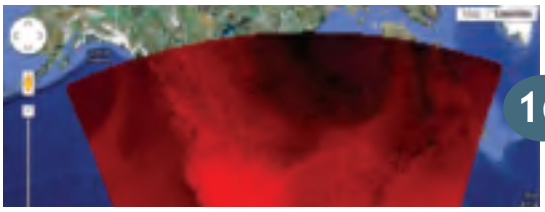
CIRA

Cooperative Institute for Research in the Atmosphere

Volume 38, Spring 2013

College of | ENGINEERING

Colorado State University



Contents

1 From the Director's Desk

2 CIRA's Partnership with NWS AWC

4 RAMMB HFIP Team Wins CO-LABS Award

6 Data Storage Innovations

8 NWS Virtual Laboratory

10 Suomi NPP – A Vision of the 'Black Marble'

16 Weather Model Ensembles, PostGIS

18 Data Visualization using Gaming Engine

20 Communiqué

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From the Director's Desk ...

Six months and a winter have passed since the last CIRA magazine that was published soon after a terrible drought and fire season here in Colorado. Unfortunately this winter, while not as dry as the previous one, has not done much to restore the moisture to normal levels yet. Our Cache la Poudre river is still fairly black from last summer's ash and water restrictions have been put into place early just to be safe. We all hope for a wetter than normal spring and summer but one never knows. Some day we may develop the necessary skill that we can make and verify precipitation forecasts at those time scales. As we learned at the Climate Diagnostics and Prediction workshop that CIRA hosted here in Fort Collins last October, however, that is not yet the case. There is work to be done and certainly work that CIRA can and should play a role in.

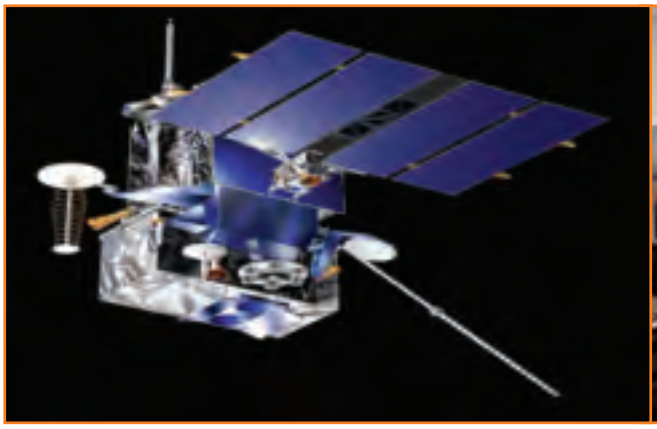
On the more immediate front we've seen the possibilities offered by the new VIIRS sensor on the Suomi/NPP satellite. Steve Miller led the effort to exploit data from the new Day/Night Band (DNB), particularly over high latitude polar winters where the moonlight capabilities of the DNB are especially useful due to the absence of solar radiation and the relatively frequent revisit times of the satellite. This channel on the VIIRS instrument can see Earth and its clouds not only under moonlight which is still relatively bright, but it has been shown to provide images with star light that is as little as 0.1% of a full moon illumination and even airglow that represents an even weaker source of light. A very nice overview article was published in the Proceedings of the National Academy of Sciences in their Sept 25, 2012 issue entitled "Suomi satellite brings to light unique frontier of nighttime environmental sensing capabilities." The work led by Steve Miller has a number of co-authors including Dan Lindsay of the Regional and Mesoscale Meteorology Branch (RAMMB) at CIRA. The work continues to provide really intriguing results that have been highlighted in both the popular press and peer reviewed literature.

On a related success story, Mark DeMaria of the RAMMB embedded within CIRA continues his steady march to win every conceivable award. As featured in this Magazine, Mark, the RAMMB Team, CIRA and the Dept. of Atmospheric Science, received the 2012 Colorado Labs Governor's award for "Contributions to Improved Tropical Cyclone Track and Intensity Forecasting." This work continues to highlight the benefits of the interaction between academia and applications that are NOAA's Hurricane Forecasts.

Finally, let me turn to the last major items featured in this magazine that are of constant interest to many of us. Whether it be model output with greater space and time resolution than we've ever had or satellites that download more data daily than satellites archived over their entire mission as little as 20 years ago, we are all faced with ever increasing data volumes that we must make sense of. At CIRA, Michael Hiatt has been steadfastly increasing the overall storage capabilities by using Network Attached Storage devices. This is a simple and inexpensive solution for a number of needs and anyone thinking about increased storage might consider contacting Michael about his experiences. On an even larger front of visualizing these large datasets, this article contains a nice overview of the system that CIRA scientists at NOAA in Boulder are putting together to visualize Earth Science data. This system is driven by the desire to use visualization for the purpose of discovering the connections in the Earth System and therefore does a really nice job not only of ingesting the myriad of datasets available, but allowing the user to search for connections among variables. It is a truly outstanding system not only from the computing and visualization perspective, but also from the philosophical perspective of how we go about discovering in an infinitely connected Earth Science discipline.

Some of the work being done at CIRA is new and I've tried to highlight that. Some work, of course, requires attention to the minutia that is not so sexy but just as important. It has all advanced over the last six months and despite all the uncertainties and a seemingly endless political stalemate, we had another outstanding year at CIRA that even saw modest overall growth. Our goals remain intact and work continues to be of the highest caliber. Thank you everyone and have a great summer.

