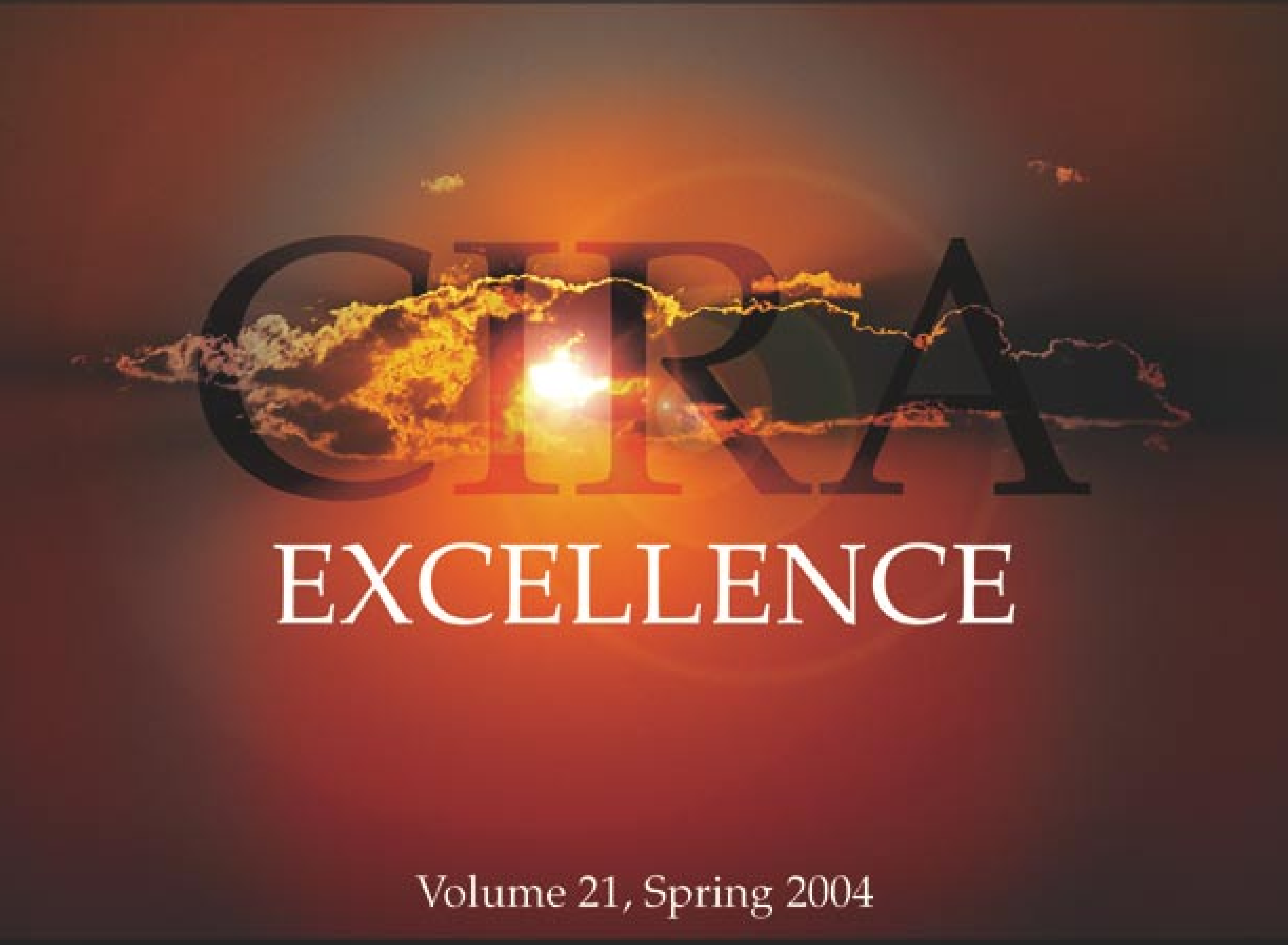
FEDERAL REVIEWS SPOTLIGHT



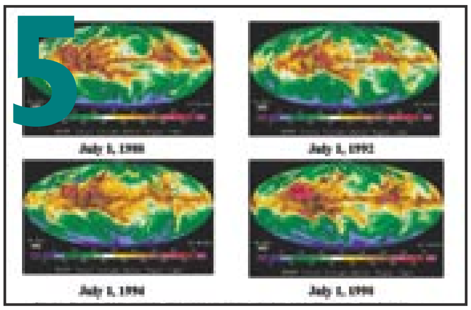
CIRA EXCELLENCE

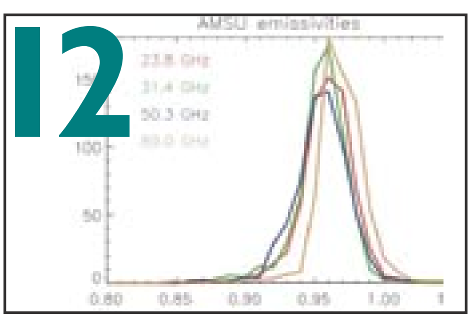
Volume 21, Spring 2004

Colorado State University

Knowledge to Go Places

Contents





CIRA

Cooperative Institute for Research in the Atmosphere

Federal Reviews Spotlight CIRA Excellence

By Ken Eis

As an institute supported primarily by federal funding, CIRA is subject to periodic reviews not only by NOAA, our main sponsor, but also by other entities that fund our research. The last few months have been busy ones for CIRA staff, as two important federal reviews took place within a few weeks of each other. On November 5-6, 2003, CIRA hosted a review by NOAA, and January 21-22, 2004, another review of CIRA was conducted by our Department of Defense (DoD) partners.

The preparations for both reviews were equally time- and labor-intensive. The review board sponsored by NOAA examined the quality of the research projects that they fund, as well as the functioning of the administrative arm of the organization. An extensive compilation of background materials was prepared for the reviewers in advance of their site visit, and can still be viewed on CIRA's Web site: http://www.cira.colostate.edu/5_year_review.html.

Among the specific areas the review board focused on were: 1) a review of CIRA's science plan (vision, mission, goals, and objectives), 2) a scientific review (highlights and accomplishments of research results), 3) an overview of CIRA's education and outreach activities, and 4) the "Science Management Plan" (identifying new intellectual opportunities, strategy for new starts, etc.). In addition to the written materials, CIRA also hosted a poster session during the two days of meetings.

Left to right: CIRA Deputy Director Ken Eis, Senior Manager Dave Cismoski, and Associate Director Cliff Matsumoto.

The final report of the review was just approved on March 16 of this year by the Science Advisory Board of NOAA. Dr. Thomas Vonder Haar, CIRA Director, is planning another round of "All Hands Meetings" to discuss the results with all staff. According to the report:

"CIRA was judged to be a successful Joint Institute based on:

- the quality of its research
- the strength of CSU's commitment to CIRA
- the vision and leadership of the CSU administrators

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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.

Federal Reviews *(continued from page 3)*

- strong relationships between CIRA and the collaborating departments at CSU, particularly Atmospheric Science
- strong partnership with the partnering NOAA labs
- the value of the Regional and Mesoscale Meteorology Team (RAMMT) with its cadre of NOAA/NESDIS employees substantial value provided to NOAA by the overall CIRA effort."

