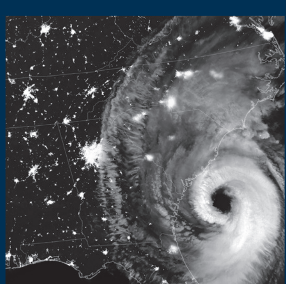

JPSS

SCIENCE SEMINAR ANNUAL DIGEST 2020

Celebrating 60 years of environmental satellites

2020

JPSS SCIENCE SEMINAR ANNUAL DIGEST

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2020 Science Seminar Annual Digest

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FROM THE PROGRAM DIRECTOR

The year 2020 has presented remarkable challenges met with equally remarkable innovations. The critical importance of JPSS providing weather satellite data and products to enable accurate weather forecasts stands in sharp focus during a year that has seen an unprecedented number of tropical storms and wildfires, as well as one of the most intense dust storm outbreaks in decades. On November 10, the 2020 Atlantic hurricane season became the most active in the National Weather Service's 169-year record, breaking the previous record-high number of storms in 2005. Historic numbers of wildfires gripped Australia and the western United States, and together the world is facing the global COVID-19 pandemic. Even as the pandemic has affected every facet of our lives, JPSS has persevered, providing life-saving data and valuable products to our users, and shown that we have much to celebrate and build upon as we now move forward into 2021.

As NOAA-20 completes its third year in orbit and Suomi National Polar-orbiting Partnership (Suomi NPP) completes its ninth, our global community continues to benefit from new applications and innovations made possible by the satellites' atmospheric, oceanographic, and environmental data. In a year when other methods of data collection may have been affected or limited by COVID-19 restrictions, the combination of these two satellites flying 50 minutes apart continues to provide critical data and products to users as they respond to changing environmental conditions. It has allowed for lower latency data and increased global coverage for numerical weather models, forecast applications, and emergency response.

It was another record-setting wildfire season in the western United States. JPSS Active Fire products, day night band imagery, and fire red-green-blue Visible Infrared Imaging Radiometer Suite (VIIRS) imagery products continued to be important tools for weather forecasters and emergency responders to help guide actions to save life and property. The High Resolution Rapid Refresh (HRRR) Smoke Model remains invaluable in tracking smoke from fires often thousands of miles away. The use of the VIIRS Active Fire product to initialize the HRRR Model remains key to its success. The HRRR Smoke Model, now operational at NOAA's National Centers for Environmental Prediction (NCEP) as of December 2, 2020, shows where the largest concentration of smoke from wildfires will be. This can provide important information for air quality managers as well as aviation forecasters who monitor smoke that could impair flight operations. Future uses of the VIIRS Fire product are being explored, including the development of satellite-based fire perimeters. The coverage provided by NOAA-20 and Suomi NPP is also helping our users monitor fires that may be too small to have dedicated assets, while providing a reliable source of data covering a wide range to help direct resources and response teams when needed.

VIIRS flood detection continues to play a significant role in providing flood extent information. In 2020, this included monitoring the spring ice break-up in Alaska and Canada, where restrictions caused impacts on traditional river ice monitoring programs. In addition, because floods are common and widespread throughout the world, knowledge of the extent of the flood can play a role in knowing which population areas are most vulnerable, especially with the added complication of the pandemic changing previous evacuation plans. Flood products, long proven valuable to the National Weather Service, are also helping internationally, providing an important tool for natural disaster response.

These innovations set the stage for the future, as the JPSS program made significant progress on the next satellites in its constellation. JPSS adapted the work environment for virtual collaboration and social distancing safety protocols, with JPSS-2 scheduled to launch in 2022. JPSS completed a major milestone shipping JPSS-2's instruments for integration at the Northrop Grumman Space Systems (NGSS) spacecraft facility in Gilbert, Arizona. VIIRS was the first instrument to be mechanically integrated onto the JPSS-2 spacecraft, with electrical integration completed in November. As of this writing, the Ozone Mapping and Profiler Suite (OMPS) began mechanical integration in mid-November, while ATMS arrived at the spacecraft facility and completed its bench acceptance testing. The JPSS-2 Cross-track Infrared Sounder (CrIS) instrument is authorized for shipment in December. The successful progress and problem solving leading to these milestones is a true testament to the dedication of the JPSS team.

JPSS-3 and -4 continue to proceed with planning launch readiness in 2027 and 2032. We are also looking to the future with Low-Earth Orbiting (LEO) sounder smallsats. Global collaboration continues to be vital to JPSS, as the program maintains important relationships with international partners such as the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the Japan Aerospace Exploration Agency (JAXA). This allows the international satellite community to leverage existing and planned capabilities from other research and operational satellite programs to deliver more capabilities to their service areas and stakeholders. Advances in the future of our LEO satellite constellation and our international partnerships are expanding the capabilities of our data and modeling. These capabilities are vitally important for ongoing weather prediction and environmental monitoring as we experience and prepare for extreme weather patterns.

Thank you to the many contributors to this Science Digest, and to our JPSS science team and community for their outstanding contributions to the program. Thank you and congratulations to Mitch Goldberg for his years of work as JPSS's Program Scientist and the architect behind its highly successful Proving Ground and Risk Reduction (PGRR) Program. Mitch has assumed the duties of the NESDIS Senior Scientist this year. In this position, he will share the JPSS PGRR vision and best practices with NOAA's entire satellite community. Thank you and welcome to Satya Kalluri, who has been detailed to JPSS as its Program Science Advisor. Satya brings more than 25 years of experience in academia, industry, federally funded research and development centers, and the government in developing remote sensing algorithms, applications, and complex satellite ground systems for Earth science missions at NOAA and NASA.

As we celebrate the achievements of JPSS, we are poised to continue tackling the challenges ahead so that we can continue to provide outstanding support to stakeholders, the nation and the world. The future awaits!

Greg Mandt
Joint Polar Satellite System (JPSS)
Satellite and Information Services
National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Commerce

FROM THE SENIOR PROGRAM SCIENTIST

The collage of historic images on the cover page of this year's annual digest, are glimpses from NOAA celebrating 60 years of environmental satellites. Legacy Polar Orbiting Environmental Satellites (POES) and the new generation JPSS satellites provide us with the longest continuous record of earth observations by a single agency. The data from these satellites have been assimilated into weather prediction models in countries around the world. They are also valuable in building extensive multi-year environmental data records that allow us to study changing climate patterns over the past few decades. It is my privilege to introduce you to this year's science digest and highlight some of the major contributions of the JPSS mission to a variety of applications.

The JPSS and Geostationary Operational Environmental Satellite (GOES-R) Programs held the first combined Proving Ground and Risk Reduction (PGRR) Summit in February 2020. The Summit provided an opportunity for algorithm developers, users, and decision makers to meet face-to- face to provide insight and guidance for the future of the NESDIS flagship satellite programs. The Summit focused on delivering user-inspired science to maximize the utility of the NESDIS operational and research products. Each day featured individual sessions on various proving ground initiatives that use both GOES-R and JPSS data. The sessions offered opportunities for algorithm developers and users to share their perspectives on the current status and future needs within each product group. Additionally, poster sessions allowed scientists to present more detailed descriptions of their work. The Summit highlighted how data from both the satellites complement each other in valuable ways and the science teams are moving towards implementing enterprise algorithms that can produce consistent products from both missions. There are several articles in this year's science digest that showcase how the data from the two missions are being exploited.

The collaboration strengthened by this summit prepared the developer and user communities to respond to the challenges to come. 2020 was a very active year for natural disasters that impacted millions of lives across the globe on top of the COVID19 pandemic. We saw a record number of hurricanes and fires in the U.S. which caused deaths and significant economic losses. JPSS data have been vital to detect and monitor these events. Wildland fire smoke emissions release Greenhouse Gases, soot and other aerosols into the atmosphere. These emissions have significant effects on weather in large parts of the world. Weather models are among the tools operational forecasters use to predict reduced visibility conditions from events such as fog and heavy precipitation. NOAA's High-Resolution Rapid Refresh-Smoke (HRRR-Smoke) model, the first NWP model in the U.S. to include the impacts of wildland fire smoke on visibility diagnostics became operational this year. With HRRR-Smoke we can better forecast smoke movement from fires to help diagnose the impacts of this smoke on downstream weather and help cities and towns prepare for the health impacts of these smoke events. This smoke can further impact areas such as ground transportation and aviation. VIIRS fire radiative power measurements are a critical input to the HRRR-smoke model.

2020 also had several periods of Saharan Air Layer (SAL) where massive amounts of Saharan dust traveled across the Atlantic. Some of these SAL events moved all the way through the Caribbean Sea and up into the Gulf of Mexico and its bordering US States. Scientists were able to track these events using VIIRS and OMPS data as well as through NUCAPS soundings. While this is not a new phenomenon, the amount of dust that was transported during the 2020 event was quite expansive. Satellite imagery helping outline the extent of these events and their movement helped tropical cyclone forecasters anticipate their impact on storm movement and strength. Also forecasters responsible for Caribbean Islands were able to prepare the public for the health impacts of these SAL events.

Volcanic activity is a perennial concern. Volcanic eruptions can produce an array of hazards including ash clouds and particulate emissions. Very large volcanic eruptions have an impact on the Earth's radiation budget, which feeds into all different components of the climate system. Volcanic ash is also a major hazard for air traffic. VIIRS data are an important input to the VOLcanic Cloud Analysis Toolkit (VOLCAT) which is operationally run at several Volcanic Ash Advisory Centers (VAAC) to provide timely detection and tracking of volcanic clouds. These types of events not only have a significant impact on air quality and human health, they also have meteorological impacts as well.

The JPSS Program has demonstrated the value of its satellite radiances to the worldwide forecast models. Following the launch of both the Suomi NPP and NOAA-20 satellites, quickly assimilating the data from the CrIS and ATMS sensors into models were JPSS' top priority. Since the launch of Suomi NPP, several enhancements have been made to improve CrIS data assimilation. These include the collection of data at full spectral resolution, using VIIRS data for detecting clouds in CrIS fields of view, techniques to improve land and ocean background parameterization, implementing polarization correction, and synergistic use of CrIS from the Suomi NPP and NOAA-20 satellites. While mid and longwave IR radiances are assimilated into NWP, the shortwave (SW) measurements are not, due to reasons such as noise, solar contamination and non-local thermodynamic equilibrium. Besides NOAA, other government research organizations such as the Naval Research Lab are continuing to investigate approaches to assimilate SW radiances to get more benefit out of CrIS.

JPSS Data Assimilation is not limited to weather forecast models. The practice of assimilating physical fields such as ocean currents and sea surface height is quite mature and routinely performed by many research groups and operational centers. Program stakeholders have taken the next step by working on the assimilation of data into ecosystem models. One challenge to this effort is model complexity. An Ocean Modeling group at the University of California at Santa Cruz (UCSC are assimilating several satellite derived data including Sea Surface Temperature (SST) and chlorophyll-a (chl-a) from JPSS into their ocean model to produce estimates of the physical and biogeochemical ocean state. The UCSC team develops products for stakeholders such as the National Marine Fisheries Service (NMFS), Pacific Fisheries Management Council (PFMC), as well as the fishing community and other stakeholders along the U.S. west coast.

User engagement and outreach has always been central to the JPSS Program. These efforts took on new urgency in a year marked with numerous natural disasters and a global pandemic. For example, the JPSS Proving Ground and Risk Reduction Program (PGRR) demonstrated the proof of concept for a Satellite Disaster Outreach Coordinator (SDOC) to help coordinate and provide integrated support in disaster related events. The COMET® Program, is part of the University Corporation for Atmospheric Research (UCAR) Community Programs (UCP). COMET is a staple of environmental science education and training for NOAA agencies including the U.S National Weather Service (NWS), and several international partners, is also part of JPSS PGRR Training Initiative, which coordinates training efforts across multiple organizations. The novel coronavirus prompted a worldwide public health crisis which, almost in an instant, moved life online. Digital tools and online platforms became an integral part of life. In response to the shift, COMET staff developed and hosted webinars to support university and other instructors in the transition to online platforms. Our scientists are continuing to develop processes to improve user engagement beginning with building trusted relationships with users to the deliver effective services and to measure the impacts of our data and products.

I continue to be impressed by the many new applications and impacts of JPSS data year after year. Organizing science workshops, meetings, training, engaging with users and understanding the impacts of our data and products continuously is a lot of work. I appreciate the dedication of the JPSS Science Team in documenting these achievements through the annual science digest.

Satya Kalluri
Joint Polar Satellite System (JPSS)
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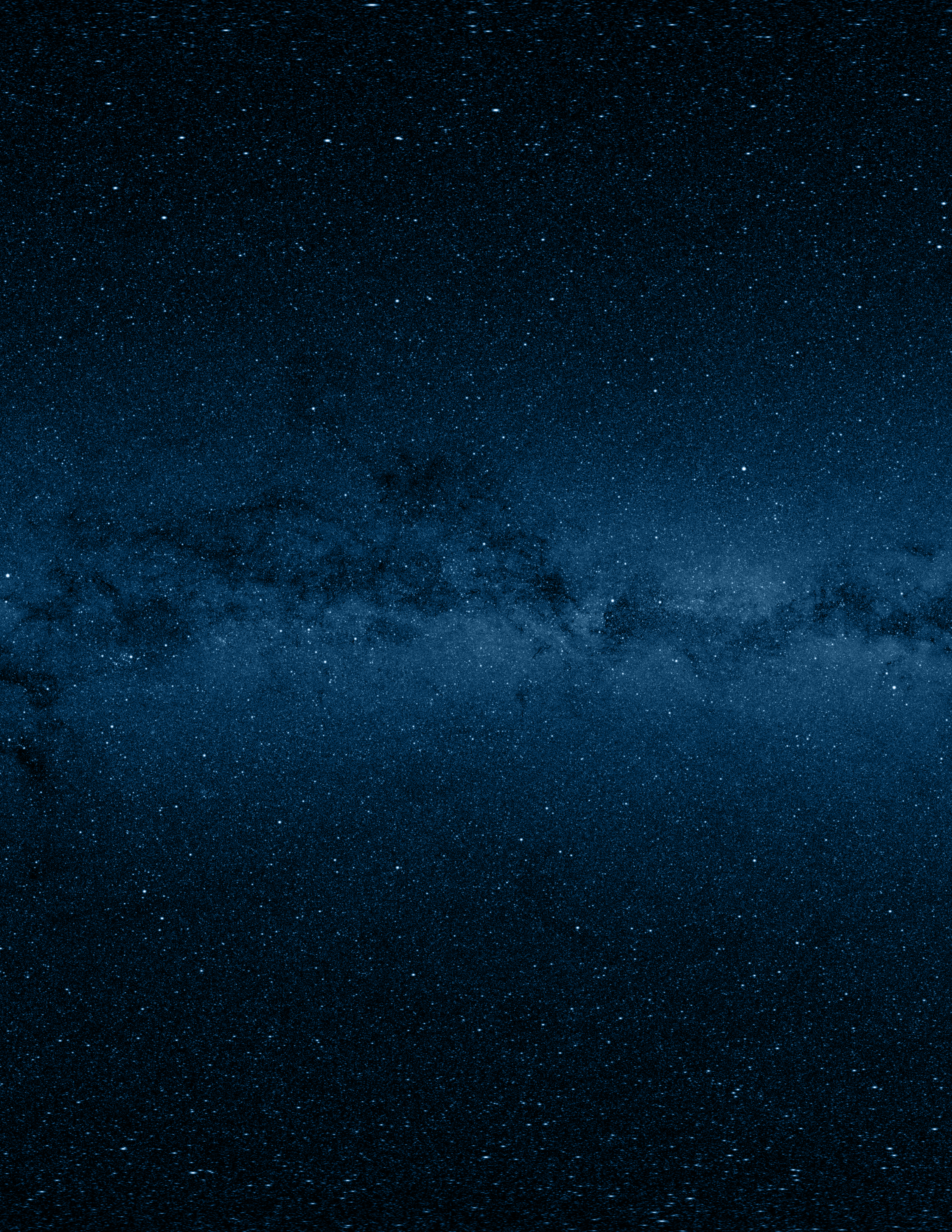
National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Commerce

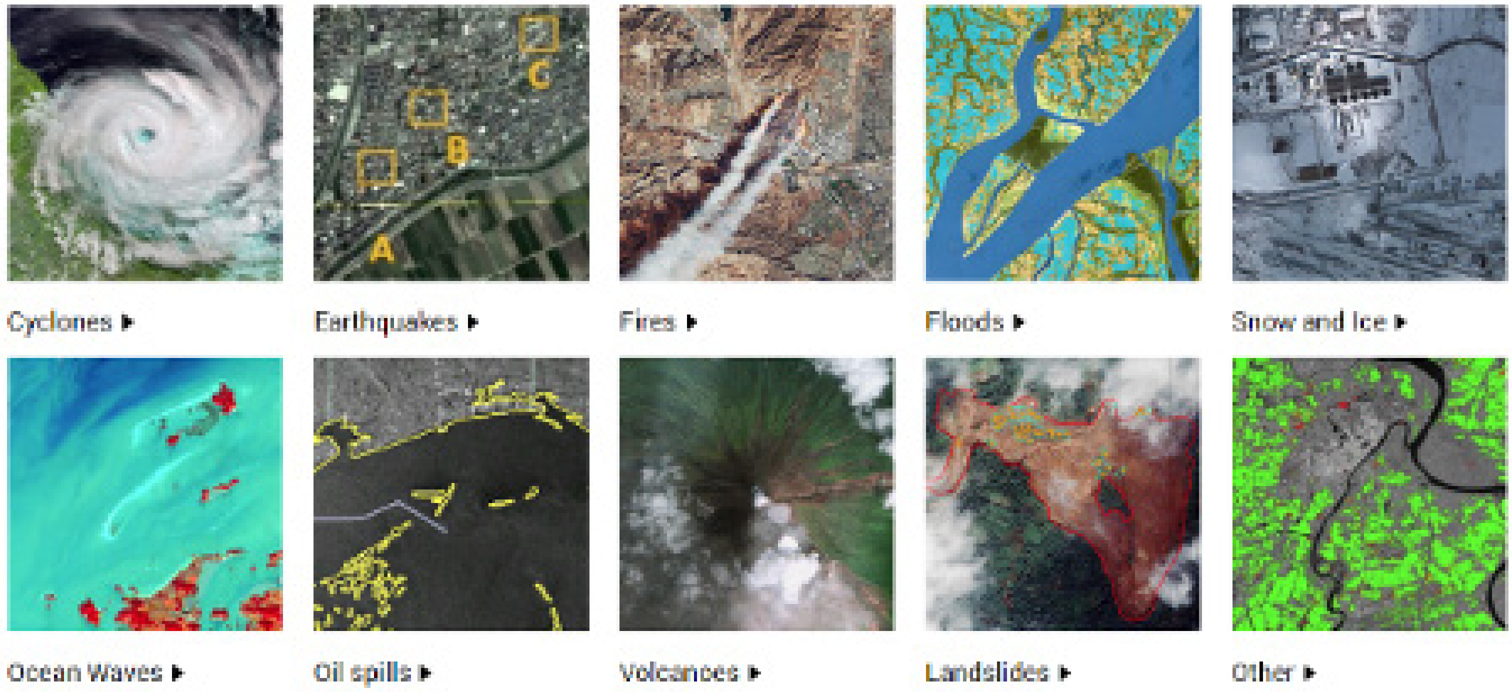


FEATURED ARTICLES

JOINT POLAR SATELLITE SYSTEM SATELLITE DISASTER OUTREACH COORDINATOR:

PROVIDING INTEGRATED SUPPORT IN DISASTER RELATED EVENTS

The information in this article is based, in part, on the October 16, 2019 JPSS science seminar presented by William Straka III, University of Wisconsin-Madison, Space Science and Engineering Center (SSEC), Cooperative Institute for Meteorological Satellite Studies (CIMSS). It also features efforts by Bill Sjoberg, Global Science & Technology/JPSS, Steve Miller, CIRA/Colorado State University, Sanmei Li, George Mason University, and many others.



Weather satellites date back to 1960 with the launch of the first Television Infrared Observation Satellite (TIROS 1). TIROS paved the way for present day satellites such as the National Oceanic and Atmospheric Administration's NOAA-20 and GOES-16 which provide higher spatial and higher temporal resolution products. In the Low Earth Orbit (LEO) satellites such the demonstration satellite Suomi National Polar-orbiting Partnership (Suomi NPP), and NOAA 20, which operate a half orbit apart from each other, have been providing a continuous stream of high spatial resolution observations in a quasi-temporal manner, while their geostationary partners, GOES-16 and 17 constantly provide high temporal imagery, allowing them to show the evolution of storms and other events.

For most of their history, weather satellites have continuously delivered data that has powered forecast models, and generated information for watches and early warnings for all types of weather and environmental conditions. In reality though, the sophisticated instruments on these satellites enable them to capture so many more events across the Earth's landscape, including volcanic eruptions, earthquakes, airplane crashes, and oil spills in ocean waters. The ability to observe such features are enabling applications of their imagery and derived products in areas outside of meteorology including pre- and post-disaster events.

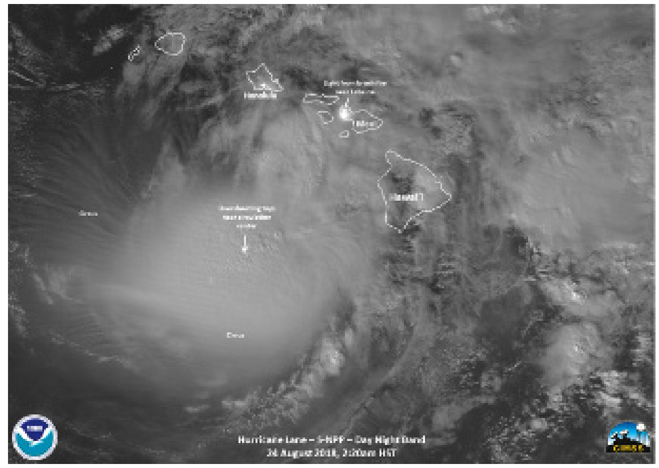
NOAA SATELLITES: FROM MONITORING EXTREME WEATHER EVENTS TO DISASTER RISK REDUCTION

The Satellite Proving Ground leverages satellite observations to feed into NOAA service areas and provide benefits to stakeholders. It works to enhance NOAA services by optimizing the use of satellite data along with that from other sources. The JPSS Proving Ground and Risk Reduction (PGRR) has developed products from NOAA-20, Suomi NPP and other observing systems, including those in the geostationary orbit, such as GOES-R to map areas affected by natural and manmade hazards such as tropical cyclones, floods, volcanic eruptions, wildfires, explosions, and so forth. The PGRR has demonstrated the use of imagery and derived products from VIIRS and other satellite instruments in various non-meteorological applications, including pre- and post-disaster situations. These demonstrations have contributed to a growing list of users of PGRR products outside of the National Weather Service (NWS). These include the Federal Emergency Management Agency (FEMA), California Department of Forestry and Fire Protection (CalFire), state National Guard units, as well as the international community including elements of the International Charter for Disasters.

To help coordinate and provide integrated support in disaster related events, the PGRR created a proof of concept for a Satellite Disaster Outreach Coordinator (SDOC). The idea is to have the SDOC coordinate the dissemination of products from the PGRR to stakeholders such as FEMA and the international charter. The SDOC can also elicit stakeholder feedback and provide it to the relevant development teams for further improvements if needed. And this where William Straka III, a researcher at the University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS), comes in. In October 2019, Straka gave a JPSS science seminar on the use of products—derived from the JPSS' VIIRS sensor as well as instruments from other satellites—in pre- and post-disaster events.

"Having a single point of contact helps to streamline communication with the stakeholder community.

"Having a single point of contact helps to streamline communication with the stakeholder community," says Straka, and he should know as he is the PGRR SDOC—which he has been since mid-2018. He is charged with creating an event catalog to highlight products that can be used in disaster response as well as working with development teams as needed, and also developing product specific websites to help stakeholders. This concept of having a single point of contact to help coordinate all of the pieces of information when providing information during a disaster is done throughout agencies, such as NASA, FEMA, and the U.S. Department of Energy. This helps provide stakeholders with the information they need in a form they can understand and convey to their decision makers.



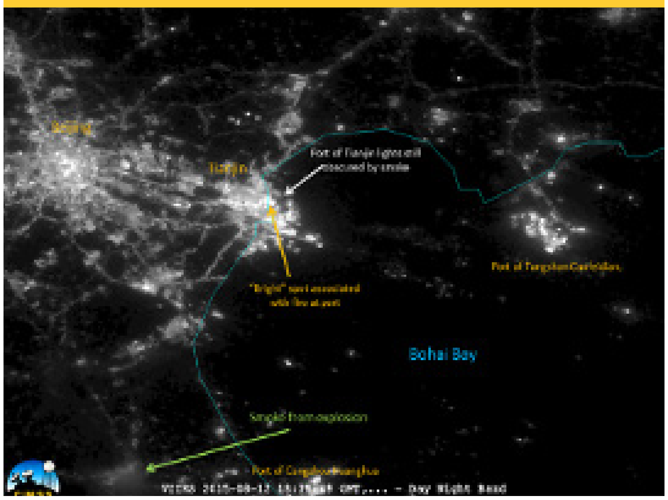
A single image, can reveal a lot of information. This is illustrated in the image above from a VIIRS overpass on 24 August 2018, which shows several disasters occurring at the same time. The most noticeable feature is Hurricane Lane, which impacted the Hawaiian Islands with hurricane force winds that helped fuel a wildfire on the island of Maui. Also in the image, although not as obvious, are volcanic fissures on Hawai'i, which had ripple effects throughout the Big Island.

OUT OF THE PROVING GROUNDS AND INTO CONSUMERS' HANDS

There are a number of examples that illustrate the ways satellite derived products and imagery have demonstrated their capability in hazard surveillance. These include using satellite imagery to: map populations facing potential exposure to flooding, keep track of tropical cyclones, and observe explosions as highlighted in the box on the right.

NOAA-20 and Suomi NPP for example, have a Day Night Band (DNB) on the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument, which is extremely sensitive in low light conditions. The DNB uses reflected moonlight and emitted natural and anthropogenic light to make observations of features such as ice cover, clouds, and fog at night. The DNB has become an essential part of hazard surveillance. Natural hazards such as tropical cyclones, floods, wildfires, tornadoes, volcanoes, earthquakes, mudslides, droughts and others have the potential to inflict considerable damage or loss on many things upon which societies depend, *On 12 August 2015, massive explosions blasted through buildings in China's northern city of Tianjin. The explosions created a giant fireball that shot into the air and fired debris on residual buildings nearby. They also left hundreds dead and multiples injured.*

The VIIRS Day Night Band onboard the Suomi NPP satellite captured scenes of the destruction from these blasts. The image below shows the bright "hot" spot from the warehouse fire along with the smoke obscuring the surrounding lights. While not a quantitative smoke detection, imagery which shows the location of the smoke can help aid in knowing where potential health impacts could occur.



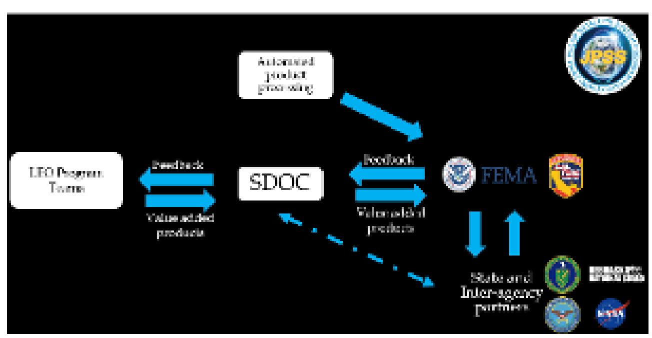
and can create serious impacts to health and well-being. This negative effect is what turns a hazard into a disaster, which, as described by the United Nations Office for Disaster Risk Reduction (UNDRR), is a catastrophic situation that causes massive disruption of social functioning that leads to far-reaching human, environmental, economic and infrastructure impacts.

The following section will provide examples of imagery from JPSS and other satellites such as Sentinel-1A/B and GCOM-W as well as other products from VIIRS, CrIS, AMSR2, ATMS and ABI to illustrate how they can be used pre-, during and post-disasters.

AN ICE JAM IN THE YUKON RIVER

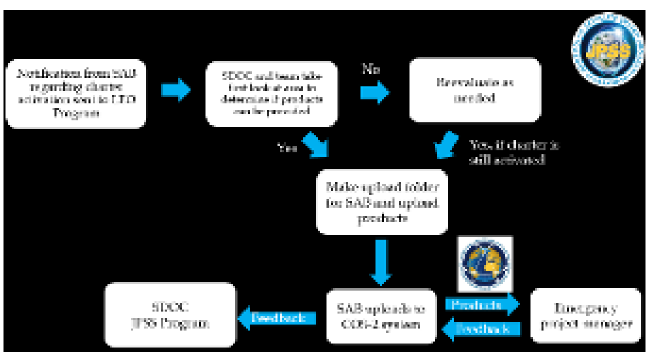
In the 2013 spring season, an ice jam formed in the Yukon River and caused major flooding, which severely impacted local communities living along the river in Galena. Even before the flooding event in Galena, the PGRR Program had worked with research teams—from GMU and CCNY—that JPSS was funding to develop and test river flood and river ice products respectively. The Galena flooding event, which in effect presented a real-world test of these experimental JPSS products, helped demonstrate the utility of VIIRS flood maps in a NWS River Forecast Center (RFC) operational environment. With these products, the timing couldn't be better, and especially in 2017 during the busy tropical cyclone season in the United States where a trifecta of storms—Hurricanes Harvey, Irma and Maria left significant trails of damage and destruction across large swaths of the country. The VIIRS Flood Map product was provided to the FEMA as well as other federal agencies, along with imagery from the DNB showing the power outages in areas impacted by hurricanes Irma and Maria. As a result, products from this initiative are now used to support FEMA's disaster management activities including preparedness and mitigation. In addition, the products are routinely employed by other federal, state, and local government agencies, as well as internationally via the International Charter for Disasters.

METHODS TO INCIDENT RESPONSE



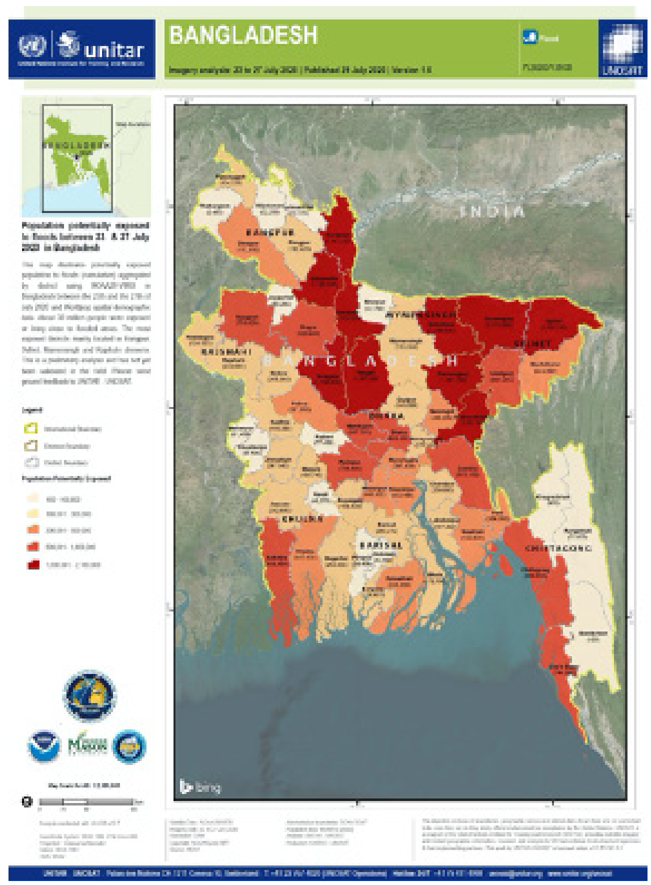
Initially, the responses for disasters came from a variety of people, which often meant that there were multiple people sending the same information multiple times with little coordination. A more streamlined approach was developed with the SDOC project. This first involved the SDOC gathering information on what the stakeholders require and then linking those needs with what is available from the various science teams. By acting as a single point of contact, the SDOC serves as a conduit for providing data to stakeholders as well as feedback to the teams so they can improve their products. This includes providing potentially new validation sources (such as on ground reports) for various algorithms.

When an event happens the SDOC interacts with the stakeholders to help determine what type of products would be most useful. The SDOC then facilitates access to those products to the stakeholders, either through automatic processing, such as the flood products, or through contacts at the various stakeholders. As these products are provided, feedback is passed back to the initiative teams to help identify any further user needs and guide actions taken by product developers.



JPSS, an important contributor to the Global Observing System, also provides data to the International Charter Space and Major Disasters, or the Disasters Charter. The Disasters Charter provides worldwide collaboration to make satellite data available for the benefit of disaster management, especially for developing countries. The Charter provides resources and expertise to be coordinated for rapid response to major disaster situations, and is described more in depth at the following website. (https://disasterscharter.org/web/guest/how-the-charter-works). Depending on the type of event and if the products would be useful, they are updated to Charter Operational System-2 (COS-2), which then provides the products to the end user.

For example in July 2020, the Satellite Analysis and Applied Research, or UNOSAT, an operational, technology-intensive program of the United Nations Institute for Training and Research (UNITAR), mapped population areas of potential exposure to floods using the flood product derived from NOAA-20 VIIRS. See map at: https://disasterscharter.org/image/journal/article.jpg?img_id=6581967&t=1596030895337



The International Charter allows the SDOC to establish contacts with international partners to gather information on their use of satellite data and products, and provide feedback to product development teams. The information gathered by the SDOC is vital for product improvement. These interactions through the Charter and other international stakeholders have led to the usage of JPSS products in other non-Charter international disasters. For example, the VIIRS daily and 5 day flood maps are now being routinely used by the United Nations Institute for Training and Research (UNITAR) Satellite Analysis and Applied Research (UNOSAT) to derived flood extents in developing countries where UN relief efforts are underway and need to be redirected. The LEO/GEO Flood extent maps are also being broadcast over GEONETCast Americas (GNC-A), which broadcasts satellite products to users in the Western Hemisphere. While the effort started in mid-2020, it has been utilized by countries in South America to evaluate where flooding has occurred. In both of these examples, these were events where the Charter had not been activated, but were events where JPSS products that had been shown previously were utilized by individual countries in responding to disasters.

NATIONAL LEVEL EXERCISE 2018

Every two years, as part of the National Exercise Program to test operational capabilities, evaluate policies and plans, familiarize personnel with roles and responsibilities, and foster meaningful interaction and communication across the nation, FEMA leads a National Level Exercise (NLE). The 2018 NLE tested the skill of all levels of government, private industry, and nongovernmental organizations at protecting against, responding to, and recovering from a major Mid-Atlantic hurricane. The scenario simulated a major hurricane making landfall near Hampton Roads, Virginia, causing severe damage to residences, businesses, and critical infrastructure throughout the Mid-Atlantic.

Straka and his counterpart from the PGRR, Sanmei Li of George Mason University (GMU) deployed simulated imagery and products to help exercise various parts of the simulated response. In order to make the exercise as realistic as possible, power outages were simulated in the areas impacted by the (simulated) Category 4 Hurricane Cora. As part of the exercise, stakeholders were provided simulated imagery from the VIIRS DNB based on where outages occurred during the hurricane. Such DNB imagery was heavily relied upon in several ‘real world’ events including the 2017 hurricane season. In another exercise, a simulated VIIRS-ABI flood map and inundation maps were demonstrated. The VIIRS-ABI flood maps are now provided to FEMA and other stakeholders, such as the NWS, on routine basis. Beyond the NLE, several events around the world prompted the use of satellite derived products in pre-, during and post disaster efforts.

In 2019 several disasters were detected and monitored by various satellites including Suomi NPP, NOAA-20, and the GOES-16 and -17 satellites. For his part, Straka participated

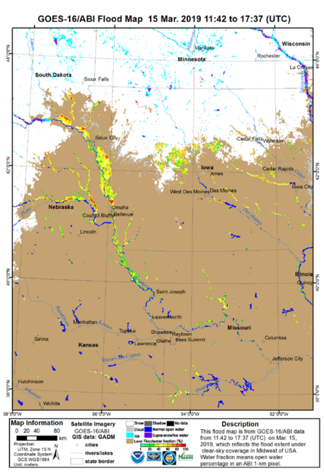
in several JPSS initiatives, and more notably, the Fire and Smoke, and River/Ice Flooding initiatives, which deal with natural and man-made disasters. As a liaison between product developers and stakeholders, Straka says, he helped convey requests and feedback from the stakeholder community to product developers. And from the developer's he helped convey the specifications of their products along with known limitations.

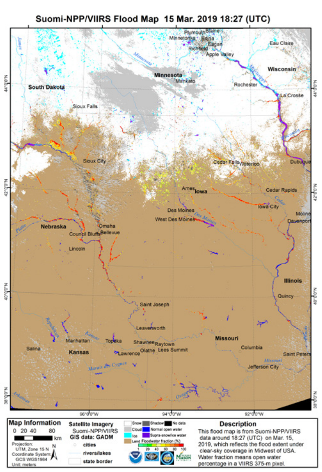
The following section provides examples of products used to support operations.

Midwest Flooding

In mid-March, 2019, a powerful storm system brought blizzard conditions to Colorado and the Upper Midwest, and severe thunderstorms and heavy rainfall elsewhere, resulted in major to record-level river flooding from the Plains to the Upper Midwest and into the lower Mississippi River.

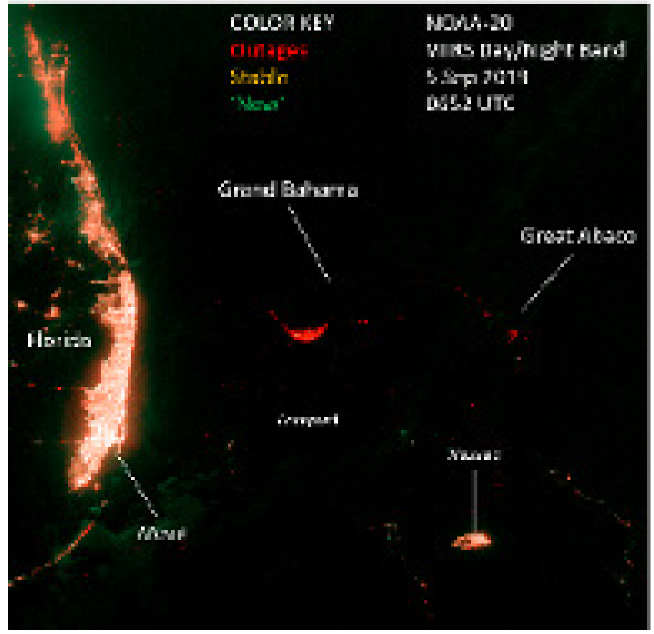
The VIIRS and ABI flood map products (below) vividly showed the flooding, particularly in the Missouri River Basin. The products are routinely produced and sent to FEMA as well as the NWS River Forecast Centers for situational awareness.





Hurricane Dorian

On September 2, 2019, a Category-5 storm, Hurricane slammed into the Bahamas and then stalled for more than 3 days with catastrophic results. It was the strongest storm on record to hit the island nation. Satellite data, and especially, imagery helps meteorologists keep



track of a tropical cyclone's movement and estimate its strength. Data from NOAA's GOES satellites helped provide information on the strength and extent of Hurricane Dorian. In addition, GOES can provide a general idea of where flooding is occurring at a low spatial resolution. The instruments on JPSS can help advance our understanding of the inner structure of the storm (ATMS and derived products on GCOM-W1's AMSR2 instrument). Beyond higher resolution images of flooding that may be taking place in clear sky regions, the VIIRS instrument on S-NPP and NOAA-20 can also provide information on impacts to infrastructure as it relates to power outages. Finally, information from the European Space Agency's (ESA) Sentinel-1 mission can provide even higher resolution flood information, even if the region is obscured by clouds.

STAKEHOLDER FEEDBACK

As is often the case, multiple disasters could be occurring at the same time or within short succession of one another. This means it is often difficult to get timely evaluations of new products. However, agencies often conduct an after-action review which provides useful feedback about products. One such example of the feedback is the direct communication from the stakeholders about how they are using the data. For example, the United States Army North

(USARNORTH), which is the land component of the United States Northern Command, has provided a letter of appreciation documenting the value of the VIIRS DNB to identify areas of power outage caused by Midwest flooding. JPSS capabilities were vital to USARNORTH's disaster response operations. In addition, feedback from agencies such as USARNORTH and FEMA have helped guide the development of various products. They were able to label imagery showing where flooding or power outages are occurring is useful for stakeholders as they brief upper-level decision makers, including the United States National Security Council. One lesson was that the "red/green/yellow" power outage products needed improvement due to the fact that 8% of the population has a red/green color vision deficiency, making the differences in outages hard to distinguish. Other guidance has come in the form of what file formats are useful to stakeholders.

SUMMARY AND CONCLUSIONS

The JPSS Program has developed products derived from its satellites and other instruments that have demonstrated utility in hazard surveillance. In addition, the program has developed a method to disseminate these products to stakeholders. This includes a single point of contact or SDOC who interacts with various stakeholders, both providing products as well as feedback to product developers. This method has proved effective in providing products which are now being routinely used by emergency response agencies including FEMA, the DoD, and the International Charter, as part of their tool box in response to disaster events. ❖

Story Source

Materials obtained from JPSS October Science Seminar titled "Usage of the JPSS' VIIRS Sensor and Instruments from Other Satellites in Disaster Response and Monitoring."

SATELLITE-AIDED REGIONAL DUST FORECASTING FOR PUBLIC HEALTH INITIATIVES

VALLEY FEVER SURVEILLANCE IN THE U.S. SOUTHWEST

The information in this article is based, in part, on the November 18, 2019 JPSS science seminar presented by Dr. Daniel Tong, Emission Scientist NOAA Air Resources Lab and Associate Professor, George Mason University. With contributions from Margaret Simon.

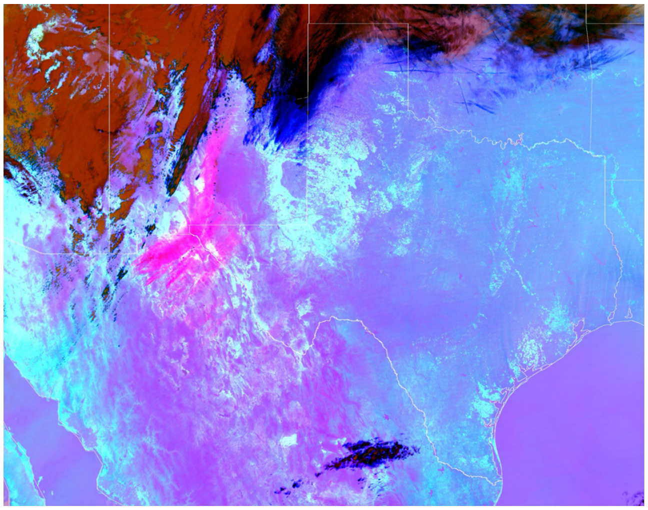
A mountain of dust approaching Rolla, Kansas on 04/14/1935. National Archives image obtained from National Weather Service (NWS) website at https://www.weather.gov/oun/events-19350414-maps

Dust is a mixture of microscopic particles of solid matter such as dirt, ash, minerals, and pollen. It is an example of an aerosol—a tiny particle that is suspended in the air. Other examples of aerosols include pollen, smoke, sea spray, volcanic ash, and industrial pollutants. Aerosols play a vital role in many Earth system processes. According to the World Meteorological Organization (WMO), almost 40 percent of aerosols in the troposphere are airborne dust particles (Terradellas, E., et al., 2015).

Strong winds can pick up large amounts of dust and transport them through the atmosphere – sometimes rising as high up as several thousand feet above the surface of the Earth and spread over hundreds of miles – and form what is known as a dust storm. Dust storms happen in many places around the world, and more notably in arid and semi-arid places such as the Middle East, North Africa and parts of Australia. The Bodélé depression, which lies on the southern edge of the Sahara Desert in north central Africa and, at one time was a massive lake in north-central Africa, is the world's largest seedbed of atmospheric dust (NOAA; NASA; Prospero, J., et al., 2002; Washington, R. et al., 2009). Dust storms are rich in mineral deposits including phosphorus, iron, and nitrates, which feed many regions of the world including the largest tropical rain forest, the Amazon. Dust storms also produce colorful and vivid sunrise and sunset displays. Still, with all of that, dust storm events pose risks to the environment, economy and society, including on health, air quality, transportation, agriculture and solar energy productivity. They also provide evidence of desertification and land degradation (Goudie and Middleton, 1992). Studying their evolution, characteristics and behavior is vital to developing an understanding of how they affect the Earth and impact lives and livelihoods.

