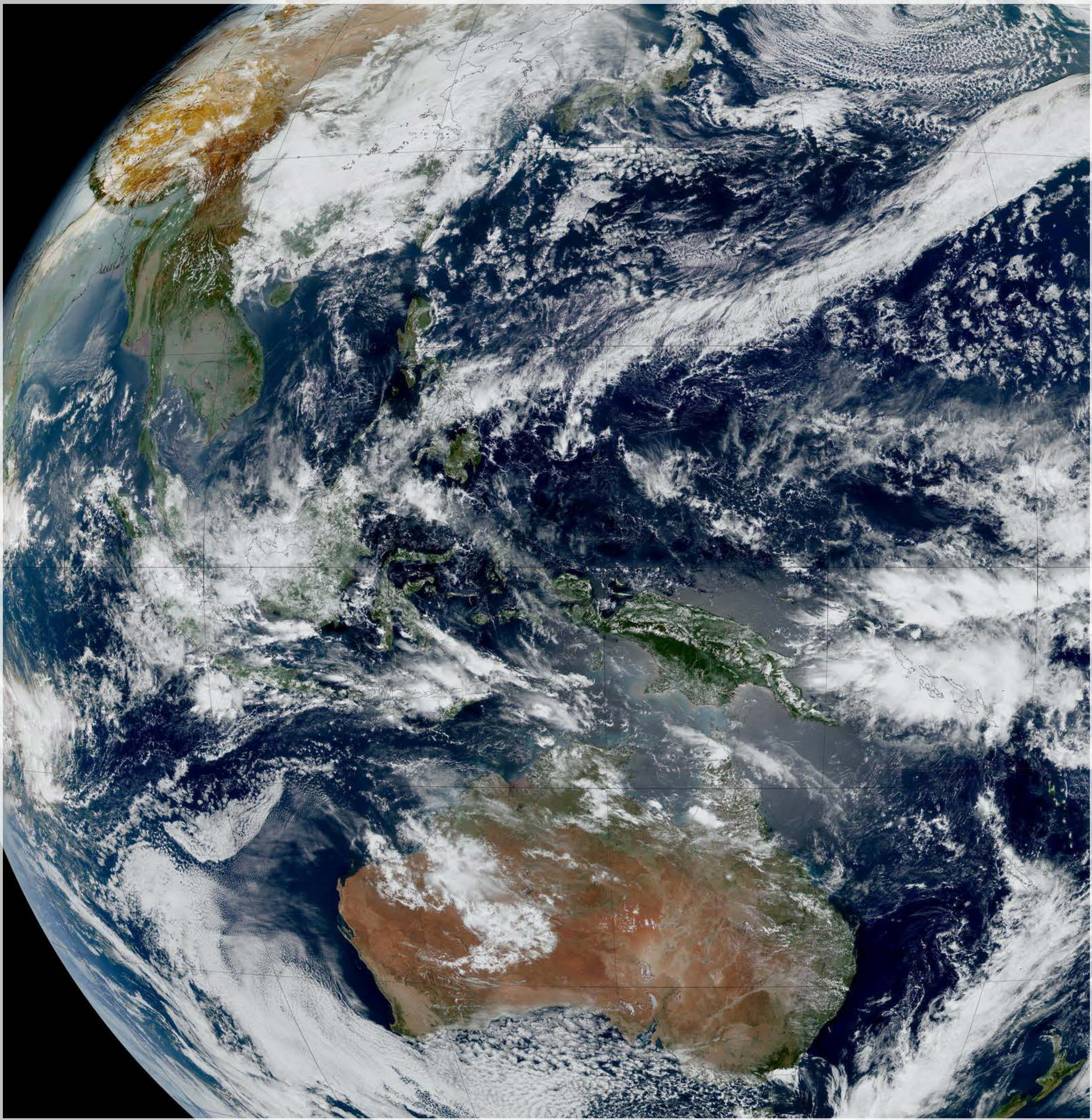
CIRA

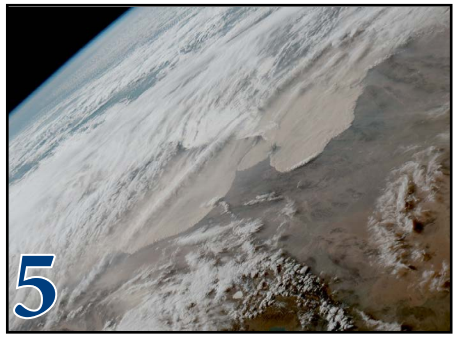
Connecting Models and Observations

Volume 43, Fall/Winter 2015
College of Engineering



Colorado State University

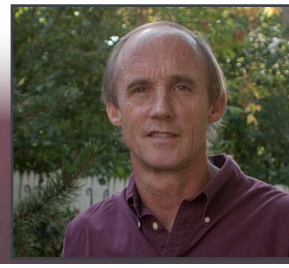
Contents



COMMUNIQUÉ

16

From the Director's Desk



In previous messages, I began talking about the vision of using the expertise across CIRA to reconnect models and observations as an important activity not only in data assimilation but also in the realm of validating and improving model processes now that global models are reaching scales at which clouds can be explicitly resolved. This is particularly true for the High Impact Weather Prediction Project being led by NOAA's Global Systems Division, as it evaluates high-resolution global cloud permitting models. We were also happy to host the 2015 Summer Colloquium on Data Assimilation here in Fort Collins on behalf of the Joint Center for Satellite Data Assimilation (JCSDA). This two week intensive workshop brings together students and recent graduates in atmospheric science to interact with leading experts in data assimilation with the goal of teaching the latest thinking and techniques to the next generation of researchers.

Another big jump in our ability to connect observations to model processes will undoubtedly come with the launch of GOES-R and its incredible new temporal and spatial resolution. With five-minute full disk images and spatial resolutions of one km in the visible and two km in the infrared, we will be able to track cloud development like we have never done before. By tracking cloud lifecycle stages along with model properties and less frequent but more comprehensive polar orbiting satellite data, the future offers tremendous potential to view clouds in an integrated way that will allow one to verify the process that governs the rate of cloud growth and transitions to precipitation. While waiting for GOES-R to be launched next October, visualization efforts using the recently launched Himawari-8 imager to provide test data already provides astounding new clarity of our planet as described in the article.

On the science front, you will find an article by our tropical cyclone group, explaining the links between the current El Niño and the 2015 tropical cyclone activity in the Atlantic which has seen less than average activity and the East and Central Pacific which has seen a great increase in activity, including the strongest recorded storm in the Western Hemisphere (Hurricane Patricia), and a number of hurricanes in the vicinity of the Hawaiian Islands. You will also find the description of a new activity being led by CIRA's Steve Miller that brings together observations and models to better understand aerosols in the littoral zone. While the focus is initially on navigation, the deeper understanding of the processes are, of course, expected to benefit all of Earth System Sciences.

Finally, I would also like to welcome new members to the CIRA team. As you will see at the end of this magazine, we've had a large number of great people join the CIRA team over the past six months; and, while we've welcomed them individually at their respective work locations, this may be the appropriate venue to welcome everyone collectively. Together we can do great things as witnessed by the large number of honors and awards that have gone to CIRA employees in the last six months.

