the modeling itself. However, this is now changing, in part, because the models have become so important to the evaluation of visibility under the regulations. The focus of the CIRA group will not be on developing new models; rather it will be on evaluating the utility of the existing regulatory models and their skill in predicting the variables needed for the regional haze program. Specifically we will be running regional air quality models to evaluate their ability to simulate measured aerosol loadings at specific National Parks and Wilderness sites. We will start by evaluating the modeling done in support of the BRAVO field experiment (the Big Bend Regional Aerosol and Visibility Observational Study) that the CIRA group helped design and conduct. The focus of BRAVO is to understand the causes of visibility degradation at Big Bend National Park, which is located in Texas near the U.S./Mexico border.

Initially CIRA will focus on the REMSAD model, which was developed by System Applications International (SAI). REMSAD (the Regional Modeling System for Aerosols and Deposition) is designed to simulate gaseous and particulate pollutants over large domains (e.g., continental scale) and for extended periods (e.g., months to years in duration). (See Figure 2). This is an important consideration when evaluating issues such as regional haze, which can be transported over long distances and may display seasonal changes. The community mesoscale weather model MM5 is used to create meteorological input data for REMSAD. REMSAD treats the physical and chemical processes that affect atmospheric pollutants and their precursors, including advection, diffusion, wet and dry deposition, and chemical transformation. A highly simplified treatment of the organic chemistry allows REMSAD to be computationally efficient. REMSAD reflects the new breed of regional air quality models which must be able to simulate aerosol concentrations, such as sulfate and nitrate, and their gaseous precursors.

The WRAP is also currently evaluating REMSAD for regulatory application in support of the regional haze program, as well as the relatively more sophisticated CMAQ model. CMAQ (the Community Multi-scale Air Quality Model) represents the current state-of-the-science in air quality modeling, and is designed to represent all relevant processes affecting air pollution in a region. CMAQ was primarily developed by the EPA and NOAA. Like REMSAD, CMAQ uses meteorological data from MM5. A key feature of CMAQ is its ability to evolve as a community model, where researchers from different institutions can improve the science algorithms within CMAQ (e.g., the aerosol thermodynamics module) and contribute those improvements to future releases of CMAQ. Because CMAQ may prove to become the regulatory model of choice, we will maintain an awareness of its development and evaluate its performance, especially with regard to specific problems such as the impact of forest fire emissions on regional haze.

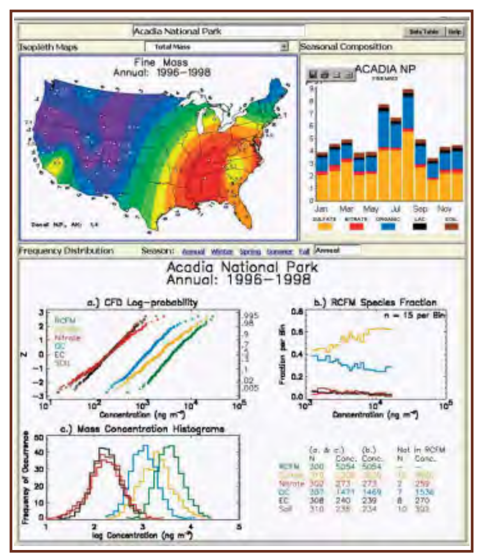

Figure 3. The Improve Web Interactive Viewer displays the annual spatial pattern of PM2.5, light extinction and the contributions of the major aerosol types. In addition, the Viewer displays seasonal bar charts of the PM2.5 and light extinction and the relative and absolute contributions of the major aerosol types.

High Performance Computing at FSL and the Scalable Modeling System

By Jacques Middlecoff and Dan Schaffer

Numerical weather prediction requires some of the world's most powerful computers to solve problems in fluid dynamics, physics and data assimilation. Massively Parallel Processing (MPP) technology offers attractive and affordable opportunities to meet these computing requirements.

MPP Technology at FSL

Recognizing the importance of MPP technologies to the research, development, and transfer of atmospheric science technologies to operational forecast agencies, FSL has been exploring these systems since 1990 in collaboration with CIRA research scientists.

In 2000, FSL purchased Jet, the latest in a series of high-performance computing systems. The phase I system has 277 Compaq XP1000 (667 MHz Alpha EV67) processors connected via Myrinet running under the Linux operating system (Figure 1). Recently, FSL added a phase II system with an additional 140 API Networks UP2000+ dual 833 MHz processors also connected via Myrinet and running on Linux.

Jet represents a new generation of supercomputer called a Commodity Parallel Processor (CPP) that integrates the best of multiple technologies from different vendors into a single high-performance system. FSL plans to use Jet to continue to facilitate the development, testing and validation of new supercomputing technologies with the goal of moving CPP technology into operational use.

Scalable Modeling System (SMS)

Programming MPP systems is difficult because the problem domain must be divided into smaller sub-domains that can each be solved in parallel. If memory is physically distributed, messages must be passed between systems when sharing of data is required. These additional considerations require extensive changes and additions to existing serial code.

Central to FSL's success with MPPs has been the development of SMS with collaboration by CIRA researchers. SMS is a directive based tool for parallelizing Fortran weather codes. Directives, which appear to the compiler as comments, are inserted into the serial code and the Parallel Pre-Processor (PPP) translates the directives and serial code into parallel code. The serial code remains unaffected. A typical weather code can be parallelized by the insertion of about 200 directives. SMS also provides debugging tools, which greatly simplify parallelization. Using SMS, a code can be parallelized an order of magnitude faster than using the industry standard Message Passing Interface (MPI). As an example, the Los Alamos National Laboratory's HYCOM model was parallelized in 9 days.

Processors	ETA/MPI sec.	ETA/SMS sec.	SMS Efficiency	SMS Faster
2	16547	16435	1.00	1%
4	7757	7707	1.07	1%
8	3633	3575	1.15	2%
16	1961	1911	1.08	3%
32	979	951	1.08	3%
64	589	562	.91	5%
88	470	437	.85	7%

Table 1: A comparison of parallelized eta with SMS versus other codes.

In addition to providing ease of parallelization, SMS also provides portability because SMS itself has been ported to many platforms. For example, FSL's RUC model, parallelized using SMS, runs efficiently on most supercomputing systems including Jet, IBM SP2, T3E, SGI Origin, and clusters of workstations without code change. Several other models (both spectral and finite difference) have been successfully parallelized using SMS. These include the Rutgers/UCLA ROMS model, the Princeton Ocean Model (POM), the NOAA Aeronomy Lab's NALROM model, the FSL LAPS model, and the NASA POM/ICE coupled model.

To measure the performance of SMS, it is necessary to compare it to an efficient, hand-coded MPI code. For this purpose, the National Center for Environmental Programs (NCEP) eta model was selected because it was parallelized with MPI by IBM and is a production code at NCEP. A CIRA researcher parallelized eta with SMS and then compared the performance of the eta/MPI code to the eta/SMS code on Jet as well as on the IBM SP2. The results on both machines showed that the SMS version of eta is faster than the hand coded MPI version. The results on Jet are shown in Table 1.

The Jet results show that not only is the SMS version faster, but the advantage of SMS increases with processor count.

Future Plans

SMS is an easy to use, efficient and portable method for parallelizing and debugging atmospheric and oceanic models. SMS allows code parallelization to be done an order of magnitude faster than can be done using MPI. Several enhancements to SMS are planned, including extended support for Fortran 90, support of irregular grids, automatic code optimizations, and reducing the number of directives required to parallelize a code.