Several sensors on weather satellites are able to detect and observe dust storm events. One of these instruments is the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Joint Polar Satellite System (JPSS) NOAA-20 and the Suomi National Polar-orbiting Partnership (Suomi NPP) satellites. VIIRS provides high-resolution imagery, which is used to monitor and track atmospheric aerosols.

On November 18, 2019, Dr. Daniel Tong, an associate professor at George Mason University (AGU) and an atmospheric scientist at the NOAA Air Resources Lab delivered a talk titled "Rising Dust Storms: Impacts on the American



The VIIRS sensor aboard the JPSS Suomi-NPP captured a large dust storm (pink color) on March 31, 2017 over the northern Chihuahua Desert (source: Shobha Kondragunta, NOAA).

Photo credit: Florida Department of Highway Safety and Motor Vehicles and Florida Highway Patrol Twitter feed.

Public," at the JPSS headquarters. Dr. Tong's research focuses on predicting air pollutants and their impacts on human health and welfare. He has published several papers on the use satellite observations to improve forecasts of dust weather hazards. His talk featured insights from a multi-agency study to document and monitor the long-term variability and trend of dust storm activity in the western United States. The talk included a 25-minute screening of a documentary titled "Dust Rising." The documentary, which was created in 2018 by Lauren Schwartzman as part of her work in the UC Berkeley Graduate School of Journalism, underlines the impacts of airborne dust. It also features insights on dust transport from NOAA and NASA scientists, including Tong and his counterpart Hongbin Yu, an atmospheric scientist with the Climate and Radiation Laboratory at the Goddard Space Flight Center (GSFC). Dust color imagery from NOAA's GOES-16 satellite, along with global aerosol simulations from NASA, as well as model output from the Geophysical Fluid Dynamics Laboratory (GFDL) are also featured in the documentary.

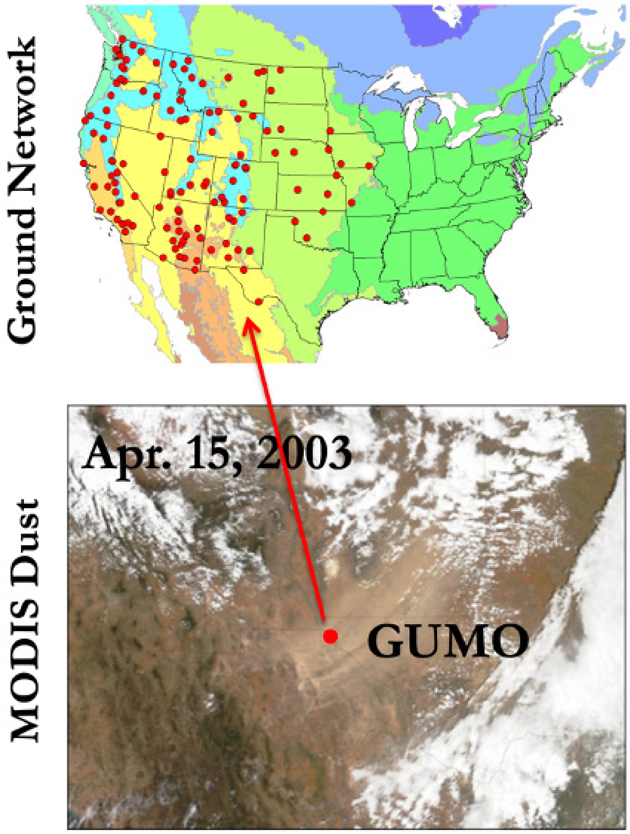
A RISING TIDE OF DUST IN THE U.S. SOUTHWEST

In the United States, dust storms are prevalent in the deserts and arid regions of the Southwest including Arizona, New Mexico, California and Texas. They typically peak in the springtime. Dust storms are not commonplace in parts of the nation, however, they are more widespread than is generally supposed. On February 6, 2020 thick wind-blown dust blanketed parts of Florida, and halted road traffic on Interstate 10 (I-10)—one of three coast-to-coast transcontinental freeways in the United States—due to closures along heavily impacted stretches.

A SNAPSHOT FROM 20 PLUS YEARS

In a 2017 NOAA-led study published in the journal of Geophysical Research Letters, researchers reconstructed the history of dust storms spanning a period of more than two decades in the western United States. Their methodology included a comprehensive dust identification method which used five criteria to separate aerosol samples representing dust storms were from non-dusty events; and continuous (collected before, during and after dust storm events) aerosol observations from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network (see image on the following page).

The scientists found that during their period of study, which covered the years 1988 to 2011, there was a 240% increase in dust storm events in the U.S. Southwest. More than that, "dust storm events in the U.S. southwest increased



Satellite observations of dust storms were used to train a detection algorithm to reconstruct long-term dust climatology in the western U.S. (Source: Tong et al., 2012)

tenfold faster compared to global trends, i.e., 12% /year compared to 1.2%/year globally," says Tong, who led the project. "We have known for some time that the Southwest U.S. is becoming drier," he says. But why?

CHANGING DUST CONDITIONS: A LINK TO THE OCEAN

One place on Earth may provide a treasure trove of information: Our oceans, which cover more than 70 percent of the Earth's surface. "The story goes all the way back to the ocean," says Tong. "Increases in ocean temperatures cause changes in almost everything, including the movement of wind," he adds. Therefore, for him and his colleagues, it was the logical area of inquiry. To give them clearer insight on the ocean's influence on the rising dust storm activity, they drew upon the connections between ocean temperatures and wind patterns. It [the ocean] offered Tong and his colleagues some clues including the one that during the decade leading up to 2000, warmer sea surface temperatures in the North Pacific drew in cooler and drier northerly winds into the Southwestern United States. The winds also blocked the warmer tropical Pacific winds, which bring moisture to the region, and as a result created conditions that were more favorable to dust storms.

So what do the changing dynamics of dust storm activity really mean? For Tong and his crew, it means an exploration of whether it's a natural variation or a foreshadowing of a shift toward desertification.

"No one has the answer." "We simply do not know how dust storms have changed in the past decade," says Tong.

Problem: No long-term dust observations

Still, the U.S. Southwest drying trend has sparked a debate within the science community. Is this a signal of a second dustbowl?

MORE OF THE SAME AHEAD?

It depends on whom you ask. Some experts assert that if historical records are any indication, then a Dust Bowl is inevitable. Their assertions are based on historical records, which extend back to more than 400 years and show that the central U.S. plains experienced severe droughts at least once or twice a century (Woodhouse & Overpeck, 1998); the last being in 1935.

Other experts, who also argue that it is inevitable, say that the confluence of drier subtropics expanded by a shift in precipitation has resulted in greater evaporation, less snow/

A dust storm approaches downtown Phoenix on August 11, 2012. Credit: NOAA

The Dust Bowl

Results of a Dust Storm, Oklahoma, 1936.
Farm Security Administration/Office
of War Information Black-and-White Negatives

Between 1930 and 1940, the southwestern Great Plains region of the United States suffered a severe drought. Once a semi-arid grassland, the treeless plains became home to thousands of settlers when, in 1862, Congress passed the Homestead Act. Most of the settlers farmed their land or grazed cattle. The farmers plowed the prairie grasses and planted dry land wheat. As the demand for wheat products grew, cattle grazing was reduced, and millions more acres were plowed and planted.

Dry land farming on the Great Plains led to the systematic destruction of the prairie grasses. In the ranching regions, overgrazing also destroyed large areas of grassland. Gradually, the land was laid bare, and significant environmental damage began to occur. Among the natural elements, the strong winds of the region were particularly devastating.

With the onset of drought in 1930, the overfarmed and overgrazed land began to blow away. Winds whipped across the plains, raising billowing clouds of dust. The sky could darken for days, and even well-sealed homes could have a thick layer of dust on the furniture. In some places, the dust drifted like snow, covering farm buildings and houses. Nineteen states in the heartland of the United States became a vast dust bowl. With no chance of making a living, farm families abandoned their homes and land, fleeing westward to become migrant laborers.

Screengrab of a U.S. History Primary Source Timeline Presentation, Library of Congress. Accessed from https://www.loc.gov/classroom-materials/united-states-history-primary-source-timeline/great-depression-and-world-war-ii-1929-1945/dust-bowl/

ice, and earlier spring seasons. According to this argument, all these conditions work together to amplify the effects of natural climatic variations further leading to intensified droughts and “dust-bowlification” (Romm, 2011).

Others disagree. They argue that the Dust Bowl was in part, a manmade catastrophe due to poor agricultural practices (Lee and Gill, 2015). They further argue that it occurred when the nation was in the throes of a deep economic crisis – the great depression! Moreover, they say that a reoccurrence is highly unlikely, given the many soil conservation measures that were administered following the Dustbowl. These include the Soil Conservation Act enacted by Congress, which led to farming regulations and better land management.

The Dust Bowl—one of the worst environmental disasters to hit the Southern Plains—occurred in the 1930s. For a decade, residents of the Great Plains faced an onslaught of severe dust storms, which destroyed ecosystems and crops, killed off livestock, caused food shortages and left many homeless. Kicking off these dust storms were natural acts such as extended droughts and man-made acts such as poor land management practices, which were precipitated by the Homestead Act of 1862 which drove settlement over the Great Plains for agriculture; introduced new agricultural machinery that enabled deep plowing and destroyed ecosystems as grasslands were eliminated in favor of farmlands (U.S. Library of Congress). The most significant event, which is referred to as “Black Sunday,” occurred on Sunday 14 April 1935. On this day, mountains of dust brought everything to a standstill as they cloaked the Great Plains and turned the day lit skies into night. Shown below is part of a description from the Norman Oklahoma NWS Weather Forecast Office.

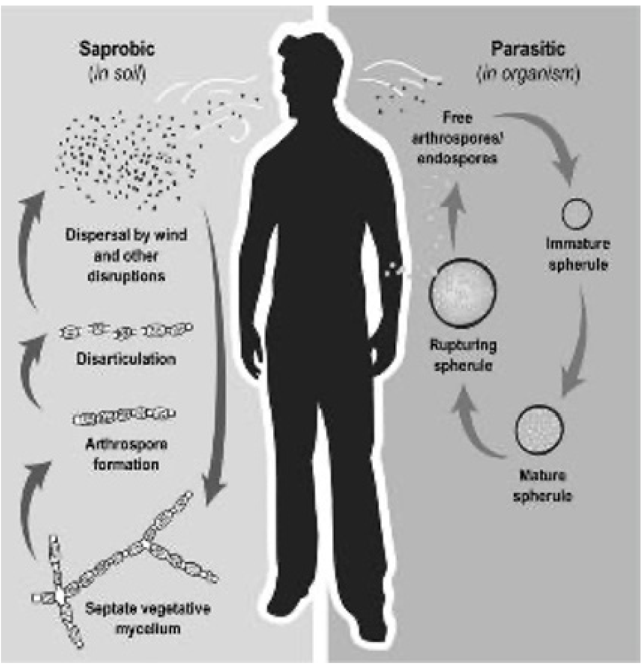
The wall of blowing sand and dust first blasted into the eastern Oklahoma panhandle and far northwestern Oklahoma around 4 PM. It raced to the south and southeast across the main body of Oklahoma that evening, accompanied by heavy blowing dust, winds of 40 MPH or more, and rapidly falling temperatures. But the worst conditions were in the Oklahoma and Texas panhandles, where the rolling mass raced more toward the south-southwest - accompanied by a massive wall of blowing dust that resembled a land-based tsunami. Winds in the panhandle reached upwards of 60 MPH, and for at least a brief time, the blackness was so complete that one could not see their own hand in front of their face. It struck Beaver around 4 PM, Boise City around 5:15 PM, and Amarillo at 7:20 PM.

https://www.weather.gov/oun/events-19350414

REGIONAL CHALLENGES

Confronting an Aerosolized Fungus

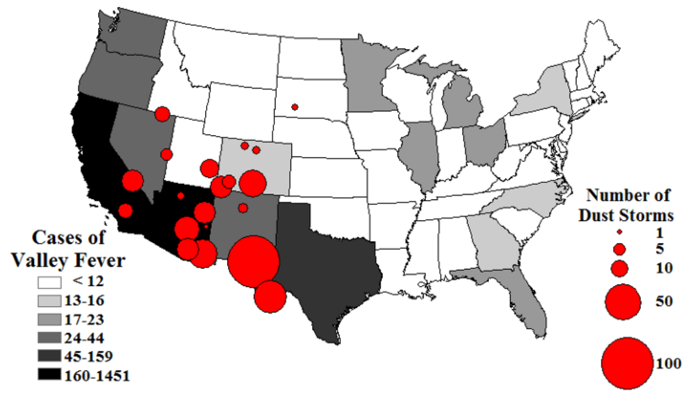
Other Indicators. A soil dwelling fungus known as Coccidioides immitis or Coccidioides posadasii is native to parts of the U.S Southwest including Arizona, California, Nevada, New Mexico, Texas, Utah, and more recently in Washington (Centers for Disease Control; https://www.cdc.gov/fungal/pdf/valley-fever-expanding-cocci-P.pdf).



Life cycle of Coccidioides spp. Image credit National Institutes of Health (NIH). Clin Epidemiol. 2013; 5: 185–197. Published online 2013 Jun 25. doi: 10.2147/CLEP.S34434 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3702223/figure/f1-clep-5-185/

Coccidioides is known to cause valley fever, or Coccidioidomycosis, which is a potentially life-threatening infectious disease, and a major public health menace in parts of the west and southwest United States. Valley Fever is caused by inhaling the soil-dwelling Coccidioides. The disease is also referred to as "San Joaquin valley fever"—where it was discovered—or "desert rheumatism, (CDC). The fungus is dispersed by wind borne dust (Brown et al., 2013). Although it primarily infects the lungs, the fungus can travel through the bloodstream and spread to other parts of the body including skin, brain, and nerves. Arizona, followed by California account for the overwhelming majority of valley fever cases. According to the CDC, people can get valley fever by inhaling the microscopic fungus from the air in these areas. These fungus pose a risk not only to area residents but to visitors as well, says the CDC.

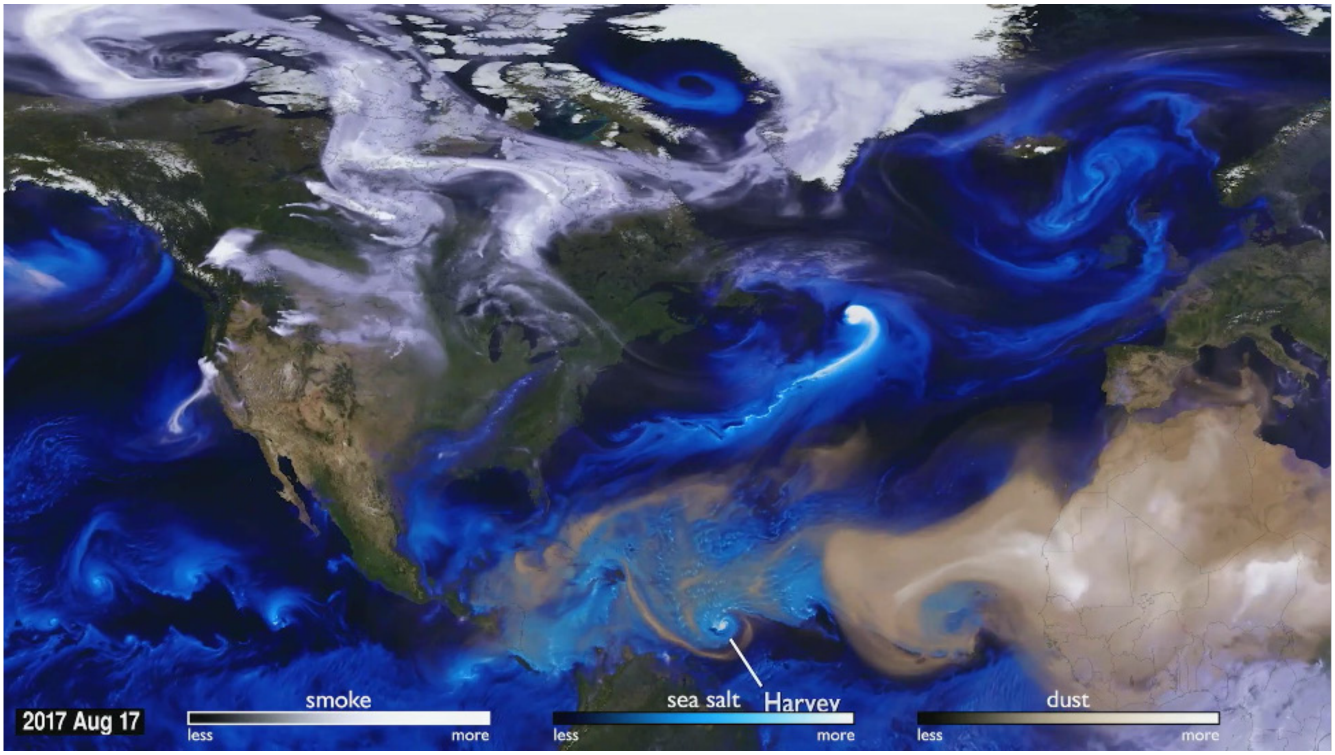
As Tong and his colleagues continued to check out the data, something else stood out. From 2000–2011, there was a significant increase —800%—in valley fever in the U.S. southwest region. And, it appears to be the related to the increasing dust storm events, they say.



The red circles depict the nation's hotspots for dust storms from 1988 to 2011. The same areas also reported the highest numbers of Valley fever cases in the nation. (NOAA.)

In Schwartzman's "Dust Rising" documentary, Sarah Aarons, a geochemist from the University of Chicago, reveals that she was surprised to see the amount of dust transport from the Asian continent, specifically the Gobi desert and other deserts in China and Mongolia, which are the sources of 18 to 45 percent of the dust transported to Sierra Nevada.

In a segment of the documentary, Hongbin Yu explains that the study of long-distance dust transport is done using satellite measurements and model simulations. In fact satellites provide global coverage of dust storm activity, and at spatial and temporal resolutions that are not available from other sources. Yu adds that each year, "close to 56 million tons of dust are transported from Asia to North America," while the Sahara—the biggest source—contributes "close to 180 million tons of dust annually to the Americas." Approximately 27 million tons reaches the Amazon—"an amount that can fill about 400 Olympic-sized swimming pools,"



Screen capture from "Dust Rising" shows dust propagating westward off the coast of Africa and over the Ocean towards North America.

says Yu. The areal extent, density, and trajectory of dust storm events is critical to the people living in regions of impact. Satellites are a really important resource to help in capturing critical information about the dust.

NEED FOR A LONGER SATELLITE RECORD

Tong cautions that even though observational data indicates that dust storm activity over the southwestern U.S. has intensified rapidly in the past decades, the dataset he and his colleagues constructed is not long enough to draw conclusions on a shift toward desertification, or the likelihood of another Dust Bowl. He explains that the limited dataset is also the reason that he and his colleagues continue to collect data from the ground and satellites, and compute these with a solid data record to help monitor dust weather hazards.

Dr. Tong and his team hope to improve dust predictability in the United States and around the world. They also plan to work on transitioning science into services, so the harmful effects of dust storms on public health and economy can be mitigated with more reliable early warning systems.

SUMMARY AND CONCLUSIONS

Aerosols pose significant environmental challenges. According to the WMO, almost 40 percent of aerosols in the troposphere are airborne dust particles. When inhaled, high concentrations of aerosols, including dust particles, can significantly affect respiratory health. Some other impacts include, air pollution, and poor visibility. Given the potential of aerosols to become public health hazards, it is important to monitor the environmental conditions that provide an understanding of their spatial extent and transport. Satellite products and imagery such as those from VIIRS, which are obtained over large spatial domains not available from ground monitoring stations help scientists to identify and evaluate events like dust storms. Tracking the changes in these events over time allows scientists to understand, anticipate, and prepare for potential future changes. In addition, the discoveries from studies on aerosols help develop the strategies needed to deal with their societal impacts. ❖

Story Source

Materials obtained from JPSS November Science Seminar titled "Rising Dust Storms: Impacts on the American Public."

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Images

Dust mountain in Rolla Kansas. National Archives image obtained from National Weather Service (NWS) https://www.weather.gov/oun/events-19350414-maps

Dust blankets Florida Highway. Florida Department of Highway Safety and Motor Vehicles and Florida Highway Patrol Twitter feed. Image accessed March 23, 2020. https://twitter.com/FLHSMV/status/1225491062573162496/photo/1

JOINT POLAR SATELLITE SYSTEM (JPSS), NOAA'S PROVING GROUND INITIATIVE ON NUMERICAL WEATHER PREDICTION (NWP) IMPACT STUDIES AND CRITICAL WEATHER APPLICATIONS

The information in this article is based, in part, on the December 20, 2019 JPSS science seminar presented by Nazmi Chowdhury, Support Scientist/Systems Engineer, JPSS Program Science, and Laura Dunlap, JPSS Algorithm Manager. It also features efforts of many including Drs. Changyong Cao, Lee Cronce, Ben Ruston, James Jung, Agnes Lim, Eugenua Kalnay, Tse-Chun Chen, Jun Li, Haidao Lin, and Stephen Weygandt.

Numerical Weather Prediction (NWP) is a scientific technique that uses computers and mathematical equations—of all the dynamic and physical processes in the atmosphere—to generate a forecast. NWP enables observed data to be converted into information and services such as forecasts and warnings for tropical cyclones, winter storms, and convection, which is extremely important on all scales from local (towns) to global (earth). NWP models ingest atmospheric and oceanic observations from various sources including satellites, ships, airplanes, weather stations and buoys, and radiosondes (airborne instruments dropped from airplanes or weather balloons), which serve as initial conditions. These initial conditions are inserted into NWP models through a process known as data assimilation (Collard et al, 2011) to produce outputs of temperature, moisture, water vapor, and other meteorological parameters from the oceans to the top of the atmosphere.

NWP IMPACT STUDIES AND CRITICAL WEATHER APPLICATIONS INITIATIVE

Satellite observations, and in particular those from microwave and infrared sounders on polar orbiting satellites, make close to 90 percent of the data ingested in NWP models. As major contributors to NWP, the impact satellite observations have on the skill of weather forecasts is extremely important. The Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) NWP Impact Studies and Critical Weather Applications initiative, which premiered in October 2015 to connect scientists engaged in JPSS data assimilation in NWP models, especially those used for critical weather purposes. Members of this Initiative draw upon data from the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) instruments aboard the Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellites. CrIS and ATMS data are assimilated in operational NWP models, such as the Global Forecast System (GFS) and the High-Resolution Rapid Refresh (HRRR) on a routine basis.

Studies show that data from polar-orbiting satellites account for nearly 60 percent of the reduction in forecast error. When assimilated into NWP models, CrIS and ATMS observations have been found to improve 5–7 day forecasts and hurricane track predictions (Goldberg et al, 2013). Such studies enable the performance of new sounders to be evaluated in context with legacy sounders, which provides feedback on instrument capabilities, and helps determine the impact of additional polar-orbiting sounder data on NWP. Microwave and hyperspectral infrared sounders significantly reduce forecasting error. These error reductions have resulted in more accurate forecasts allowing the public to better prepare for high impact weather events like hurricanes.

JPSS PROVING GROUND AND RISK REDUCTION (PGRR) NWP IMPACT STUDIES AND CRITICAL WEATHER APPLICATIONS INITIATIVE

Dr. Nazmi Chowdhury, a scientist and systems engineer and Laura Dunlap, an algorithm manager for data product management and services—both with the Science and Technology Corporation, serve as facilitators for the NWP Impact Studies and Critical Weather Applications initiative. In December 2019, as part of the monthly science seminars at the JPSS headquarters, the duo gave a presentation on the initiative, in which they highlighted their current portfolio of eight projects. For each project, they shared the importance of its research, goals, rationale, as well as desired outcomes, which gave attendees an idea of the breadth and diversity of activities covered within this initiative.

As facilitators, Chowdhury and Dunlap help formulate the initiative's aims and objectives as well as the actions needed to meet those objectives. In addition, they schedule meetings, ensure access to briefing material, and document action items. They also communicate with the JPSS Program Scientist, PGRR Executive Board and JPSS Leadership to keep them informed about relevant issues and other news. The initiative team also communicates key project details through outreach to internal and external stakeholders and the public.

Current members of the initiative include representatives from the Center for Satellite Applications and Research (STAR), Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin—Madison, Naval Research Laboratory (NRL), Earth Science Research Laboratory (ESRL), and University of Maryland.

Like the other PGRR initiatives, members of the NWP initiative work together in multi-disciplinary 'hands on' environments to improve product applications including forecasts of tropical cyclone tracks and intensities. They also focus on calibration/validation, assimilation, forecast improvement, regional and global models, and new observing systems. In this context, the projects aim to exploit the benefits of the 50-minute separation between the Suomi NPP and NOAA-20 orbits, as there is an opportunity to highlight the benefits of increased global coverage. Additionally, projects aim to leverage improved data assimilation methods, better impacts of data latency and improved error characterization, and instrument performance, to enhance the use of JPSS sounder data in NWP models.

ADVANCES IN CRITICAL WEATHER FORECASTING AND NUMERICAL MODELING

Projects in this initiative (see table on following page) are utilizing JPSS data in various stages of the forecasting system to: improve tropical cyclone track and intensity forecasts; evaluate the impact of CrIS and ATMS data assimilation in operational NWP models; quantify model sensitivity to detector differences and provide feedback on instrument capabilities; enhance direct broadcast satellite radiance assimilation capabilities for regional and global models; and improve data denial and quality control methods in NWP models.

Project Title	Project PI	Organization
CRTM Development for Direct OMPS UV Radiance Assimilation	**Cao, Changyong**	NOAA/NESDIS/STAR
Using JPSS Moisture and Temperature Retrievals to improve NearCasts of Geostationary Moisture and Temperature Retrievals	**Cronce, Lee**	UW-Madison/SSEC/CIMSS
Advanced EFSO-based QC Methods for Operational Use and Agile Implementation of New Observing Systems	**Kalnay, Eugenia**	University of Maryland
ATMS/CrIS Calibration and Validation and Assimilation Improving Correlated Error, Clouds, and the Surface	**Ruston, Benjamin**	Naval Research Laboratory, Monterey, CA
Improving the Assimilation of CrIS Radiances in Operational NWP Models by Using Collocated High Resolution VIIRS Data	**Li, Jun**	CIMSS, UW
Quantifying NCEP's GDAS/GFS Sensitivity to CrIS Detector Differences	**Lim, Agnes**	CIMSS, UW
Enhancement of direct broadcast satellite radiance assimilation capabilities for regional and global rapid update models and assessment of forecast impact	**Lin, Haidao**	NOAA ESRL GSD, CIRA
Using Full Spectral Resolution CrIS in GFS	**Jung, James**	CIMSS, NESDIS/STAR

DEVELOPMENT THE COMMUNITY RADIATIVE TRANSFER MODEL FOR DIRECT ASSIMILATION OF THE UV RADIANCE MEASURED BY THE OZONE MAPPING AND PROFILER SUITE

Ozone is a gas that occurs naturally in trace amounts in the earth's atmosphere, distributed mostly in the lower and middle stratosphere. It plays a crucial role in the series of intricate feedback mechanisms that dynamically link the troposphere and the stratosphere. It blocks most of the harmful Ultraviolet Solar radiation from reaching the Earth's surface and impacts air quality near the surface. Daily measurements of the ozone distribution is an important component of a more realistic treatment of the stratosphere in operational weather forecast. This is especially true in the vicinity of jet streams at the mid and high latitudes, which play a major role in the formation and steering of tropospheric weather systems, including large-scale thunderstorm complexes and hurricanes. Improved forecasting of jet streams should lead to improved long-term forecasting of tropospheric weather. NWP centers worldwide are extending their data assimilation and forecasting codes to provide a more realistic treatment of the stratosphere, thus the need for direct assimilation of OMPS UV radiances.

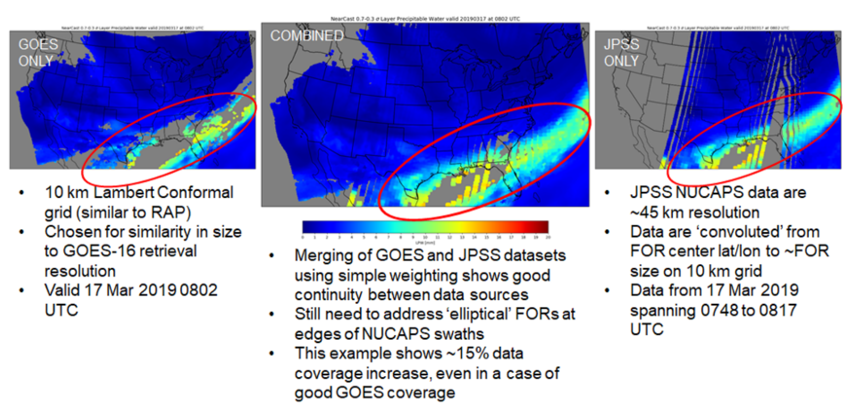
Currently, the assimilation of ozone information from satellites is carried out only in retrieval space. What this means is that from the direct radiance measurements by the OMPS instrument, ozone is retrieved based on theoretical models and a number of assumptions. This becomes the retrieved ozone product used by NWP, but unfortunately also inherits uncertainties in the retrieval process. As a result, the assimilation of ozone retrieval products has two major drawbacks. One is that retrieval is an ill-posed problem and the result may depend on the first guess (or assumptions in the retrieval). The other is the inconsistency between the ozone retrievals from different satellite instruments, for example, from OMPS and CrIS. In addition, the spectral radiance measurements contain rich information about the atmospheric chemistry which may be lost after retrievals. Therefore, the NWP community prefers to assimilate the OMPS radiances directly in the weather models.

NOAA scientist Changyong Cao is looking to ease the aforementioned challenges by developing a UV capability in the Community Radiative Transfer Model (CRTM) to assimilate OMPS radiances directly for weather forecasting. The CRTM is a fast radiative transfer model which is used to calculate radiances and Jacobians for satellite IR or MW radiometers. It was developed by the Joint Center for Satellite Data Assimilation (JCSDA) as an important component in the NOAA/NCEP data analysis system. This new capability "requires substantial development for a new version of the CRTM that can treat polarized radiation correctly (called Vector CRTM)," says Cao. Adding that it will "enable the CRTM to assimilate daily measurements of the ozone field from OMPS." As of November 27, 2019, Cao and his team released the Vector CRTM (Version 3.0 alpha) to the community for testing, and in the near future, they are gearing up to demonstrate the direct radiance assimilation of OMPS UV radiances.

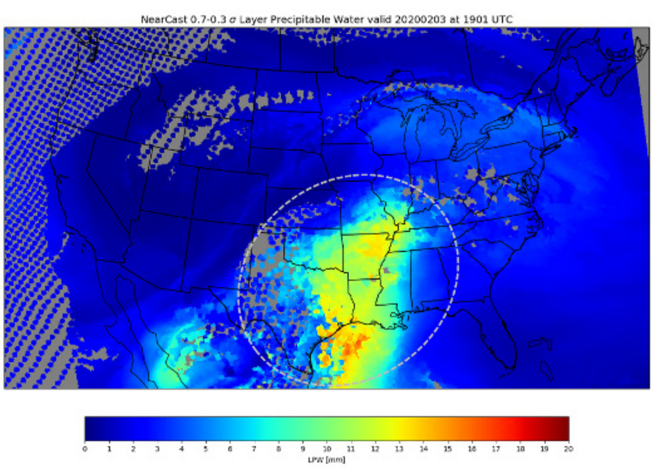
USING JPSS MOISTURE AND TEMPERATURE RETRIEVALS TO IMPROVE NEARCASTS OF GEOSTATIONARY MOISTURE AND TEMPERATURE RETRIEVALS

Vertical profiles of moisture and temperature provide vital information of rapid changes in the vertical and horizontal structure of the atmosphere at any given location and time. These atmospheric profiles can be derived from various sources including satellites, radiosondes, and aircraft. However, the full benefits of these data often go unrealized due to spatial, temporal, fiscal, and data assimilation limitations. Radiosondes offer the most complete vertical resolution, but their coverage is limited to mainly twice-a-day launches at 0000 and 1200 UTC, and they are also spatially coarse given a coverage area of every 400km or so over the continental U.S. Aircraft offer valuable data up to flight level but with many lacking suitable moisture sensors, their observations are limited to temperature and wind only. Profiles obtained by geostationary satellites offer a much more continuous and spatially detailed representation of the atmospheric moisture and temperature due to both full CONUS and OCONUS coverage at higher spatial resolution (~10 km) compared to the radiosonde network (~100s of km) and at a higher temporal frequency (5-60 minutes for satellite, compared to 12 hours for radiosondes). Even with a coarser vertical resolution, these data (especially the moisture profiles) have been shown to be critical in isolating areas where/when severe convection is expected to occur in the next few hours.

However, geo-based profiles are not available in cloudy regions. Moreover, GEO observations are seldom used in operational NWP systems over land. These challenges are known all too well to Lee M. Cronce and Ralph A. Petersen, both scientists at the University of Wisconsin – Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies (CIMSS). The pair developed a short-range, observation-driven model originally envisioned to analyze and project forward in time GOES satellite-based observations of moisture and temperature to support operational very-short-range predictions of hazardous weather events. Although the system has received favorable reviews from forecasters in the U.S. and Europe, Cronce and Petersen have recognized that data gaps in cloudy regions pose one of the biggest obstacles to usage of GOES retrievals that inherently in the GOES atmospheric profiles that are limited to infrared (IR) spectral band data which cannot penetrate thick cloud layers, thereby limiting useful information only to cloud-free areas.



Learning from and building upon the observationally-driven CIMSS "NearCast" system (previously developed under the GOES-R program), the pair are looking to alleviate the deficiencies noted in their system by incorporating temperature and moisture retrievals from the JPSS space crafts into the analysis and forecast system. The JPSS profiles are generated using an operational retrieval package known as the NOAA Unique Combined Atmospheric Processing System (NUCAPS) along with other microwave data sources. Specifically, real-time S microwave retrievals will be used to fill gaps left by GOES IR observations in cloudy areas. Microwave profiles have the advantage that they are 'all-weather' due to their ability to see through the clouds. Cronce and Petersen expect that the system could be an effective means for forecasters to use satellite moisture information over land that is not fully incorporated in NWP assimilation



Early example of combining GOES IR and JPSS/MiRS microwave observations into merged NearCast. Circled areas show greatest influence of microwave observations, which can improve coverage from ~10% (using JPSS alone) to ~33% (when including MiRS) in areas of highest moisture content.

ATMS/CRIS CALIBRATION AND VALIDATION AND ASSIMILATION IMPROVING CORRELATED ERROR, CLOUDS, AND THE SURFACE

Since 1995, the Naval Research Laboratory in Monterey California (NRL-MRY) has assimilated radiances and evaluated and disseminated imagery from a constellation of polar-orbiting and geostationary satellites for distribution to the Department of Defense and the global community. NRL started to pursue testing and assimilation of data from a new generation of instruments – the Advanced Technology Microwave Sounder (ATMS) and Cross-track Infrared Sounder (CrIS) – in its NWP model and data assimilation systems (DAS), after the launch of the ground-breaking Suomi National Polar-orbiting Partnership (Suomi NPP) satellite in 2011.

As part of the Numerical Weather Prediction (NWP) Impact Studies and Critical Weather Applications initiative, an NRL project led by Dr. Benjamin Ruston is exploring the use of data from the ATMS and CrIS sensors aboard Suomi NPP and its follow on NOAA-20, with the goal of enhancing its usage in operations. Efforts under development for the enhancement of assimilation methodology include correlated observation error, enhanced use in cloudy scenes, and improved use of surface sensitive channels. In previous efforts this project demonstrated that error correlation among CrIS Full Spectral Resolution (FSR) channel data and conservative use of ATMS/CrIS near surface sensitive channels enabled increase use of JPSS and a greater impact in the NRL Atmospheric Variational Data Assimilation Accelerated Representer (NAVDAS-AR). Efforts continue to increase the uptake of the JPSS datasets in

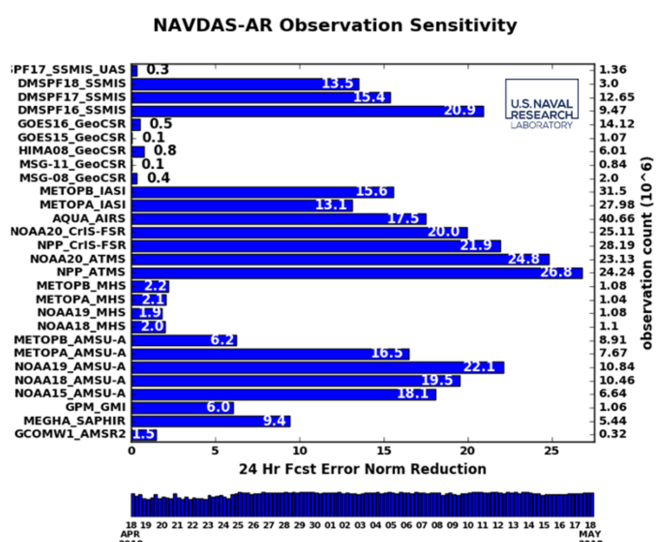
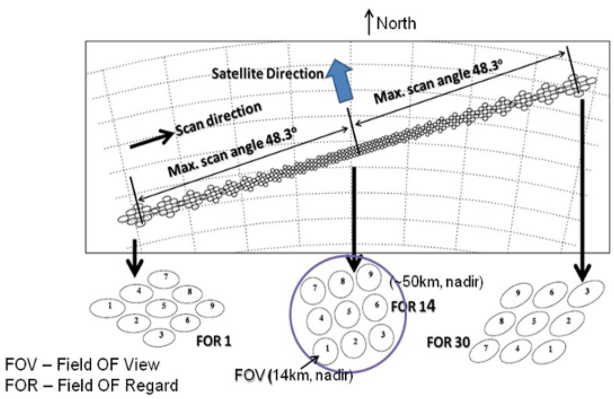


Figure 1. Accumulated Forecast Sensitivity to Observation Impact (FSOI) for suite of sensors in the U.S. Navy Global Environmental Model (NAVGEM) using the NAVDAS-AR assimilation system.

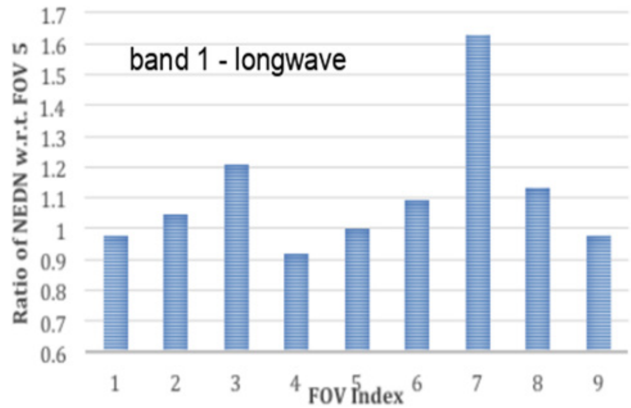
all-sky (i.e., cloud and aerosol affected scenes) and all-surface (i.e. over land and sea-ice) to take full advantage of the JPSS sensor suites. Shown in Figure 1 is the accumulated impact of various radiance sensors including SNPP and NOAA-20 ATMS and CrIS on the reduction of a 24-hour forecast error norm, the Forecast Sensitivity to Observation Impact (FSOI).

QUANTIFYING NCEP'S GDAS/ GFS SENSITIVITY TO CRIS DETECTOR DIFFERENCES



Newer hyperspectral infrared (IR) instruments are using an array of detectors to make simultaneous observations. CrIS (diagram of the detector array is shown on the left) has nine fields-of-view (FOV), arranged as a 3x3 array of 14km diameter spots (nadir spatial resolution). Differences in detector properties contribute to the inter-detector bias despite they are thought to be manufactured the same. Current radiometric uncertainty and noise-equivalent changes in radiance (NEdN) requirements for IR sounder instruments do not fully capture or constrain the noise characteristics between detectors. Different noise between detectors have been observed (diagram of the ratio of NeDN of each of CrIS FOVs with respect to FOV 5) for each CrIS detector. These differences can result in major users like the Numerical Weather Prediction (NWP) centers, to reduce data usage if a choice has to be made to select observations from one detector so as to avoid complication.

The project investigators note that no systematic studies have been conducted to determine the degree of match needed between detectors



Noise differences between the CrIS detectors derived from real NOAA-20 data.

in an array used for IR sounding instruments that support NWP. This project, which seeks to understand what level these inter-detector biases begin to affect NWP analysis and forecast systems and help define the inter-detector design requirements, is somewhat an important first step. Instrument providers will need this information to assure that all instrument field-of-views (FOVs) are matched well enough to support NWP radiance assimilation.

JPSS DATA ASSIMILATION IMPROVEMENTS AND DATA DENIAL EXPERIMENTS

Operational NWP models, such as the Global Forecast System (GFS), which is run at the NOAA National Centers for Environmental Prediction (NCEP), rely on data assimilation techniques to combine observations with their predictions and generate initial conditions for a subsequent forecast. Hyperspectral instruments such as the Cross-track Infrared Sounder (CrIS) contribute to the data that are assimilated in NWP models. Improved instrument characterization and reduction of errors in the assimilation techniques are two main areas of focus to improve these initial conditions.

This project, led by Cooperative Institute for Meteorological Satellite Studies (CIMSS) scientist James Jung, is collaborating with NCEP and NESDIS scientists on projects to improve the use of the CrIS instrument and reduce errors in the assimilation techniques. Recent improvements in CrIS instrument characterization include;

characterizing all nine fields-of-view (FOVs), transitioning NCEP's data assimilation software from the CrIS normal spectral resolution (NSR) to the full spectral resolution (FSR), adding cloud information from the Visible Infrared Imaging Radiometer Suite (VIIRS) to the NWP datasets for improved profile selection, and characterizing the effects of the CrIS polarization correction developed by Space Science and Engineering Center (SSEC) scientists for the NWP community. Various changes to the CrIS profile selection and quality control procedures have also been added to NCEP's operational data assimilation software.

Current and future plans of this project are focusing on improving infrared radiance assimilation techniques in the atmosphere's boundary layer and adding information to the surface-atmosphere interactions with the CrIS instruments.

ADVANCED EFSO-BASED QC METHODS FOR OPERATIONAL USE AND AGILE IMPLEMENTATION OF NEW OBSERVING SYSTEMS

Occasionally, operational NWP forecast models go through abrupt drops in forecast skill, a phenomenon referred to as "forecast skill dropout." To date, several studies have linked these dropouts to degraded or "bad" observations. More specifically, they have revealed the inability of the operational NWP quality control (QC) system to (1) detect the flawed observations, and (2) filter them out.

Eugenia Kalnay, a professor at the University of Maryland, and her former students Tse-Chun Chen, and Daisuke Hotta, have developed a diagnostic technique called Ensemble Forecast Sensitivity to Observations with Proactive Quality Control (EFSO/PQC), which can identify whether the impact of each individual observation assimilated into a NWP model is beneficial or detrimental to the skill level of a forecast. The EFSO/PQC determines this independent of the presence or absence of any other observation, meaning that results on the critical impact of any assimilated observing system can be simultaneously obtained from a single model run.

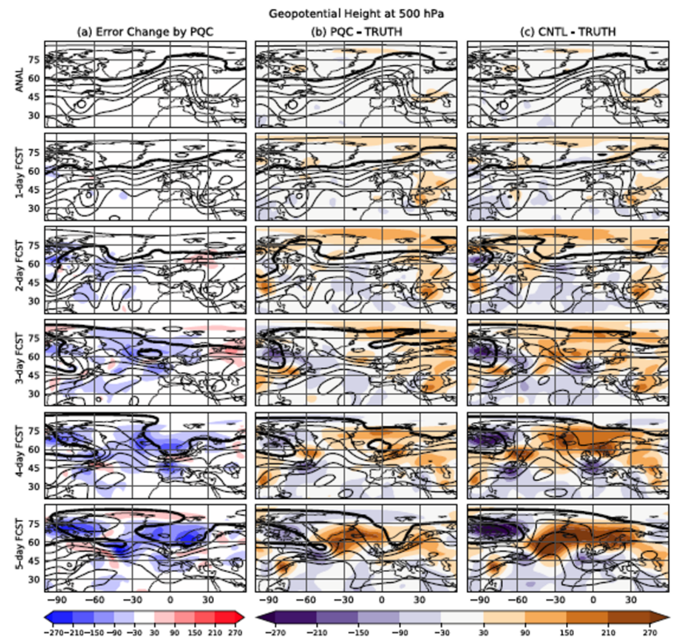


Figure 2. The 5-day evolution of the geopotential height [m] forecast and forecast error changes at 500 hPa from one of the cycles (Jan. 28, 2008, 00Z) in the experimental period. (a) Geopotential height from verifying truth (CFSR) in contours and the forecast error changes from accumulated PQC-updates in colors. Blue colors represent forecast improvement; red colors represent forecast degradation. The thick lines highlight the contour of 5100 m. (b) Geopotential height modified by accumulated PQC-updates (PQC-30) in contours and the difference between the modified fields and the verifying truth in colors. Orange colors represent an overestimation of heights; purple colors represent an underestimation of heights. (c) As in (b), but for the control geopotential height (CNTL).

