CIRA

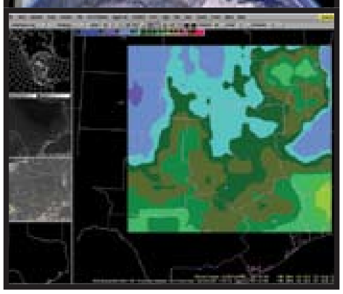
VOLUME 28, FALL 2007

New Technology for Global Observations Takes Wing

CloudSat mission celebrates one-year anniversary. See page 13.

Colorado State University

CONTENTS



About the cover: General Atomics Altair UAS in flight.

Photos at left, from top: General Atomics Altair UAS in flight over the Channel Islands National Marine Sanctuary during the November 2005 NOAA/NASA demonstration; Nolan Doesken receives NOAA Environmental Heroes 2007 Award; the A-train satellite constellation; Nudge "whole field" screen shot.

CIRA

Cooperative Institute for Research in the Atmosphere

www.cira.colostate.edu

Magazine Staff

Mary McInnis-Efaw, Editor
Laura Leinen, Assistant Editor

Design

Colorado State University, Communications and Creative Services

Technical Committee

Cliff Matsumoto, Donald Reinke, Renate Brummer, Marco Rodriguez

UNMANNED AIRCRAFT SYSTEMS

An Overview of NOAA's Unmanned Aircraft System Program

Nikki Privé

Unmanned Aircraft Systems (UAS) are a developing technology with a broad range of potential applications for atmospheric and climate observations. UAS are multiple component systems that include the aircraft platform, the ground control station from which pilots operate the plane, satellite communications, and data retrieval network. Previously known as Unmanned Aerial Vehicles (UAV) or Remote Operated Aircraft (ROA), the common name was changed by the Department of Defense to emphasize that these are integrated systems and not merely aircraft.

A wide range of aircraft types and capabilities are under development, ranging from "micro-UAS" to large platforms that can fly in the lower stratosphere. The aircraft are frequently categorized by their altitude range and endurance, such as Low-Altitude Long-Endurance (LALE) and High-Altitude Long-Endurance (HALE) platforms. There is generally a tradeoff between payload, endurance, and altitude for each platform; different types of UAS are suited for different observational missions.

Low-altitude UAS are those with limited vertical flight capability – these aircraft are small in size, ranging from a few-inch wingspan for micro-UAS to several feet in wingspan for platforms such as the Aerosonde or Manta UAS. Micro-UAS have very limited payload capability but can be deployed in a swarm formation; these UAS have been proposed for air quality monitoring where they can extensively sample a limited volume. Larger LALE UAS have a modest payload but can travel hundreds to thousands of miles in a single trip. These UAS have many potential uses for observations, particularly of the surface and boundary layers. Many of the smaller low-altitude UAS do not require an airstrip for launch or recovery but can be launched by a mobile unit such as a portable catapult, vehicle, or even by hand. They may similarly be recovered by touching down into an open field or other space.

Mid- and high-altitude UAS have large payload capacity and can travel thousands to tens of thousands of miles on a single trip but come with a high price tag. These larger aircraft have the potential to loiter for long periods and take observations over remote areas such as the open oceans and polar regions – too far for manned planes to fly. They may carry a suite of remote-sensing instruments, such as lidar, as well as dropsondes or *in situ* instruments such as chemistry sensors. A runway is generally needed for launch and recovery of these platforms.

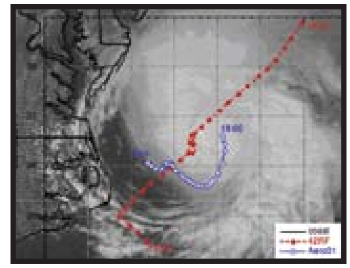


Figure 1. Aerosonde (blue) and P-3 (red) flight tracks into tropical storm Ophelia on September 16, 2005. Storm intensity at the time was 55 kts.

Fellowships in Atmospheric Science and Related Research

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

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

UNMANNED AIRCRAFT SYSTEMS

UAS offer complementary capabilities to manned aircraft and satellites, with flight capabilities in regions too dangerous for manned airplanes, such as at low levels in a tropical cyclone. They may be flown over areas that are currently only observed by satellites, offering rich *in situ* observations as well as satellite verification. Technically difficult missions, such as flying in strict formation, are also possible with UAS.

There are several limitations to the capabilities of current UAS technology. Most UAS do not have the safety margins of manned aircraft, such as active de-icing systems, limiting the conditions under which they can fly. A major hurdle to UAS operations in the United States National Airspace System (NAS), are the Federal Aviation Administration (FAA) regulations, which severely restrict the times and space in which UAS may fly. The FAA is in the process of defining a coherent strategy for UAS integration into the NAS. At this time, UAS operations in the national airspace must be approved by means of a certificate of authorization.

NOAA UAS Demonstrations

NOAA has been involved with several field missions demonstrating the use of UAS in atmospheric observations. In September 2005, the low-altitude Aerosonde UAS was flown on a successful mission into Tropical Storm Ophelia (Figure 1), wherein the UAS was able to transmit real-time wind observations directly to the National Hurricane Center for operational use. Ramanathan of Scripps demonstrated the versatility of low-altitude UAS in a NOAA-sponsored mission in 2006 studying pollution over the Indian Ocean. Three Manta UAS were flown in a stacked formation to collect vertical data – a task difficult to impossible for manned aircraft to perform. The Manta and another low-altitude UAS, the Silver Fox, were used for fisheries enforcement and marine mammal monitoring in a demonstration based in Hawaii in 2006.

In addition to low-altitude UAS demonstrations, the General Atomics Altair UAS was flown in 2005 in conjunction with NASA; a series of five flights were completed, including a long-duration flight of 18.4 hours at altitudes up to 43,000 feet. The Altair carried a suite of instrumentation used to study atmospheric rivers, ocean color, tropopause folds, and marine mammal populations (Figure 2). In 2006, NOAA participated in the Western States Fire Mission with NASA and the USDA Forest Service using the Altair to monitor forest fires in the western United States.

Future UAS Testbed Proposals

NOAA is proposing the creation of three testbeds that would act as bases of operation for UAS missions, located in regions where UAS observations may be particularly advantageous. Two testbeds would be located near the Arctic and the Pacific regions with a third testbed proposed in the Gulf of Mexico region for studying tropical cyclones.

The Arctic UAS testbed would be used both for monitoring purposes and for process studies to advance the understanding of atmospheric behavior near the pole. Due to extreme conditions and its remote location, the Arctic is not readily accessible for *in situ* studies by manned aircraft, but unmanned aircraft may be deployed to make long-distance flights without risk to humans; a possible polar observing flight is illustrated in Figure 3. Some of the possible UAS missions in the Arctic include monitoring of sea ice, forest fires, volcanic eruptions, and marine mammals, as well as fisheries enforcement,

Figure 2. General Atomics' Altair UAS in flight over the Channel Islands National Marine Sanctuary during the November 2005 NOAA/NASA demonstration.

investigation of carbon sources and sinks, satellite verification, and atmospheric observations for operational forecasting and climate studies.

The Pacific region is a large, remote area with limited observing stations, making it a good candidate for a UAS testbed. Since many of the weather systems that impact the west coast of North America originate over the Pacific, UAS observations over the mid-latitude oceans may positively impact the 3-5 day operational forecast. Monitoring of the Northwestern Hawaiian Island Marine National Monument and other ocean resources to detect coral bleaching, marine debris, algae blooms, and illegal fishing may also be performed by UAS.

The Hurricane UAS testbed would support both operational monitoring and research missions for Atlantic tropical cyclones. With long endurance times, high-altitude UAS can loiter in the vicinity of a tropical cyclone, constantly monitoring the environment around the storm and observing cyclogenesis in regions that are too distant for manned planes to reach (Figure 4). Low-altitude UAS can observe the interior of the storm where critical but poorly understood processes such as fluxes between the atmosphere and ocean occur.

UAS Observing System Simulation Experiment

There are many different possible UAS platforms and instruments that might be implemented for atmospheric observations. In order to optimally design potential observation systems, an Observing System Simulation Experiment (OSSE) is currently underway in the Global Systems Division at the NOAA Earth System Research Laboratory as part of a large collaborative Joint OSSE project involving the European Center for Medium-Range Weather Forecasting; NASA; the National Center for Environmental Prediction; the National Environmental Satellite, Data, and Information Service; and other institutions. The OSSE will be used to determine the potential impact of UAS observations on operational forecasts and will assist in selecting the best flight path, UAS type, and instrument payload for each mission.

CIRA researchers are contributing to the planning and development of NOAA's UAS program. Researchers have worked to screen potential bases for UAS deployment by evaluating the climatological occurrence of hazardous conditions for ground operations as well as determining optimal flight paths for the aircraft. Ongoing work includes the generation of synthetic UAS observations and diagnostic evaluation of the Nature Run for the OSSE.

Unmanned Aircraft Systems are a promising new technology that may enable direct observations of data – poor regions too remote or dangerous for traditional observing methods, filling a gap in the existing global observing system. NOAA, in participation with universities, industry, and other government agencies, is taking a leading role in understanding how Earth's systems interact by studying the improved data and observations collected by UAS. The societal benefits of these observations translate into saving lives, property, and resources.

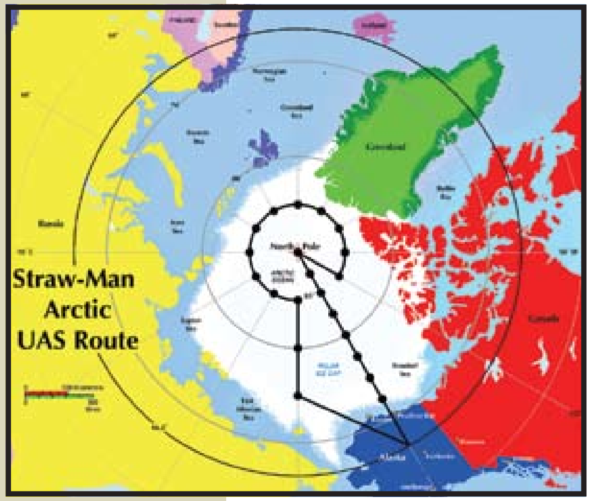
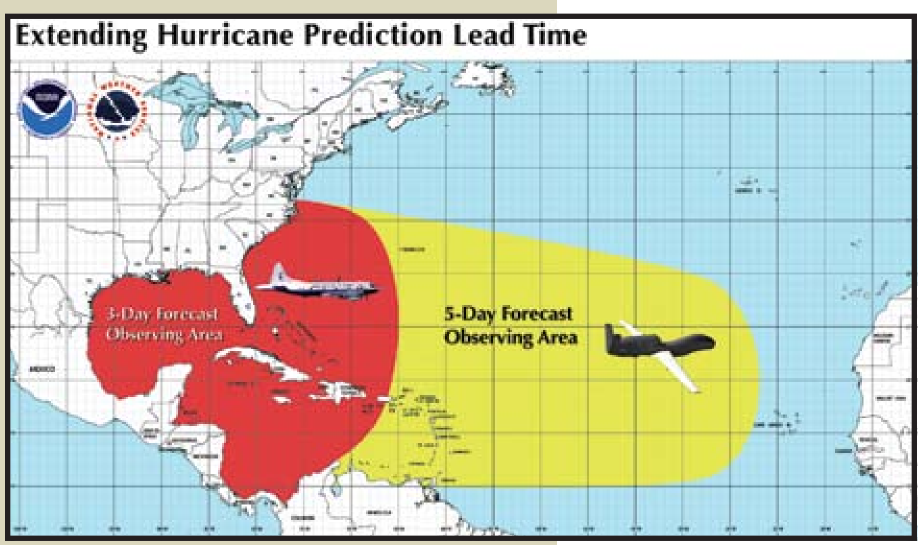


Figure 3. Straw-man Arctic testbed flight path for a long-endurance UAS. Observations such as dropsondes are taken at the locations indicated by black circles along the path.