The annual DoD review of our DoD-sponsored Center for Geosciences /Atmospheric Research (CG/AR) is still awaiting its formal final report. The informal feedback received by our staff was all very positive. One note is that the Technology Transition of CG/AR science to the DoD operational centers has improved significantly. Data assimilation, satellite cloud products, and soil moisture determinations sparked the most interest.

CIRA staff, NOAA partners, and University partners around the table for the CIRA Administrative Review.

Reviewing CIRA research at the poster sessions.

CIRA Director Dr. Tom Vonder Haar and Associate Director Cliff Matsumoto present an overview of CIRA's research activities.

A nice spread to keep reviewers and staff alike fueled during the review.

Listening to opening remarks.

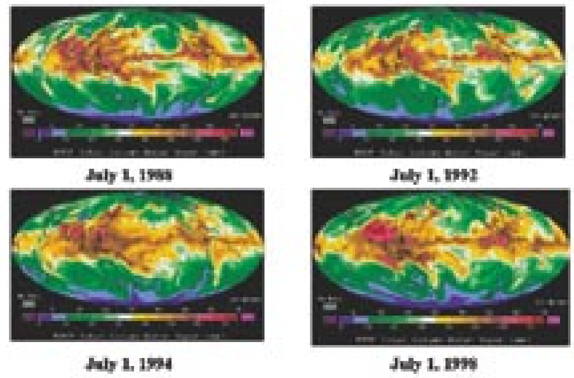
Water Vapor Variability on Timescales from Days to Decades

By John Forsythe and Thomas Vonder Haar

Water vapor is Earth's most important variable greenhouse gas. The NASA Water Vapor Project (NVAP) is a NASA Pathfinder project designed to measure via satellite the distribution of global water vapor on a daily basis. The Climate Data Records (CDRs) developed by NVAP have given us an increasing ability to monitor Earth's water vapor fluctuations on a variety of timescales. The NVAP CDRs address many of the NASA Earth Science Research Questions posed by Asrar (2001). Fronts, hurricanes, and droughts are captured in NVAP, as well as longer-term variability such as El Niño episodes and volcanic eruptions. A key question related to global climate change is: Will the amount of water vapor in the atmosphere increase if Earth warms? This could provide positive feedback in greenhouse warming versus that due to CO_2 alone.

The NVAP dataset now covers the period 1988-2001. It was processed for NASA by the Science and Technology Corporation, METSAT Division. They have provided the entire dataset to CIRA for scientific analysis. More details on the NVAP dataset can be found at http://www.stcnet.com/projects/nvap.html. The NVAP dataset has been reviewed by Simpson et al. (2001) and found to possess sufficient accuracy for variability studies. NVAP data is used by researchers worldwide. NVAP is a relative of other long-term, satellite-based, global climate datasets created for the Global Energy and Water Cycle Experiment (GEWEX). Examples of these are the International Satellite Cloud Climatology Project (ISCCP), the Global Precipitation Climatology Project (GPCP), and the Global Aerosol Climatology Project (GACP). These types of datasets have played a fundamental role in understanding Earth's climate and assessing the results from general circulation models.

CIRA scientists have played a key role in the development of the NVAP dataset and its scientific application. CIRA-affiliated researchers past and present who have worked on NVAP include Dave Randel, Tom Greenwald, Johnny Luo, Darren McKague, Garrett Campbell, Ben Ruston, Cindy Combs, and Don Reinke. A journal paper summarizing Earth's water vapor as depicted by NVAP will be submitted by Vonder Haar, Forsythe, Randel, Luo, and Ruston in the spring of 2004. This article gives a glimpse into the type of science questions CIRA is addressing about Earth's water vapor. More detailed results can be found in Vonder Haar et al. (2003) and Forsythe et al. (2003). Additional information on climate research at CIRA is available at: http://www.cira.colostate.edu/Climate/overview.htm.



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Observing Global Water Vapor with Multiple Satellites

Daily fields of total column and layered water vapor, along with oceanic cloud liquid water, are the foundation of NVAP. A variety of satellite observations have been brought together to create this dataset. The construction of the NVAP dataset was performed by the Science and Technology Corporation, METSAT Division, in Fort Collins, Colorado. Extensive quality control has been a key part of NVAP production.

NVAP was begun in 1988, the first full year for which data from the Special Sensor Microwave / Imager (SSM/I) was available. Passive microwave sounders provide a reliable estimate of total precipitable water (TPW) over the ocean. Currently these microwave retrievals are not possible over land due to the variable and complex microwave surface emissivity. Andrew Jones and colleagues at CIRA are continuing research to understand land surface emissivity. In the future, more microwave retrievals over land will become possible.

NVAP from 1988-1999 merged a number of SSM/I instruments, operational NOAA TOVS soundings, radiosondes, and results from an optimal estimation retrieval using High Resolution Infrared Sounder (HIRS) data. The product was 1-degree resolution, gridded fields of 4 layers of precipitable water and total precipitable water, along with a data source code field. Cloud liquid water over the ocean was produced as well. In 2000 and 2001, NVAP entered the 21st century by creating twice per day, ½ degree resolution products at five vertical levels. The radiosonde data were not merged in this effort due to their difficulty in measuring upper-tropospheric water vapor. A microwave optimal estimation retrieval developed at CIRA was used to obtain water vapor profiles from the Advanced Microwave Sounding Unit (AMSU) and the Special Sensor Microwave/Temperature-2 (SSM/T-2) instrument. Over ten low-Earth orbiting satellite instruments were used in 2000 and 2001 for NVAP.

Water Vapor: The Atmosphere's Most Variable Gas

Since NVAP is a daily dataset with a record of more than 10 years, it captures weather as well as climate. Figure 1 shows TPW from July 1 of 1988, 1992, 1994 and 1998. While there are some broad structures in common (e.g. the Intertropical Convergence Zone and the dryness over Antarctica) there are large differences between the four days. How much latent energy does the atmosphere transport via water vapor? How variable are the fluxes on a regional scale?

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Water Vapor Variability *(continued from page 5)*

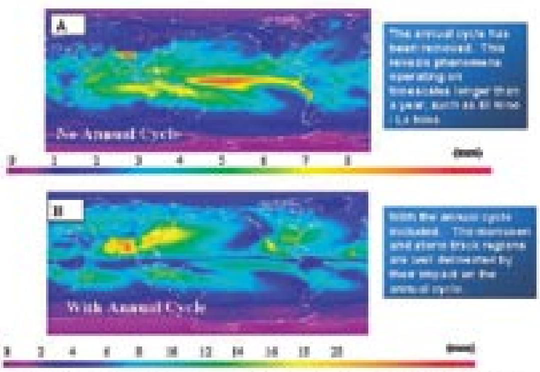

Figure 2. The global standard deviation of total column water vapor for 1988-1999. A) The annual cycle has been removed. This reveals phenomena operating on timescales longer than a year, such as El Niño / La Niña. Note the high variability in the Tropical Pacific. B) With the annual cycle included. The monsoon and storm track regions are well delineated by their impact on the annual cycle.

How does the water vapor distribution relate to drought or floods? Is there some seasonal predictability? These are all questions which the daily fields allow us to probe.