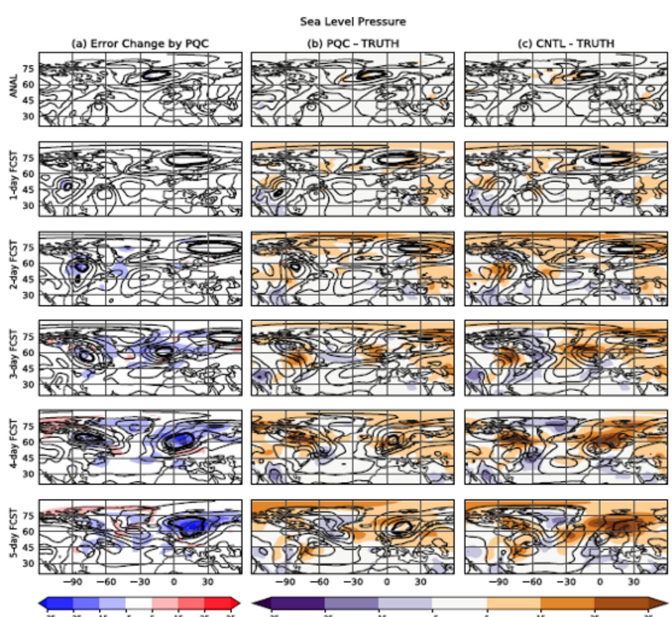


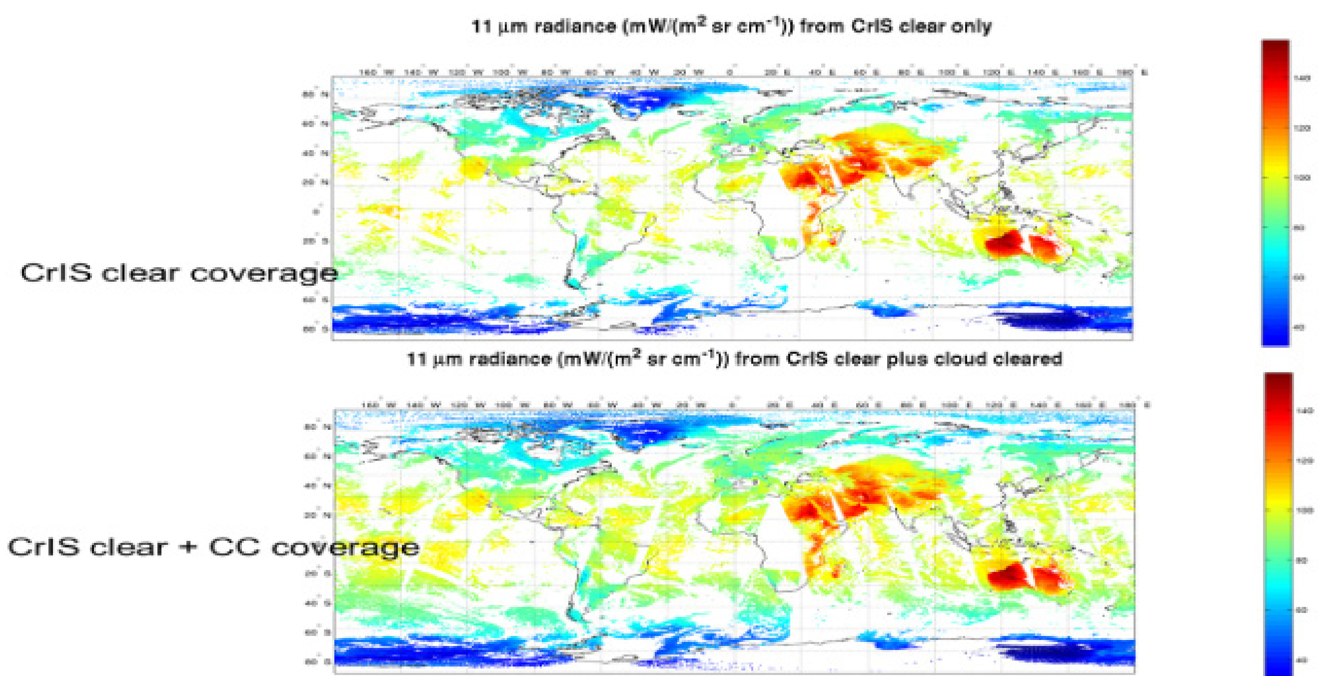
Figure 3. SEQ Figure * ARABIC 3 As in Figure 2, but for sea level pressure [hPa]. The thick lines highlight the contour of 985 hPa.

The goal of this project is to expedite the research to operations transition of a new observing system or asset through end-to-end application of the demonstrated benefits of applying EFSO and PQC to data assimilation. The idea is that the EFSO/PQC will expand the ability of the National Environmental Satellite, Data, and Information Service (NESDIS) to estimate the impact of observations as a quantitative complement to Observing System Experiments (OSEs). Preliminary results suggest that, when operationally implemented, EFSO/PQC will improve by more than 12 hours the quality of forecasts. Fig. 2 shows an example of a forecast skill dropout that was avoided by applying EFSO/PQC (Chen and Kalnay, 2020, MWR, submitted).

IMPROVING THE ASSIMILATION OF CRIS RADIANCES IN OPERATIONAL NWP MODELS BY USING COLLOCATED HIGH RESOLUTION VIIRS DATA

Hyperspectral infrared (IR) sounders such as CrIS onboard the Suomi NPP and NOAA 20 satellites, provide atmospheric temperature and moisture vertical structure information that can improve the forecast skill in numerical weather prediction (NWP) models. What IR sensors cannot do, is see through most clouds. This limitation, along with the uncertainty of radiative transfer models (RTMs), which is usually larger in cloudy skies, only spectral radiances less affected by clouds are assimilated in weather analysis systems at operational NWP centers. RTMs link observations and the state of the atmosphere in NWP. However, several research efforts are seizing this opportunity to look into the utilization of infrared radiance data in cloudy conditions.

One of these efforts is an imager based cloud-clearing (CC) technique, which provides an alternative and effective way to remove the cloud effects from a partially cloudy field-of-view (FOV) and derive the equivalent clear sky radiances, or the cloud-cleared radiances (CCRs) for assimilation in NWP models. Data from the Visible Infrared Imaging Radiometer Suite (VIIRS) can be used to create CrIS Cloud Cleared Radiances (CCRs) that allow for radiance measurements to be used by NWP models in cloudy skies. Assimilation of these CCRs has been successfully demonstrated in NOAA's operational GFS and HWRF models. The image on the left illustrates the increase in usable radiance measurements when adding CCRs compared to only clear data for a given time period.



Example of 1 day CrIS coverage from one month data

ENHANCEMENT OF DIRECT BROADCAST SATELLITE RADIANCE ASSIMILATION CAPABILITIES FOR REGIONAL AND GLOBAL RAPID-UPDATE MODELS AND ASSESSMENT OF FORECAST IMPACT

The ability to assimilate radiance data from polar orbiting satellites in rapidly updated regional models has traditionally been limited by long data latency times (often more than two hours) for the availability of these observations, and the very short data cutoff window (approximately 30 min) for these models. Short-range forecasts (3-24 hours) are crucial for day-to-day weather guidance and hazard warnings of meteorological phenomena, such as severe thunderstorms, winter storms, and tropical systems. Direct broadcast (DB) provides regional users rapid access to satellite data, which enhances forecasters' ability to predict and monitor severe weather events. DB capabilities have also allowed for satellite radiance data to be used in many of the rapidly-updating, regional weather prediction models, such as the NCEP operational Rapid Refresh (RAP) and High Resolution Rapid Refresh (HRRR) models.

A PGRR project led by CIRA research scientist, Dr. Haidao Lin, is focused on optimizing the use of direct broadcast data in the hourly updating RAP and HRRR models and applying traditional and novel verification techniques (along with subjective evaluation) to provide comprehensive documentation of the forecast impact from these data. Lin and his research team have documented the enhancement in skill levels for short-range forecasts, including better predictions of hazardous weather, such as severe thunderstorms and high impact aviation weather. Through extensive retrospective experiments with the RAP and HRRR models, the impact of assimilating direct broadcast radiance data has been evaluated with the short-term forecast verification against the traditional radiosonde observations as well as against CrIS observed radiance observations.

Suomi NPP ATMS and CrIS radiance data generated from DB have been operationally assimilated into the Rapid Refresh RAPv4 model since July 2018, with a further expansion planned for the RAP/HRRR upgrade scheduled for June 2020. These direct broadcast data will also play a key role in improving the forecast skill for the Unified Forecast System (UFS) based Rapid Refresh Forecast System (RRFS) planned for NCEP implementation in 2023.

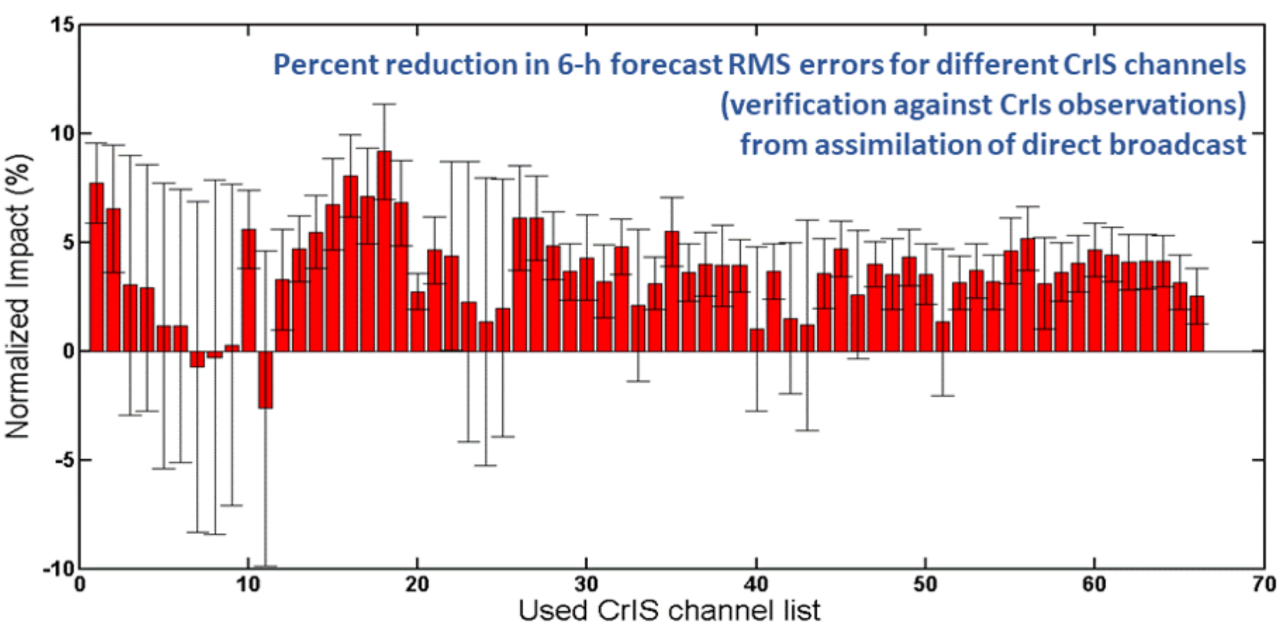


Figure 4. Normalized RMSE reduction (%) from the DB radiance data denial run 6h forecasts against observed CrIS brightness temperature over the RAP domain, from one month retrospective experiment. Error bars show 95% confidence threshold for statistical significance.

The significant data impact from the direct broadcast data is illustrated in Figure 4, which shows the 6-h normalized RMSE (%) from the radiance DB data against observed CrIS radiance for the 66 CrIS channels over the RAP domain. Overall, the use of direct broadcast data accounts for about half of the total forecast improvement from all radiance data assimilation in the RAP.

LOOKING AHEAD

In closing, Dunlap provided some plans for the future. Thus far, ATMS and CrIS data have been integrated into critical weather models leading to improvements in tropical cyclone track and intensity forecasts. In addition, improvements were made to data selection and uncertainty of numerical weather prediction models via assimilation of ATMS, CrIS, and VIIRS data including enhancement of operational ATMS/CrIS usage with the NRL NWP model and data assimilation systems. The initiative plans to continue incorporating new and improved data products.

There are also plans to exploit multi-satellite configuration. Currently the Suomi NPP and NOAA-20 satellites occupy the same orbit 50 minutes apart from each other. This provides double the data per orbit to be used in forecasts and models. JPSS-2 is planned to launch in 2022, adding another satellite to the same orbit to get more data into forecast models. In the next call for proposals, the NWP initiative also plans to exploit the benefit of adding non-NOAA satellite data such as products from the MetOp series of satellites. With JPSS-2 and the MetOp Second Generation satellites set to launch in the coming years, assessing the impact of additional data from polar orbit can help prepare for future use of products from these satellites and address a key user challenge of optimizing the use of high volume data sets.

Additionally, there are plans to expand the use of direct broadcast data. This helps mitigate latency issues and makes forecasters more inclined to use the products. ❖

Story Source

Materials obtained from JPSS December Science Seminar titled "Joint Polar Satellite System (JPSS), NOAA's Proving Ground Initiative on Numerical Weather Prediction (NWP) Impact Studies and Critical Weather Applications."

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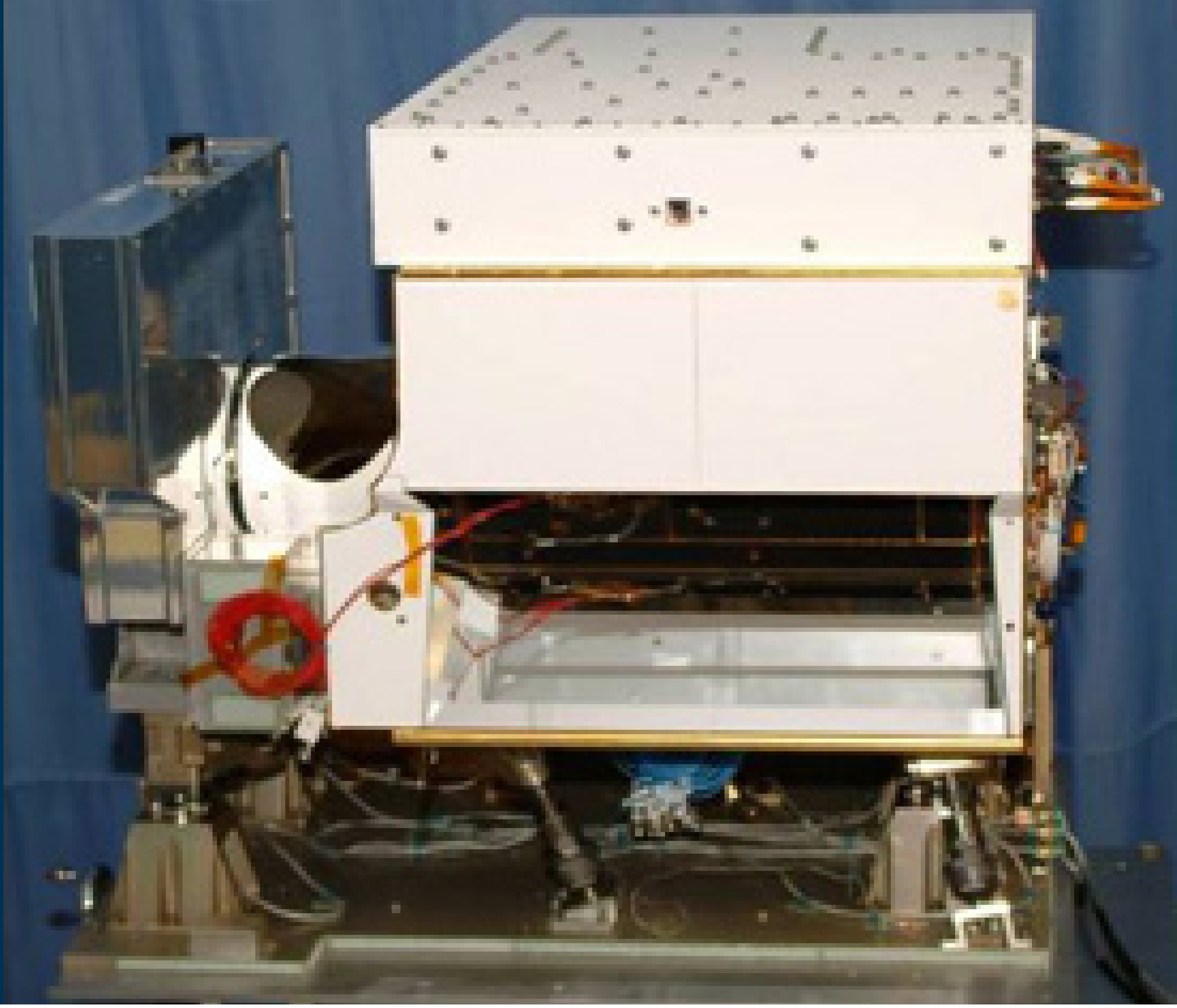
CHALLENGES IN AND OPPORTUNITIES FOR ASSIMILATING THE CROSS-TRACK INFRARED SOUNDER (CRIS) CHANNELS:

PAST, PRESENT, FUTURE

The information in this article is based, in part, on the February 19, 2020 JPSS science seminar presented by Dr. James Jung, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin, Madison. In collaboration with NCEP/EMC, NCEP/NCO, NESDIS/JPSS, NESDIS/STAR, NESDIS/ASPB, NASA/GMAO, NASA/NCCS, STC, JCSDA, and BOM, Australia.



Most Numerical Weather Prediction (NWP) centers including National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Prediction (NCEP), use operational weather prediction models. These models rely on data assimilation (DA) techniques to combine observations with their predictions and generate initial conditions for a subsequent forecast. The Cross-track Infrared Sounder (CrIS) is one of the key instruments onboard the NOAA-20 and the Suomi National Polar-orbiting Partnership Satellite (Suomi NPP) spacecrafts. CrIS is a Fourier transform spectrometer, which, until recently has been operated in a normal spectral resolution (NSR) mode on Suomi NPP and in full spectral resolution (FSR) mode on NOAA-20. In NSR mode, CrIS provides a total of 1305 channels compared to 2211 in FSR mode. Hyperspectral instruments such as CrIS contribute to the data that are assimilated in NWP models. However, due to a variety of reasons, many centers do not fully capitalize upon the full spectral and horizontal resolution data from the CrIS instrument.

This feature story highlights the efforts of Dr. James Jung, a scientist with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) to improve the use of the CrIS instrument and reduce errors in the assimilation techniques. Jung presented the highlights – which include collaborative efforts with partners from the NCEP, the National Aeronautics and Space Administration (NASA) and the National Environmental Satellite, Data, and Information Service (NESDIS) to maximize information content from the CrIS instrument and boost its data use in operations – in February 2020 to a Joint Polar Satellite System (JPSS) science seminar audience. The efforts highlighted included improvements in CrIS instrument characterization with all of its nine detectors, transitioning NCEP's data assimilation software from CrIS NSR to FSR, and adding cloud information from the NOAA-20 and Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) instruments to the NWP datasets for improved profile selection. Funding for Jung's recent research was provided by JPSS, and computing resources were provided by the NASA Center for Climate Simulations and the University of Wisconsin-Madison Space Science and Engineering Center (SSEC).

THE EARLY YEARS: ASSIMILATING AIRS

To set the tone Jung began his presentation with a recap of his early work in assimilating data from the world's first hyperspectral sounding instrument, the Atmospheric Infrared Sounder (AIRS), which launched on NASA's Aqua platform in 2002. Jung explained that circa 2005 or 2006, when he started his project AIRS data was already in the data assimilation system. And, by all accounts, it was operating quite well. "Still," he says, he and Dr. John Le Marshall, the then Director of the Joint Center for Satellite Data Assimilation (JCSDA), were looking to see if it was possible to make AIRS better. The pair sat down and came up with a few steps, which included: adding cloud tests to the thinning routine, using more channels in the 281-channel subset, and investigating the use of a Minimum Variance Technique to compute surface emissivity.

Minimum Variance Technique

To compute surface emissivity Jung used the Minimum Variance Technique (MVT), which he adopted from R. Knuteson et al. 2003. With this technique, skin temperature is iterated to find minimum variance in emissivity from surface channels. Jung explained that the use of skin temperature and model atmosphere to derive new surface emissivity requires a significant number of surface channels with water vapor lines in them, such as those on hyperspectral instruments like CrIS, AIRS and Infrared Atmospheric Sounding Interferometer (IASI) on the European Space Agency's MetOp-A, -B,

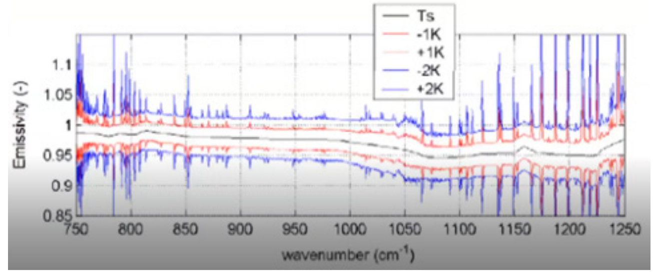


Figure 1. Illustration of deriving the surface temperature using the minimum variance technique. From Knuteson et al. (2003).

and –C space crafts. He added that the technique is very sensitive to various errors including noise, trace gases, and so forth.

Infrared Sea Surface Emissivity

To determine the accuracy of the MVT in deriving the surface emissivity, results—which were obtained globally for approximately one month—were compared to the Wu and Smith (1997) IR sea surface emissivity (IRSSE) model results. At first glance, the errors in calculating the IRSSE from the MVT did not look very promising as shown in Figure 2. But later it was determined that surface temperature and scan angle dependencies were unaccounted for in the Wu-Smith model, and the AIRS derived emissivity is actually closer to reality.

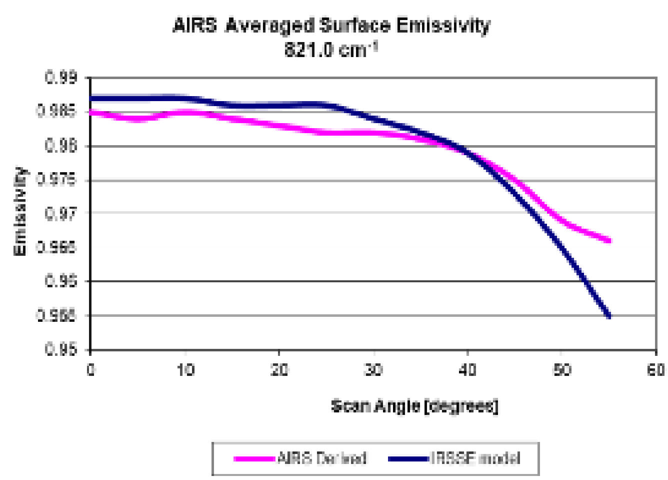


Figure 2. Ocean emissivity vs instrument scan angle for the Wu-Smith model (blue) and computed from AIRS observations (magenta) using the minimum variance technique. From Jung (2008).

IR Land Surface Emissivity

Jung (2008) took his experiment with the MVT one step further, and applied it over land. This time using the Community Radiative Transfer

Model (CRTM), which has various categories for land surface emissivity. The CRTM initially used a land type mask consisting of 24 classes. This scheme did not account for seasonal vegetation changes. The most recent infrared surface emissivity scheme was developed by Vogel et al. (2011). It was designed to use the International Geosphere-Biosphere Program (IGBP) classification scheme and accounts for seasonal changes in emissivity. Even here, Jung encountered large errors in categorical emissivity values. Such errors create large differences between the observations and the model, causing the observations to be rejected. Two examples are shown in figure 3. Jung says that these problems are the impetus for his research.

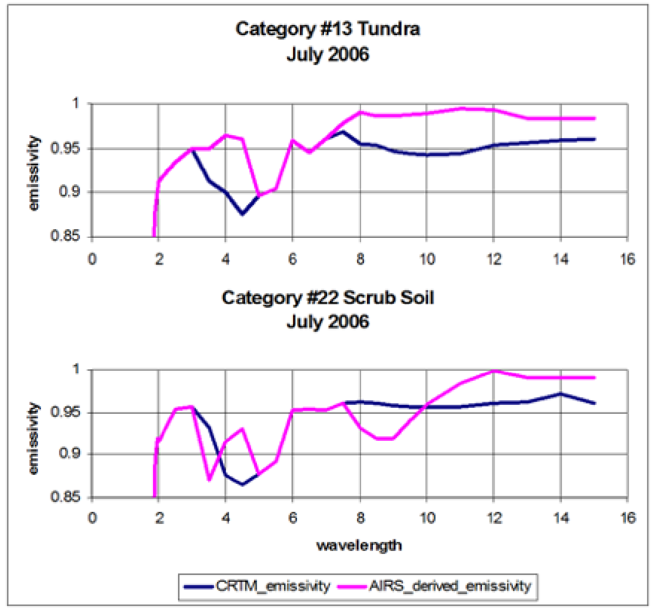


Figure 3. Differences in surface emissivity between the CRTM (blues) and derived using AIRS (magenta) for land types tundra (top) and scrub soil (bottom). From Jung (2008).

LESSONS (AT THE TIME)

By the end of his experiments, Jung had reached several conclusions. Among them was that “errors within the MVT calculation of the surface emissivity (model(s), data, etc.) can overwhelm the signal.” Just following the MVT can lead to inaccurate, and in some cases, unphysical results. Major contributors to these errors include bias correction; cloud contamination; trace gas (contamination for this purpose); instrument noise (NEDT); water vapor content (errors between the model and radiances); and the number of surface channels used.

Adding to the challenges, land emissivity categories in the CRTM are not adequate for NWP. But hyperspectral instruments, may offer a way to derive emissivity in NWP data assimilation systems. However, he cautions that several factors, including the number of channels and computing time it takes, may curtail the implementation of deriving surface emissivity with hyperspectral instruments in operations. Furthermore, many of these errors/problems are still valid today and serve as the foundation for where his research is going. But to really understand, where he is going, Jung walked his audience through where he has been.

CRIS ASSIMILATION, PAST

Bias correction scan angle modifications (NCEP/EMC)

Several items needed to be changed, fixed, added or verified within NCEP’s GFS before surface emissivity could be investigated using the CrIS instrument(s). This list included; modifying the scan angle calculations to allow for the CrIS detector twist, removing the hyperspectral channel subset restrictions, exploit the VIIRS cloud information now within the Binary Universal Form for the Representation of meteorological data (BUFR) file, adjust the thinning criteria to use the clearest profile, and redesign the CrIS read routine to work for both the NSR and FSR data.

Scan Angle Modifications (NCEP/EMC)

According to Jung, NCEP’s scan angle capabilities were very rigid in the beginning. That is the number of channels and the way of computing bias correction was hard wired into the code. As a result, it took quite a bit of work to make any adjustments. Some adjustments, for example adding or removing a channel (e.g. shortwave or water vapor) literally took months, as one had to redo all the arrays, modify the code, and spin up bias corrections for the new channel(s) before incorporation. Yanqiu Zhu of NCEP/EMC incorporated a new scan angle routine for the bias correction that facilitates the field-of-view "twist" of the CrIS instrument. This new method, which uses a 4th order polynomial instead of "bins," is better able to accommodate non-fixed scan angles, and enables scan angle computation for all fields-of-view within all fields-of-regard. The NCEP GFS is now able to assimilate all CrIS fields-of-view instead of just field-of-view #5, which was not always the best profile. This adjustment added approximately 30,000 observations per every 6-hour assimilation cycle.

Hyperspectral Sensor Channel Restrictions

NWP centers use a subset of channels from AIRS, IASI, and CrIS. These channels were fixed and difficult to change. Dr. Jung reiterated his points on the amount of work and time it took to make a change to the hyperspectral channel selection in the GFS to add/remove even a single channel in the system. A process that required new CRTM radiative transfer coefficient files, changes to array sizes throughout the code, as well as a manual spin-up of the bias correction files.

The late Paul van Delst, wrote a subset routine for the CRTM to allow all combinations of channels from the hyperspectral instruments (AIRS, IASI, and CrIS). Jung combined the two software modifications allowing him to edit a text file to add/remove channels and connect to the new data file expeditiously. A move that enables him to incorporate all or any of the 2211 CrIS spectral channels into his dataset.

VIIRS Clear / Cloud Information

Given that IR sounders are highly affected by clouds, only those clear profiles or instrument channels that are not affected by clouds are assimilated. Removing the effects of clouds requires additional or supporting information, which can be obtained from other instruments including imagers. Adding the VIIRS clear/cloud information into the CrIS BUFR took the contributions from the NCEP Environmental Modeling Center (EMC), and the NESDIS Advanced Satellite Products Branch (ASPB) and Center for Satellite Applications and Research (STAR). The VIIRS clear/cloud information was developed by the ASPB cloud team and is explained in Heidinger et al. (2016) and Heidinger et al. (2017). This information was mapped onto the CrIS field-of-view by STAR and is explained in Sun et al. (2014) and Sun et al. (2017). The BUFR template for CrIS was modified to add the cloud height and cloud amount to each CrIS field-of-view. STAR and EMC coordinated with the World Meteorological Organization (WMO) on the BUFR changes. STAR coordinated with the NWP Centers to provide test data sets and transitioned changes into NESDIS Operations. During the test phase, Jung acquired the data through EMC and conducted various statistics to verify and validate the new information.

The previous version of the NCEP GFS, the CrIS thinning routine was based on finding the warmest surface channel (profile) within the thinning box. This technique creates two biases within the assimilation system and degrades the use of the CrIS data. The first bias is the field-of-view selection. Due to temperature gradients across the CrIS field-of-regard, the corner fields-of-view (1, 3, 7, and 9) are chosen more often than others regardless if they are actually the clearest profile. The second bias comes from choosing the warmest surface channel. Changes related to the Noise Equivalent differential radiance (NEdN). A field-of-view with a large NEdN has a tendency of being chosen more than one with a low NEdN. Including clear/cloud information from an independent source, like VIIRS, significantly reduces these biases (sources of errors).

Jung conducted several statistical tests to verify there were no field-of-view biases and that the clear/cloudy ratios were consistent with other studies showing ~10% clear profiles at the CrIS resolution. Jung then incorporated the cloud/clear information into the NCEP GFS read_cris subroutine to minimize the bias (errors) induced from using the warmest spot. Assimilation tests were then conducted to verify there was little cloud contamination in the VIIRS clear product and the other biases (errors) were minimized. Results were presented at the American Meteorological Society (AMS) annual meeting by Jung et al. (2020).

The various code changes to the NCEP GFS were coordinated with NCEP/EMC and transitioned into NCEP Central Operations. This adjustment added approximately 20,000 observations per assimilation cycle.

Center of Box Criteria

When using cloudy radiances, “NCEP weights their profiles towards the center of the thinning box,” says Jung. A move that impacted both the microwave and infrared channels, and allowed more cloudy profiles to be used over clear profiles. Jung’s contribution to this work has been to relax the “distance from center of thinning box” criteria for CrIS. This allows the GSI to choose the clearest CrIS profile. If the thinning box has more than one clear profile, the closest to the center is selected. These changes to the thinning criteria, slightly changed the chosen profile distribution, as shown in figure 4. Jung worked with EMC to transition these changes into NCEP Central Operations. These adjustments added approximately 50,000 observations per assimilation cycle.

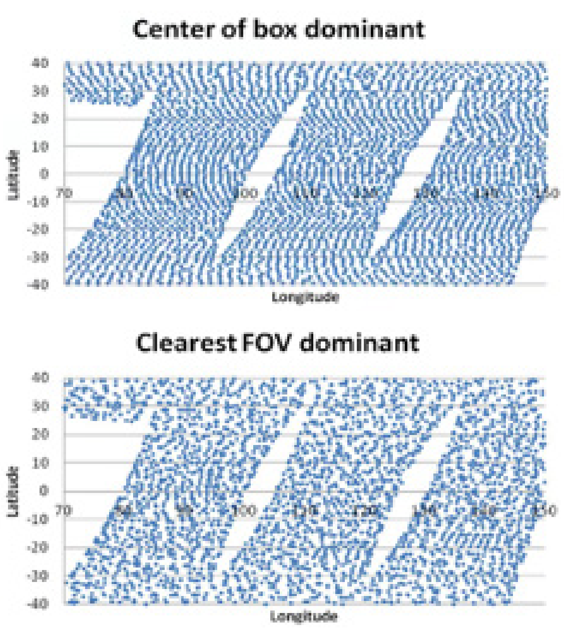


Figure 4. Depicts the distribution of CrIS profiles when using the center of the thinning box criteria (left) and using the clearest profile (right) for one assimilation cycle. Using the clearest profile added approximately 50,000 more observations per assimilation cycle.

ANOTHER ENORMOUS STEP: SUOMI NPP CRIS TRANSITION TO FULL SPECTRAL RESOLUTION MODE

In NSR mode, CrIS provides a total of 1305 channels, whereas in FSR, it provides 2211 channels. Since being made operational the CrIS instrument on Suomi NPP had been available in NSR mode only, however modifications from NESDIS and NCEP science teams enabled a switch to FSR mode in December 2014. The original NCEP plan was to use the 2211 channel data from NESDIS/OSPO, along with a 431-channel subset which distributes CrIS-FSR data from European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Advanced Retransmission Service (EARS) / Direct Readout And Relay System (RARS) as well as Direct Broadcast sites. Things didn’t go exactly as planned. Constraints due to communications and the disk space requirements reduced the plan to the 431-channel subset only, from which, NCEP selected 102 channels for assimilation (94 temperature and 8 water vapor). Still, the switch from the NSR to FSR mode had added roughly 100,000 observations per assimilation cycle. Better still, the Forecast Sensitivity Observation Impact (FSOI) from CrIS has resulted in improvements in the humidity field from new channel selection, and consequently elevated the CrIS FSOI ranking from ninth to fifth in NCEP’s Global Forecast System as shown in figure 5.

For the CrIS instrument on NOAA-20 FSR was the only mode available. Even before NOAA-20 (JPSS-1) was poised to launch, Jung had developed and tested the software modifications necessary to assimilate its CrIS-FSR. Efforts that he was able to perform using, the near real time FSR data from Suomi NPP, and the help and coordination of NESDIS and EMC. Thereafter EMC incorporated the software modifications into their pre-implementation tests. An even bigger milestone was reached the day all NOAA operational requirements were met, the same day that NCEP Central Operations assimilated CrIS-FSR data from NOAA-20.

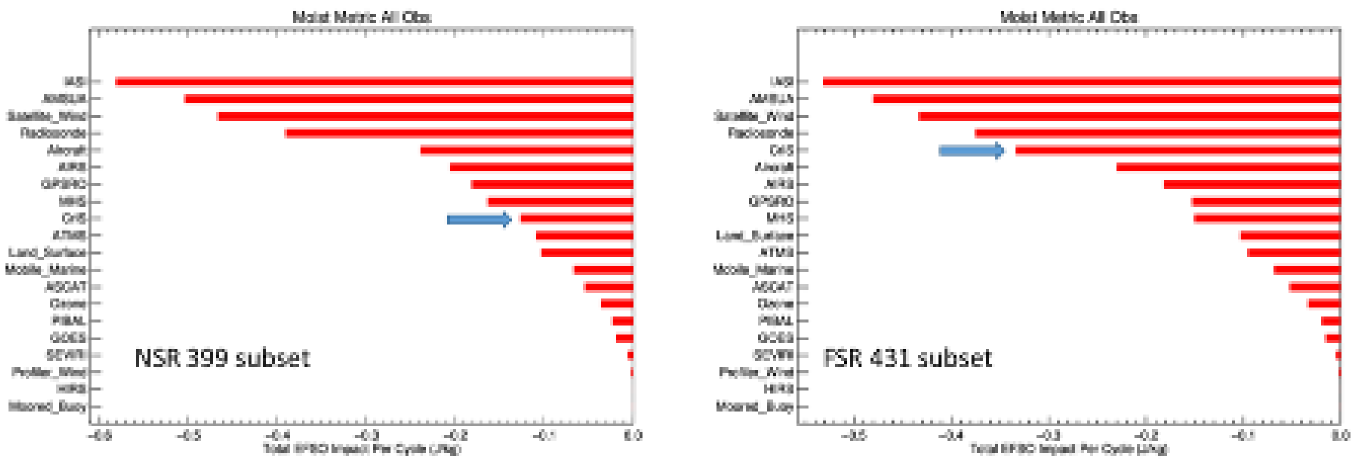


Figure 5. The forecast sensitivity to observation impact (FSOI) from the NCEP GFS. The CrIS-NSR impact is 9th overall as shown in the left panel. The transition to CrIS-FSR increased the impact to 5th overall as shown in the right panel.

As with any research, there's always more to be done. And in this case Jung says he is exploring "what's going to be needed to derive land surface emissivity as the number of surface channels in the 431-channel subset may not be sufficient."

OPPORTUNITIES ABOUND: DBNET

The purpose for the DBNet is to provide low latency satellite data to NWP Centers running global and regional models that have short data assimilation windows and do not receive satellite data in time from the operational stream. When Jung started to make improvements to the EUMETSAT EARS/RARS and the NESDIS/JPSS Direct Broadcast data (both groups have combined and are now called DBNet) there were available data from several instruments, albeit only used sparingly. This was due to larger errors in DBNet microwave data than in the operational stream. Jung traced the errors back to inconsistent antenna corrections between the operational stream and the DBNet. Dave Groff (NCEP/EMC) and others on the CRTM team resolved the inconsistencies and put them in a new CRTM release. Jung then reviewed the data flow and verified the DBNet microwave sensors were consistent with operations. He also modified the NCEP GFS software to use IASI, CrIS and ATMS data from the DBNet. NCEP/EMC completed software and science reviews and promoted the software to NCEP Operations. These data are now available to the GDAS/GFS and any other models using NCEP's data assimilation system.

"The Earth System Research Laboratory (ESRL) continue to be the most aggressive at using the DBNet," says Jung. They run the Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) models that have hourly data assimilation cycles. Improving the amount of satellite data available for the hourly assimilation cycles has improved the forecast skill for the Rapid Refresh and High-Resolution Rapid Refresh as documented in Lin et al. (2017) and Lin et al. (2020).

CRIS DETECTOR DIFFERENCES ON NOAA-20 AND SUOMI NPP

To use CrIS data in NWP, it is important that its radiometric accuracy be understood.

-James Jung

Several studies have looked at satellite inter-calibration (Goldberg et al., 2011, Chandler et al., 2013), however few have addressed instrument detector-to-detector differences (Gunshor et al., 2012, Strow et al., 2013, Tobin et al., 2013)," Jung explains. Not accounting for any potential differences can lead to inaccuracies. Thus, understanding these differences is very important for NWP. In 2013, Tobin et al., described a methodology for on-orbit adjustment of nonlinearity correction parameters to reduce the overall contribution to radiometric uncertainty and reduce the detector-to-detector variability of CrIS on Suomi NPP and NOAA-20. If detector–to-detector differences are large, and not accounted for in the data assimilation system, they can lead to errors in the forecast analysis (initialization) and subsequent forecasts. To quantify the detector-to-detector differences that remain, a low resolution of NCEP's GFS was used. To be consistent and reduce surface biases, only profiles over ocean were used. The shortwave channels are only used at night to reduce radiative transfer model errors. Figures 6-8 show standard deviation statistics for bands 1, 2, and 3 respectively, figures 9-11 are bias statistics for bands 1, 2, and 3 respectively.

Suomi NPP detector 5 of band 1 has oscillations in the bias, especially in the first 30 channels. Suomi NPP detector 7 of band 2 is the most out of family. NOAA-20 detector 5 has the highest standard deviation. NOAA-20 detector 9 of band 2 is the most out of family. These detectors also have the largest potential instrument errors.

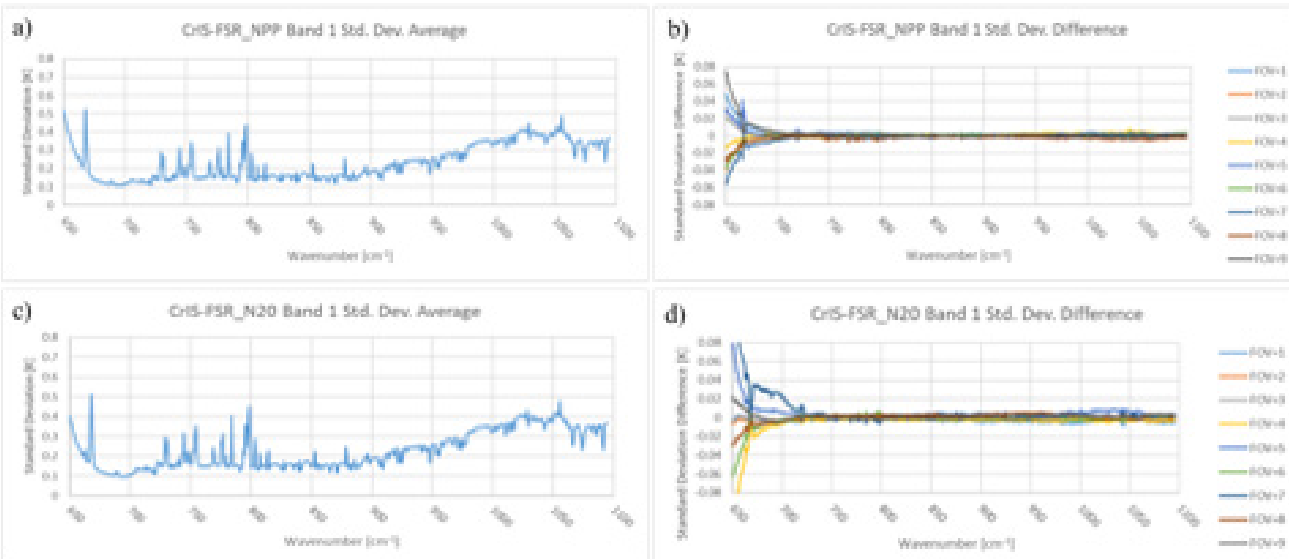


Figure 6. CrIS band 1 (650–1095 cm-1) standard deviations a) average of all detectors (FOV) for Suomi NPP, b) difference from mean for each detector, c) average of all detectors for NOAA-20, and d) difference from mean for each detector.

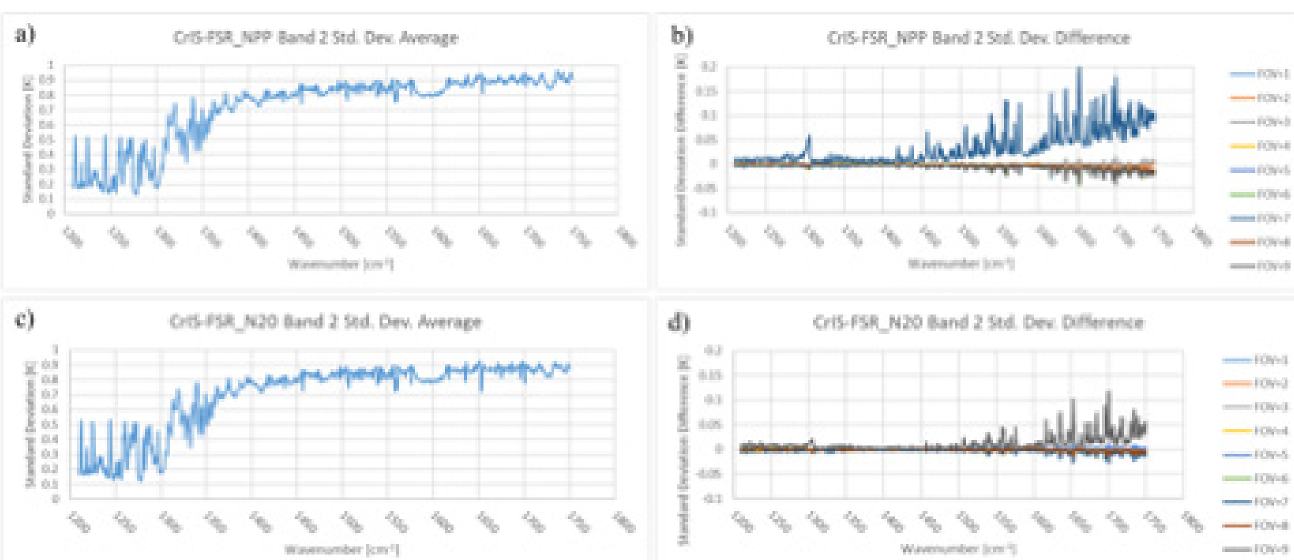


Figure 7. Same as Figure 6 but for band 2 (1210–1750 cm-1).