Figure 4. HALE UAS platforms could extend tropical cyclone monitoring across the central Atlantic to observe cyclogenesis and improve forecasting.



International Activities: Weather Briefings and Training Via the Internet

Bernadette Connell, Mark DeMaria, and James F. W. Purdom

The VISITview teletraining and real-time collaboration tool provides a "slideshow" format that allows image animations, zooming, and chalkboard capabilities, and connects one or more instructors to many students via the internet (http://www.ssec.wisc.edu/visitview/).

Participation in monthly satellite weather briefings or training events via the Internet has become something to look forward to for many forecasters and researchers in countries in Central and South America and the Caribbean. It has become a relatively easy and inexpensive way to simultaneously connect people from as many as 24 different countries, view satellite imagery, and share information on global, regional, and local weather patterns, hurricanes, severe weather, flooding, and volcanic eruptions. Forecasters and researchers are able to "build capacity" by being able to readily communicate with others in their discipline and discuss the impacts of their forecasts or impacts of broad reaching phenomena such as El Niño. They were also recently able to receive virtual training through the High Profile Training Event (HPTE) on October 16-27, 2006.

The idea for the satellite weather briefings was born at the World Meteorological Organization (WMO) Satellite Training Workshop held in Barbados in December 2003. At that time, a WMO Virtual Laboratory Focus Group was formed with support from CIRA, the National Oceanographic and Atmospheric Administration (NOAA), the Virtual Institute for Satellite Integration Training (VISIT), the Cooperative Institute for Meteorological Satellite Studies (CIMSS), and the Regional Meteorological Training Centers of Excellence (CoE) in Costa Rica and Barbados. During the first year, the focus group was composed of participants and workshop instructors; the sessions were conducted in English and occurred on a monthly basis. After the WMO workshop held in Costa Rica in March 2005, the focus group expanded considerably and evolved to include monthly bilingual and Spanish-only sessions.

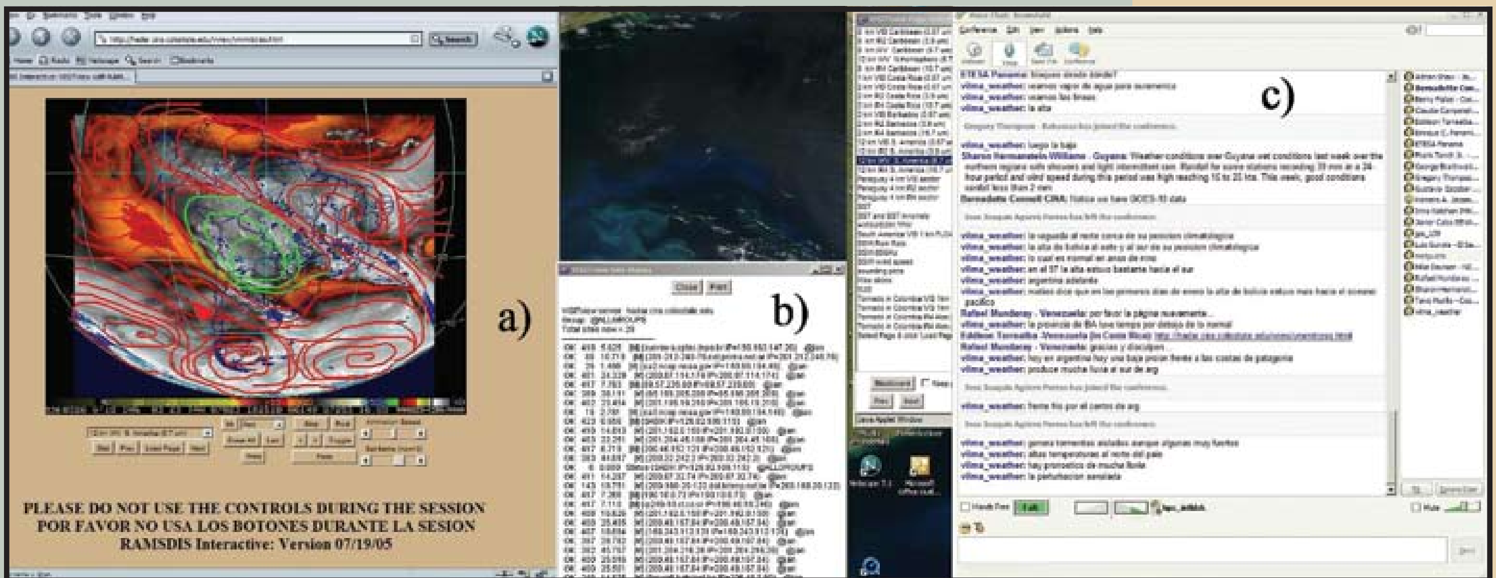
Besides the overwhelming interest from participants in the focus group generated at the March 2005 workshop, the focus group leadership expanded to include the NOAA's International Desk at the Hydrometeorological Prediction Center (HPC). The mission of the HPC International Desk is to provide visiting scientists with meteorological training an emphasis on the operational use and application of numerical model products. They brought with them an extensive history of positive interaction with countries in Central and South America and the Caribbean and hence a strong following of participants.

Just prior to the Costa Rica workshop, the concept for HPTE was introduced to the WMO. The Virtual Laboratory Management Group (VLMG) proposed that four core lectures be presented simultaneously through the Internet throughout the globe by the various regional focus groups.

Software "Recycling"

The VISITview tool utilized for the weather briefings and the training activities was developed for the National Weather Service (NWS) under the well-established VISIT program (http://rammb.cira.colostate.edu/visit/visithome.asp). The VISITview teletraining and real-time collaboration tool provides a "slide show" format that allows image animations, zooming, and chalkboard capabilities and that connects one or more instructors to many students via the Internet (http://www.ssec.wisc.edu/visitview). VISITview continues to function extremely well and provide excellent training for the NWS. It is being "recycled" and expanded for use by the international community.

VISITview is being used in two similar but different capacities for the training and the focus group sessions. VISITview was designed to



Computer screen grab of a monthly weather briefing session showing (a) the VISITview window depicting water vapor imagery with contours drawn on during the session, (b) the VISITview status window, and (c) the Yahoo messenger conference window with chat display on the left and participant list on the right.

provide a complete lecture that is downloaded onto a remote computer. During a training session, students and teachers are connected to a single server. The controls in the lecture are transmitted through the server to individual participants and allow the teacher to advance pages, point out features of interest, and draw on the imagery. This approach uses minimal bandwidth during the session because the large image files are pre-loaded on the remote computer. For the VISITview online focus group sessions, the real-time imagery resides on the server and is downloaded when requested for viewing. Being able to draw on the imagery or point out features is also available. This approach requires a larger bandwidth during the session.

COOPERATION: Weather Briefings

In order to have success at running the monthly sessions, the workload is distributed among the many partners so that it is "doable" by all involved. For a typical monthly session, one person is responsible for scheduling and moderating the session and making sure the announcement and summary get sent out to all participants. A VISITview server at CIRA provides the framework and real-time geostationary and polar orbiting imagery and products for viewing. Initially, only "standard" geostationary satellite images (visible, short- and long-wave infrared, and water vapor) were available on the site. This has evolved to including specialized polar orbiting products such as total precipitable water from the Advanced Microwave Sounder Unit, rain rate and wind speed from the Special Sensor Microwave/Imager, sea surface temperature and anomalies derived from Advanced Very High Resolution Radiometer, and potential vorticity anomalies for Madden-Julian Oscillation analysis. Each month, special interest topics, products, or imagery of significant events can be added to the standard suite of images and product to customize the session.

The Yahoo Conference feature is used to provide voice-over Internet. A session is initiated by a person from either CIRA or the CoE in Costa Rica. All participating persons need to be sent an invitation to join a session. The CoE helps out tremendously by inviting participants and providing assistance during the session. HPC provides invaluable guidance in both English and Spanish. Text messaging is used during the conference as

It is amazing to see how patient, persistent, and understanding people can be when it comes to participation in a training or discussion that is important for improving the work they do and benefiting the communities that they live in.

a backup to voice communications. Following each session, the CoE in Costa Rica prepares a summary.

The sessions have proven to be a very powerful training tool. People learn how to use new and existing satellite products in real-time situations. Having pauses for translations between English and Spanish has also proven beneficial – it gives people time to digest what has been said and formulate new questions.

COOPERATION: High-Profile Training Event

The HPTE provided four core online lectures, which were designed to give an overview of four important topics: how WMO operates within the realm of satellites to help us all, basic characteristics of environmental satellites and applications, examples of creating satellite products, and applications of satellite products for analysis of severe convection. The lectures were created in PowerPoint format, reviewed by VLMG members, and then converted to VISITview format. The HPTE also offered two weather briefings with a format similar to the monthly weather briefings.

The HPTE was designed to encourage participation in the lectures offered and provide a certificate of completion to the participants. Since a similar process occurs with the VISIT program, the HPTE event for the focus group followed their activities. A webpage (http://rammb.cira.colostate.edu/training/wmovl/) in both English and Spanish was created and provided a summary of the event, calendar and registration, and student guides. Some of the lectures were large (135MB) because they included imagery animations. Many countries did not have sufficient bandwidth to download the lectures, so they were written to CD and express-mailed to those who had registered.

Because the focus group had regular monthly weather briefings, the implementation of the individual training sessions went rather smoothly. Sessions were offered in English-only or Spanish-only. Two of the lectures – lectures B and D – were translated to Spanish prior to the sessions. The other lectures were translated afterwards and made available to the participants.

One of the combined weather briefings/lectures drew 128 participants from 21 countries (Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guyana, Guatemala, Honduras, Panama, Paraguay, Peru, Trinidad and Tobago, and Venezuela). This was the largest session to date with 40 computer connections and multiple participants at many sites.

VISITview also has the capability to record voice and annotations on imagery for later playback. Many of the sessions from the HPTE are also available to those who were unable to participate.

Challenges

The weather briefings and trainings have been highly successful, but they have also had their share of challenges – particularly in connecting so many people from many different countries with varying Internet bandwidth capabilities. For the weather briefings, there have been two issues to deal with: viewing the images and hearing voice. To help with download capabilities, loops are generally limited to four images. In the case of training events, the bandwidth poses problems beforehand for downloading of the session. Sending CDs via mail is a viable alternative to downloading, but allowing sufficient time for the material to get to its destination is a high priority. Remember that when people are volunteering their time, expertise, and energy, not everything goes according to schedule.

For voice, the conference feature under Yahoo Messenger has been used. For the most part, it has been fairly reliable. Over the past three years, only one session has been canceled due to unexplained difficulties with connecting to the Yahoo server. We have found that we are less likely to have problems with groups that have fewer than 20 participants. With groups of more than 20 participants, those with less bandwidth will experience dropped connections. As with any computer or software connecting to the Internet, Yahoo security vulnerabilities are being exposed on a regular basis. A certain amount of time needs to be dedicated to making sure everyone is using the same version of Yahoo Messenger to reduce compatibility issues between participants and to prevent malicious interruptions.

It is amazing to see how patient, persistent, and understanding people can be when it comes to participation in a training or discussion that is important for improving the work they do and benefiting the communities that they live in.