Chris Kummerow



New CIRA Research Partnership with the NWS Aviation Weather Center

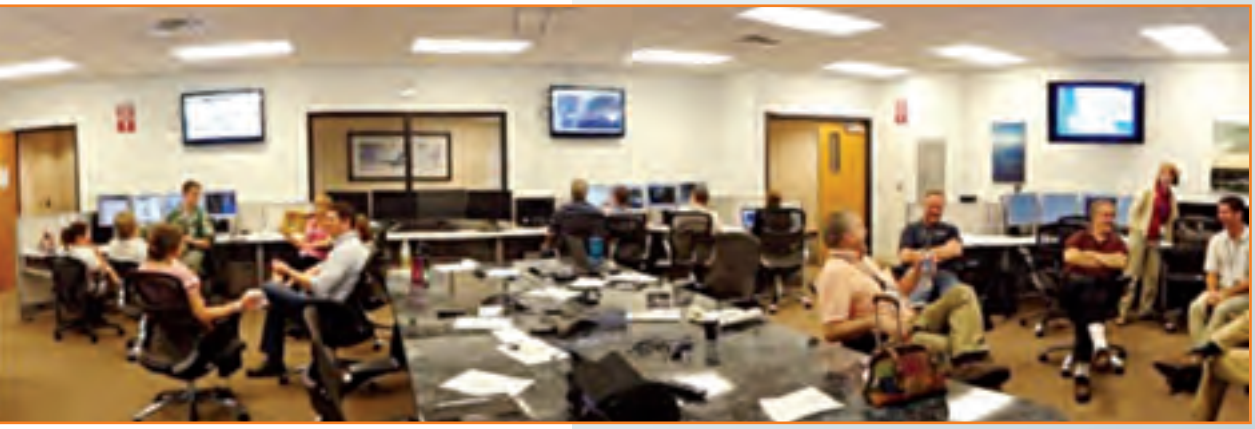
by Cliff Matsumoto and Sher Schranz

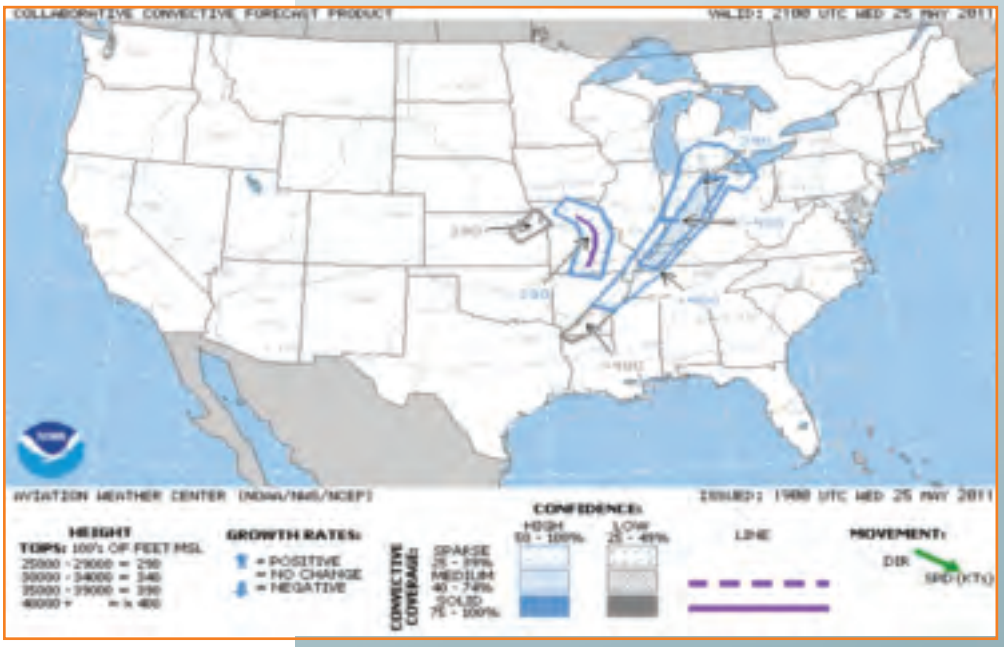
The Aviation Weather Center (AWC) in Kansas City, Missouri has a long history of supporting and transitioning research into operations for the National Weather Service (NWS) to support the FAA and other aviation interests. The AWC is online at: http://aviationweather.gov. The Aviation Weather Testbed (AWT) at the AWC provides the infrastructure and facilities to develop, test, and evaluate new and emerging scientific techniques, products, and services. The AWT actively engages in the research-to-operations process by supporting applied research, verifying the quality and scientific validity of new techniques and products, and providing a common venue for both forecasters and researchers to engage in developing and testing state-of-the-art aviation weather services. Examples of recent accomplishments include evaluation and implementation of Current and Forecast Icing Potential, Graphical Turbulence Guidance, Aviation Digital Data Services, and convective and climatological research projects.

AWC and CIRA began a multi-year research partnership on October 1, 2012.

To enhance AWT's collaboration with universities to maintain a leading edge in aviation meteorology hazards training, operations, and forecast techniques development, AWC and CIRA began a multi-year research partnership on October 1, 2012. Federal scientists, now with CIRA researchers at the AWT, will strive to continue to 1) provide a path to operational use for experimental products and services, 2) promote collaboration among stakeholders, 3) provide a test environment for the purpose of refining and optimizing experimental technologies, 4) verify the scientific validity of experimental products, 5) educate stakeholders about experimental tools and the latest research related to aviation weather, 6) and educate researchers about operational needs and constraints.

In addition to transitioning experimental FAA Aviation Weather Research Program (AWRP) algorithms to the AWC operational environment, research collaboration will emphasize support for the NextGen weather initiative in building a 4-Dimensional Weather Data Cube (4-D Cube) that will improve access and accuracy of weather information to improve aviation services in the NextGen era. The NextGen 4-D Cube will contain a subset of data known as the Single Authoritative Source (SAS), which will provide Air Traffic Management decision makers a single, consistent forecast for all critical aviation weather





An example of a collaborative convective forecast product from the project.

parameters. Refer to the NextGen and the Future of Air Traffic Control article in the Spring 2012 issue of the CIRA Magazine for additional details on the FAA NextGen Program.

As part of the overall AWT goals and objectives for "operational bridging," CIRA will collaborate on a number of required research projects and activities to assist the AWC with developing, testing, and transitioning promising aviation weather research results to National Weather Service operations in support of various programs, including the NOAA NextGen Weather Program, the FAA AWRP, the FAA World Area Forecast System (WAFS) Internet File Service (WIFS), and the FAA Aviation Digital Data Service (ADDS). Planned activities will fall under two related areas—1) meteorology and weather observations and forecasts, along with 2) information technology and computer processing. An example of the former activity is the Aviation Winter Weather Experiment being hosted at the AWT during the week of February 11, 2013. For more details, visit the Aviation Weather Testbed website and click on the 2013 Winter Weather Experiment link. The Collaborative Convective Forecast Product (CCFP) shown above is a prime example of the types of aviation weather forecast product that are developed, tested, and transitioned to operations via the AWT.

CIRA Hurricane Forecast Intensity Program Honored with Governor's Award

by Matt Rogers

Left to right: Andrea Schumacher, Dan Bikos, Mark DeMaria (NOAA/NESDIS), Governor John Hickenlooper, Director Christian Kummerow, John Knaff (NOAA/NESDIS), Kate Musgrave, Deb Molenar (NOAA/NESDIS), Renate Brummer

The Hurricane Forecast Intensity Program (HFIP), part of the RAMMB team at CIRA, was awarded the CO-LABS Governor's Award for High-Impact Research in October, 2012. Led by Dr. Mark DeMaria, the teams' work on tropical storm forecasting has created several products that are used by forecasters at the National Hurricane Center, and have greatly improved the national ability to accurately forecast tropical storm tracking and intensity. Awarded by Colorado Governor John Hickenlooper at a gala awards ceremony on October 25th, 2012, attended by the HFIP team as well as other awardees from laboratories in Colorado.

CO-LABS is a non-profit organization that informs the public about the breakthroughs and impacts from the 24 federal labs in Colorado, and is sponsored the 2012 Governor's Award for High Impact Research. The annual reception where the HFIP team was awarded is the major CO-LABS event showcasing the research facilities and the work of the CO-LABS organization.

The HFIP team at CIRA creates advanced software that transforms forecasts from numerical weather prediction models into products that can be directly compared against satellite observations, giving a complete picture of tropical storms and their environment. One specific product plots the likelihood of encountering 34, 50, and 64-knot winds at a given location from the storm's present location – an example of this product for Hurricane Isaac is shown as Figure 1. Additionally, creating 'ensemble plots' of output from different numerical weather predictions helps provide a guiding envelope for forecasters – an example image from Tropical Storm Debby is shown as Figure 2.

Continued work in providing improved forecast tools for meteorologists will continue to bear fruit, and CIRA researchers, including the HFIP team, will continue to provide these improvements in transforming cutting-edge observations and theory into better forecasts of hurricane intensity for operational meteorologists, saving lives and property.

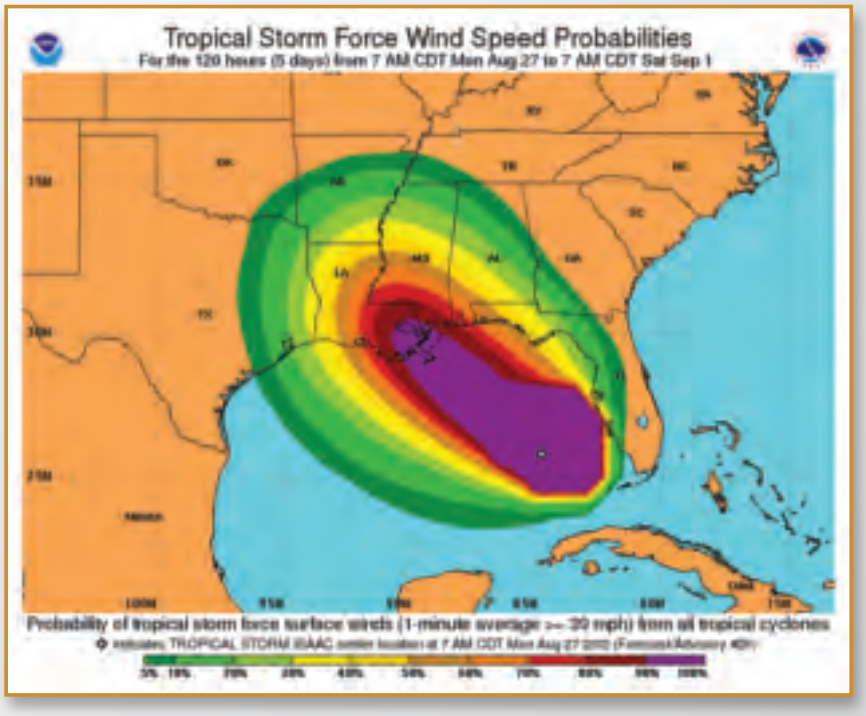


Figure 1. Probabilities of encountering windspeeds in excess of Tropical Storm force (35 knots) for Hurricane Isaac. Operational product at the National Hurricane Center, developed by the HFIP team at CIRA.