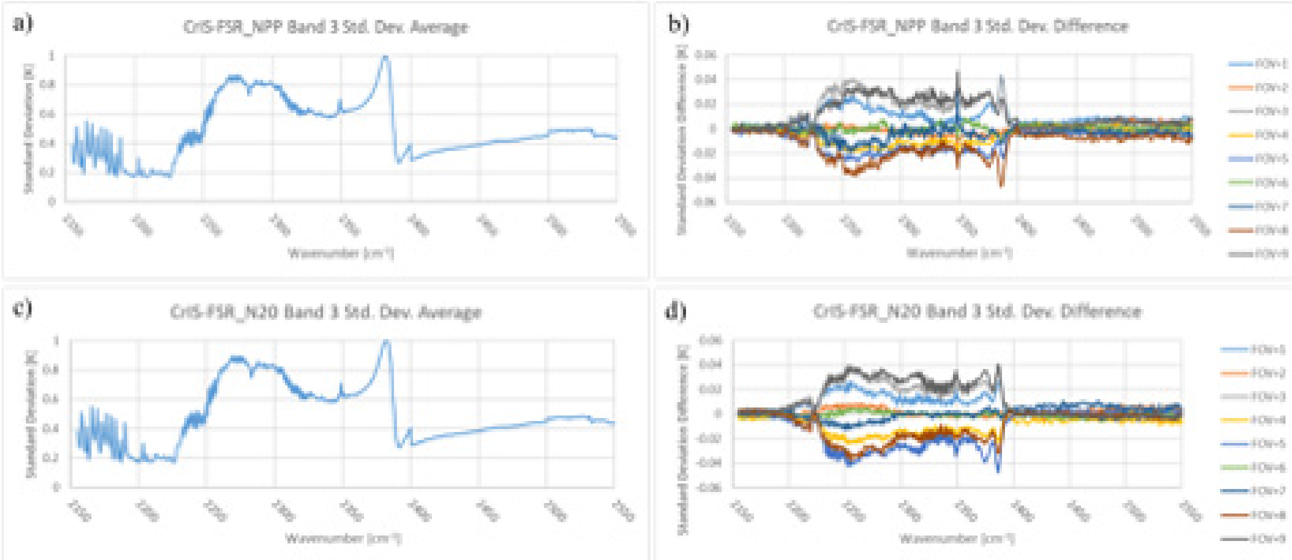


Figure 8. Same as Figure 6 but for band 3 (2155–2550 cm-1).

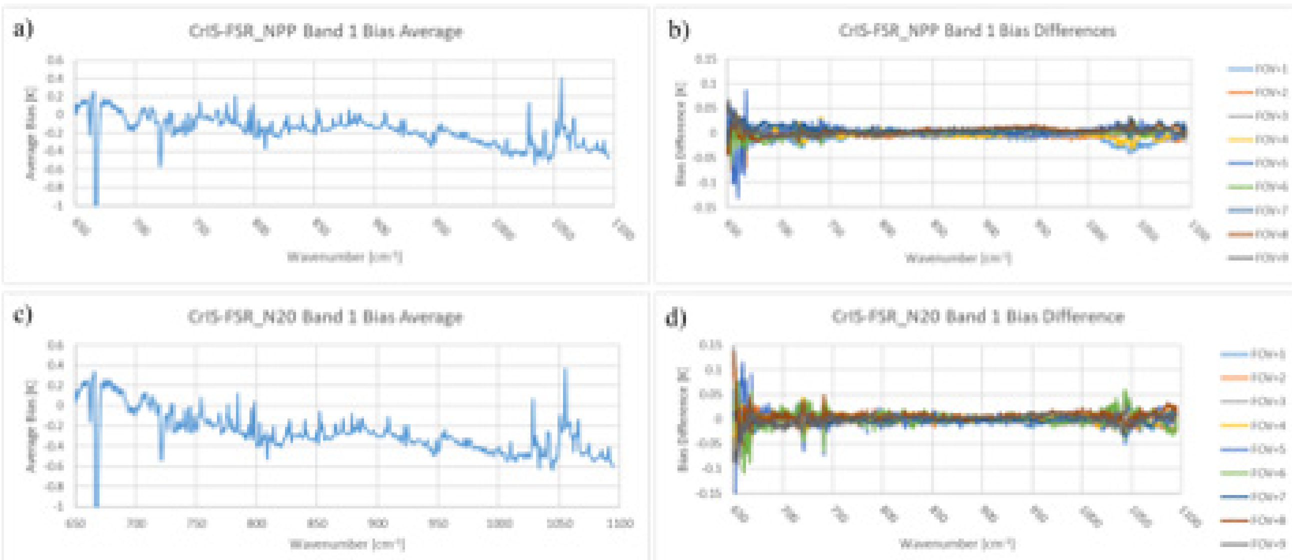


Figure 9. CrIS band 1 (650–1095 cm-1) biases a) average of all detectors for Suomi NPP, b) difference from mean for each detector for, c) average of all detectors for NOAA-20, and d) difference from mean for each detector.

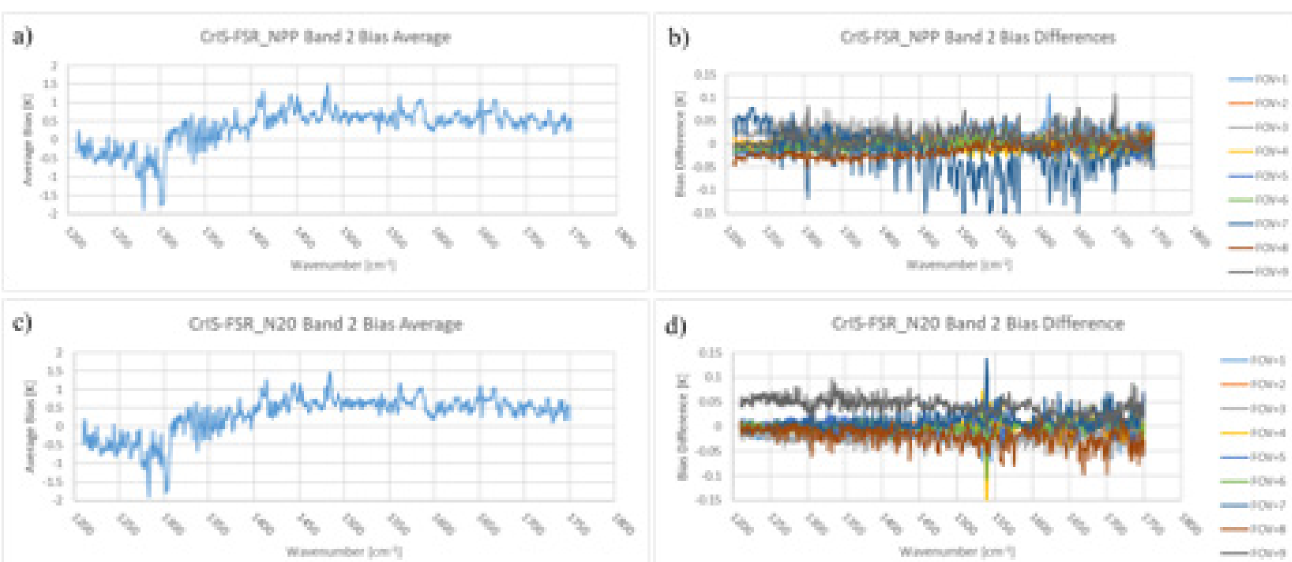


Figure 10. Same as Figure 9 but for band 2 (1210–1750 cm-1).

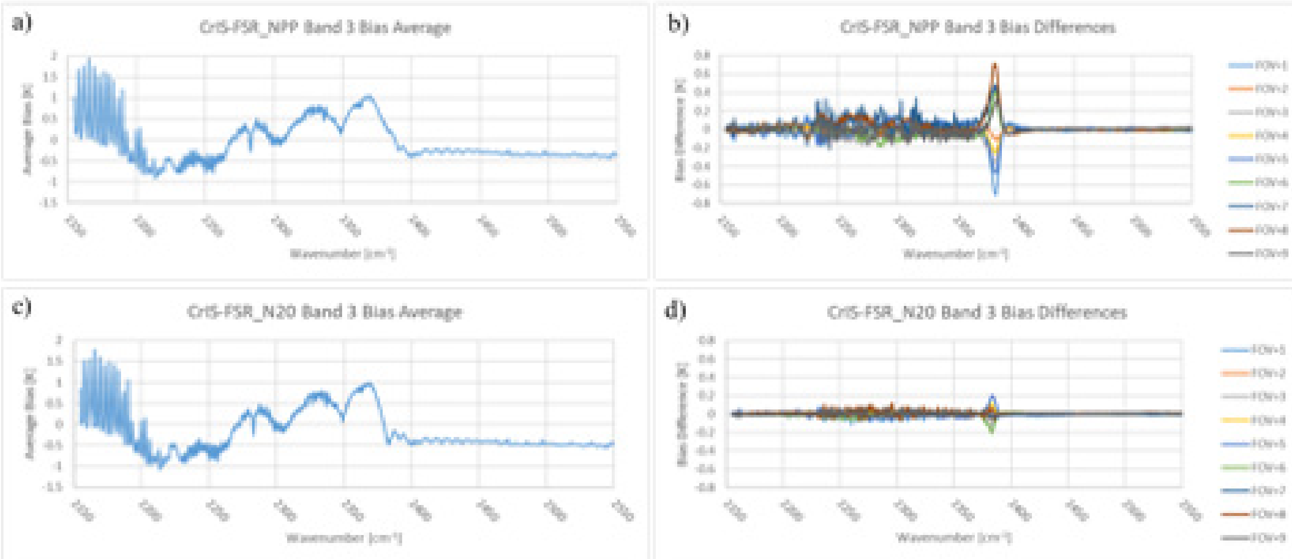


Figure 11. Same as Figure 9 but for band 3 (2155 – 2550 cm-1).

POLARIZATION CORRECTION ON NOAA-20 AND SUOMI NPP

The CrIS instruments have polarization effects due to their design. These polarization effects may be significant to NWP, especially for the shortwave band. Scientists at the University of Wisconsin-Madison SSEC developed a theoretical model and correction for the polarization induced calibration errors. Data acquired by the CrIS instrument during a February 2012 Suomi NPP pitch maneuver helped determine the polarization parameters required for the correction. During a typical orbit, the nadir side of the satellite always faces the Earth, but in a pitch maneuver it is reversed to view space. Thus, all of the CrIS cross-track fields of regard (FORs) that normally view the Earth, were looking to deep space. In this configuration, field of regard and detector dependent differences are dominated by the instrument polarization. Something which, "makes this an ideal dataset for derivation of the polarization parameters," says Jung. For band 3 (shortwave), the uncorrected polarization induced calibration errors can be as much as several degrees for cold Earth scenes.

The CrIS-FSR radiances, from both Suomi NPP and NOAA-20, with and without the polarization correction were generated by SSEC and made available to the NWP Centers. NCEP/EMC processed these data for use in the NCEP Global Data Assimilation System (GDAS) to quantify differences in assimilation statistics. All 2211 CrIS channels were monitored. Each detector was monitored independently and the bias corrections were derived unique to each detector. These statistics are for ocean only. Shortwave channels were restricted to night only.

Suomi NPP and NOAA-20 detector specific differences, for both the control and polarization_corrected data, are consistent with previous work. Detector 5 in band 1 and detector 7 in band 2 on Suomi NPP and detector 9 on NOAA-20 continue to be the most "out of family" or significantly different from the others. The control-polarization corrections for Suomi NPP and NOAA-20 statistics for bands 1-3 are shown in Figures 12-14 and 15-17 respectively. The bias difference average, detector difference bias, standard deviation difference average and detector difference standard deviation are shown in panels a, b, c, and d respectively. Overall differences between the control and polarization_corrected data are small with the greatest differences in the high peaking band 3 (shortwave) channels and minimal differences in the longwave surface channels. Polarization corrections are greater for Suomi NPP than NOAA-20 and the bias correction statistics confirm this. Polarization correction differences in the standard deviation statistics are minimal, especially for NOAA-20.

Observing System Experiments (OSEs) help assess the impact of any given assimilated observation(s) on NWP forecast skill. So naturally, one was conducted to quantify the polarization correction on the analyses. Included in the experiment were the operational CrIS channel selection and observation errors along with all of the operational quality control procedures. “Analysis differences between the control and polarization_corrected data are minimal throughout the 21-day experiment. The results show no dominant changes in the synoptic features in both the analyses and forecasts,” says Jung. He explained that average temperature changes are greatest at the tropopause and are generally less than 0.1K.

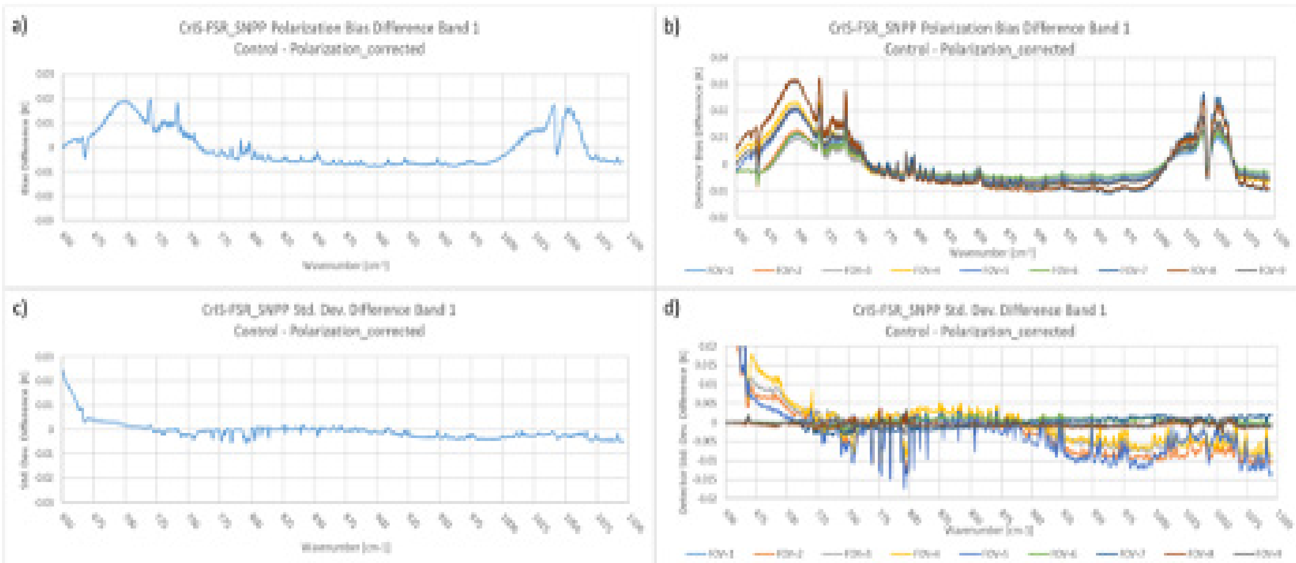


Figure 12. Suomi NPP control – polarization_corrected statistics for CrIS band 1. The bias difference average, detector difference bias, standard deviation difference average and detector difference standard deviation are shown in panels a, b, c, and d respectively.

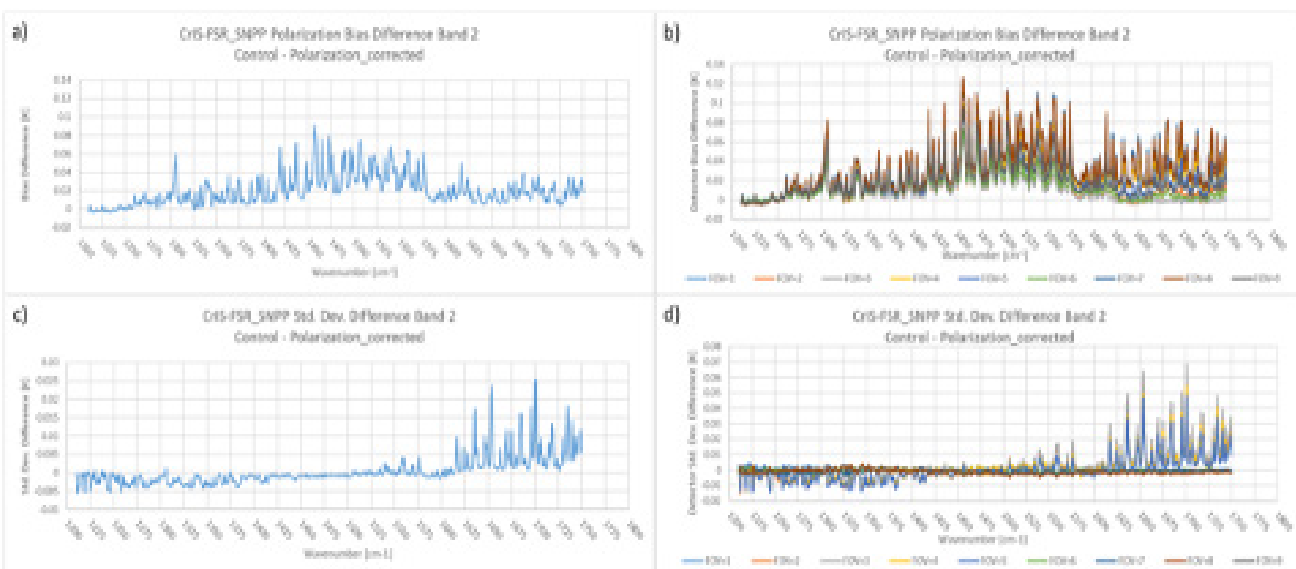


Figure 13. Same as Figure 12 except band 2.

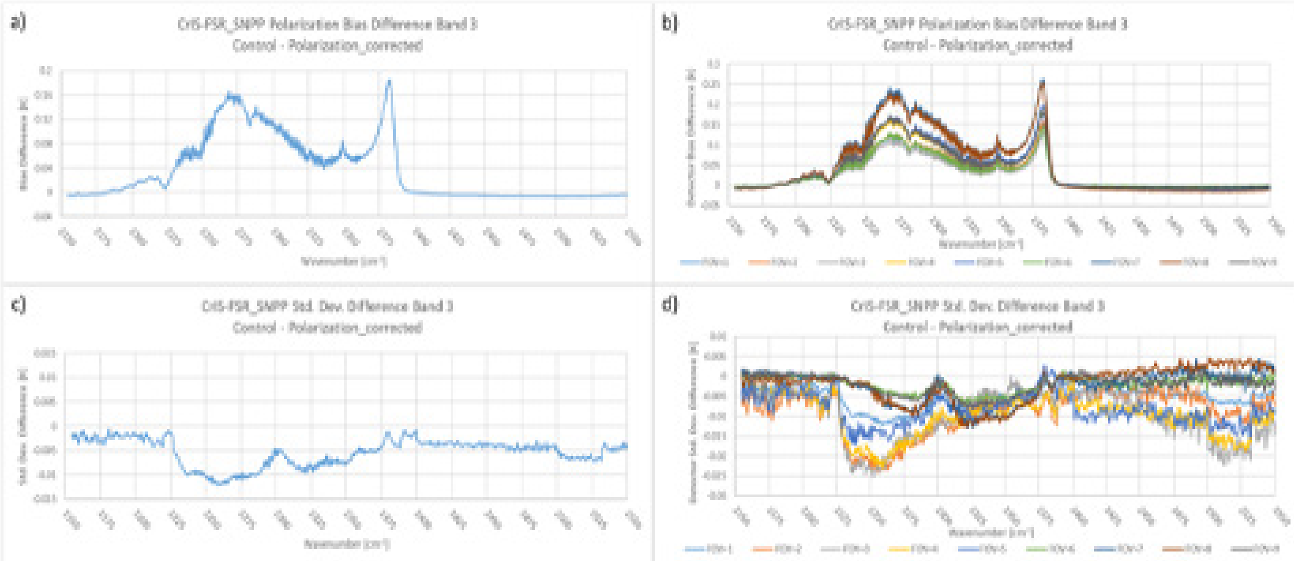


Figure 14. Same as Figure 12 except band 3.

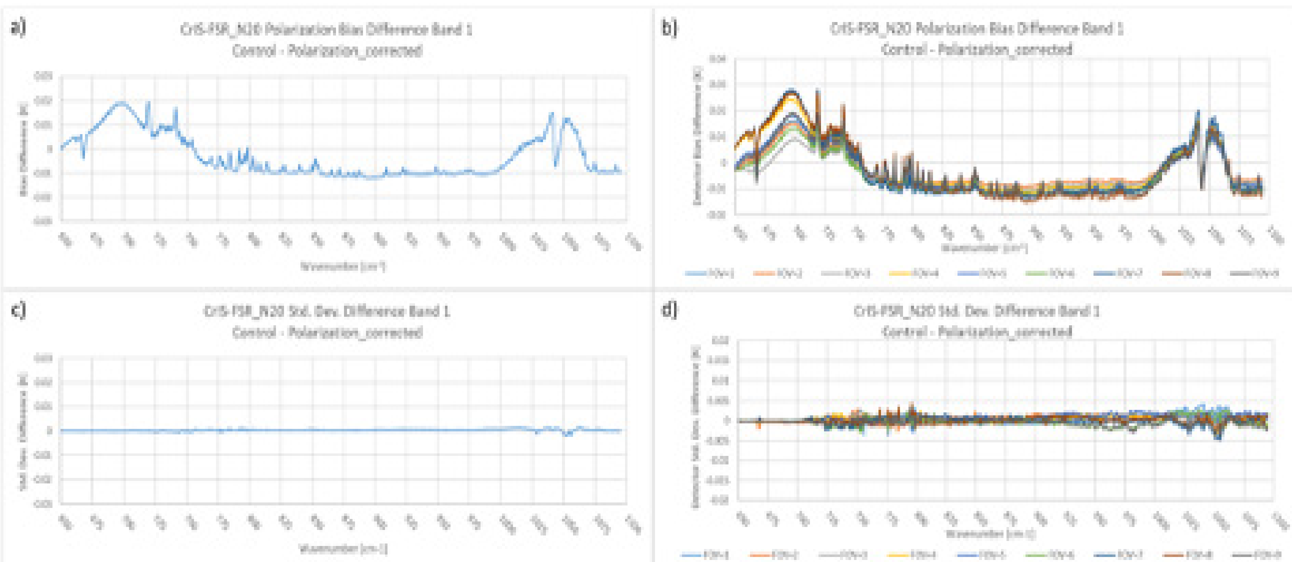


Figure 15. NOAA-20 control – polarization_corrected statistics for CrIS band 1. The bias difference average, detector difference bias, standard deviation difference average and detector difference standard deviation are shown in panels a, b, c, and d respectively.

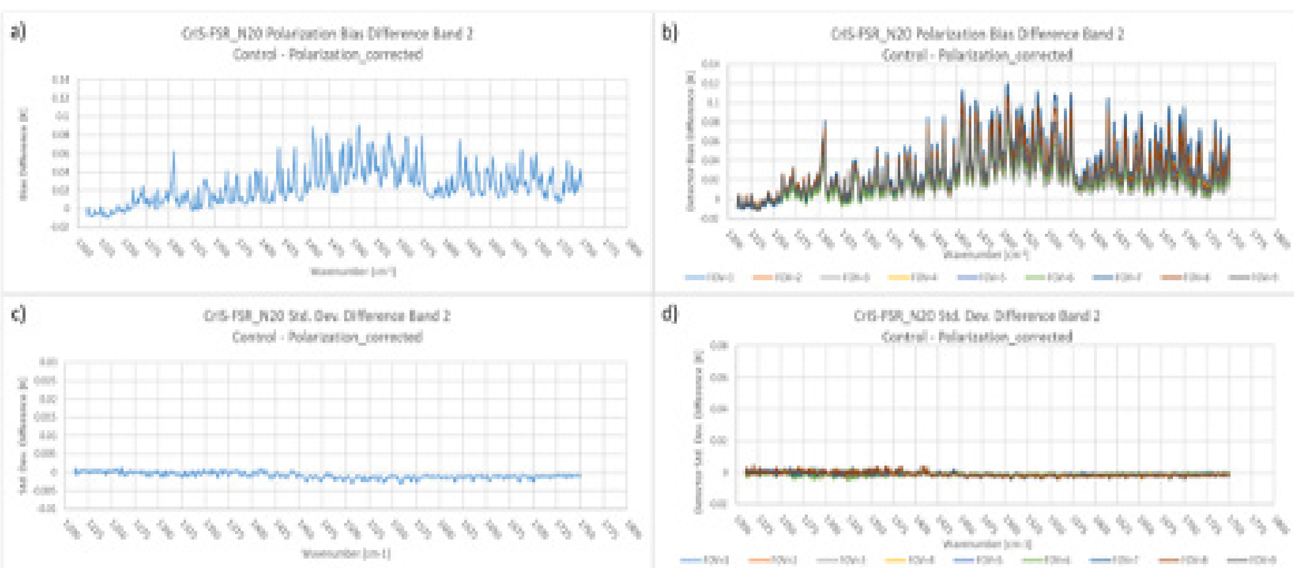


Figure 16. Same as Figure 15 except band 2.

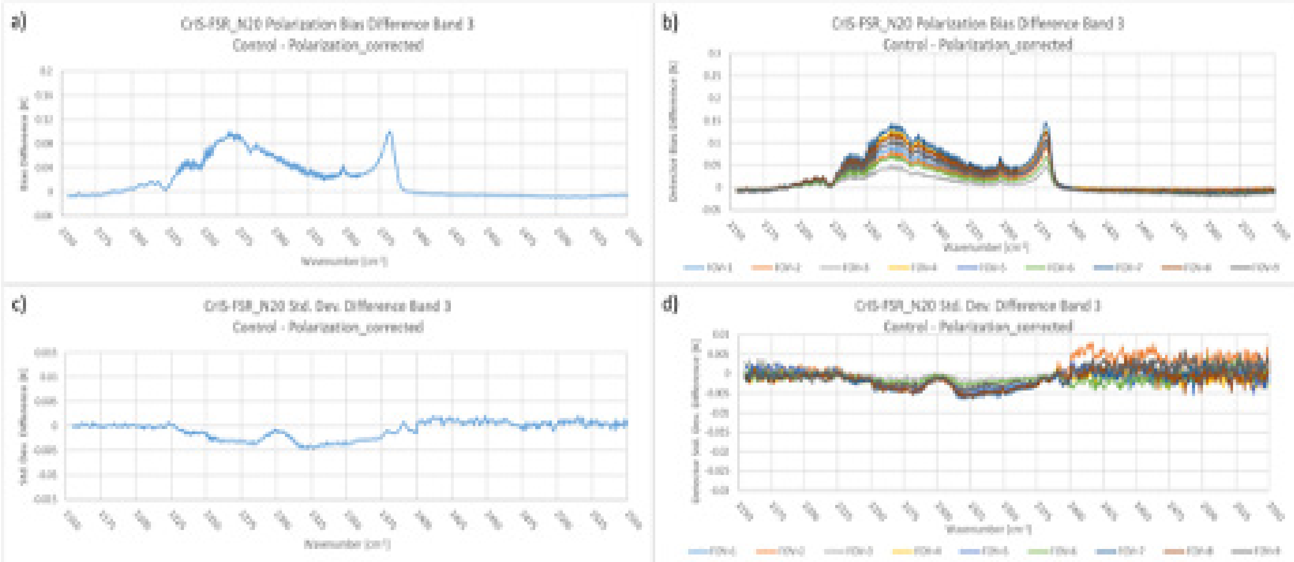


Figure 17. Same as Figure 15 except band 3.

CRIS ASSIMILATION, PRESENT

Data Addition Experiments

Suomi-NPP and NOAA-20 have an approximate 50-minute orbit differential with a considerable data coverage overlap. Is there any value to Numerical Weather Prediction in having 2 polar orbiting satellites this close? To answer this question, Jung conducted “data addition” type experiments. These experiments start with a minimum amount of data known as the baseline. Suomi-NPP was added to this baseline (NPP), then NOAA-20 (N20) was added to the baseline plus NPP. For verification purposes, the final experiment contained all available data called the control. With this scenario the improvement in forecast skill from one JPSS satellite (Suomi-NPP) and from two JPSS satellites (Suomi-NPP and NOAA-20) can be quantified in the context of minimal observations and the entire NCEP data base.

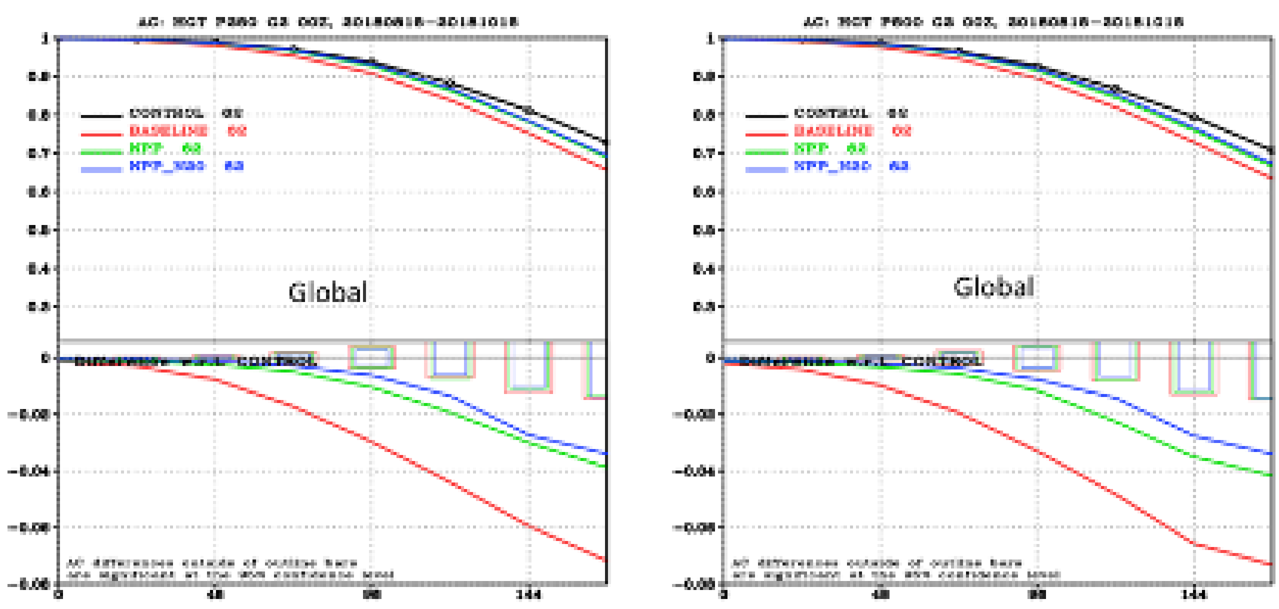


Figure 18 Global average anomaly correlations at 250 hPa (left) and 500 hPa (right). Top panels are actual scores, bottom panels are differences with respect to the control. Differences outside the color boxes indicate significance at the 95% confidence level.

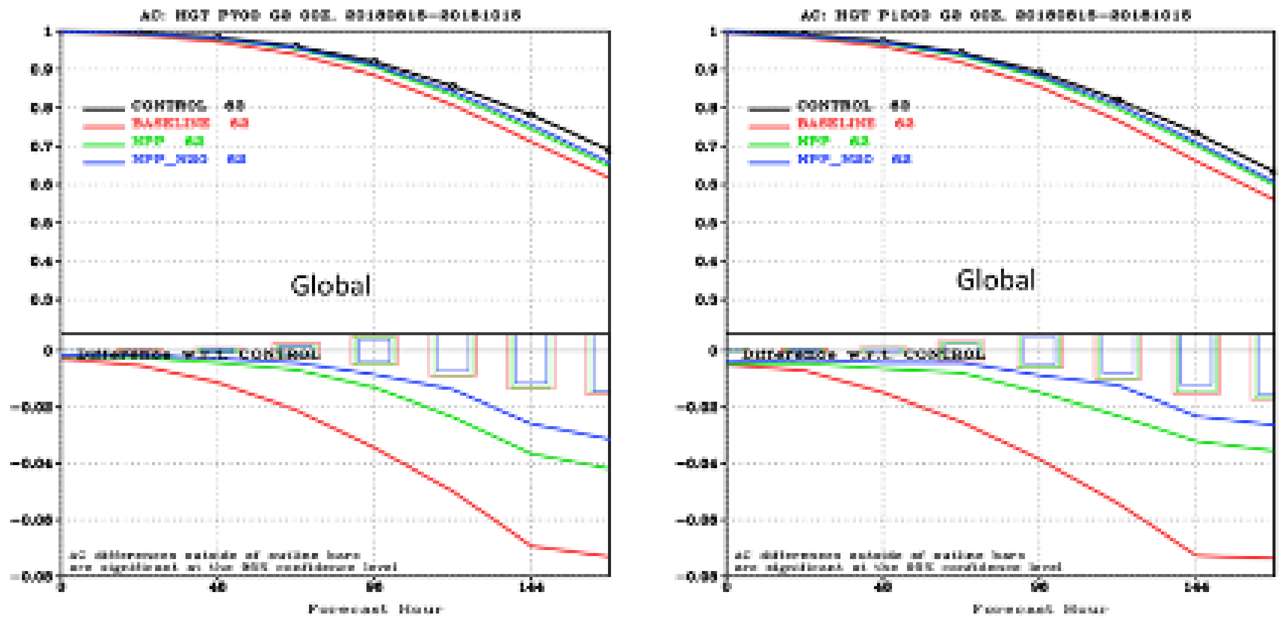


Figure 19 Same as Figure 18 except at 700 hPa (left) and 1000 hPa (right).

To quantify the forecast skill, NCEP's low resolution GFS (T670) 4D-EnVar with 80 ensemble members was used. This low-resolution forecast system is consistent with NCEP's operational system. The best scenario would be to use a full 4D-EnVar system but resources were not available. The global forecast anomaly correlations were used to quantify the forecast skill. The anomaly correlations for 250, 500, 700 and 1000 hPa are shown in figures 18 and 19. In general, adding Suomi-NPP to the baseline increases the forecast skill to about 60% of the all data (control) experiment. Adding NOAA-20 increased the forecast skill by another 10-15% and is consistent through the vertical extent of the troposphere. The forecast improvements were greater in the Southern hemisphere than the Northern hemisphere (not shown) which is consistent with more conventional data.

INFRARED SEA SURFACE EMISSIVITY EXPERIMENTS

In order to derive emissivity over land, a stable and consistent baseline must be established. The sea surface emissivity is chosen for this role because it is well known and covers enough area to generate stable statistics. However, there are known errors that need to be removed. There remains a scan angle bias and the sea surface temperature dependency must be accounted for. Nick Nalli, with JPSS funding, is investigating and reducing these errors in a new emissivity model. Jung is working with Nick Nalli and the CRTM Team to incorporate this new infrared sea surface emissivity model into NCEP's Global Forecast System.

The first step is to verify and quantify the errors to be removed. To do this Jung is using the VIIRS defined clear CrIS profiles over ocean. The CrIS Channels dependent on the sea surface temperature are identified by their difference with other surface channels. Channels which have a sea surface temperature dependence (800–900 cm-1) are identified by subtracting brightness temperatures from channels known not to have this dependence (900–1000 cm-1). Computing the slope with respect to temperature quantifies this dependence as shown in Figure 20. Results are consistent with theory and will be confirmed by Nick Nalli from field campaigns using the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI).

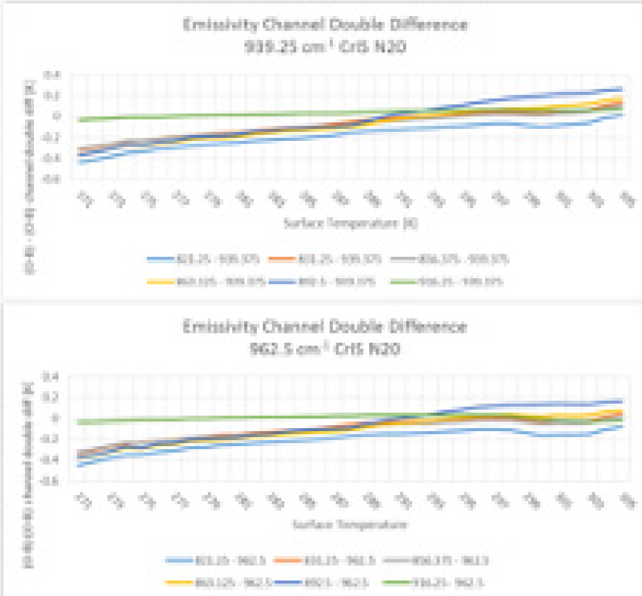


Figure 20. Differences between channels with and without temperature dependent emissivity vs surface temperature for two specific non-temperature dependent channels. Top panel uses 939.25 cm-1, bottom panel uses 962.5 cm-1. Lines with larger slopes have greater temperature dependency.

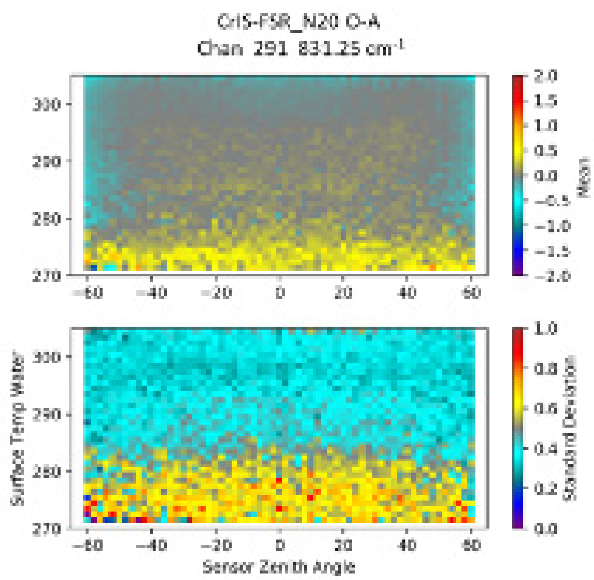


Figure 21. 2-dimansional plots of observation minus model (O-A) temperatures to highlight the zenith angle and surface temperature dependence. Upper panel is mean, lower panel is standard deviation. The surface temperature and zenith angle dependencies are depicted by the temperature gradients from top to bottom and left to center to right respectively.

A way to highlight both the scan angle and surface temperature errors is to generate 2-dimensional plots of observation minus model (O-A) derived brightness temperatures. Figure 21 shows this kind of plot where the X-axis is zenith angle and the Y-axis is ocean surface temperature. If there were no errors there would be no vertical or horizontal O-A temperature gradients. Larger error standard deviation is also consistent with the emissivity temperature dependence as the current ocean surface emissivity model was derived using tropical ocean surface temperatures.

CRIS ASSIMILATION, FUTURE

There are several portions of the CrIS data assimilation system that still have errors greater than the (CrIS) data. To fully exploit the information from CrIS these errors should be reviewed and reduced when possible. Some areas of future investigation include; bias correction, cloud tests, snow emissivity model, and error associated with using the shortwave channels.

The goal remains to fully exploit the CrIS information over land. This requires being able to derive surface emissivity over various land types. Work is planned to continue toward these goals.

SUMMARY

Advanced hyperspectral instruments such as CrIS have thousands of channels that contribute a large volume of the data that are assimilated in NWP models. However, many NWP centers are unable to use all of the channels from the various hyperspectral infrared instruments. Many interventions, including thinning routines have helped reduce the data to a more manageable volume. Other interventions, like Dr. Jung's, to improve CrIS instrument characterization with all of its nine detectors, transition NCEP's data assimilation software from CrIS NSR to FSR, and add cloud information from the NOAA-20 and Suomi NPP VIIRS instruments to the NWP datasets for improved profile selection have helped maximize the information content from the CrIS instrument.

Already, where users were once constrained to assimilating one of the designated subsets or receiving all of the channels, systems are now able to accommodate user-defined subsets of channels. The switch from the NSR to FSR mode and other software modifications has added roughly 100,000 observations per assimilation cycle. Better yet, the FSOI from CrIS has resulted in improvements in the humidity field from new channel selection, and consequently elevated the CrIS FSOI ranking from ninth to fifth in NCEP's GFS.

Data latency is critical for the use of satellite data in NWP forecast models. It plays an important role in determining the accuracy and timing of numerical guidance. Without low latency platforms such as DBNet, some forecast models would have little or even no satellite data in several of their assimilation cycles. Researchers have documented improvements in forecast skill for the Rapid Refresh and HRRR following advancements in the amount of satellite data available for the hourly assimilation cycles.

And there's more on the horizon. Jung says "it is also important to coordinate and support the priorities of collaborators such as NCEP, NASA, NESDIS and JPSS." As a result, he has several plans for improving CrIS assimilation including: the ocean emissivity model (STAR); atmosphere/ocean model coupling (NCEP); atmosphere/land model coupling (NCEP); bias correction predictor re-evaluation; cloud test and clear profile evaluation (UW-Madison); shortwave evaluation and assimilation; VIIRS value added products (cloud phase, cloud water path, ice water path, dust, smoke and etc.); principal component / reconstructed radiance assimilation (NCEP); cloudy radiance assimilation; and Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM).

Even then, "there are items within the data assimilation system whose errors may still be too large to adequately compute surface emissivity," says Jung. So, it's perhaps most important that he has not lost sight of his long-term goal, which he says, "continues to be deriving land, snow and ice surface emissivities within the assimilation system to make better use of infrared hyperspectral radiances." ❖

Story Source

Materials obtained from JPSS February Science Seminar titled "Assimilating CrIS: Past, Present, and Future."

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USING CROSS-TRACK INFRARED SOUNDER (CRIS) TO EXAMINE FEASIBILITY OF SHORT-WAVE SMALLSAT ASSIMILATION

The information in this article is based, in part, on the March 30, 2020 JPSS science seminar presented by Dr. Benjamin Ruston, Naval Research Laboratory, Monterey CA. In collaboration with Drs. Nancy Baker, Rolf Langlang, Elizabeth Satterfield and William Campbell. We'd also like to thanks Xu Liu, Chris Barnet, Andrew Collard, Fiona Smith, Peter Weston, Reima Eresmaa, and Anthony McNally for help in implementation of AIRS, IASI and CrIS; and, Chris Barnet, Zhenglong Li and Paul Menzel for helpful comments generated by the seminar.

Hyperspectral infrared (IR) sounding instruments on board several polar orbiting satellites including—the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua platform, the Infrared Atmospheric Sounding Interferometer (IASI) on the European Space Agency's MetOp-A, -B, and –C, and the Cross-track Infrared Sounder (CrIS) on the Suomi National Polar Orbiting Partnership, and the National Oceanic and Atmospheric Administration's (NOAA's) NOAA-20 provide radiance measurements from which profiles of atmospheric temperature and moisture can be retrieved. These instruments have demonstrated positive impacts in numerical weather prediction (NWP) forecast skills. Modern day hyperspectral sounders were a leap in impact over older radiometers such as the High Resolution Infrared Radiation Sounder (HIRS), which has flown on various polar-orbiting satellites between the late 1970s and the present day. Details of these improvements will be presented later in this article.

Modern sounders have thousands of channels, which provide large volumes of data that are assimilated into National Weather Prediction Models. For example AIRS has 2,378 channels in the IR range, and CrIS has 2,211. Computational and data storage limitations limit the amount of data that can be used. Model experts have had to choose carefully which channels provide the most value to each model. Most operational activities employing hyperspectral radiances rely on the longwave alone or in combination with the water vapor sensitive mid-wave, which can leave some valuable channels in other parts of the infrared spectrum, particularly the shortwave, relatively underutilized. As developers look at future satellite designs some focus on the long, mid or short wave portions of the IR band. With the shortwave often a preferred design. To better understand the potential impact of these future sensors, using the current instruments to emulate proposed systems is a logical first step.