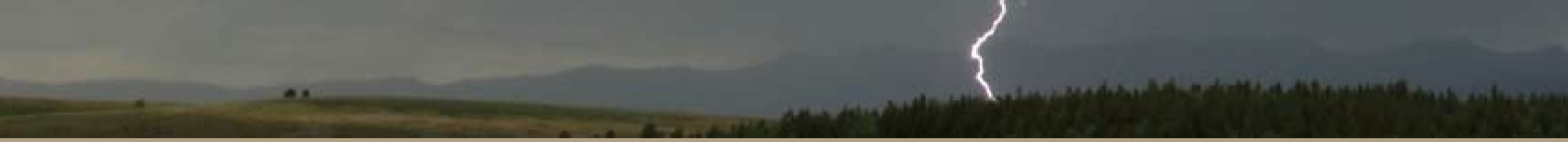
Acknowledgments

We gratefully acknowledge all the participants and instructors for their patience and invaluable contributions to the training events and monthly weather briefings.

Group lead, Mike Davison, from the International Desk at the National Center for Environmental Prediction.

Participant, Gloria Marin, of Columbia.

One of the combined weather briefings/lectures drew 128 participants from 21 countries (Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guyana, Guatemala, Honduras, Panama, Paraguay, Peru, Trinidad and Tobago, and Venezuela). This was the largest session to date with 40 computer connections and multiple participants at many sites.



NESDIS STUDENT EXCHANGE

NESDIS Cooperative Institutes Host Student Exchange

For the second consecutive year, the five NESDIS-sponsored Cooperative Institutes (CIs) have had a student exchange program during the summer. Students from universities associated with each of the institutes were selected to visit other NESDIS CIs and related NOAA facilities for a few days of interaction and discussion of work. Students are selected for a visit, then make arrangements with a federal employee at the host CI. The goal of the program is to avail students of the intellectual resources within NOAA and the Cooperative Institutes, to help them towards their research goals and to expose the students to the NOAA workforce.

In 2007, CIRA sent two students for exchanges. Aaron Schwartz visited the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison, to discuss Arctic climate. His host was Jeff Key of NOAA. Curtis Seaman visited the Joint Center for Satellite Data Assimilation, which was established in July 2001 and is partnered by NASA (GSFC), NOAA (NESDIS, NWS, OAR), and the DoD (Navy and Air Force). His hosts were Fuzhong Weng and Min-Jeong Kim. CIRA also hosted two visiting students in August, Emily Becker and Matthew Sapiano, both from the University of Maryland and associated with the Cooperative Institute for Climate Studies (CICS). All students reported that the student exchange program was a real benefit towards their goal of obtaining a degree and embarking on a successful career in the sciences.

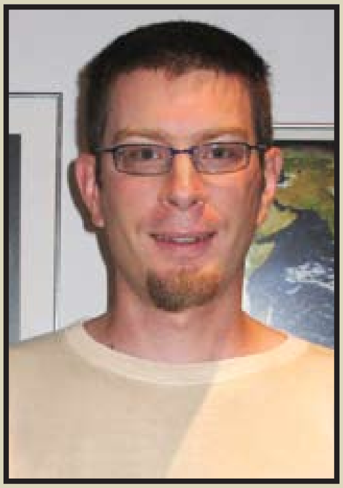
Aaron Schwartz

Aaron Schwartz

As I am still in an exploratory stage of my master's thesis on arctic clouds and climate at CSU/CIRA, my visit to CIMSS provided a valuable opportunity to extend my research network and meet with experts working in my field of study. I shared my research ideas, plans, and preliminary results, and the above-mentioned scientists provided helpful and constructive feedback. I was able to ask (and received answers to) technical and general questions about my work and their work. In addition to an extended sit-down meeting, Jeff Key also arranged for me to tour the building and facilities and meet with several NOAA and CIMSS scientists one-on-one.

Overall, this trip helped me focus my research thesis and develop a process to move forward with my work. In addition, I was given background literature and papers of relevance, which have so far proved very useful.

I'd like to thank Jeff Key, Xuanji Wang, Yinghui Liu, Mike Pavolonis, Elizabeth Weisz, and Ralph Khuene (of NASA Langley) for taking the time to meet with me.



Curtis Seaman

Curtis Seaman

I participated in the NOAA student exchange program with a visit to the headquarters of NOAA at the World Weather Building in Camp Springs, Md., which took place August 6-8, 2007. The two-and-a-half day visit included meeting many of the researchers working for a variety of divisions of NOAA and the Joint Center for Satellite Data Assimilation (JCSDA) – including the Center for Satellite Applications and Research (STAR) and the NCEP Environmental Modeling Center (EMC). I was invited to give a seminar on my past and current research, and that seminar was focused on the results of CIRA's CLEX (Cloud Layer EXperiment) and 4DVAR research. The talk included my master's research investigating the dynamics, microphysics, and radiative properties of altocumulus and altostratus clouds and also my current Ph.D. research, which involves the assimilation of GOES Imager and Sounder data to improve cloud forecasting. The talk was very well received and prompted a number of meaningful discussions with scientists from a wide range of backgrounds. Some were interested in the altocumulus/altostratus microphysics for their work in satellite retrievals of cloud properties and mixed-phase radiative transfer, others were interested in the recent CLEX-10 and Canadian CloudSat/CALIPSO Validation Project (C3VP) for microwave retrievals over clouds and snow, and still others were interested in the 4DVAR assimilation of cloudy radiances from infrared satellite channels. JCSDA is currently developing a 3DVAR data assimilation system, which to this point has been focused on assimilating microwave radiances. Overall, the visit was a wonderful experience and will hopefully serve to connect CIRA's DoD-funded research and NOAA's research.

Emily Becker

I visited the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University August 13-15, 2007, on a student exchange from the Cooperative Institute for Climate Studies (CICS) at the University of Maryland. John Forsythe had arranged a schedule of meetings with several members of CIRA and the CSU Department of Atmospheric Science. Richard Johnson, department head, and Mark DeMaria of CIRA provided overviews of the department and of the Cooperative Institute. I became acquainted with the wide range of activities at CIRA, including merged total precipitable water products, hurricane intensity forecasting, and the Virtual Institute for Satellite Integration Testing (VISIT), among many others. Meetings with the scientists of CIRA were very rewarding, as I was able to discuss my research into the statistics of daily precipitation and hear their ideas, particularly regarding the strengths and weaknesses of various precipitation data products. The people with whom I spoke include John Forsythe, John Knaff, Wes Berg, Stan Kidder, Dan Lindsey, Jack Dostalek, Paul Ciesielski, Yoo-Jeong Noh, Dan Bikos, Jeff Braun, and the graduate students of Tom Vonder Haar. The friendly, welcoming environment of CIRA allowed for open and productive conversation, for which I am very grateful; this visit will likely lead to collaborative efforts in the future.

Matt Sapiano

Matt Sapiano, a post-doc from the Cooperative Institute of Climate Studies (CICS) at the University of Maryland, visited CIRA August 19-24, 2007. Matt is currently working on several projects, each of which involve precipitation estimated from satellites. The purpose of his visit was to meet with CIRA/CSU scientists to discuss current work and to learn more about the issues around using satellite estimates. During his trip, Matt met with many CIRA scientists including Stan Kidder, John Forsythe, John Knaff, Chris Kummerow, Wes Berg, Yoo-Jeong Noh, and Nolan Doesken. Jack Dostalek provided training for Matt on the use of McIDAS and RAMSDIS, which Matt is hoping to implement at CICS in the near future. Additionally, Matt gave an informal seminar at CIRA, "A New Global Analysis of Precipitation," covering some of his recent work. The trip proved to be very useful, with Matt getting many new ideas for his work from both his discussions with CIRA and CSU scientists and from the questions from his talk. Matt also learned more about many of the intricacies around the use of satellite data (such as the issues around orbital drift and the many possible errors and the complex corrections required for the diurnal cycle) and enjoyed hearing about some of the new products being created by CIRA scientists. Finally, Matt attended the daily hurricane discussions – he chose a good week for his trip, as he arrived in time for Hurricane Dean to make landfall over the Yucatan.

From left: Matt Sapiano, Mark DeMaria, and Don Hillger.

From top: Mike Biere, Nikki Privé, and Brian Jamison

ESRL/GSD Team Members of the Month

Three CIRA employees were recently honored by their NOAA Earth Systems Research Lab/Global Systems Division colleagues with Team Member of the Month awards. Mike Biere, Nikki Privé, and Brian Jamison were honored in June, August, and September, respectively. Congratulations for making CIRA proud!

June 2007 – Mike Biere

The following nomination comes from Technology Outreach Branch Chief Bill Bendel:

"Mike Biere, Technology Outreach Branch/Science On a Sphere® senior software engineer, is designated as GSD's Team Member of the Month for June 2007. He is receiving this in recognition for superb efforts in furthering the SOS mission. In particular: contributing innovative ideas on improving the current SOS system; continuing to support customers at many sites with real-time answers; providing training during the installation of SOS systems at several museums and science centers; developing the software for the five-projector configuration for SOS; and interacting with vendors, suppliers, and sphere builders to get the work done right and on time."

August 2007 – Nikki Privé

GSD Director Steve Koch stated:

"Dr. Nikki Privé, who has worked with GSD for almost two years, is the recipient of August's GSD Team Member of the Month. Dr. Privé has developed an Observing Systems Simulation Experiment (OSSE) in conjunction with Yuanfu Xie, also from GSD. OSSE's help show the importance to weather forecasts of adding additional measurements. The joint effort involves contributions from several parts of NOAA, as well as NASA and ECMWF. Dr. Privé has also been supplying some of the Science on a Sphere® images, which are often shown to visitors. Dr. Privé still finds time to do weather briefings and to assist with the briefings of others."

September 2007 – Brian Jamison

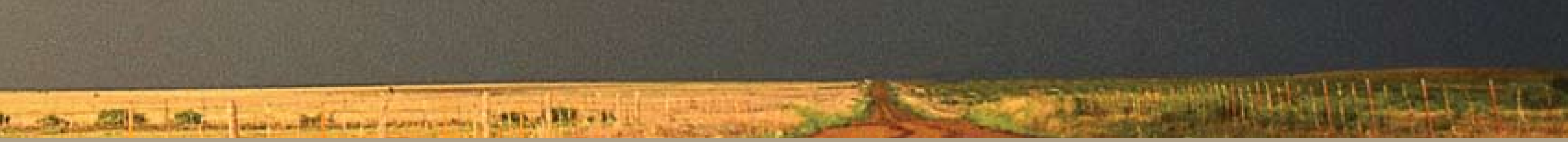
Assimilation and Modeling Branch Chief Stan Benjamin says:

"Brian Jamison of the Assimilation and Modeling Branch (AMB) is nominated for GSD's Team Member of the Month for September. In the recent past, Brian has superbly managed a series of 10-day retrospective tests for impact of experimental TAMDAR aircraft observations, as well as other observation types. These experiments on GSD's supercomputer have clearly revealed the impact of a variety of data sources and assimilation schemes on RUC model skill. Brian has been a key scientist for the ongoing FAA TAMDAR project over the last 2+ years. Brian has also developed new visualization tools for products from the experimental High-Resolution Rapid Refresh (HRRR), critical for evaluation.

Beyond this work, Brian is in great demand because of his varied skills, creativity, dedication, attention to detail, and hard work. His work supporting research (some through DTC) on clear air turbulence, boundary layer flow in complex terrain, and gravity wave generation, has resulted in visualization products of high value. These products have been indispensable in helping scientists understand the effects of subtle changes to numerical equations and physical parameterization schemes."

Tom Vonder Haar Elected Chairman

Tom Vonder Haar, University Distinguished Professor in the Department of Atmospheric Science and director of CIRA, has been elected chairman of the Interdisciplinary Section of the National Academy of Engineering. The Academies of Engineering and Science and the Institute of Medicine were founded by President Abraham Lincoln to serve as advisors to the nation. The Interdisciplinary Section includes 140 academicians



from industry, research laboratories, and the university community.