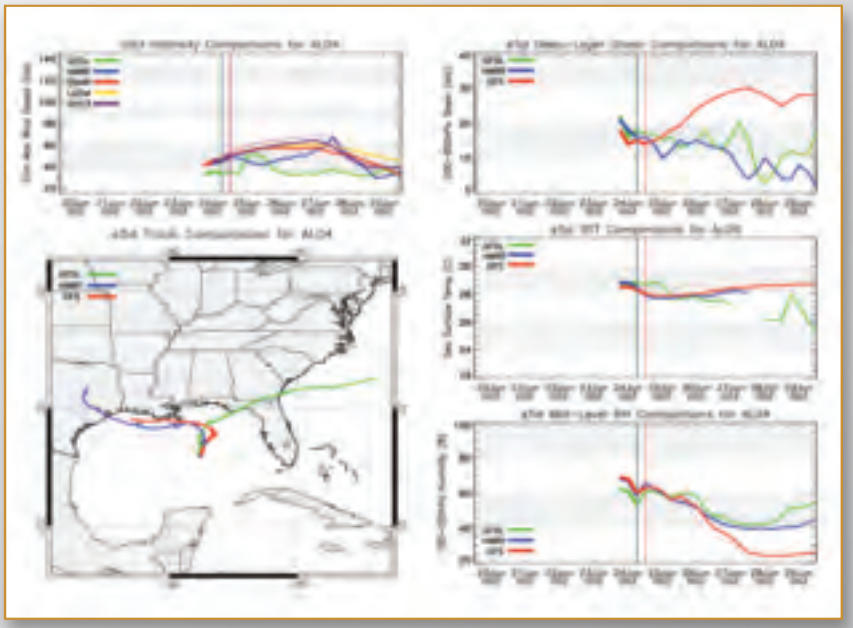
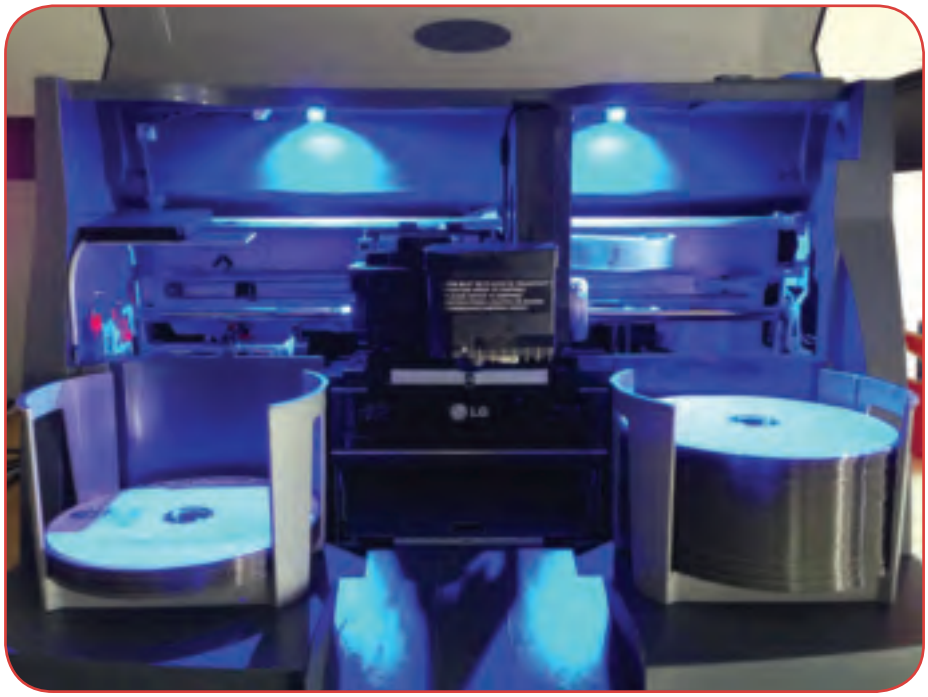


Figure 2. Comparison of model output for forecast track, wind speed, wind shear, sea surface temperature, and midlevel relative humidity for Tropical Storm Debby.

CIRA Archive: Data Storage Innovations

by Michael Hiatt

Storing data for future use is a critical component in any data collection system. CIRA's archive provides past meteorological data for future research. This article highlights CIRA's archive history and unique archive solution.



Robotic Disc Handling System

CIRA deployed a Geostationary Operational Environmental Satellite (GOES) earthstation in 1978 and started an archive using 9-track tape. As technology improved, 9-track tape was replaced by 8mm tape in 1992, and 8mm tape was replaced by Digital Linear Tape (DLT) in 1999. Although each new tape medium provided more storage and handled the daily data volume, the tapes and tape drives were expensive, prone to frequent failures, used slow sequential access, required controlled environmental storage, and had limited shelf life. In 2003 (Robotic Disc Handling System) a new robotic DVD archive system was developed (CIRA Newsletter Volume 20, Fall 2003) to overcome these disadvantages. The automated system improved reliability and requires virtually no human intervention besides adding blank discs and removing completed discs. The CIRA-developed software automatically queues, writes, verifies, and labels each DVD. The DVDs are inexpensive, easy to read and duplicate with no special software, and easy to store, with a much longer shelf life. Since all CIRA computers contain DVD drives, DVD access was setup similar to a library checkout greatly improving researcher access. Once the DVD archive system was operational, student employees spent several months restoring all of the tapes into the DVD system. This effort saved many years of valuable meteorological data from the aging tapes. Since 2003, the DVD archive has proven itself by writing more than 44,000 DVDs for CIRA's Earthstation and projects. The system was also chosen by NASA's CloudSat mission and has successfully archived the entire mission.

NAS Data Storage Units

Today, hard drives provide tremendous storage for low cost. It is now possible to store CIRA's entire archive on these inexpensive drives. The catch is how to safely store this data without loss. In 2006, CIRA started using a storage technology called Network Attached Storage (NAS). These storage devices are inexpensive and can be populated with standard 3.5" hard drives. The drives are configured as one large array and each unit is simply connected to the network. To prevent data loss, a technology called Redundant Array of Independent Disks (RAID) is used. RAID6 configures the array such that two drives can fail without data loss. When a hard drive fails, the NAS sends an alert and the drive is easily replaced via a hot-swappable bay. The NAS then rebuilds the array without needing to take the array offline.

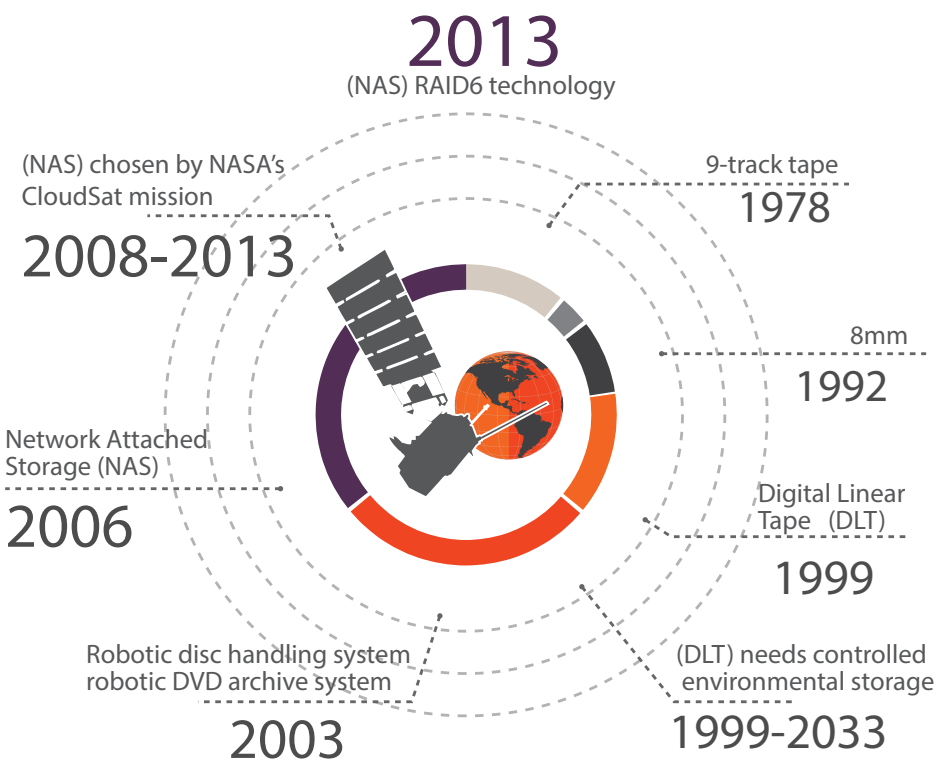
To take advantage of this storage, in 2008 CIRA's DVD archive system was modified such that as data flows into the archive queue, it is written to a NAS first, and then to DVD. Although RAID6 is reliable, it is still possible to have an array failure in extreme circumstances. To protect against a RAID failure, a DVD is created as a backup for each product. Data on DVDs prior to 2008 were uploaded to the NAS units using a new CIRA proprietary software module that allows a second robotic system to automatically restore discs in batches of 100.