Chris Kummerow,
CIRA Director

Chris Kummerow

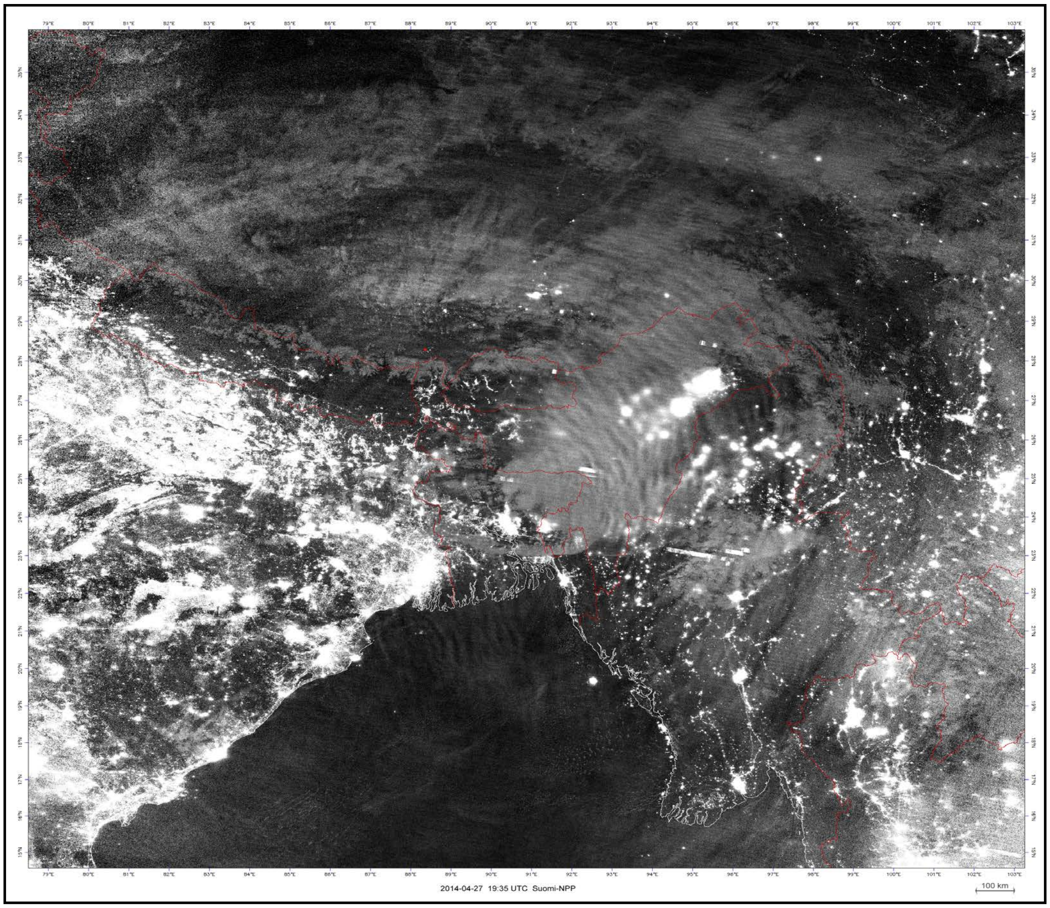
Making Waves: Seeing Into the Upper Atmosphere Through Observations of Gravity Waves with the Day-Night Band

Matt Rogers and Steve Miller

A team of researchers led by the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University has helped to shed light on detailed properties of upper-atmospheric motions, utilizing low-light satellite imagery from the Suomi National Polar-Orbiting Partnership (Suomi NPP) mission. The research has been published in the November 2015 issue of the Proceedings of the National Academy of Sciences, and details several interesting interactions between surface phenomena and their subsequent impact on the upper atmosphere.

The layers of the atmosphere undergo complex and intricate interactions. Here at the surface of the earth, we are most familiar with the lowest layer of the atmosphere where the bulk of our significant weather occurs. Called the troposphere, and comprising approximately 70% of the atmosphere's mass, this layer makes contact with terrain, water sources, aerosols, and cools as you go from the surface of the earth upwards. Five or six miles up above the troposphere, beginning around where the ozone layer starts, the second layer of the atmosphere, the stratosphere, continues upwards for another 50 miles or so. As the atmosphere thins, moving away from the protection of the thicker lower layers, the presence of high-energy radiation from the

Concentric gravity wave structures as seen from the Tibetan Plateau. Image courtesy of Jeff Dai.



Nightglow imagery from the DNB. Amid bright patches of light from various cities and rectangular-shaped streaks caused by lightning flashed during the DNB scans, a well-defined concentric-ring pattern emanates from the southern storms.

sun begins to impact the structure of the atmosphere. Finally, at altitudes between 50-60 miles (~90 km), the mesosphere begins. Although our knowledge of this part of the atmosphere has grown substantially in recent years, very little is well-understood about this region of the atmosphere. What we do know is that various photochemical processes at this altitude create a faint emission of light, called nightglow, which is so dim it is not visible during the day but can be seen in the darkness of the night. Following the initial discovery that the Day/Night Band instrument on Suomi NPP held an unexpected sensitivity to this faint light source, enabling the first visible detection of clouds on moonless nights, the researchers have discovered that the instrument can detect the signals from atmospheric gravity waves which impact the structure of the nightglow layer itself. The imagery details these structures at a resolution of 742 meters, which is unprecedented from space-based observations. Gravity waves are created by a variety of phenomena in the lower atmosphere, including weather systems, tropical storms, strong thunderstorms, the flow of air over mountain ranges, and even volcanic eruptions (the first documented example of which is included in the article). The wave structures, sometimes appearing as ripples reminiscent of a stone dropped into a pond, provide detailed insights on the processes that drive the circulation of the upper atmosphere. Figure 1a shows one example of the phenomena as seen from a surface vantage point in southern Tibet, while Figure 1b shows the same phenomena as seen from Suomi NPP. Concentric rings of light emanating from the mesosphere detail the peaks and troughs of the gravity wave as revealed in the photochemical glowing layer; measuring the properties of these rings can help unravel the dynamics of upper-atmospheric gravity waves. The new measurements could be significant for their ability to improve our basic understanding and potentially to improve long-term climate forecasts.

Led by CIRA Deputy Director Steve Miller, the research team includes other CIRA scientists as well as partners from the University of Wisconsin-Madison, Hampton University, Boston University, the North Western Research Associates, the Jülich Supercomputing Centre in Germany, and the Czech Hydrometeorological Institute. The international team draws together leaders in satellite remote sensing and upper atmospheric dynamics to address a new frontier of interdisciplinary research.

Global Observations for Basic Research in Aerosols for Naval Coastal Operations:

CIRA's Newest Research Opportunity

Matt Rogers and Steve Miller

According to Merriam-Webster, littoral means "of, relating to, or situated or growing on or near a shore, especially of the sea." The vast majority of life on the planet lives within a hundred miles of a coastline, and the littoral environment represents an important component of this complex part of the earth's biogeosphere. Shipping, fishing, tidal zones, and international borders – all of these fundamental mechanisms in our global interactions depend on the state of the littoral environment. The defense of these industries depends on naval capabilities to effectively operate in littoral zones worldwide.