Vonder Haar was named to the academy in 2003. He joined CSU faculty Larry Roesner, civil engineering; George Seidel, Jr., biomedical sciences; and Barry Beaty, microbiology, immunology, and pathology in this honor. CSU faculty emeritus Jack Cermack and A. Ray Chamberlain, civil engineering, with Albert Meyers and Marshall Fixman, chemistry, are also active members of the academy.

CIRA Research Initiative Awards

Please join us in congratulating Jebb Stewart and Glen Liston who each were presented the CIRA Research Initiative Award for 2007! This honor acknowledges their contributions to the overall research environment at CIRA. The staff in Boulder gathered to honor Jebb, and Glen was honored at a recent Coffee Confab on August 22.

Jebb was behind the system design and technical leadership necessary in the development of enabling technology for the Gridded FX-Net system. The system has since been adopted by operational fire weather forecasters working for the National Forest Service, Bureau of Land Management, and National Interagency Fire Center. The data provided by the system is essential to daily fire prediction forecasts.

Glen is well known among his peers for his innovative blowing snow model. His modeling suite represents a tremendous advance forward in the field, and he has been sought as a collaborator on a number of projects (including treks across Canada and the Antarctic) both here and abroad. Snow research promises to be a growing area, thanks to the expertise and reputation Glen brings to CIRA.

NASA Honor Award goes to SDPC Team

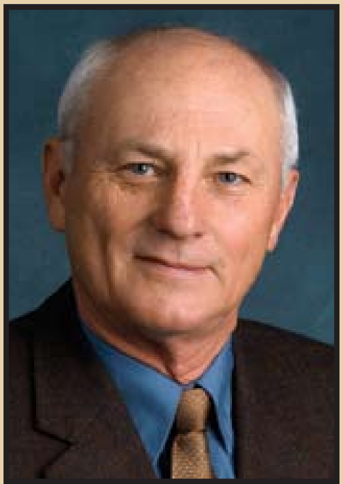
A NASA Group Achievement Award was presented to the CSU-CIRA-STC team comprised of Kenneth Eis, Phil Partain, Dale Reinke, Donald Reinke, and Laura Sample for "exceptional contributions to the CloudSat mission in the design, development, and implementation of the CloudSat Data Processing System." CloudSat launched on April 28, 2006, and the Data Processing Center has processed 100 percent of the data collected by the instrument since it became operational on June 2, 2006.

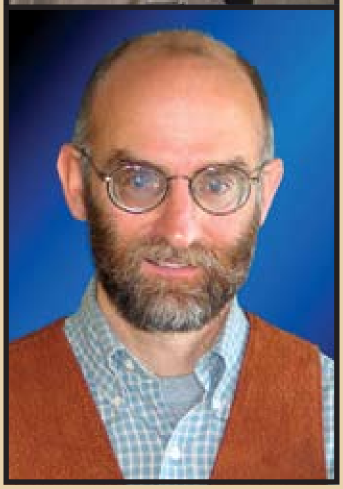
A formal announcement of this award was made at the awards ceremony at JPL on June 21. Phil Partain traveled to JPL to accept the award for the DPC. Phil is an employee of Science Technology Corporation, METSAT Division, and is working under a subcontract to CIRA as the CloudSat Data Processing Center System Engineering and Operations manager.

Congratulations to the CSU-CIRA-SDPC Team!

NOAA Environmental Heroes 2007

The NOAA 2007 Environmental Hero Awards were presented by retired Navy Vice Admiral Conrad Lautenbacher, Ph.D., undersecretary of commerce for Oceans and Atmosphere and NOAA administrator, at the National Press Club in Washington, D.C., on April 20.

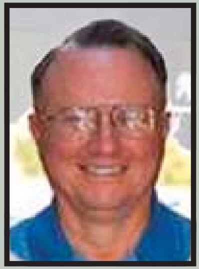




From top: Tom Vonder Haar, Jebb Stewart, and Glen Liston







CloudSat Group from left: Phil Partain, Laura Sample, Dale Reinke, Don Reinke, and Ken Eis.

CIRA COMMUNIQUÉ

Jim Frimel

Nolan Doesken, right. Photo courtesy of NOAA.

Don Reinke

Nolan Doesken was one of ten recipients of the prestigious award. "Doesken organized a network of citizen volunteers to measure and report precipitation from their homes following a flash flood that killed five people in Fort Collins, Colo., in 1997. Starting with a few volunteers in 1998, the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network involves thousands of volunteers in 17 states and enhances the forecasting and warning capabilities of the NOAA National Weather Service." Photo courtesy of NOAA.

Earth Day team.

Awards Go to Don Reinke and Jim Frimel

Please join us in congratulating Don Reinke on his selection as recipient of this year's College of Engineering Distinguished Administrative Professional Award for his exceptional performance as Leader of the CloudSat Data Processing activity since 2001. CloudSat is a NASA-managed cloud imaging satellite that has been making unique vertical structure measurements since June 2006.

Don was presented his award at the annual College of Engineering Visual Arts and College Awards Reception held April 12.

Congratulations also go out to Jim Frimel for his selection as one of the recipients of this year's CSU Distinguished Administrative Professional Award. This annual award recognizes administrative professionals for continuing meritorious and outstanding achievement in outreach, teaching, administration, and/or research at CSU.

Jim is recognized for his key leadership of several high visibility research projects, including the FAA- and NWS-sponsored Volcanic Ash Coordination Tool project that recently received the 2006 NOAA Bronze Medal. He was presented his award at the *Celebrate Colorado State!* luncheon on April 26 at the Lory Student Center.

Congratulations, Don and Jim, on these outstanding awards!

Earth Day Open House (Education and Outreach)

To commemorate Earth Day on April 20th 2007, CIRA participated with NOAA at its Boulder facility to showcase to the public its science through displays and interactive demos. CIRA's exhibit included brief descriptions of its extensive research, a poster showing a rendering of the CloudSat satellite cloud profiling capability, a program showing the tracking of the CloudSat satellite orbit in real time, and the Beta test version of an animated educational program, on the Earth's Energy Balance.

CLOUDSAT

CloudSat's One-Year Anniversary: An Abundance of Exciting New Cloud Observations

Don Reinke

In the *CIRA Magazine* article "CloudSat Data Processing Center – *Putting a Gorilla in a Shoebox* (Fall 2003) we presented an overview of the then-planned CloudSat mission and the data processing support that CIRA would provide. On April 28 of this year, we celebrated the one-year anniversary of the CloudSat launch and, on June 2, 2007, the anniversary of the first day of operations of this exciting new mission.

On May 20, 2006, less than a month after launch, the mission project manager asked the radar team to turn on the instrument and transmitter for a three-orbit test. Within two minutes of the time the first operational data arrived at the DPC, a browse image of those first data appeared on the CloudSat Data Processing Center (DPC) website (Figure 1). The ingest system, which was designed and tested on simulated CloudSat data, worked flawlessly and has since processed 100 percent of the raw data that it has received. In the first 14 days of the mission, CloudSat collected more CPR data than had previously been collected from all of the ground-based or aircraft radars prior to that date.

The image in Figure 1 is an example of the QuickLook images that are available on the DPC website (www.cloudsat.cira.colostate.edu). These images are generated from the raw CloudSat radar data and made available within a few minutes of the arrival of the data from the Air Force command center in Albuquerque, N.M. The solid blue line, just above the text in Figure 1, indicates that these data were collected over the ocean. The two vertical jumps in the data window are where the timing parameters onboard the satellite were adjusted to account for the changing distance to the geoid – thus keeping the imaged region inside of the 30-km window. Figure 2 provides an overview of these browse images and a link to the website where you can view these images as they are posted.

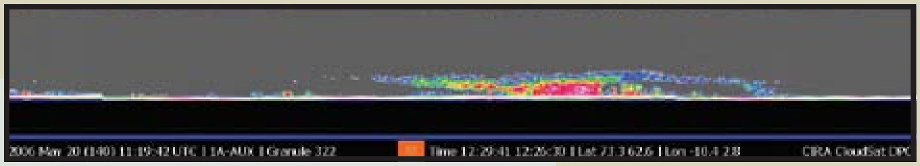


Figure 1. "QuickLook" image of first minutes of CloudSat data, collected at 12:26-12:29 UTC on May 20, 2006. The "data window" (see Figure 2) is approximately 30-km high, and the colors represent radar return echo power (reflectivity), with red being the strongest return (precipitation) and blue the weakest (thin cirrus clouds).

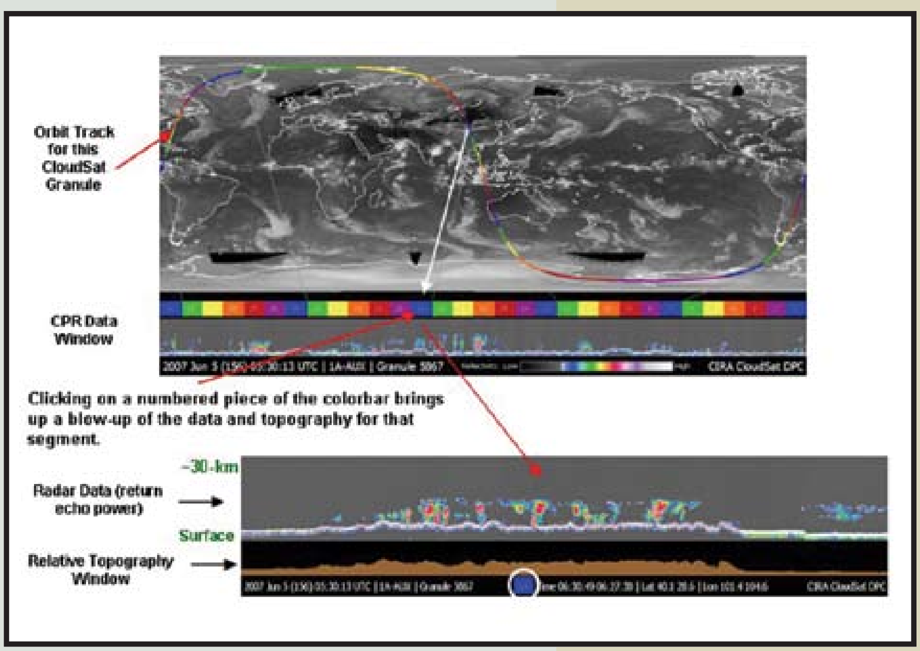
In Figure 2, the data were collected over land, thus the blue line is replaced with the brown shading that provides a relative elevation of the land surface beneath the CloudSat ground track. Here the satellite is flying over the rugged terrain of central China. The surface return of the CloudSat CPR "return echo," as expected, exactly matches the terrain data and provides a quick quality check as well as an aid for interpreting the cloud features shown in the data window.

CloudSat Mission Overview

CloudSat is a satellite experiment designed to measure the vertical structure of clouds from space and, for the first time, is simultaneously observing cloud phase and radiative properties. The primary CloudSat instrument is a 94-GHz, nadir-pointing Cloud Profiling Radar (CPR). (Note: The CloudSat CPR is pointing 0.16 degrees off nadir, in the forward direction, to minimize the noise caused by specular reflectance of a true nadir-pointing instrument.)

In the first 14 days of the mission, CloudSat collected more CPR data than had previously been collected from all of the ground-based or aircraft radars to date.

Figure 2. CloudSat "QuickLook" imagery. To view these images and learn more about the content, visit the quicklook page at http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php.