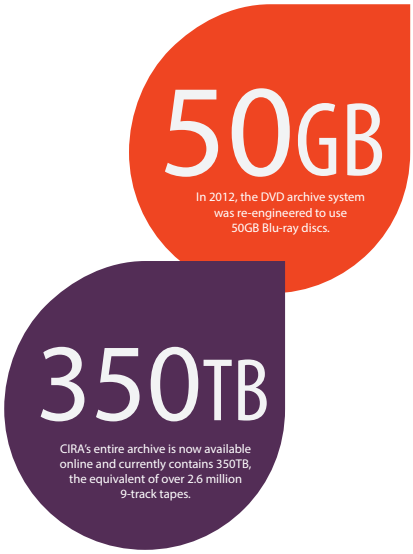
CIRA's entire archive is now available online and currently contains 350TB, the equivalent of over 2.6 million 9-track tapes.

New data sets are requiring more data to be stored at faster rates. The NAS units are easily expandable, however the 4.7GB DVD media has become too small. In 2012, the DVD archive system was re-engineered to use 50GB Blu-ray discs with the ability to use 128GB Blu-ray discs when this higher capacity media is cost effective. One robotic archive system can now handle up to 2TB per day. Additional robotic units can be added as needed for additional capacity.

CIRA's NAS storage system with Blu-ray backup provides CIRA researchers a reliable, easy to use system to access CIRA's meteorological data sets. This is the first time in CIRA's history that all data in CIRA's archive is available online, saving projects time and money.

NAS Data Storage Units





by Ken Sperow

NWS Virtual Laboratory

Imagine a laboratory accessible 24 hours a day from all over the world where scientists can collaborate, innovate and easily transition their innovations. This is the idea behind the National Weather Service's (NWS) Virtual Laboratory (VLab). The VLab will provide an environment where collaboration and innovation among geographically diverse scientists can thrive.

The VLab is a service and IT framework, being built out by the NWS Office of Science and Technology (OST) and led by Dr. Stephan Smith, Decision Assistance Branch Chief of the Meteorological Development Laboratory (MDL), and CIRA Research Associate Ken Sperow. The VLab enables NWS employees and their partners to share ideas, collaborate, engage in software development, and conduct applied research. The VLab will enable the NWS to:

- Reduce the time and cost of transitions of NWS field innovations to enterprise operations,
- Minimize redundancy and leverage complementary, yet physically separated, skillsets,
- Forge scientific and technical solutions based on a broad, diverse consensus, and
- Promote an NWS culture based on collaboration and trust

Principles:

The VLab operates under the following set of guiding principles:

- Transparency - The VLab and its staff are open and transparent in all communications and decision-making
- Teamwork - The VLab and its staff facilitate and support collaborative teamwork
- Flexibility - The VLab and its staff adapt to different and/or changing user needs
- Responsiveness - The VLab and its staff respond quickly to user needs
- Accountability - The VLab and its staff are accountable to its users through meaningful metrics

Capabilities:

The VLab is built upon a set of 5 foundational capabilities (Figure 1.) which are conceived to promote innovation across NWS through communication, collaboration, and the application of the skills and expertise of NWS employees. The first phase of the VLab promotes science sharing within the NWS and provides an Innovation Collaboration Framework which provides support and services to facilitate the transition of innovation projects to NWS operational systems. The second phase of the VLab will provide the other three foundational capabilities; 1) subject matter experts cadre, 2) adjunct science and software development team, and 3) innovation project database.

Implementation:

The VLab is comprised of two main components:

- Virtual Lab Portal (VLP)
- Virtual Lab Development Services (VLDS)

The VLP is built upon a feature rich open source Java portal framework. The VLP enables NWS users to share and contribute science and participate in dynamic virtual communities. The VLP provides powerful tools for collaborating such as document libraries, WIKIs, message boards, blogs, announcements, dynamic forms with workflow, and a content management system (CMS). All tools within the VLP are searchable and centralized. The VLP provides a full featured administrative console and robust roles and permissions framework that allows VLP administrators to delegate power to members of the VLab. The VLP is also the gateway to the VLDS.

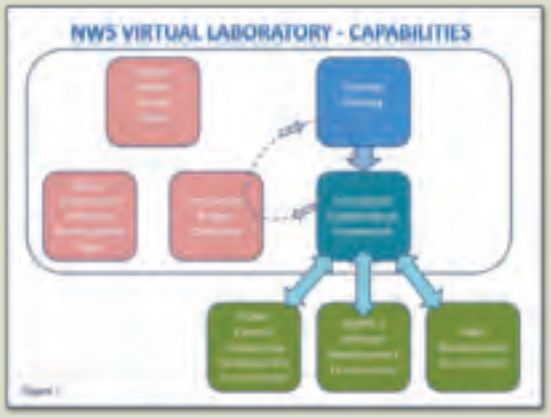


Figure 1. Flowchart of NWS Virtual Laboratory Capabilities (credit Ken Sperow/CIRA)

The VLDS provides web based services to help manage projects via issue tracking, source control sharing, code review, and continuous integration. **Redmine** is being used for issue tracking for all projects and access control for simple project's source code repositories within the VLab. Git, a distributed configuration management (CM) system, is being used for source code control within the VLab and integrates very nicely with Redmine. The distributed nature of Git fits well with the NWS' highly geographically distributed developers. **Gerrit** provides web based code review and project management tools to Git based projects in the VLab. **Jenkins** provides a web based continuous integration tool within the VLab. Projects can use Jenkins to automate the building of their code, execute unit tests, and perform custom checks anytime code is modified. It is also possible to schedule builds based on a cron pattern within Jenkins. Projects within the VLab have the option to use Gerrit and Jenkins.

In the future, the VLP will include portlets that will allow users to "share their projects" and "share their expertise." This sharing will increase visibility and transparency of projects and users' expertise further promoting collaboration.

As of this writing the VLDS is successfully supporting 11 projects and 168 developers. These projects range from AWIPS II development projects, including the "Hazard Services" project being developed by Global Systems Division (GSD) and Raytheon and overseen by the Systems Engineering Center (SEC) in OST, to develop the next generation warning tool, that uses all components of the VLab, to a field driven project called "Iris" with developers throughout the NWS. The growth of the VLDS thus far has been through "word of mouth". We are just beginning to open up the VLDS to other projects. Users can request new NWS VLab development projects within a form within the VLab. Please visit the VLab for more information.

The VLDS currently runs within a virtual machine on redundant blade servers at NWS Headquarters. Plans are being developed to move all AWIPS II development within the VLab and potentially host the VLDS within the cloud or shift hosting to the NWS Internet Dissemination System (NIDS), where the VLP is hosted today. Moving all AWIPS development to the VLab will promote transparency and ease the transition of projects from development to the operational baseline.

We are excited by our flagship AWIPS collaboration community that will be rolled out this Spring. The AWIPS community contains important information for AWIPS users and developers, ranging from how to setup your development environment to the latest AWIPS II release plan. The VLab will be the place to go to find out the latest regarding AWIPS as well as provide an interactive and dynamic environment to collaborate with other NWS users. Users will be able to request their own community within the VLab that includes forums, blogs, WIKI, and CMS.

The future looks bright for the VLab.

Figure 1. Airglow, moonlight, starlight from ISS (credit NASA)

Suo MI NPP
A Light in the Darkness
– A VISIoN oF t He 'BLACK MAr BLe'

by Matt r ogers

The setting sun paints the sky in glorious colors, followed by streetlights and house lights turning on everywhere. Another day has ended, and darkness falls as people turn in for the night. But the darkness is not complete - perhaps a full moon shines high in the sky, or twinkling starlight provides a faint shimmering light to the quiet Earth below. High up in the atmosphere, a photochemical process creates a still fainter glow, creating new light out of the remains of the bright sunlight from earlier that day. It seems that the dark of night is perhaps not so dark at all, and in its orbit 825 kilometers above the Earth's surface, a research satellite is using a sophisticated sensor to see the Earth's nighttime side in a completely new light.

The Suomi National Polar-orbiting Partnership (Suomi NPP) mission, a joint endeavor between NOAA and NASA, is an atmospheric observation and research satellite that was launched on October 28, 2011. (Details of the launch of Suomi NPP can be found in the Spring 2012 issue of CIRA Magazine.) Five scientific instruments are aboard the Suomi NPP satellite: the Advanced Technology Microwave Sounder (ATMOS), which provides vertical profiles of temperature and water vapor; the Cross-Track Infrared Sounder (CrIS) which provides 3D observations of temperature, pressure, and moisture; the Ozone Mapping and Profiler Suite (OMPS) which measures ozone; a copy of the Clouds and the Earth's Radiant Energy System (CERES) sensor, which is measures short- and longwave radiation from the Earth; and the Visible Infrared Imaging Radiometer Suite (VIIRS), a 22-channel advanced radiometer which sees the Earth at multiple wavelengths in the visible and infrared spectrum, including a revolutionary Day-Night Band (DNB) sensor capable of seeing extremely low levels of visible light.

