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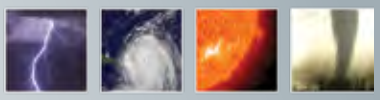
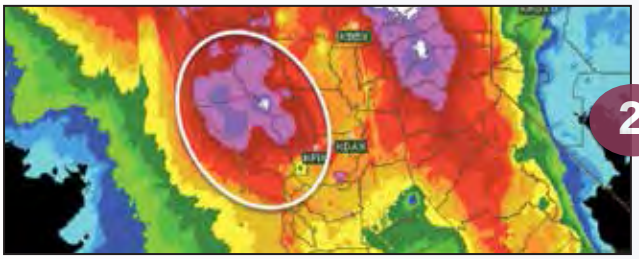
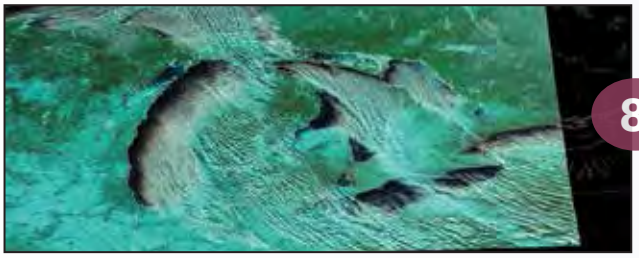


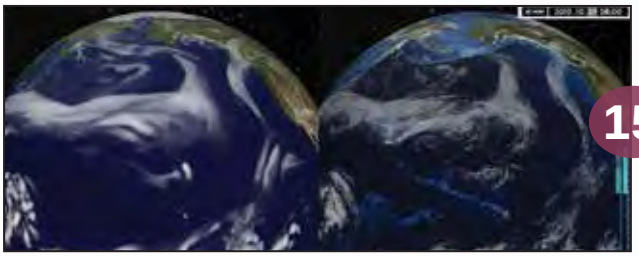
College of ENGINEERING

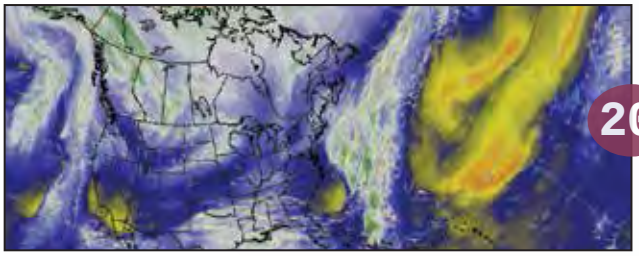
In the Wake of Hurricane Sandy: Improved Global Forecasts

Colorado State University









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From the Director's Desk . . .

In the previous CIRA magazine, I began talking about reconnecting CIRA to its origins dealing with the improvement of models through the use of observations. Some of that was motivated by the great strides being made within NOAA and a number of CIRA folks with respect to high resolution global models. As these models begin to embody the physics of clouds and precipitation, the scales that need to be observed become the same scales with which we generally observe clouds and precipitation from our current satellite systems. Leading the way in this modeling activity is the High Impact Weather Prediction Project – a bit of which is laid out in this issue. Indeed, we are planning a retreat involving a diverse set of CIRA experts from modeling, satellite observations and data assimilation to specifically explore mechanisms for strengthening the cross-disciplinary communication needed to improve the model physics in addition to more traditional data assimilation approaches. I strongly believe that new 5 minute full disk images that will be available from GOES-R next year will revolutionize what we can do to put geophysical parameters derived from a large constellation of polar orbiting satellites into the temporal context needed to understand the underlying physics of cloud processes.

The launch of GOES-R early next year was certainly made more real recently with the release of preliminary data from JMA's Himawari-8. Its early images are both spectacular and revolutionary in the insight they offer. Here at CIRA, we are getting ready to receive and process the GOES-R data. With an antenna system about to be installed, and a GOES-R software simulator on loan from NOAA, we are getting ready to use the data as soon as it becomes available early next year.

Also in this issue, you will find a longer article on a concept we've called "Sea to Summit to Sea" to reflect the cycling of water, particularly on the West Coast of the United States. Unlike many meteorological studies of water cycling, this study includes water budgeting and decision support that is critical to properly model water that often is not sufficient to meet the requirements of competing stakeholders. As with the process studies above, we hope to continue building this theme to integrate observations and models into decision support tools as part of NOAA's mission of providing services rooted in science.

While not covered in this issue of the magazine, I would like to take this opportunity to thank everyone from CIRA who participated in NOAA's Satellite Science week that was held in Boulder the week of February 23rd. A number of keynote and invited talks were given by CIRA members, including Tom Vonder Haar, who gave an historical overview of the NOAA satellite record, Steve Miller who gave an overview of the VIIRS Day/Night band capabilities, John Knaff who discussed tropical cyclone structures, and John Forsythe who talked about blended Hydrometeorological products for the JPSS/GOES-R era. This was in addition to Dan Lindsey's overview of the GOES-R risk reduction activities and my own talk on new opportunities in the climate observation from GOES-R and JPSS.

Finally, I would also like to welcome new members to the CIRA team. Biljana Orescanin and James Taylor are part of the first class of Data Assimilation Interns to be hosted by CIRA. They will be with us for one year while learning basic theory and practical aspects of the NOAA Data Assimilation enterprise. In addition, Julie Schramm has joined our ESRL team as a Research Associate while Vanessa Vincente has joined the COMET team after getting her degree at CSU. Yiaoxing Huang is the latest Post-doc to join our team in College Park while Robyn Tessmer has joined our team at the Aviation Weather Center in Kansas City. In addition, Matthew Sienkiewicz has joined us, albeit remotely from Stony Brook and Christopher Panella is a new research associate in Fort Collins. Welcome to all, as well as our new hourly employees - Colleen Goodwin, Isabelle Granger-Frye and Patrick Sobolewski.

Chris Kummerow

Sea to Summit to Sea Modeling

Total Water Budgeting and Decision Support

Lynn Johnson, Rob Cifelli, V. Chandrasekar, James Halgren, Chengmin Hsu,
Mimi Hughes, Chris Fields, John Labadie, Gary Wick, and Robert Zamora

The overarching goal of our research is a "Sea to Summit to Sea" integration of observations, numerical models and forecast systems to advance the science and obtain improved public safety and water management services. Advances in precipitation tracking and forecasting from the sea and across the landscape provide the foundation for improving land surface water budgeting and river flow forecasting. Given these "natural" flows it is further required that water management influences of reservoir storage and diversion be accounted to obtain accurate flow estimates throughout a watershed as the rivers track back towards the sea.

The Hydrometeorology Modeling and Applications (HMA) Team at NOAA ESRL Physical Sciences Division involves CIRA, NOAA and CIRES meteorologists, hydrologists, water resources and systems engineers working to develop and test an integrated system of observations, models and networks to demonstrate new environmental services that might be obtained for the National Weather Service (NWS) and other water management entities in the Russian River basin, CA. Partners involved include the California-Nevada River Forecast Center (CNRFC), the NWS Weather Forecast Office for San Francisco-Monterey (WFO-MTR), the Sonoma County Water Agency, the California Department of Water Resources (CA-DWR), the National Marine Fisheries Service (NMFS) and various other local water management agencies. These activities are an outgrowth of NOAA's 10-year Hydrometeorology Testbed (HMT) program.

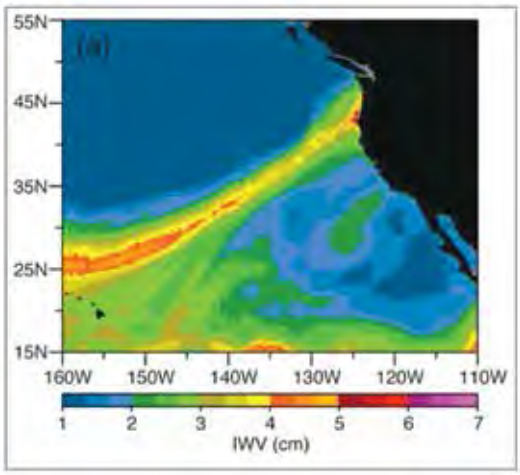
Russian River, California

The Russian River watershed encompasses 1,485 square miles within Sonoma and Mendocino Counties, CA. It is one of the most flood-prone rivers in the State of California because of the watershed's unique geography and its exposure to atmospheric rivers (ARs) which produce heavy wintertime rainfall, frequent flooding and mudslides. In addition to the flood threat, ARs provide a main source of water volumes for water supplies for a burgeoning population of more than 600,000 in Sonoma County. There are tradeoffs between reservoir storage for water supply versus maintaining capture volumes for floods. And diversions for vineyard irrigation and frost protection continue to expand in response to high value wine industry demands. Further, endangered salmon fisheries require tributary and main stream flows during the late summer and early fall spawning season when precipitation is scarce and agriculture, recreation, and other water supply demands are high.

Russian River basin

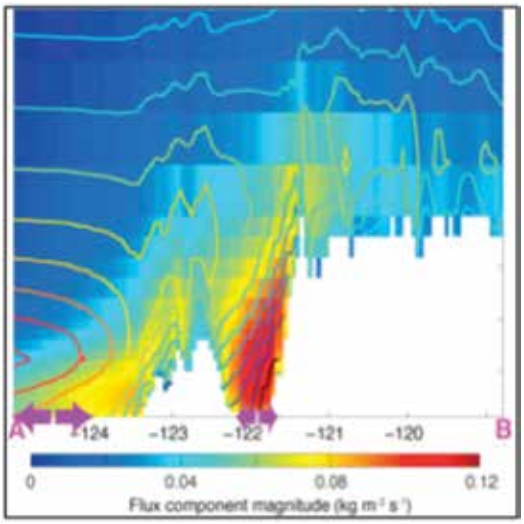
Gridded Precipitation Information

Gridded precipitation information involves mapping of precipitation occurrence and forecasts as storms advance from the ocean over the land. An automated, objective tool for identifying and characterizing the integrated water vapor (IWV) signature of atmospheric rivers (ARs) based on satellite-observed or model derived IWV fields has been developed, demonstrated, and validated (Wick et al 2013). AR detection and tracking provides advanced lead time on incoming storms which can inform reservoir operations for floods and water supply. This tool is currently being tested in other parts of the U.S. to see if it has skill in identifying ARs and forecasting heavy rain events outside of the west coast region.