CLOUDSAT

A unique aspect of this mission is the fact that CloudSat is flying in formation with other Earth Sciences missions dubbed the "A-Train" (Figure 3). CloudSat is flying approximately 70 seconds behind NASA's EOS Aqua, and 15 seconds in front of CALIPSO (lidar), which is flying one minute in front of the CNES PARASOL (polarimeter). The NASA EOS Aura mission is approx. 12.5 minutes behind PARASOL.

CloudSat must fly a precise orbit to enable the field of view of the CloudSat radar to be overlapped with the lidar footprint and measurements from other instruments of the constellation. The precision of this overlap creates a unique multi-satellite virtual platform observing system for studying the atmospheric processes of the hydrological cycle. Additional information about the CloudSat mission may be found at http://cloudsat.atmos.colostate.edu.

Figure 3. "A-Train" satellite constellation. The lead satellite in the A-Train is the NASA EOS Aqua. The other A-Train satellites that follow are CloudSat, a NASA-CNES lidar satellite (CALIPSO), a CNES satellite carrying a polarimeter (PARASOL), and the NASA EOS Aura.

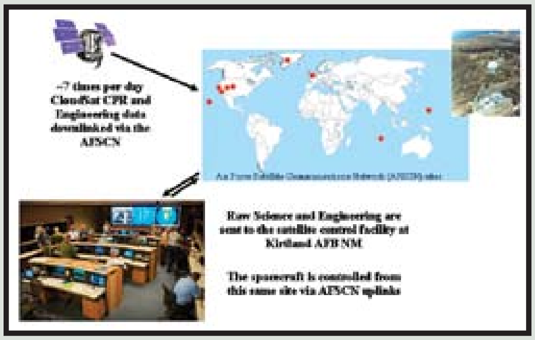


Figure 4. CloudSat data flow – satellite to USAF site at Kirtland AFB.

The CloudSat Data Processing Center (DPC)

CIRA provides all of the science data processing support for the mission. Four universities and the NASA Jet Propulsion Lab (JPL) are participants on the CloudSat algorithm development team. During the current operational (on-orbit) phase, the DPC is staffed by CIRA employees, Science and Technology Corporation personnel (under a subcontract to CIRA), and part-time university or high school students.

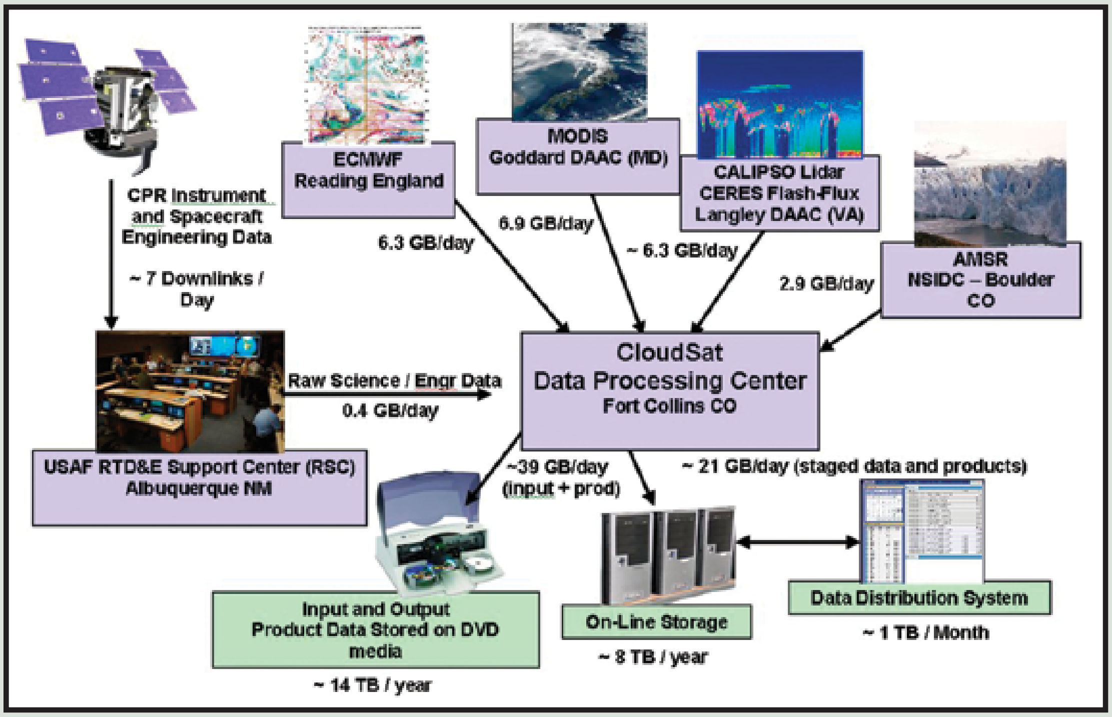


Figure 5. Data flow through the CloudSat Data Processing Center.

Figure 4 shows the flow of CloudSat data from the satellite to the USAF Research Testing Development and Evaluation (RTD&E) Support Center at Kirtland AFB NM (referred to as the "RSC"). The RSC receives CloudSat data, as well as maintaining command and control of the spacecraft, through the Air Force Satellite Communications Network (AFSCN) depicted as red dots in Figure 4.

Figure 5 shows the flow of CloudSat data from the RTD&E Support Center (RSC) to CIRA; from several remote environmental data centers to CIRA; and the flow of CloudSat products through the DPC system.

Over the past year, the USAF/RSC has collected 99.9 percent of the possible CloudSat Science Data downlink opportunities, and the CloudSat DPC has ingest and processed 100 percent of the CloudSat data provided by the RSC.

Data Distribution

The CloudSat DPC is also responsible for maintaining an archive of the CloudSat data products and the distribution of products to the science community. As of June 1, 2007, the data distribution system has provided data to more than 600 users/groups in 17 different countries. Some pertinent statistics as of June 1, 2007:

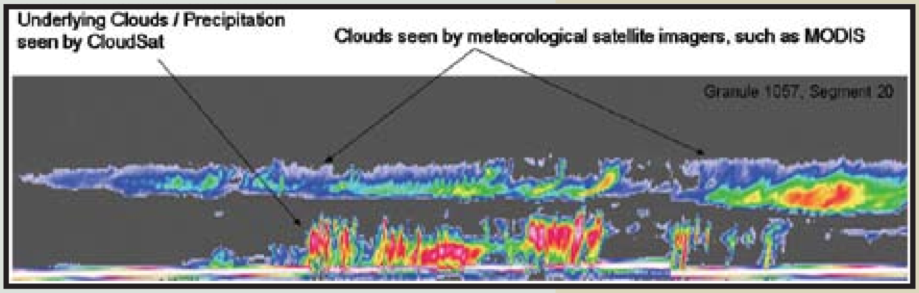
- more than 196 million vertical profiles of clouds
- more than 450 thousand products distributed (~ 14 Terabytes)
- products distributed to the United States, Japan, China, France, Canada, South Korea, United Kingdom, Germany, Italy, Sweden, The Netherlands, Israel, Brazil, Australia, Finland, Switzerland, and India (in order by volume)

More information about the DPC can be found at http://www.cloudsat.cira.colostate.edu.

Some Interesting Findings

Figures 6 and 7 are examples of some of the exciting features of CloudSat data that will be of interest to researchers.

One of the most significant features of CloudSat CPR data is the ability to see "hidden" (lower) layers of cloud beneath the top cloud layer that is the only one that is detected by passive sensors. In addition, the cloud base of the top layer is also evident – again, a feature that is not detected by conventional satellite sensors.



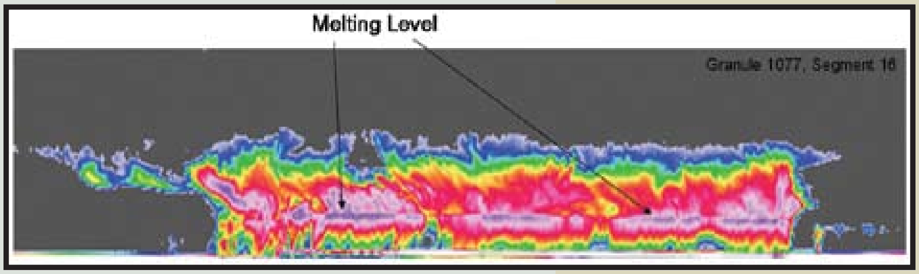


Figure 6 (top). "Hidden" Clouds. Figure 7 (bottom). Detection of the "melting level."

Another feature of the CPR data is the detection of the "melting level" (evident in Figure 7 as a horizontal line of brighter echo returns in the middle of the cloud layer).

This signature happens when snow/ice crystals fall below the freezing level (air temperature of 0°C) and begin to melt. At 94GHz, the water-covered ice is highly reflective compared to the reflectivity of snow or ice. (The melting level is generally less than 1 km

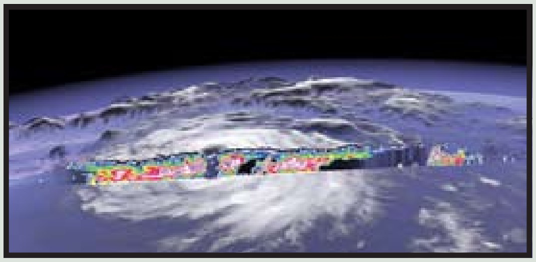


Figure 8. CloudSat slice through Hurricane Ileana. The CloudSat vertical profile "curtain" is superimposed on a GOES-W image taken within five minutes of the overflight. (Photo courtesy: NASA/JPL/CIRA)

The quick turnaround of data products and the generation of QuickLook images was identified as one of two NASA "firsts" for this mission, the other being the accomplishment of formation flying.

At the end of CloudSat's first year in orbit, the DPC has processed 100% of the CPR Science Data that it received, providing about 1.4 TB/month of CloudSat data products to more than 600 users/groups in 17 countries.

below the freezing level). This provides a direct measurement of the potential for aircraft icing – a significant flight hazard that is impossible to measure directly with standard meteorological satellite sensors.

Another pleasant surprise has been the number of tropical storm overflights. CloudSat has more than 200 passes over named storms, including 30+ within 75 km of the storm center. In all, CloudSat has more than 1,000 overflights that imaged clouds associated with tropical storms. Figure 8 shows a spectacular view of the interior of Hurricane Ileana. These overflights have provided new insights into the convective processes and precipitation distribution inside these destructive storms.

Additional examples of tropical storm overflights, plus examples of other interesting CloudSat images, can be found on the Data Processing Center website at: http://www.cloudsat.cira.colostate.edu/CaseStudies.php and in the accompanying article by Graeme Stephens. One unique pass that is shown on the website is a direct overflight of the eye of Typhoon Prapiroon.

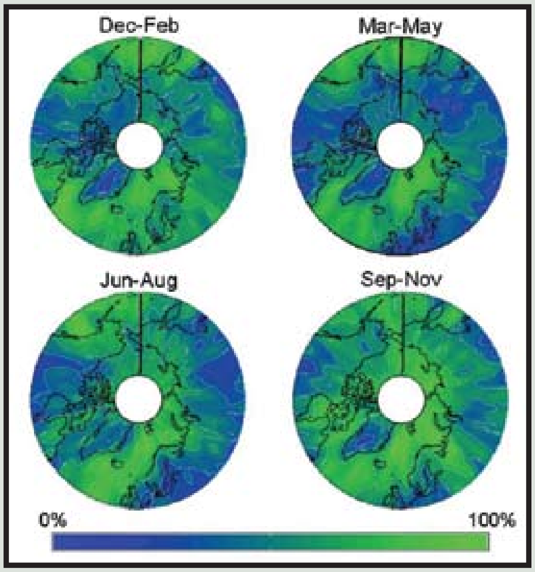


Figure 9. Seasonal cloud fraction (0-1) from the combined CloudSat/CALIPSO cloud mask product (polar stratospheric clouds removed) for the period of June 2006 - May 2007.