Dr. Benjamin Ruston, a scientist at the United States Naval Research Laboratory (NRL) is at the frontline of scientific work to expand and exploit more information from current hyperspectral IR sounding instruments, particularly from the Carbon Dioxide (CO_2) sounding channels in the shortwave region. Dr Ruston specializes in satellite meteorology, remote sensing from infrared and microwave sensors, radio occultation, and data assimilation for environmental analysis and numerical weather prediction (NWP). He has worked closely with scientists from NOAA and NASA, mostly through the Joint Center for Satellite Data Assimilation (JCSDA). He has close ties with scientists around the world including at the European Centre for Medium Range Weather Forecasting (ECMWF), European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and the United Kingdom's Meteorological Office (Met Office). NRL has a long history of research in hyperspectral infrared (IR) sounding instruments, and in March 2020, Dr. Ruston gave a science seminar highlighting some novel examinations which include using the CrIS instrument to examine the feasibility of assimilating short-wave hyperspectral radiances from small satellites.

HISTORY OF HYPERSPECTRAL IR AT NRL

Aqua (4 May 2002)
2378 channels
Received a 324 subset
Collocated and Remapped to AMSU-A footprint
1650km wide swath
30 FOR, 9 FOV
+/- 48.95 scan angle
13.5km at NADIR
21.4 x 41km at edge of swath

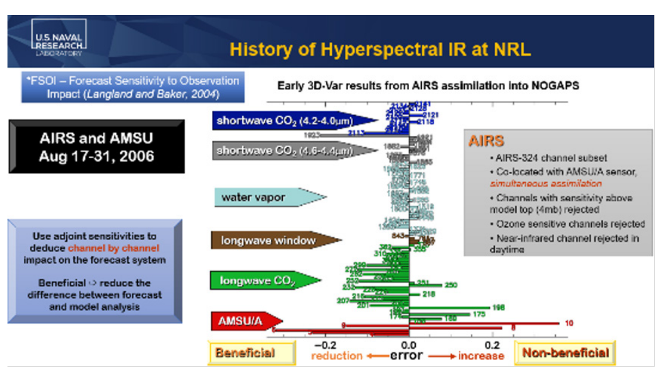
MetOp –A (19 Oct 2006) –B (17 Sep 2012) –C (07 Nov 2018)
8461 channels
Receive a 616 channel subset
2130 km wide swath
30 FOR, 4 FOV
+/- 48.33 scan angle
12km at NADIR
20 x 39km at edge of swath

Suomi NPP (28 Oct 2011) NOAA-20 (18 Nov 2017)
2211 channels (1305 truncated/nominal)
Receive all channels unapodized
2200 km wide swath
30 FOR, 9 FOV
+/- 48.33 scan angle
14km at NADIR
24 x 46km at edge of swath

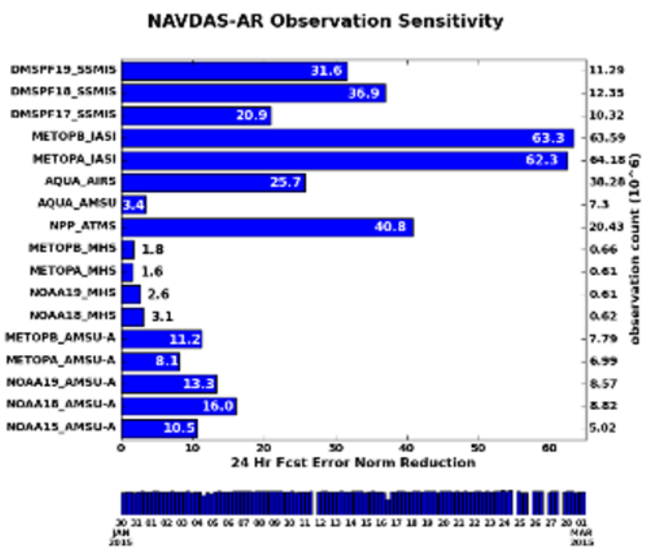
Dr. Ruston's talk mainly focused on three instruments: AIRS, which has been operating in the afternoon orbit since 2002; IASI, which has been in the morning orbit since 2006; and CrIS, which has been in the afternoon orbit since 2011. IASI and CrIS are both interferometers while AIRS is a spectrometer. He noted that interferometers have better signal to noise in the longwave, while spectrometers are better in the shortwave.

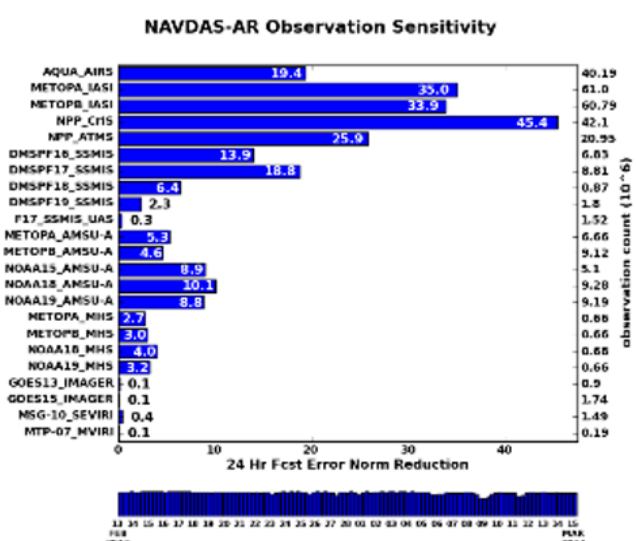
In his recount of the use of data from hyperspectral sounders at NRL, Dr. Ruston stated that AIRS was implemented at Fleet Numerical Meteorology and Oceanography Center (FNMOC). FNMOC is the Navy's primary operational NWP center, and it has used AIRS data since 2008 in the NRL Atmospheric Variational Data Assimilation System (NAVDAS)—a three-dimensional variational (3D-Var) system. IASI on board MetOp-A became operational in September 2009, and is also used in NAVDAS. The most recent hyperspectral sensor, CrIS, was put to use by FNMOC in December 2015.

All three instruments, AIRS, IASI and CrIS, were initially assimilated with the assumption of no inter-channel correlation. Further, the operational requirement was to process all observations, every 6-hours in 5 minutes wall clock time. In 2020 the total observations from these instruments is about 4.5 million. To achieve this timing and to not violate the assumed independence of each channel from each other, channel sub-selection was introduced. To identify which channels were most beneficial for assimilation, Dr. Ruston conducted experiments on the impact of radiance observations from various hyperspectral instruments. In 2006, in one of the very first looks at hyperspectral IR in the Navy system, experiments were run using a subset of channels from AIRS and the Advanced Microwave Sounding Unit (AMSU-A) which also flies on the AQUA satellite. During the assimilation run, Dr. Ruston looked at the observation impact of AIRS and AMSU on the Navy's Weather Models. Initially several channels were rejected including those with sensitivity above the model top, those with Ozone sensitivity, and those effected incoming solar radiation in the near-infrared. The figure on the next page shows some early Forecast Sensitivity to Observation Impact (FSOI) results from the August 2006 run. Channels reducing a 24-hour forecast error have negative values (left), and positive values show increasing errors (right). This figure shows the then operational Navy Operational Global Analysis and Predictions System (NOGAPS) and 3D-Var (NAVGEM) have no beneficial impacts from the higher peaking longwave CO_2 channels (AIRS channels <200) and higher peaking AMSU (channels 8 and 10). Using this FSOI metric, fits of the NWP model background to the observations, as well as traditional forecast metrics a channel set similar to this one shown was implemented in the 2008 promotion to operations at FNMOC.



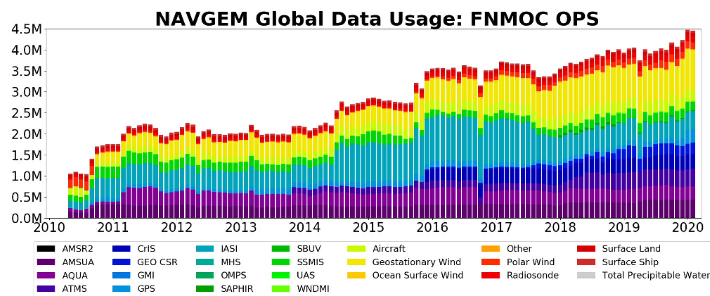
In a 2012 study, AIRS and IASI were the leading instruments in reducing the FSOI. Channels sensitive to water vapor were introduced with the implementation of the IASI from METOP-B in 2015. However it was shown that they had little impact on FSOI. Additional study after these studies revealed issues with lingering water vapor in the NWP model stratosphere were identified and corrected. Large beneficial impacts were seen with the inclusion of ATMS in 2015 (top), and CrIS in 2017 (bottom).





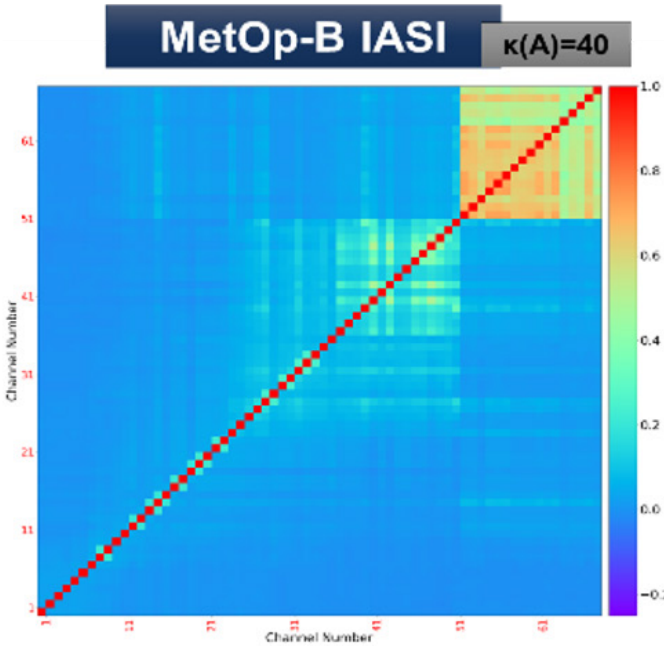
LARGE GROWTH IN SENSOR USAGE

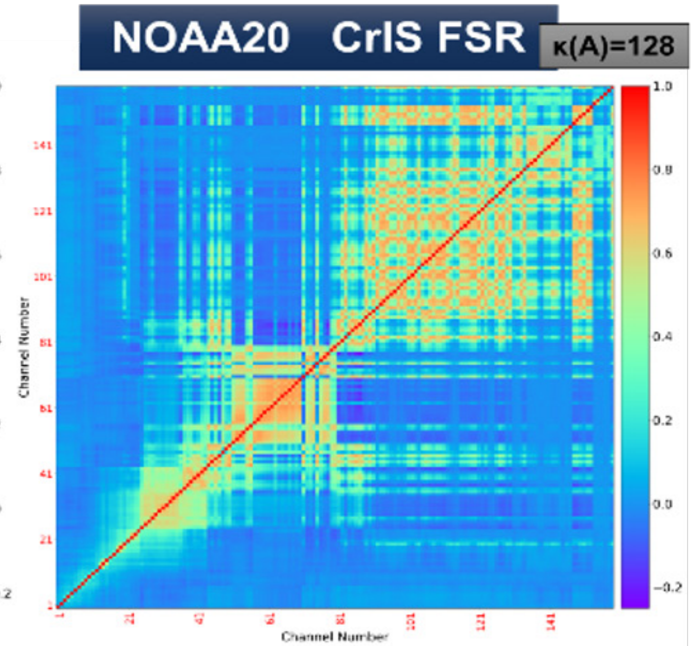
The figure below shows the growth in usage of sensor data over time for the NAVGEM system and associated 4D-Var system NAVDAS-AR (note 3D-Var NAVDAS is not shown). "In 2009, with the 3D-Var system there were about 600, 000 observations assimilated every six hours which included AIRS, this has grown to roughly four and a half million observations every six hours for use in operations," Ruston says.



INTRODUCTION OF CORRELATED ERROR

The introduction of inter-channel correlation marked an important step in the assimilation of hyperspectral IR radiances. In 2005 Desroziers, Berre, Chapnik and Poli introduced a method to estimate and diagnose observation, background and analysis-error. This method also allowed estimation of the observation error correlations. "Though not a perfect method," says Ruston, "these observation error correlations have proved useful and beginning with the Weston, Bell and Eyre in 2014 have also provided a pathway to using these estimates for operational NWP." The correlation matrices shown (next page) for the MetOp-B IASI instrument and full spectral resolution (FSR) CrIS instrument from NOAA-20 have undergone mathematical conditioning (symmetrization and Steinian linear shrinkage) to allow them to be used in the 4-Dimensional solver. A result of the conditioning of the matrices is a broadening of the correlations, the resulting conditioning number is shown as K(A).

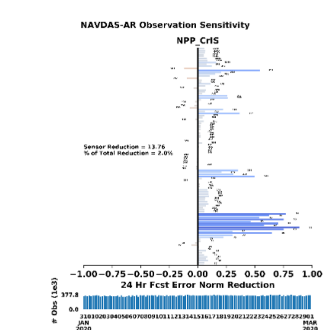


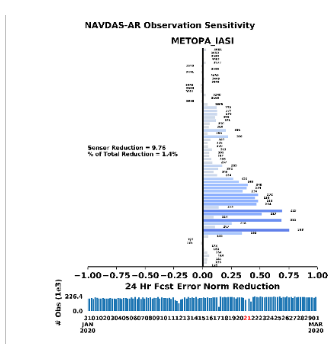


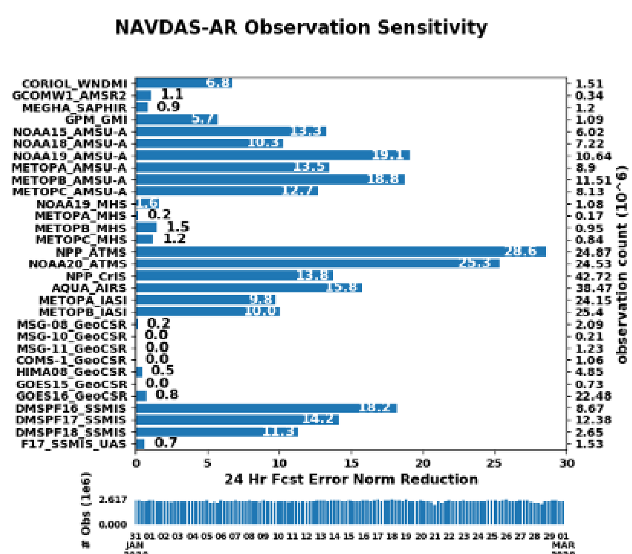
In the correlation matrix for the IASI sensor the group of water vapor channels is clearly seen in the block in the upper right of the figure. For the CrIS sensor there is not as consistent of a correlation between the water vapor channels (indicated by indices greater than 81). Further there is a stronger correlation in the stratospheric temperature channels about index 50-80.

Observation error correlation matrices have been put to effective use in the current NAVDAS-AR implementation for NAVGEM for both sensors, and currently IASI and CrIS (at nominal spectral resolution) are operational at FNMOC. "The move to transmit CrIS data at Full Spectral Resolution provided a chance to reanalyze the channel usage in the water vapor region (the longwave was already transmitted at full resolution)," says Ruston. Adding that "an even more aggressive use of the water vapor region is planned with the promotion of the CrIS FSR at FNMOC."

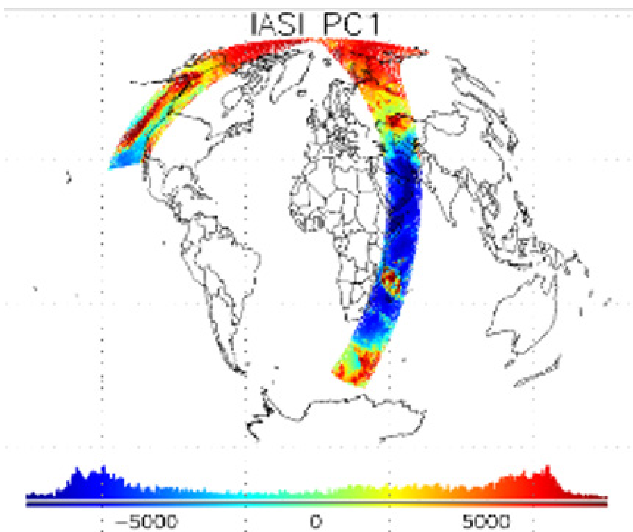
Fast forward to present day (2020) and for the NAVGEM system "ATMS is now the most impactful sensor," says Ruston. A unique difference in the current system is the introduction of correlated error. A readjustment of the observation errors was also performed, which effectively raised the observation error for the hyperspectral sensors more so than that for the microwave. This resulted in a shift of impact from the hyperspectral IR to the microwave. New pre-conditioning methods are being tested which show a strong promise to lower the variances which will return them to values closer to those before the introduction of the correlated error.

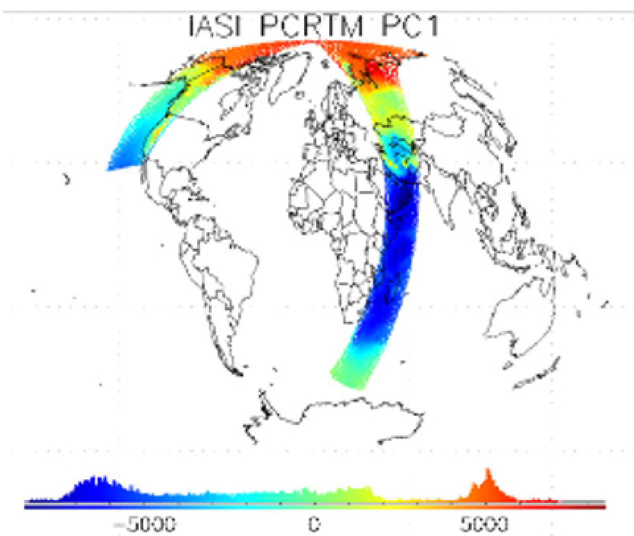




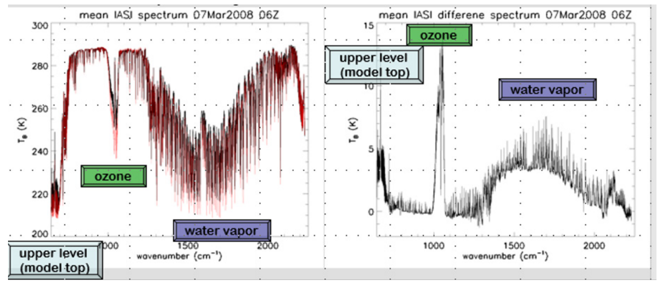


"Another important development for the future of hyperspectral instruments," says Ruston, "is the ability to directly simulate principle components in the data. The idea is to effectively compress the data by performing a principal component analysis (PCA)." A version of the JCSDA Community Radiative Transfer Model (CRTM) was developed to directly simulate the principal components by Xu Liu (2006). Experiments run using IASI data in the copy model showed the potential for an effective simulation in the clear sky regions.





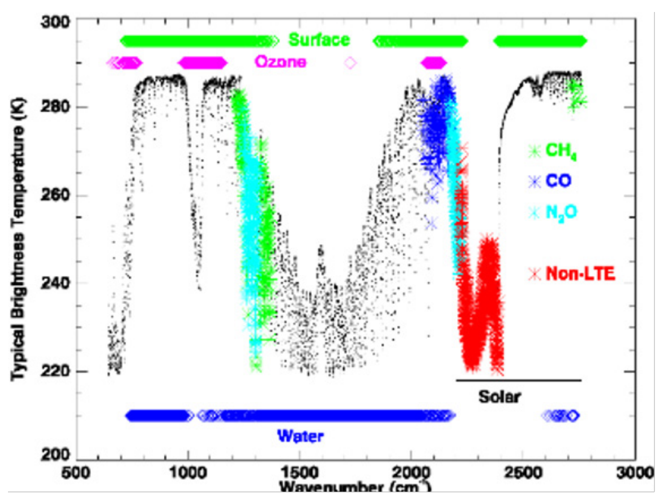
"The method has great promise," says Ruston, but has been hampered by challenges surrounding practical implementation and labor issues. "The effort towards all-sky assimilation will likely have to address these concerns," he adds. To use a principal component radiative transfer model (PCRTM), different sets of PCA basis functions would potentially need to be disseminated for the different cloud regimes. This is also an area of continued pursuit in the research community as future hyperspectral sensors such as the MeteoSat Third Generation InfraRed Sounder (MTG-IRS) will transmit PCA compressed data, as well as future SmallSats, which may also use this method to reduce data transmission volumes.



ASSIMILATING THE SHORTWAVE

Isn't as Easy as a Flip of a Switch.

-Ben Ruston



The radiances from hyperspectral IR generally have focused in the longwave infrared and are used in the water vapor at much lower volumes. A long term goal of Ruston's has been to expand and exploit more information from current assets, and especially the shortwave channels.

Experiment	CrIS			IASI			AIRS			Convergence
	LW	WV	SW	LW	WV	SW	LW	WV	SW	
Baseline	X	X		X	X		X	X	X	YES
Full Usage	X	X	X	X	X	X	X	X	X	NO
No IASI	X	X	X				X	X	X	YES (if truncated)
No CrIS				X	X	X	X	X	X	NO
No IASI CrIS LW		X	X				X	X	X	NO

It's a goal that's been met with varying issues over the years. To begin with, Ruston envisioned that it would be relatively easy to kick start his experiments. Or at least, that was the general plan. In fact, when he started his trials in the shortwave, he had "an abundance of optimism," he says. At the time he thought all he needed to do was to, "turn on all the shortwave channels for IASI, CrIS and AIRS with a high observation error; evaluate the statistics; drill down on channel set; and estimate some more appropriate observation error." He also planned to keep the longwave IR channels for the initial cloud screening and turn them off later in the process. He would then use the run with the longwave channels for quality control (QC) against the shortwave only methods, beginning with the CrIS FSR, then move onto use "both sides" of shortwave CO_2 absorption band 2200-2300 and 2400-2500cm^{-1}. Instead, he had "nothing but trouble," he recalled.

The table above shows various experimentation attempts, and the introduction and exclusion of the various longwave (LW), water vapor midwave (WV) and shortwave (SW) bands for the CrIS, IASI and AIRS sensors. The column on the far right shows that besides the baseline run, only 1 of the four experiments has consistently converged. As Ruston explains, "convergence," or a lack thereof, has been the biggest hurdle in his experiments to integrate the shortwave CO_2 channels. The focus, though, has turned primarily to an effective way to introduce the CrIS shortwave in addition to the AIRS, with Ruston noting that he "has not given up on use of the shortwave channels from the IASI instrument," as there are "many more combinations to try." After removing IASI, he tried both sides of the shortwave CO_2 band (Non-LTE 2200cm^{-1}/4.5µm; and 2380cm^{-1}/4.2µm) in full usage case. But, there was no convergence. Then not long afterward, he examined the CrIS FSR against the slightly wider shortwave channel bands in the truncated (or nominal) resolution. While he did not achieve the desired result, the truncated CrIS performed better than the FSR. Thus far he's been more successful with AIRS as he is able to assimilate both sides of the shortwave CO_2 band. However, he noted that the impacts are much better for the AIRS channels in the shortwave CO_2 (4.6-4.4µm) region. What's more, "after the seminar other experts offered a lot of beneficial feedback and ideas for the next round of experimentation," Ruston says.

EVALUATING THE CHANNELS

"One of the most common methods for the NWP centers to examine the performance of microwave and infrared instruments is the radgram," Ruston says. He explained that a radgram is "a line plot, which shows the time means and standard deviations of the observation minus simulated observation for a single channel on an instrument." These show the stability of the channel which can be compared between nearly-identical sensors on different platforms, or between sensors. Erratic behavior in these often shows degradation in the sensor, changes in sampling, or issues in the forward modeling. "Another diagnostic which is in use at most NWP centers is the fit-2-observations," Ruston says. This can be used to examine changes to the system, which may be a change in the model, to the data assimilation (DA) methodology, or with the introduction of a sensor. The fit-2-observations diagnostic shows the change of the other instruments fit after the change has been made. It is effectively a difference between times means of the radgrams for a control and an experiment. By using a time series of the differences in mean and standard deviation, a statistical significance due to the change can be made. Ruston says the fit-2-observations diagnostic has proven to be a useful indication "of the benefit or degradation due to a change from a much shorter time series 2–3 weeks," compared to "the typical forecast metrics which require 2–3 months of model integration."

SUMMARY AND FUTURE WORK: MORE GRAND CHALLENGES, MANY GREAT OPPORTUNITIES

Ruston's research on enhancing the use of short wave (SW) channels from hyperspectral infrared instruments will help break some of the barriers influencing their underutilization in NWP, and also help scientists understand how better to assimilate their data. Despite the challenges with the interferometers (CrIS and IASI) Ruston noted that the opportunities ahead are pretty substantial as he concluded his talk on a decidedly upbeat note, saying he "remains hopeful, and continues to seek longer term solutions about assimilating their shortwave channels in the future." Solutions that are also critical for potential future SmallSats which carry only this portion of the infrared spectrum.

> "...there's still a lot more to do!

Indeed, there are other complex problems to keep up with including the CRTM Jacobian issues, which Ruston plans to review, particularly for change in brightness temperature as a function of the model state input. He also has plans to more carefully screen out for Non-LTE effects potentially restricting the study area to lower latitudes, and watch for the non-linearity in the noise of these channels in the interferometers. With many ideas left to put into practice, efforts to expand and exploit more information from current hyperspectral IR sounding instruments, particularly from the CO_2 sounding channels in the shortwave region, is aptly summed up in Ruston's words, "there's still a lot more to do!" ❖

Story Source

Materials obtained from JPSS March Science Seminar titled "Short History of Hyperspectral Usage at NRL and Using CrIS to Examine Feasibility of Short-Wave Small Sat Assimilation." And comments received from experts in attendance.

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COMET METED TRAINING RESOURCES TO SUPPORT USER APPLICATIONS FOR NEW-GENERATION SATELLITE SYSTEMS

The information in this article is based, in part, on the April 22, 2020, JPSS science seminar presented by Amy Stevermer (COMET scientist/program lead) and Patrick Dills (COMET meteorologist/scientist). This work was funded by the University Corporation for Atmospheric Research cooperative agreement award #NA16NWS4670042 from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce.

The COMET® Program (www.comet.ucar.edu, formerly Cooperative Program for Operational Meteorology, Education, and Training) has been part of the fabric of environmental science education and training for the United States National Weather Service (NWS), other NOAA agencies, and several international partners for more than three decades.

COMET, which is part of the University Corporation for Atmospheric Research (UCAR) Community Programs (UCP), was originally established to promote a better understanding of mesoscale meteorology among weather forecasters and to maximize the benefits of new weather technologies during the NWS's modernization program.

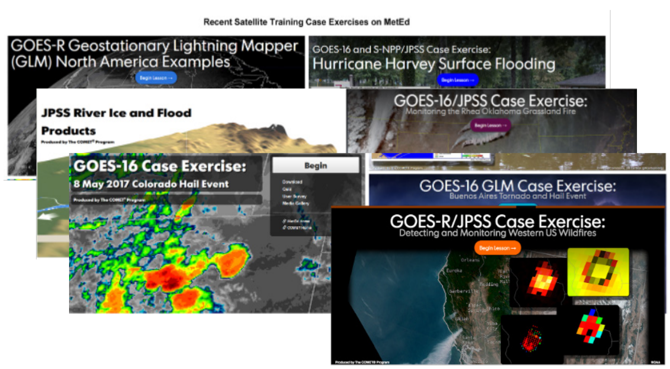
The COMET® Program has been funded for years by NOAA organizations including the Joint Polar Satellite System (JPSS) program and the GOES-R program. Other sponsor agencies include the National Weather Service (NWS) and the National Geodetic Survey (NGS), as well as several domestic and international agencies including the Bureau of Meteorology of Australia; Bureau of Reclamation, the United States Department of the Interior (DOI); the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT); the Meteorological Service of Canada (MSC); the Naval Meteorology and Oceanography Command (NMOC); the U.S. Army Corps of Engineers (USACE); and more.

COMET is part of the Joint Polar Satellite System (JPSS) Proving Ground Risk Reduction (PGRR) Training Initiative, which coordinates training efforts across multiple organizations. On April 22, 2020, as part of the JPSS monthly science seminars, COMET Scientist and Program Lead, Amy Stevermer, and Meteorologist and Scientist, Patrick Dills, shared their expertise in and experience with the training and educational resources the COMET® Program offers to help users apply current polar-orbiting satellite capabilities and products to several types of hazards, including monitoring floodwater, assessing the wildland fire environment, fire detection and monitoring, and diagnosing heavy rainfall events.

COMET, through the MetEd website (meted.ucar.edu), and the COMET Meted YouTube channel provides over 500 online self-paced training materials, including over 100 satellite-focused lessons, to help forecasters and users of weather information worldwide make use of the latest advancements in observing and prediction systems and decision support services. The materials cover a range of topics from convective weather, satellite meteorology, social science, numerical weather prediction, oceanography to decision support and impacts-based forecasting, and more. The MetEd website currently delivers training to more than half a million registered users.

CASE EXERCISES TO ILLUSTRATE SATELLITE APPLICATIONS

During recent years, COMET has focused on developing interactive lessons that provide demonstrations of integrated geostationary (GEO) and low Earth orbit (LEO) observing system strengths and capabilities for various applications. Some of the lessons involve case exercises for satellite applications. The goal is to present this training on an online platform that immerses the learner, particularly the forecaster, directly into a scenario based lesson. In addition, the learner also gets to work though questions and interactions associated with that event. This design allows the learner to interact, explore, experiment, and analyze the information right up front. Shown below are seven case exercises available as of spring 2020. A full set of cases of exercises is available on MetEd at https://www.meted.ucar.edu/training_course.php?id=73. Some of these, as well as a sampling of other COMET offerings, will be discussed in more detail later in the article.

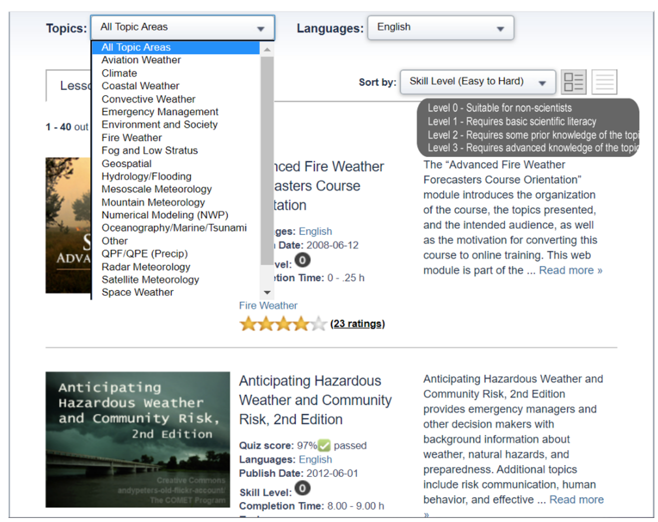


NAVIGATING METED

Finding Lessons and Topics

As an eLearning platform, MetEd's self-paced training content can be accessed any time and over an unlimited number of times. The MetEd training content is free, but requires access through registration. Once signed in, users can view the available lessons by clicking on the Education and Training tab to open a "Lessons/Resource Listing" page which delivers content as single lessons or courses. Lessons are stand-alone learning materials, while courses are bundles of lessons focused on common theme. The site offers options to search by keyword or by any word in a lesson title.

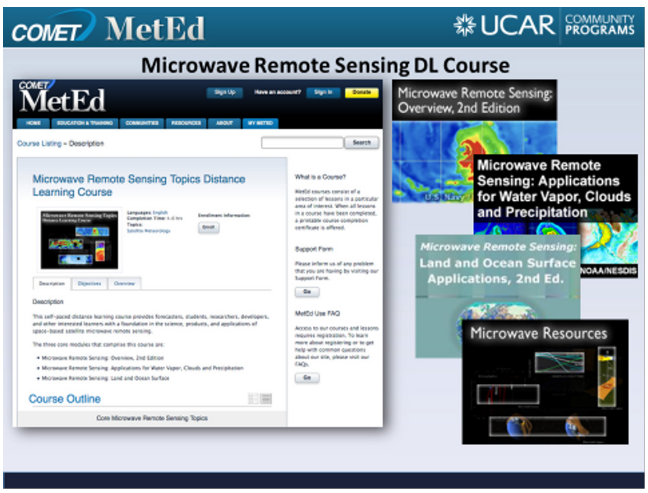
Through the Education and Training tab, one can search topics from a variety of different subject areas including aviation weather, environment and society, numerical modeling, and satellite meteorology. There is also an option to sort by skill level, from materials that are suitable for non-scientists to those requiring advanced prior knowledge. COMET's MetEd website contains lessons in nine languages, which makes the training more easily accessible to an international audience. While designed to accommodate varying levels of skills (illustration shown on the following page), most COMET resources are geared towards professionals working in the field or at the university level, and therefore require at least basic science literacy or some prior meteorological or other topic knowledge.



METED MULTISPECTRAL REMOTE SENSING APPLICATIONS COURSES AND LESSON UPDATES

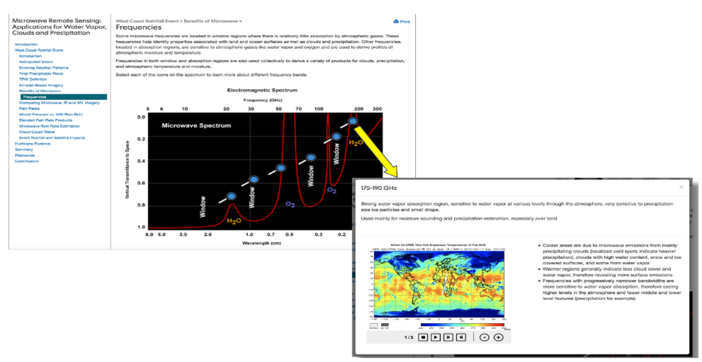
A course is a collection of lessons that relate to broader topics, for example, winter weather, numerical weather prediction, hurricanes, etc. They consist of typically three or more required lessons that one has to complete to receive certification. In addition, there are often optional lessons that are related to a topic but explore other areas, specific applications or more foundational science and so forth.

An example is the Microwave Remote Sensing Topics Distance Learning course shown below. This course consists of three required and four optional lessons focused on microwave remote sensing and various atmospheric, land and ocean surface applications. The course, which was produced in the late 1990s, was first based on the advanced microwave sounding unit (AMSU), one of the earliest in the series. The AMSU-A and AMSU-B have flown together on the three on three earlier NOAA satellites (NOAA-15, 16, and 17).

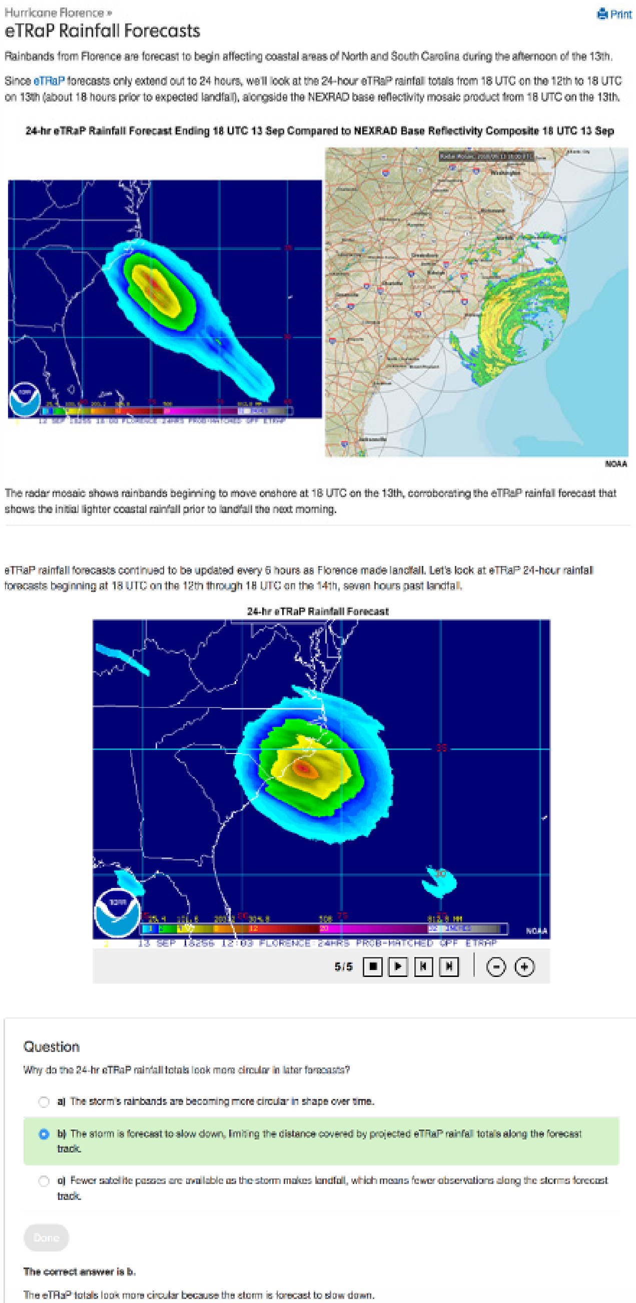


The *Microwave Remote Sensing: Overview, 2nd Edition* lesson gives an overview of space-based microwave remote sensing for environmental applications with a focus on meteorological applications. It delivers basic information on polar-orbiting satellite characteristics, current microwave instruments, and the products they provide. Special attention is given to the newer capabilities of the U.S.'s Suomi National Polar-orbiting Partnership (Suomi NPP) and JPSS satellites with additional information included for those missions being operated by international partners. This lesson also serves as an introduction to other, more in-depth lessons covering the science and application of cloud, precipitation, water vapor, and land and sea surface observations.

The *Microwave Remote Sensing: Applications for Water Vapor, Clouds and Precipitation* lesson introduces passive microwave products for depicting clouds, precipitation, and atmospheric moisture, including total precipitable water (TPW), cloud liquid water (CLW), rain rate, and other products from JPSS and other LEO satellites. The lesson uses two cases to demonstrate product interpretation, analysis, and impact on precipitation forecast guidance. One case focuses on an atmospheric river event that impacted California in February 2019, and the other on Hurricane Florence, which impacted the Mid-Atlantic Region in September 2018. The lesson presents microwave sensing concepts such as spectral selection, atmospheric absorption, emission and scattering by cloud and precipitation particles. Learners can explore the MW electromagnetic or EM spectrum to relate spectral selection and radiative transfer concepts to applications. https://www.meted.ucar.edu/satmet/microwave_topics/clouds_precip_wv_v2/navmenu.php?tab=1&page=2-7-1&type=flash#hs06. As illustrated below, pop-up windows are used to provide more information on products, show application examples and provide interpretation guidelines. Pop-up windows deliver content in a condensed format, and serve as an effective way of avoiding lengthy pages filled with in-depth discussions.



In the Hurricane Florence example, learners explore and apply derived MW products, such as Ensemble Tropical Rainfall Potential (eTRaP) forecasts. The eTRaP product is derived from several polar orbiting satellites with microwave sensing capabilities. This exercise allows learners to follow the hurricane across the Atlantic from its intensification to weakening phases, using several products including TPW and rain rate products and microwave imagery to analyze the scene. Questions and other forms of interaction serve to reinforce learning by engaging the learner with the content and challenging the learner on topics related directly to prescribed learning objectives.



JPSS SATELLITES: CAPABILITIES AND APPLICATIONS COURSE

The Capabilities and Applications Course for the JPSS satellites bundles many of the lessons that were first introduced a decade ago to prepare user communities for the enhanced data, products and services from upcoming mission satellites. The course includes four core lessons:

1. Suomi NPP: A New Generation of Environmental Monitoring Satellites
2. Introduction to VIIRS Imaging and Applications
3. Advances in Space-Based Nighttime Visible Observation, 2nd Ed. (2017)
4. Microwave Remote Sensing: Overview, 2nd Edition

The course also offers several optional lessons on the benefits and applications of JPSS observations in various areas including land and ocean surfaces, river ice and flooding, wildland fires, atmospheric profiling, numerical weather prediction and climate.

In 2018–2019, COMET released multiple lessons as part of the NWS Satellite Foundational Course for JPSS: SatFC-J. The course was designed by the NWS satellite training advisory team (STAT) with contributions from the Cooperative Institute for Research in the Atmosphere (CIRA), the Cooperative Institute for Meteorological Satellite Studies (CIMSS), the Short-term Prediction Research and Transition Center (SPoRT), COMET, and the NWS Office of the Chief Learning Officer (OCLO), to bring forecasters up to speed with the new and improved capabilities the JPSS satellites introduced. COMET is responsible for five of the 19 lessons in the course. The lessons are currently available on MetEd (Meted Resource link), and are more specifically focused on instruments. The full course is available in NOAA's Commerce Learning Center (CLC) and also released by CIRA http://rammb.cira.colostate.edu/training/shymet/satfc-j_intro.asp.

CASE EXERCISES

Each case-based exercise is designed to teach about the latest satellite products within the context of a hazardous and impactful weather event. Many of these exercises integrate the capabilities and products from both JPSS and the Geostationary Operational Environmental Satellite (GOES) – R Series. Currently available case exercises are accessible through the GOES-R/JPSS Satellite Applications Case Exercises course (https://www.meted.ucar.edu/training_course.php?id=73).

Flooding

An example is the JPSS River Ice and Flood Products lesson which describes the need for information on river ice and flooding, and showcases the capabilities of the Suomi NPP and NOAA-20 Visible Infrared Imaging Radiometer Suite (VIIRS) instruments to provide products, such as the JPSS River Ice and Flood Product suite, for monitoring river conditions.

In the lesson are several case exercises including one, which COMET unveiled in 2015 that covers a late spring ice jam event in 2013 that led to severe flooding in the town of Galena, Alaska. The lesson also includes cases that address winter and spring season flooding events in the lower 48 states, and highlight additional applications in flooding. These applications include an ice formation event that occurred in January 2015 in the Upper Mississippi River and greatly impacted navigation in the area, and a springtime flooding event in the Upper Midwest along the Red River of the North in 2014.

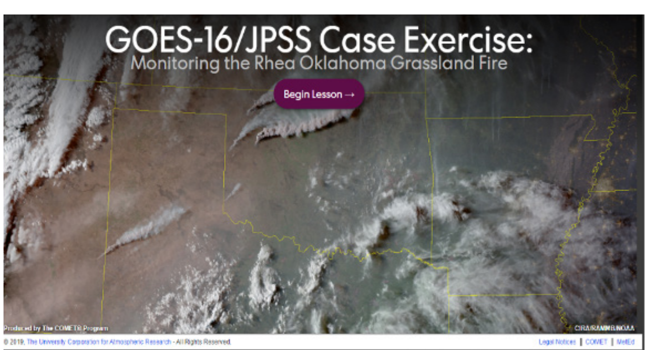
Some would say product evolution is not just an option, but a necessity. This was the case for the JPSS River Ice and Flood product. The evolution, which was in part due to vital feedback from user communities, led to the development of a merged product—which includes components from the GOES – R Series satellites—that combines high-temporal resolution GEO with high-spatial resolution of LEO. For greater utility and functionality, the merged flood map product leverages the imaging instruments from both satellites, VIIRS on JPSS and the Advanced Baseline Imager (ABI) on GOES-R. In addition to ice flood analyses, forecasters now have the additional functionality to perform short-term assessment of surface floodwater. In July 2018, the COMET Program introduced a case exercise titled GOES-16 and S-NPP/JPSS Case Exercise: Hurricane Harvey Surface Flooding (https://www.meted.ucar.edu/training_module.php?id=1397). The question-focused 30-minute lesson highlights the August 2017 flooding associated with Hurricane Harvey in southeastern Texas. The lesson is designed to familiarize the trainee with the tools to use and interpret satellite imagery in regions with surface flooding.

Wildfires

Every year, wildland fires occur in regions across the United States, particularly the western states. The merged satellite fire products have garnered the interest of the wildland fire community and COMET has developed wildland fire scenario-based training on these products. The lessons, as with all others, are developed by several team members including instructional designers working in consultation with various experts, who in this case included fire weather forecasters, NWS fire weather program leads, and satellite experts, to develop learning objectives. The objectives are critical in guiding the development of lesson plans.