The most obvious long-term variability in global water vapor is that which occurs with an annual cycle. By removing the annual cycle, longer-term variability becomes visible. Figure 2 shows two plots of the standard deviation of TPW. In Figure 2a, TPW is shown with the annual cycle removed. In Figure 2b, the annual cycle is present. The annual cycle manifests itself most strongly in the monsoon regions and in the storm track regions to the east of Asia and North America. There are some modest north-south fluctuations in the tropical oceans associated with the movement of the ITCZ. In Figure 2a, where the annual cycle has been removed, an entirely different picture emerges. Now we begin to see atmospheric states not directly related to seasonal change. In particular, the strongest changes are in the tropical East and Central Pacific Ocean, the area most strongly reflecting sea surface temperature changes during El Niño and La Niña periods. During the 12 years covered by Figure 2, there was a major El Niño in 1997-1998 with a weaker event in 1991-1992. La Niña periods occurred in 1988-1989 and again in 1996 and 1999. The fourteen years of the NVAP dataset are now allowing us to characterize the atmospheric water vapor response to these events.

Perhaps the most timely question CIRA is researching with the NVAP data is: Do we detect a long-term trend in water vapor? Is the hydrologic cycle intensifying? Next to the distribution of clouds, changes in atmospheric water vapor are a major uncertainty in predicting Earth's climate in the coming millennium. Our research with NVAP has shown that the TPW in the atmosphere does fluctuate on annual scales. Figure 3 shows a plot of NVAP TPW anomalies (blue), along with sea surface temperature anomalies (green) and Microwave Sounding Unit (MSU) lower tropospheric temperature anomalies (red) for 1988-1999. Note that the water vapor anomaly amount has varied by about 1 mm, with a maximum during the 1997-1998 El Niño and a minimum during 1992-1993. Given a mean global TPW value of ~25 mm, this implies that TPW has varied by about 4 percent during the 1990s. Our research continues to explore the important question of whether we observe any global or regional trends in water vapor.

A Promising Future

Although we have posed daunting questions about water vapor, fortunately there are a number of quality observational tools which are or will be available for water vapor research. NASA's Aqua satellite, dedicated to measure water in all forms as reflected by its name, has a number of state-of-the-art sensors which measure water vapor. The first of five Special Sensor Microwave Imager/Sounder (SSMIS) instruments, which combines for the first time the profiling and imaging channels in a common view, was successfully launched in 2003. The NPOESS (National Polar Orbiting Environmental Satellite Series) Preparatory Project (NPP) is scheduled for launch in late 2006, with the NPOESS fleet to follow a few years afterwards. A very capable European polar orbiter will come on line as well. A large portion of Earth is covered by Global Positioning System (GPS) sensors, which provide highly accurate measurements of TPW.

In addition to leaps in instrumentation, improved algorithms and reanalysis of historical data will combine to provide the vital Climate Data Record of water vapor. CIRA scientists will remain on the leading edge of this exciting research effort.

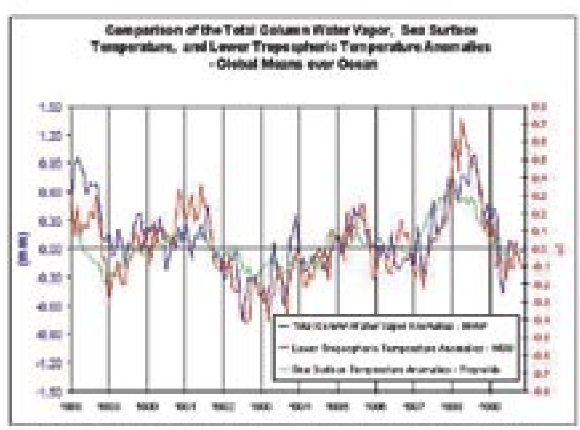

Figure 3. NVAP TPW anomalies (blue) compared to sea surface temperature anomalies (green) and MSU tropospheric temperature anomalies (red) for 1988-1999. The fields show a high degree of correlation, particularly for the large 1997-1998 El Niño and the global cooling after the 1991 Mount Pinatubo eruption. (see Vonder Haar et al, 2003 and 2004).

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National and International Training Activities at CIRA

By Bernadette Connell, Dan Bikos, Dan Lindsey, John Weaver, and Tony Mostek

The Regional and Mesoscale Meteorology (RAMM) Team supports both National and International training activities at CIRA that are specifically directed towards increased use and understanding of satellite data. Nationally these include the Virtual Institute For Satellite Integration Training (VISIT) program and a newly emerging Satellite Hydrology and Meteorology (SHyMET) program. Internationally, they include interaction with the Regional Meteorological Training Centers (RMTCs) in Costa Rica and Barbados.

VISIT was created in 1998 with funding from the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) and the National Weather Service (NWS). Distance learning became necessary as NWS training requirements outpaced the availability of travel funds for classroom training. A software package, VISITview, was developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) to meet the specific distance learning requirements of VISIT. The VISITview software, along with a telephone conference call, allows for a synchronous teletraining session to take place so that training sessions may be administered to NWS offices. VISIT is composed of staff from CIMSS, the NWS training division, NESDIS, and CIRA.

A new ShyMet course dedicated to operational satellite meteorology is currently under development. NOAA's space-based remote sensing program will go through a major increase in observing capability over the next decade. NOAA is preparing for the next generation of both the National Polar Orbiting Environmental Satellite System (NPOESS) and Geostationary Operational Environmental Satellites (GOES-R+) with initial launches scheduled near the end of the decade. Although utilization of data from NPOESS and GOES-R+ is years away, the GOES Users subcommittee on Training, Education and Outreach (October 1-3, 2002) recommended that training and education resources be addressed immediately to avoid impending shortfalls. The ShyMet course will use a blended training format similar to that employed by NOAA's Distance Learning Operations Course (DLOC) for the WSR-88D radar. This format includes a combination of teletraining, which will be provided by the VISIT program, CD-ROM, Web-based instruction, and on-site training.

NOAA/NESDIS/CIRA partnered with NOAA/CIMSS and the RMTCs in Costa Rica and Barbados in 1996 at the recommendation of the 45th session of the World Meteorological Organization (WMO) Executive Council. The Council recommended that the major satellite operators share their expertise and knowledge with the designated specialized satellite applications training centers. The project was designed around the concept of the virtual laboratory, which focuses on using PCs with the McIDAS/RAMSDIS[1] software, case data sets, and Internet connections to demonstrate the invaluable use of digital satellite imagery. The RMTCs have recently started exploring the use of the VISITview software.

This paper presents an overview of the activities of each of these national and international programs.

Teletraining session topic	Number of certificates of completion issued
Use of GOES/RSO imagery with other Remote Sensor Data for Diagnosing Severe Weather across the CONUS	111
Wildland Fire Detection Using Satellite Imagery	186
Lake-Effect Snow II	119
Subtropical Cyclone Analysis with Satellite Data	54
Cyclogenesis: Analysis using Satellite Imagery	788
Lightning Meteorology II	567
Mesoscale Analysis of Convective Weather Using GOES RSO Imagery	480
Lightning Meteorology I	957
Natural Disaster Information Cards	105
Using GOES Rapid Scan Operations (RSO) in AWIPS	263
CONUS Cloud-to-Ground Lightning Activity	285
Tropical Satellite Imagery and Products	138
Lake-Effect Snow I	210
Using AWIPS to Evaluate Model Initializations	440
Detecting Low-Level Thunderstorm Outflow Boundaries at Night using GOES	186
GOES Enhancement / Color Tables in AWIPS	109

Table 1. Teletraining session topics developed/taught at CIRA and number of certificates of completion for each.