Figure 1: *An illustration of Jet. The nearest "wall" contains one hundred processors with ten systems per column and ten columns. Each Compaq Alpha system is rack mounted in standard desktop system boxes.*

Weather Impacts Homeland Defense and the War on Terrorism

By Ken Eis

CIRA has been involved in research for some time that addresses weather phenomena and support issues associated with the U.S. war on terrorism. The Center for Geosciences, the Department of Defense (DOD)-funded portion of CIRA, has been engaged in militarily relevant research since 1986 and some of our NOAA research activities are also relevant.

The weather context of the war is mainly associated with chemical and biological defense, high-resolution forecasts and modeling, and improved use of satellite sensors.

Chemical and biological agents are transported by low-level winds and water. CIRA is very active in improving our understanding of how complex terrain impacts these low-level winds. This terrain is not just mountains and hills, but includes urban terrain such as buildings, parks, and most importantly variations of terrain that are marked by irrigation, forested areas, and various land use criteria that mark abrupt changes. Winds and weather are impacted by these features that cause different heating rates during solar heating and different rates of cooling at night. CIRA research is currently exploring these effects and how they impact forecast accuracy.

Another area of study CIRA is involved in is the characterization of nighttime wind structures. As the land cools at night, low level jets form. These rivers of fast moving air are just a few hundred feet above our heads at night when the surface winds are calm. Several times a night these jets break through to the surface causing a few minutes of gusty winds. If this happens to an area contaminated with chemical or biological materials, these materials can be mixed into the low level jet which then transports the dangerous materials harmlessly above our heads until the next time the jet breaks through to the ground. At this point a new contamination area occurs that is not physically joined to the original source point. CIRA is conducting scanning lidar experiments where the creation and nature of these low level jets can be observed so they can be predicted, including the critical breakthrough events to the ground.

Photo courtesy of Department of Defense

Water too acts as a transport mechanism for chemical and biological materials. CIRA researchers are currently modifying the CASC2D hydrological model that has been used for years to predict river floods and levels to predict dilution and concentration values.

New weapons sometimes reintroduce very old weather problems. During WWII, turbulence and icing were concerns for aircraft. With the advent of high flying jet aircraft these phenomena became less important. With the introduction of slow flying Unmanned Air Vehicles (UAVs) such as the Predator, these concerns are back. Several UAVs have been lost in Afghanistan due to icing and winds during landing. CIRA is working on an improved understanding of icing, where it forms in clouds, and its development cycle. Weather is still in the news when the deployment of ground troops are delayed due to storms, or when major dust storms ground helicopters and hamper target detection. Forecasting these events requires good observational data.

Going down the list of rogue states – Afghanistan, Iraq, North Korea, Somalia – these countries have one thing in common. All of them report little in the way of surface weather reports. Afghanistan has not generated a weather report for decades. Consequently support of military operations can't depend on surface-based weather reports, nor can it depend on climatological records for operational planning. CIRA is busily engaged in data assimilation research that will vastly improve our use of satellite sensors to provide the one and only source of weather information in these areas. New data assimilation techniques are currently being developed that will take full advantage of the visible and infrared images taken by weather satellites as well as the microwave readings that can see through clouds. Instead of coping with data void areas, forecast models will soon have the benefit of millions of data points a day. These data are not only timely, but provide more data than even the best instrumented areas in the U.S. or Europe.

The war of terrorism offers weather researchers the opportunity to provide U.S. military forces with new information, unavailable to the terrorist community, that will help identify and quell their activities. CIRA researchers are in the forefront of that effort.

CIRA Communiqué: Employee News

Hails and Farewells at CIRA

Employees Who Have Moved On:

Alfaro, Rosario - Visiting Scientist in Maryland, last day: January 31, 2002

Cary, Larry - Research Associate in Fort Collins, last day: November 9, 2001

Csizar, Ivan - Postdoctoral Fellow in Maryland, last day: December 31, 2001

Dougherty, Richard - Non-Student Hourly, position ended October 8, 2001

Johnston, Korrie - Coordinator with NPS, last day: April 18, 2002.

Koch, Colin - Non Student Hourly, Supervisor: Bret Schichtel

Motta, Brian - Research Associate in Ft. Collins, last day: February 22, 2002

Zajac, Bard - Research Associate in Fort Collins, last day: January 31, 2002 (Non-Student hourly position to start in February)

Hourly Employees Who Have Moved On:

Joe Goldman
Paul Key
Tim Lyons
Ruth McReynolds
Nusret Osbay
Robert Samuels
Phil Stephens
John Tipton

New Employees:

Butler, Charles - Student Hourly, Supervisor: Bret Schictel

Davey, Christopher - ended Admin Pro position August 31, 2001, started Student Coordinator position September 1, 2001, Supervisor: Ken Eis.

Davis, John - Research Scientist, Supervisor: Tom McKee, start date: December 1, 2001.

Ervens, Barbara - Postdoctoral Fellow in Ft. Collins, start date: April 15, 2002.

Ge, Ming - Research Associate, Boulder, start date: November 15, 2001. Ming has been working with CIRA since April 1998 as a Visiting Scientist. Ming's Visiting Scientist appointment ended on September 30, 2001.

Howard, David - Coordinator, Boulder, Supervisor: Cliff Matsumoto, start date: November 1, 2001.

Kinkade, Chris - Post Doctoral Fellow in Camp Springs Maryland, start date: August 1, 2001.

Knipp, Matt - High School Student, Supervisor: Cindy Combs.

Lindsey, Daniel - Student Hourly in Ft. Collins, start date: February 26, 2002.

Lyons, Tim - Student Hourly, Supervisor: Nan McClurg, starat date: February 11, 2002.

McKee, Tom - Acting Director, start date: August 1, 2001.

Miller, Deborah - Coordinator, Boulder, Supervisor: Cliff Matsumoto, start date: November 12, 2001.

Pagowski, Mariusz - Research Associate in Boulder, Supervisor: Cliff Matsumoto, start date: February 19, 2002.

Prentice, Robert - Research Associate, Boulder, start date: November 8, 2001, Supervisor: Cliff Matsumoto.

Purdom, James - Senior Research Scientist, Fort Collins, start date: September 6, 2001.

Ruddick, William - Student Programmer, Supervisor: Renate Brummer, start date: September 13, 2001, International Division, Boulder.

Samuels, Bob - Student Hourly, Supervisor: Nan McClurg, start date: February 11, 2002.

Skirving, William - Post doctoral Fellow, Camp Springs Maryland, start date: March 1, 2002.

Solheim, Inger - Non-Student Hourly, start date: January 15, 2002, supervisor: John Knaff.

Walko, Ernest - Non-Student Hourly, Supervisor: Kelly Dean

Walters, Katherine (Katie) - Student Coordinator, Supervisor: Don Reinke, start date: September 17, 2001.

Youngren, Carol - Non-Student Hourly, Supervisor: Loretta Wilson, start date: November 12, 2001.

Zajac, Bard - Non-Student Hourly in Ft. Collins, start date: February 12, 2002.

Title Changes:

Bonnie Antich has been named Assistant Manager of Human Resources

Mary McInnis has been named Assistant Manager for Research Support

Two CIRA Scientists Win Presidential Award


Dr. James W. Purdom

Dr. James W. Purdom, a Senior Research Scientist in CIRA's Fort Collins office, and Alexander "Sandy" MacDonald, the Director of FSL and a CIRA Fellow, were among the chosen few to receive the 2001 Presidential Rank Award. The award is a prestigious honor for federal employees, and in fact, while Dr. MacDonald still is employed by NOAA, Dr. Purdom recently retired from NOAA's National Environmental Satellite, Data, and Information Service to join CIRA last year. The Meritorious Executive award is given in acknowledgement of long-standing accomplishments, and its rarity is demonstrated in the statistic that only 5 percent of career senior executives receive the award. Among other things, the honor includes a certificate signed by the President.