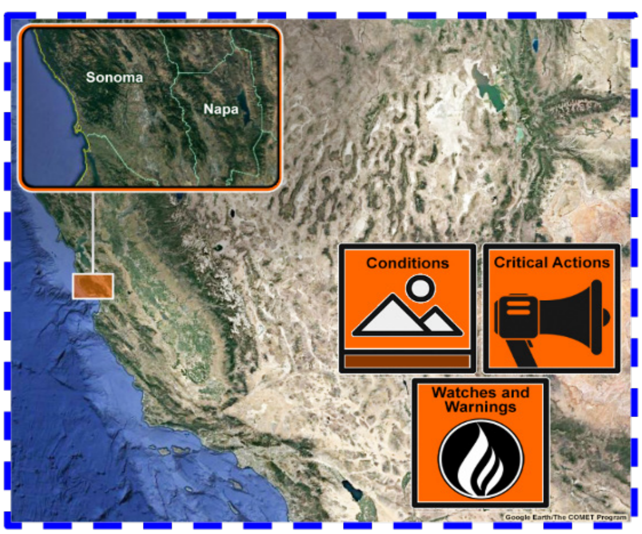
Among the lessons designed to help assess the strengths and limitations of JPSS and GOES-R satellite products in detecting and monitoring wildfires is the Rhea Fire case exercise, based on a grassland fires which affected western Oklahoma from April 12–18, 2018. Another case exercise focuses on the northern California Kincade fire of October 2019.

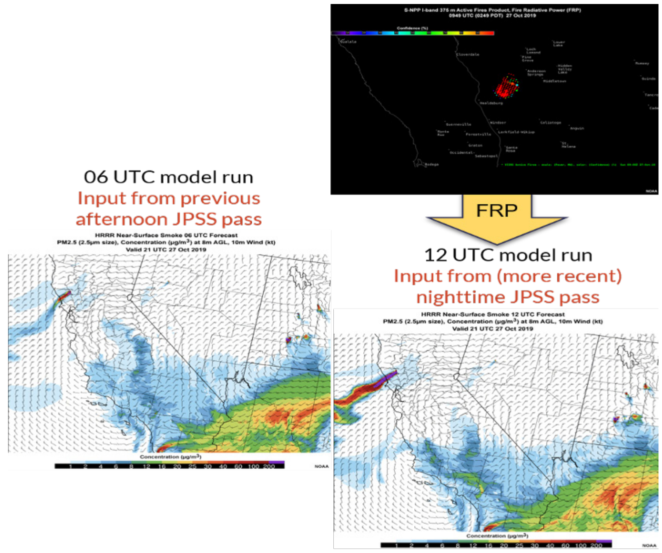
The Rhea Fire lesson focuses on various satellite products of use during a large grassland fire event. These include longwave-shortwave IR difference, Fire Temperature RGB, GeoColor, GOES-R Fire Mask, JPSS Active Fire, and others. The other lesson is based on the Kincade Fire, one of northern California's largest fires in 2019. The lesson enables learners to closely examine two significant points in the life of the fire, both of which occurred in the nighttime: its initiation on October 23 onset, and a rapid spread period on 27 October. The nighttime environment is inherently more difficult due to reduced visibility, particularly with regard to smoke. This lesson highlights multiple satellite products that can be useful when monitoring the conditions involving a potentially rapidly spreading fire. In the Kincade Fire example, the initiation and rapid spread were impacted by high wind events. Information on environmental and weather conditions, watches & warnings, critical actions, and communications is synthesized with the available tactical information from satellites. This set-up, along with clickable links with contextual information, allows the learner to run through products that can help identify fire initiation events and rapid spread associated with high winds and low relative humidity in the difficult western U.S. terrain. Additional learning tools in this lesson include an interactive image visualization interface that enables the learner to compare multiple image products synchronized in time, similar to the multi-panel/multi-product views available to forecasters that allow for quick comparison of selectable products of interest. As the learners answer the questions embedded within the lesson, they are provided with feedback within the exercises. The questions and associated correct answer feedback are considered to be an essential



element of improving the learning process, which "reinforces a product's capabilities, strengths and limitations, and even some of the best practices," says Dills.

Smoke forecasts are essential inputs to air quality advisory systems. They play a key role in public health preparedness. This Western Wildfires lesson highlights the role of JPSS Active Fire Radiative Power (FRP) data for the High-Resolution Rapid Refresh (HRRR)-Smoke model initialization. It also highlights FRP updates and how they can affect model forecasts, as illustrated in the figures below of two model runs (roughly six to 12 hours apart) of HRRR-Smoke forecasts derived using input from JPSS. The output on the left is derived from an afternoon pass, while that on the right is derived from a more recent nighttime pass. In this case, the more recent FRP data provided updated input based on the fire's rapid growth and intensification, and therefore provided a more realistic near-real time forecast of smoke conditions. The HRRR-Smoke model combines several data including FRP, atmospheric temperature, rain and wind speed, along with information from vegetation maps. One goal of this lesson is to make the users see how different inputs can affect models and the importance of paying attention to when the updates come along.





NWS SATELLITE APPLICATIONS WORKSHOP

In the summer of 2019, the NWS hosted a Satellite Applications Workshop in Kansas City, Missouri. COMET livestreamed and recorded the workshop. The recordings, now part of a digital collection (shorturl.at/gzOZ7) on the COMET/MetEd YouTube site, include 12 forecaster-delivered video presentations that cover a range of applications from flash flooding; winter weather, convection; the Weather Prediction Center (WPC) and the Ocean Prediction Center (OPC); the Geostationary Lightning Mapper (GLM); volcanic ash; and wildfires.

MERGED SATELLITE PRECIPITATION GUIDANCE

In March 2020 COMET released a lesson (https://www.meted.ucar.edu/training_module.php?id=1605) on two atmospheric river events that produced heavy precipitation and flooding in different locations within the United States to demonstrate some of the capabilities of merged satellite precipitation products. The products, the CPC MORPHing Techniques (CMORPH) and the Integrated Multi-satellite Retrievals from GPM (IMERG) rely on low-Earth orbiting microwave satellites and Geostationary Operational Environmental Satellites (GOES) to establish the shape, magnitude, and movement of precipitation areas.

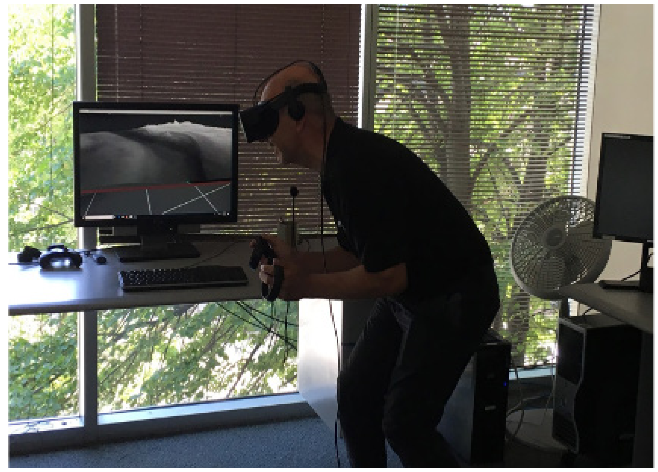
COMMUNITY SATELLITE PROCESSING PACKAGE

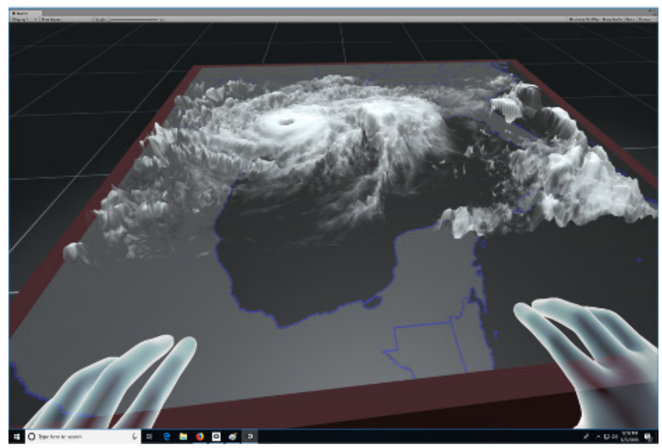
COMET has also produced a lesson on the Community Satellite Processing Package (CSPP) (https://www.meted.ucar.edu/training_module.php?id=1321) from the University of Wisconsin. CSPP provides access to meteorological and environmental satellite data through direct broadcast (DB). The training covers the advantages of direct broadcast data, and how to find resources for downloading and installing CSPP. In conjunction with the training COMET has also prepared two YouTube videos on operational applications, one focuses on CSPP imagery products (https://youtu.be/UrzMl1BOP0o), and the other focuses on CSPP microwave products (https://youtu.be/2RVqHiqgD6E).

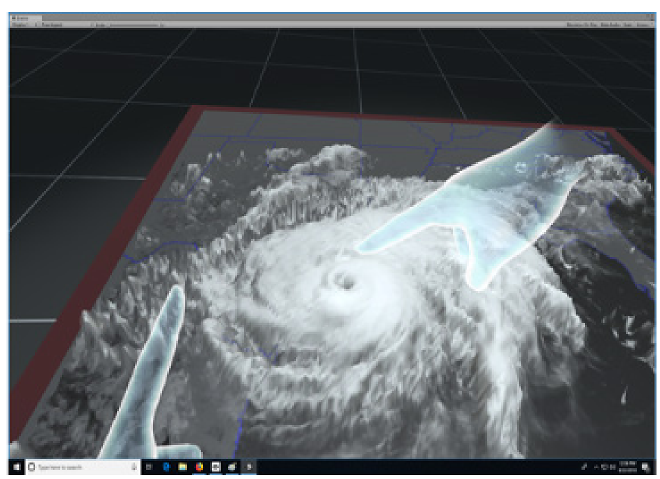
SATELLITE IMAGERY VISUALIZATION—VIRTUAL REALITY

Augmented reality (AR) and virtual reality (VR) are powerful tools to help enhance people's understanding of atmospheric and Earth system physical processes. Augmented reality layers digital information over physical spaces and objects, which allows users to see three-dimensional visualizations of invisible processes through the camera of a mobile device. In contrast, virtual reality immerses the users in an environment, through a headset or other viewer. In the case of satellite imagery, it can provide learners with a view of satellite data in three dimensions and in greater detail. COMET's AR efforts underway in the past year include a Storm Surge app. The app allows users to see the potential impacts of inundation and visualize how it could affect their own homes. In terms of satellite visualizations using VR, COMET has used channels that have a pseudo-height component, specifically the infrared (IR) and water vapor Ch 13, 8, 9, 1 on GOES-R to produce three-dimensional versions of the imagery. The imagery is put into a Virtual Reality environment (Unity 2018) to provide user-driven interactivity: select channels, rotate views, & explore content if using Oculus, GearVR, and Google Cardboard.

Example videos of these visualizations are available on COMET's YouTube channel: https://www.youtube.com/playlist?list=PLsyDI_aqUTdEdCKxs7tX4WswnpCYgV2m5.







LEARNING IN THE MIDST OF A PANDEMIC

In 2020, the novel coronavirus pandemic gripped the world, and along with it came unexpected challenges. The virus and responses radically upended life worldwide. It also forced many institutions to move their teaching instruction to online delivery platforms. In response to this evolving societal need, COMET staff developed and hosted webinars to support university and other instructors in the transition to online platforms. The webinars demonstrated best practices, for instructors, in how to structure their online content and live sessions to foster connections, actively engage learners, and create effective assessments in both synchronous and asynchronous environments. Although, "the best practices were based on multi-week, multi-month course models for the World Meteorological Organization (WMO), they can apply to virtual workshops or single-week courses as well," says Stevermer. COMET's instructional designers also hope to align MetEd's existing satellite training materials to university-level courses. The efforts involve collaborations with university communities to develop linkages to typical course syllabi, and to work with university instructors to define lessons that are most useful. Additionally, COMET offers some select resources at middle school/high school levels, which are available at https://www.meted.ucar.edu/communities/education/. Even more resources are available at the UCAR Center for Science Education, https://scied.ucar.edu/help-k-12-students-learn-about-earth-home.

LEARN MORE ABOUT COMET

More information on the COMET Program is presented in a paper titled "COMET's Education and Training for the Worldwide Meteorological Satellite User Community: Meeting Evolving Needs with Innovative Instruction." The paper, which was published in 2019 (https://www.mdpi.com/2220-9964/8/7/311), gives a background of COMET's satellite training efforts, as well as details on its instructional design, opportunities for practice, and emphasis on learning retention, the NWS & international applications, and reach of training.

SUMMARY/CONCLUSIONS

Since its inception in 1989, the COMET Program has imparted education and training to users of environmental satellite information worldwide, including those at the NWS, other NOAA agencies, and international institutions. Both NOAA's JPSS and GOES-R programs have been long-time sponsors of COMET. Through these sponsorships, COMET has contributed significantly to efforts helping train the present and future workforce on the full suite of environmental satellite capabilities. These efforts include participation in the JPSS PGRR Training Initiative, which coordinates training efforts across multiple organizations. COMET's training deliverables address a range of topics from satellite meteorology, environment and society, social science, NWP, oceanography to decision support and impacts-based forecasting, and more. Lessons are designed to help forecasters and users of weather information worldwide make use of the latest advancements in observing and prediction systems and decision support services. To date, COMET has delivered over 500 online self-paced training materials, including more than 100 satellite-focused lessons,

COMET's Education and Training for the Worldwide Meteorological Satellite User Community: Meeting Evolving Needs with Innovative Instruction

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through the MetEd website and the COMET Meted YouTube channel. Many of the lessons are available in other languages, including Spanish and French.

In 2020, the novel coronavirus prompted a worldwide public health crisis which, almost in an instant, moved life online. Digital tools and online platforms became an integral part of life, from work, school, social interactions, to health care, and etc. In response to the shift, COMET staff developed and hosted webinars to support university and other instructors in the transition to online platforms. The webinars demonstrated best practices for structuring online content and live sessions to foster connections, actively engage learners, and create effective assessments in both synchronous and asynchronous environments.

Over the years, the deliverables have adapted and expanded as remote sensing capabilities and applications have evolved, spacecraft such as NOAA-20, Suomi NPP and GOES-16 and -17, have come online, and new products and visualization capabilities have emerged. In addition, the Program continues to evolve its instructional approach to better meet the shifting needs of learners. These approaches include the deployment of technologies such as AR and VR, which offer a view of satellite data in three dimensions and in greater detail, to help enhance learners' understanding of atmospheric and Earth system physical processes. ❖

Story Source

Materials obtained from JPSS April Science Seminar titled "COMET MetEd Training Resources to Support User Applications for New-Generation Satellite Systems."

References

Dills, P.; Stevermer, A.; Mancus, T.; Guarente, B.; Alberta, T.; Page, E. COMET's Education and Training for the Worldwide Meteorological Satellite User Community: Meeting Evolving Needs with Innovative Instruction. ISPRS Int. J. Geo-Inf. 2019, 8, 311.

THE JPSS VOLCANIC HAZARD INITIATIVE

The information in this article is based, in part, on the May 21, 2020 JPSS science seminar presented by Dr. Michael Pavolonis NOAA/NESDIS.

Airborne volcanic aerosols are major threats to transportation, health and infrastructure. At best, they're disruptive. At worst, they're deadly. Not only do they produce an array of hazards, volcanic eruptions are also capable of altering global climate—which can happen when large amounts of sulfur dioxide are injected high into the atmosphere during an eruption. The sulfur dioxide layer gradually transforms into a layer of sulfate aerosol that diminishes the amount of sunlight reaching the earth's surface, which can temporarily cool the planet and alter weather patterns.

Volcanoes frequently generate clouds of ash and sulfur dioxide (SO_2), which are aviation hazards. Aircraft encounters with ash clouds can diminish visibility, damage flight control systems, and cause jet engines to fail. Aircraft passengers and crew exposed to SO_2 and sulfate byproducts may experience irritation of the skin, eyes, nose, and throat. Volcanic ash and SO_2 are a global aviation hazard because atmospheric winds often transport ash and SO_2 great distances from the source volcano. Closer to the source volcano, ash fall, heated debris flows, lava flows, and poor air quality are common hazards. As with any other disaster or catastrophic event, routine operational monitoring of volcanoes and volcano byproducts, such as ash and SO_2 clouds, is critical to protect life and property, and to mitigate impacts from volcanic eruption events.

Mike Pavolonis, a physical scientist at the NOAA Center for Satellite Applications and Research (STAR) who works within the Advanced Satellite Products Branch (ASPB), located in Madison, WI. Dr. Pavolonis leads a science team that focuses on volcanic clouds, severe weather and fog below stratus, as well as the ensuing hazards. On May 21, 2020, as part of the Joint Polar Satellite system (JPSS) monthly science seminars, Dr. Pavolonis presented a talk on the Volcanic Hazard Initiative.

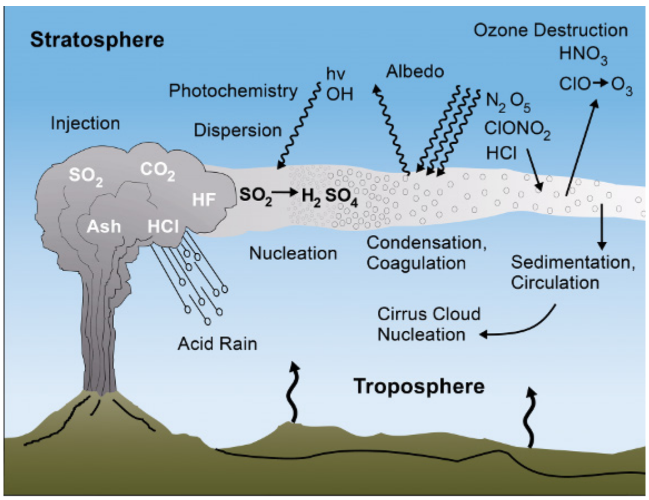
The Initiative was established in response to underserved and emerging needs for volcanic hazard mitigation, where JPSS measurements, in combination with other data sources, have potential for adding significant value. More specifically, the Initiative is working towards addressing user needs in support of aviation, volcano monitoring, and weather/ climate applications.

WHY IS THIS IMPORTANT?

The overarching needs the initiative seeks to address are partitioned into three broad categories.

CLIMATE

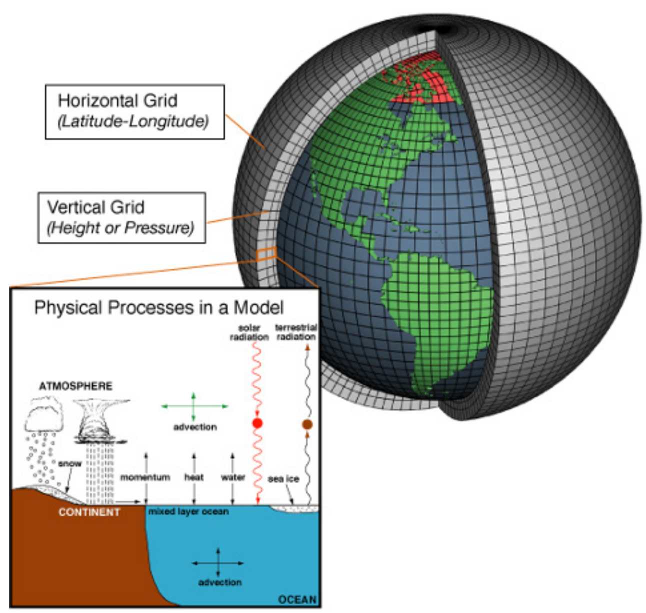
Very large volcanic eruptions have an impact on the Earth's radiation budget, which feeds into all different components of the climate system. Being able to characterize the emissions associated with these significant events has a huge impact on our ability to understand how these events impact climate over the course of years.



DEGRADATION IN WEATHER PREDICTION SKILL

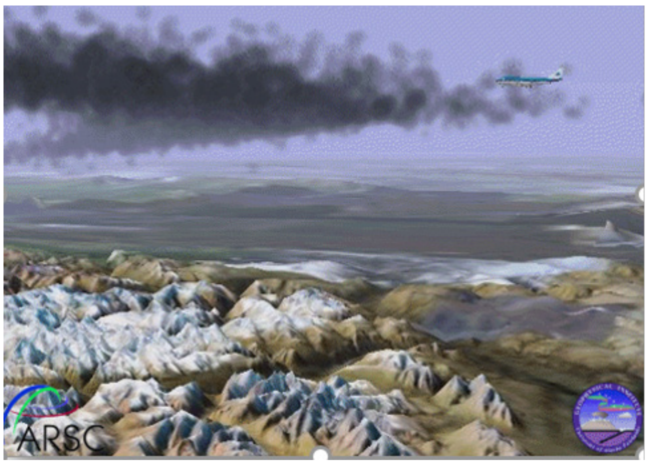
An impact on climate also affects another major part of the Earth system, which we experience everyday—the weather! Numerical Weather Prediction (NWP) models compute forecasts ranging from a few hours up to ten days ahead. Satellite observations, especially the polar-orbit satellite observations, provide critical data to enable accurate medium-term forecasts, three to seven days in advance of severe weather events. Close 90 percent of the data assimilated into forecast models are from infrared and microwave sounders on polar orbiting satellites contributing close to 60% of forecast error reduction (Goldberg, 2017). However, Pavolonis stated that there is one aspect that isn't given enough thought, which is "the next time there is a large eruption, like that of Mount Pinatubo (Philippines) in 1991, what kind of impact will that have on our ability to forecast the weather?" Pavolonis asks. Aerosol particles scatter and absorb incoming sunlight, and thus have a cooling effect on the Earth's surface. According to the NASA Langley Research Center Aerosol Research Branch (https://earthobservatory.nasa.gov/images/1510/global-effects-of-mount-pinatubo) the particulates from the Mount Pinatubo eruption dispersed an inordinate amount of sunlight that led to measurable cooling.

Pavolonis noted that NWP forecasts can go seven to ten days into the future with some skill. While this is great, the atmosphere is constantly changing, which makes estimates over long periods more difficult to model and predict. To this point, Pavolonis asked: "will that skill be maintained in the wake of a really large eruption where the data that gets assimilated in the model may have large errors associated with it because of volcanic aerosols? Or that the NWP models themselves, "are they handling the radiation feedback associated with these aerosols?" There is a chance that large scale volcanic eruptions can lead to a degradation in weather prediction skill.



AVIATION

Volcanic eruptions can eject ash into the atmosphere to great heights, and potentially threaten the safety of any flight in their path. When volcanic ash is ingested into jet engines it can cause severe damage, and even cause them to stall. In addition, volcanic ash particulates pose significant health and infrastructure threats to the local communities in the areas where they occur. Beyond safety, volcanic ash can produce widespread disruption and large economic impacts. Volcanic ash clouds also present serious cost considerations such as maintenance and delays for the air traffic system as a whole. This article will primarily focus on the aviation component of the problem.

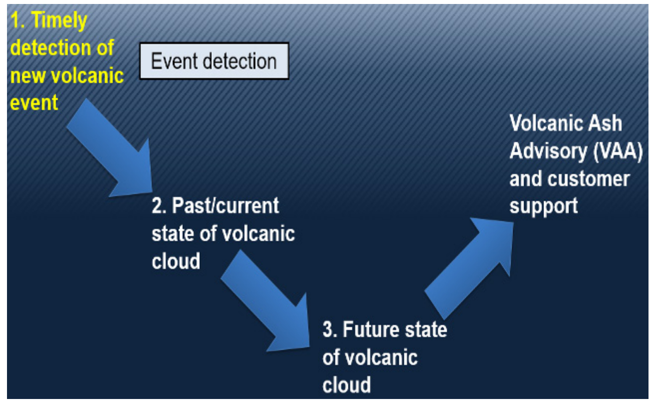


SAFE AND EFFICIENT AVIATION

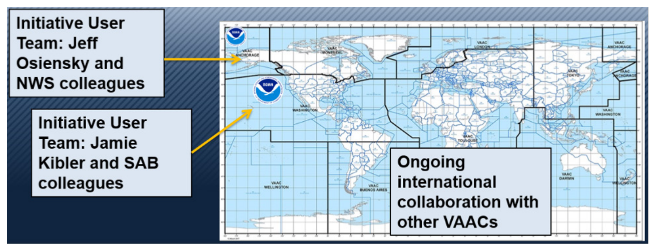
Volcanic Ash Advisory Centers (VAAC) were created in recognition of the need to keep aviators informed of volcanic hazards. There are nine VAACs in the world today. Each is tasked with issuing timely and accurate volcanic ash advisories to aviation stakeholders according to standards set by the International Civil Aviation Organization (ICAO). NOAA operates two VAACs—one in Anchorage, Alaska, the other in Washington, D.C.

VAAC WORKFLOW

The VAAC workflow starts with timely detection of a new volcanic event. The next step involves getting knowledge of how the feature evolves in time. This knowledge of the past state helps put into context the present state of the cloud. This information feeds into the ability to forecast the future state, or dispersion and transport, of the cloud. VAACs are required to produce 6, 12 and 18 hour forecasts.

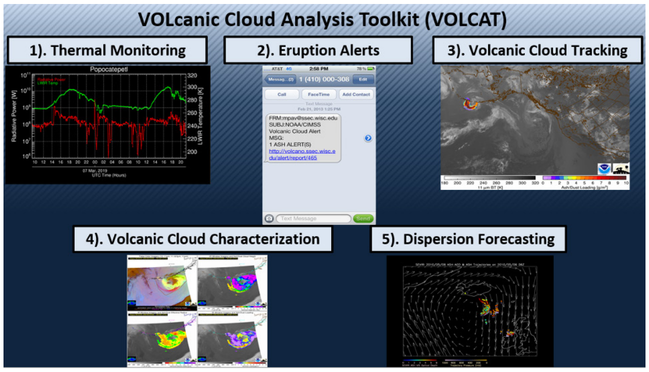


The product development work, is performed in close collaboration with the user community. It is driven by the "jobs to be done" model, where solutions are built to directly support user workflows. The centerpiece of the effort



is the NOAA VOLcanic Cloud Analysis Toolkit (VOLCAT), which is a collection of software designed to house all the capabilities needed to tackle various problem aspects. VOLCAT, which was developed by NOAA, in partnership with the University of Wisconsin—Madison http://volcano.ssec.wisc.edu, is a multi-faceted system that can detect and characterize nearly all types of volcanic clouds. The toolkit generates alerts when volcanic unrest or an eruption is detected and also automatically tracks and characterizes volcanic clouds. Its capabilities, some of which are shown in the figure on the following page, range from early indicators of eruption onset, volcanic cloud tracking to support for forecasting the dispersion of volcanic clouds.

The VOLCAT system ingests data from various instruments including those onboard spacecraft in the Low Earth Orbit (LEO) such as NOAA-20 and Suomi NPP and in the geostationary orbit such as GOES-16 and -17. Each day, the system processes and turns close to 15 billion Earth located pixels into targeted environmental information.



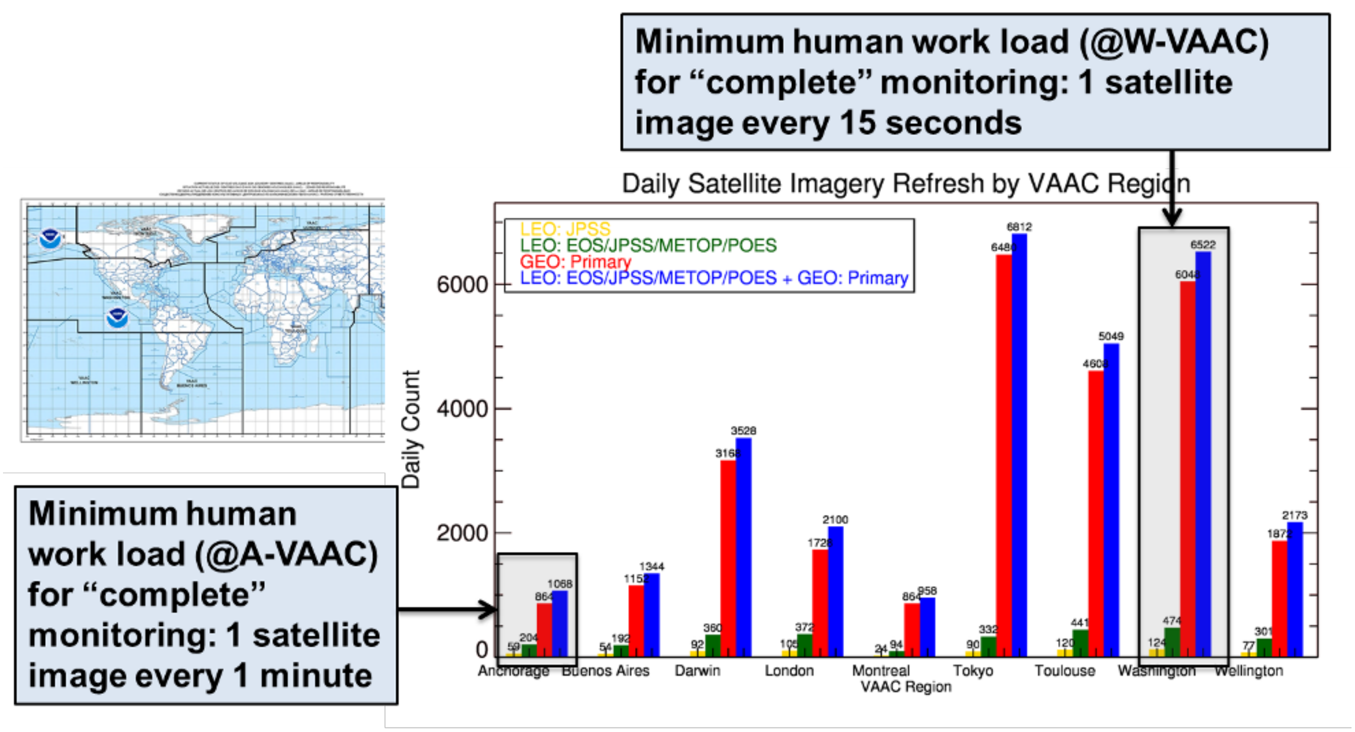
DATA OVERLOAD

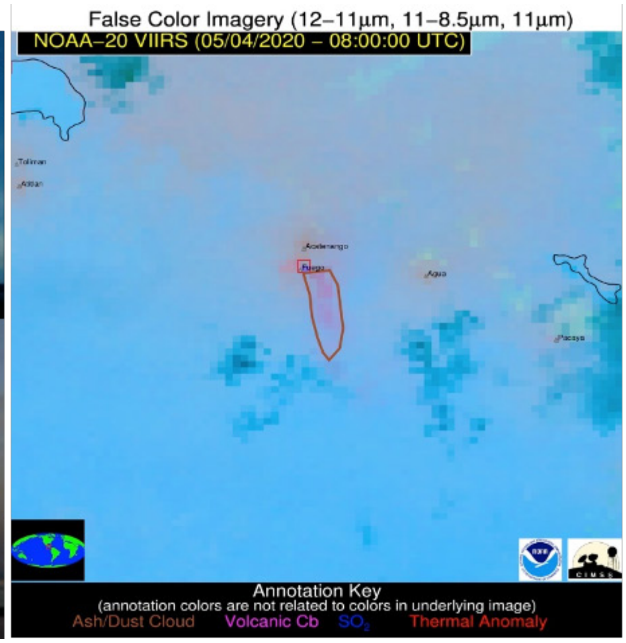
Accurate and timely detection of new volcanic ash emissions is the critical first step of the VAAC workflow. Human experts are inherently good at identifying nuanced features, such as new ash emissions, in satellite imagery. However, detailed manual examination of every pertinent satellite image is not feasible given the near continuous rate at which new satellite data are acquired.

Data overload occurs when the amount of environmental data a human analyst is confronted with, is much greater than what they can consistently analyze in real time. The figure on the next page shows the minimum number of satellite images from both GEO and LEO platforms that a human analysts at a VAAC would have to manually interrogate daily to have complete monitoring of all the volcanoes in their region. The Anchorage VAAC, for example would have to manually interrogate over 1000 images daily (equivalent to one new satellite image every minute), whereas the Washington VAAC, which has a larger area of responsibility and more volcanoes, would have to manually interrogate over 6500 satellite images every day (equivalent to one satellite image every 15 seconds). These manual interrogation demands can quickly become overwhelming. And, according to Pavolonis, the issue is now more profound as newer geostationary satellites, such as Himawari-8, produce approximately 100 times more data each day compared to their predecessors.

A CLOUDY ANALYSIS

Cloud properties can also impact human expert analysis techniques, especially volcanic clouds that are produced by explosive types of events. Early in the evolution of an event, explosive volcanic eruptions are more difficult to manually distinguish from meteorological clouds, especially in convectively active environments. VOLCAT utilizes advanced techniques, such as detection of new rapidly developing clouds and thermal heat signatures, to detect complex volcanic clouds that are more challenging to distinguish from other types of clouds.





On the right above is a NOAA-20 VIIRS False color image of the Fuego Volcano in Guatemala. Photo credits: J. Warren, USGS (bottom left)

QUANTITATIVE DETECTION

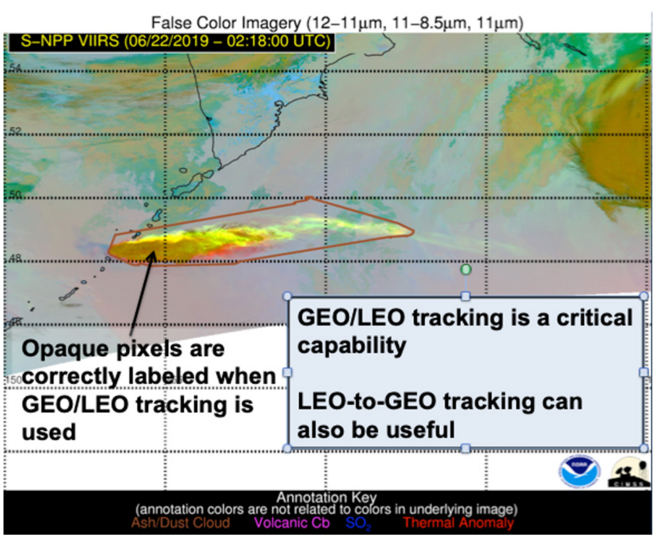
For several years now, the Volcanic Ash Hazards Initiative has been looking into real time eruption detection methods—that work over a wide range of cloud properties, and also take into account the highly variable background/foreground—to address these challenges. Many years of work, including Initiative sponsored work, has led to the development of a general artificial intelligence (AI) solution that can be applied to many sensors. This solution results in automated detection (of new volcanic events that generate clouds) that has skill that is comparable to human experts. The spectral, spatial, and temporal aspects of satellite data must be exploited to achieve such skill. For instance, the automated algorithm detects subtle volcanic ash signatures in VIIRS imagery by incorporating information on feature shape and orientation, relative to active volcanoes.

Volcanic ash appears red in the false color image above. The VOLCAT algorithm automatically generates polygons that define the bounds of a detected event or cloud. These polygons are then overlaid on multispectral images, such as the one shown above on the right, which allows users to readily interpret the results of the automated ash detection algorithm. The VOLCAT volcanic ash detection approach is source agnostic, consisting of machine learning and feature engineering components. The machine-learning step identifies pixels that have a multi-spectral signature that is consistent with volcanic ash. Because there is significant overlap in the spectral signature of ash and other features (e.g. clouds, land surfaces, noise), subsequent processing examines the spatial and temporal (when available) attributes of spatially connected candidate volcanic ash pixels identified by the machine-learning algorithm. The spatially connected candidate pixels, known as cloud objects, are labeled as ash/no ash. Small-scale volcanic ash clouds are more readily identifiable in VIIRS data than geostationary satellite data as a result of the higher spatial resolution of VIIRS. However, VOLCAT utilizes temporal metrics to offset the lack of coherent spatial patterns in geostationary satellite associated with small and emerging volcanic ash clouds.

Volcanic clouds, generated by highly explosive eruptions, may not have a unique multispectral signature, which makes it difficult to distinguish from meteorological clouds. When such cases arise, the time evolution and other indicators, such as lightning frequency and the recent history of volcanic activity, are critical. VOLCAT automatically detects clouds, generated by explosive eruptions, as they emerge from the volcano by identifying development patterns that are anomalous compared to clouds associated with weather (Pavolonis et al., 2018). The cloud evolution approach to eruption detection is further enhanced when combined with lightning data and recent indicators of volcanic unrest. VOLCAT utilizes lightning data and the record of satellite derived thermal hot spots, associated with volcanic activity, to improve the timeliness and accuracy of event detection.

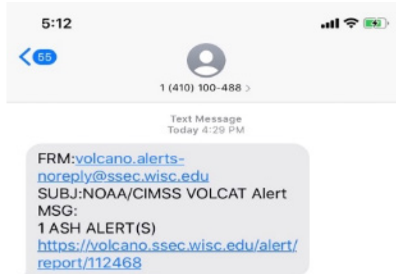
CLOUD TRACKING

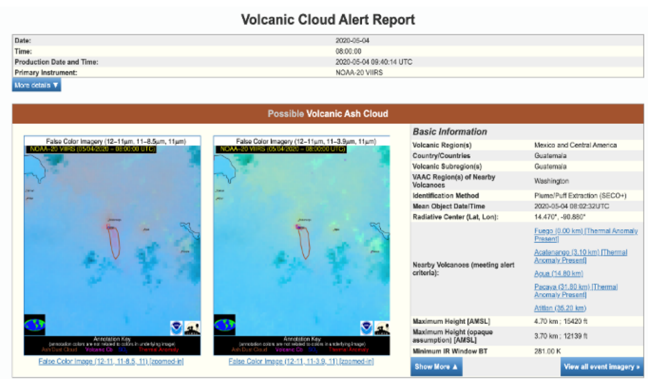
After initial detection, feature tracking largely drives volcanic cloud detection. Feature tracking also allows VOLCAT to distinguish between new and existing volcanic clouds, which are essential bookkeeping information for higher order applications such as alerting and dispersion and transport forecasting. The VOLCAT feature-tracking algorithm utilizes a multi-dimensional nearest neighbor-based approach that is driven by a “k-dimensional tree” procedure. The tracking approach aims to identify “matching” pixels in two consecutive satellite images. Cloud movement is accounted for as the nearest neighbor algorithms seeks to find local matches that minimize differences in the same spectral metrics that allow human experts to visually track features in satellite imagery. The algorithm tracks volcanic clouds using a single geostationary satellite or a combination of geostationary and low earth orbit satellites. The geo/low tracking option allows volcanic clouds that are more readily detectable in one type of satellite data to be located in another type.



A complex volcanic cloud from Raikoke volcano (Kuril Islands, Russia) is automatically detected in VIIRS data by transferring the geostationary satellite based feature tracking to VIIRS via a multi-dimensional nearest neighbor approach.

Volcanic Cloud Alerting



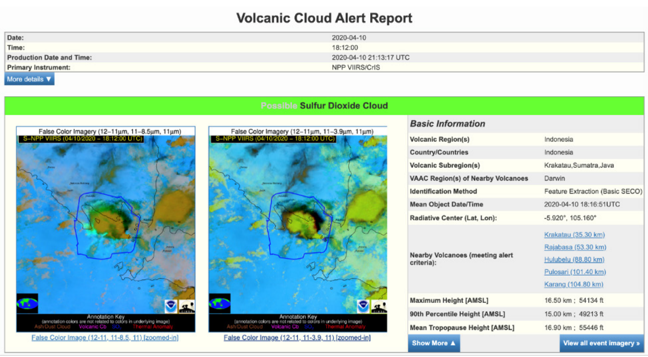


Another reason feature tracking is critical is that it helps in managing alerts. Feature tracking enables the detection of new events and consequently for VAACs and other key users to receive alerts of these detections. The alerts are disseminated as email or text messages

Above is an example of a text message volcanic alert. The message contains a hyperlink, which, when clicked upon opens a webpage containing an alert report, with pertinent information including the event location, the name of the most likely source volcano, and pertinent imagery.

Volcanic SO_2 Alerting

Low Earth orbit satellites, such as NOAA-20 and Suomi NPP, provide important measurements for volcanic SO_2 detection. Hyperspectral ultraviolet measurements have been commonly used for SO_2 loading retrievals. Now supplemental loading measurements and estimates of the SO_2 layer altitude from infrared sounders are adding significant value to real-time monitoring of volcanic emissions as well as climatological analyses. These methods leverage the relative simplicity of infrared radiative transfer calculations, providing fast and accurate physics-based retrievals of loading and altitude. Hyman and Pavolonis (2020) provide details of a retrieval method which uses the Cross-track Infrared Sounder (CrIS) on the JPSS series of satellites. The method, which is based on a modified trace-gas retrieval provides probabilistic estimates of SO_2 loading and altitude. The CrIS algorithm is used to generate SO_2 emission alerts like the one shown below. SO_2 alerts are an important complement to ash alerts, as some volcanic clouds are dominated by ash encased in and/or obscured by ice, but SO_2 remains detectable from CrIS.

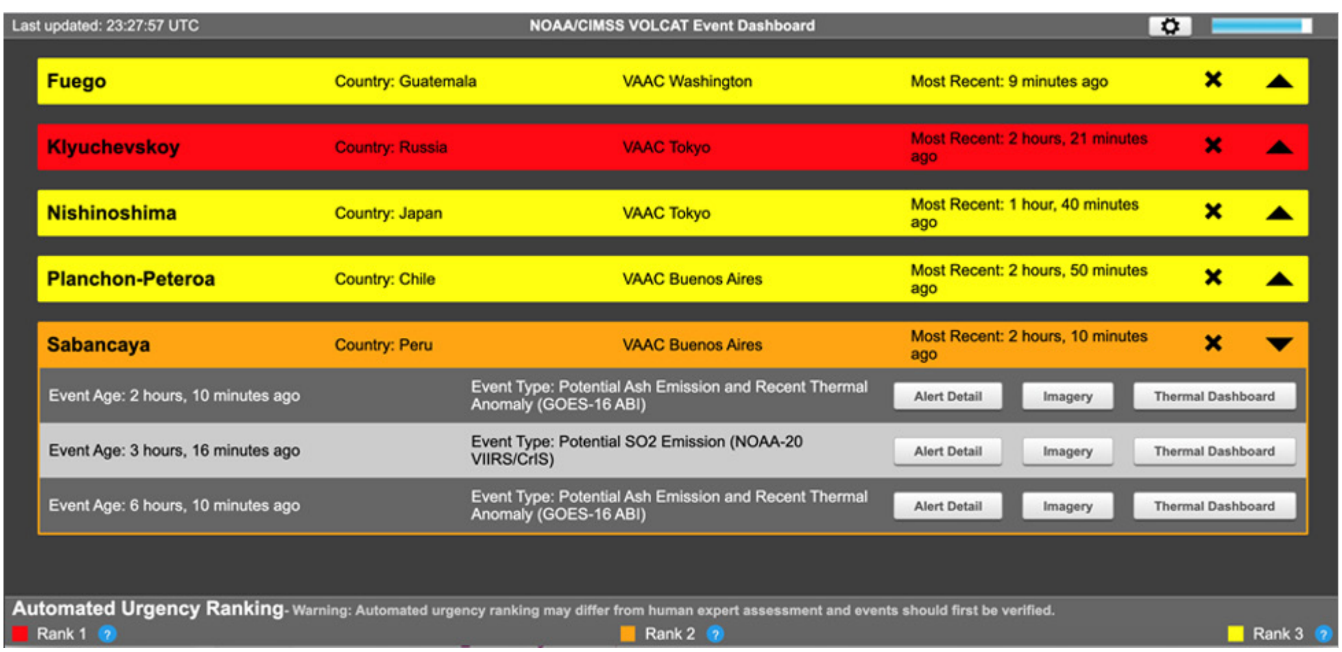


VOLCAT EVENT DASHBOARD

Text and email messages provide an important means to convey alerts. But, there is no guarantee that the intended recipients will receive the alerts in the time frame that they really need to see them. A web-based volcanic event dashboard, which automatically updates every 30 seconds in real time (image above) addresses this issue. The dashboard allows users to customize their dashboards using volcano and time filters. Events are generated using all GEO and LEO satellites processed by VOLCAT. Users can also remove events from their board display. As illustrated in the image below, each event can be expanded to access supporting information such as alert reports, imagery, and thermal time series of volcano radiative power (VRP) as derived from all observations gathered during LEO and GEO overpasses.