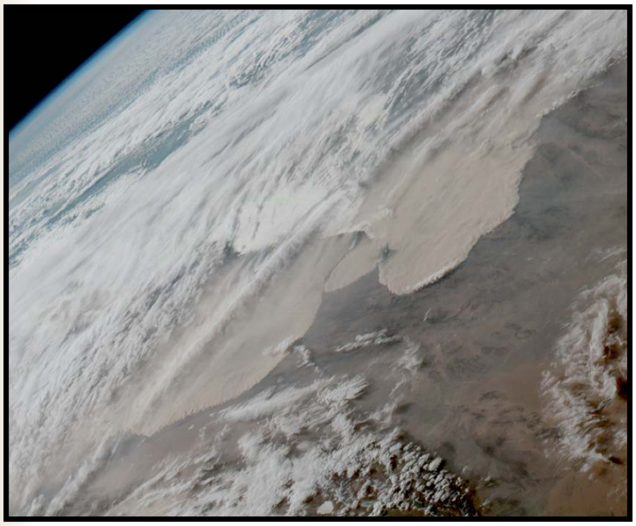
Of special interest are the impacts of aerosols in the littoral – the impact of aerosol concentrations on aircraft operation, clandestine operations, maneuvering, and the utility of anti-missile weapons such as the U.S. Navy's Laser Weapons System (LaWS), among others, have direct implications on effective warfighting capability in the littoral environment. Aerosol events, such as the powerful sandstorm that engulfed Syria and Lebanon in early September 2015, have direct impact on military operations – effectively halting the barrel-bomb attacks by the Assad regime on separatist forces for a period – and can impact logistics and supply-chain operations that further impact where naval resources deploy and operate.

Clearly, having an advanced ability to understand and accurately forecast the complex mechanisms that govern aerosol in the littoral environment is a high priority. To that end, a recent proposal by CIRA researchers to the Multidisciplinary University Research Initiatives (MURI) program sponsored by the Office of Naval Research (ONR) of the U.S. Navy to address the issues facing aerosol research in the littoral environment has borne fruit as one of CIRA's newest research programs.

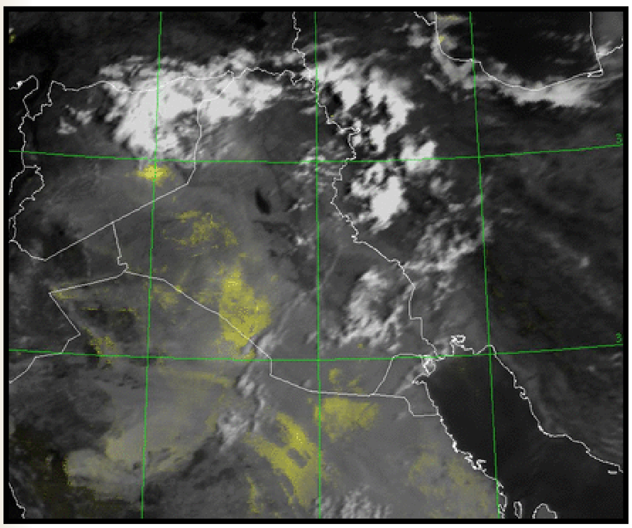
Combining satellite and data assimilation capability from within CIRA with the input of experts in mesoscale meteorology and aerosol, atmospheric chemistry, and modeling expertise from the Department of Atmospheric Science at Colorado State University, the newest MURI program, led by CIRA Senior Research Scientist and Deputy Director Steve Miller, seeks to address the issues at the forefront of littoral aerosol research. At a kickoff meeting in mid-September 2015, representatives from ONR, the DoD, CIRA, the CSU Atmospheric Science Department, and other partner organizations gathered to plan the forthcoming five-year project.

Understanding how aerosols interact with the atmosphere and the shoreline environment is a complicated endeavor. Large-scale systems such as cold fronts can drive large-scale dust storms which impact the littoral environment on a scale of hundreds to thousands of kilometers. Mesoscale systems can drive smaller dust storm activity in complex manners that often defy model forecast capabilities. Thunderstorms can leave outflow boundaries that modify the interaction of airborne aerosols with atmospheric motions. Even at small scales, turbulent mixing of the atmosphere along dust fronts and haboobs can influence the vertical distribution of aerosols, with potential impact for naval operations. The coastline environment itself can modify how shore and sea breezes interact and modify aerosol concentrations in the littoral environment, and ensuring that forecast models correctly account for these issues is a key research topic.

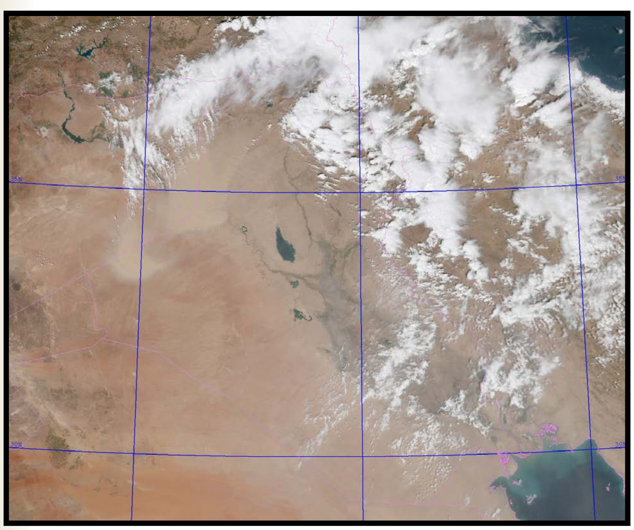
Aerosol chemistry, detecting different aerosol species and their physical and optical properties, aerosol detection from remote sensing systems including active and passive instruments, using the full spectrum of available viewing platforms, including low-light sensors such as the Day-Night Band aboard Suomi



Dust storm over the Gobi Desert, northwest China, as seen in true-color Himawari-8 imagery



Dust storm over Iraq as seen in DEBRA



Dust storms over the Iraq-Syria border as seen in true color imagery from the VIIRS instrument aboard Suomi NPP

NPP, and critically, getting these observations accurately into forecast models, are all topics of interest – and all of which speak to strengths offered by the CIRA-led MURI team.

Over the next five years of the MURI project, CIRA researchers and partners are expected to utilize their capabilities in mesoscale modeling, satellite observations, aerosol chemistry, and data assimilation. Led by Professor Sue van den Heever, a research team dedicated to understanding and modeling aerosol interactions with cloud-resolving numerical prediction models will tackle the complex issues in understanding aerosol concentrations. University Distinguished Professor Sonia Kreidenweis will lead a talented team in aerosol chemistry to improve our understanding of the complex chemical interactions unique to the littoral to improve our understanding of the chemical species of the aerosol environment near the coast. Senior Research Scientist and CIRA Fellow Milija Zupanski will spearhead data assimilation, getting the best possible observations into numerical models in the most accurate and timely manner possible. A large satellite remote sensing team led by Steve Miller will integrate a wide variety of sensor platforms: geostationary and polar-orbiting, active and passive, and other observations to more accurately detect and diagnose aerosol systems in the littoral environment.

One example of the capabilities already extant at CIRA is the Dynamic Enhancement Background Reduction Algorithm (DEBRA), a dust-detecting algorithm capable of use with multiple satellite platforms. Utilizing imagery from three infrared channels, DEBRA can detect regions of dust and aerosol; when combined with high spatial- and temporal-resolution imagery, the algorithm can detect airborne dust over a variety of surface conditions – even an underlying desert composed of the same material as the airborne dust cloud. Additional retrieval capabilities can provide physical and optical properties of these aerosol events. Combine that with enhanced progress in modeling, chemistry, and data assimilation through MURI research, the project will develop the critical understanding of littoral aerosols that will drive and inform naval applications. As always, CIRA researchers are at the forefront of emerging needs for atmospheric research, utilizing deep resources in research topics to advance operational capabilities for a wide variety of end users.

"Earthrise" by Colonel William Anders

True Color Shining Through: Enhanced Imagery from Himawari-8 Shining New Light on Planet

Matt Rogers

One of the first three humans ever to leave the gravitational pull of our home planet, Colonel William "Bill" Anders, the lunar module pilot aboard the NASA Apollo 8 mission, turned a singular and unique experience while in lunar orbit in late December 1968 into a powerful image that changed humanity's understanding of our world and our place within it. Dubbed "Earthrise", the photo taken by Colonel Anders has been described by renowned environmentalist and landscape photographer Galen Rowell as "the most powerful nature photograph ever made". A simple image on color film of the earth rising above the moon brought into powerful perspective the true nature of the human condition – far above the political intrigue of the Cold War, the disease, and poverty raging a quarter-million miles away, "Earthrise" showed a different view of our home, one of a planet without borders, of a blue and green marble graced by cloud and light, peacefully shining in the darkness.