Dr. Alexander "Sandy" MacDonald

Milestones at CIRA

Several employees at CIRA were recently named as having reached significant service milestones with Colorado State University. All reaching service milestones were honored at a special ceremony and reception held at the Lory Student Center on February 19, 2002. Below is a list of the employees from CIRA and their number of years of service. Sincerest congratulations to you all.

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CIRA Communiqué *(continued from page 9)*

CIRA Research Associate Receives Awards

Shirpad D. Deo, a CIRA Research Associate based in the Kansas City National Weather Service (NWS) regional office, was recently awarded a Certificate of Recognition and a Regional Excellence Award for his work with NWS. The certificate and the award were presented to Deo by Mr. Dennis McCarthy, Regional Director of the Central Region National Weather Service. Deo has been working with NWS colleagues on the Advanced Hydrologic Prediction Services (AHPS) website. As the certificate states: "Mr. Deo is recognized for his exceptional efforts in creation and development of Central Region AHPS Web Services, which implemented the new AHPS web page. Mr. Deo and other developers adopted a consistent look and a simplified web navigation process. By his actions, Mr. Deo assisted Central Region Headquarters in meeting 2001 Annual Operating Plan goals, helped improve public safety, and contributed directly to NWS mission to save lives and prevent property damage."

CIRA Associate Director Recognized by Campus Community

The November 8, 2001 edition of the campus faculty and employee newsletter, *The Comment*, featured one of CIRA's own. Cliff Matsumoto, CIRA's Associate Director, was featured and recognized for his efforts on the job and also in his work with the Administrative Professional Council.

As the article pointed out, Matsumoto's relationship with CSU was first as a student in the Atmospheric Science Department. After graduation and a military career, he came back to CSU to work with CIRA. As the Associate Director in charge of the Boulder operations, he provides technical and management oversight for the approximately 60 CIRA researchers involved in collaborative research with NOAA laboratories in Boulder.

Until quite recently he was a member of the Administrative Professional Council where he worked to improve the standing of APs (Administrative Professionals) on campus. Among the efforts he's been working on is a proposal to expand the study privilege for those working outside Larimer County; a compromise-involved choice of medical plans and the university's benefit compensation for those electing to opt out; and the AP career track/promotion ladder which had just been approved for implementation on July 1, 2002.

Performance Award

Mike Biere, Coordinator in the Boulder CIRA office, was presented a certificate for "AWIPS Systems Performance Award" by Ward Seguin, development branch chief in the National Weather Service's Office of Science and Technology. The award was presented November 20th at FSL's Weather Forecasting Office-Advanced Technical Review. He was recognized for implementing AWIPS performance measurement tools, notification server improvements, and for investigating IGC shared memory problems.

Internship Granted to DeMuth

Julie DeMuth, a former student of Dr. Vonder Haar's recently received a National Research Council internship award, and will be working in Washington for a couple of months this spring. The internship is officially called the "Christine Mirzayan Internship Program" sponsored by the National Academies. Specifically, she'll be interning for both the Natural Disasters Roundtable (NDR) and the Board on Atmospheric Sciences and Climate (BASC) in Washington, D.C. Her work will include background research and writing to support:

(1) a forum on natural disasters research implications on our nation's response to terrorism

(2) a study on the role of the atmospheric sciences community in modeling the transport/dispersion of biological and chemical agents

(3) a forum on climate variability and natural disasters research

The internship is 12 weeks with the possibility of extending up to an additional four weeks if funding allows. It will run from January 14 through April 5, and possibly through May 3.

CIRA Award Winners

Although the recipients of the second annual Research Initiative Award were featured in an article in the last issue of the CIRA Magazine (Volume 16), here (at left and page 11) are some photos taken during award ceremonies in Boulder and Fort Collins which occurred after the Volume 16 publication deadline. At left: Thomas Vonder Haar, Director of CIRA, presenting award to John Knaff, CIRA/Fort Collins.

CIRA Research Initiative Award Winners

From left to right: Boulder CIRA winners Evan Polster, Ning Wang, Sean Madine, Renate Brummer, and John Pyle. Not pictured, Amenda Stanley.

Thomas Vonder Haar, presenting award to Dan Schaffer, Boulder CIRA.

Advances in GPS Meteorology

By Yuanfu Xie

Great advances have been made in Global Positioning System (GPS) meteorology in recent years. Many research organizations have participated in the effort to improve the current numerical prediction of precipitation using GPS slant water vapor (Kuo et al., 1996 and MacDonald et al., 2001). Water vapor is the most important meteorological component to predict; yet, it lacks sufficient observations to be accurately predicted. Ground-based GPS receivers are potentially the providers of high-resolution water vapor observations. CIRA, in close collaboration with the NOAA Forecast Systems Laboratory (FSL) and other research and operational agencies, plays an important and active role in GPS data assimilation and observation.

Applying GPS raw measurements to improve forecasts requires many careful processes of the data. The receivers can measure the phase delay of the microwave signals transmitted from the GPS satellite to the receivers due to the refractivity of the atmosphere. The refractivity is related to the moisture field:

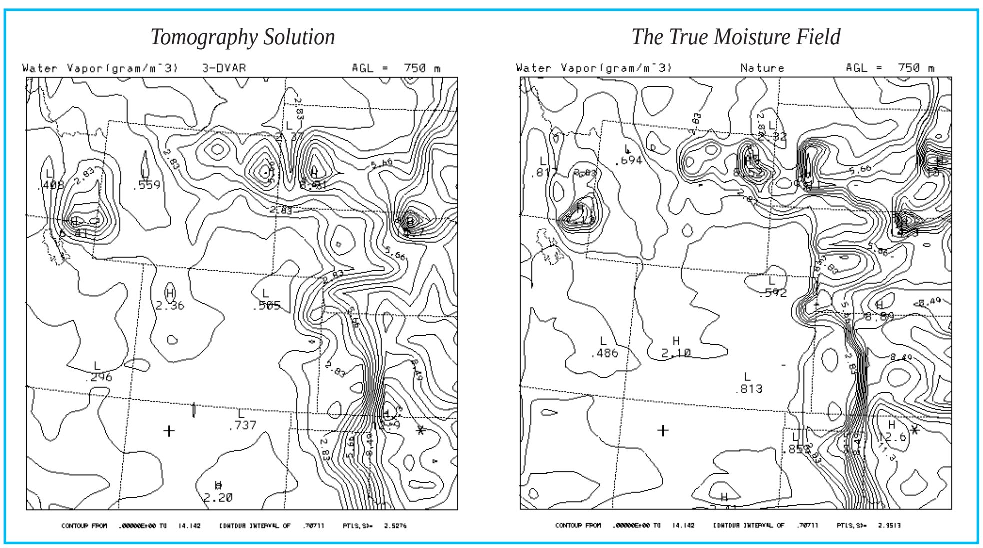

Figure 1: Comparison of Tomography solution vs. the truth at 750m.

$$N = N_{dry} + N_{wet} = 77.6\frac{P}{T} + 71.6\frac{q}{T} + 3.7\times 10^5\frac{q}{T^2}$$

where P is the atmospheric pressure, T is the temperature, and q is the water vapor pressure. The phase delays are integrals of this refractivity along the slant paths. The use of these data requires careful study of measurement/data process and data assimilation. The collaborative research effort with FSL has shown advances in both fields.