SUMMARY AND FUTURE WORK

Volcanic ash is a major aviation hazard and disruptor to global aviation. NOAA operates two Volcanic Ash Advisory Centers (VAACs), which are staffed at all times. The VAACs issue Volcanic Ash Advisories (VAAs) to aviation in accordance with International Civil Aviation Organization (ICAO) International Airways Volcano Watch (IAVW) standards. Currently, VAAs consist of simple latitude/longitude polygons with a valid altitude range denoting where ash is thought to be present at the time of VAA issuance, as well as 6, 12, and 18 hours in the future. The VOLcanic Cloud Analysis Toolkit (VOLCAT), which was developed by NOAA and UW-CIMSS, supports VAAC operations by providing volcanic event alerts and information on important volcanic



cloud (ash and sulfur dioxide) properties. At NOAA-operated VAACs, VAA forecasts are largely based on the NOAA HYSPLIT model. Aviation stakeholders have emphasized the need for more quantitative VAAs (including probabilistic characterization) that can support quantitative risk management systems, as the risk to aircraft is now known to depend upon ash concentration and cumulative exposure time. As a result, changes to IAVW requirements will begin to go into effect as early as 2023. The new IAVW requirements specify that VAACs provide 3-dimensional ash concentration forecast data at regular time intervals. Further, additional requirements on uncertainty characterization and volcanic sulfur dioxide (SO_2) will likely be added in later years. The provision of high quality quantitative VAAs is an enormous challenge that requires sophisticated observational and modeling capabilities that are not yet fully in place. We will continue to develop the JPSS based capabilities needed to meet future IAVW requirements by continuing the work of the JPSS Volcanic Hazards Initiative, which brings together product developers and key representatives from the user community (VAACs, Volcano Observatories, and NWP). In targeting the changing IAVW, we propose to enhance existing volcanic cloud monitoring tools within VOLCAT to provide high-fidelity probabilistic ash and SO_2 products based on JPSS and other data. Additionally, we will continue to collaborate with NOAA/OAR/ARL to enable propagation of these probabilistically characterized volcanic clouds through HYSPLIT forecasts in support of the new IAVW forecast requirements. The proposed developments are anticipated to become operational, within the NESDIS Common Cloud Framework, as part of the VOLCAT Data Agnostic Common Services (DACS) project. Under the Volcanic Hazards Initiative, products are developed in close collaboration with end users, where quarterly meetings, a training/demonstration blog, near-real time product evaluations, and user feedback surveys are used to ensure robust communication. The proposed sophisticated capabilities, developed to benefit the aviation community, will also significantly aid weather and climate applications. ❖

Story Source

Materials obtained from JPSS May Science Seminar titled “The JPSS Volcanic Hazard Initiative.”

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HIGH-RESOLUTION PREDICTIONS OF SMOKE, VISIBILITY AND SMOKE-WEATHER INTERACTIONS USING THE SATELLITE FIRE RADIATIVE POWER DATA IN THE OPERATIONAL RAP/ HRRR-SMOKE MODELS

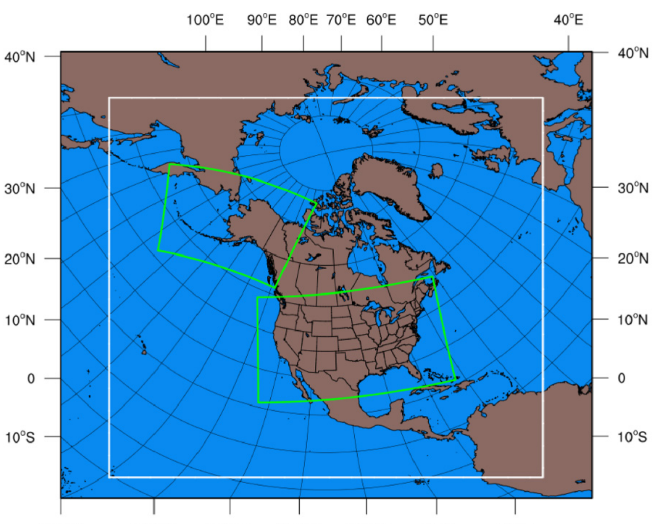
Satellite Image of the Woolsey fire (California), November, 2018. Inset. A plume of smoke fills the sky as residents evacuate along the Pacific Coast Highway (PCH). Inset image by Cyclonebiskit - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=74297315

Wildland fires release greenhouse gases, soot and other gaseous and aerosol species into the atmosphere. These emissions pollute the atmosphere with significant harmful impacts on public health. Large concentrations of smoke emissions are especially harmful to public health, and more so for those with preexisting respiratory conditions such as asthma and chronic bronchitis. Beyond adverse health effects, wildfire smoke can also reduce visibility. Severely reduced visibility conditions are a major concern as they can lead to closures, serious or even fatal incidents, and even cause severe economic losses. In addition, smoke can have significant effects on weather in some parts of the world.

Weather models are among the tools operational forecasters use to predict reduced visibility conditions from events such as fog and heavy precipitation. Wildfire smoke can travel hundreds or thousands of miles away from its source, cross geographical boundaries, and affect atmospheric conditions globally. Consequently, timely and accurate forecasts of the amount and movement of smoke emitted by wildfires has become increasingly important. Data from satellite instruments such as the Visible Infrared Imaging Radiometer Suite (VIIRS) on-board the Suomi NPP and NOAA-20 satellites, which are fed into NOAA's operational High-Resolution Rapid Refresh-Smoke (HRRR-Smoke) model help provide insight on where the greatest or least concentration of smoke will be, out to 48 hours. HRRR-Smoke is rapidly improving our ability to forecast where smoke is as well as where it is headed. But more than that, it is the the first NWP model in the U.S. to include the impacts of wildland fire smoke on weather and visibility diagnostics.

A CLEARER PICTURE

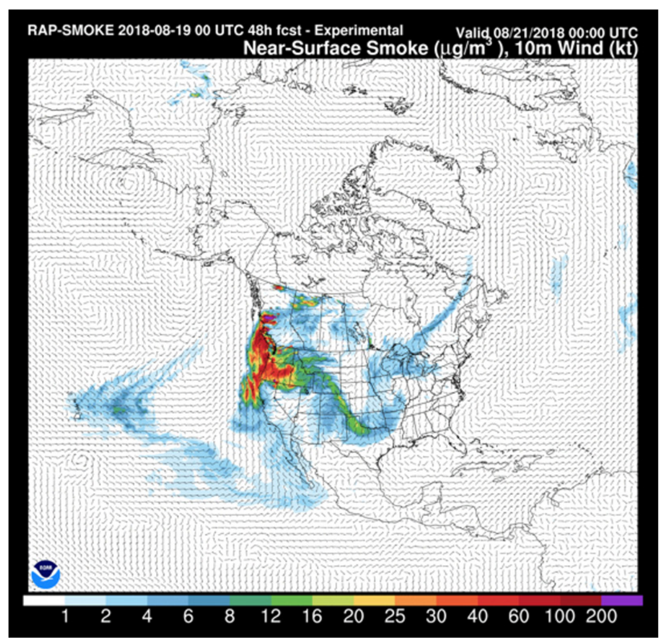
The Rapid Refresh (RAP) is a NOAA's continental-scale numerical weather prediction (NWP) system with 13.5 km horizontal grid spacing. The model runs operationally at the National Centers for Environmental Prediction (NCEP). The hourly-updated RAP is used in concert with the HRRR model, which is also an hourly-updated operational model running at the NCEP, but at much higher spatial resolution (3km). There are two HRRR domains, the first one covers the contiguous U.S. (CONUS), and the second one covers Alaska as shown in the following figure. Both of the HRRR models use the initial and boundary conditions for meteorological variables from the RAP model in real time. The 3km horizontal grid spacing of HRRR enables simulation of mesoscale flows and smoke dispersion over complex terrain, which is crucial for the western U.S., where most of the wildfires occur. Together the RAP/HRRR-Smoke models forecast smoke distributions on local, regional and continental scales.



Operational weather forecast models at NCEP: RAP - 13km resolution (white), HRRR, 3km resolution (green). https://rapidrefresh.noaa.gov/

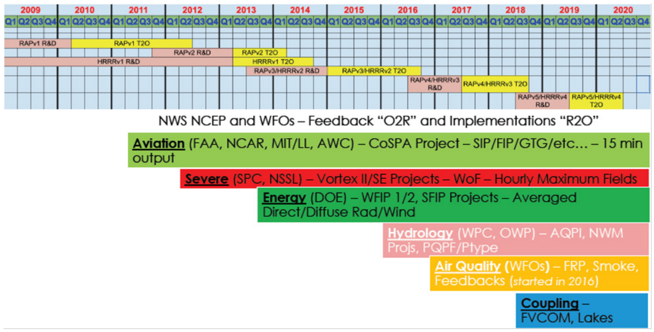
Initially the RAP and HRRR-Smoke models were developed as experimental extensions of the RAP/HRRR weather forecasting systems developed by NOAA Earth System Research Laboratories (ESRL) Global Systems Laboratory (GSL). The novelty of the RAP/HRRR-Smoke is that it implements an additional tracer (smoke) from wildland fires in a coupled modeling framework, which is simulated by ingesting the fire radiative power (FRP) data from four satellite instruments – the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20, and the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra and Aqua. The FRP data are also used to simulate the fire plume rise by RAP/HRRR-Smoke.

RAP-Smoke's area of coverage is huge -- the entire North American domain, Central America, and parts of South America and Russia. One of its biggest advantages is the ability to capture smoke emitted and transported over great distances, e.g. from Canada and Mexico to CONUS as shown in one of the RAP-Smoke forecasts (see the Figure below). The RAP-Smoke smoke forecast products are displayed at: https://rapidrefresh.noaa.gov/RAPsmoke/.



THE EVOLUTION OF RAP/HRRR

The RAP and HRRR models have been running experimentally for weather forecasting at the NOAA/ESRL/GSL since 2009. The RAP was implemented operationally at NCEP in 2012 and the HRRR in 2014 (NOAA Technical Memorandum, 2020). The models allow scientists to better capture rapid meteorological changes in the environment (Benjamin et al., 2016). These



models are designed to enable forecasts of high-impact weather events. Over the years, improvements in the models have widened their contributions in weather-sensitive sectors such as aviation, energy and hydrology. The experimental HRRR-Smoke model was first started running in real time in summer 2016. Later the RAP-Smoke and HRRR-Smoke-Alaska models were developed for experimental smoke forecasting. After extensive testing all 3 models (RAP-Smoke, HRRR-Smoke for CONUS and Alaska) became operational at NOAA/NCEP on December 2, 2020.

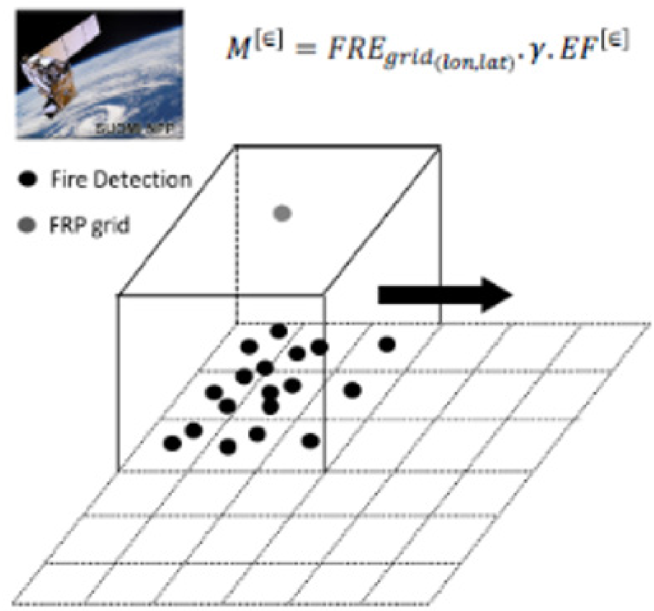
As posted on its website (https://rapidrefresh.noaa.gov/hrrr/), the first version of the HRRR was implemented at NCEP on 30 September 2014. The second version, which includes smoke and began running in real-time for CONUS, followed almost two years later on 23 August 2016. The third version followed suit on 12 July 2018, along with RAP-Smoke the same year.

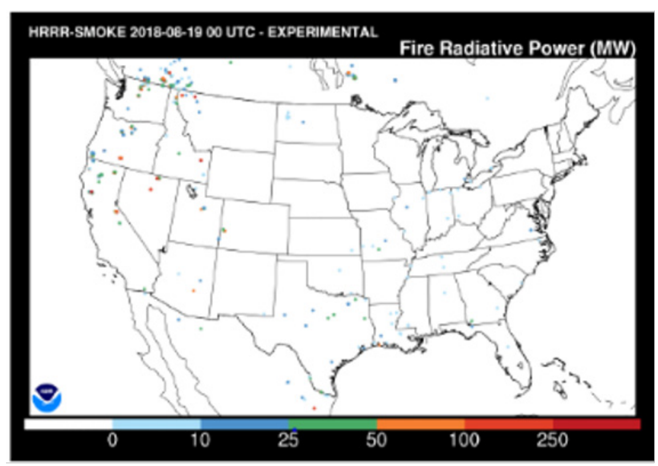
WHAT DOES HRRR-SMOKE DO?

HRRR-Smoke forecasts weather, 3D concentrations of smoke and surface visibility out to 18 hours, but up to 48 hours 4 times a day (00, 06, 12 and 18Z). Every hour, a new HRRR-Smoke forecast starts by ingesting the satellite FRP data obtained within 24 hours prior to the forecast start time. The hourly refresh cycle allows ingesting the latest fire detections into the model. This helps to forecast smoke from "new" fires. And with each new forecast meteorological data are assimilated into the models. RAP-Smoke provides boundary conditions to the HRRR-Smoke model, both for the smoke and meteorological data. The hourly refresh cycle enables better forecasts of events such as storms and other severe weather developments, and now, smoke.

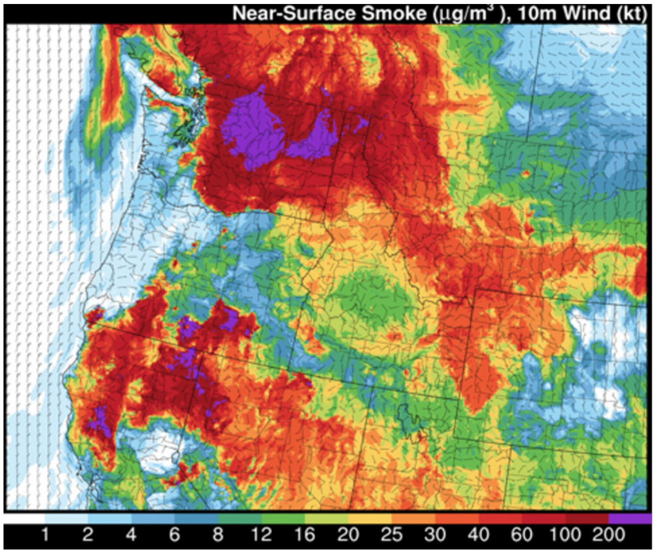
SATELLITE FRP DATA

Below is an illustration of the clustering procedure, which performs a combination of all detected fires—according to the model spatial resolution and grid configuration—from VIIRS onboard Suomi NPP and NOAA-20 and MODIS onboard NASA's Terra and Aqua satellites. Fire Radiative Energy (FRE) is estimated by multiplying the FRP and the assumed duration of the fire. Emission and other combustion parameters are applied to the FRE to calculate the total burned biomass and how much smoke or particulate matter a given fire emits.





The VIIRS and MODIS FRP values are collected and then aggregated to the model grid's 3x3 km grid cells as illustrated above by the satellite fire detection HRRR-Smoke CONUS grid map for August 19, 2018.

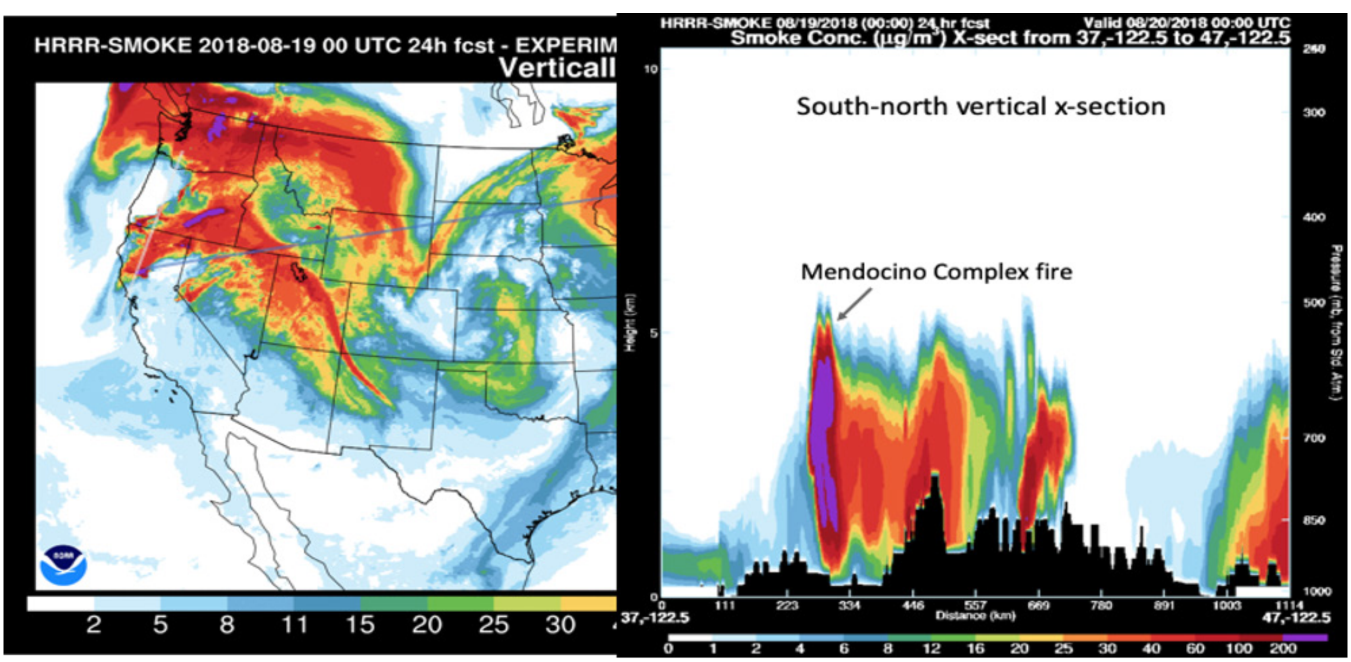


After ingesting the satellite FRP data and estimating the wildland fire emissions the HRRR-Smoke model does simulate the advection and vertical mixing of smoke, and its removal processes. The figure above shows the distribution of near-surface smoke and surface wind over the northwestern U.S., simulated by HRRR-Smoke for 12 UTC August 19th, 2018. The plot shows very high (~100-200 in micrograms per cubic meters (ug/m3)) smoke concentrations over the northwestern U.S. due to the multiple wildfires burning in the western U.S. and Canada during summer 2018. Such smoke and wind forecast plots for different parts of the CONUS domain are provided on the HRRR-Smoke web-page (https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/).

PLUME RISE

An additional advantage of HRRR-Smoke is that it includes an inline plume rise parameterization based on the satellite FRP data. Plume rise is an important variable. If fire emissions are injected above the planetary boundary layer, then smoke can travel to long distances before it is removed in the atmosphere. Also, the height of the fire injection plays an important role in forecasting the impact of smoke on radiation, cloudiness and air quality in large distances downwind of the fires. To date, only a small number of operational and quasi-operational smoke forecast models use satellite FRP data to estimate wildfire emissions and plume rise. Some atmospheric models do not consider fire plume rise parameterization. Moreover, many of these models are run at relatively coarser spatial resolutions.

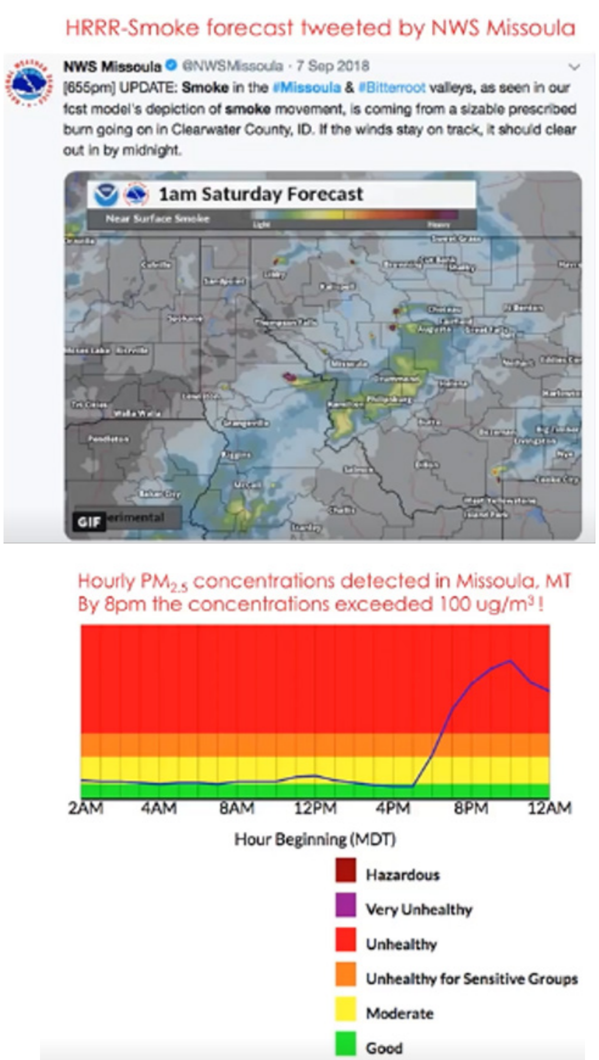
The plot on the left panel below shows the forecasted vertically integrated smoke distribution over the western and central U.S. for 00UTC August 20th, 2018. The plot on the right panel shows the distribution of smoke concentrations in the south-north direction between 37-47 degrees latitude range at the 122.5W longitude, and vertically. The vertical cross-section plot demonstrates several fire plumes reaching ~5km above sea level, whereas the densest smoke plume is from the Mendocino complex fire. These plots show how significantly the vertical distribution of smoke varies



depending on the intensity of wildfires, which is parameterized by using the satellite FRP data.

WHO IS USING HRRR-SMOKE?

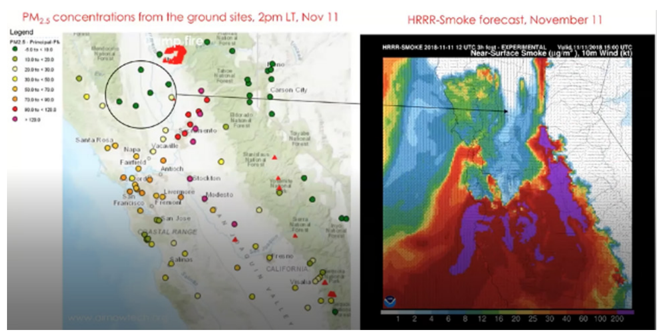
The weather forecasters, incident meteorologists, air quality forecasters and public use the HRRR-Smoke forecasts. An incident on 7 September, 2018 helps illustrate the importance of ingesting the short latency VIIRS data into the models, and starting a new forecast every hour. On this day, heavy smoke rolled into and blanketed Missoula, Montana. Most immediately to blame for this was a sizable prescribed burn in Clearwater County, Idaho. The particulate matter (PM2.5) concentrations reached ~100 ug/m3 in Missoula, MT. The local NWS office in Missoula tweeted (see below) the HRRR-Smoke forecast, which showed the smoke plume from the prescribed fire affecting the town.



Unanticipated smoke impacts from a prescribed fire, September 7, 2018

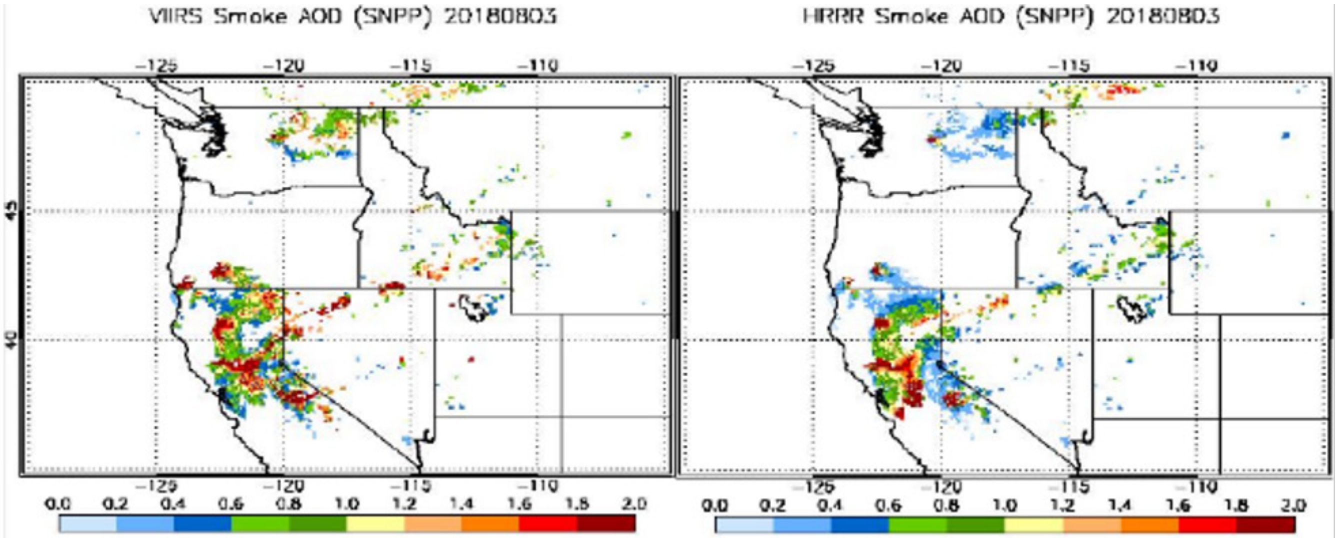
THE CAMP FIRE CASE

During the devastating Camp fire (started on November 8, 2018) the Bay area and other parts of California were covered by dense smoke. The very unhealthy levels of PM2.5 affected millions of people in the region for about two weeks. During this time experimental HRRR-Smoke forecast products were used widely by the forecasters and public. The image in the left panel below shows PM2.5 concentrations from the AirNow network for November 11. The image in the right panel shows near-surface smoke distributions forecasted by HRRR-Smoke. The distribution of smoke around the Bay area and Central Valley was forecasted by the model reasonably well.



MODEL VALIDATION

The HRRR-Smoke forecasts are evaluated by various in-situ and remote sensing atmospheric measurements. Another VIIRS data aerosol optical depth (AOD) data provides an additional source of verification as it is not assimilated in the HRRR-Smoke. Since the model neither includes anthropogenic aerosol emissions, nor simulates the aerosol composition and chemical aging, it is not straightforward to accurately calculate the optical properties of the aerosols in the model. Nevertheless the VIIRS AOD data provides a great dataset to qualitatively verify the smoke forecasts over large regions. The plots on the next page show the VIIRS AOD observations and forecasted smoke AOD by HRRR-Smoke for August 3, 2018 over the western U.S. The plots show how well the model captures the smoke transport from the wildfires in California, Oregon, Washington and other regions.



SUMMARY AND FUTURE WORK

Some consequences of smoke in the atmosphere include polluted skies, changed weather, and reduced visibility. Smoke emissions pollute the atmosphere with significant harmful impacts on public health. Reduced visibility conditions are a major concern as they can lead to closures, serious or even fatal incidents, and even cause severe economic losses. Data from satellite instruments such as the VIIRS feeds NOAA's HRRR-Smoke, which in addition to helping forecasters diagnoze where smoke is, its amount as well as where it is headed, is the first NWP model in the U.S. to include the impacts of wildland fire smoke on weather and visibility diagnostics. Knowing the amount of wildfire smoke that travels through the atmosphere is also critical for visibility—an important forecast product which is widely used in the weather community for application in areas such as ground transportation and aviation.

In addition to the polar orbiting satellite data, high frequency satellite FRP data from the Geostationary Operational Environmental Satellite (GOES) –16 and -17 will be ingested to HRRR-Smoke. In the future the smoke simulation schemes from HRRR-Smoke will be transitioned to NOAA's new weather forecast model based on the Finite Volume Cubed-Sphere dynamical core (FV3) dynamical core. The VIIRS AOD data will be assimilated into the model to improve the forecast accuracy.

Story Source

Materials obtained from JPSS June Science Seminar titled "High-Resolution Predictions of Smoke, Visibility and Smoke-Weather Interactions Using the Satellite Fire Radiative Power Data in the RAP/HRRR-Smoke Models"

Acknowledgement

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The information in this article is based, in part, on the June 3, 2020 JPSS science seminar presented by Ravan Ahmadov, Research Scientist at CIRES, University of Colorado, and affiliated with NOAA/ESRL Global Systems Laboratory, Earth Prediction Advancement Division. The article also features the research efforts and contributions by E. James[1,2], G. Grell[2], C. Alexander[2], S. Benjamin[2], J. Hamilton[1,2], B. Jamison[1,2], S. Albers[7,2], K. Wong[7,2], S. Freitas[3], G. Pereira[4], I. Csiszar[5], M. Tsidulko[8], S. McKeen[1,2], M.Bela[1,2], S. Kondragunta[5], C. Xu[8], G, NASA MODIS team, NOAA/NCEP, FIREX-AQ team.

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ASSIMILATING JPSS SEA SURFACE TEMPERATURE AND SURFACE CHLOROPHYLL-A ESTIMATES INTO CALIFORNIA CURRENT OCEAN MODELS

The information in this article is based, in part, on the July 20, 2020 JPSS science seminar presented by Chris Edwards, Professor of Ocean Sciences, University of California–Santa Cruz. In collaboration with J. Paul Mattern, Patrick Drake, Andy Moore (UCSC), and Mike Jacox (NOAA SWFSC).

Why should we care about the ocean? National Ocean Service. https://oceanservice.noaa.gov/news/june14/30days.html

NOAA MISSION

To understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources.

Marine ecosystems are an essential part of the Earth system. They are complex environments where physical (e.g., temperature) and biogeochemical (e.g., nutrient, plankton) components interact constantly and drive ecosystem changes. Photosynthesis by phytoplankton and bacteria is responsible for a significant fraction of oxygen gas on the planet, and this primary (biological) production supports diverse marine animals from microscopic zooplankton to the largest baleen whales. Photosynthesis also fixes carbon dioxide from near surface waters but originating in the atmosphere into organic material, and the sinking of dead organisms transfers this carbon to great depths, contributing to the carbon cycle on Earth. Marine ecosystems provide food and raw materials such as medicines to human populations, and they support the economy through various activities including jobs, recreation, and transportation.

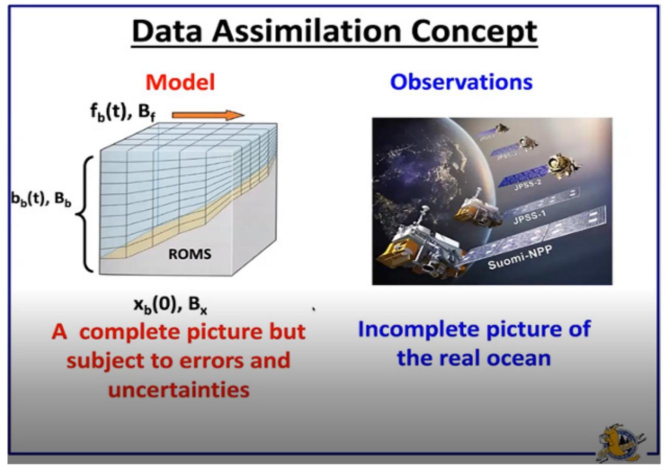
Satellites offer an outstanding platform to observe the marine ecosystem. Some instruments record light transmission from the ocean that can be related to chlorophyll concentrations of phytoplankton in the upper ocean. These observations provide information on the general state of the marine ecosystem. Computer models also simulate the marine ecosystem by solving equations that represent the interactions between different components of the system. Models provide information on what can happen. "Satellites provide observations to constrain models and ensure fidelity to nature, while models, which are routinely run at fine spatial resolutions (10 km or less) with output available at daily or even higher temporal frequencies, help fill data gaps." Moreover, models "resolve the full three-dimensional ocean including subsurface conditions that are missed by satellites and seldom observed in situ," says Chris Edwards, a professor at the University of California at Santa Cruz (UCSC), who studies problems in ocean circulation, biogeochemical processes, data assimilation, and marine connectivity mostly focused on the California Current. Edwards also notes that both observations and models include errors and uncertainty in their representation.

Ecosystem monitoring means measuring over time to provide information on ecosystem change. Consequently, it is imperative that "Accurate, reliable environmental data at temporal and spatial resolutions that are consistent with ecosystem dynamics and management objectives provide consistent, reliable biogeochemical data products for end users in fisheries and elsewhere," says Edwards. In addition to helping measure physical, chemical, and/or biological variables in ecosystems, and providing a way to observe changes, Edwards says that the use of satellite data along with ocean models (e.g., in ocean reanalyses) can help stakeholders, such as fisheries managers, develop a better understanding of coastal ecosystems.

It is imperative that consistent, reliable biogeochemical data products are developed and maintained for end users in fisheries and elsewhere.

Christopher A. Edwards (UCSC)

Data assimilation is used by ocean modelers to improve upon model predictions. It refers to formal methods to constrain ocean models using available observations (e.g., collected by satellites



Both ocean models and observations include a variety of unavoidable uncertainties.

or in situ platforms). The procedure is the same as is used to improve weather forecasts. A model run is performed, discrepancies between this output and available observations are calculated, and adjustments to control variables (e.g., the model conditions at the start of the run) are made such that the revised model run with adjusted variables, now referred to as a state estimate, is closer to the observations than the first prediction. Data assimilation methods are widely used in oceanography and meteorology across a range of scales (global, basin-wide, regional, and coastal).

While the practice of assimilating physical fields such as ocean currents and sea surface height is quite mature and routinely performed by many research groups and operational centers, the field of biogeochemical data assimilation, which focuses on the marine ecosystem, is relatively new and rapidly growing. One challenge to the practice is model complexity. Choosing the number of organisms or organism types to represent and the mathematical rules that govern their interactions is less constrained than in physical systems. In addition, observations of the marine ecosystem are very limited. Satellites observe only near surface waters, and operational centers generally estimate the total chlorophyll-a for all phytoplankton together rather than accounting for its diversity. Despite these issues, the field is improving, with updated models, new algorithms to convert satellite measurements into a few phytoplankton types, and new autonomous platforms to measure other ecosystem components (e.g., nutrients, oxygen, and pH).

Ocean state estimates have a number of potential uses. They can be used to improve forecasts or to produce more accurate representations of past conditions and, in turn, of changes to the natural system over time. Ocean state estimates in coastal waters can be used to predict how drifting elements move and disperse (e.g., for oil spills, search and rescue, or microplastics), and to estimate probabilities of occurrence of harmful algal blooms. Recently, species distribution models that predict probabilities of occurrence for a variety of fisheries of management interest have been developed, making use of the ocean state estimates in coastal waters. Such information can potentially inform groups such as NOAA's Integrated Ecosystem Assessments.

Models are imperfect and subject to errors and uncertainties in things like initial conditions, lateral boundary conditions and forcing at the surface. Meanwhile, disparate observations from various sources including space borne assets such as JPSS satellites and in situ assets such as gliders, Argo floats, ships, high frequency (HF) radar, etc., come with their own idiosyncrasies and uncertainties, which in consequence limits their capabilities. Furthermore, in situ observations generally tend to be coarser in space and/or time compared to space borne assets. For example, satellites, for the most part, observe the upper ocean, and in situ sensors provide direct characterization, but they are not uniformly distributed in space or time and are quite sparse compared to space borne assets. The main idea behind data assimilation is to incorporate these imperfect pieces of information to produce a better posterior estimate of the ocean state than one had in advance of the data assimilation. Over the last decade, the UCSC Ocean Modeling Group has pioneered development of a particular approach to biogeochemical data assimilation. It uses an advanced method, called 4-dimensional variational data assimilation, that applies model dynamics to connect observations collected at one time to the control variables at a different time. This procedure is like fitting a line to data, but in a very large dimensional system ($\sim 10^6 - 10^7$ dimensions) instead of two (for the slope and intercept). The UCSC group has adapted traditional methods developed for physical variables to work well with biogeochemical variables, whose distributions are highly skewed and better represented by lognormal rather than Gaussian statistics. This was the upshot of a talk which was delivered in July 2020, as part of the Joint Polar Satellite System (JPSS) monthly science seminar series, in which Edwards explained the significance of JPSS derived Sea Surface Temperature (SST) and chlorophyll-a (chl-a) estimates in a regional ocean model of the California Current. Edwards is part of a research team that develops products for the fishery managers from NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), and the Pacific Fisheries Management Council (PFMC), as well as the fishing community and other stakeholders along the U.S. west coast. His team's portfolio includes products using state-of-the-art satellite data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument currently flying on the Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellite missions.

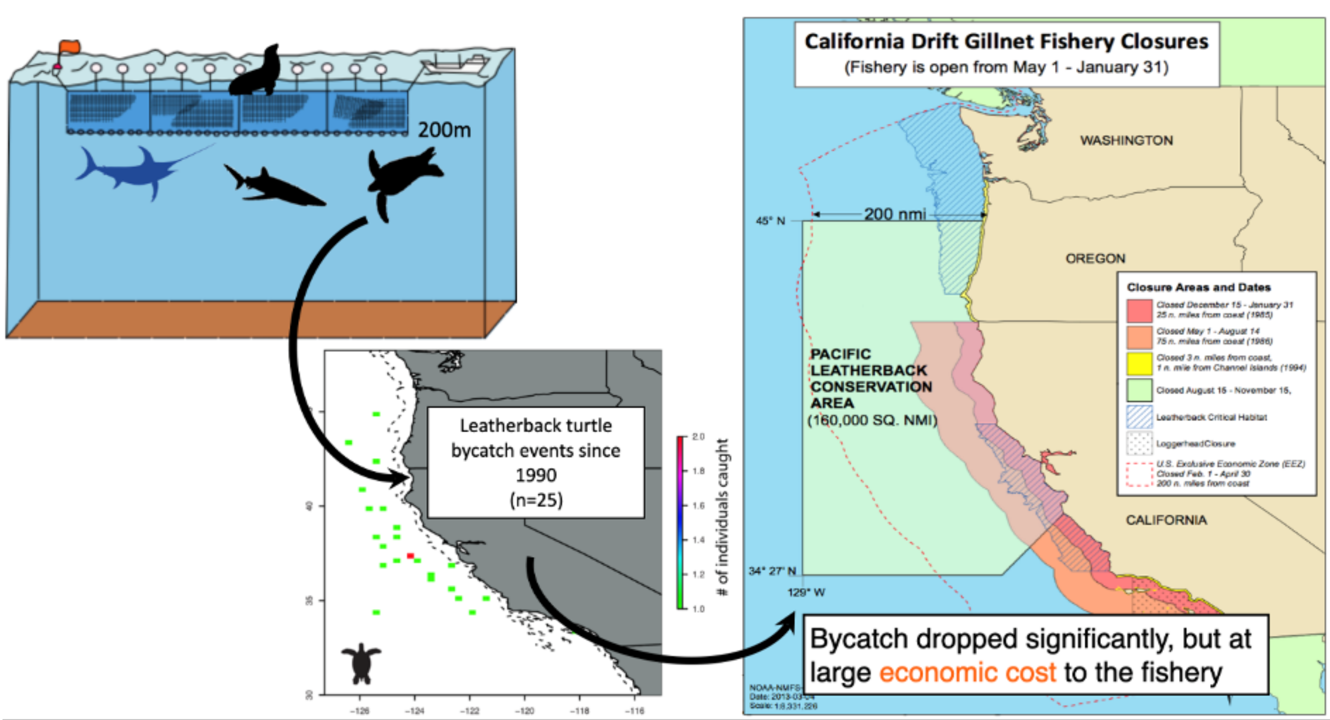
FISHERIES USE OF OCEAN STATE ESTIMATES

"Variability and long-term change in physical and biogeochemical ocean conditions can dramatically impact the productivity and distribution of marine species, including commercially fished species and protected species," says Research scientist Michael Jacox of NOAA Fisheries' Southwest Fisheries Science Center. "As a result, there is now a widely recognized need to include environmental information in fisheries management decisions that aim to promote resilience of both marine ecosystems and the communities and economies they support," says Jacox. In this pursuit of climate-informed fisheries management, there are several important roles for ocean state estimates.

Managers of fisheries and other living marine resources are increasingly considering the marine ecosystem holistically rather than treating individual species independently. For the U.S. west coast, NOAA's California Current Integrated Ecosystem Assessment (IEA) provides this holistic perspective in Ecosystem Status Reports that are delivered annually to the Pacific Fisheries Management Council. These reports include indicators that characterize bottom-up forcing of the ecosystem (particularly upwelling indices), which are derived from UCSC's historical and near-real-time ocean state estimates (Jacox et al. 2018).

To determine how species of interest respond to their physical or biogeochemical environment, historical ocean state estimates can be matched with metrics of species productivity or distribution, obtained from data sources including fisheries catch and scientific surveys. The availability of accurate, high-resolution, gap-free environmental information is essential for identifying empirical ecological relationships, which then form the basis for models used to predict species abundance or distribution when they cannot be observed directly. For example, UCSC's state estimates have been used to model the productivity and/or distribution of many ecologically and commercially important species, including fished species such as sardine, anchovy, petrale sole, sablefish, albacore tuna, and swordfish (Muhling et al. 2019, Tolimieri et al. 2018, Haltuch et al. 2020, Brodie et al. 2018, Scales et al. 2017) as well as bycatch species including cetaceans, sharks, sea lions, and turtles (Abrahms et al. 2019, Becker et al. 2019, Brodie et al. 2018, Welch et al. 2019a).

Once ecological relationships have been established that characterize species responses to their environment, there are a number of ways this information can be used in fisheries management. Improved estimates of fishery recruitment (i.e., the number of fish entering the fishery) are valuable for developing catch advisories and making sure that catch limits are adjusted to account for climate-driven changes in fish stocks. Another key management consideration is the interaction of fisheries with non-target (bycatch) species such as marine mammals and turtles. For example, in the California Drift Gillnet Fishery, which targets a healthy swordfish stock, bycatch species such as turtles and marine mammals can be captured accidentally in fishing nets (see



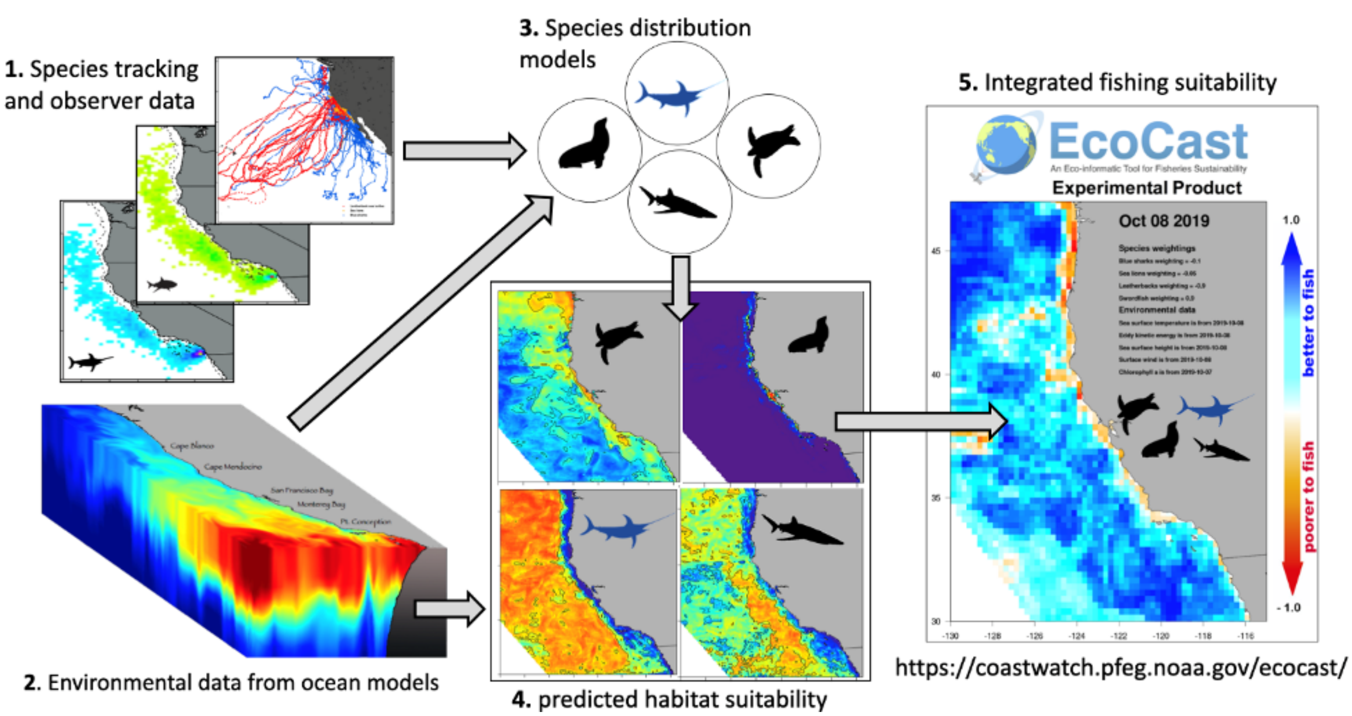
The California drift gillnet fishery uses nets that hang in the water column to target swordfish (blue) but can also catch non-target species including sea lions, sharks, and turtles (black). Due in particular to occasional catch of endangered leatherback turtles, the fishery is heavily regulated with static closure areas to reduce bycatch.

image on the previous page). Large seasonal closures enacted to prevent these interactions have helped mitigate the bycatch problem, but at a large economic cost to the fishery. In a proposed alternative approach, termed dynamic ocean management, statistical models that predict species distributions based on ocean state estimates are then used to develop a fishing suitability habitat map to help guide fishing activity (Hazen et al. 2018, Welch et al. 2019b). In a similar application, UCSC's ocean state estimates are being used to predict blue whale habitat for the WhaleWatch tool (https://coastwatch.pfeg.noaa.gov/projects/whalewatch2/), which is designed to reduce blue whale ship strikes off the California coast.