The VIIRS instrument represents an evolution of previous radiometers such as the Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments flown on previous missions. VIIRS data, which collects information about visible and infrared energy from the Earth, can be used to compute properties of clouds and aerosols, ocean color, surface temperature, and fires as seen from space. The instrument, which continually scans the surface of the Earth, has a pixel resolution of 750m, and based on the orbital parameters of its parent satellite, gets a complete view of the Earth roughly every six orbits, which takes a little more than eight hours.

The DNB sensor, part of the VIIRS instrument, is a sensor that sees primarily visible light between 0.505 and 0.890 microns, but is much more sensitive than most traditional sensors. The DNB sensor has three 'stages' of electronic gain that allow the sensor to take measurements during the daylight, twilight, and nighttime. By selecting the high-gain mode, the DNB can 'see' in the dark, collecting light that would register below the noise threshold for most instruments.

r emote Sensing at Night: *Light Sources In The Dark*

During the daytime, the visible light that we see comes from the sun. From space, what a satellite sees during the daytime is the sunlight reflected by different components of the Earth's systems; reflection from the land surface, including plants, cities, snowfields, deserts, etc., as well as reflection from the ocean and from clouds.

Scientists can learn more about these features by observing how sunlight reflects off of each object — for example, the differences in how sunlight reflects from low clouds composed mostly of liquid water droplets versus how sunlight reflects from high, thin ice clouds can tell us more about the properties of each cloud. When these observations are combined with other sources of radiation (such as infrared radiation emitted by clouds and by the Earth's surface) even more can be learned about the Earth's systems. Of course, there's a catch — the bulk of the visible light available to see comes from the Sun. What happens during the nighttime, when the Sun's rays aren't available to use as an illuminating source? Several light sources are available – Figure 1. shows many of these sources as seen from the International Space Station using special low-light cameras. A brief description of these light sources include the following:

Moonlight

One source of light at night is the Moon. Light from the Moon is, of course, just sunlight that has been reflected off the Moon's surface that illuminates the Earth, as if the Moon were like a mirror in space redirecting sunlight to the Earth's surface. Light from the Moon is a strong source of visible light during the night when the Moon is full (or, in other words, when the Moon in its orbit is ideally located to reflect the maximum amount of light to the Earth's surface). Scientists can use the known orbital properties of the Moon to compute the amount of light available to the surface of the Earth, but even at its fullest, the maximum amount of light from the Moon is still almost a million times less than that from the Sun.

Starlight

Another source of visible light at night comes from the stars. Consisting of light from the stars we can see from the Earth (including from the Milky Way galaxy) and the combined light from all the stars that are too distant to be seen individually from the Earth, starlight provides a small amount of visible light that can be seen by a sophisticated sensor such as the DNB. Starlight, which is approximately 1000 times dimmer than moonlight, can also be predicted by scientists using the known orbital properties of the Earth in relation to the location of the stars.

Zodiacal Light

Zodiacal light is sunlight that is scattered off of interplanetary dust in the solar system and reflected towards the Earth. This very weak source of light bathes the solar system in a faint glow at all times, and contributes to the amount of visible light that can be seen at night. Zodiacal light is approximately 1000-2000 times dimmer than moonlight.

Airglow

An interesting source of light at night is called 'airglow'. To understand airglow it helps to take a moment to understand the structure of the Earth's atmosphere, which is made of several layers. The first layer, called the troposphere, extends from the surface to an altitude of approximately 10-20km, depending on latitude and season, and contains most of the Earth's air and water vapor, and effectively all of the weather on the planet. Above the troposphere is the stratosphere, which extends from ~10km up to ~50km, and includes the ozone layer, which

shields the Earth's surface from ultraviolet radiation and cosmic rays. Above the stratosphere, from 50km through 100km, is the mesosphere. Here, the density of the atmosphere is 1000 times less dense than at the surface of the Earth, and ionizing radiation can interact freely with the tenous gases of the upper atmosphere.

During the daytime, ultraviolet radiation from the Sun continually breaks apart molecules of oxygen-containing molecules. In breaking apart, these molecules acquire some of the energy from the incoming radiation. During the nighttime, these energized molecules chemically recombine, and in the process, release their acquired energy in the form of visible light. The resulting glow, which is approximately 100-1000 times dimmer than moonlight, is called 'airglow'. Airglow is easily seen from space, as the photo from the ISS above demonstrates, but predicting the strength of the light is difficult — the variability in the photochemical processes that create airglow is not a process that is well understood by scientists yet.

Human-created light

Finally, one additional source of light is available for satellites: city lights! A sensitive instrument such as the DNB can easily see the emitted lights from human civilization on the planet, as is also seen in the photo from the ISS.

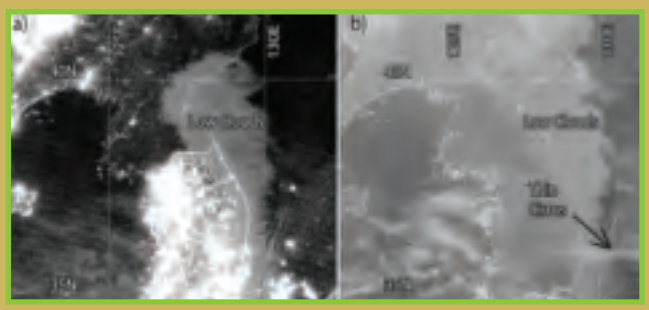


Figure 2. DNB (left) and infrared (right) images of Korea taken from VIIRS. (credit CIRA)

Seeing the earth at Night: Low Clouds

All of these light sources can be used to look at the Earth — the VIIRS DNB sensor lets us see using only airglow and starlight. So what does the Earth look like at night using only airglow and starlight sources? Figure 2. provides a comparison picture, taken over the Korean peninsula from VIIRS. The image on the left was taken using the DNB sensor, while the image on the right was taken using one of the infrared sensors aboard VIIRS.

Infrared light, which is constantly being emitted by the Earth, is easily detected at night, and prior to the advent of the DNB, represented one of the few ways to 'see' clouds at night. The amount of infrared light generated depends on the temperature of the object emitting the infrared light; in the case of very low clouds, whose temperature is very close to the surface temperature of the Earth, this results in an infrared signature that is difficult to discern from the surface. In other words, certain types of clouds are very difficult to see at night using infrared emissions, and this can be seen in the comparison images. In the image, a low cloud deck starts roughly in the middle of the peninsula and extends eastward over the ocean. The temperature of this cloud deck is very nearly the same as the ground temperature, meaning both cloud and ground have nearly identical infrared signatures. And in the infrared image on the right, the cloud layer is difficult to see — one flat gray feature in a sea of flat gray features.

The low cloud deck, however, looks very different in the visible spectrum, however, since the water drops that make up the cloud reflect visible light very differently than does the soil, vegetation, and other surface feature of the ground. In the image on the left, taken from the DNB sensor, reflected starlight and airglow from space reflect off the low cloud feature, giving it a light grey hue over the much darker surface of the Earth's land and ocean features. Combined with the city lights of urban South Korea, the DNB image provides much more detail and information for locating cloud features at night.

Seeing the earth at Night: Atmospheric Interactions

Another revolutionary way in which data from the DNB sensor is changing our understanding of the Earth's atmosphere is by looking at previously unseen interactions between the Earth's lowest layer, the troposphere, and the upper layers, including the mesosphere.

As mentioned previously, nearly all of the Earth's weather (and certainly, all of the weather we encounter) occurs in the troposphere. In Figure 3., a thunderstorm is moving across the Texas plains, just outside of Midland. Again, the image is a comparison image, with an infrared picture of the cloud on the right, while the DNB visible image is on the left. Because the thunderstorm is much colder than the surface, this time it is very easy to see the thunderstorm's signature in the infrared; a faint reflection of airglow and starlight is also visible off the cold cloud tops in the DNB image as well. Besides the prominent city lights, one other feature is clearly noticeable in the DNB image: 'waves' of light appearing to radiate away from the center of the image.