(continued on page 15)

CoCo RaHS – The Community Collaborative Rain and Hail Study

By Nolan Doesken and Mary McInnis

The Community Collaborative Rain and Hail Study (CoCo RaHS) is about to begin its 5th summer measuring rain and hail in Colorado. The project, under the direction of Assistant State Climatologist and Atmospheric Science employee Nolan Doesken, recruits volunteers from the campus as well as the community at large to volunteer as weather observers. Colorado's variable storm precipitation patterns make for interesting observing. Many CIRA employees have played critical support roles in CoCo RaHS, and Doesken noted their and other volunteer's contributions recently.

Since CoCo RaHS began in 1998, the evidence of its success is in the numbers. In 2001, the staff equipped and trained nearly 200 new weather observers with ages ranging from 8 to 80. In addition, several training programs and presentations were given to groups of teachers and several other organizations. More than 450 volunteers are participating in the project this summer and close to 800 volunteers of all ages have now been trained. Hundreds more may join this year as the program expands to Denver, Boulder and the surrounding foothills.

This past year, CoCo RaHS provided challenging employment opportunities to four young scientists, as well as a science teacher from eastern Colorado. Renny James from Liberty School was a great asset to the project (*see the CIRA magazine, volume 16, for more details*). Another teacher in the Denver area is developing lesson plans for utilizing CoCo RaHS data for flash flood planning exercises for students.

All in all, employment for 21 high school and college students has been funded through sponsor support since the program began. In fact, this year a student who had first begun helping out as a young volunteer when he was only in the 7th grade came back to help with web design and hail research. Last year his scout troop made and donated over 1,000 hail pads to help the project. This year, he is helping design web pages to display hail pads so that interested students anywhere in the world can help study hail storm characteristics.

As the project grows, local leadership becomes increasingly important. This year, local volunteer coordinators took over recruiting and training responsibilities in Adams County, Boulder County, Morgan County, Estes Park and Greeley. There is also an independent CoCo RaHS program now underway in El Paso County utilizing their own computer system.

Director of CoCo RaHS, Nolan Doesken, presenting a poster about the program to a science teachers' conference.

In exchange for the data that volunteers so willingly collect and share, CoCo RaHS continues to offer educational opportunities to help volunteers learn more about weather, climate and water. On July 31, 2001, 80 people attended the program the staff organized at the Loveland Public Library remembering the Big Thompson Flood 25 years before. They also had a great turnout at an all-day Rocky Mountain Weather and Climate Workshop held in Boulder at NCAR and NOAA back in April 2001. More programs like this will be conducted in 2002.

Clearly the success of CoCo RaHS has resulted in exponential growth over the years. CIRA's involvement in the inception and continued growth of the study is not only essential to the outreach mission of the Institute, but also because of our sincere personal interest in weather.

Local Boy Scouts making the hail pads used by the community volunteers of CoCo RaHS.

Changes in the GOES-12 Imager

By Don Hillger

GOES-M, the latest in the current GOES[1] series, was successfully launched into geostationary orbit on July 23, 2001 becoming GOES-12. Two GOES (GOES-8 and 10) already occupy the east and west slots at 75ºW and 135ºW providing operational satellite imagery covering the United States. Therefore GOES-12 was put into storage mode in orbit awaiting a failure of either GOES-8 or GOES-10.

Whenever a new GOES satellite is launched, the CIRA/RAMM Team is tasked to evaluate and provide feedback during the scheduled checkout period before the satellite is either stored or put into operation. Since some significant changes have been made to the 5-band Imager on GOES-12, the purpose of this article is to explain those changes: one is a new band at 13.3 µm, replacing the 12.0 µm band, and the other is increased spatial resolution for the water vapor band.

Changes to the GOES-12 (and Successive GOES) Imagers Compared to Previous GOES-8 through 11

Table 1 explains the differences between bands utilized by the two versions of the GOES Imager. Both versions have five bands. The current Imager (on GOES-8 through 11) contains bands 1 through 5. The new Imager (on GOES-12 and future GOES) contains bands 1 through 4 and band 6. Note as well the change in the spatial (line) resolution of the band-3 image.

GOES Imager Band	Wavelength Range (µm)	Spatial Resolution (km) at Nadir (Element x line resolution)	Meteorological Objective
1	0.55 to 0.75	0.6 x 1	Cloud cover and surface features during the day
2	3.8 to 4.0	2.3 x 4	Cloud phase (day and night)
3	6.5 to 7.0	2.3 x 8 **(GOES-8 through 11)** 2.3 x 4 **(starting GOES-12)**	Upper-level water vapor
4	10.2 to 11.2	2.3 x 4	Surface or cloud top temperature
5	11.5 to 12.5	2.3 x 4 **(GOES-8 through 11)**	Surface or cloud top temperature and low-level water vapor
6	12.9 to 13.7	2.3 x 8 **(starting GOES-12)**	Cloud detection

Table 1: GOES Imager bands

Changes to the GOES-12 Imager compared to previous GOES (8 through 11) include:

- A new band-6 image at 13.3 µm at 8 km spatial (line) resolution at nadir. This band replaces the band-5 image at 12.0 µm.
- The water vapor (band-3) image is now available at an increased 4 km spatial (line) resolution, compared to the 8 km (line) resolution on current GOES. (Both bands are collected at an over-sampled 2.3 km element resolution.) The spectral response of the water vapor band was also shifted slightly and broadened.

Examples of both of these new features of the Imager are shown and explained below.

New Band-6 at 13.3 µm

Figure 1 contains examples of each of the five bands available on the GOES-12 Imager. If a band-5 image were available from this satellite it would look very similar to the band-4 image, with only slight differences in radiance or temperature for most of the scene. The image would appear almost identical to the band-4 image to the untrained eye. Larger differences between the images generally occur only when viewing thin cirrus or cloud edges. There are also important differences in atmospheric trans-

(continued on page 14)

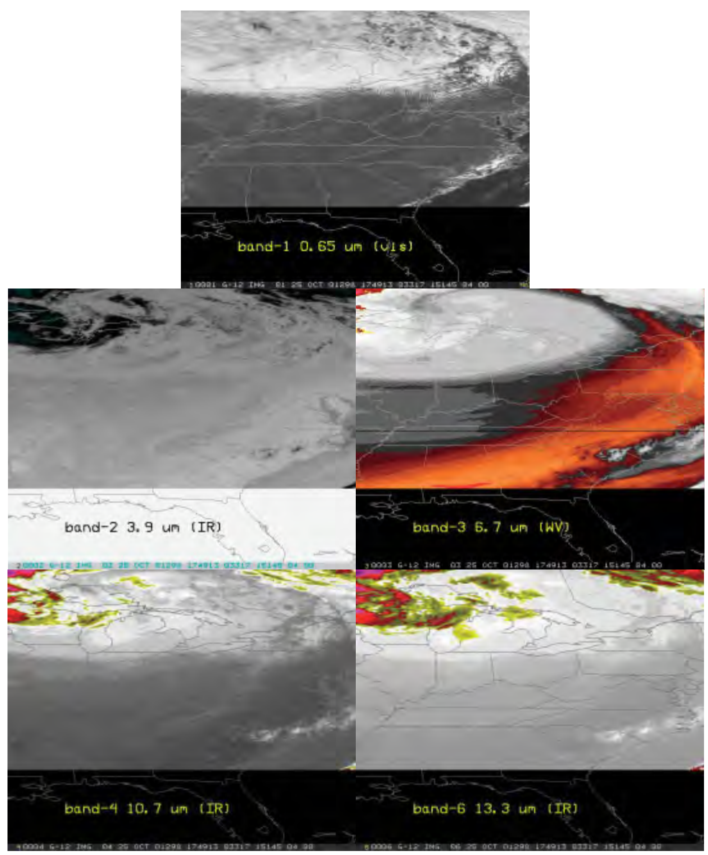

Figure 1: Examples of GOES-12 bands 1 through 4 and 6 with color enhancements applied to the infrared bands.