Atmospheric river as seen in water vapor analysis

Numerical weather prediction models are also being applied to provide forecasts of heavy rainfall events for the region. High resolution versions of the Weather Research Forecast (WRF) system are being applied that attempt to better represent orographic influences on wind patterns (i.e., barrier jet) and precipitation gradients in this mountainous region (Hughes 2012). Other forecast models being applied include the Global Forecast System (GFS) and High Resolution Rapid Refresh (HRRR) models.



Orographic impact on Californian wind patterns in WRF

Within the basin a primary research focus is to advance the capabilities of the Multi-Radar/Multi-Sensor System (MRMS). MRMS is a system with automated algorithms that quickly and intelligently integrate data streams from multiple radars, surface and upper air observations, satellite data and forecast models. HMA Team research has involved assessment of accuracy of alternate configurations of rain gage and radars for improved multi-sensor quantitative precipitation estimation (QPE), and refinement of radar Z-R relationships to west coast storms (Cifelli et al. 2013). Gap-filling radars provide a means to detect and track low-level precipitation fields as they progress inland. CIRA's Dr. V. Chandrasekar leads a team which develops and deploys these X-band radars in the mountainous terrain of coastal California (Lim et al 2013).

Gridded Hydrological Model

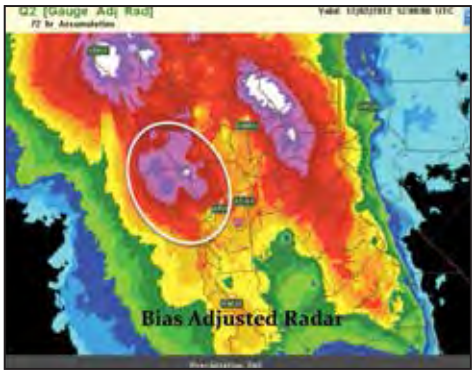
Coupling quantitative precipitation information (QPI) fields to a gridded hydrologic model (GHM) provides unregulated flow estimates at any grid location in the watershed. The Research Distributed Hydrologic Model (RDHM) developed by National Weather Service (NWS) is the GHM deployed for modeling surface runoff and soil moisture processes at the 4-km HRAP and 6-hr time step resolution; a 1-km, 1-hr version of the RDHM has also been developed (Hsu et al 2012; Johnson et al 2014). The GHM is based on data sets for terrain, grid connectivity, soils and vegetation. Various GPI fields noted above have been coupled to the GHM to provide a means for assessing model performance and forecast accuracy. Model ensembles will be developed soon for probabilistic forecasts and uncertainty estimates. GHM calibrations have focused on flood peaks, low flows and the total water budget for the simulation periods.

The coupled QPI/GHM system is being prototyped for real-time operations to determine its accuracy and help examine how it might be used to support NWS flash flood services. For this we have used the CHPS-FEWS system with RDHM developed by the NWS-OHD, which provides network ingest of real-time precipitation feeds (HRRR, CNRFC, MRMS). Remote logins allow researchers to access the GHM to perform retrospective model studies of various kinds as well as tracking flood events as they happen (e.g. December 2014). The FEWS workflows automatically trigger updating of the input data and forecast execution based on latest-available observed and forecast precipitation data.

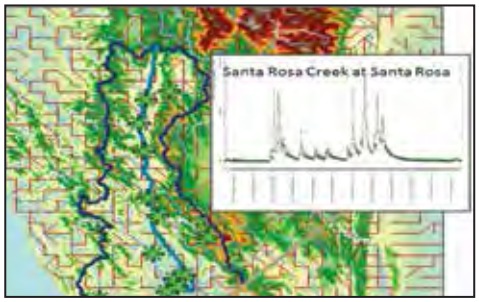
Web-oriented displays of GHM output have been developed to provide animations of precipitation, flood runoff and soil moisture. These products can be accessed by any interested users and provide a means for extending the GHM assessment to the wider emergency and water resources management community in the basin.

Water Management Modeling

The remaining need is to apply water management models (WMM) to represent the influence that reservoirs and diversions have on the water balance on specific stream reaches. A key component for water management is Lake Mendocino located on the East Fork Russian River in the upper portion of the basin. This multipurpose reservoir is operated for flood control during the winter-spring seasons through maintenance of vacant space to capture flood flows. It is also operated for water supply and low flow augmentation for downstream fisheries and recreation purposes. Reservoir storage and release decisions are based on fixed “rule curves” which dictate release of flood waters to reduce storage levels regardless of whether there is another storm coming or not. There is interest in implementing more adaptive operation schemes that account for forecasts; so-called forecast-based operations (FBO).



Adjusted rainfall estimates from QPI/GHM system



Potential use of QPI/GHM system

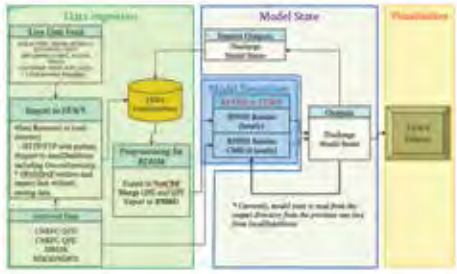
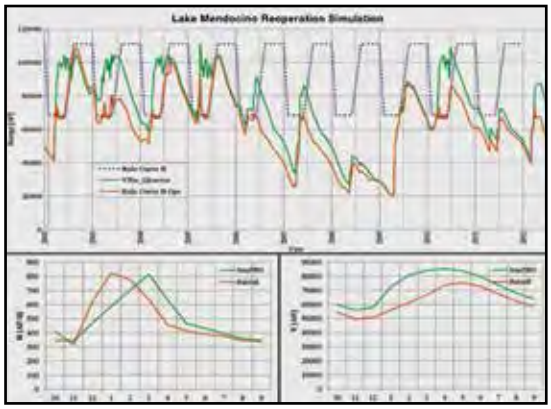


Diagram of QPI/GHM/FEWS system

Web deployment of GHM surface flows

A deterministic simulation model, called “FLDOPS”, has been developed to examine how much additional water might be captured taking account of forecasts while maintaining flood mitigation levels (Johnson 2015). Preliminary analysis indicates that average water supply storage levels can be increased on the order of 10% (10,000 acre-ft) if account is taken of forecasts of no rain. If a large storm is forecast then a “pre-release” strategy can be used to evacuate storage space to maximize capture of flood waters. Further work is required to refine characterization of flood risks with the FBO strategy.



Simulation of storage at Lake Mendocino using model

Uncertainty of forecasts must be translated into the risks that reservoir operations incur, especially for floods. Ensemble precipitation forecasts are routed through a hydrologic model to obtain ensemble streamflow predictions (ESPs) which can be routed through the reservoir using alternate operations policies. Reforecasts (Hamill 2006) provide ensembles of precipitation forecasts which can then be input to the Hydrologic Ensemble Forecast System (HEFS; Demargne et al 2014), which then generates the ESPs. The focus here is on applying intelligent agent-based modeling tools (Rieker and Labadie 2012) for learning optimal rules for reservoir forecast-based operations (FBO) that involve accounting for weather forecast-based anticipated runoff for reducing flow variability while increasing freshet runoff capture for balancing aquatic ecosystem preservation and flood control. We are investigating the most appropriate approaches for effective FBO under weather forecast uncertainty.

High resolution modeling of water demands for agriculture and environmental flows is being addressed using the GeoMODSIM software. Activities for the GeoMODSIM are described in the companion insert.

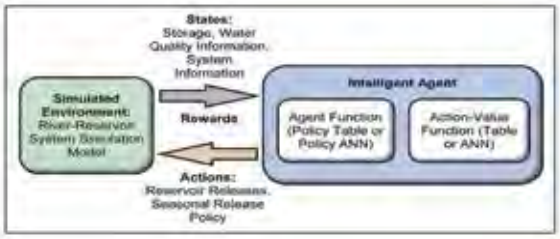
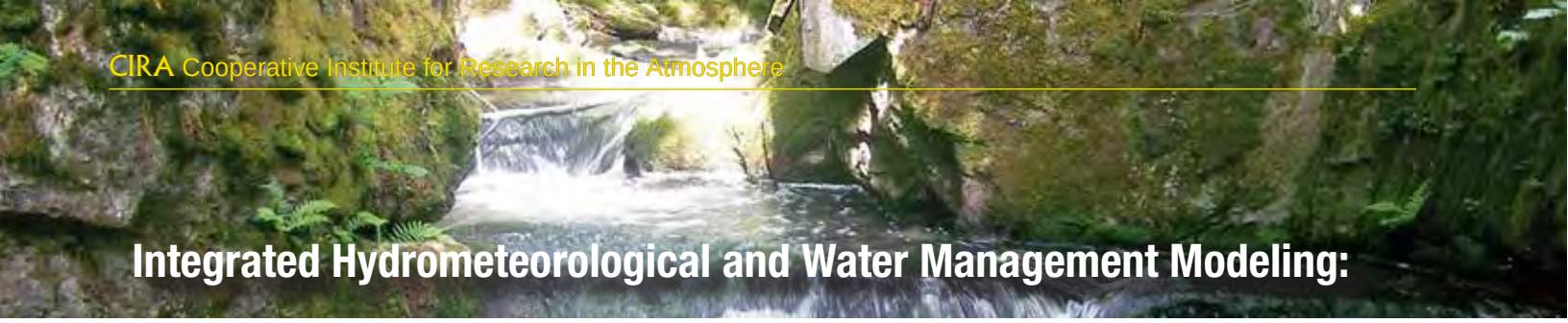


Diagram of intelligent agent interacting with simulated river-reservoir system.

Next Steps

Assembly of the collection of observations, models and systems integration tools provides a foundation for progressing on refinement of the tools and deployment to support real world applications for forecasting floods and environmental flows. Anticipated specific activities include:

- Generation of ensemble forecasts as input to stochastic optimization procedures directed to identifying optimal forecast-based reservoir operations policies.
- Seeking to advance the accuracy of current and forecast precipitation amounts through higher resolution monitoring (e.g. gap-filling radars) and advanced numerical weather and hydrological prediction modeling.
- Conducting assessments of the GHM to determine requirements for NWS flash flood operations, and concept of operations.
- Advance the coupling of precipitation forecasts with the GHM and WMM modules to obtain real-time guidance for water system operations that incorporates forecast uncertainty.
- Develop WMM tools to support collaborative examination of alternate water system operations by stakeholders in the basin.