What could be causing these waves? The overall structure looks similar to ripples in a pond caused by a thrown stone; here the center of the ripples is just to the west of the thunderstorm, at a location that the thunderstorm would have passed through perhaps a few hours previously. The thunderstorm over Texas is occurring in the troposphere, and consists of a large central updraft plume at the core of the thunderstorm, bringing air from the surface to the top of the troposphere, perhaps 15km up. We know very little about the small-scale details of the structures of the upper atmosphere, but we do know that the stratosphere, the layer of the atmosphere immediately above the troposphere (and our thunderstorm) is very stable; disturbances at the bottom of the stratosphere could be transmitted through to the top of the stratosphere like a wave through a spring. Once into the mesosphere, where there is a drastic decrease in temperature with height compared to the stratosphere, these disturbances would radiate outwards like waves in a pond. If we know the strength of the thunderstorm (which we can measure with radars and other instruments) we can compute the strength of the vertical disturbances through the stratosphere; if we know the depth of the stratosphere we can compute how long it should take to those disturbances to be made known in the mesosphere, giving us indirect observations of how motions in the lower atmosphere affect the upper atmosphere.

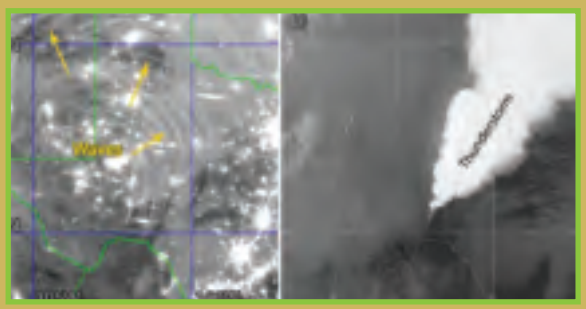


Figure 3. DNB (left) and infrared (right) images of Texas thunderstorm from VIIRS. (credit CIRA)

This is all well and good, but why do we see these waves? The answer: airglow! The mesosphere is the region of the atmosphere where airglow is created, and the disturbance from the lower atmosphere is creating waves in the light-emitting upper atmosphere, creating regions of higher- and lower amount of light-emitting air. Thunderstorms are ubiquitous in the troposphere, and the disturbances they create in the upper atmosphere must be happening all the time, but thanks to airglow and the DNB, we now have the ability to see the disturbances, for the first time.

Putting it all together

What else can we expect to learn by looking at the Earth at night using starlight and airglow? For the first time, we have the capability to leverage techniques previously only usable during the day at night, using natural light sources. Effectively, the day is now twice as long for research scientists using the DNB sensor aboard the Suomi NPP satellite.

- Low level features like tropical clouds can be seen, which means these clouds can be masked out, making measurements of sea surface temperature more accurate, for one. The amount of low-level cloud also has an important role in understanding climate records, and nighttime observations of low cloud will improve that dataset as well.
- Additional imagery of tropical storms at night, such as the image of Hurricane Isaac making landfall in the Gulf of Mexico (Figure 4.) will help forecasters make more accurate forecasts, potentially saving lives.
- Snow fields and sea ice can be seen at night now as being distinct features from non-ice surface features.

- Polar winter observations are now possible in the visible – previously, no visible observations over Antarctica, for example, were available for much of the year. Starlight and airglow observations make those measurements possible.
- Understanding features of the mesosphere are also now possible – few instruments can see the mesosphere, and direct measurements aren't easy to take, outside of rocket launches. Seeing mesospheric structures due to changes in the light-emitting layers in the mesosphere will give us the first long-term view of how the mesosphere works.

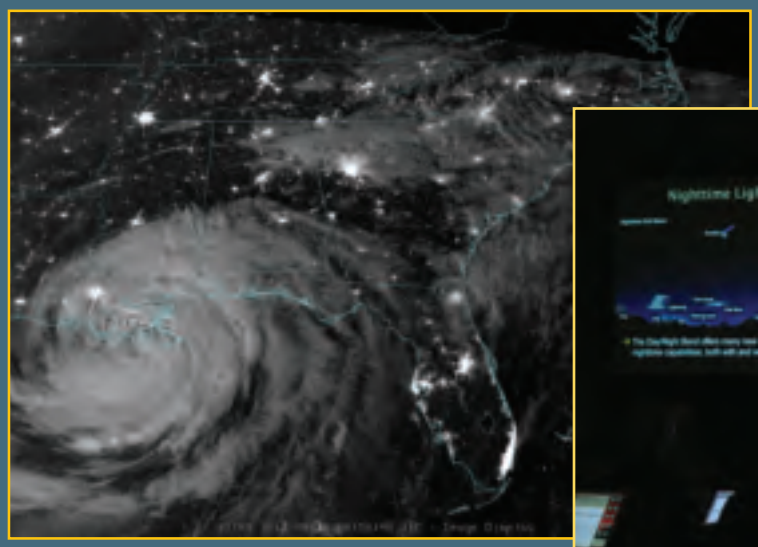


Figure 4. Isaac landfall image at night (credit CIRA)

CIRA Deputy Director Steve Miller (far right)

Several of the advances listed here are underway already – groundbreaking research detailed in the September, 2012 issue of the Proceedings of the National Academies of Science, led by CIRA Deputy Director and scientist Dr. Steve Miller, in collaboration with colleagues from CIRA/RAMMB, NOAA/NGDC, and other partners including Northrup Grumman, and the Naval Research Laboratory, provide the images and insight used for this article.

Finally, at the Fall 2012 meeting of the American Geophysical Union, a joint NASA/NOAA press conference detailed still more results from the DNB sensor, including a first-ever series of compilation images of the nighttime Earth, dubbed the 'Black Marble' (in reference to the popular 'Blue Marble' series of photos of the daytime, starting with the iconic photo from the Apollo 17 mission, and including compilations made by MODIS observations in 2002 and from the VIIRS instrument in 2012.) These extremely high-resolution images, (Figures 5.-7.) composed of multiple overpasses of the DNB instrument over several disparate weeks in April and October, 2012 shows the impact of humanity on the night – city lights blazing under clouds detailing where

Figure 5. Artist's composite of the 'Black Marble', from over the Atlantic Ocean

Figure 6. Whole-Earth composite of cloud-free nighttime observations from the DNB instrument, showing city lights visible from space.

Figure 7. The continental United States as seen in a cloud-free nighttime composite

humanity has scratched out a home in the blackness of space CIRA Deputy Director Steve Miller co-chaired the conference, and with his colleagues from NASA and NOAA showed still more compelling images of the Earth at night.

The capabilities of the DNB instrument will provide scientists and researchers with years of new observations and should contribute to many new breakthroughs in our understanding of the Earth and its systems. Moreover, our ability to see the Earth at night gives us perspective to our place on this planet. From the darkness, and what we can learn from it, a new dawn of understanding becomes possible, and CIRA scientists work at the forefront of this exciting new field of research.

Moving Weather Model Ensembles to a PostGIS Database

by Jeff Smith

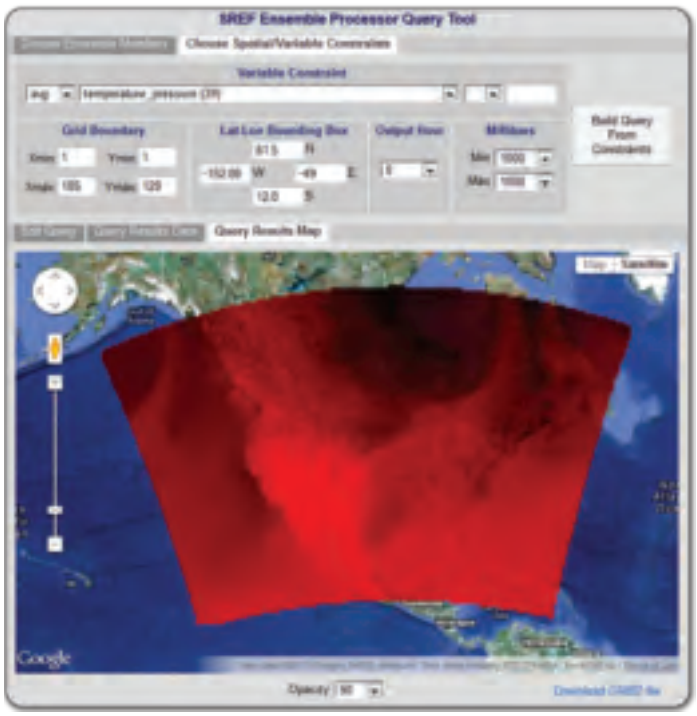
Moving weather model gridded data to a geospatial database such as PostGIS (an extension to Postgres) will enable forecasters to access and analyze the data in novel ways. For our initial development, we chose the NCEP 40km SREF (Short Range Ensemble Forecast) that contains 21 ensemble members from several weather models and 90 meteorological variables, each for 56 different forecast output times. This large amount of data is split into ~1200 grib2 files, and it gets updated every six hours. That's a lot of data and it is difficult to examine that many files and mine this forecast data to answer questions such as

- "What is the maximum wind between 250-500 mb over the United States from forecast hour 30-35, and which ensemble member predicted the highest value?"
- "What is the mountain obscuration along the Colorado Front Range at forecast hour 22?"
- "What is the ensemble mean temperature at every grid point at 950mb within an air corridor along the East Coast at forecast hour 10?"

once the data is in the PostGIS database, it is very easy to query.