[1] *GOES = Geostationary Operational Environmental Satellite*

Changes in the GOES-12 Imager *(continued from page 13)*

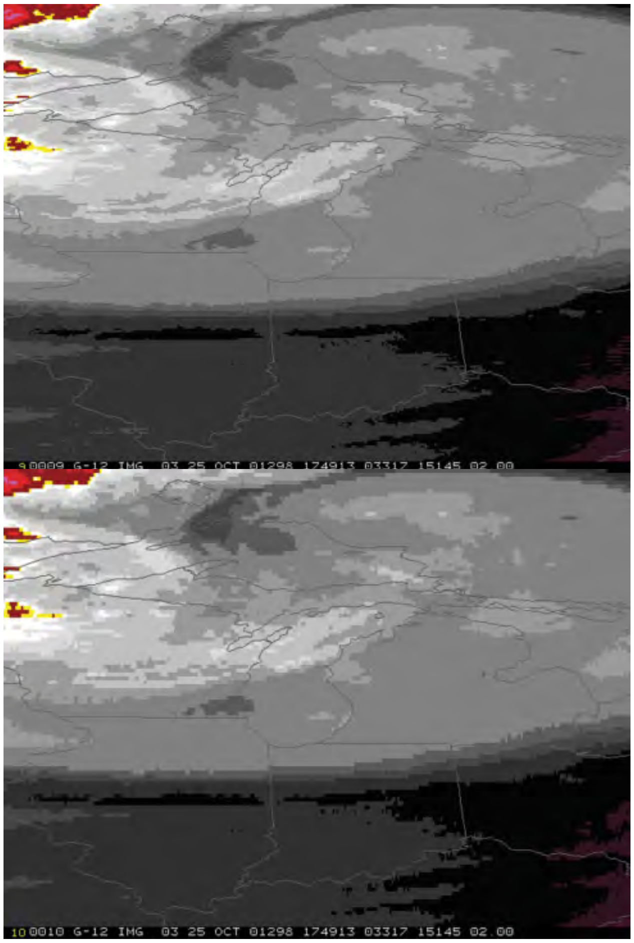

Figure 2: Upper-left portion of the water vapor (band-3) image from Figure 1. That image is shown both at full line resolution (4 km, on top) and at reduced line resolution (8 km, on bottom) to show the effect of the change in spatial resolution. The coldest, cloud-top portions of both images are color enhanced.

mittance between the band-4 and band-5 images. Those differences can be used to measure the low-level moisture field or can be used to correct radiances emitted from the earth's surface for the determination of sea-surface temperatures. Without band-5 on the new Imager these capabilities will be degraded. However, efforts are underway to generate alternative image products that compensate for the change in bands that has occurred.

The new band-6 image has less transmittance of surface radiation and more emission of radiation from the lower levels of the atmosphere, making it easier to detect cloud features in the band-6 image when utilized along with the band-4 image. In addition, there is reduced line resolution (8 km) for the band-6 image compared to the line resolution (4 km) of the other infrared bands. This discrepancy, however, will be remedied on future GOES Imagers (GOES-O and beyond) when the line resolution of all bands will become 4 km.

Water Vapor (band-3) Images at 4 km Spatial Resolution

To show the effect of the increased spatial (line) resolution for the water vapor (band-3) image, a water vapor image from GOES-12 was processed to simulate the lower spatial resolution available on previous GOES Imagers. Figure 2 contains two reproductions of the upper-left portion of the water vapor image in Figure 1. That image is shown in Figure 2 both at full resolution (4 km, on top) and at reduced resolution (8 km, on bottom). The "blockier" look of the bottom image is accentuated by the 2 km display, replicating each pixel in the image by a factor of two. The lower spatial resolution of the bottom image is best noted at the points where the gray shades are changing.

GOES-12 Data

Data from GOES-12 were transmitted to earth during the 5-week NOAA Science Test period (23 September through 27 October 2001). During that test period, GOES-12 imagery was collected under many different scan scenarios, mostly for testing the quality of the imagery obtained from GOES-12. After that period the satellite was put into storage mode. The Science Test data were collected at CIRA for research purposes and future product development. A web page with a schedule of the tests executed each day of the Science Tests is available at: http://www.cira.colostate.edu/ramm/goesm/test_schedules.htm, and results of the Science Tests are being compiled at: http://www.cira.colostate.edu/ramm /goesm/test_retsults.htm

Conclusions

GOES-12 will provide new spectral information from geostationary orbit, but the loss of band-5 at 12 µm band is a drawback that is being addressed. Efforts are underway to compensate for the switch from band-5 to band-6, by creating new image products to replace those that will be affected by this change in the GOES Imager.

An artist's rendering of the GOES satellite in orbit.

Advances in GPS Meteorology *(continued from page 11)*

Assimilation

Since 1999, Dr. A. E. MacDonald (Director of FSL) has led a team of FSL and CIRA research scientists in the development of the GPS slant water vapor analysis. The group formed a variational problem, GPS tomography, to investigate the usefulness of GPS signal delays for retrieval of the meteorological moisture field. The tomography method minimizes the cost function

$$\text{minimize} \quad \sum_{r,s}\left(SWV_{rs} - SWV_{rs}^{obs}\right)^2 + \sum_{profilers}\left(q - q^{obs}\right)^2$$

where r and s represent a receiver and satellite, SWV_{rs} is a grid generated slant water vapor, and SWV_{rs}^{obs} is the observed one. MacDonald et al. (2001) demonstrated accurate retrieval of the water vapor field using GPS slant water vapor based upon an Observation Simulation System Experiment (OSSE). With the assumption of a 40-km ground-based GPS receiver network, the group obtained a good solution with support from microwave profilers (16 profilers used). Figure 1 (page 11) shows the comparison between the tomography solution and the true moisture field at 750m altitude. The tomography project is very important because it reveals how much information is contained in the GPS signals. For the tomography approach, the solution structure of the tomography problem was also analyzed and the existence of multiple solutions was shown no matter how many slant paths are used. For more general conditions, the group explored the solution in more detail, and found that other water vapor observation data can be used to uniquely determine the solution of interest. This is the first such analysis of the solution structure for GPS meteorology.

In studying the impact of GPS meteorology on the mesoscale precipitation forecast, another group of researchers at FSL succeeded in assimilating the real-time GPS data into the MAPS/RUC-2 mesoscale numerical prediction model (Smith et al., 2000). They used real-time GPS data in their three-dimensional variational analysis (3DVAR) to show the impact of the GPS observation by comparing the forecasts with/without the GPS.

GPS data assimilation showed promise. To effectively use GPS data, we need to improve the tomography and assimilation techniques, e.g., GPS correlation analysis, direct assimilation of refractivity, and so on.