Ever since that pivotal moment, we have been captivated by images of the earth from space. Even as our technological capabilities have advanced to the point where the practical use of remote sensing imagery for forecasting and research purposes is far and away the primary reason for making such images, every scientist who works with satellite data has stopped for a moment during their work to appreciate the elegant beauty of the earth as seen from the remarkable vantage point of outer space. With the launch of the Himawari-8 satellite in October of 2014 and with the cooperation of the Japan Meteorological Agency with NOAA, our view of the earth once again shows us color, as a human eye might see our planet; researchers at CIRA are taking full advantage of this capability to produce imagery of the earth with stunning clarity.

True color imagery of the earth isn't all about aesthetics, of course; researchers have long since understood the value of multispectral analyses of the earth. With respect to the visible spectrum, true color imagery gives us insight into topics such as flooding, snowfall, and biological processes on the surface of the earth (for more details, see the Spring issue of CIRA Magazine.) By leveraging our understanding of how different properties of the earth's atmospheric system interact with electromagnetic radiation, we can separate snow-covered plains underneath high-level cloud cover, track the growth or retreat of polar ice, track dust storms over a vast desert, or track and identify regions of drought and stressed forest growth which may lead to higher fire danger. By combining our understanding of the physics of light with satellite observations of visible radiation, we have the opportunity to recreate what the earth might look like from space to a human eye – a potentially powerful and useful tool for forecasters and researchers alike.

Himawari-8 wasn't the first satellite to see the earth in glorious color, of course – as far back as 1967, a full year before Colonel Anders' remarkable photograph, NASA's Applications Technology Satellite 3, or ATS-3 satellite, was making full-color imagery of the planet. Aboard ATS-3 was the Multi-Color Spin Scan Cloud

How Himawari-8 Sees the World

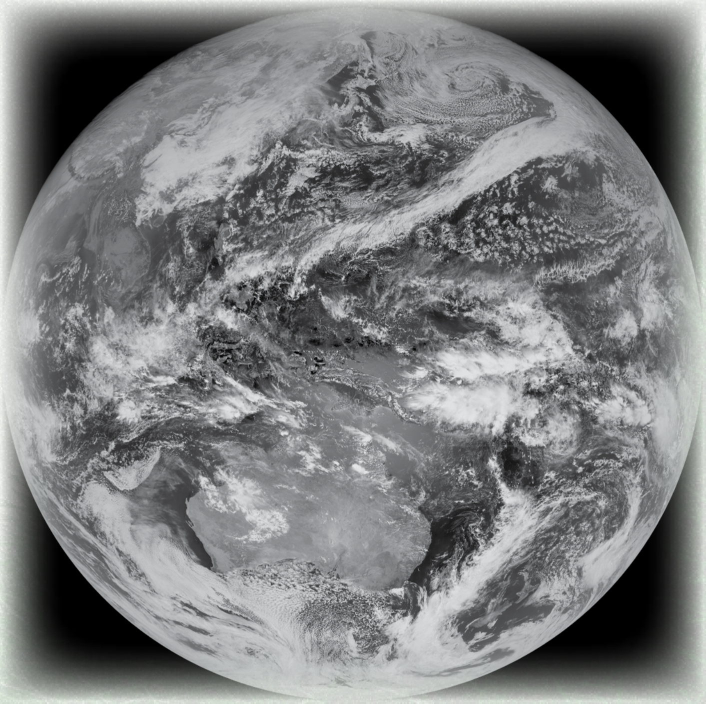


Figure 1: Red channel

Figure 2: Three color channel

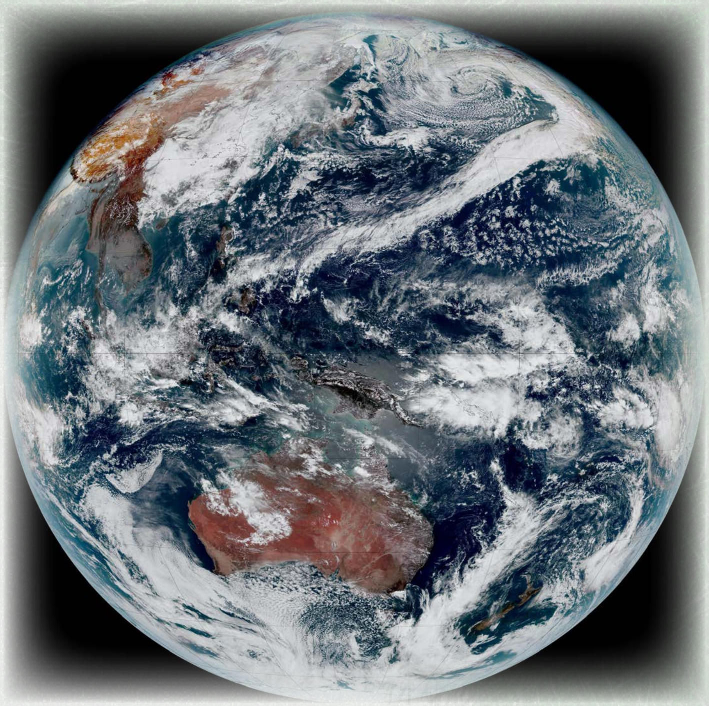


Figure 3: Three color channel with Rayleigh scattering correction

Figure 4:Three color channel with Rayleigh scattering correction and hybrid-green color

Camera (MSSCC), developed by renowned remote sensing expert Verner Suomi, which took imagery of the earth in red, blue, and green color channels that could be combined to create true-color images of the earth from geostationary orbit. Although crude by modern standards, the images made by the MSSCC aboard ATS-3 provided color imagery of the earth for three months before the red and blue channels failed. ATS-3 continued sending black and white imagery of the earth using the remaining green channel for another seven years, and the communications instruments aboard ATS-3 continued to provide service until the mid-1980s.

Fast forward nearly 50 years, and the Advanced Himawari Imager (AHI) aboard Himawari-8 shows the rapid advance in technological and imaging capabilities made since our early efforts to view the earth from space. Although numerous polar-orbiting satellites carrying instruments capable of seeing the earth in color have flown in the intervening period, no geostationary satellite has done so until the launch of Himawari-8; the capabilities of the AHI are impressive indeed – with visible bands of red, green, and blue at 0.46, 0.51, and 0.64μm, respectively (along with a band in the near-infrared at 0.86μm). The AHI instrument can, for the first time since the late 1960s, create true-color imagery of the full disk of the earth.

Fast forward nearly 50 years, and the Advanced Himawari Imager (AHI) aboard Himawari-8 shows the rapid advance in technological and imaging capabilities made since our early efforts to view the earth from space.

The current generation of GOES imagers have a single visible channel, centered in the red at 0.65μm (with wings out to 0.55 and 0.75μm, in the green and near-infrared spectrum, respectively.) The visible imagery we see from GOES-W and GOES-E, therefore, are simply the red component of the earth's complement of visible light as seen from orbit. An image from the red channel of Himawari 8 (Figure 1) shows us a familiar image – one that our current GOES platforms might see. Adding in the green and blue channels, and mapping true color based on the combination of the three color channels, gives us the image in Figure 2 – a true rendition of what the satellite sees from orbit.