Figure 8 shows some initial results from work done by CSU atmospheric science M.S. student Aaron Schwartz on the detection of polar clouds using the combined CloudSat and CALIPSO cloud mask product. These images depict the seasonal cloud fraction (with polar stratospheric clouds removed).

An accompanying article on page 17 of this magazine, Dr. Graeme Stephens details a number of exciting new findings related to the detection of precipitation. And with CloudSat data products being accessed by more than 600 scientists/teams around the world, we anticipate a significant number of new discoveries in the second and successive years of the mission.

Accomplishments of Note

CIRA was given a requirement, by the CloudSat program manager, to provide Level 0 and Level 1 products within 30 days of the receipt of data. We are currently generating both products and displaying a geolocated browse image of the CPR science data within two minutes. The quick turnaround of data products and the generation of QuickLook images (Figure 2) was identified as one of two NASA "firsts" for this mission, the other being the accomplishment of formation flying.

In the Fall 2003 *CIRA Magazine* article, we presented three challenges that the Data Processing Center (DPC) would have to meet: implementing science software that is developed at remote locations; operationally merging science data from different A-Train platforms; and providing a data distribution system for CloudSat data. In June of this year, the CloudSat DPC was presented with a NASA Honor Award for not only meeting all of these challenges but also for exceeding every implementation and operations requirement.

The CloudSat DPC website contains a wealth of information about the mission, data products, interesting case studies, detailed product specifications, and instructions for ordering data. Visit http://www.cloudsat.cira.colostate.edu for all of these topics and more.

A Dream Come True

Graeme Stephens

(The following is taken from an article written by Stephens titled "Reading the Clouds," written for the Perspectives *magazine section of the* Denver Post *on August 26, 2007).*

Graeme Stephens is a CSU Distinguished Professor in the Department of Atmospheric Science and a CIRA Fellow. He is the P. I. on the CloudSat mission, a Distinguished Visiting Scientist at the Jet Propulsion Laboratory in California, and a science team member on the MMAP project here at Colorado State University. He is on numerous committees such as the co-investigator of the CALIPSO mission, member – NOAA's National Climatic Data Center Climate Panel, member – National Academy of Sciences Climate Change Feedbacks Working Group, member – NOAA's Climate and Global Change Advisory Panel, member of the U.S. National Academy of Science – Committee on Earth Sciences (CES), and has remained as a member on several other advisory panels for more than a decade through his dedication to the atmospheric science community.

Reading the Clouds

CloudSat – a $217 million satellite designed in Colorado to peer deep into clouds for clues on weather and climate – has given scientists around the world a wealth of information since its April 2006 launch.

Despite the enormous number of images of clouds from space, previously there had been little information collected about the internal properties of clouds. CloudSat is the first radar to look vertically at the characteristics of clouds, particularly their water and ice content. These data will help scientists better understand and predict weather patterns and climate changes.

CloudSat flies in NASA's "A-Train" constellation of satellites, maintaining a separation of about 15 seconds in front of the CALIPSO spacecraft. CALIPSO carries a lidar instrument to measure clouds and aerosols, which complements the CloudSat radar. Together, they give a complete picture of clouds from the thinnest cirrus high in the atmosphere to the thickest, most heavily precipitating clouds.

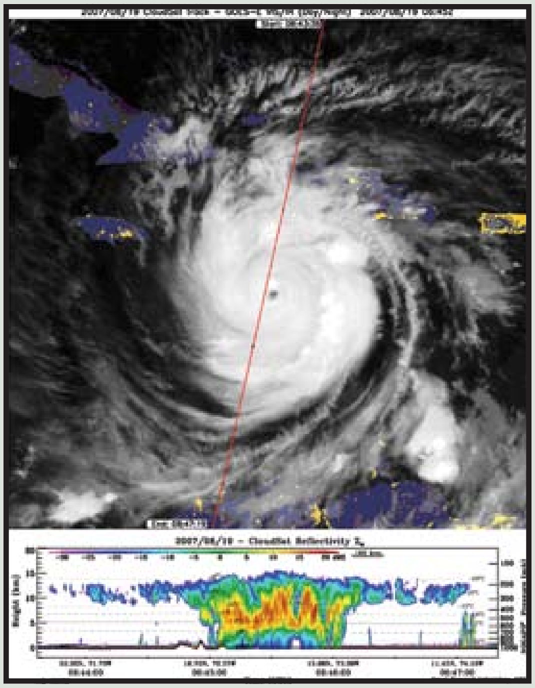
Since 1993, I have dedicated my career to proposing and implementing the CloudSat mission. Working with NASA's Jet Propulsion Laboratory, CIRA, and my research staff, we saw the immense potential of multi-satellite observations to provide improved data to the scientific community and championed the approach of formation-flying CloudSat with CALIPSO, Aqua, and the other A-Train satellites.

Among some of the new discoveries gathered in the first 12 months of CloudSat's operations:

- CloudSat research is leading to a promising new technique for estimating the intensity of hurricanes from space. The method could one day supplement existing techniques, assist in designing future tropical cyclone satellite observing systems, and improve disaster preparedness and recovery efforts. Developed by scientists at CSU, NASA's Jet Propulsion Laboratory, and the Massachusetts Institute of Technology, the technique uses NASA satellite data, including data from CloudSat, to remotely estimate hurricane intensity.
- CloudSat has provided new insights on the fraction of clouds that produce precipitation. Over the Earth's oceans, CloudSat has shown that precipitation is much more common than was previously thought, due to the fact that precipitation over oceans is extremely hard to measure, and the light rain that often falls has been completely missed by satellite observations until now. CloudSat has shown that 15 percent of all oceanic clouds produce rain that falls to the surface.
- Weather and climate prediction models predict that the majority of rain that falls comes from deep thunderstorms. CloudSat has revealed that this is not the case, and instead the observations show that a large proportion of rain falls from much shallower clouds.
- CloudSat has provided new insights on the greenhouse effects of clouds, identifying where and when clouds trap heat in the atmosphere and

The DPC was given a requirement to provide Level 0 and Level 1 products within 30 days of the receipt of data. We are currently generating both products and displaying a geolocated browse image of the CPR science data within two minutes.

CLOUDSAT



Hurricane Dean shown on a GOES-E/DMSP composite image at approximately 06:45 UTC on Aug. 19th, 2007 (top) and as a cross-section view by CloudSat as it flew over the storm between 06:44 and 06:47 UTC. Photo courtesy Office of Naval Research, Monterey, Calif., Program Element (PE-0602435N)

In the first 14 days of the mission, CloudSat collected more CPR data than had previously been collected from all of the ground-based or aircraft radars to date.

where and when they increase the amount of heat lost from the atmosphere to space. This dynamic trade-off between heating and cooling is one of the basic controls on global climate, and the new knowledge gives scientists better tools to measure these processes.

• The CloudSat radar also provides observations of clouds over the polar regions during winter. These clouds have been largely invisible to earlier satellite observations because of the lack of sunlight and the difficulty of sensing a difference, from space, between cold clouds and cold ice-covered surfaces. As we are finding out, the polar regions are extremely sensitive to climate warming, and the complex interplay between the polar surface and polar clouds can now be studied for the first time.

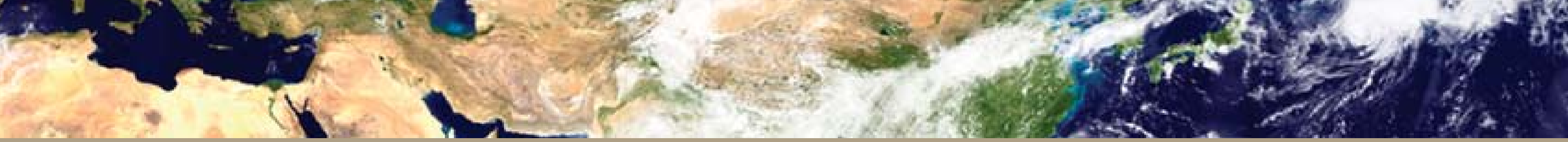
Water is our planet's most precious resource. Through evaporation, water moves from the land surface and ocean to the atmosphere and returns back to the surface in the form of rain and snow. This recirculation of water is known as the water cycle. Not only are clouds one of the most commonly recognized aspects of weather, they are the way that the water cycle transports the fresh water that we depend upon, replenishing the freshwater reservoirs in lakes, rivers, snowpack, and even underground aquifers. Without clouds, our freshwater resources would eventually disappear, and all water on this planet would be locked in the saltwater of the oceans.

Clouds also exert a large influence on the climate of our planet, not only by way of the precipitation they produce but also by altering the Earth's greenhouse effect in ways that are not yet fully understood. It is for these reasons that clouds and their effects on climate are one of the most uncertain aspects of the recent Intergovernmental Panel on Climate Change projections of climate change.

Perhaps the most urgent issue of climate change is associated with uncertainties of how rainfall and snowfall may change in a warming climate. Will wet regions get wetter and dry regions get drier? Will storms become more frequent and more severe? Answers to these questions depend upon improving our understanding of how clouds form, how much water they carry, what determines when and how much they precipitate, and how precipitation may be influenced by temperature and pollution. CloudSat goes a long way toward fulfilling scientists' desire to answer those questions.

Missions such as CloudSat take a decade or more to conceive, propose, and implement. CloudSat owes its success to the scientific leadership of scientists at Colorado State University; a team of engineers and mission designers at NASA's Jet Propulsion Laboratory in Pasadena, Calif.; spacecraft designers at Ball Aerospace and Technologies Corp. in Boulder, Colo.; satellite controllers at the U.S. Air Force in Albuquerque, N.M.; the CIRA-hosted CloudSat Data Processing Center; and a host of international and interagency scientific collaborators.

NASA has recently recognized the enormous early success and promise of the CloudSat mission by extending its funding by three years, to 2011. That decision makes CloudSat the only Earth science mission selected by NASA to receive additional funding for enhanced scientific research beyond the mission's original purpose.



AUTO-NOWCASTER MIGRATES TO AWIPS

The Migration of NCAR's Auto-Nowcaster into NWS AWIPS

Scott O'Donnell

The National Weather Service (NWS) is emphasizing the role of automated, short-term forecasting to improve its ability to detect and warn for high-impact weather events associated with thunderstorms such as heavy rain, hail, lightning, and high winds in the 0- to 1-hour time frame, particularly for its aviation and public customers.

This prototype project brings National Center for Atmospheric Research (NCAR) AutoNowcast products into the Advanced Weather Interactive Processing System (AWIPS) environment. The project is an expansion of a demonstration conducted by NCAR to provide AutoNowcasting tools and products to the Fort Worth, Texas, WFO (Weather Forecast Office). In their demonstration, NCAR placed an AutoNowcast workstation next to the Short-Term Forecaster workstation. In this way, the forecaster could use the NCAR workstation without moving very far from the AWIPS workstation. While the demonstration proved beneficial, the unfamiliar command sequences and the inability to use and overlay AWIPS data with AutoNowcaster products limited its usefulness.

However, based on the successes of NCAR's demonstration, the Federal Aviation Administration (FAA) requested that the NWS integrate much of the NCAR AutoNowcast system into AWIPS for the FAA's Center Weather Service Unit (CWSU) offices. Through deliberate, incremental advances, the NWS has brought many of the AutoNowcast system elements directly to the short-term NWS forecasting workstation at the Fort Worth/Dallas (FWD) WFO.

The goal of this CIRA project is to bring NCAR AutoNowcast products into AWIPS to provide the NWS Short-Term Forecaster the additional tools to determine where thunderstorms are most likely to occur. These improvements increase warning lead-times, probabilities of detection (PODs), and reduce false alarm rates (FAR).