Observation

The GPS-Met Observing Systems Branch of the Demonstration Division (DD) at FSL has been operating a GPS observation network at 123 sites, which are grouped into three categories: NOAA Wind Profilers (34 sites), Other NOAA Sites (10 sites), and Other Agency Sites (79 sites). Figure 2 shows the network distribution over the states, and for data site descriptions, refer to web site http://gpsmet.fsl.noaa.gov/cgi-bin/get_site_info.cgi.

This group at FSL demonstrates the major aspects of an operational GPS integrated precipitable water vapor (IPWV) monitoring system, facilitates assessments of the impact of these data on weather forecasts, assists in the transition of these techniques to operational use, and encourages the use of GPS meteorology for atmospheric research and other applications.

A significant challenge inherent to GPS measurement is verifying the accuracy of the signal delays of slant paths with low elevation angles. For example, there can be clock errors among receivers and satellites. Double differencing seems to be a very successful method, assuming that the differences satisfy a certain linear equation. Consideration is also being given to the possibility of using more accurate clocks on receivers and satellites. Ensuring accurate measurement of these low-angled GPS signals is very important to incorporating GPS tomography and data assimilation into numerical models.

Collaboration

Thus far in the investigation of GPS applications in meteorology, close collaboration has been established internally within FSL as well as strong cooperation between various research institutes. Dr. Ware from the GPS Science Technology Program (GST) at UCAR has made recommendations in using microwave profilers in FSL's GPS meteorology tomography method. FSL and GST worked together on many issues of GPS data processing and assimilation, particularly on GPS tomography. GST developed a GPS tomography technique and GPS techniques that can retrieve the integrated water vapor along the GPS slant paths in sight with high accuracy (Braun et al., 2001).

There are also strong international interests in GPS meteorology. In 1997, Japan launched a 5-year GPS meteorology (GPS/MET Japan) research project. They built two major GPS networks – GEONET and the Tsukuba Dense GPS network with 30-km and 1-3 km resolution, respectively. They applied different GPS slant data analysis software, e.g., GIPSY, Bernese and GAMIT, and also developed their own GPS tomography method. Last November, the Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA) invited Dr. Xie (CIRA Research Scientist) to visit MRI for 3 weeks and participate in an international workshop at the University of Kyoto on GPS data analysis and tomography. The visit was sponsored under a fellowship provided by the Japan Society for the Promotion of Science (JSPS) Invitation Program. This began the collaboration between MRI and CIRA/FSL. CIRA/FSL advanced the tomography methods by its solution structure analysis and MRI developed a moving cell technique dealing with the slant path correction during assimilation time intervals. During the international workshop at the University of Kyoto, CIRA/FSL, MRI, University of Kyoto, and other universities in Japan set up a collaboration project for verification of the solutions obtained by different GPS tomography techniques. MRI and the Geological Survey Institute of Japan will provide the real-time GPS observation dataset from GEONET and Tsukuba Dense GPS network for this project. All participating institutes will perform their GPS tomography techniques on the same dataset. This investigation of the GPS impact on mesoscale precipitation forecasts is very exciting and important. It provides us the confidence in the GPS observation of improving forecasts in the future.

Future Plans

The FSL/CIRA collaboration has been successful in establishing an observation demonstration network and data assimilation techniques. It will continue to play an important role in GPS meteorology. Based upon the slant water vapor analysis (MacDonald et al., 2001), feasibility of deploying a 40-km GPS ground receiver network will be investigated. This is crucial to improving precip-

(continued on page 17)

CIRA Participation in the Joint Center for Satellite Data Assimilation

by Milija Zupanski and Mark DeMaria

It is expected that in the next 10 years there will be a five orders of magnitude increase in the number of available satellite measurements. An enormous challenge is to process these measurements, and to obtain their full benefit in operational weather forecasts. In achieving this "end-to-end" goal, data assimilation will play a critical role. New developments in forward radiative transfer algorithms, and current and future high-resolution satellite measurements, all create additional challenges for data assimilation. The complexity of data assimilation makes the optimal use of satellite measurements even more difficult, and more time consuming. Operational centers realize the need for implementing new research and development, but are faced with limited funds and facilities. Research institutions, on the other hand, would like to benefit from operational experience by using a code tested in an operational environment, reducing the need to "re-invent the wheel." In Figure 1, current and near-future satellite instruments and their information content are shown. The atmospheric sciences community is already faced with the problem of optimally utilizing existing satellite data, and there are more data coming, as shown in Figure 2.

As a response to the ever-increasing number and complexity of satellite measurements, NOAA and NASA recently coupled their efforts to maximize the utilization of satellite data to improve weather forecasts. A plan was proposed in 2000 by Franco Einaudi (Chief, NASA Laboratory for Atmospheres), Louis Uccellini (Director, National Centers for Environmental Prediction), James Purdom (Director, NESDIS Office of Research and Applications), and Alexander MacDonald (Director, NOAA Oceanic and Atmospheric Research). The plan calls for a collaborative effort by NOAA (NESDIS, ORA, NCEP) and NASA (DAO), with the goal to fully exploit the satellite data for both research and operational purposes. The idea of bridging the gap between research and operations, sometimes called "the valley of death," is not new, but remains extremely challenging. The need for community fast radiative transfer models, a common model and data assimilation infrastructure, and for education and training of satellite data assimilation experts, were recognized as obvious common interests.

In order to achieve this goal, a Joint Center for Satellite Data Assimilation (JCSDA) was founded. The original 13 points of the JCSDA science prioritization process are:

1. Assimilation of precipitation
2. GOES wind impact studies
3. Assimilation of GOES-10 radiances
4. Maintain and extend OPTRAN radiative transfer code
5. Operational evaluation of Quikscat
6. NOAA Polar Orbiter backup
7. Data utilization of satellite-derived land parameters
8. Cloud and liquid water
9. Improved SST analysis (higher time and space resolution)
10. Neural Network techniques for SSM/I and Quikscat products
11. Assimilation approaches for advanced sounders
12. GPS meteorology
13. Observing System Simulation Experiments for advanced instruments.

The original 13 points can also be classified in terms of 7 Impact Groups:

1. Atmospheric Soundings
2. Upper Air Winds
3. Precipitation and Clouds
4. Ozone and Aerosols
5. Ocean and Sea Ice
6. Land Products, and
7. Data Assimilation Techniques.

The JCSDA is expected to provide general benefits to the research and operational community, such as: (i) improved weather forecasts, (ii) extension of range of useful forecasts, (iii) greater return on investment by earlier and enhanced use of space assets, and (iv) improved planning of future satellite instruments. More specific benefits of JCSDA provided to the research community are: (i) timely access to global environmental data from satellites and other sources, (ii) data and information services, (iii) support of oceanic, land, and atmospheric research on the use of satellite data for monitoring environmental characteristics and their change, (iv) developed applications of satellite data and algorithms (and their adjoints) to produce satellite products, (v) calibrate and validate satellite data to ensure its quality for both the long-term studies and real-time applications, and (vi) conduct a strong technology transfer program to ensure maximum utilization of satellite data.