Photo by Mark Efaw

To answer questions such as these, a forecaster typically writes a computer program that opens and reads each of these ~1200 files, potentially writes the intermediate results to some multi-gigabyte intermediate file, scans this intermediate file to build an array of data values, and then writes these data values back to disk in the form of a grib2 file. This is a time-consuming process involving developing and testing complicated program code, and the run time performance is poor.



To make this process much faster and simpler (requiring no programming effort on the part of a forecaster viewing data or performing research in a specific area), as part of the Aviation Weather Center (AWC) Ensemble Processor project, I wrote a program that dynamically builds a PostGIS database schema from a user supplied xml file, then imports the grib2 files into it. Since this import process must run every 6 hours when a new SREF is available, I "tricked out" the PostGIS database with a number of optimizations, made the Java import program multithreaded to take advantage of multicore processors, and leveraged the Postgres bulk load (copy) feature to achieve tens of thousands of data inserts per second.

Ultimately, the AWC server was able to import the data in a little over an hour, with the table indexes requiring another 45 minutes. The database contains a couple of billion rows of data and the size of the data tables is 115 GB with the indexes consuming another 75 GB, for a grand total of 190 GB.

Once the data is in the PostGIS database, it is very easy to query. Here's an example of a simple PostGIS query for the ensemble mean temperature at 1000 mb within the CONUS lat-lon bounding box. 'This query, equivalent to reading/aggregating approximately 1200 multi-megabyte GRIB2 files, executes in a lightning-fast five seconds within PostGIS:

```
select avg(V.temperature_pressure) as value, G.x, G.y,
ST_AsText(G.geom) as latlon
  from  sref_member M, sref_grid G, var39_f1 V, table_levels L
  where M.sref_member_id = V.sref_ member_id
   and G.sref_grid_ID = V.sref_grid_id  and  L.table_levels_id =
V.table_lev- els_id
   and L.mb = 1000  and  L.total_levels  =  39
   and  G.geom  &&  ST_MakeEnve- lope (-153,12,-49.3, 61.5,4326)
   group  by  G.x,  G.y,  G.geom
   order  by  G.x,  G.y
```

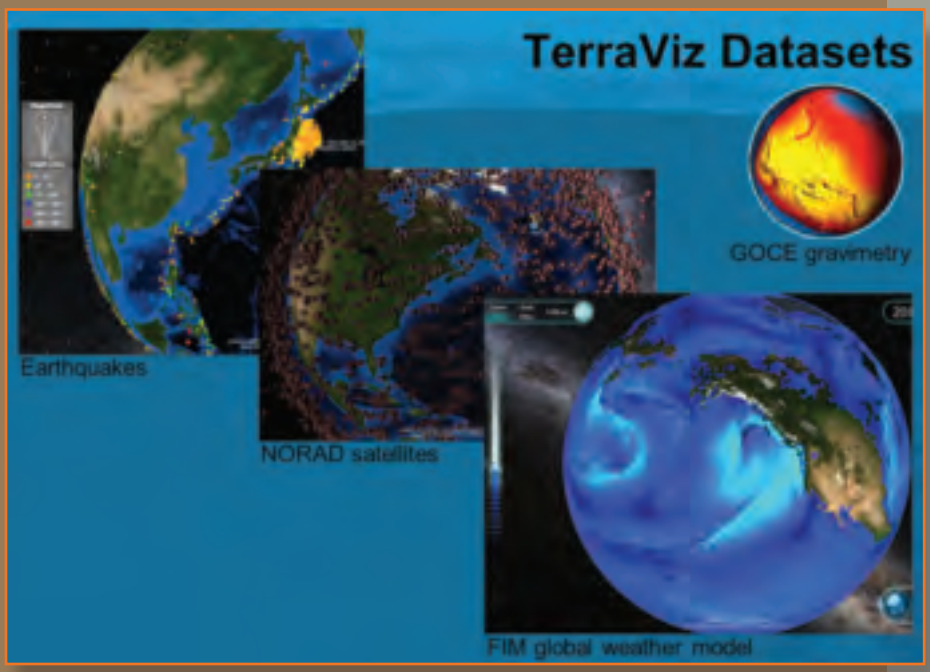
Users can quickly formulate and submit their queries via a web service interface so they can use the PostGIS database as a building block for their own custom applications (which can be run on demand or automatically in batch mode), or they can use the HTML 5 web application.

This web application runs in web browsers, including on tablets such as the iPad, and it enables users to type in and save custom queries, or users can simply select constraints (shown on the screen below) and then press the "Build Query From Constraints" button to have the software build the query for them. Plottable results are displayed on top of Google Maps and a grib2 file is also generated. This grib2 file can be imported into NAWIPS or the new AWIPS2.

Making the SREF and other weather forecast ensembles available for easy data mining will empower forecasters to create new data products (such as mountain obscuration) and perhaps find new insights into the underlying weather models themselves.

3D Data Visualization Using the Unity Game Engine

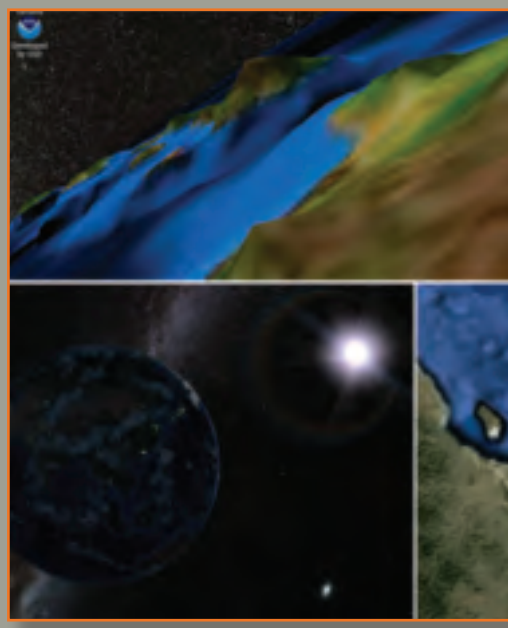
by Jeff Smith



Visualizing 3D data is an ideal task for game engines because they have been optimized over many years to leverage GPU video cards and generate high frame rates (screen updates per second) for video games running on Mac/Win/Linux PCs, mobile devices like the iPad, and game consoles like the Xbox360, Wii U, and Playstation. With this blindingly fast performance, game engines can just as easily visualize millions of environmental data points as display the millions of polygons that comprise a scene in a game like Call Of Duty.

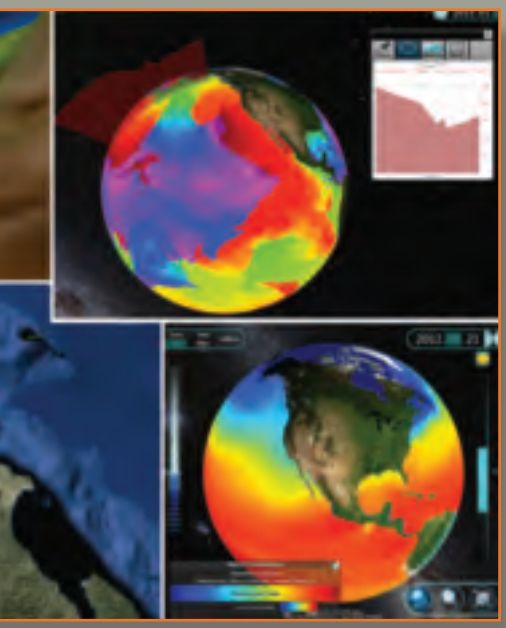
My group at NOAA/GSD (which includes Julien Lynge and Eric Hackathorn) has created a spinning globe application in Unity called TerraViz which can, among other things, visualize millions of coupled ocean-atmosphere model polygons on the screen at one time (from a vast, 28 GB dataset), enabling users to rapidly "fly" through the data both temporally and spatially, from the bottom of the ocean to the top of the atmosphere. TerraViz can also render satellites in orbit, KML, videos, images from web mapping services (WMS), as well as wrap hi-res satellite imagery over the 3D topography of the Earth.