A weather forecast is generally developed to provide information about the near future; 24, 12, and 6 hours are common forecast periods. These forecasts give us the ability to anticipate the weather later in the day. However, our lives are often dominated by more immediate events. We look to the sky to see whether we should take our umbrella with us or whether we might need a jacket or sweater. In essence, we use "nowcasts" to determine our immediate weather-related needs.

The AutoNowcast project involves this nowcast time frame – the short, 0- to 1-hour time frame when the immediate future is influenced by imminent or current weather events. The NCAR's AutoNowcast application is an automated, short-term thunderstorm nowcasting application designed to help the forecasters anticipate and track convective storms in the 0- to 1-hour time frame. The AutoNowcast application uses weather feature detection algorithms, which include analyzing the locations of surface-level convergence boundaries between moist and dry boundary layers and/or thunderstorm outflow boundaries. The forecast convection products are generated every six minutes.

NCAR's stand-alone AutoNowcast display system was installed at the NWS Fort Worth/Dallas WFO several years ago. The NCAR AutoNowcast system uses its own data display system and its own set of tools and commands to interact with the system. Consequently, to use it, the forecaster must leave the AWIPS workstation.

Our activities have been implemented in a very systematic manner to develop techniques to:

- integrate the AutoNowcast products to AWIPS;
- provide a natural inter-face to the visualization of AutoNowcast products; and

The goal of this CIRA project is to bring NCAR AutoNowcast products into AWIPS to provide the NWS Short-term Forecaster the additional tools to determine where thunderstorms are most likely to occur.

AUTO-NOWCASTER MIGRATES TO AWIPS

In essence, we use 'nowcasts' to determine our immediate weather-related needs.

- use AWIPS-developed techniques to acquire, view, overlay, and interact with the displayed data.

The interface was designed to be almost intuitive, drawing on commonly used methods within the workstation. As a result, even though we are introducing new datasets, no additional training is required for the forecasters to use or work with these new data. And most importantly, everything is available at the forecaster's workstation. No need to leave and risk losing the focus of the rapidly changing events to look at or use the AutoNowcast products.

The NCAR and AWIPS AutoNowcast application provides the forecaster with the ability to influence the model results by applying their knowledge and forecasting experience into the model providing a more accurate model depiction. These parameters are returned to the AutoNowcast computational engine and are incorporated in the next nowcast products.

Task Descriptions

The AutoNowcaster integration task was broken down into six implementation stages:

- **Phase 0**
- Deliver AutoNowcaster data to NWS/MDL (NCAR)
- Receive AutoNowcaster data from NCAR (NWS)
- **Phase 1**
- Decode and store AutoNowcast data
- Reformat AutoNowcast products into AWIPS formatted netCDF
- **Phase 2**
- Display nowcast data products on AWIPS's D2D
- Add menu selections
- Display looping
- Provide basic forecaster interactions to allow forecaster to define stationary Convective Boundaries
- Manage all human actions by NCAR
- **Phase 3**
- Add boundary motion
- Allow forecaster enhancement area definitions (polygons)
- Return forecaster-generated data to NCAR server (xml)
- Manage all human actions by AWIPS
- **Phase 4**
- Install operational software at WFO
- Migrate computational engine and data distribution to AWIPS
- **Phase 5**
- regional center operation (NWS)

The completion of each phase provided a concrete deliverable, each built on previous progress. One can see that as the project progresses, each subsequent task becomes more complex. Each phase has a set of well-defined deliverables that needed to be complete before moving on to the next phase.

Phase 0

Phase 0 required NCAR and the NWS to agree to send and receive the AutoNowcast data products. NCAR has an in-house-developed data communications system, which it needed to install on the NWS-owned hardware to receive the data stream.

This has presented some security risks at the FWD WFO and Southern Region Headquarters (SRHQ). The risks were mitigated by installing a router and firewall between the AWIPS network and the local nowcast system receiving the AutoNowcast data. The router isolates the data receiver from AWIPS, and a very tight set of firewall rules restricts access to a single port and user. All other data transfers use secure shell protocols requiring user ID and password authentication.

Phase 1

In this phase, we created a persistent process to detect the arrival of new AutoNowcaster products. This process decodes each one and stores the decoded data into netCDF data files, configured for AWIPS data displays.

This phase must decode and store four gridded AutoNowcaster products. The products are divided into three surface layer forecasts received a few minutes after every radar scan.

- Init60: A 60-minute forecast convective initiation index grid

- Growth60: A 60-minute forecast convective growth index grid
- Gandi60: A 60-minute forecast convective growth and decay index grid

Init60 data provides a surface wind grid (among other parameters). Growth60 data provides a grid of steering flow, maximum reflectivity, and convective growth index parameters. The Gandi60 data provides a different analysis of forecast convection likelihood.

- The fourth data set is the Adjoint data (sometimes known as VDRAS, Variational Doppler Radar Analysis system), which are delivered three to four times per hour.

The Adjoint (VDRAS) data provides forecast wind vector grids from the surface (1,000 mB) to 325 mB heights.

Phase 2

This phase required an adaptation of D2D to add menus and other internal metadata necessary to add AutoNowcaster products to the AWIPS D2D visualization system.

The first "extension" application, the Boundary Editor, was introduced to allow the forecaster to draw convective boundaries on the D2D display and return these data to the NCAR AutoNowcaster computational engine. The extension at this stage only supported stationary boundaries.

All data management details and process accounting remain in NCAR's control. NCAR keeps a record of all active boundaries and when to schedule the retrieval of forecaster-generated data.

Phase 3

In this phase, forecaster-entered convective boundaries are enhanced to allow boundary motion. As boundary locations change with time, their positions are tracked on the D2D display. Motion is assigned by first defining a stationary boundary, then dragging the boundary to its new location in a subsequent display frame.

A Polygon Editor extension was added to allow the forecaster to increment or decrement the Init60 convection initiation index product. Either the entire domain can be modified by a fixed weighting, or arbitrary areas may be circumscribed and individually weight-adjusted. This provides the forecaster with a great deal of control over the model results.

In each of the extensions, the forecaster actions are returned to NCAR in XLM-formatted test files. The data exchange format, XML, was selected for its flexibility, simple definition, and data clarity. By adopting this format, future new features or additional data will be very simple to incorporate.

All data management details are transferred to the AWIPS application. NCAR no longer retains the "state" of the application. AWIPS keeps a record of active boundaries and polygon areas.

Phase 4

In this phase, the AWIPS application becomes operational. In each previous version, the AWIPS/AutoNowcaster system was installed at MDL on test platforms to simulate operational use. Forecasters were invited to visit MDL to test and evaluate functionality, but operational use could only be simulated.

To complete this phase, we will move the AutoNowcaster computational engine to the NWS. Currently, it resides off-site at the NCAR RAP laboratory in Boulder, Colorado. By placing it on-site, data communication issues become less difficult, and faster modeling times may be possible by having all the necessary data locally available.

Phase 5

Phase 5 is an expansion of the modeled area. Currently, a 720 Km by 660 Km spatial domain is analyzed and forecast. This area was selected to fully cover the area centered over the FWD WFO. Moving from small WFO-centered domains to regional centers (incorporating multiple WFO domains) will expand the computational domain. Among many of the challenging topics that we will need to address in this final phase are the merging of many discrete data sets and

AUTO-NOWCASTER MIGRATES TO AWIPS

Figure 1. D2D AutoNowcaster menu

forecaster-entered data and data dissemination to multiple WFOs.

AWIPS User Interface

The forecaster accesses the AutoNowcaster data displays and extensions from the "SCAN" drop down menu and selecting "AutoNowcaster." This pops up a tear-away menu as shown in Figure 1.

The user selects items by clicking on the menu selector. Applications start by clicking on "Edit ANC Boundaries," "Edit ANC Polygons," or "Select ANC Regime." AutoNowcast data are displayed by clicking on the menu items, "Adjoint Fields," "cronusInit60," "HumanInit60," "cronusGrow60," or "gandi60."

Boundary Editor

The Boundary Editor is one of the major tools provided to the forecaster in the AutoNowcast system. The AutoNowcaster is not very good at detecting the location of convective boundaries without some forecaster help. A forecaster can easily detect the location of converging air masses, dry slots, bow echos, etc., and quickly draw the convective boundary over the displayed data. These data are then returned to AutoNowcaster. Initialized in this manner, the AutoNowcaster is very good at tracking the meteorological parameters responsible for causing convection.

The AWIPS D2D interface provides easy-to-use methods for drawing the boundary's location, editing the boundary, applying a motion vector to the boundary, and adjusting the speed and direction to the entire boundary or to an individual vertex. The Boundary Editor provides methods for correcting the boundary's motion or location during its lifetime should its track be progressing too quickly or lagging somewhat.

The user initiates the Boundary Editor application from AWIPS' SCAN drop-down menu and selecting the AutoNowcaster selection with the workstation mouse. This starts the Boundary Editor (BE) extension application (see Figure 2). The user can take several actions at this time. The BE allows the forecaster to draw a boundary ("Insert New Boundary"). The application assigns an initial boundary numeric identifier (limited to 0-99), which the user may initialize if there is another preference. Initially, a short, 3-vertex boundary is drawn vertically at the center of the display. Each vertex is dragged to its respective location. If additional segments are required, a point-and-click action on an existing boundary segment will insert an additional vertex to be dragged to its required position. As many vertices as are needed may be included in the boundary definition.

By clicking on the "Send To ANC" button in the BE,

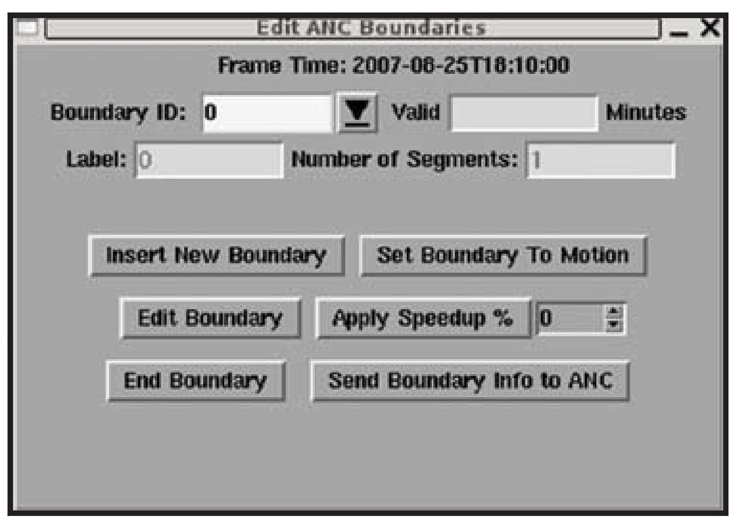


Figure 2. Boundary Editor interface

the new boundary data are formatted into XML and returned to the AutoNowcaster computational system to be included in the next set of AutoNowcaster products. There is an arbitrary limit of 100 unique boundaries that can be active at any time.

The initial boundary is stationary (see Figure 3). As time moves forward, each active boundary's position may need to change. At a subsequent display frame, the user may select to provide motion to the boundary. This is done by selecting the "Set Boundary Motion" button in the BE and dragging each vertex to its new location (see Figure 4). This associates a velocity vector to each vertex, allowing differential motion along the length of the boundary; i.e., each vertex moves independently relative to the other boundary vertices. As time moves forward, a proportional, incremental movement is computed for each vertex, and the boundary is plotted in its new location. If the assigned motion needs to be adjusted, a percentage adjustment can be made to the boundary to speed up or slow down the entire boundary using the "Apply Speedup" button in the editor.