Of course, there are always improvements to be made of any image. At the short wavelengths that the red, green, and blue channels from Himawari 8 represent, scattering of light due to the atmosphere (especially for the blue channel, and somewhat so for the green channel) gives us a hazier picture than is necessary. Known as Rayleigh scattering, the phenomenon responsible for giving us blue skies during the day (and red sunsets to boot); researchers can use our knowledge of physics to reduce the component of scattered light, giving us just the light moving directly from the surface of the earth to the satellite. By removing the Rayleigh scattering component signal from each channel, we can recombine our de-hazed red, green, and blue channels to get a clean true color image, shown as Figure 3.

Looking at Figure 3, we see a familiar picture of the earth: white clouds drifting over blue oceans and the varied colors of the earth's continents interspersed. Looking at the deserts of Australia, however, we see a lot more red tones than we might expect. Similarly, the forested island of Papua New Guinea appears nearly black, instead of a rich green. Glancing at a color spectrum gives a hint why; the center of the green band is more near 0.555μm, while the green band of Himawari-8 is at 0.51μm – more in the blue-green part of the spectrum than pure green. In other words, we're using a not-really-green channel in our green calculations – leading to some color error.

There's a way around this; the chlorophyll found in leaves has a property that strongly reflects light in the near-infrared spectrum. If we had a channel that saw light in this spectrum – say around 0.86μm, we could use that image to map where chlorophyll-rich green regions of our planet are, and combine that with our blue-green 0.51μm to create a hybrid green channel that more closely represents what we might see at 0.555μm. The final image, shown as Figure 4, gives us a hybrid-green, Rayleigh-corrected true color image of the planet, one which more closely represents what we might see with our own eyes from the vantage point of geostationary orbit.

Another benefit of Himawari imagery is the rapid scanning capability the satellite offers. With full-disk scans every ten minutes and targeted imagery over meteorological sites of interest every two and a half minutes, Himawari-8 offers much higher temporal resolution than the current GOES series, which provides imagery every 30 minutes, with full-disk scans occurring three hours apart. With the higher temporal resolution comes the ability to track individual cloud features much more closely. When combined with true-color imagery, which allows for more discriminating imagery relating to clouds, surface features, and other atmospheric phenomena (such as smoke), a powerful synergy results in feature-rich imagery. Figure 5 shows high time resolution imagery of a wildfire in Indonesia as it progresses throughout the day; the brown, billowing smoke over southern Borneo is distinguishable from the convective anvils over northern Borneo, and the development of both natural phenomena are more easily tracked.

The early results from Himawari offer convincing evidence for the regular improvement of our satellite observing platforms. GOES-R, anticipated to launch in the latter half of 2016, will carry a similarly advanced imager as Himawari-8. Dubbed the Advanced Baseline Imager (ABI), the imaging instrument aboard GOES-R will see the earth with 16 different channels, as many as those on the AHI (which was inspired by the design of the ABI, despite being the first of the two instruments to fly).

One very critical difference between the AHI and the ABI exists, however. The ABI will carry one extra channel dedicated to water vapor absorption in the near infrared, at 1.378µm. In order to carry this channel, which the AHI aboard Himawari lacks, the GOES-R team had to make room in the instrument band plan by deleting one of the channels that Himawari does carry – in this case, the 0.51µm channel. In simpler terms, the ABI does not have a green channel, which at first flush makes true-color imagery using red, green, and blue imagery extremely difficult, if not impossible. It's possible to simulate true-color imagery using red, blue, and near-infrared channel data, and playing fast and loose with color tables, but with Himawari data available, another solution presents itself – simulate the missing green channel only using red, blue, and near-infrared channels that are available from the ABI. And the hybrid-green research being done by CIRA researchers on Himawari-8 data is already providing methods to simulate the missing green channel on the ABI, allowing true-color imagery, with the high temporal resolution and other benefits that Himawari offers. By leveraging what we can learn from Himawari-8, researchers preparing for GOES-R can have the best of both worlds: enhanced water vapor information and true-color imagery.

As advanced spacecraft take to geostationary orbit in the decades to come, we will see more and more true color imagery products online, with better color fidelity and spatial and temporal resolution. The forthcoming era of satellite imagery in true color promises further advances in our knowledge and understanding of the earth's atmosphere system, as well as a deeper aesthetic appreciation of the beauty of our home. The data, imagery, and hard work of the Himawari-8 team, along with the efforts of researchers devoted to constantly improving the products produced by this remarkable spacecraft, represent the vanguard of a truly inspiring era to come. From the rudimentary views of the earth provided by early spacecraft and pioneering space travelers to the eye-popping products being generated by the next generation of satellite observations, seeing the true colors of our world drives scientific progress while it inspires our imaginations.

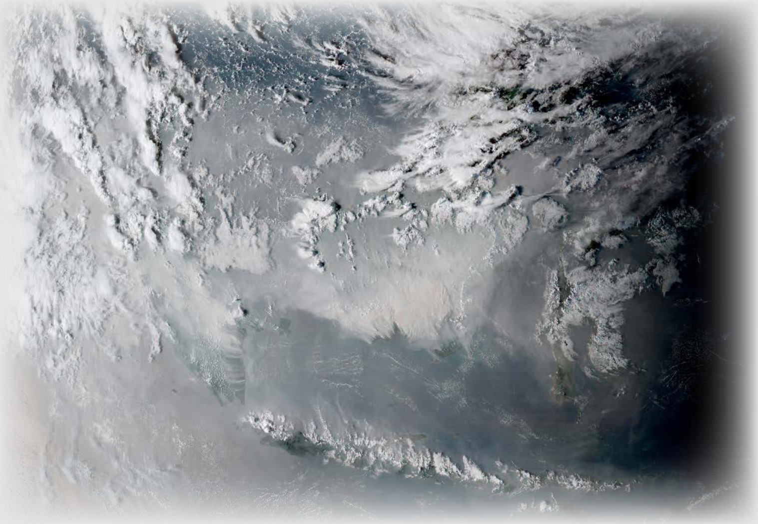


Figure 5: Indonesian wildfire as seen from Himawari-8

Connecting Models and Observations: CIRA Hosts the JCSDA Summer Colloquium on Satellite Data Assimilation

Matt Rogers

"Connecting Models and Observations" are the words that adorn the latest revision of the CIRA logo, and data assimilation lies at the core of that connection. Combining the real-time observational capabilities of satellite observations and retrievals with the analytic and predictive abilities of numerical weather prediction (NWP) models offer forecasters and researchers alike a holistic and rich view of the atmosphere – if everything is ingested in the proper manner. Constantly improving the subtle and complex mechanisms that lie at the heart of data assimilation is at the forefront of atmospheric science research, and this past summer, CIRA hosted an assortment of the best and brightest minds in this field, with the goal of enriching the next generation of data assimilation experts.

The Joint Center for Satellite Data Assimilation (JCSDA), a cooperative program between NOAA, NASA, and the Department of Defense, coordinates data assimilation efforts among remote sensing specialists, model experts, data assimilation researchers, and end users with the goal of reducing lag between the launch of new satellite products and the use of those products in research and forecasting applications. To that end, the JCSDA coordinates several workshops across the country, as well as developing cross-platform products such as the Community Radiative Transfer Model (CRTM). One of JCSDA's more well-known activities is the Summer Colloquium Program, a two-week intensive workshop where students and recent graduates in the atmospheric sciences can interact with leading experts in satellite data assimilation, working on projects collaboratively while learning about the latest techniques.