Integrated Hydrometeorological and Water Management Modeling:

Russian River Tributaries Project

Christopher Fields, John Labadie, and Lynn Johnson

For basin-wide water management, we are coupling the GHM generated "natural" flows with the GeoMODSIM model to obtain "managed" flows at any location. Together, the coupled natural and managed flow models provide an estimate of the total water budget, allowing researchers and stakeholders together to better understand the relationships between reservoir storage, streamflow, agricultural diversions, and return flows at any location in the basin.

GeoMODSIM

GeoMODSIM is a GIS-based version of the MODSIM generalized river basin management decision support system (DSS) tool (Labadie, 2012; Triana and Labadie 2007; Triana, et al 2010), developed by Dr. John Labadie in the Civil and Environmental Engineering Department at Colorado State University. GeoMODSIM allows the user to efficiently model complex stream networks and to evaluate management strategies with consideration of water rights, agricultural diversions, and environmental flow requirements, while taking advantage of the spatial data base management and modeling tools available in the GIS environment.

Integration of a gridded hydrologic model (GHM) for flow data with the stream network structure of the MODSIM river basin management software is a key to developing a fully coupled model of the system that combines MODSIM with GHM and gridded demand models within GeoMODSIM. Shown here is the integration of a map layer for the National Weather Service gridded hydrologic model (GHM) into the custom ArcMap TM (ESRI, Inc.) interface with GeoMODSIM for providing spatially distributed natural or unregulated inflows generated from quantitative precipitation information (QPI) fields. In addition, we are working to generate vineyard irrigation demands for grape frost and heat protection from a high resolution gridded frost and heat model (Reynolds et al 2014). Integration of the gridded U.S. Geological Survey Modular Ground-Water Flow Model (MODFLOW) into GeoMODSIM has also been accomplished (Triana et al, 2010; Morway et al, 2015).

Prototype Tributary Water Management Model

To demonstrate the potential of a full-scale tributary model, a prototype model was developed for a tributary within the Russian River basin. The selected tributary is characterized by the proximity of vineyards to the stream as well as its classification as critical endangered species habitat. Overall, the tributary watershed encompasses 14.6 square miles, with the stream network model automatically created in GeoMODSIM using NHD-Plus hydrography data readily available from the USGS. GeoMODSIM can be applied to planning the geospatial placement of proposed irrigation ponds, allowing analysis of the best locations for proposed instream and off-stream pond storage.

Recent water management trends in the Russian River basin include increased restrictions on agricultural diversions in order to sustain environmental flows for fisheries. In 2010, the California State Water Resources Control Board (SWRCB) adopted new policies intended to maintain environmental flows for the protection of fishery resources, in particular threatened and endangered anadromous salmonids (SWRCB, 2010). Additionally, in 2011 the SWRCB adopted further restrictions on diversions and groundwater pumping for purposes of frost protection against late-spring frost events (SWRCB, 2011). Although legal proceedings surrounding these restrictions are ongoing, there is increasing recognition by all stakeholders of the need for better understanding of the effects of agricultural activities on tributary flows and how to improve water management so as to mutually benefit both interests.

Agricultural aspects of the system include demands for both irrigation and frost protection, as well as on-stream and off-stream agricultural ponds for enhancing timely water supply for irrigation as well as maintaining environmental flows. Although irrigation water demands for vineyards are relatively small in terms of total streamflow rates, during the dry season, even small diversions from a stream can be detrimental to environmental flows.. In the early spring, vineyards spray irrigate to form a protective layer of ice on the developing grape buds when a frost event is predicted. While there are generally only 5-6 frost events per season, their sporadic nature and the high flow rates required for frost protection can have significant impacts on streamflow.

For this demonstration, environmental flow requirements in the system were approximated based on minimum estimated streamflow rates in the tributary. Future work will focus on developing environmental streamflow requirements based on California State Water Resources Control Board guidelines for minimum flow requirements. For this demonstration, proxy input flows were estimated throughout the system based on scaled streamflow gage data from the main stem Russian River, whereas future work will focus on use of the gridded RDHM model for spatially distributed natural inflow prediction.

The system was modeled based on two scenarios – the historic case and a managed case. The historic scenario does not include any environmental instream flow requirements on the tributaries but does impose irrigation and frost agricultural demands, as well as hypothetical on-stream ponds for supply and diversion. The historic simulation was run in daily time steps over a one year period, revealing that downstream of the agricultural diversions, instream flows were frequently reduced to zero during periods of peak demand associated with frost events, as well as during extended dry periods that are prevalent during the summer irrigation season. At the same time, most agricultural ponds remained at or near capacity.

Development of the managed scenario starts with the same base assumptions of the historic scenario, but then includes two key modifications. First, instream flow requirements are imposed downstream of each agricultural pond. Second, the on-stream agricultural ponds are modified to include improved operations that allow more flexibility for downstream releases. The results of the managed scenario demonstrates that with improved operation of the agricultural ponds, the environmental needs of the endangered fish species can be met while satisfying nearly all of the agricultural demands.

Future Work

Given the successful demonstration of the prototype tributary model, further development of the model is warranted. Current efforts include the coupling of the GHM gridded model with GeoMODSIM to provide a capability for forecasting flows and support adaptive water management strategies. Similarly, the gridded frost model is being integrated to help refine the timing of frost and heat demands. Additionally, the GHM model will be used evaluate of a variety of hydrologic scenarios (wet, dry, normal, etc.). Management scenarios will also be improved by further refining the agricultural demands as well as the instream environmental flow demands. The prototype tributary model not only demonstrates use of GeoMODSIM for guiding management decisions, but also informs the design process of potential watershed improvements, such as incorporation of new on-stream and off-stream ponds in the basin for improved water management.

The ultimate goal of this research is to provide a means for collaborative learning of water management alternatives by competing stakeholders in the agricultural and environmental protection stakeholders in the basin. The GIS platform that the GeoMODSIM model is built on will be helpful for creation of an internet-based tool for the visualization of model results and the dissemination of information to stakeholders. With the availability of these powerful on-line tools, competing stakeholders can be presented with easily comprehended information for developing a “shared vision” of how water resources in the basin can be managed in an integrated manner as a means formulating strategies with the potential for satisfying the requirements of all stakeholders.

Viewing the Earth from VIIRS:

What We See from Space

"Visible Infrared Imaging Radiometer Suite (VIIRS)." NASA

Curtis Seaman and Matt Rogers

We live in a world full of data – on each of our desks sits at least one (if not more than one) computer, each of which boasts capabilities and features that would boggle the minds of our forebears. The computational power in the average smartphone, for example, far exceeds the computational ability of the computers used to land humankind on the Moon (a salient point the next time you fire up Candy Crush!). With this technological advance in computation, our observation platforms have become similarly potent – high-resolution imagery from space over virtually every point on the globe is a reality, and with the multi-year lifespan of our spacecraft, hundreds of thousands of images bearing all manner of information (and requiring impressive amounts of storage to contain it all!) is the norm.

A scant sixty years ago, seeing the Earth from space was an incredible feat made only once or twice by high-altitude rockets, and were grainy affairs of extremely local scope (and perhaps of limited value, especially if the film canister was damaged during re-entry). When astronauts first left the Earth on their way to the moon, the first full-disk images of our planet captured the public imagination in a way that transformed how humans view our home – psychologists actually have identified a cognitive shift, most strongly felt in astronauts, called 'overview effect' which minimizes human division and seeks to unify humanity that results from seeing the Earth from on high. The famous Apollo 17 image of the Earth from space taken in 1972, symbolizes this galvanizing of human thought, and its wide distribution seemed to foment a new era in humanity.

Fast-forward forty years, however, and we have satellites that make images similar to those from Apollo 17 dozens of times per day. Hundreds of images of our home arrive at data processing centers every hour, and the thousands of megabytes of data covering every facet of our planet on a continual basis simply overwhelms the imagination of the common mind. CIRA, however, is happy to never lay claim to simple commonality, and for a select few of the employees in our halls, the continual barrage of data and information is never enough, never too much. For them, there is always something new to see, something interesting to discover, and fortunately for the more common among us, these highlights are continually produced for our discovery as well.

The RAMMB group is fortunate to have several individuals who contribute to a WordPress blog, including frequent contributions based on observations from the VIIRS instrument aboard Suomi NPP. Curtis Seaman, who provides frequent updates to the blog (online at http://rammb.cira.colostate.edu/projects/npp/blog/) has the unique ability to catch interesting, new, or news-making events through the 'lens' of VIIRS, accompanied by insightful discussion behind the physics of the feature and the remote sensing behind the imagery. Let's look at three recent examples.

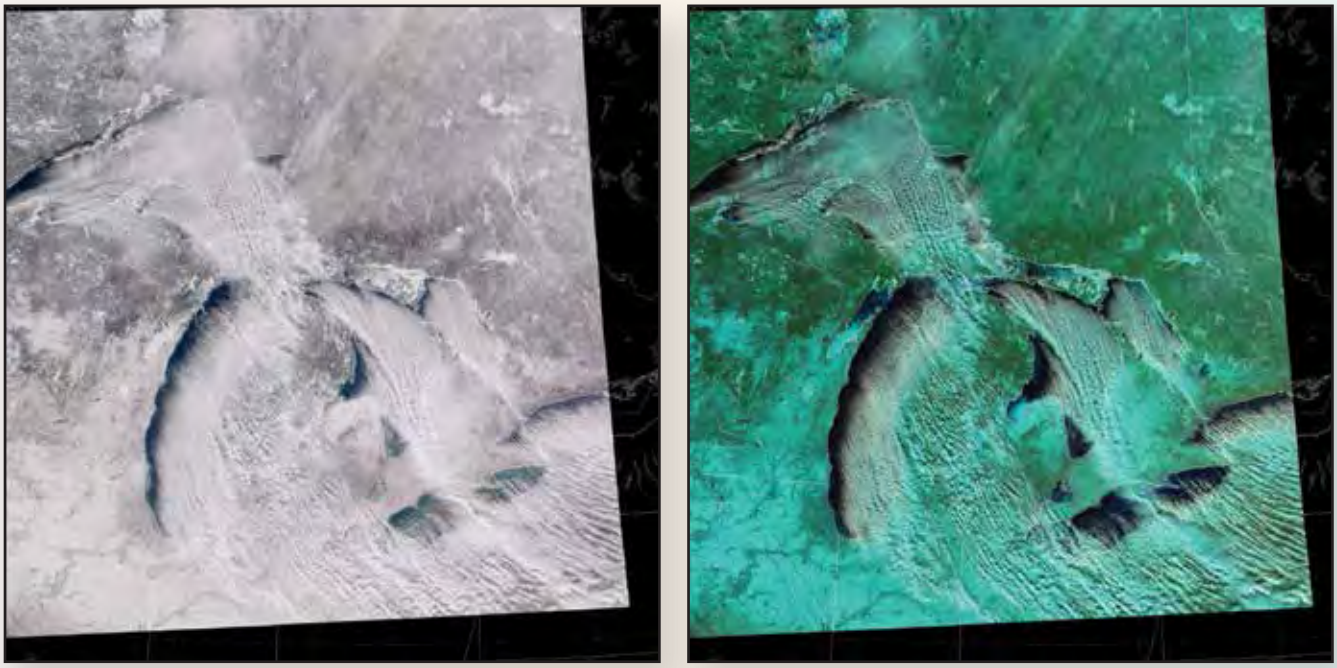


Figure 1. True (left) and natural (right) color imagery of the Great Lakes from January 7th, 2015, showing the presence of cloud streets associated with lake-effect snowfall in the natural color imagery.