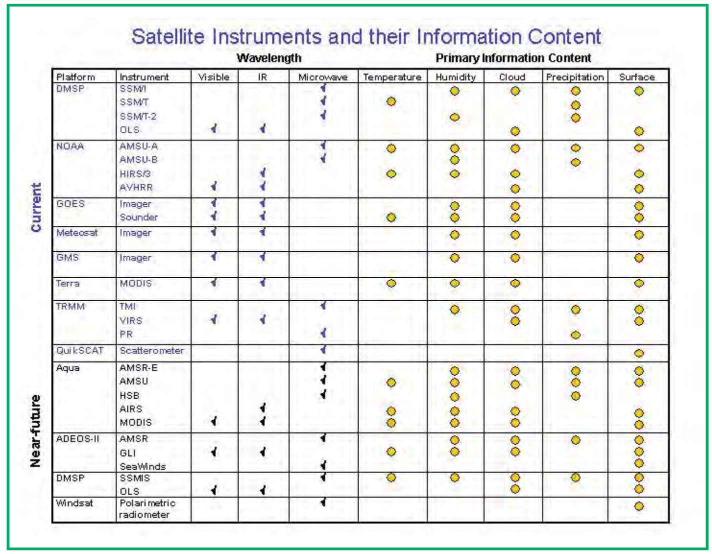

Figure 1. Current and near-future satellite instruments. Very little is done in assimilation of cloud, precipitation and surface related measurements (Figure provided by Dr. Tom Greenwald).

(continued on page 17)

CIRA Participation *(continued from page 16)*

In addition to the JCSDA primary goals, there is also a component in satellite data assimilation development directed toward supporting the U.S. Weather Research Program, mainly to: (i) increase understanding and prediction of Hurricanes At Landfall (HAL), (ii) improve Quantitative Precipitation Forecasts (QPF), and (iii) extend accurate weather forecasts to day 7 and beyond.

Recent data assimilation development at CIRA (Regional Atmospheric Modelling and Data Assimilation System – RAMDAS), combined with already existing expertise in satellite measurements, forward models, and NWP modeling, has created a unique opportunity for CIRA's participation in JCSDA efforts. The RAMDAS is based on the Four-Dimensional Variational (4DVAR) algorithm; and the inclusion of GOES Visible and Infrared data, Microwave Land Surface Model is now under way. In addition, the RAMDAS is using the WRF (Weather Research and Forecast) observation operator, which serves as an interface between the research and future operations. Great potential of CIRA's satellite data assimilation system is recognized by NOAA and NASA, and CIRA is now joining the JCSDA efforts with NOAA ORA. The leaders of the CIRA JCSDA team are Dr. Milija Zupanski (CIRA/CSU) and Dr. Mark DeMaria (NOAA/RAMM). At present, the CIRA personnel involved in JCSDA include: Dr. Louis Grasso, Dr. Tom Greenwald, Dr. Andrew Jones, Dr. Tomislava Vukicevic, and Dr. Dusanka Zupanski.

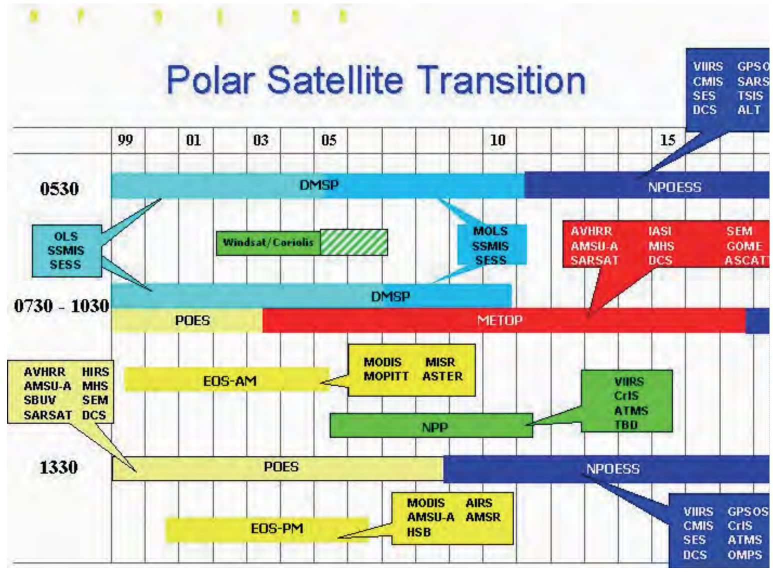

Figure 2. Future satellite measurements planned until the year 2018. The horizontal axis represents years. The problem of satellite data assimilation is getting even more complex.

It is anticipated that the CIRA's JCSDA efforts, in collaboration with CSU's Atmospheric Sciences Department, will be additionally funded by JCSDA in support of education and training of future satellite data assimilation experts. This will present an unrivaled opportunity for synergetic collaboration between CIRA's JCSDA group and CSU's Atmospheric Science Department.

Advances in Meteorology *(continued from page 15)*

itation forecasts using GPS observations. The analysis of GPS tomography is currently based upon the slant water vapor. However, the receivers measure the phase delays due to the refractivity of the atmosphere. Assimilating refractivity and combining all other types of observations is currently under investigation at FSL. Measuring the slant delays is another important and critical task for GPS meteorology. Although there are many challenges, the future is full of promise.

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Milestones at CIRA

(continued from page 9)

10 years

Helene Bennett
Gerald Browning
David Cismoski
Derek Day
Kenneth Eis
Yuanfu Xie

15 years

Michael Hiatt
Andrew Jones
Lance Noble
Donald Reinke
James Sisler
Robert Walko

20 years

Joanne DiVico

Regional Satellite Cloud Composites for Forecast Offices

By Bernadette Connell, Cynthia Combs, and Mark DeMaria

Many satellite-based cloud frequency studies have focused on the characteristics and distribution of clouds and how they affect the earth's climate. A primary user of this information is the global climate modeling community. Many of the datasets have been collected at a coarse resolution and offer limited information to a forecaster wanting to use the information for a local region. The NOAA/NESDIS/CIRA RAMM Team is making cloud frequency composites available to forecast offices by developing high-resolution products for mesoscale areas and tailoring the product to address forecast needs. The RAMM Team has interacted with the National Weather Service (NWS) Weather Forecast Offices (WFO) in Tallahassee, Florida, and Wakefield, Virginia to develop wind regime stratified cloud composites to help evaluate the interactions between convection, large-scale synoptic flow and local surface characteristics such as coastline or mountainous terrain. The results provide information for the challenging task of forecasting the timing, location, and intensity of convection.

Focus at the Tallahassee WFO

Since 1995, Ken Gould has been the focal point for the summer sea-breeze satellite cloud frequency project at the Tallahassee WFO (TAE). Much of the convection over the Florida panhandle and peninsula during June, July, and August is directly related to the sea-breeze circulation. Nine regimes were selected to reflect the strength and development of the sea breeze front under various synoptic winds and the resulting effect on convective development (Table 1). The regimes were designated daily by forecasters at TAE by mean boundary layer wind speed and direction calculated from model output over the region of interest.

Light to moderate wind speeds are separated from stronger wind speeds because of the different effects on the development and inland penetration of the sea breeze. Opposing synoptic flow, as is found in regimes 8 and 9, inhibits the inland penetration of the sea breeze, but can also enhance convergence and upward vertical motion along the sea breeze front. Conversely, onshore synoptic flow (regimes 1, 6, and 7) aids the inland penetration of the sea breeze, but limits the development of convergence along the sea breeze front. The regimes do not fall into strict numerical bins on the compass, but rather allow for user input on the synoptic interpretation of both the current situation and the evolution of the flow patterns.