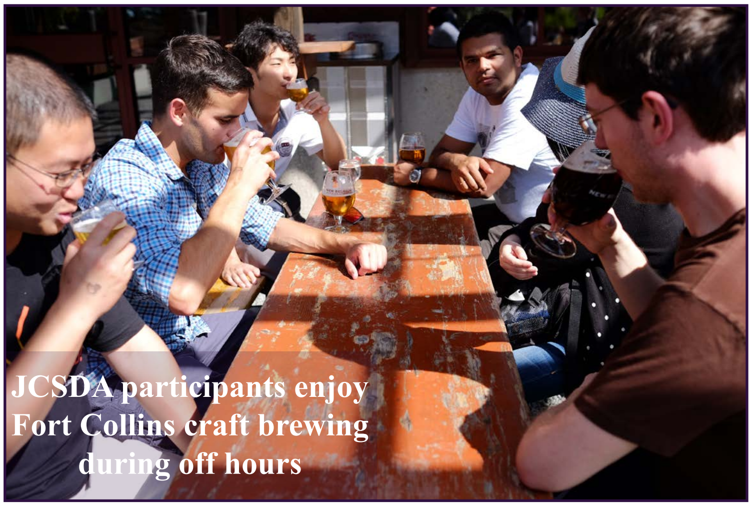
The 2015 JCSDA Summer Colloquium on satellite data assimilation was hosted at CIRA during the last week of July and the first week of August. Seventeen advanced study students and postdoctoral researchers from around the United States spent two weeks in intensive study of data assimilation techniques, including fundamental topics such as variational and ensemble assimilation, infrared and microwave remote sensing products, the unique issues facing assimilation of satellite data into NWP models, applications to atmospheric, oceanic, and land assimilation products, and a general overview of the global observing system. To provide this valuable information, CIRA also hosted nearly thirty experts in the field to provide lectures and examples. Participants in the workshop engaged with project based work and presented their own work.

Of course, the most valuable component of any workshop, colloquium series, or meeting is the after-hours networking, and the scenic locale of Fort Collins and Northern Colorado makes such networking that much more effective. Participants and lecturers were able to chat about variational assimilation techniques over

craft brews during visits to the New Belgium and O'Dells breweries, hear about successes and failures experienced by experts while cruising Fort Collins on rental bikes, or experience the majesty of mountain convection while hiking along Trail Ridge Road at Rocky Mountain National Park.

Working with the JCSDA to ensure the success of the colloquium was CIRA researcher Steve Fletcher, who coordinated with NOAA and NWS counterpart Jim Yoe to bring in the top minds in data assimilation, as well as coordinate the smooth and professional conduct of the colloquium. CIRA researcher and staff members Matt Rogers, Holli Knutson, Jordon Jensen, and Joanne DiVico covered logistics, travel, and social duties, and the entire CIRA community welcomed and nurtured participants and lecturers alike.

Within the mathematics and logic of every NWP model lies a virtual representation of what the planet's atmospheric system could be doing. Data assimilation is the process that refines that representation into what *this* planet's atmosphere *is* doing, and satellite data assimilation offers one of the most powerful tools researchers have to perform this task. Improving satellite data assimilation is a challenge researchers are glad to take on, and CIRA's contributions to that field continue to lead the way, both through scientific contributions and through education and professional development efforts.


JCSDA participants enjoy Fort Collins craft brewing during off hours

JCSDA Director Dr. Thomas Auligne addresses JCSDA participants during a summer workshop held at CIRA


Participants, presenters, and staff of the 2015 JCSDA Summer Workshop

Feast or Famine: The 2015 Pacific and Atlantic

Matt Rogers and Kate Musgrave

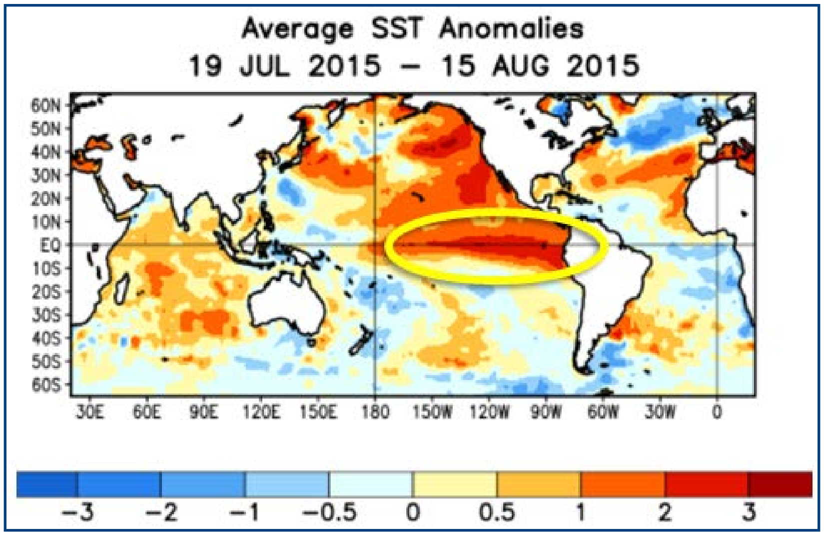


Figure 1: El Niño Water Temperatures

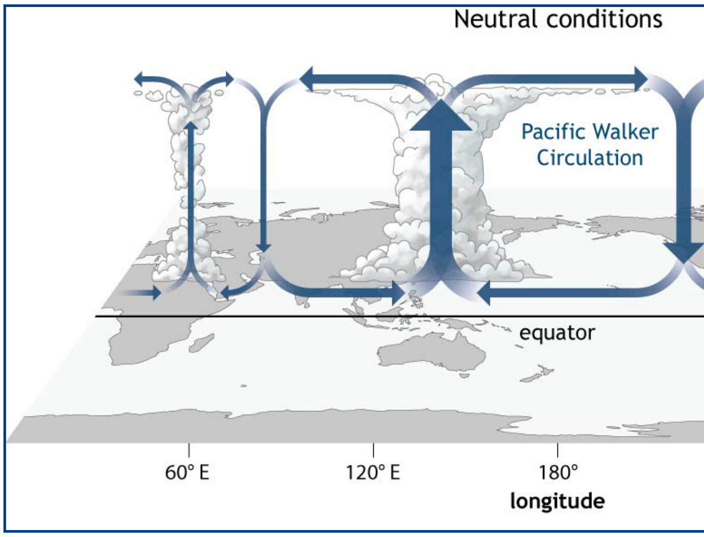


Figure 2: Walker Circulation

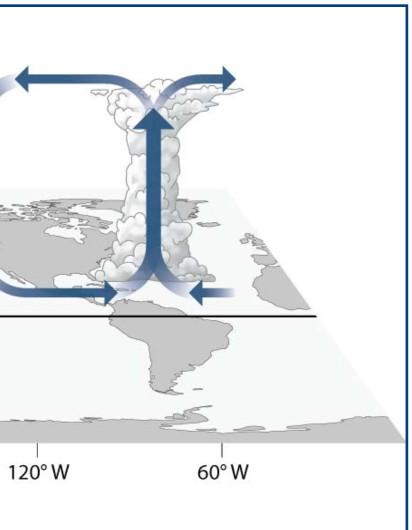
A record-setting number of tropical storms roaming the Central Pacific, including several storms threatening Hawaii. The strongest-ever recorded storm in the Western Hemisphere in terms of barometric pressure, boasting some of the highest sustained wind speeds on record. Double the climatic average of hurricane strength storms in an ocean basin named by the Portuguese for its peaceful waters. These are the highlights of the East and Central Pacific hurricane season for 2015. The Atlantic season, by contrast, is notable for its relative dearth of activity.