Lake Effect Snow

As described in a blog post from January 13th, the impact of lake-effect snow (seen in regions such as the Great Lakes) is impressive. Occurring on the downwind side of lakes, lake effect snowfall is an enhancement of snowfall that results from cold, dry air upwind of the lake being warmed and moistened by the lake as it travels across the surface, resulting in enhanced convection (and snowfall) once it reaches the far shore. Oftentimes, snowfall caused by lake effect events is measured in feet, not inches, and the effect happens anywhere on the planet where winter air transits a warmer water surface, including the ocean (sea-effect snowfall on the Korean peninsula, for example).

Photo by: Wasrts - Lake Michigan shore in winter at Van Buren State Park, Michigan USA

Seeing this effect from space requires some sophisticated analysis – looking for white snow under white clouds is a difficult challenge. Imagery detailing how Suomi NPP can utilize several channels in its 'Natural Color' compositing technique to separate cloud from snow cover is one of the many useful observations commonly made by Suomi NPP. Here, we show images of this from January 7th, 2015, over the Great Lakes (snowfall in turquoise, clouds in white in the 'Natural Color' imagery.)

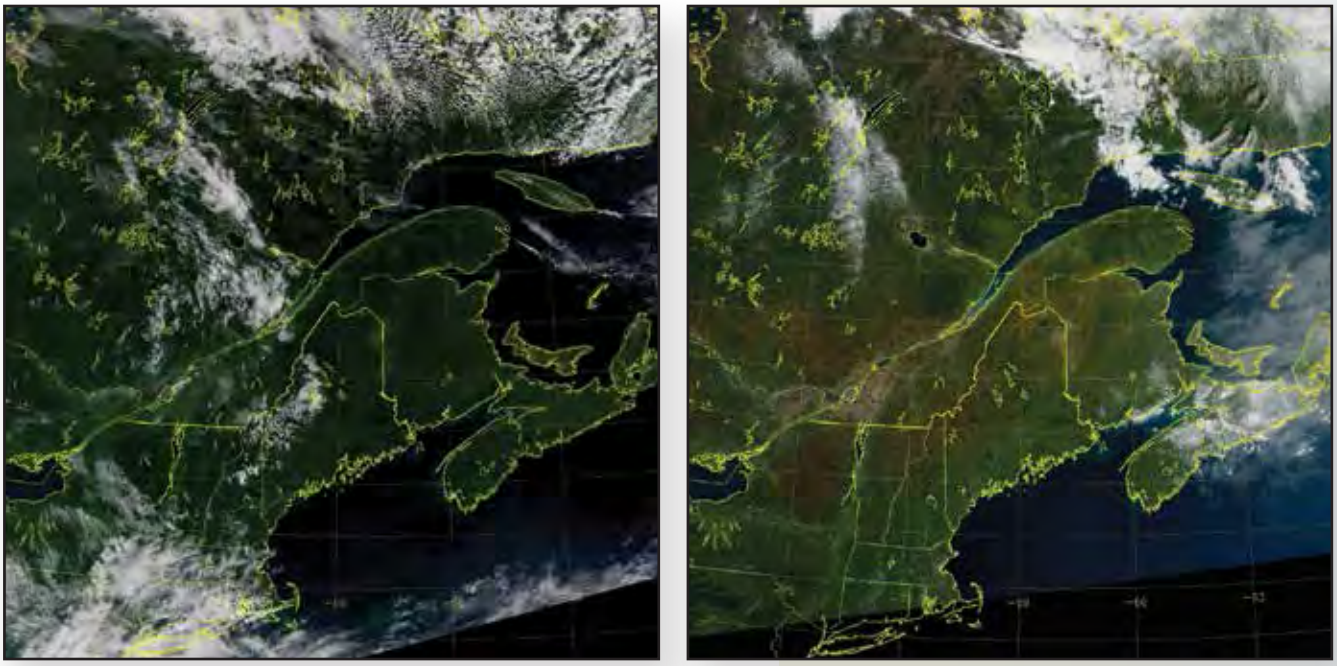


Figure 2. True color imagery from VIIRS showing New England before (left) and after (right) the change in color of leaves from September 2014.

Leaf Color Changes – Fall in New England

Viewing the beautiful change of colors in trees during autumn marks the end of summer and heralds the beginning of winter- long a staple of human interest. It wasn't until very recently, however, that this was observable from space. In a post from October 2014, we can see what's new and improved with our observations from Suomi NPP. Of more interest, however, is the science behind why leaves change color, and moreover, what that color change looks like from space based on the channels aboard the instruments that are observing the health and coverage of our planet's flora. Leaf cover has long been a valuable observational marker for scientists – estimates of carbon uptake, fuel availability for wildfires, and impacts of human development are among the many reasons scientists have a keen interest in observing leaf color from space.

Photo by: Danny Steaven -Fall Fagus-Autumn

Every now and then, however, it's nice to simply enjoy a beautiful image of the passing of the seasons, from five hundred miles up.

NASA Satellite Data Give Early Clues to Flood Danger

U.S. Army Corps of Engineers

Flooding in Paraguay

Natural disasters are a common occurrence around the globe, and observing the impact of these disasters as they happen from space informs us about the extent of the danger while giving us information about why these disasters occur in the first place. All of this knowledge hopefully helping us to develop better warning systems and emergency response plans. The June 2014 flooding of the Rio Paraná in Paraguay provides an example of this – from a post from July 11th, imagery of the extent of the flooding as it occurred. And again, information gleaned from comparing the difference in observing algorithms – in this case, a comparison of the true-color vs the natural-color composite imagery – provided additional insight.

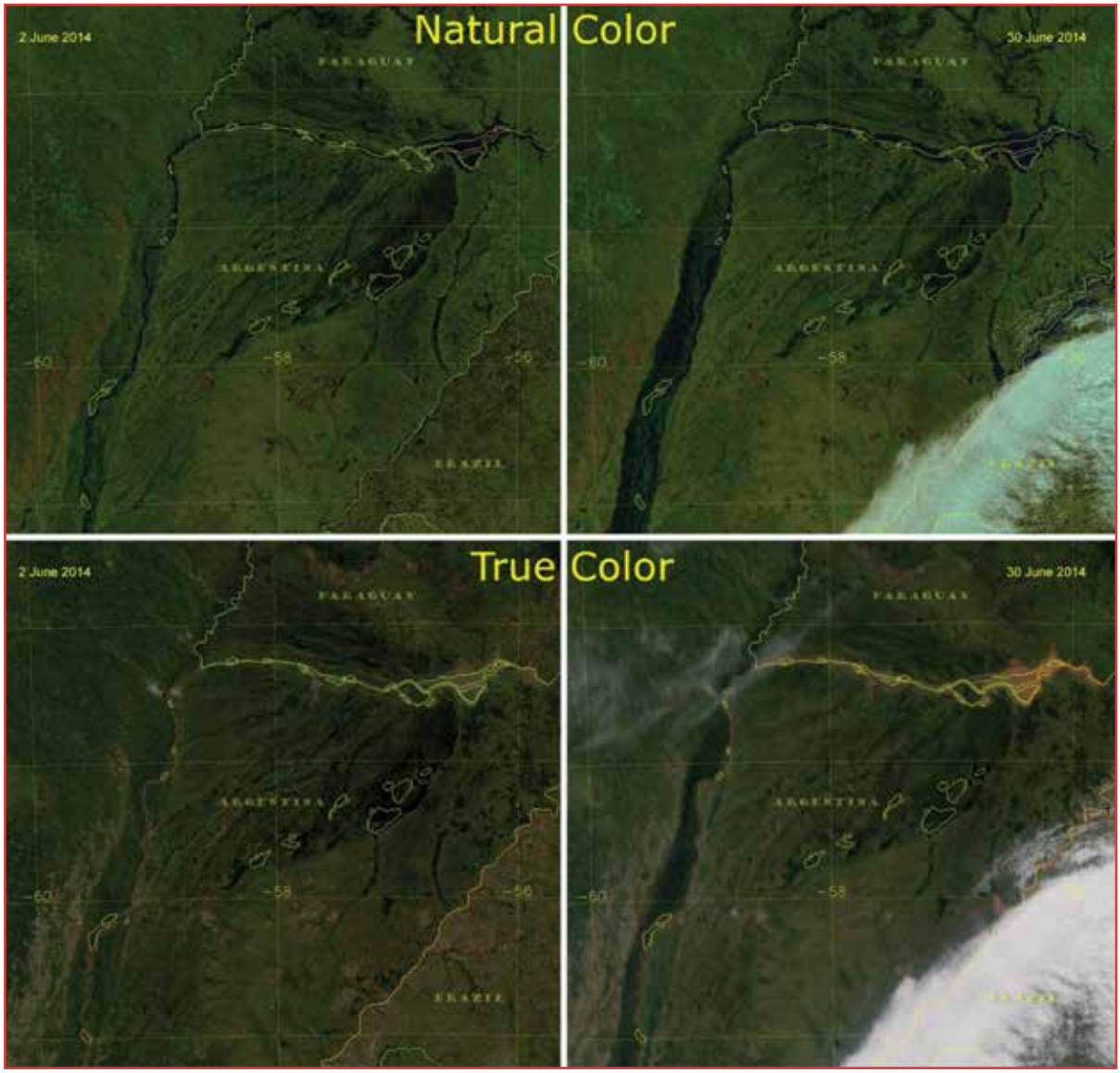


Figure 3. Natural- and true-color composite imagery of flooding in central Paraguay from June 2014, showing differences in color due to sedimentation in the floodwater.