As a software engineer, migrating from more conventional software development in Java, C, Fortran, or Python to 3D development in Unity, involves a major mental paradigm shift. You create a virtual world (or scene) of 3D objects, be they mountains, atmospheric rivers, or particles being emitted from a volcano. You add



lighting to illuminate your scene, add cameras at advantageous locations which can be moved by the user in real-time (by mouse, keyboard, or multi-touch), and then let the game engine render the scene at run-time. As a developer, you think in terms of concepts such as game objects that have 3D transforms, colliders, meshes, materials, textures, and shaders.

With Unity development, you spend part of your time in the Editor, manipulating assets, moving game objects in 3D space, modifying lighting, adjusting cameras, and perhaps editing graphical user interface widgets like buttons, text boxes, and drop down lists.



The Unity Editor

The majority of your time, however, is spent writing scripts and additional program classes for your project. Unity supports JavaScript, Python, and C# (which is similar to Java and is the language we chose). The Unity API (application programming interface) follows an object oriented model that is well documented on the Unity website. C# is easy for Java developers to learn and made the transition for our development team as painless as possible. Unity's advantage over other game engines include price (there is a free version and the professional version that we use is $1500 which sounds like a lot until you compare it to some other game engines with $100,000+ price tags) and the online development forums that can be "Googled" to find answers to many common questions.

While there is a steep learning curve involved with adopting Unity as a platform for data visualization, the effort is rewarded with on-screen results that are simply stunning. To learn more about TerraViz, visit our website at http://www.esrl.noaa.gov/neis/.

Communiqué

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Banner I. Miller Award in 2012

Mark DeMaria won the Banner I. Miller Award in 2012 for the 4th time. The award is presented for an outstanding contribution to the science of hurricane and tropical weather forecasting published in a journal with international circulation during the 48 months prior to the November 1st deadline for nominations. The award is presented at each Conference on Hurricanes and Tropical Meteorology. Recommendations are prepared by the STAC Committee on Tropical Meteorology and Tropical Cyclones.

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VIIRS Imagery Team for the Suomi NPP mission

CIRA Affiliates Don Hillger and Dan Lindsey, along with CIRA staff including Steven Miller, Curtis Seaman and Stan Kidder received Certificates of Recognition from NASA, as a result of their work on the VIIRS Imagery Team for the Suomi NPP mission. (December 2012)

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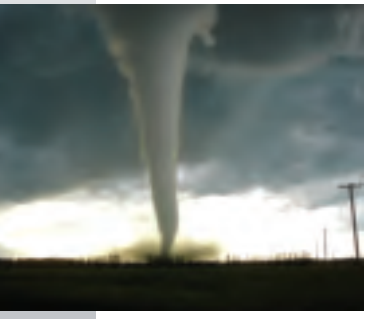
Honored him for his in-depth analysis of convective cloud interactions and large-scale atmospheric circulation

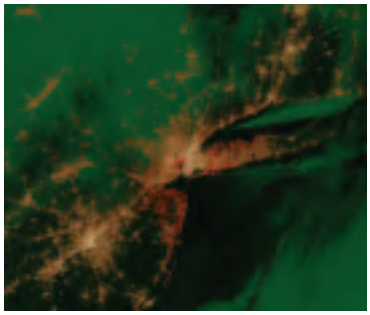
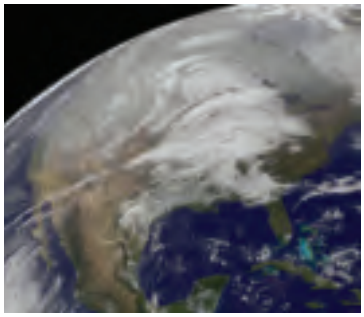
CIRA Fellow and CSU Department of Atmospheric Science professor, Dr. Richard Johnson received the 2013 American Meteorological Society's Verner E. Suomi award at this year's annual gathering in Austin, Texas. The award is named for the father of satellite meteorology and recognizes significant technological achievement in the atmospheric or hydrologic and oceanic sciences. Dr. Johnson was honored for his design of rawinsonde networks in field campaigns, which use balloon-borne meteorological sensors to measure wind, temperature and moisture in the atmosphere. The AMS honored him for his in-depth analysis of convective cloud interactions and large-scale atmospheric circulation.

AGu r eSeAr CH SPot LIGHt

AGU Research Spotlight

John Haynes, a CIRA Research Scientist will have the "spotlight" trained on his work in an upcoming publication. A recent Haynes et al (2013) paper has been selected by the American Geophysical Union for their "AGU Research Spotlight" on the back page of an upcoming edition of their widely-read EOS publication. The paper titled, "Radiative heating characteristics of earth's cloudy atmosphere from vertically resolved active sensors," describes research using instruments onboard the CloudSat and CALIPSO satellites to study the radiative heating and cooling characteristics of the layers of the cloudy atmosphere. Among the co-authors was CIRA Director Emeritus Thomas H. Vonder Haar.



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OAR RAP team responsible for the development, integration, and transition of the next generation of NOAA's hourly North American prediction

A collaboration between CIRA and NOAA staff known as the "Rapid Refresh Team" received an estimable commendation for their work. The announcement occurred on February 7th and honored the OAR RAP team responsible for the development, integration, and transition of the next generation of NOAA's hourly North American prediction, a foundation for realizing NOAA's "Weather Ready Nation" strategies as well as position NOAA for emerging service areas.

Group Effort: Brian Jamison, Haidao Lin, Kevin Brundage, Tracy Lorraine Smith and Bob Lipschutz

The following CIRA employees were recognized as part of this group effort: Brian Jamison, Haidao Lin, Kevin Brundage, Tracy Lorraine Smith and Bob Lipschutz. Director Christian Kummerow offers "my sincerest congratulations. Not only does this award recognize your personal accomplishments, it also reflects positively upon all CIRA employees who are ultimately elevated by your efforts."

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"Webbies" recognize "VERIFIED" and "SOS" website

Every Year, NOAA Global Systems Division staff nominate and vote on the "Webbies" or web awards to recognize outstanding websites. CIRA folks that were honored by their co-workers include those involved with two of the five winning sites": called "VERIFIED" and "SOS."

VerIFICAt IoN o F IMPACt -tr ANSLAted Fore CASt S For INt eGr Ated deCISIo N-MAKING

http://esrl.noaa.gov/fiqas/tech/impact/verified/

The team included Missy Petty and Paul Hamer of CIRA, along with Geary Layne and Matt Wandishin of NOAA. The website allows aviation decision makers and forecasters access to weather information that is provided in a form directed toward operational traffic flow decisions. Users can render images that are developed in real-time with hover capability, looping, toggle functionality and product selections. Users have access to real-time graphics, which are updated as newer information becomes available, as well as access to historical information.

SoS - SCIeNCe oN A SPHere®

http://sos.noaa.gov/

The web team includes Irfan Nadiadi (lead) and Michael Biere of CIRA, as well as Shilpi Gupta and Beth Russell of NOAA. As we featured in our fall 2012 issue of the CIRA Magazine, the SOS site has been completely redesigned – from the aesthetics to the structure of the content. The result is a more intuitive and user-friendly site with improved navigation and organization and a database implementation to manage a data catalog of over 350 data sets.

CIRA Vision and Mission

The Cooperative Institute for Research in the Atmosphere (CIRA) is a research institute of Colorado State University.

The overarching Vision for CIRA is:

To conduct interdisciplinary research in the atmospheric sciences by entraining skills beyond the meteorological disciplines, exploiting advances in engineering and computer science, facilitating transitional activity between pure and applied research, leveraging both national and international resources and partnerships, and assisting NOAA, Colorado State University, the State of Colorado, and the Nation through the application of our research to areas of societal benefit.

Expanding on this Vision, our Mission is:

To serve as a nexus for multi-disciplinary cooperation among CI and NOAA research scientists, University faculty, staff and students in the context of NOAA-specified research theme areas in satellite applications for weather/climate forecasting. Important bridging elements of the CI include the communication of research findings to the international scientific community, transition of applications and capabilities to NOAA operational users, education and training programs for operational user proficiency, outreach programs to K-12 education and the general public for environmental literacy, and understanding and quantifying the societal impacts of NOAA research.

Cooperative Institute for Research in the Atmosphere

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Colorado State University

Photo credit: Dan and Cindy Duriscoe
Dan Duriscoe stands next to NPS Night Skies team member Jeremy White taking data on top of Mauna Kea summit.