The VISIT Program

VISIT offers a broad range of topics for teletraining. As of March 2004, 48 topics had been developed, 16 of which were developed at CIRA. For a list of session topics that have been developed at CIRA, see Table 1. After each teletraining session, an evaluation form

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[1] RAMM Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS)

National and International Training Activities *(continued from page 7)*

is sent to the individual who registered their office for the training (generally the Science Operations Officer). In the evaluation, we ask for the names of the students who participated so that a certificate of completion, signed by the instructors, can be mailed to them. Based on positive student feedback, VISIT teletraining has fulfilled the goal of providing distance learning to operational forecasters.

The teletraining design process begins with the selection of a topic as suggested by NWS personnel or VISIT instructors. Once a topic is selected, VISIT instructors and subject matter experts from outside the project determine an outline for the session. The model design used for most sessions includes theoretical background knowledge and follow-up case studies. Once the first draft of a session is completed, a test run of the lesson is presented to selected NWS offices, subject matter experts, and other VISIT staff to refine the contents. Attendees provide formal reviewer comments that the authors are required to address (similar to the review process for refereed journal articles). Modifications are made or justifications are provided should authors disagree with individual comments. When the modifications are completed, dates are selected for instruction, the VISIT teletraining calendar Webpage is updated, and a formal announcement is sent via e-mail to NWS offices. After an office registers for a teletraining session, they receive setup instructions via e-mail about a week before the scheduled session. The setup instructions contain download information for the file to be used for the training as well as a conference call phone number. Instructors often wish to insert new or updated material into their training session so they may easily modify the file and edit the setup instructions accordingly before the training session takes place.

At the scheduled time of the session, offices call in using a telephone conference number. The previously downloaded file is initiated on an office PC. The software automatically connects to the instructor over the Internet, allowing the instructor to control the session remotely. The controls include advancing of slides, annotations, animation controls, etc. (Fig. 1). Any actions by the instructor are seen synchronously at every participating office (Fig. 2). During the teletraining session, interactivity is encouraged through instructor questions and case studies. The questions are designed to generate thought-provoking discussion and practical reinforcement of principles for the student. The exchanges often lead to refinements and updates of session material.

Since April 1999, more than 750 VISIT teletraining sessions have been administered, and over 12,000 certificates of completion have been awarded to teletraining participants. All 122 NWS forecast offices have participated. We calculated that 835 unique students have taken 5 or more sessions, which is equivalent to roughly one day of classroom training. Thus, considerable travel expenses plus time out of the office have been saved. Preparation for the VISIT material takes more time than comparable classroom presentations, given the extensive peer-review process used for the teletraining. However, the cost benefits gained by teletraining more than outweigh the expenditure for classroom training. Another benefit of teletraining is the availability of asynchronous versions for students that cannot attend the live teletraining. The VISIT Web site (http://www.cira.colostate.edu/visit) contains stand-alone versions of most sessions, with embedded instructor notes, that can be viewed using a Web browser. Additionally, some sessions are available with recorded instructor audio and annotations. The Web/audio versions make it possible to view the material at any time. VISIT teletraining applications continue to expand as more NOAA offices turn to this approach as a cost-effective solution to the problem of increased training requirements coupled with shrinking training and travel budgets.

Figure 2. VISIT instructor John Weaver leads a teletraining session as the NWS office in Cleveland, Ohio, follows along. Cleveland photo courtesy R. LaPlante.

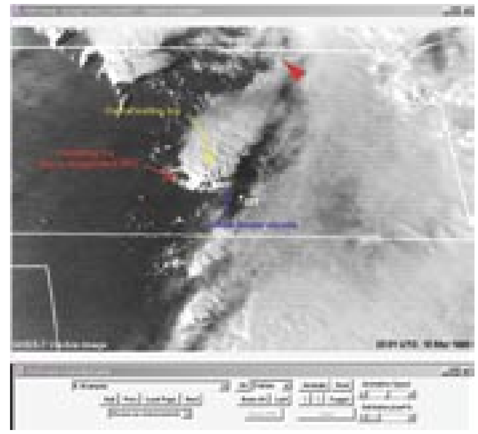

Figure 1. An example of one of the VISIT teletraining sessions developed at CIRA. The software allows instructors and students to view the material synchronously. This includes annotations, animated loop controls, etc.

SHyMet Program

The SHyMet Course is being designed to cover some of the basics of satellite instrumentation, orbits, calibration, navigation, and radiation theory while also including identification of atmospheric and surface phenomena, and the integration of meteorological analysis with satellite observations and products into the weather forecasting and warning process. This course will be taught through a combination of teletraining, CD-ROM, Web-based instruction, and on-site training. At the end of the distance training portion of the program, participants will attend a 3.5-day SHyMet Workshop offered at the COMET Classroom in Boulder, Colorado. Although distance training has significantly improved over the years, experience has shown that a dedicated in-class training effort is also highly beneficial. Upon successful completion of SHyMet, participants will be certified to use satellite data and products as part of the NWS weather forecasting and warning program.

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National and International Training Activities *(continued from page 8)*

A key aspect of this satellite-training program will be the inclusion of new data, products, and forecasting techniques developed by NOAA's joint centers such as the Joint Center for Satellite Data Assimilation (JCSDA), the Short-term Prediction Research and Transition Center (SPoRT), the NWS National Centers, and Cooperative Institutes such as CIRA and CIMSS.

The target audience for the training includes the satellite focal point and Science and Operations Officer at each NWS operational office. The proposed first offering is in 2005. See http://www.cira.colostate.edu/RAMM/SHyMet/ShyMet_main.htm to view the proposed curriculum.

RMTC Interaction

The RMTC in Costa Rica is closely associated with the Universidad de Costa Rica, and the RMTC in Barbados is closely associated with the Caribbean Institute of Meteorology and Hydrology. Activities with the RMTCs have focused on building case studies of heavy rain events associated with hurricanes, tropical waves and the incursion of mid-latitude systems during northern hemisphere winter. Research has also focused on fire detection, volcanic ash detection, satellite rainfall estimation, and satellite cloud climatologies. Real-time use of satellite imagery is encouraged by making GOES-East satellite imagery available in java loops on the Web.

CIRA has helped organize and execute three WMO sponsored two-week satellite meteorology training events in the regions, the most recent occurring in December 2003 in Barbados (Fig. 3). Because of involvement with the RMTC in Costa Rica, CIRA took the lead role in the NESDIS portion of the Hurricane Mitch Reconstruction Project, which placed two RAMSDIS units in each of the seven Central American countries (Belize, Costa Rica, El Salvador, Honduras, Guatemala, Nicaragua, and Panamá) and conducted three one-week training events in Costa Rica. Examples of the various RMTC activities and available satellite image loops can be viewed at: http://www.cira.colostate.edu/RAMM/TRNGTBL.HTM#vlab

In 2001, the WMO organized a meeting of the International Satellite Data Utilization and Training Focus Group. At this meeting, a decision was made to establish a Virtual Laboratory to foster the international exchange of satellite data and training material. The focus includes the development of an online library of resources for training and the establishment of centrally located sites to provide easy access to real-time satellite imagery (http://www.wmo.ch/hinsman/vl.htm). Recently, the Virtual Laboratory Task Team initiated a VISITview exercise using GOES satellite Imagery from the University of Wisconsin and voice via Yahoo Messenger. There were participants from the U.S.: CIRA and COMET in Colorado, and CIMSS in Wisconsin; as well as outside the U.S.: Australia, Barbados, Brazil, Honduras, Martinique, and Peru. Similar sessions are planned to encourage the exchange of information and use of training materials.