One of the ancillary issues with flooding is the continual erosion of riverbeds and surrounding highlands, and in the case from Paraguay, you can see the erosion in the form of brown sediment in the water in the true-color imagery. By utilizing the difference in reflection and absorption by sediment in the channels used to construct the composites, additional information about the nature of erosion for the flood became available, and further research based on these observations was made possible.

In these modern times, when the availability of data threatens to overwhelm our ability to interpret it, it's good to have dedicated professionals continually monitoring select datasets, pulling out the new and noteworthy, and bringing the science out in a meaningful way. There is a wealth of information in the data we receive and process, and in every image lies the potential to see the Earth in a new, more unifying manner. We are fortunate to work in a field that offers this continually renewing source of potential, and we look forward to the many new discoveries yet to come, buried in the rush of information that makes up our daily lives.

Himawari 8
Launch Success –

A Vision of What's To Come

Matt Rogers

Capping off a successful year in major launches of earth observing satellites, the Japan Aerospace Exploration Agency (JAXA) recently launched their next-generation geostationary platform. Aboard an H-IIA F25 rocket, the Himawari-8 satellite successfully launched to its orbit at 140° East on October 7, 2014.

The H-IIA rocket that carried the Himawari-8 satellite into space launches from Tanegashima Space Center in Japan. Photo Credit: Narita Masahiro

The eighth satellite in the Himawari family (meaning 'Sunflower' in Japanese) is a new spacecraft carrying the Advanced Himawari Imager, a 16-band instrument that will image the earth at higher temporal and spatial resolution than previous Himawari satellites. Largely similar to the Advance Baseline Imager planned to launch on GOES-R (see the summer issue of CIRA Magazine, number 35 for more), the AHI instrument is capable of imaging a broad range of visible, near-infrared, short- and mid-infrared, and thermal infrared channels to greatly improve the quality and quantity of retrievals of atmospheric properties. Notable differences of the AHI compared to the ABI include the use of a 0.51μm visible channel aboard the AHI while deleting the 1.35μm channel found aboard the ABI. AHI sub-micron channels will image with a spatial resolution of 1km, with the exception of the 0.64μm channel, which will image at 500m resolution. Longer wavelengths imaged by the AHI will have a spatial resolution of 2km, again matching the capabilities of the ABI instrument.

One of the key benefits of observing the earth from a geostationary standpoint is the ability to continuously monitor regions of interest, an especially valuable feature for operational forecasting. Because of the enhanced scanning capability of the AHI, scan times for Himawari-8 will happen much more frequently; previous Himawari satellites using the MTSAT spacecraft offered full-disk scans once

Artist's rendition of the Himawari-8 satellite with solar panels deployed.
Image Credit: Japan Meteorological Agency (JMA)

every hour, with hemispheric scans interposed in between. The Himawari scan plan incorporates a ten-minute 'timeline,' each of which includes the following: a full-disk scan, two sub-disk scans including an area covering the entirety of the Japanese island chain, an additional area of interest (called 'target' scans) and two small-scale 'landmark' scans. 'Target' scans will occur every 2.5 minutes, and the 'landmark' scans will occur every 0.5 minutes. By using a sophisticated scanning algorithm, the above scans can occur simultaneously on Himawari-8, making the smaller-area scans interspersed between the sector scans for the larger-area scans.

The inclusion of more spectral information greatly improves the ability of Himawari-8 to make increasingly sophisticated retrievals of cloud properties. The inclusion of several of the near- and short-infrared channels, for example, improves the ability to observe cloud top properties including particle size and water phase. Cirrus detection and observations of aerosol, fog and other properties will also be feasible. Among the products JAXA and the Japan Meteorological Agency (JMA) hope to offer based on the wealth of new data produced by Himawari-8 is wind information derived from atmospheric motion vectors (AMVs). By utilizing the comparatively high-frequency observations of cloud motion (up to 30 seconds resolution for the smaller 'landmark' scans) in concert with sophisticated algorithms, it is possible to derive cloud motion and wind vectors from an earth-observing perspective. Given the ability of a geostationary platform to continuously observe the same area, this amounts to a continuous observation of wind over a very large area of interest, which is a tremendous leap forward in wind observations. Other planned products include improved observations of volcanic ash and aviation nowcasting, both of which are extremely valuable products for a number of industries as well as for academic research.

Planning the launch of an advanced spacecraft is a lengthy and meticulous process – geostationary is quite a distance from home and making the trip is an expensive proposition. Consequently geostationary platforms tend to spend many years on orbit, making the planning process for what flies and what doesn't extremely important. Oftentimes the instruments that fly on geostationary spacecraft were carefully thought out and tested on multiple polar-orbiting satellites (such as MODIS aboard Aqua and Terra, and VIIRS aboard Suomi-NPP). It all starts, however, with the science behind why each instrument is selected, and then tested, and the bands of the AHI, as with those of the ABI, were originally developed years ago by ITT (now Exelis Corporation.) Assisting ITT in their development were some of the brightest minds in remote sensing, including CIRA Fellow Stan Kidder and CIRA Founding Director Prof. Thomas Vonder Haar.

The vision of what could be made manifest in real data only occurs after an extensive and thoughtful process – what can be done with that vision when realized, however, is truly revolutionary. The observations from the AHI aboard Himawari-8, as with the anticipated observations from the ABI aboard the next generation of GOES spacecraft, will not only better inform us about the world we live in, but will inspire further development of visions yet to come.

In the

Wake of Hurricane Sandy

Improving Global Forecast Models

Bonny Strong

After the devastation wrecked by Hurricane Sandy in October 2012, the media highlighted the fact that the European Centre for Medium-Range Weather Forecasting provided a better forecast than did the U.S. operational global models, and brought attention to the need within the United States to improve global forecast models. The U.S. Congress responded with the Disaster Relief Appropriations Act of 2013, commonly referred to as "Sandy Supplemental funding", which provided an opportunity to bring together the nation's global weather modeling community and to focus them on a common goal: developing the world's best medium-range weather forecast model by the end of this decade.

The High Impact Weather Prediction Project (HIWPP) is one of the larger projects funded by the Disaster Relief Appropriations. Led by NOAA/OAR's Earth System Research Laboratory (ESRL) in Boulder, it is a 3-year project funded at $12.9M, with the goal of improving time-zero to two-week prediction of nature's most dangerous storms, such as hurricanes, floods, and blizzards, over the whole globe. In order to reach this goal, HIWPP formulated these objectives:

Figure 1. Hurricane Sandy, October 28, 2012; image captured by GOES-13 satellite. NASA Earth Observatory image by Robert Simmon.

1. Improve the current generation of hydrostatic global numerical weather prediction models, run them at higher resolutions and for longer forecast periods, and generate new ensemble products.

2. Accelerate the development of the next generation of non-hydrostatic, cloud resolving global models for medium range forecasts.

3. Develop and integrate new scale-aware physical parameterizations of key atmospheric processes, and a new approach to data assimilation known as four-dimensional ensemble-variational (4D-En-Var) assimilation into both the hydrostatic and non-hydrostatic models.

4. Optimize models to run on state of the art computer systems, namely the massively parallel fine grain (MPFG)/graphical processing unit (GPU)-based computers.

5. Create low latency tools built on high-speed networks to collect, access, extract, evaluate and visualize high resolution, gridded global earth information, and make it available to the broader weather community, and solicit their feedback.

HIWPP is a large, highly collaborative project, so to effectively address its goals and objectives, it has been broken into five sub-projects, and those sub-projects have been further broken into tasks. The Work Breakdown Structure is shown in the chart in Figure 2.

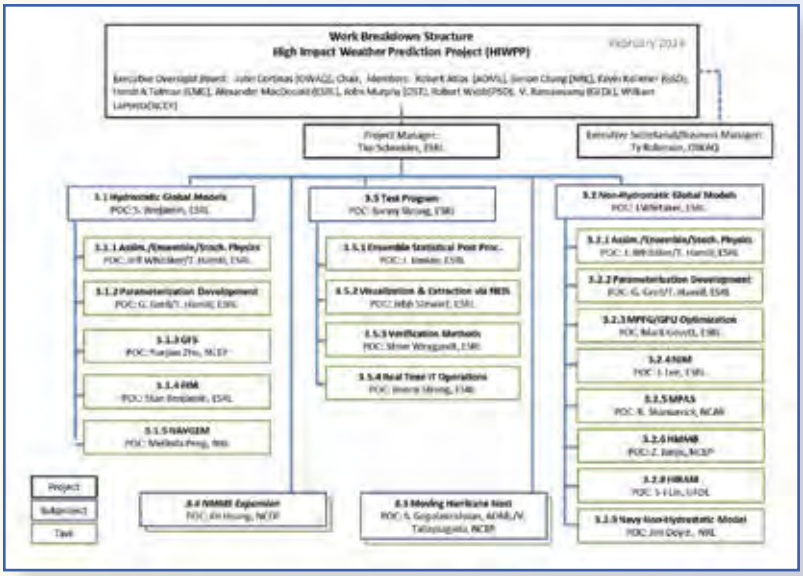


Figure 2. Project organization; a high-level work breakdown structure. Numbers inside of the task boxes correspond to section numbers in the project plan.

CIRA is playing a major role in HIWPP, with grants covering 4 areas of effort:

- Test Program: Ensemble Statistical Post-Processing (led by Isidora Jankov)
- Test Program: Visualization and Extraction via NEIS (led by Jebb Stewart)
- Test Program: Real-Time IT Operations and overall Test Program management (led by Bonny Strong)
- Fine Grain computing (led by Tom Henderson)

The project officially completed its first year of performance on September 30, 2014 and submitted a 90-page report summarizing results from this year. As the Test Program laid foundations for much of the effort in the other sub-projects, many of the first year milestones and results were achieved within the Test Program and will be described here.