Ten named storms (as of the time of this article) are not far off the Atlantic's average mark of 12, but only three of those ten storms achieved hurricane strength (defined as a storm with sustained winds greater than 74 mph) – an average season would see six hurricane-strength storms. Of those three storms, two managed to reach "major hurricane" status (sustained winds of 111 mph or greater), including Hurricane Joaquin, which nearly reached Category 5 status (sustained winds of 157 mph or greater – Joaquin peaked at 155 mph) before ravaging the Bahamas. In the East and Central Pacific, by comparison, ten major hurricanes formed, including Hurricane Patricia, which wowed meteorologists with one of the most rapid developments from disturbance to major hurricane on record.

As might be expected, scientists have some ideas that explain the disparity of storm frequency and intensity between the two basins this year. As background, tropical storms are generally creatures of the warm environs of the earth, beginning life as loosely organized convective structures surrounding some form of disturbance in the atmosphere. Development of these storms is predicated on atmospheric instability to allow for convection to grow, warm ocean waters to provide fuel for the storm's latent-heat engine, and a lack of atmospheric wind shear to better organize the storm's convective cells into the cohesive, self-sustaining structure.

And typically, the tropical Atlantic offers fertile grounds for the development of these storms; notably in the case of the so-called "Cape Verde" storms, where westward moving disturbances born of thunderstorm activity in sub-Saharan Africa move offshore into warm waters, where gentle steering from high-pressure systems normally endemic to the North Atlantic guide the nascent storms further westward, where they develop into tropical storms, often strengthening in the Caribbean before interacting with weather systems that guide them out to open oceans – or to landfall. Hurricanes Hugo, Andrew, Isabel, Ivan, and Emily are notable members of this family of storms, each of which caused billions of dollars of damage, as well as a human death toll.

Hurricane Seasons Compared



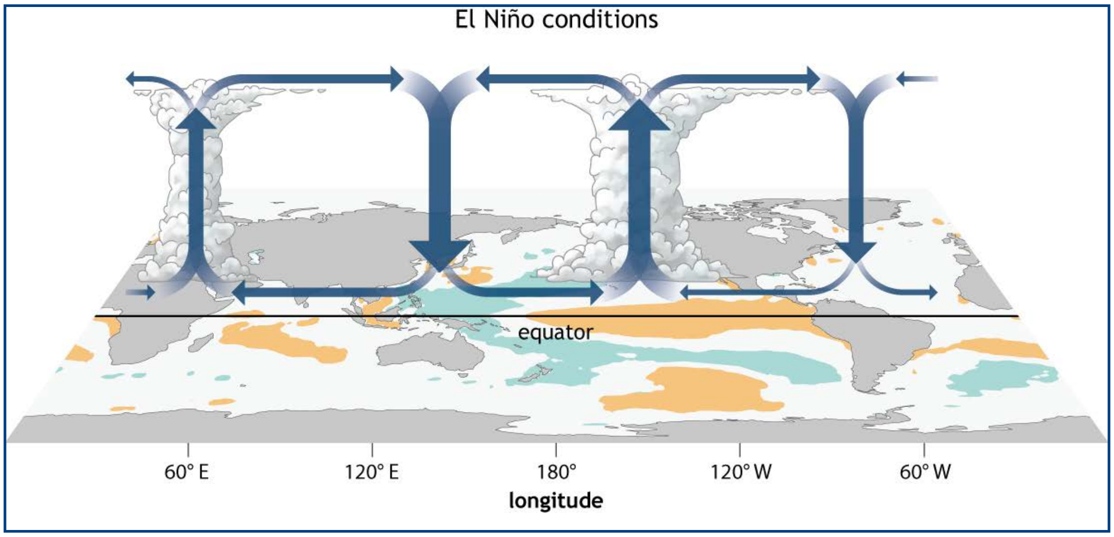


Figure 3: El Niño Air Circulation

The East and Central Pacific Ocean Basins are no less an ideal place for tropical storms to form; the outcome of those storms, however, are usually different in their impact. Warm waters south of Mexico, coupled with disturbances departing the Intertropical Convergence Zone (ITCZ), the belt of convection that spans the equatorial Earth, provide ideal conditions for tropical storm development and intensification. In the Pacific Basin, however, the increased presence of strong mid-latitude storm tracks steers newly formed tropical systems northward – either into the cold water of the easternmost branch of the North Pacific gyre or into regions of strong atmospheric shear, ripping the nascent storms apart. Moreover, these storms form near the populated coastline of southern Mexico and move westward over open water, typically dissipating far from population centers.

So what's the deal with this year's storm situation? A simple answer would be El Niño, a topic of intense research in the atmospheric science community and an important driver of atmospheric events – especially of the anomalous variety – in global weather patterns. Fundamentally, El Niño conditions are marked by a shift in the oceanic temperatures of the Pacific Ocean; the warm waters of the Western Pacific (typically the warmest waters in the basin) cool while the normally cooler waters of the Eastern Pacific warm up (Figure 1). Associated with this change in sea surface temperature are a host of other conditions, several of which feed back into the conditions needed to grow and sustain tropical storm development. In the East Pacific, for example, warmer waters promote more storm formation, while reduced wind shear conditions allow for storms to continue organization and persist much longer – increasing the odds that they develop into stronger storms, interact with population centers, or both.

In the Atlantic Basin, a curious connection occurs. Increased storm development over the Eastern Pacific changes the overall pattern of rising and sinking air over the tropics. Known as the Walker circulation (Figure 2), rising air associated with convection in the Western Pacific creates cells of rising and sinking air, leading to sinking air in the Eastern Pacific Ocean during normal years. In El Niño years, however, these cells shift eastward (Figure 3), leading to sinking air over the Caribbean and Western Atlantic Ocean. This creates unfavorable stability conditions in the Caribbean, reducing the overall formation of tropical storms in that basin. Additionally, shifts in the global storm tracks due to El Niño often increase wind shear in the Atlantic Basin, causing the storms that do form to struggle to organize. In other words, El Niño conditions would favor enhanced storm development in the East and Central Pacific and inhibit development in the Atlantic.

Not that there haven't been some interesting storms to see in the Atlantic – despite the hostile conditions presented from this year's El Niño Tropical Storm Ana, which formed in the warm waters off of Bahama in early May, making it one of the earliest-forming tropical storms in the Atlantic Basin since records began (notably, the only earlier storm in the basin was also named Ana, which formed in April of 2003, at the tail end of another El Niño event). Hurricane Danny became the first major hurricane of the Atlantic season; a Cape Verde storm, Danny was notable for its relatively small stature.

The most notable Atlantic storm of 2015, Hurricane Joaquin began its development north of the Caribbean island of Hispaniola in late September and immediately caught the attention of forecasters as the storm began to develop many similarities to Hurricane Sandy, which ravaged the New York metropolitan area in October of 2012. Joaquin began a northward march, as did Sandy, but was intercepted by a strengthening mid-latitude ridge, which drove the storm into the Bahamas, where it gradually strengthened to Category 4 status. After ravaging the Bahamas, the storm moved back northeastward over the Atlantic, weakening over the cooler waters before transitioning to an extratropical storm system that marched across the Atlantic, with remnants of the storm lashing Portugal with rain in mid-October.