Figure 3. Trainers and participants of the Regional Training Seminar on the Use of Environmental Satellite Data in Meteorological Applications held in Bridgetown, Barbados, 2-12 December 2003.

Summary

The underlying goals of the national and international training activities have been to increase awareness, understanding, and utilization of satellite imagery and image products within weather forecast offices. The imagery must be readily accessible and must provide additional information to be used. In the NWS forecast offices, the amount of all types of weather information available locally to the forecaster has significantly increased over the years. Our experience has shown that it is important to have directed training that shows where satellite imagery and products are located on the system as well as how to utilize it properly under various situations – under day-to-day operations as well as under severe-weather warning operations.

Outside the U.S., the challenges have been to make digital imagery available locally and where this is not possible, provide Internet links where products can be viewed. The added training component has greatly increased the utilization of satellite imagery as well as communication among various countries involved.

These efforts are ongoing: researchers at CIRA, CIMSS, NOAA, and other universities and government organizations are evaluating data from the new satellite technologies and developing new and advanced products and tools to be used operationally. At the same time, educators at CIRA are uniquely positioned to transfer this advanced research through their training programs. The VISIT program has provided an excellent tool with which to present information and encourage participant interaction in a distance-learning setting. The new ShyMet course will ensure that a framework exists for coverage of basic and advanced topics on satellite image interpretation. The new training information will also be shared with the international community.

GOES-R Risk Reduction Activities at CIRA

By Don Hillger, Mark DeMaria, and Louie Grasso

Introduction

The current Geostationary Operational Environmental Satellite (GOES) series was inaugurated in 1994 with the launch of GOES-8 and will continue with four more satellites beyond the most recent GOES-12 launched in 2002. The next generation GOES (beginning with GOES-R) will be launched in the 2012 timeframe. This new series of satellites will include improved spatial, temporal, spectral, and radiometric resolution. The last two characteristics are manifest by an increased number of spectral bands and increased precision for measurements from those bands. Because of the long lead time needed to design, build, and test this new and complex satellite system, it is already time to do the background work needed to prepare for the development and implementation of GOES-R.

Preparations for GOES-R are well underway at CIRA. This work is focused on applications to forecast mesoscale weather events including severe storms, tropical cyclones, lake-effect snowstorms, and fog outbreaks. Two approaches are being used for these "Risk Reduction" activities. In the first approach, data from existing operational and experimental satellites are used to create subsets of observations that will be available from GOES-R. In the second approach, numerical cloud models are being coupled with radiative transfer models to create simulated imagery. In this article, GOES-R is briefly reviewed, and some examples of CIRA risk reduction activities are described.

GOES-R Instrumentation

The GOES-R series will include several instruments that will be more advanced than those on the current GOES series. The current GOES Imager will be replaced by an Advanced Baseline Imager (ABI), which will be explained in more detail below. The current GOES Sounder will be replaced by a Hyperspectral Environmental Suite (HES) with both broader spatial coverage and higher spatial resolution. The HES will be designed to give both large-area lower-resolution (10 km infrared) coverage and higher-resolution (4 km infrared) severe weather/mesoscale capabilities. This portion of the HES will cover the visible and infrared portions of the spectrum with a very large number of spectral measurements as the term 'hyperspectral' implies.

The HES will also include a Coastal Waters imaging instrument that will have much higher spatial resolution (300 m) capabilities in the visible/near-infrared. This capability will be useful for looking at the coastal ocean environment which is the subject of great concern and which is greatly impacted by man. This instrument will also be used to look at other weather-related phenomena such as air quality, flooding, severe weather, and hurricanes.

Additional components of the GOES-R series will be a lightning mapping instrument, and solar/space environmental instrumentation. The solar and space instruments will improve the monitoring of the sun and the electromagnetic environment of the earth that is an important operational aspect of the current GOES series.

GOES-R ABI

The main instrument on the GOES-R will be the ABI (Advanced Baseline Imager). The exact configuration of spectral bands has not been fixed, but the spatial resolution will be improved (0.5 km visible, 2 km infrared) over the current geostationary imaging. Table 1 shows the proposed spectral bands for the ABI compared to the current GOES bands, showing the more complete spectral coverage of the ABI. The current GOES Imager is limited to only 5 of the 6 numbered spectral bands on any satellite. The ABI, with 16 bands, will have three times the spectral coverage as the current GOES Imager as well as improved radiometric capabilities (such as precision and signal-to-noise) for those bands.

Case Study Database

The CIRA GOES-R activities are focused on mesoscale weather events. For the initial phase of this research, five cases studies were chosen as listed in Table 2. The cases were chosen because of their meteorological interest, and the availability of satellite and in situ observations that can be used to simulate GOES-R observations.

Table 1: Proposed ABI Bands

ABI Band	Central Wavelength (µm)	Current GOES Band
1	0.47	
2	0.64	1
3	0.86	
4	1.38	
5	1.61	
6	2.26	
7	3.9	2
8	6.185	
9	6.95	3
10	7.34	
11	8.5	
12	9.61	
13	10.35	4
14	11.2	
15	12.3	5
16	13.3	6

Much of the initial emphasis has been on gathering the various satellite data and making it available to multiple researchers involved in this study. For this purpose, a mass-storage device is being used which involves uniquely-linked hard disks that are capable of redundancy and failure recovery. All the satellite data, as well as derived products and numerical model output from these cases, are being saved on this mass-storage device. The observations collected for these cases include those from the current GOES and POES satellites, and data from the 36-band MODIS (Moderate-resolution Imaging Spectrometer) and the hyper-spectral AIRS (Advanced Infrared Sounder) instrument on the EOS-series polar-orbiting satellites called Aqua and Terra. Conventional observations and the initial fields from the NCEP eta model are also being collected. For the hurricane cases, GPS soundings in the

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GOES R Risk Reduction *(continued from page 10)*

Table 2: Case Studies for First Phase of CIRA's GOES-R Research

Case	Region	Study Dates
Hurricane Lili Landfall	Gulf of Mexico	30 September - 4 October 2002
Hurricane Isabel Near Peak Intensity	Central Atlantic	12 September 2003
Severe Weather Outbreak	Oklahoma, Kansas	8-9 May 2003
Lake-Effect Snow	Western New York	12-14 February 2003
Fog Outbreak	California, Utah, Colorado	11 January 2004

storm environments obtained from the NOAA Gulfstream jet are also being collected to help evaluate atmospheric profiles from the AIRS instrument.

Sample of Initial ABI Capabilities

Some of the initial work in preparation for GOES-R has been to simulate the capabilities of the increased spectral resolution of the ABI using MODIS data. With 16 rather than 5 bands, the ABI will provide increased capability to discriminate among various features within an image, such as better differentiation between types of cloud, atmospheric and surface properties. Simple spectral band differencing works well when only a few bands are available. More sophisticated techniques are needed to handle the increased number of spectral bands, as there are limits on the ability to randomly combine the spectral bands to learn all the capabilities that will be available. Once the GOES-R ABI data are simulated, image combination techniques are being employed to learn the capabilities of the ABI.

Two of the preliminary image products generated from this study are shown in Figures 1 and 2, for the severe weather and fog cases, respectively. These three-color images are combinations of various image products that arose from multiple image differencing techniques normally applied to multi-spectral data. These techniques are designed to remove the redundant information in the imagery and to emphasize the image differences so that important cloud, atmospheric and surface properties can be seen.