Ensemble Statistical Post-Processing

The goal of this task in year 1 was to produce a real-time system that would use the inputs from the participating global hydrostatic models and produce the best estimate and associated probability and distribution for surface temperature, wind, precipitation and 500mb geopotential height at each grid point on the globe. Methods were developed using a sample set of GFS and FIM model output. In the first phase, the question of how much training data was needed to produce optimal results was addressed. In this study, it was determined that 25-30 days was where the benefit of recent data plateaued, so 30 days was selected as the training period for the system. The first step of the post processing was to remove the bias, or the mean error in the statistical training period, 30 days. After the bias was removed from the models, the remaining error was used to determine how to weight the models to yield a single result that has greater skill than an arithmetic mean. Using the model forecasts with bias removed at each point on the global grid, the weight of each model at each grid point was defined as inversely proportional to its Mean Absolute Error (MAE) over the training period.

In addition to producing a statistical forecast with greater skill than the arithmetic mean of the models, a probability distribution around the weighted mean was created for all variables except precipitation. Study of histogram distributions at points on the global grid led to the conclusion that data were normally distributed, so probability distributions were represented with the single metric of the standard deviation of the error in the weighted

hindcasts. The 'weighted hindcasts' are the forecasts in the training data weighted with the current forecast weights (Figure 3).

This method has been built into a flexible, real-time software package that is now one of the model outputs viewable in NEIS and distributed through the Open Data Initiative, described below.

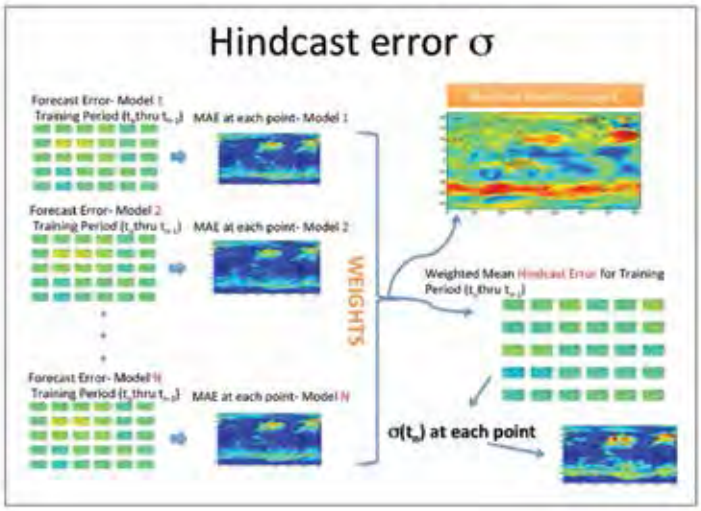


Figure 3. An illustration of hindcast error calculation and its use for distribution estimation at each grid point.

NOAA Earth Information System

HIWPP built upon an early NEIS prototype visualization system, to develop an advanced, low-latency visualization system capable of handling the "big data" produced by multiple high-resolution global models. During this first year, different hardware processors and architectures were analyzed and tested to enable the ambitious performance targets set for this new system. With the purchase of the new hardware, the team was able to complete version 1 of HIWPP NEIS in September 2014. Some of the key features of this system include:

- An ingest system for new high resolution gridded model data and point data for existing global operational models and global satellite observations, as well as new experimental HIWPP data. All data is available from at least the previous 24 hours, up to 7 days
- A high performance service layer that allows fast access, visualization, and integration capabilities to real-time research data
- An initial high performance processing capability, allowing users to run analytics or algorithms remotely only sending relevant data for display
- Side by Side or Multi sphere display, allowing users to visually compare forecasts in real-time. The image in figure 4 provides an example of the side-by-side capability with forecasted simulated IR imagery on the left and actual observed global composite IR imagery on the right.

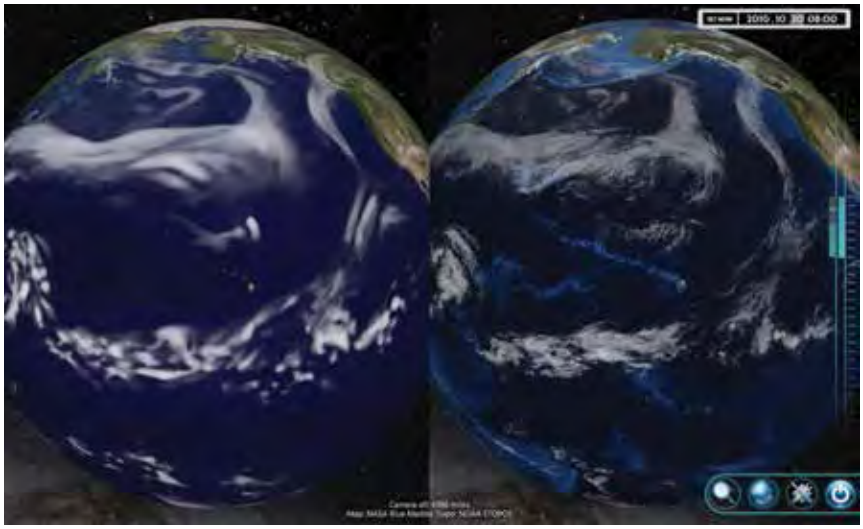


Figure 4. Image created using NEIS visualization tool comparing cloud images simulated from FIM model output on the left to actual satellite images on the right of tropical cyclone Megi of October 18, 2010

Real-Time IT Operations

The Real-Time IT Operations task covers several infrastructure pieces that are necessary to support the rest of the Test Program, along with management of a data distribution network. Under this task a major new storage system was purchased and installed at NOAA/ESRL/GSD in order to manage the high volumes of data that are part of HIWPP. Data transfer hardware and software were also updated in order to collect all HIWPP data in a central location for additional post-processing, verification, and distribution.

Open Data Initiative: One of the goals of HIWPP is to actively involve the broader weather forecasting community in the evaluation of models in late stages of research, running in a "real-time research" mode. Recently, the Forecast Improvement Group within the American Meteorological Society recommended that the community needs to "strengthen relationships within the public, private, academic, and user communities to assure economic and efficient development and use of forecasting capabilities." Toward this end, the HIWPP project developed its Open Data Initiative. The enhanced hydrostatic global models developed within HIWPP are now being delivered to the wider weather community in real-time research mode for early evaluation, and a forum is available for Open Data Initiative participants to provide feedback on the models. Participants will also be able to download and use NEIS to view model data.

From November 2014 through January 2015, Open Data Initiative user access tools were in Beta test mode. CIRA staff in Fort Collins were critical in helping test that infrastructure was accessible and performed well outside NOAA or federal facilities. The Open Data Initiative went live to the public on February 9, 2015. For more information, see http://hiwpp.noaa.gov/open-data/.

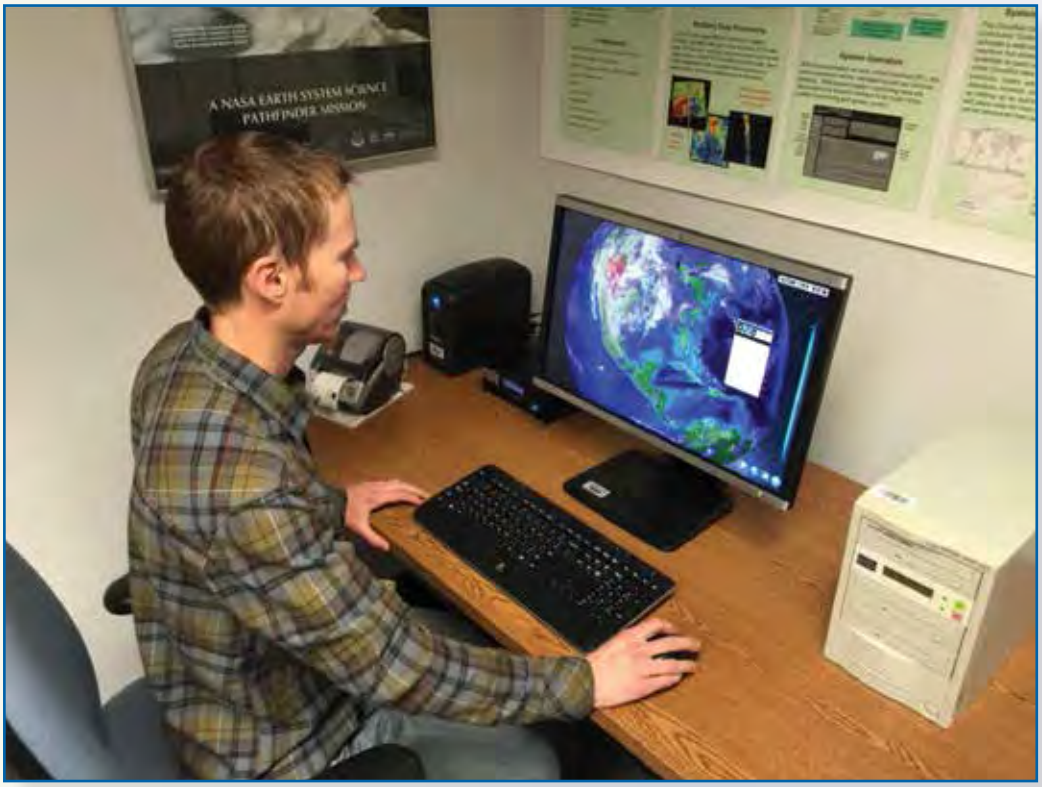
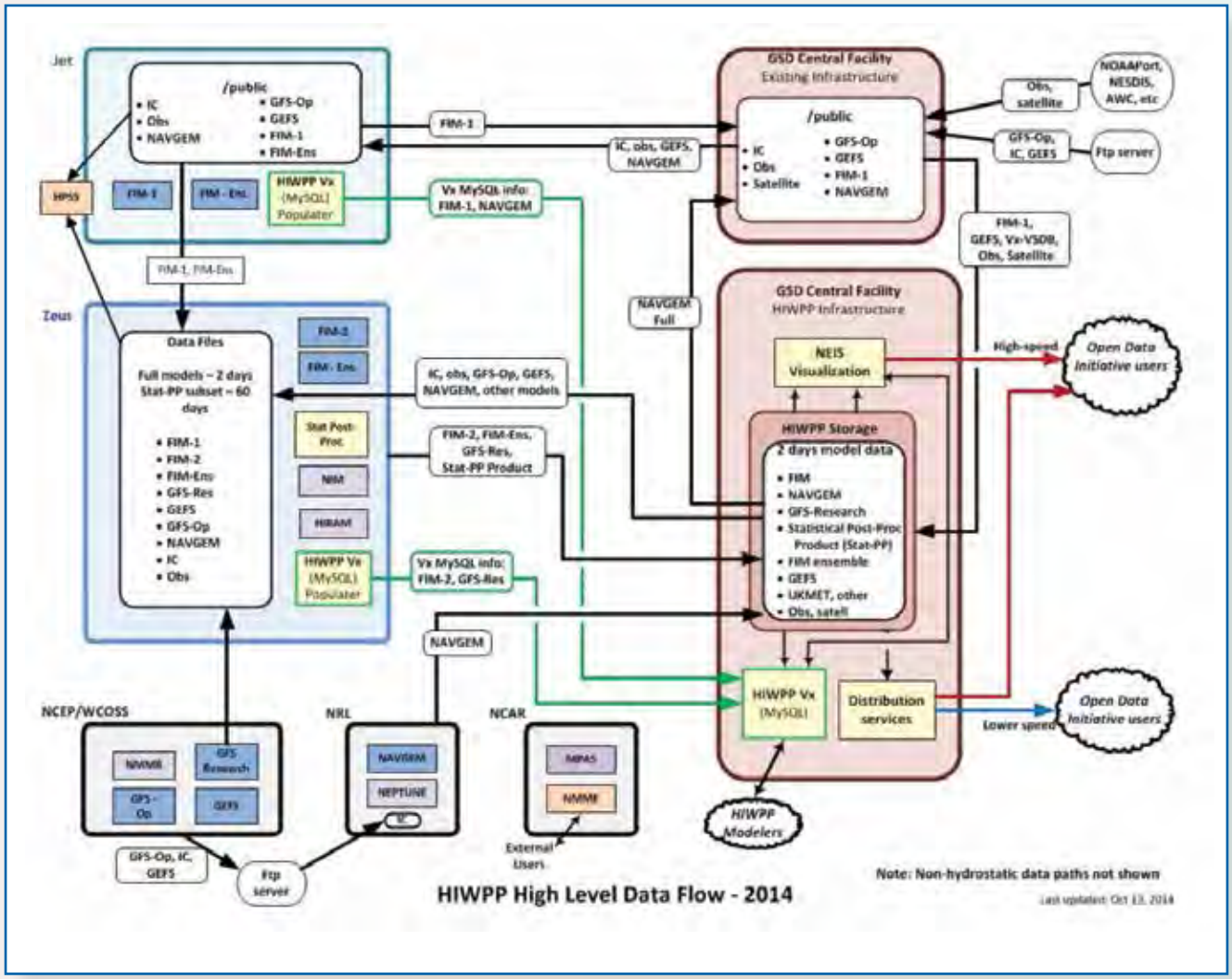