Regime	Description
1	Light and variable or light SE (< 3 kts)
2	Light to moderate (3 to 10 kts) E to NE
3	Strong (> 10 kts) E to NE
4	Light to moderate (3 to 10 kts) W to SW
5	Strong (> 10 kts) W to SW
6	Moderate (6 to 10 kts) SE to S
7	Strong (> 10 kts) SE to S
8	Light to moderate (3 to 10 kts) N to NW
9	Strong (> 10 kts) N to NW

Table 1. Tallahassee WFO Summer Sea-breeze Regimes

Cloud frequency composites derived from GOES-8 hourly visible and infrared imagery collected during June, July, and August, over a 5-year period (1996-2000) have been examined so far. The high-resolution visible composites provide detailed information for each regime on the small-scale features (bays and rivers for instance) that affect the development of clouds over time. The infrared composites provide information on the location and timing of deep convection for the various regimes. An example of the visible cloud frequency composites for 1715 UTC (1315 EDT) for opposing flow regimes 2 and 4 are presented in Figure 1 to show the distribution of small-scale cumulus clouds before the period of maximum deep convection is reached. A GOES-8 10.7 µm cloud frequency by temperature threshold (235 K) for 2115 UTC (1715 EDT) for opposing regimes 1 and 8 are presented in Figure 2 to demonstrate the varying regions of deep convection and to show regions with 40% or more cloud frequency that we designate as convective "hot spots." More information about the project and image loops can be viewed at: http://www.cira.colostate.edu/ramm/clim/menutala.html

Focus at the Wakefield WFO

As with many other forecast offices, the Wakefield WFO is interested in examining products that will help predict the location and timing of the onset of convective precipitation in their warning area. Research to date has utilized GOES-8 visible cloud frequency composites and focused on the warm season, from May through October, for the years 1998-2000. Neil Stuart has been the focal point at the Wakefield WFO. Nine generalized wind regime categories were selected for analysis. These include a designation of calm for a mean layer wind (1000-700 mb) of <5 m/s, and designation by the 8 points of the compass for the mean layer wind greater than 5 m/s (Table 2).

The warm season was further evaluated for the warmer, more convectively active period of May through July and the relatively cooler August through October period. An example of the more frequently occurring calm regime for the May through July period is shown in Figure 3. The influence of the complex coastline with the warm land surface versus cooler water surface around the Chesapeake Bay and the Atlantic Ocean are highlighted here. Heating of the land locally increases the formation of clouds while the cooler water locally suppresses cloud for-

(continued on page 19)

Regional Satellite Cloud Composites *(continued from page 18)*

mation. One feature of interest during the cooler season of August through October for the Wakefield region is the “Bay Plumes/ Streamers,” an enhanced convective line over the Chesapeake Bay. These plumes can sometimes enhance other convection in the area and trigger severe weather such as waterspouts. Even with the limited data set for a three-year period, this feature can be discerned in the northerly wind regime (Figure 4). A summary of this project can be viewed at: http://www.comet.ucar.edu/outreach/0024228.htm

Ongoing and Future Activities

Currently at the Tallahassee WFO, the regime cloud frequency results are being used extensively in aviation and public forecasting to supplement other information. In short-term forecasts, it is being used to ‘fine tune’ convective initiation and the timing of frontal passages. In zone forecasts, cloud frequency information is being used subjectively to produce more accurate and detailed probability of precipitation as well as severe weather or flood potential. In marine forecasts, it has provided more insight into the occurrence of land breeze convection and the sea fog/stratus potential. In aviation forecasts, the cloud frequency results have also been used subjectively to give better information on ceilings, timing of convection, and convective coverage en route.

The cloud frequency results are being developed and viewed outside the Advanced Weather Interactive Processing System (AWIPS) used by forecasters at the NWS. While ongoing efforts will continue to build, evaluate and fine tune the cloud composites/ climatologies, the next step is to incorporate the results into the AWIPS system so that forecasters can readily view and utilize the products.

Other future efforts will focus on building new relations with Forecast Offices to develop regime-based climatologies applicable to their forecast area. Interactions have already been initiated with the Cheyenne, Wyoming WFO to develop cloud composites looking at the forecast challenges of high wind events and heavy snow events. Another interaction is being proposed with a WFO in California to evaluate the use of regime-based cloud composites for fog forecasts.

Acknowledgements

This work was funded by the GOES I-M Product Assurance Plan (under NOAA Grant number NA17RJ1228) and by the Cooperative Program for Operational Meteorology, Education and Training (COMET) Partners Project, SOO-24228.

Regime	Description
1	Calm (< 5 m/s)
2	North
3	Northeast
4	East
5	Southeast
6	South
7	Southwest
8	West
9	Northwest

Table 2. Wakefield WFO warm season regimes

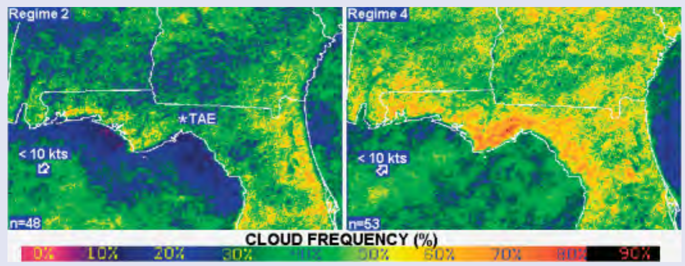

Figure 1. GOES-8 visible cloud frequency composites centered over the Tallahassee WFO (TAE) for 1715 UTC for regimes 1 and 8. The number of images used to create each composite is shown in the lower-left corner of each image (n=sample size). The study period includes Jun- Aug for 1996-2000. The arrows and wind speeds correspond to the background synoptic conditions for each regime as summarized in Table 1.

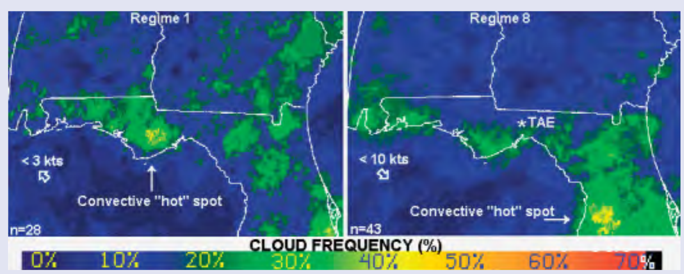

Figure 2. GOES-8 10.7 µm cloud frequency composites by temperature threshold (235 K) centered over the Tallahassee WFO (TAE) for 2115 UTC for regimes 2 and 4. The number of images used to create each composite is shown in the lower left corner of each image. The study period includes Jun-Aug for 1996-2000. The arrows and wind speeds correspond to the background synoptic conditions for each regime as summarized in Table 1.

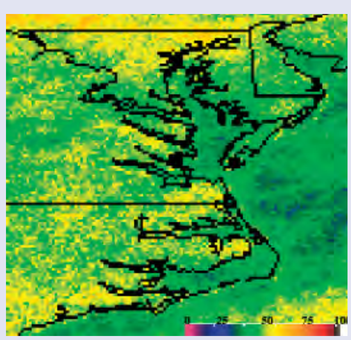

Figure 3. Percent cloud cover for the Calm regime, May-July, 1998-2000, 1645 UTC.

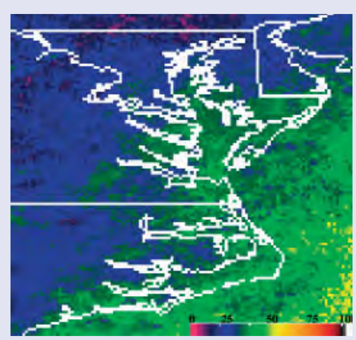

Figure 4. Percent cloud cover for the North wind regime, Aug-Oct, 1998-2000, 1245 UTC.

CIRA Mission

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

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

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

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