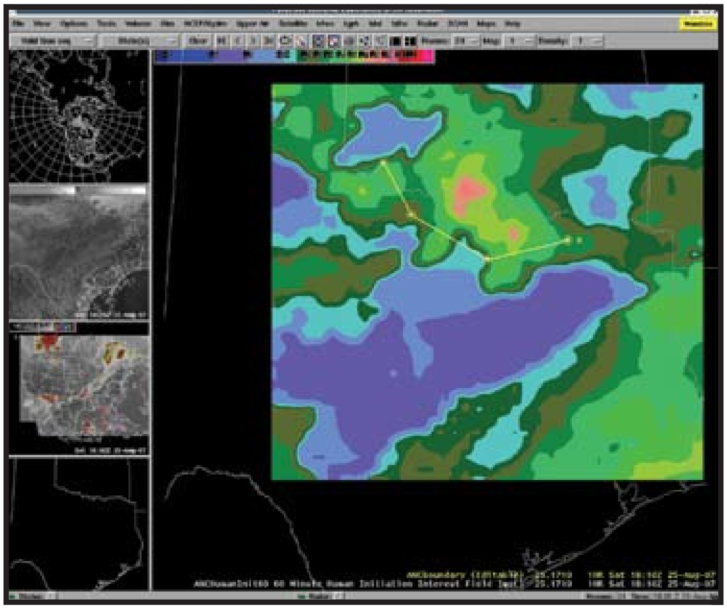


Figure 3. Create a stationary boundary

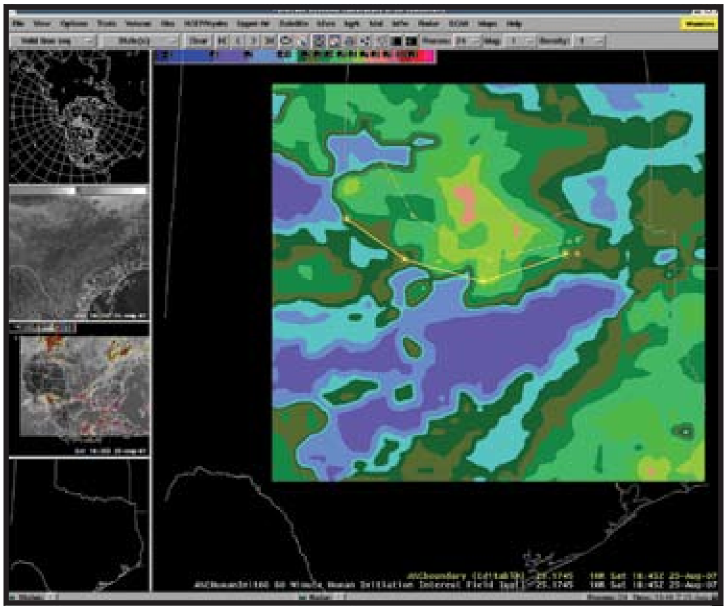


Figure 4. Adding motion to boundary

After each action, the user must select the "Send to ANC" button to apply the modifications to subsequently generated products. When a boundary is no longer needed, it can be deleted using the "End Boundary" button. Boundaries that are older than eight hours are assumed to no longer represent current conditions and are automatically terminated. This eliminates the need to delete every boundary that was created, as some may have traveled outside of the displayed domain and are no longer visible. Removed boundary IDs are returned to the pool of unassigned boundary IDs.

AUTO-NOWCASTER MIGRATES TO AWIPS

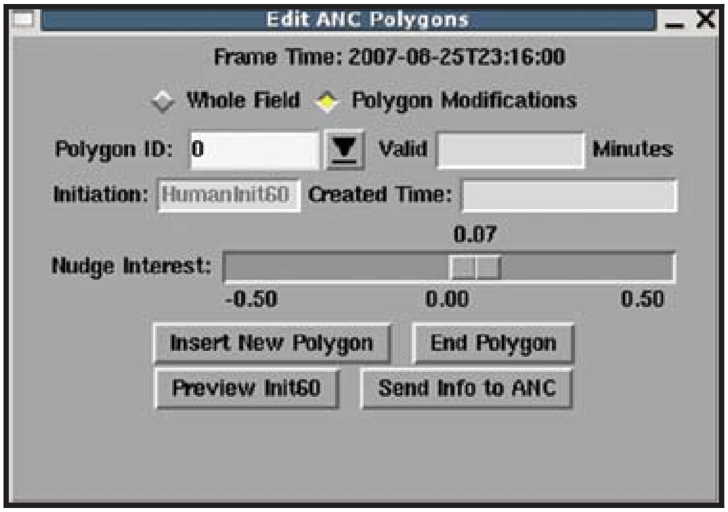


Figure 5. Polygon Editor interface

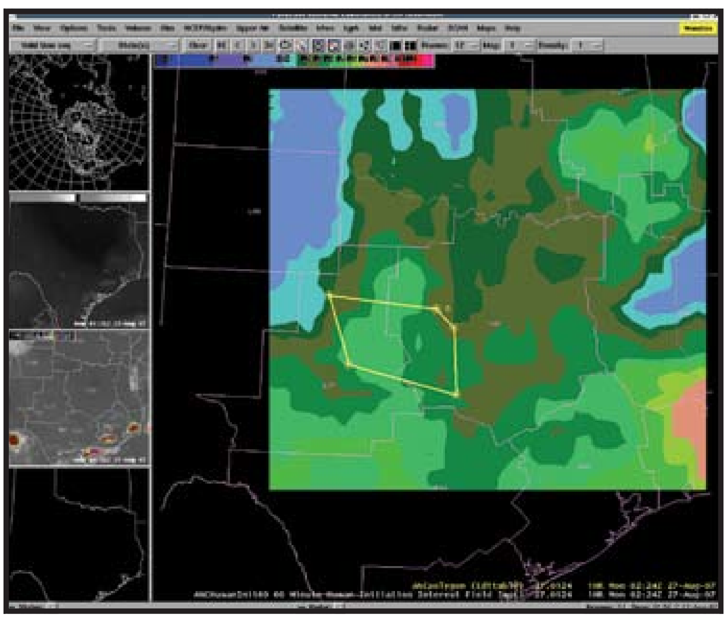


Figure 6. Define a polygon area

Polygon Editor

The Polygon Editor is a tool that allows the forecaster to change the forecast convection index grid. If the forecaster believes the AutoNowcast-computed grid should be enhanced or de-emphasized, the Polygon Editor provides tools to apply a correction to either small, arbitrarily shaped areas or to the entire domain.

Like the Boundary Editor, the Polygon Editor is an AWIPS Extension application. It is started from the SCAN/AutoNowcaster menu by clicking on the "Polygon Editor" list selector (see Figure 5).

If the forecaster wishes to apply an adjustment to the entire domain of the forecast area, the user selects the "Whole Field" radio button at the top of the Polygon Editor tool. If the forecaster chooses to modify a smaller area, the "Polygon Modifications" button must be selected. The "Insert New Polygon" button allows the forecaster to draw a border around the area to be modified. An identifier number will be automatically assigned if the forecaster does not assign a particular ID value. As with the Boundary Editor, up to 100 polygons can be managed at a time.

When "Insert New Polygon" (Figure 6) is selected, a four-sided polygon is placed in the middle of the display. Each vertex can be moved independently. However, a polygon edge cannot be dragged over an adjacent vertex. This prevents inadvertent polygon edge crossings. However, polygons are allowed to overlap. This has an additive effect of each polygon weight over the overlap area.

Whether making whole field changes or an adjustment to a smaller area, the adjustment weight is determined by using the "Nudge Interest" slider bar. Movement to the left decreases the index value adjustment, and movement to the right increases the adjustment factor. The range of values is -0.5 to +0.5, with the selected value indicated directly above the slider.

A "Nudge" weight must be assigned to each entity created. Each polygon adjustment weight assignment is independent of all other polygons. The default weight is 0.0, so if no adjustment is selected, no change will be made to the Convective Index grid for the selected polygon.

Polygon modifications are enabled by selecting the "Send to ANC" button. This sends the provided polygon data to the AutoNowcaster computational engine. The new data will be applied to the next set of products.

Due to the time delay between when the polygons are created and when the new set of products are delivered, the Polygon Editor provides a "Preview" button that allows the forecaster to review the set of area weighting changes before they are committed to the computational engine (using the "Send to ANC" button). Adjustments can be made to any polygon at any time, and "Preview" can be reused to verify the index grid any number of times until the forecaster is satisfied with the new grid.

The "End Polygon" button is used to remove a polygon. This can be used at any time, either before or after committing the polygons to the computational engine.

Regime Editor

The AutoNowcaster uses different forecast algorithms depending on the dominant type of forcing. The forecaster can specify the weather regime using the "ANC Regime" extension.

In Figure 8, the forecaster has selected the "Warm/Stationary front" regime. The stationary front and warm front algorithms are similar and share convection initiation characteristics.

The regime characteristic is returned to NCAR, where subsequent computation will take this type of forcing caused by the weather regime into account when determining the convection forecast until changed to a different regime.

Conclusion

Over the course of the past two years, this CIRA project has reached the midpoint of Phase 4. The AWIPS AutoNowcaster interface is delivered and installed at NWS FWD WFO. This represents a major milestone and proof of concept.

Most applications in AWIPS' D2D give forecasters the ability to review gigabytes of data in very sophisticated ways, but they provide limited opportunities for forecasters to review the data and make modifications if they believe the model output is in error. The AutoNowcaster system not only encourages this interaction, it is also enhanced by the interaction.

This is an important, new technique to add to the NWS Weather Forecast Office; it allows forecasters to use their skills to adjust model

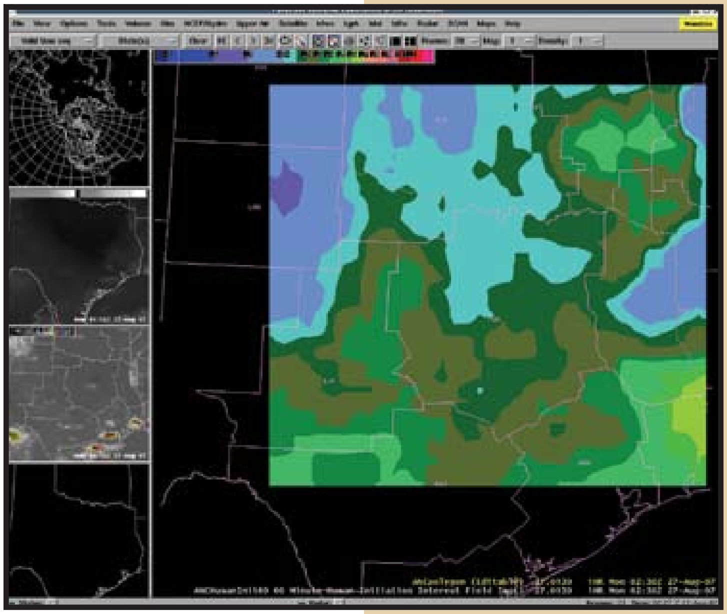


Figure 7. Nudge Whole Field

parameters by enhancing a model's input parameters and returning these data back to the model, then recomputing the model products and incorporating the enhancements to regenerate an improved forecast.

This human-machine interaction has been missing from most forecasting models because the computational overhead was large and communicating with the server was slow, difficult, and risky. In the future, we will see more of this type of interaction, essentially making the human an active component of the model. This leading-edge approach of putting the human into the model forges a new, significant pathway to achieve improved forecasts in the weather service.

Figure 8. Select weather regime

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.

Cooperative Institute for Research in the Atmosphere

College of Engineering – Foothills Campus, Colorado State University
1375 Campus Delivery, Fort Collins, CO 80523-1375
(970) 491-8448

www.cira.colostate.edu

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

Colorado State University