Figure 5. Phil Partain of CIRA tests the NEIS visualization system



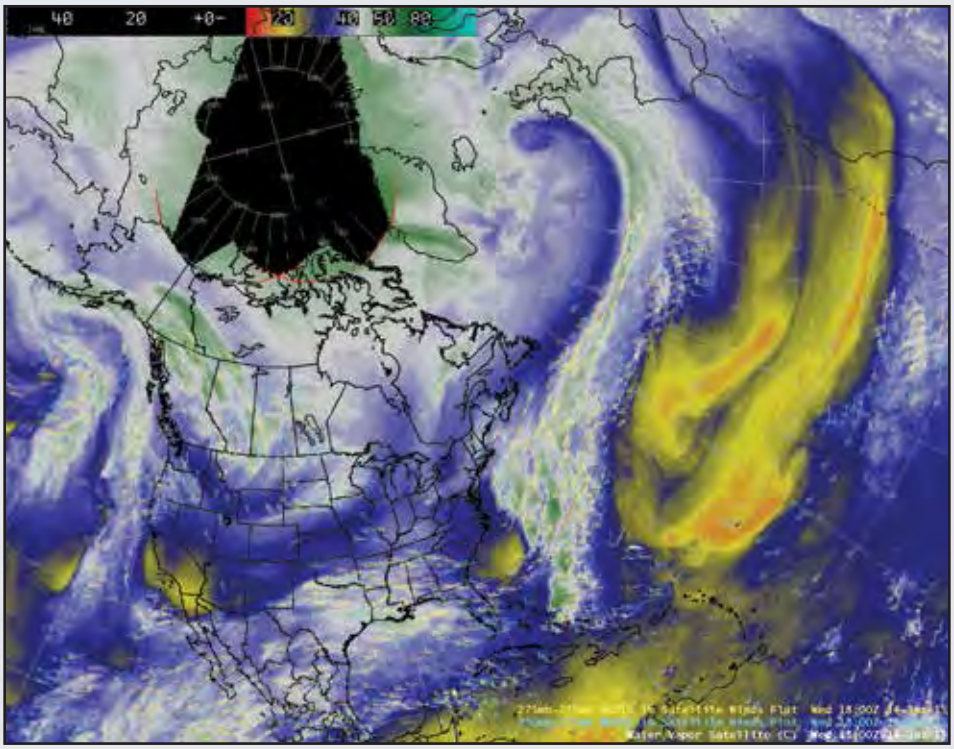
HIWPP Work Breakdown Structure, showing collaboration between HIWPP collaborators

One year into the 3-year HIWPP project, the investment in Sandy Supplemental has already produced new tools and new collaborations to accelerate global model development. Within the next year, the project expects to report results from testing on non-hydrostatic global models. Results will also be produced from the Moving Hurricane Nest and NMME expansion sub-projects. Another major step forward will be optimizing code and porting high-resolution models to the new Massively Parallel Fine Grain computers, where CIRA is also making major contributions.

MADIS

Successfully Transitioned from Research to Operations

By John Osborn (NOAA)

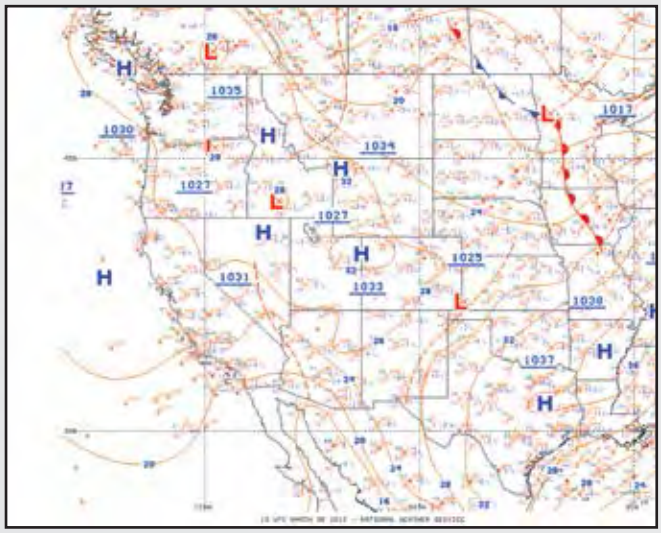


The collaborative effort between the Office of Oceanic and Atmospheric Research (OAR) Earth System Research Laboratory (ESRL) Global Systems Division (GSD), the National Weather Service (NWS) Office of Science and Technology (OST), the NWS National Centers for Environmental Prediction (NCEP) Central Operations (NCO), and the National Environmental Satellite, Data, and Information Service (NESDIS) National Climate Data Center (NCDC) culminated in the Meteorological Assimilation Data Ingest System (MADIS) being declared operational on Wednesday January 21, 2015. MADIS was established in 2001 to prototype new access, integration, quality control, and distribution techniques for real time observation data. MADIS provides easy access to quality-controlled data from a wide variety of observing infrastructures that is standardized, more accurate, and higher density. These data will definitely help improve climate and weather model assimilation and verification, weather applications, and weather products.

To create a finer density higher quality NOAA global observational database and delivery system, MADIS developed partnerships with international, federal, state, and local agencies; universities; volunteer networks; and the private sector to integrate observations from their stations with those of NOAA. MADIS currently partners with over 160 non-NOAA providers.

MADIS observational products and services were first provided to the public in July of 2001 and consisted of close to 250,000 observations a day from surface and upper air stations. MADIS mesonet sites surpassed 20,000 in 2006 and now consist of over 64,000 unique sites. The site number continues to grow. Today, MADIS provides access to over 7 million observations a day from NOAA observational sites and non-NOAA providers. In 2005 talks started between NWS and OAR to move MADIS to operations within the NWS. In 2008, a Letter of Agreement (LOA) was signed by NWS and OAR for the transition. In September of 2010, MADIS achieved Initial Operating Capability (IOC) at NWS. Lessons learned from the IOC systems led to the drafting of a new LOA that was signed by NWS, NESDIS, and OAR in May of 2012 and provided the pathway to realize an operational MADIS.

MADIS, through partnerships with non-NOAA providers, is helping to fill data gaps in NOAA's observational systems which helps improve NOAA's climate and weather modeling and verification efforts and the NWS' forecast applications and product services. MADIS' data integration, quality control, and standardized delivery services provides the greater meteorological community an easy to use, standardized, high quality observational database and delivery system for use with their applications and decision support process. MADIS helps to improve NOAA's ability to protect life and property.



More Information: https://madis.ncep.noaa.gov

Contact: Greg.Pratt@noaa.gov - (303) 497-7237

The MADIS Team includes:

- Greg Pratt
- Leon Benjamin
- Tom Kent, CIRA
- Gopa Padmanabhan
- Leigh Cheatwood-Harris, CIRA
- Michael Vrencur
- Randy Collander, CIRA
- Jim Frimel, CIRA
- Amenda Stanley, CIRA

Communiqué

Two of CIRA's own honored at All College Meeting - December 2014

Congrats to both Director Kummerow and Joanne DiVico!

Chris Kummerow and Joanne DiVico were both recognized with prestigious College of Engineering awards at the All College Meeting this past December. COE Dean David McLean presented CIRA Director Kummerow with the Abell Outstanding Faculty Research Award, while Joanne received the Outstanding Classified Employee Award.

Chris Kummerow

The Abell Award is presented annually in recognition of high quality, nationally acclaimed research productivity with a particular focus on the proceeding five years of work. Chris has been extremely busy with his research since coming to the Department of Atmospheric Science in June 2000. In that time he has worked on multiple missions (TRMM, CloudSat and most recently GPM) and has participated in multiple steering committees over the years that include AMSR. Chris plays an active role in planning and defining new space borne missions geared towards a better understanding of the Global Water and Energy Cycle, all the while still fulfilling his teaching duties and leading as the director of CIRA as well.