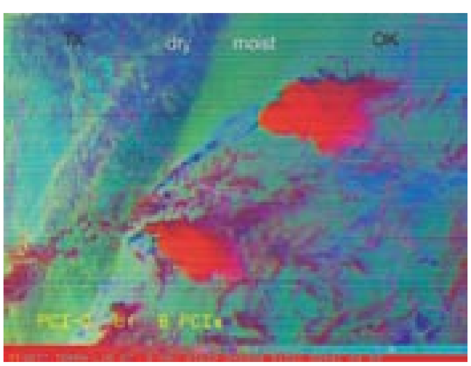

Figure 1: Three-color composite image for a severe weather case. Colors denote various types and heights of clouds (high clouds are red, low clouds are blue) as well a more subtle variation in the low-level moisture seen along a dryline in Texas and Oklahoma.

Figure 1 contains two potentially severe storms that formed along a dryline extending from Texas into Oklahoma on this day. Low-level moisture appears greener to the east and drier to the west of this dryline. Note also that surface features are more easily seen through the drier air than through the moist air. High cloud tops are colored red along with thinner cirrus cloud, whereas lower-level and feeder-cloud bands related to the individual storms are colored blue.

Figure 2 is a fog detection case where valley fog is clearly differentiated from both dry terrain and surrounding snow-covered mountain peaks. This case is an event from Utah and Colorado where valley fog is often hard to discern from other image features with normal visible imagery alone.

Simulated GOES-R Imagery from Numerical Cloud Models

As shown in the examples above, it is possible to simulate some aspects of GOES-R using currently available observations (primarily from polar-orbiting satellites). However, until the launch of GOES-R, it will not be possible to simulate observations with the temporal resolution that will be possible from a geostationary platform. For this reason, numerical model runs are being coupled with radiative transfer models to produce synthetic ABI observations.

Figure 2: Three-color composite image for a fog case in Utah and western Colorado. Magenta colors denote fog in patterns determined by the terrain. Changes in the thickness of the fog are seen in the variations of color, and surface- type differences are noted by more subtle changes in greens and yellows.

The cloud model for this work is the Regional Atmospheric Modeling System (RAMS). The RAMS model is non-hydrostatic and contains a sophisticated cloud microphysical parameterization. Simulations are typically performed on a series of nested grids with a horizontal grid spacing of 1 km on the innermost domain. The output from the RAMS model is used as input to the radiative transfer model (which accounts for clear and cloudy atmospheres) to create the synthetic imagery.

As a first test of this method, synthetic imagery for the infrared window (10.7 μm) channel (channel 4) of the current GOES was created from a RAMS simulation of the 8 May portion of the severe weather case described in Table 2. RAMS was initialized with the 1200 UTC 8 May 2003 initial analysis from the National Centers for Atmospheric Prediction (NCEP) eta model. Figure 3 shows the simulated GOES channel 4 from the RAMS/radiative transfer model at 2340 UTC. The innermost grid (1 km) was centered over the storm system in central Kansas. Figure 4 shows the actual GOES channel 4 from this same time. Although the model did not reproduce the exact location and timing of the severe storms on this day, the magnitude and variability of the cloud top brightness temperatures in the model and observations are quite similar for this case. This agreement provides confidence that the model can produce atmospheric structures that are reasonably similar to those that are observed. As such, the inferences made from

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Microwave Land Emissivity

By Benjamin Ruston[1], Andrew Jones[1], Thomas Vonder Haar[1], Nancy Baker[2]

In August of 2003, a collaborative opportunity arose between CIRA and the Naval Research Laboratory (NRL) in Monterey, CA. This allowed microwave land emissivity results, derived at CIRA, to be implemented into a 1-Dimensional Variational (1DVAR) temperature and moisture profiling algorithm developed by Baker et al. (2001) at NRL. Baker's algorithm has been used with success over ocean areas, while the collaboration extended its use to a case study over the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site in northern Oklahoma. Atmospheric profiles of temperature and moisture were retrieved for July and August of 2001. The rewards of this effort were not just the profiles themselves, but also a wealth of knowledge on the sensitivity of the boundary layer temperature and moisture to microwave land emissivity.

To prepare for this project, a six-month climatology of Land Surface Temperature (LST) and microwave land emissivity was created at CIRA. Land emissivity values gathered from July and August of 2000-2002 defined error characteristics of emissivity, and populated covariance matrices used in the 1DVAR retrieval. LST was retrieved using the Geostationary Operational Environmental Satellite (GOES) and the microwave emissivities were retrieved from the Advanced

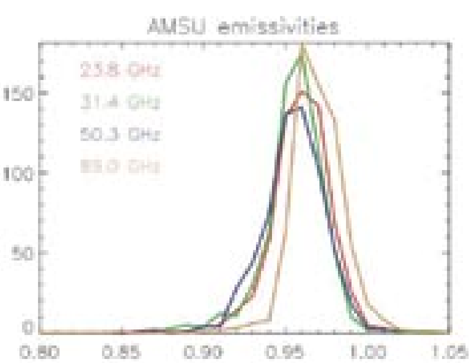

Figure 1: Histograms of retrieved AMSU-A emissivities over the ARM-SGP site from July and August 2000-2002. Channels 1, 2, 3, and 15 (23.8, 31.4, 50.3, and 89.0 GHz) are shown respectively.

Microwave Sounding Unit (AMSU). Shown in Figure 1 are histograms of the emissivities retrieved for AMSU-A channels 1, 2, 3, and 15 (23.8, 31.4, 50.3, and 89.0 GHz) for June and July during three consecutive years over the ARM-SGP study region.

The 1DVAR retrieval procedure requires atmospheric temperature and moisture profiles, land surface temperatures, and microwave radiances from AMSU-A with accompanying emissivity estimates for each of its channels. The Naval Operational Global Atmospheric Prediction System (NOGAPS) provided weather analysis, which for this study, became a priori profiles of temperature and moisture. A GOES-based retrieval provided land surface temperatures, and microwave radiance observations were obtained from AMSU-A, which is designed primarily as a temperature-profiling instrument. The AMSU-A instrument has fifteen channels, four of which are considered window channels (1-3 and 15). A window channel has the least contribution from the atmosphere and can see through to the surface. Channels 4-14 progressively move into an oxygen absorption feature, and have sensitivity to subsequently higher levels in the atmosphere, which is the theoretical basis for its temperature sounding capability.

A radiative transfer model is used by the 1DVAR retrieval to simulate AMSU-A radiances for comparison to observational data. An estimate of error in the radiative transfer model, and each of its input parameters is fundamental to the retrieval procedure. Small perturbations are made to the atmospheric profiles, the land surface temperature, and the microwave emissivities to find the sensitivities among all these parameters. To find the solution, an iterative minimization procedure follows, which utilizes the estimates of error. In each iteration, a variety of solutions are found which can reproduce the AMSU-A radiances. The optimal solution is that in which the changes made to the atmospheric parameters are small compared to their estimates of error, while still reproducing the observations within the error of the radiative transfer model.