In the Pacific Ocean, Hurricane Andres kicked the season off in May, becoming one of the earliest major hurricanes in the basin, reaching Category 4 strength over the open ocean southwest of Baja California. Soon thereafter, Hurricane Blanca, another Category 4 storm, began a cycle of rapid strengthening and weakening, repeating this cycle twice before making landfall on the southern Baja Peninsula in early June. Further east the state of Hawaii, typically sheltered from tropical storms, would see increased action as Hurricanes Ignacio and Jimena, both forming within a day of each other in late August, both of which reached Category 4 status, and both of which passed to the northeast of Hawaii in early to mid-September, brought strong surf conditions and heavy rainfall to the island chain. Remnants of Ignacio would continue to propagate through the North Pacific before making landfall in British Columbia. Hurricane Kilo formed off the western shores of the Hawaiian island chains before undergoing multiple growth cycles, before transitioning into the Western Pacific where it became Typhoon Kilo, continuing on for a total lifespan of over three weeks – unusually long for a tropical system.

Hurricane Patricia began life as a tropical depression on October 20th offshore of the southern coast of Mexico. Forecasters immediately took notice of the extremely favorable conditions of the East Pacific in the vicinity of the nascent tropical depression, including unusually warm waters and a very low level of atmospheric wind shear, and noted the high likelihood of rapid intensification of the storm. What followed was a master class in storm development, as the newly formed storm reached tropical storm intensity on October 21st, reached hurricane status on October 22nd, and reached Category 5 status early on October 23rd, increasing its wind speed by 100 mph in a 24-hour period. Reconnaissance flights of Patricia began thereafter, where the Western Hemisphere record for lowest barometric pressure was observed – 879 mb. Estimated sustained winds of 200 mph were noted as well. Later on October 23rd, the storm made landfall in the Mexican state of Jalisco, neatly between the resort community of Puerto Vallarta and the important port city of Manzanillo. As of the time of this article, the storm was responsible for eight fatalities and approximately $283 million in damages, including those caused by landslides from heavy precipitation as the storm moved onshore.

For researchers of tropical storms, understanding the complex mechanisms that govern their development and sustainment is a demanding task that demands a long memory and an intricate understanding of a wide variety of atmospheric processes. During El Niño years, the opportunity to observe unique phenomena such as the rapid intensification displayed by Hurricane Patricia or the long life of Hurricane Kilo offers a refreshing challenge in a difficult and rewarding field.

Team Members of the Month

April

Isidora Jankov

It is our pleasure in the Earth Modeling Branch (EMB) to nominate Isidora Jankov as GSD Team Member of the Month for April. Isidora has stepped up to take a crucial role in several EMB activities. A partial list includes:
-Developing and running a prototype of the NARRE (North American Rapid Refresh Ensemble, a possible successor to the RAP at NCEP in 2017) running on Zeus for the past few months
-Taking leadership in organizing, preparing for and running the NMMB (Nonhydrostatic Multiscale Model, version B) tutorial at NCEP next week, sponsored by the Developmental Testbed Center (DTC)
-Serving as DTC Task Lead for ensemble forecasting
-Initiating work in GSD on stochastic physical parameterizations for numerical models, also tied in with her work on design of ensembles for numerical weather prediction
-Participating in the evaluation of global ensemble forecasts for HIWPP with the FIM
Isidora does all this with admirable energy and enthusiasm. We are indeed fortunate to have her as a colleague.

May

Jacques Middlecoff

The Advanced Technology and Outreach Branch nominates Jacques Middlecoff as May 2015 GSD Team Member of the Month for his outstanding work on improving inter-process communications of the FIM and NIM over the last 18 months. During this time, Jacques rewrote portions of GSD's Scalable Modeling System (SMS) to eliminate message packing and unpacking buffers used by MPI to send data between CPU, GPU, or MIC processes. Reorganizing data to eliminate these operations reduced the percentage of runtime spent doing inter-process communications in the NIM from 50 percent to less than 20 percent. Further work to reduce MPI communications focused on enabling direct memory transfers that resulted in a further three times reduction in inter-GPU communications. Collectively this work allows the NIM and FIM to scale better on CPU-, GPU-, and MIC-based HPC systems.

June

Tracy Hanson

Kevin Manross

GSD Team Members of the Month for June are Tracy Hansen and Kevin Manross of the Evaluation and Decision Support Branch. Tracy and Kevin both do excellent work on several projects, and are recognized for their role in securing a significant grant from the U.S. Weather Research Program. Working with the co-PI at the National Severe Storms Laboratory (NSSL) under a tight time limit, Kevin and Tracy put together a detailed three-year work plan. The resulting proposal, plus another from GSD, received all of the available $2.5M funding for this R2O solicitation. Partnering with NSSL, National Weather Service, and others, this three-year project is a step toward incorporating probabilistic information into the NWS hazards forecasting process. The work will be on early phases of the FACETs (Forecasting a Continuum of Environmental Threats) program, focusing on testing conveyance of uncertainty through calibrated, model-derived, probabilistic information for severe convective and flash flooding phenomena.

Posters of the Month

CIRA Staff in Bold

May 2015

"A Comparison of RUC-Derived and RAP-Derived CIP and FIP Icing Products"

Geary Layne
Andy Loughe
Joan Hart
Matt Wandishin
Missy Petty
Jennifer Mahoney

June 2015

"The Meteorological Assimilation Data Ingest System - Current Operational Status and Future Plans"

Greg Pratt
Leon Benjamin
Tom Kent
Gopa Padmanabhan
Leigh Cheatwood-Harris-
Mike Vrencur

August 2015

"Preliminary results on assimilation of AIRS radiances and retrievals in the Rapid Refresh"

Haidao Lin
Steve Weygandt
Ming Hu
Stan Benjamin
Patrick Hofmann
Bill Moninger
Brian Jamison

September 2015

"Ensemble Transform Sensitivity and Targeted Observations: An OSSE Case Study"

Hongli Wang
Yuanfu Xie
Yu Zhang
Ross Hoffman
Robert Atlas
Zoltan Toth

October 2015

"Comparison of Cloud-Radiation Feedback in a Non-Hydrostatic Global Model"

Jung-Eun Kim
Jin Lee

CIRA Reseach Initiative Award

Steve Albers

Welcome to New CIRA Members

In this issue of *CIRA Magazine*, we are happy to welcome all of the new hires that began this year. Due to the large quantity of new hires at CIRA, we have not included introductory paragraphs for everyone, but we encourage you to catch up with our new hires if you haven't already had a chance to meet them. Welcome to CIRA!

Beck, Jeffrey
Research Scientist/Scholar I

Bohannon, Warren
Student Hourly Coordinator

Chu, I-Wen Mike
Research Scientist/Scholar II

Dagg, Erin
Non-Student Hourly Research Coordinator

David, Timothy
Student Hourly Coordinator

Ding, Yanni
Postdoctoral Fellow

Herbst-Tessmer, Robyn
Technical/Support II

Huang, Yaoxian
Postdoctoral Fellow

Jones, Ivy
Student Hourly Intern

Kim, Jung-Hoon
Research Associate III

Kren, Andrew
Research Scientist/Scholar I

Little, Elizabeth
Student Hourly Coordinator

Liu, Shuyan
Research Scientist/Scholar II

Olbrys, Gibson
Non-Student Hourly Coordinator

Orescanin, Biljana
Research Associate II

Partain, Zachary
Non-Student Hourly Intern

Prenni, Anthony
Physical Chemist

Schmidt, Dustin
Research Associate II

Schramm, Julie
Research Associate II

Sienkiewicz, Matthew
Research Associate II

Taylor, James
Research Associate II

Verlinden, Kathryn
Non-Student Hourly Intern

Walton, Renee
Research Associate III

Wu, Ting-Chi
Postdoctoral Fellow

CIRA Vision and Mission

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

Our Vision:

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 in areas of social benefit.

Our Mission:

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

College of Engineering - Foothills Campus, Colorado State University
1375 Campus Delivery, Fort Collins, CO 80523-1375

www.cira.colostate.edu

Colorado State University