Joanne DiVico

Joanne DiVico is a well-known staff member to all of us at CIRA having joined the team in 1982. In fact, it would not be an exaggeration to say that her contributions have played an important role in the overall success of CIRA. The example she sets has much to do with the character of the workplace today: efficient, competent and friendly: all the right ingredients to create an environment which supports and helps foster the varied endeavors of our research staff. Joanne is also invaluable to all of us at CIRA when it comes to her Herculean effort to prepare the CIRA annual report each spring. Her award noted her daily contributions, particularly in support of the Director, but also in preparing this 400+ page document each year for CIRA.

NOAA Bronze Medal (2015)

Awarded to the Science on a Sphere Team

Congrats to Mike, Jebb and Steve!

Steve Albers and Steven Miller

Mike Biere

Jebb Stewart

The NOAA Bronze Medal is the most prestigious award that the Under Secretary of Commerce for Oceans and Atmosphere may present to Federal employees. In keeping with the spirit of the NOAA-University Cooperative Institute program, a group comprised of both NOAA and CIRA scientists was selected to receive this high honor. Although technically ineligible for a Bronze Medal owing to their non-Federal status, CIRA would like to formally recognize the efforts of Mike Biere, Jebb Stewart and Steve Albers for their participation in the winning Science On a Sphere (SOS) Team. The impressive achievements of the SOS team would not have been possible had it not been for their tireless efforts in collaboration with their NOAA colleagues.

The group was cited for achieving the 100th worldwide SOS installation thereby continuing to grow the reach of NOAA science to a worldwide audience. In fact, last year over 33 million visitors saw the SOS system in 15 countries and 28 states and the network continues to grow with 3 new distributorships, 12 new installations and 3 temporary exhibits last year. At the same time, the SOS team also managed to develop 75 new data sets to bring the current total to over 450 data sets! Such a vast library greatly enriches the potential programming for SOS users. Indeed, the spherical display is now found in 106 locations worldwide.

In short, thanks to the efforts of our 3 CIRA staff and their NOAA partners, the accomplishment of over 100 SOS installs and 33 million annual viewers exceeds by orders of magnitude any anticipated requirements. This impressive milestone is the product the entire team's will, determination and focus while never losing sight of the quality and excellence for which SOS is known. Congrats to Mike, Jebb and Steve!

CIRA Exceptional Service Award

Dale Reinke

Dale Reinke, a Research Associate III at CIRA and a member of the CloudSat Data Processing Center team, was recently nominated by his Federal colleagues for going above and beyond expected duties in support of a key operational processing transition. Dale is responsible for the ingest of all CloudSat spacecraft and instrument data at the DPC and the algorithms that convert them to data products. In anticipation of a move from one system to another, Dale developed a shadow structure to provide verification and validation capabilities for new the CloudSat Multi-Mission Satellite Operations Center (MMSOC). This effort was developed under the existing scope of work and was solely the product of Dale's incredible ingenuity. Dale's vision was the key to the success in transitioning to the new ground system at Kirtland, delighting the otherwise apprehensive transition team. As a result of his resourceful efforts, Dale was lauded by JPL and awarded a CIRA Exceptional Service Award in December.

National Academy election for Dr. Graeme Stephens

Graeme Stephens

CSU Atmospheric Science University Distinguished Professor Emeritus Graeme Stephens has been elected to the National Academy of Engineering. He will be formally inducted at the NAE annual meeting in October 2015. Dr. Stephens has many connections with CIRA in that he currently serves as a CIRA Fellow and he was CIRA Director from 2008-2010. As explained on the NAE website, election to the National Academy of Engineering "is among the highest professional distinctions accorded to an engineer. Academy membership honors those who have made outstanding contributions to "engineering research, practice, or education, including, where appropriate, significant contributions to the engineering literature," and to the "pioneering of new and developing fields of technology…" Dr. Stephens was recognized for his work studying the Earth's cloud system and radiation balance. He carries out his research today as Director of the Center for Climate Sciences, Jet Propulsion Laboratory, Pasadena, CA. Congratulations to Dr. Stephens on behalf of all of us at CIRA.

Book Chapter Co-authored by CIRA Scientists

Chris MacDermaid and Jebb Stewart

CIRA's own Chris MacDermaid and Jebb Stewart co-authored a chapter in the new paperback release entitled, "Mapping and Modeling Weather and Climate with GIS." Jebb and Chris wrote chapter 17, "Interoperability Interfaces." As for the book itself, the summary on Amazon describes it thusly:

Mapping and Modeling Weather and Climate with GIS is a contributed volume of 23 chapters from leading climatologists, meteorologists, and other experts about how geospatial cartography and analysis helps to advance atmospheric science research. Coverage includes data and software resources, data representation, observations, modeling, data-model integration, web services, and the areas of current and potential cross-fertilization of atmospheric and geospatial sciences. Providing both the concepts and practices of mapping and modeling projects, the book is useful to novices using GIS on weather and climate projects. Practitioners and managers will gain a clear picture of the advances in GIS for atmospheric sciences and appreciate the helpful lists of available geospatial resources. http://www.amazon.com/Mapping Modeling-Weather-Climate-GIS/dp/1589483766

GSD Posters of the Month: January, February 2015 Hongli Jiang and Missey Petty

CIRA staff are on a roll winning two consecutive months in the GSD Poster of the Month award! Congratulations to January winner Hongli Jiang for her AMS poster entitled, "Case Studies of Severe Storms during HWT 2013 Using Variational LAPS." The February winner was Missy Petty for her poster entitled "Use of the Flow Constraint Index: Combining Weather and Traffic Information to Identify Constraint." Each of the winning posters is displayed for the month outside of the GSD Director's Office. Congratulations to both winners!

GSD Team Member of the Month ~ Leslile Ewy

CIRA Research Scientist III Leslie Ewy was just selected as the March 2015 Team Member of the Month at GSD in Boulder. Leslie was cited for her work in developing and maintaining GSD's Central Facility real-time point data decoding software. The commendation noted that Leslie's proficiency with and in-depth knowledge of all of the NWS operational point data formats makes her an invaluable resource for users of GSD's Central Facility data. More specifically her colleagues noted how in the past year Leslie has been instrumental in allowing ITS to decommission the last of several legacy hardware and software systems. She is the 'point' person for all new data types, which have recently included data from several lightning data providers and tower/nacelle observations from several wind farm operators. She also just implemented a new capability to handle SYNOP global precipitation observations, supporting the HIWPP verification team. Congratulations to Leslie for her outstanding efforts!

Please Welcome the Following New Employees

Isabelle Granger-Frye

Isabelle Granger-Frye is currently a student at Rocky Mountain High School and plans to attend college in the Washington DC area after graduation, majoring in political science. She currently serves as President of DECA at her school. Isabelle is working on administrative tasks related to VISIT and SHyMet training. This includes production and mailing out training certificates of completion, recording keeping in the Learning Management System and mailing out DVD's of training sessions to offices with low bandwidth. She will also be assisting other RAMM team members with projects as needed. Dan Bikos is her supervisor.

Colleen Goodwin

Colleen Goodwin is also a student at Rocky Mountain High School and will graduate in 2015. While taking AP and CSU Succeed courses, Colleen is also an active member of the Kiwanis Club. Her position at CIRA is focused on administrative tasks related to VISIT and SHyMet training: ordering and downloading satellite data for CIRA scientists, assisting with scientific poster preparations and document scanning. Jack Dostalek is her supervisor.

Robyn Herbst-Tessmer

Robyn Herbst-Tessmer joined fellow CIRA researchers at the NOAA/NWS/Aviation Weather Center in Kansas City in December. Robyn is a Budget Analyst working with the federal program management team in support of research conducted in the Aviation Weather Testbed and the IT support branch for AWC. Robyn has her Bachelor's degree in Physics from Saint Cloud State University in Minnesota and her Masters in Physics from San Diego State University. Sher Schranz is her CIRA supervisor.

Yaoxian Huang

Yaoxian Huang is a Postdoctoral Fellow who joined CIRA in College Park, MD in January 2015 as a member of the SST Team within the Satellite Oceanography and Climatology Division of the NESDIS Center for Satellite Applications and Research (STAR) to help develop improved cloud mask and SST algorithms for AVHRR, MODIS, VIIRS, SEVIRI, AHI and ABI satellite sensors. Yaoxian recently obtained his PhD in Environmental Engineering from Michigan Technological University in Houghton, MI. His supervisor is Cliff Matsumoto.

Julie Schramm

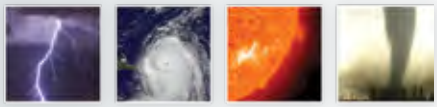
Julie Schramm joined CIRA in Boulder at NOAA/ESRL/GSD with the Advanced Technology and Outreach Branch. She will be working with researchers in the High Performance Computing Section on Flow-Following Finite-Volume Icosahedral Model (FIM) software development. She comes to us from a previous Software Engineering position with Precision Wind, Inc. in Boulder. Julie has her Bachelor of Science Degree in Mathematics and Meteorology from the University of Wisconsin – Madison and her Master of Science Degree in Meteorology from Penn State University.

Patrick Sobolewski

Patrick Sobolewski joined CIRA/Boulder at NOAA/ESRL/GSD's Evaluation and Decision Support Branch in December as a part-time software engineer. He is an Electrical Engineering and Computer Science student at Colorado School of Mines. Working with researchers on the National Weather Service's Forecast Decision Support Environment (FDSE) program, Patrick will be developing techniques to effectively use numerical forecast ensemble information during the forecast process. Jennifer Raab is his supervisor.

Vanessa Vincente

Vanessa Vincente is a Research Associate II who joined CIRA in Boulder in October 2014 to work in a collaborative role between the CIRA VISIT training program in Fort Collins and the COMET training program at UCAR in Boulder. Her work focuses on the development of education and training materials that will fill critical gaps on assessing tropical cyclone threats and communicating their risks and impacts. Vanessa recently completed the CSU Master's Program in Atmospheric Science and was involved in Hurricane Research as part of the Significant Opportunities in Atmospheric Research and Science (SOARS) program that is run by UCAR. Bernie Connell is her supervisor.



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.

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