To illustrate the dramatic impact land emissivity has on reproducing AMSU-A observations, two cases are selected for comparison. The first is a control case using the NOGAPS default land surface temperature and a fixed emissivity of 0.90. The second uses the GOES retrieved LST and the AMSU-A emissivities retrieved at CIRA. Figure 2 shows the difference between the observed and simulated brightness temperature for the first iteration of the retrieval. The control case produces differences that are an order of magnitude greater in the window channels. Since the initial brightness temperature estimate is so far off in the control case, the 1DVAR procedure will make large adjustments wherever possible (in atmospheric fields with large errors) to match the AMSU-A observations. As these adjustments become large comparable to the parameter errors, the χ2 statistic becomes larger. The case using CIRA retrieved GOES land surface temperature and AMSU-A emissivities has a small χ^2 value, within a 95 percent confidence limit for the degrees of freedom defined for the problem (about five). The control case produced an χ^2 value several times greater than the 95 percent confidence limit, implying that the retrieval errors were not consistent with the a priori and observation error assumptions. This emphasizes that well-characterized microwave land emissivity is needed for the retrieval to perform within the errors in the parameters and the forward radiative transfer model.

Of 81 retrieval cases performed, 67 had co-located radiosonde data that could be used for comparison. The Root Mean Square (RMS) difference between the retrieval and the radiosondes was found for these 67 cases and is presented in Figure 3. In this figure, three RMS difference values are shown. The first is from the original NOGAPS profile, or a priori, which is the point from which the retrieval starts. The second is from the retrieval that begins iterations using the CIRA retrieved AMSU-A emissivities and GOES LST. The third RMS difference values are from the control case retrieval, which begins iterations using a fixed AMSU-A emissivity of 0.90, and LST estimated by the NOGAPS

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[1] Cooperative Institute for Research in the Atmosphere (CIRA)
[2] Naval Research Laboratory

Microwave Land Emissivity *(continued from page 12)*

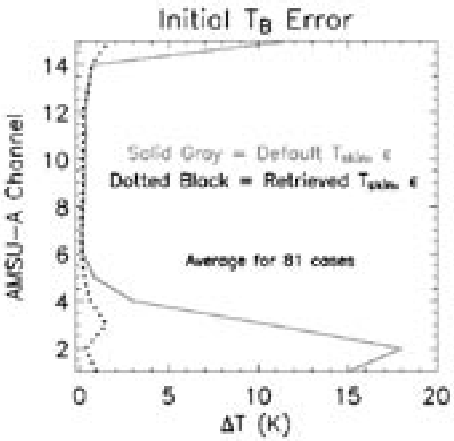

Figure 2: Initial brightness temperature error in two retrieval approaches implemented using the NRL 1DVAR routine. The gray line corresponds to retrievals which used NOGAPS land surface temperature and a fixed emissivity of 0.9; while the dotted black line corresponds to retrievals which included the CIRA retrieved GOES land surface temperature and AMSU-A emissivities.

analysis. The temperature RMS difference, in Figure 3a, shows that the retrieved profiles using the explicitly calculated AMSU-A emissivities has improved performance, in the lower 2 km, over both the a priori and fixed emissivity cases. The specific humidity RMS difference, in Figure 3b, shows that the retrieval using the CIRA calculated AMSU-A emissivities does not alter greatly from the original a priori profile, while the control case has increased the specific humidity error over that seen in the a priori. This is because the simulated brightness temperatures have such a large error: the retrieval tries to correct for this by modifying a parameter with a large radiometric impact, and large associated errors, both typical of the lower atmosphere moisture. The CIRA retrieved emissivities allow the retrieval to intelligently add information from observations, within the estimated errors of the parameters, and not degrade good information given by the a priori.

Another useful diagnostic is to examine the response of temperature and specific humidity to perturbation in microwave land emissivity. Figure 4 displays a level-by-level response of temperature and specific humidity to perturbations in emissivity for each AMSU-A channel. The atmospheric response is scaled by the error standard deviation for the parameter, and the emissivity perturbation used is one standard deviation of the emissivity error for each AMSU-A channel. Only the first five AMSU-A channels and channel 15 are shown. The remaining AMSU-A channels (6 through 14) have virtually no direct sensitivity to the surface and their contribution to the temperature and moisture in the lower atmosphere is zero for all practical purposes. The response of the low-level temperature profile to emissivity, in Figure 4a, can be divided into two groups. The AMSU-A window channels 1-3 and 15 all have strong sensitivity to the surface, and exhibit a positive response up to about 3 km and a negative response from 3-8 km. Channels 4 and 5 do not see all the way to the surface, and have a temperature response signal that in a gross sense, is opposite to that in the window channels. The strongest temperature impacts for channels 4 and 5 are above the surface, at about 4 and 6.5 km respectively. The specific humidity response to microwave emissivity,

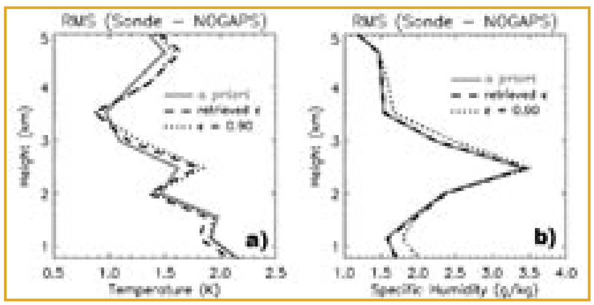

Figure 3: The Root Mean Square (RMS) difference between 67 NOGAPS profiles and profiles from co-located radiosondes. The RMS differences between radiosonde and NOGAPS profiles are shown for a) temperature, and b) specific humidity. Three cases are shown: the original a priori data (gray); a case beginning with CIRA retrieved AMSU-A emissivity (black dashed), and a case beginning with fixed AMSU-A emissivity of 0.90 (black dotted).

shown in Figure 4b, reveals that channels 1-3 and 15 have similar structures, with channel 15 exhibiting the strongest signal. Channel 15, centered at 89 GHz, has a much greater atmospheric attenuation than the other channels due to water vapor, and it is consistent that the moisture signal would be strongest in this channel. Channels 4 and 5 display negative sensitivity, where to maintain a nearly constant outgoing radiance a rise in emissivity is compensated by drying of the atmosphere in the lowest few kilometers. The atmospheric responses shown in Figure 4 simply display the fact that to effectively extract boundary layer atmospheric data from AMSU-A observations, a well-characterized microwave land emissivity is necessary.

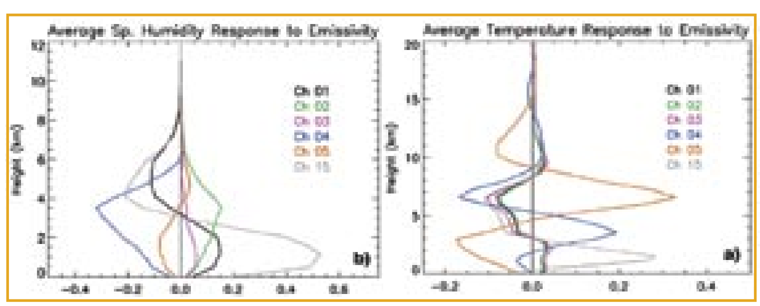

Figure 4: Response of atmospheric temperature and specific humidity profiles to perturbations in emissivity for AMSU-A channels. Shown are responses of a) temperature to emissivity, and b) specific humidity to emissivity.

The collaborative opportunity to test CIRA derived Land Surface Temperature (LST) and microwave land emissivity over the ARM-SGP site proved to be a success in both the retrieved profiles, and the knowledge gained about the sensitivity of the retrieval system to microwave land emissivity. Though the changes in the profile were not dramatic, especially in the case of specific humidity, the study showed poor land emissivity characterization adversely affects the retrieval by degrading rather than improving upon the a priori or first guess. This case study has provided proof that there is an observational signal to boundary layer temperature and moisture from AMSU-A, which with proper well-defined land emissivity statistics, can be utilized to the fullest extent.

Acknowledgements:

This research was supported by the DoD Center for Geosciences/Atmospheric Research at Colorado State University under Cooperative Agreements DAAL01-98-2-0078, DAAD19-01-2-0018 and DAAD19-02-2-0005 with the Army Research Laboratory, and by the National Oceanic and Atmospheric Association under grant NA17RJ1228.

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CIRA Communiqué: Employee News

Celebrating Service Milestones

Several CIRA employees were honored February 17th for reaching service milestones in 2003-2004. The Colorado State Community recognized the outstanding service of Jeffrey A. Lemke – 10 years of service, G. Garrett Campbell – 15 years of service, Dale G. Reinke – 15 years of service, Dave L. Watson – 15 years of service, and Loretta L. Wilson – 20 years of service. Congratulations and many thanks for your dedication and hard work!

NOAA David Johnson Award

It has recently been announced that Dr. John Knaff, one of our research scientists at CIRA, is the winner of the prestigious National Oceanic and Atmospheric Administration (NOAA) David Johnson Award in 2004. This award is presented by the National Space Club, in honor of the first Administrator of what was to become the National Environmental Satellite, Data, and Information Service (NESDIS). This award was established in 1999 to recognize young scientists who have developed an innovative use of Earth observation satellite data that is, or could be used for operational purposes to assess and/or predict atmospheric, oceanic, or terrestrial conditions.

Dr. Knaff is being recognized for basic research for improving the understanding of tropical phenomenon and predicting tropical cyclone intensity, accompanied by exemplary transfer of the results into operational products. He received his award March 19 at the 47th Annual Goddard Memorial Dinner hosted by the National Space Club. He and his wife traveled to Washington, D.C. to receive the award.

Dr. John Knaff (center)

"Dr. Knaff is an outstanding example of the new generation of environmental scientists developing and applying our newest satellite observations to practical problems of weather and climate," said Thomas H. Vonder Haar, director of CIRA and University Distinguished Professor of Atmospheric Science at Colorado State. "He carries his research from innovative new ideas into the hands of forecasters and analysts who put it to optimum use. We are proud to have him as part of the CIRA team."

Women of Achievement

Gracelyn J. Edwards

Gracelyn J. Edwards, Research Associate II in our Boulder office, received a certificate of achievement at the 2003 Women of Color Research Sciences and Technology Awards Conference held in Nashville, Tennessee. The conference was sponsored by the Career Communications Group. Ms. Edwards had many positive remarks about her experience. "I am truly grateful for being nominated for the Women of Color Science and Technology award, and even though I did not receive an Emerald award, the certificate itself was a form of recognition. It is so gratifying to be recognized by one's peers as well as management as someone deserving of such an award. The conference was very enlightening. I attended a number of workshops on leadership and emerging technologies and received a book written by one of the workshop leaders. Of prime importance was the opportunity to meet so many inspirational women from all walks of life."

Leslie Ewy April FSL Employee of the Month

Leslie Ewy

Leslie Ewy, a CIRA Research Associate, was awarded the April FSL Employee of the Month. During the past year, Leslie has taken on and completed several important and difficult projects. She has consistently put in the extra effort needed to ensure the success of each. Probably the most challenging was the Center Weather Advisory (CWA) decoder she did for the Aviation Division Real-Time Verification System (RTVS). Because these advisories are hand entered, they can vary radically from the accepted standard. Leslie went to great lengths to get enough information out of them for the RTVS project.

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Communiqué *(continued from page 14)*

For the AD GAMET area forecast project, Leslie participated in creating the project plan and was responsible for all software design and implementation. An example of the extra effort Leslie put in was calling in while home sick (as to not infect others with the flu) to check on its status. With Leslie's excellent work, this project continues to be very successful. It has received praise from several quarters, including the Director of NCEP.

Last, but not least, as the third developer to undertake this task, Leslie successfully completed the NIMBUS-to-Linux port.

NOAA TECH 2004

Dan Schaffer

Two presentations at the NOAA TECH 2004 Workshop October 21-23, 2003, received special awards for work undertaken by CIRA researchers. In the category of "Collaboration-Computers," Ingrid Guch delivered a paper based on her work with Andy Jones and Stan Kidder. This project, entitled: "Harnessing the Spare Computing Power of Desktop PCs for Improved Satellite Data Processing and Technology Transition," for the CIRA portion, has been underway since 2001. Also, in the category of "Grid Computing," Dan Schaffer, a CIRA Research Associate based at FSL in Boulder, received recognition for his paper, "Prototype of a NOAA Computational Grid." For more information see: http://www.noaatech2004.noaa.gov/awards.html.

Spengler Award to Brent Shaw

Major (Res) Brent Shaw, a CIRA Research Associate, was presented the Spengler Award for the Most Outstanding Air Force Weather Individual Mobilization Augmentee (IMA) during his most recent active duty tour with the Air Force Weather Agency at Offutt Air Force Base in Omaha, NE.

In announcing the winners of the 2002 Air Force Weather Awards on 1 April 2003, Brig. Gen. (Ret.) David L. Johnson, then Air Force Director of Weather (AF/XOW) stated, "It is with great pleasure that I announce the winners of the CY 2002 Air Force Weather (AFW) Awards. All AFW personnel performed superbly during a demanding, high ops tempo year, which made selecting the winners extremely difficult. The selected winners epitomize the efforts of the entire AFW community and all can share the pride of a job well done."

Brent Shaw

GOES R Risk Reduction *(continued from page 11)*

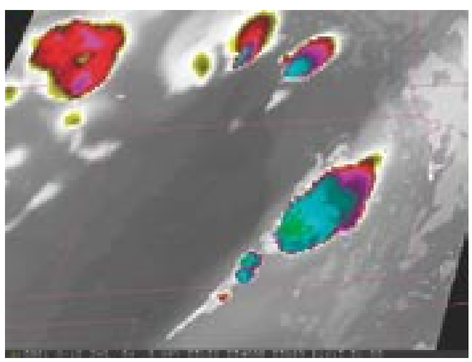

Figure 3: Synthetic GOES channel-4 imagery from the RAMS/radiative transfer model at 2340 UTC on 8 May 2003.

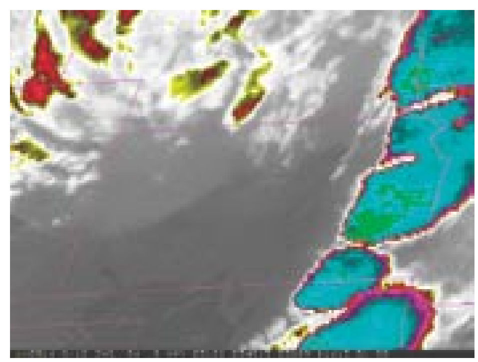

Figure 4: Observed GOES channel-4 imagery at 2340 UTC on 8 May 2003

the synthetic ABI imagery will have applicability to the actual observations when it becomes available from GOES-R.

Conclusions

Data gathering and preliminary analysis of some of the weather cases chosen for analysis have characterized the beginnings of this multi-year study in preparation for GOES-R operations. Additional research on these cases will be done with the goal of developing the new capabilities of the ABI instrument, especially the capabilities that are not available from the current-GOES Imager.

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