Finally, each of the management actions outlined above would benefit from additional lead time for decision making, which has motivated a push for similar tools based on ocean forecasts rather than historical or real-time information (Jacox et al. 2020). The UCSC team, working with NOAA fisheries, is developing high resolution seasonal (1-12 month) forecasts to inform fisheries management off the U.S. west coast. In this application, regional data assimilation is used to provide the best possible initial forecast state; due to the ocean's relatively long memory, an accurate initial state can impart forecast skill for months.

PHYSICAL VS. BIOGEOCHEMICAL ASSIMILATION

Approaches to ocean data assimilation vary widely. Some, like OI and 3D-Var, perform analysis on instantaneous as opposed to time-varying ocean fields (Edwards et al., 2015). To approximate the ocean as static, data is collected into bins of short duration, like one day, and treated as coincident in time. As a result, assimilation takes place in a series of short (e.g., 1-day) cycles with rapid updates. In contrast, the 4D-Var method, which includes time as the fourth dimension, allows data to be incorporated at times corresponding to each observation. The method explicitly includes model dynamics to relate data collected at different times to the assimilation-adjusted variables (e.g., initial conditions at the start of a cycle). As a result, observations spanning a longer time-window (e.g., 4- or 8-days) can be simultaneously assimilated into a more constrained estimate with fewer jumps when one cycle ends and another begins.



The EcoCast tool provides an example of ocean state estimate use in dynamic ocean management. The ocean state estimate (2) is combined with species distribution data (1) to formulate species distribution models that predict distributions based on their environmental associations. Those models can then be used to predict distributions of multiple species in near real time (4) and combine them to produce a map that characterizes areas as better or poorer to fish based on the likelihood of catching target and non-target species (5).

The assimilation of physical models in oceanography has matured to the point that observations are used routinely in regional and global models around the world (Moore et al., 2013, Chassignet et al., 2009). However, the assimilation of ecosystem models is fairly new and is still lagging relative to physical models.

Two ecosystem models are used predominantly at USCS. One, referred to as NPZD (Powell et al., 2006), is a simple model which simulates the interactions of the four components: nutrients (N), phytoplankton (P), zooplankton (Z) and detritus (D). It is used primarily to develop tools and to understand methodology. The other, the North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO; Kishi et al., 2007), is considered the workhorse for really understanding processes; it is more complex, constructed with multiple phytoplankton and zooplankton components, as well as other nutrients and organic matter. This model is better suited for the California Current where diatoms (relatively larger eukaryotic microalgae) tend to dominate closer to the shore where wind-driven upwelling supplies plentiful nutrients, and much smaller phytoplankton live in the less nutrient rich waters offshore.

All models are imperfect approximations of nature. With physical models, these approximations lead to errors in ocean currents, temperature, and salinity. Because ecosystem models are coupled to physical models (e.g., ocean currents transport biological constituents), errors in physical fields are then combined with additional approximations for biological processes in ecosystem models, leading to errors in the representation of the biological standing stock and other biogoechemical components. Ecosystem models can be coupled to data assimilative physical model output, which leads to some improvements, for example in spatial correlations between modeled and observed biological fields. But discrepancies between modeled and observed biology still exist due to decoupling of physical and biological fields at data assimilation cycle updates (Raghukumar et al., 2015). As a result, we apply our methodology to the fully coupled system, in which both physical and biological data constrain both the physical and biological output (Song et al., 2016, Mattern et al., 2017).

IMPLEMENTATION USING JPSS DATA

The JPSS Proving Ground and Risk Reduction (PGRR) program works with user communities to see if JPSS data has an impact on their mission activities. The UCSC ocean modeling group has long been focused on producing physical and biogeochemical ocean state estimates in the waters off the U.S. west coast using a 4-dimensional variational (4D-Var) approach. Satellite derived observations of sea surface height, sea surface temperature, sea surface salinity, HF radar estimates of surface currents, and a host of in situ data are used to constrain the physical fields, and satellite chlorophyll is the main data source for biogeochemical model assimilation. With support from the Central and Northern California Ocean Observing System (CeNCOOS—a NOAA IOOS Regional Association), the UCSC model runs quasi-operationally in 4-day assimilation cycles with output served publicly on UCSC and CeNCOOS servers.

The group has recently been investigating the utility of VIIRS surface chlorophyll data specifically on their operations. In the California Current, the spatial coverage of VIIRS chlorophyll data meaningfully exceeds that of the previously used MODIS AQUA platform. Data availability for the VIIRS near real-time product is approximately double that obtained from MODIS AQUA in the study region, but this rapid release information also exhibits a modest bias relative to the more science-quality, delayed-time product. This latter product still has about 50% improved coverage relative to MODIS and thus represents a significant advance in data availability to constrain biogeochemical estimates. The coupled physical, biogeochemical 4D-Var assimilation system functions well with the new data, with statistically similar performance. The procedure effectively eliminates model bias over the California Current domain and reduces the standard deviation of the log-space error to roughly one half that of the model with no assimilation.

OBSERVATION IMPACTS

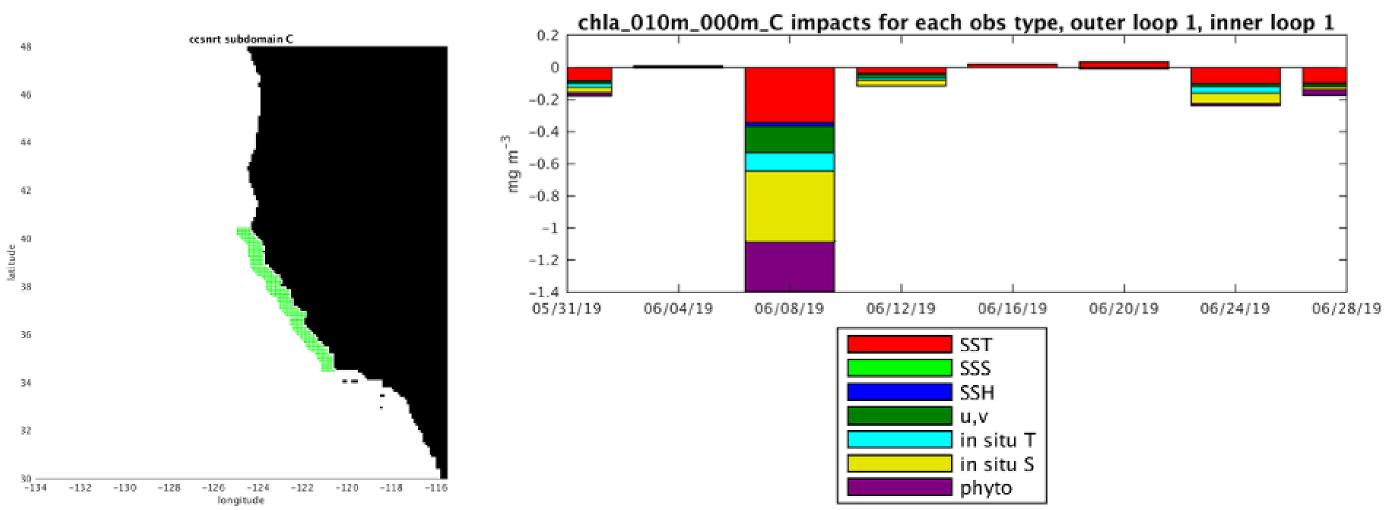
At the end of the day you'd like to know how much impact the observation is having on quantities of interest. One specific benefit of the 4D-Var approach is that it allows precise calculation of each and every observation's quantitative contribution to a modeled change in a metric of interest resulting from assimilation. These quantified changes to the model estimates are referred to as observation impacts (Moore et al., 2017). For the biogeochemical system, a natural metric is the near surface chlorophyl biomass in the near-shore region that is influenced strongly by coastal upwelling. With thousands of observations of different types contributing to each assimilation cycle, it is convenient to sum contributions from each platform to get an idea of each platform's overall impact.

When looking at the observation impacts of VIIRS Chl on this nearshore near-surface Chl metric, VIIRS accounts for close to 20% of the change to the chosen metric with physical observations accounting for rest. But the story, Edwards says, is more complex. A related impact study is referred to as an Observing System Simulation Experiment, or OSSE, in which data is included and withheld from assimilation in two separate calculations. Here, an OSSE-like study is made in which surface chlorophyll (SChl) observations are assimilated or not at all. VIIRS SChl assimilation induces a much larger change than suggested by the impact calculation alone, with more than a 50% reduction in model bias and about a 25% reduction in error standard deviation as opposed to an increase in error when not included. Both of these analyses show a substantial impact of VIIRS Schl data on biogeochemical ocean state estimates in the California Current System.

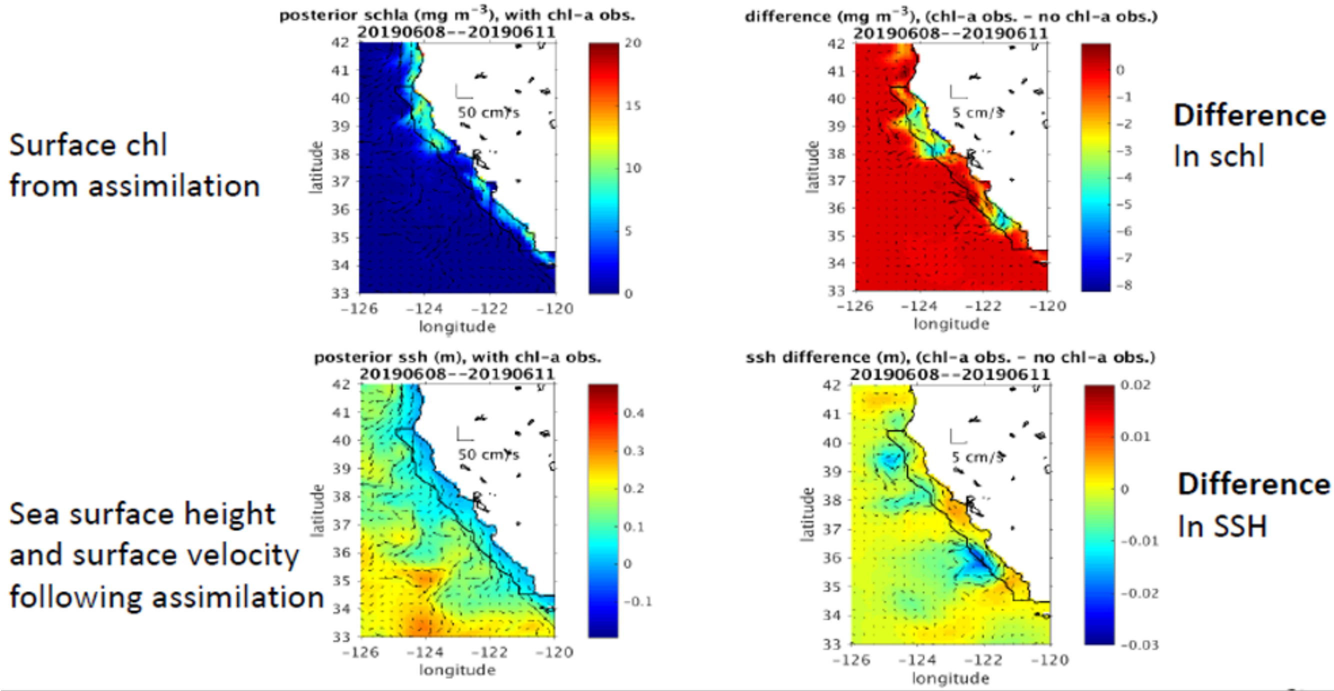
An added benefit of the UCSC coupled assimilation procedure is that the information provided by the VIIRS surface chlorophyll also impacts how the physical state estimate is obtained. The physics turns out slightly better as well. When the new data, in this case VIIRS SChl is added, it alters the physical state that the assimilation system determines through its efforts to reduce the overall misfit between the model and data. While chlorophyll concentrations naturally change due to biological processes, like primary production and zooplankton grazing, they also act like a dye or tracer that is moved by ocean currents. Thus, observations of the Schl distribution over a 4-day assimilation cycle provide valuable information on those currents and the VIIRS SChl also improves the physical state estimate.

SUMMARY AND FUTURE WORK

The assimilation of data into physical models in oceanography is mature and widely used operationally in regional and global models around the world. However, the assimilation of data into ecosystem models remains fairly new and still lags relative to the physical systems.



An example spatial domain near the central CA coast over which near surface chlorophyll biomass is averaged along with the resulting observation impacts from assimilation, organized by observation type and assimilation cycle.



Example of posterior estimates for surface chlorophyll, sea surface height (SSH), and ocean currents following and due to assimilation. SChl data results in small changes in physical properties that locally benefit the physical state estimate.

Data assimilation offers a rigorous way to incorporate disparate pieces of information from varied sources including space borne assets such as JPSS satellites and in situ assets such as gliders, Argo floats, and ships to produce better estimates of the ocean state than one has in the absence of data assimilation.

Several satellite derived observations including sea surface temperature and sea surface height, HF radar estimates of surface currents, as well as in situ data, are used by the UCSC Ocean Modeling Group to constrain modeled physical fields, and satellite observations of surface chlorophyll are the main data source for biogeochemical model assimilation. This group has produced estimates of the physical and biogeochemical ocean state for stakeholders such as NOAA Fisheries. These estimates have been used to aid management decisions that aim to promote resilience of both marine ecosystems and the communities and economies they support. They are also used to help model the productivity and/or distribution of many ecologically and commercially important fished species such as albacore tuna and swordfish, and bycatch species such as sea lions and turtles. ❖

Story Source

Materials obtained from JPSS July Science Seminar titled “Assimilating JPSS SST and surface chl-a estimates into an ocean model of the California Current.”

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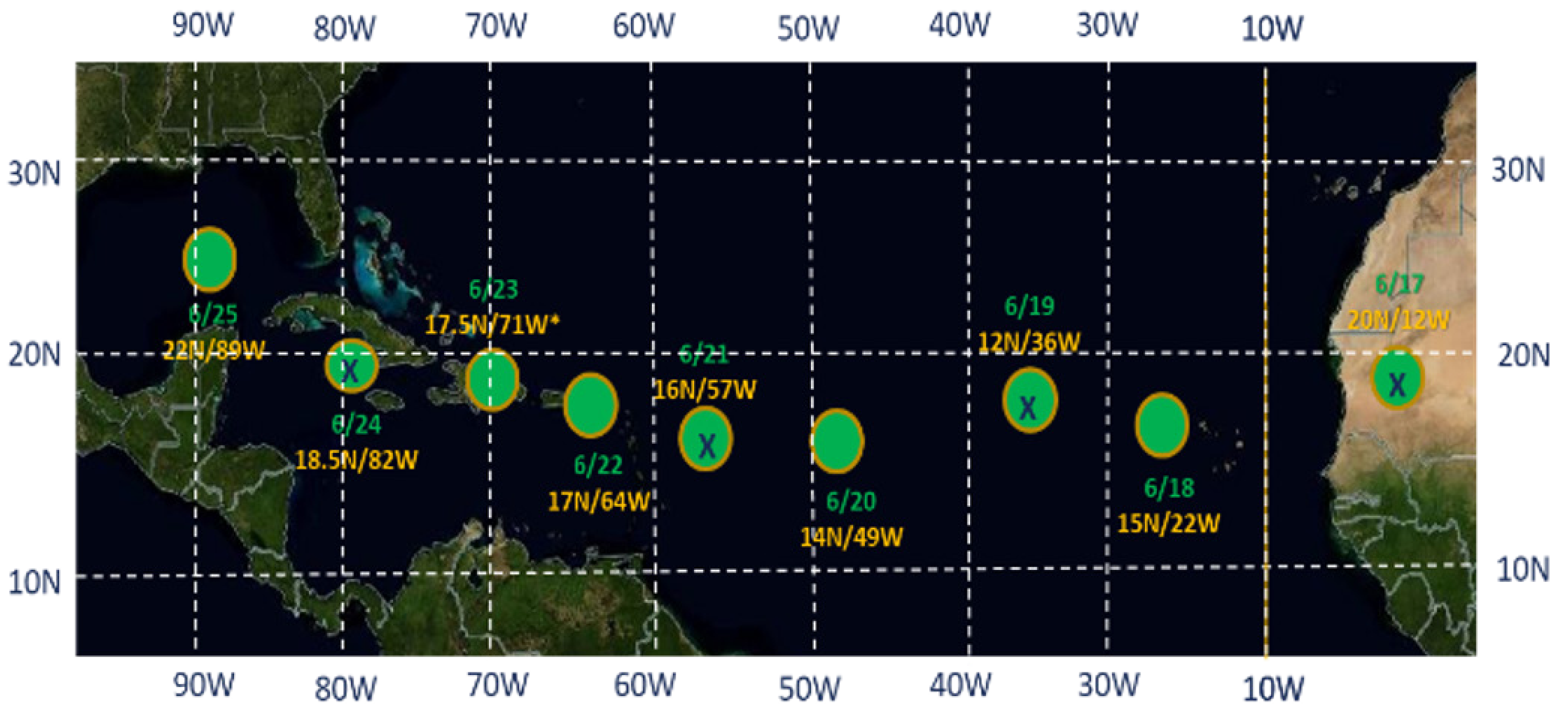
THE APPLICATION OF NUCAPS IN RECENT SAHARAN AIR LAYER AND WILDFIRE EVENTS

The information in this article is based, in part, on the August 31, 2020 JPSS science seminar presented by Arunas P. Kuciauskas, Naval Research Laboratory (NRL), Marine Meteorology Division, Monterey, CA. It includes contributions from Anthony Reale, Emily Berndt, Rebekah Ismaili, and Nick Nalli.



On June 17, 2020, a massive plume of dust was uplifted off the northwest coast of Africa and into the atmosphere to begin a transatlantic journey towards the Americas. The elevated mass, better known as the Saharan Air Layer (SAL), is an extremely hot/dry elevated air mass, which originates from the Saharan Desert in North Africa mostly during the late spring season through early fall. In the U.S., the SAL is most prevalent during the summertime months. It is also accompanied by Low Level Easterly winds at levels typically below 10,000 feet which helps to transport the SAL westward through the tropical Atlantic Ocean.

The SAL is laden with minerals such as phosphorus, iron, and nitrates, which fertilize many regions of the world including the Amazon rainforest. The SAL also produces colorful and vivid sunrise and sunset displays. Additionally, according to NOAA, the SAL's sand deposits have over several millennia helped build beaches across the Caribbean. But, the SAL also has an adverse effect on the environment. During its formation, the SAL usually kicks up enormous quantities desert dust high into the atmosphere, and as it propagates westward, the associated dust pollutes the air at both global and regional scales. The airborne dust also presents serious health risks particularly to vulnerable groups like children, the elderly, and people with respiratory and cardiac conditions who can suffer profound and permanent adverse health effects. SAL events are also likely to cause poor visibility conditions and increase the risk of accidents, including local aircraft operations. Understanding the environmental and dynamical characteristics of the SAL is thus critical, given the impacts on human health, safety and the environment.

FOR MORE ON THE POTENTIAL HEALTH IMPACTS, REFER TO THE AGENCY THAT TRACKS AIR QUALITY FOR YOUR STATE OR TO THE CDC AT CDC.GOV.

REMOTE SENSING CAPABILITIES

Space-borne instruments including polar orbiting satellites such as NOAA-20, the NOAA/NASA Suomi-National Polar-orbiting partnership (Suomi NPP), and geostationary satellites such as GOES-16 carry instruments which have visible, infrared and microwave channels that can be used to track temperatures, moisture, winds, and suspended dust in and around SALs. These satellites provide imagery and data that can be used to detect SAL signatures within elevated dry and warm layers of the atmosphere; this allows forecasters and research scientists the ability to detect, monitor and study SAL events.

DUST CLOUD HUNTER

A team of scientists—including Mr. Arunas Kuciauskas at the United States Naval Research Laboratory (NRL) in Monterey California—was primed and ready to track the SAL event. Mr. Kuciauskas is a researcher whose NRL team has been providing the global military and civilian operational communities with near real time image products that also includes world class global and regional model output. Since the mid 1990's, Mr. Kuciauskas has played roles in satellite image processing, aerosol algorithm and model development, as well as training both METOC (U.S. military forecasters) and civilian communities in weather satellites. Mr. Kuciauskas is also a Principle Investigator (PI) in several NOAA proving grounds efforts including the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) program where he has been responsible for demonstrating the capabilities of the NOAA-Unique Combined Atmospheric Processing System (NUCAPS), in weather impact phenomenology's such as outbreaks of SAL and Pyrocumulonimbus (PyroCb) events.The NUCAPS algorithm derives vertical profiles of temperature, humidity, trace gases, and cloud properties from infrared and microwave sounders including the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) onboard the Suomi NPP and NOAA-20 satellites, as well as from sounding instruments onboard the Meteorological Operational (MetOp) A/B/C satellites from the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT).

NUCAPS soundings augment the less frequent conventional radiosonde launches, which typically occur at 00 and 12 UTC (and occasionally at 18 UTC). Moreover, these sites are often hundreds of kilometers apart over land and are nonexistent over water. NUCAPS soundings also observe a much larger portion of the environment compared to a single radiosonde launch or reconnaissance aircraft dropsondes. In SAL work, Arunas has been actively involved in promoting NUCAPS as an invaluable resource in profiling the vertical aspects of SAL, especially within the open waters of the tropical Atlantic basin. This is particularly true for the greater Caribbean region where, "NUCAPS collocation with radiosondes typically provide the gap filing that is necessary for forecasters such as those in San Juan, Puerto Rico, to be able to predict the intensity and the vertical profiling they need, says Arunas.

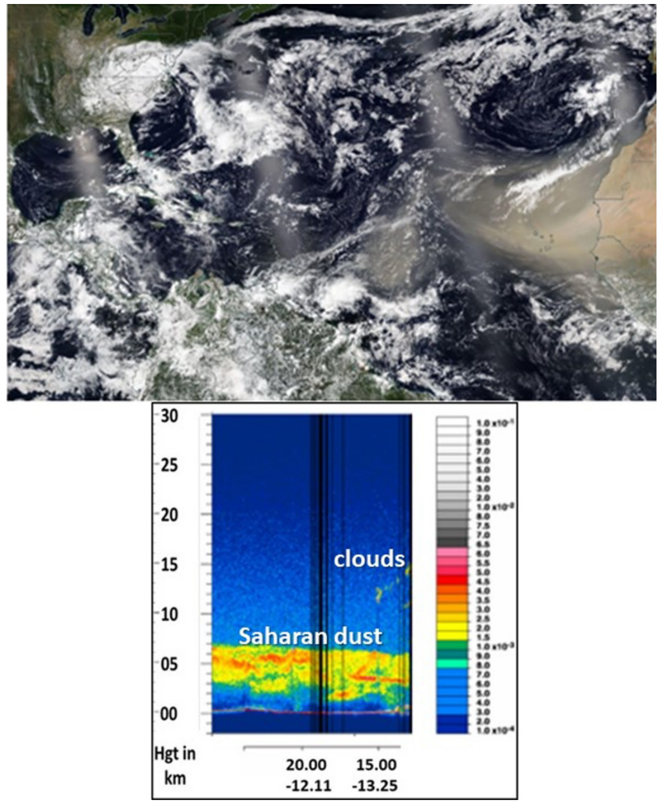
The following section describes the use, strengths and weaknesses of NUCAPS performance during an epic semi-centennial SAL outbreak during the middle of June in the North Tropical Atlantic, and Pyrocumulonimbus (PyroCb) eruptions that occurred in August 2020 in Northern California.

CASE STUDY ONE

June 17–27, 2020, Epic SAL outbreak

On June 17th, several instruments including the NOAA-20 and NASA Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellites captured the massive dust plume's movement over the Atlantic Ocean. In the images below, the upper panel shows a true color image of the dust plume being transported westward off the Northwestern African coast and across the tropical

Atlantic basin toward the Caribbean. The lower panel is a vertical profile of the plume from the CALIPSO Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument, which shows a seven kilometer height structure of the SAL dust. This height indicates that the plume was quite high up and deep within the atmosphere.

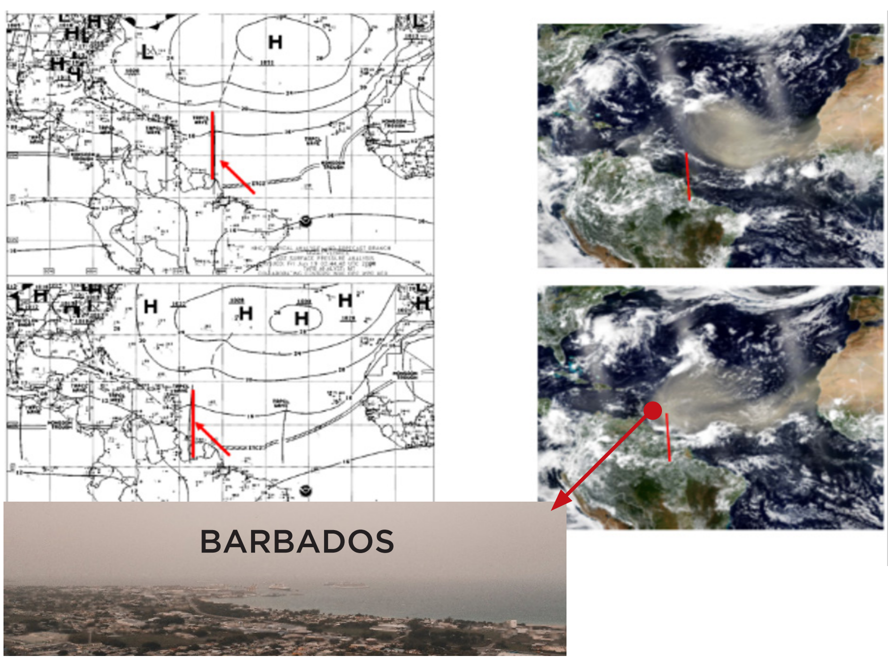


To properly view this product, let's go through some of the Caliop basics. The higher aerosol content is visualized within the warmer colors (yellow, orange, and red shades). The Saharan dust plume typically resides within the low levels, below 8,000 km, as shown. In this case, the top of the Saharan dust reached 7 km. The bottom is not so smooth, reflecting the complexity of the dust distribution and interaction just above the surface. The elevated faint warm color pattern within the right side of the image (above 10 km) are comprised of clouds. The value pairs at the bottom of this figure are the positions of the CALIPSO overpass in latitude and longitude coordinates.

MORE ON THE 2020 SAL: THE JOURNEY CONTINUES

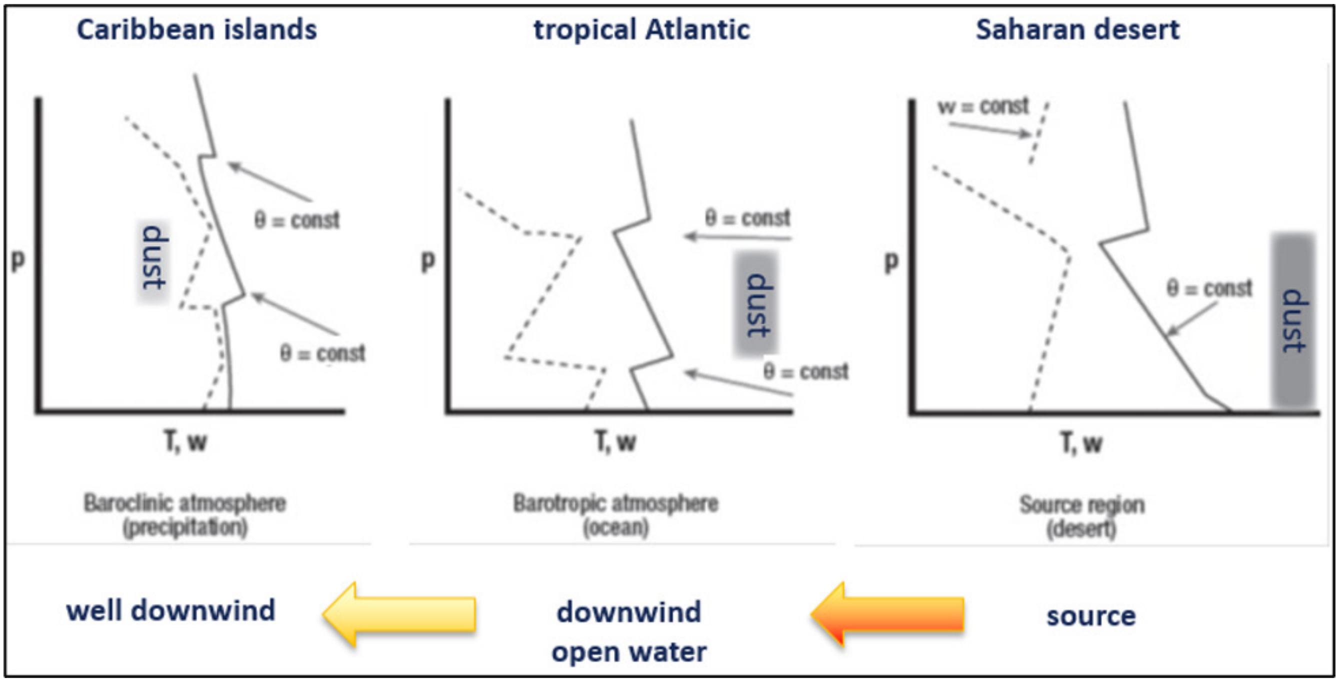
Midstream: 19 and 20, June

The figures on the left below show the analyzed easterly wave that is occurring out ahead of the SAL. The red line translates with the SAL products shown on the right. The lower figures show the SAL progression toward the northern parts of South America as it moves across into the Caribbean. Beneath the figures is a photo of the Saharan dust plume sweeping over Barbados and potentially impacting visibility in the region as well as individuals that are highly sensitive to exposure.



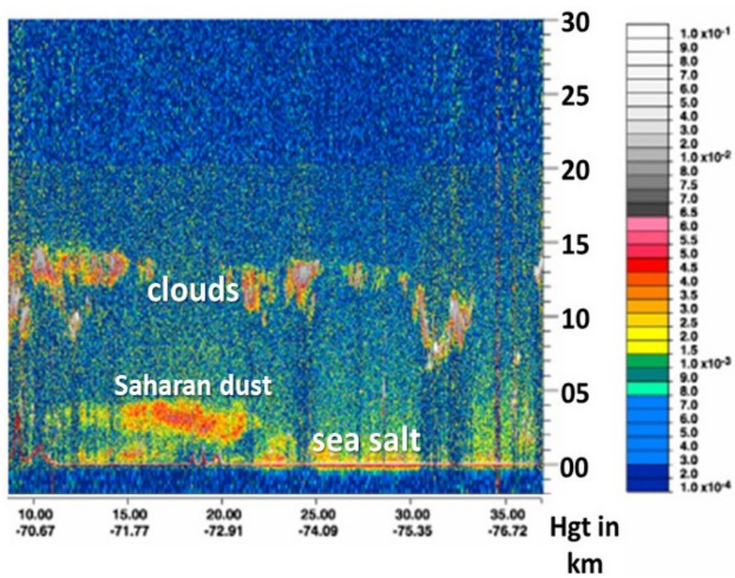
Far downstream: 21 and 22, June

Intuitively, as dust plumes move farther west over and into the Atlantic Ocean, they lose their dust source and eventually they are expected to become diffuse (or weakened), and descend to the surface, thanks to gravity. “But this is not the case with SAL,” says Kuciauskas; the Saharan dust circulates within the SAL and can continue for thousands of kilometers, impacting the Caribbean, South America, the Gulf of Mexico, and Southern U.S. But to get to that explanation, let’s start with the atmospheric dynamics. In the figure below, one can see the temperature lines in solid black and the dewpoint temperature lines in dashed black. Starting on this right, the dust is shown from the surface to that point in the atmosphere (as high as say 18,000 feet), where the temperature stops cooling off and actually rises for a short time until it reaches another temperature drop.

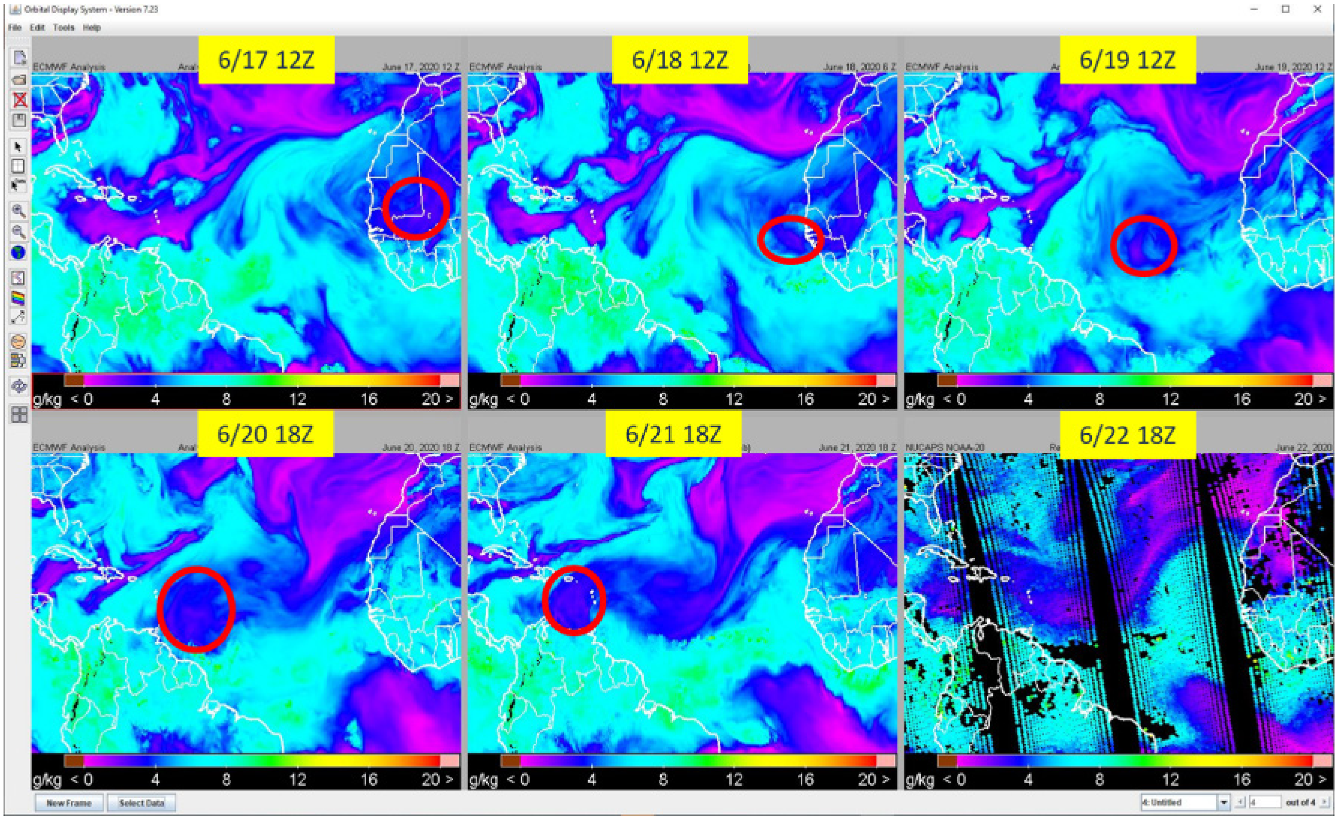


Figures courtesy of Toby Carlson, Open Atmos. Sci. J., 10 2016. Right side location over Western Sahara. Center; elevated Saharan mixed layer sounding for a location over the tropical Atlantic Ocean, showing the dust layer overlying the shallow marine boundary layer. Shading suggests relative concentration of dust in the SAL. Middle sounding: As it’s being transported across the Atlantic, the SAL base has been decoupled thus lifted but the top remains unaffected, as shown by the arrows. Left side; the layers in the center figure have experienced dynamic lifting at all levels upon encountering a baroclinic region—a zone of deep horizontal temperature gradient. Results in extensive saturation at various levels and a decreased SAL depth due to condensation.

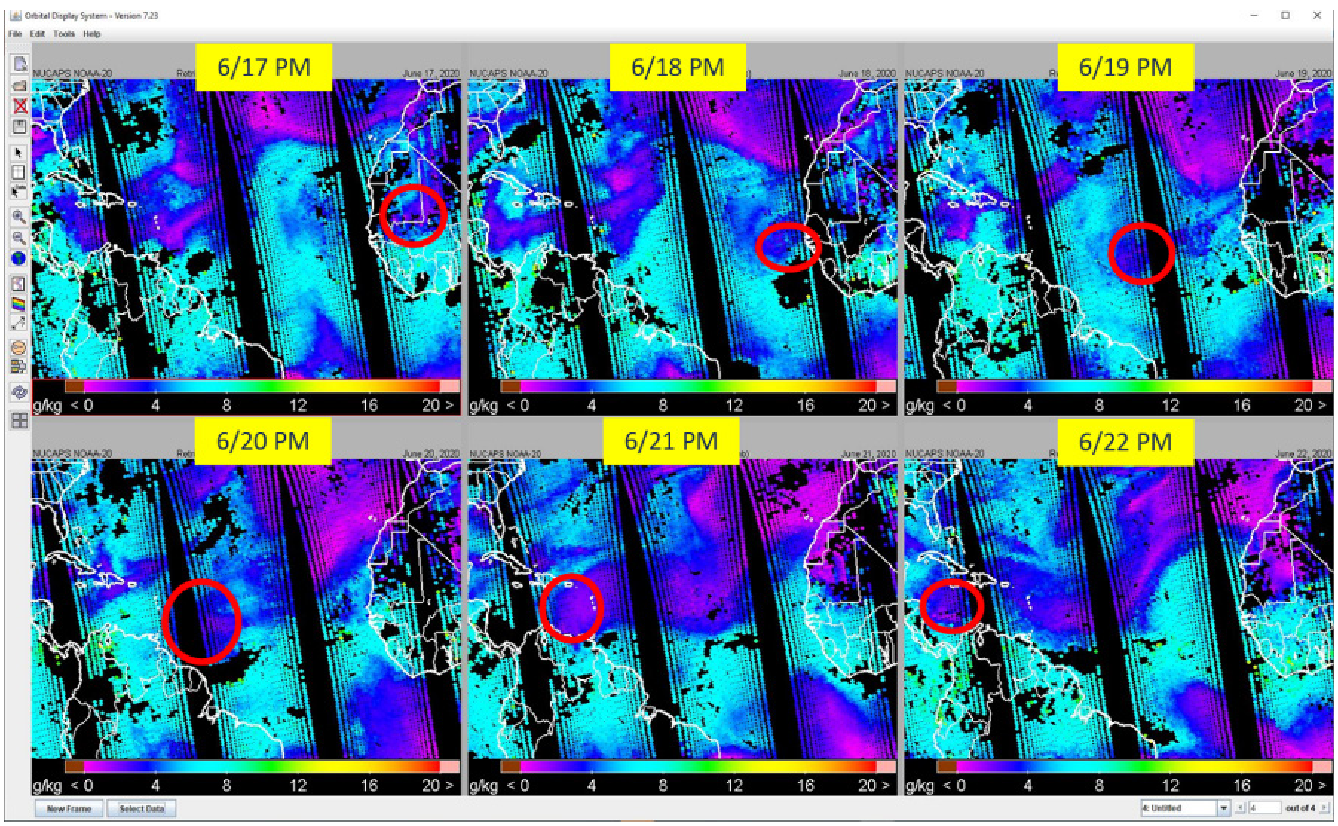
In contrast to the first Caliop image above, the Saharan dust dropped down from 7 km on June 17 down to 5 km on June 22 as shown in this figure. The SAL dust is shown to be decoupled from the surface. The annotated “sea salt” region exists around the surface region and is not part of the SAL structure.



The European Centre for Medium-Range Weather Forecasts, or ECMWF, NOAA-20 NUCAPS also tracked the atmospheric water vapor content associated with the SAL's movement from June 17 to the 22. Both analyses showed almost identical moisture patterns, where the red circles (see figures below) of the SAL dryness were very similar in shape and position.



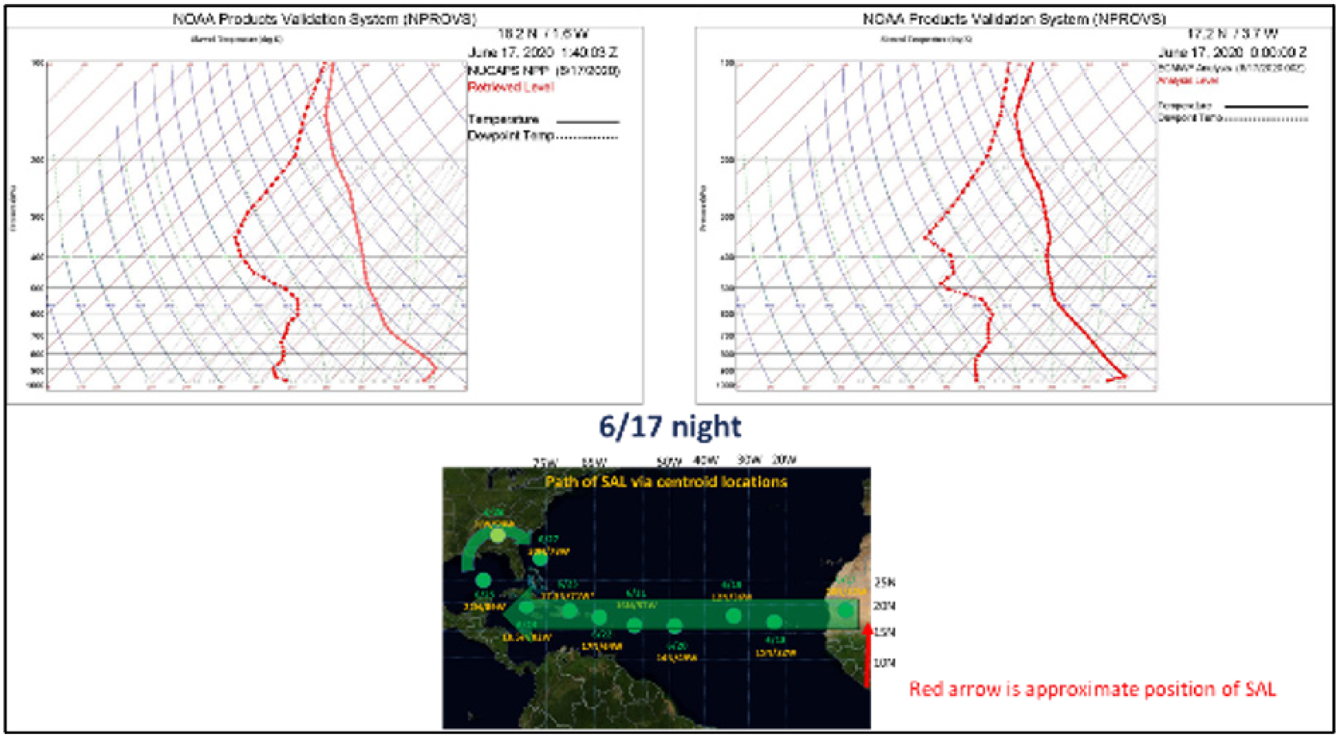
ECMWF Analysis of WV at 695 hPa. Red ovals indicate the position of the SAL on each of the days.



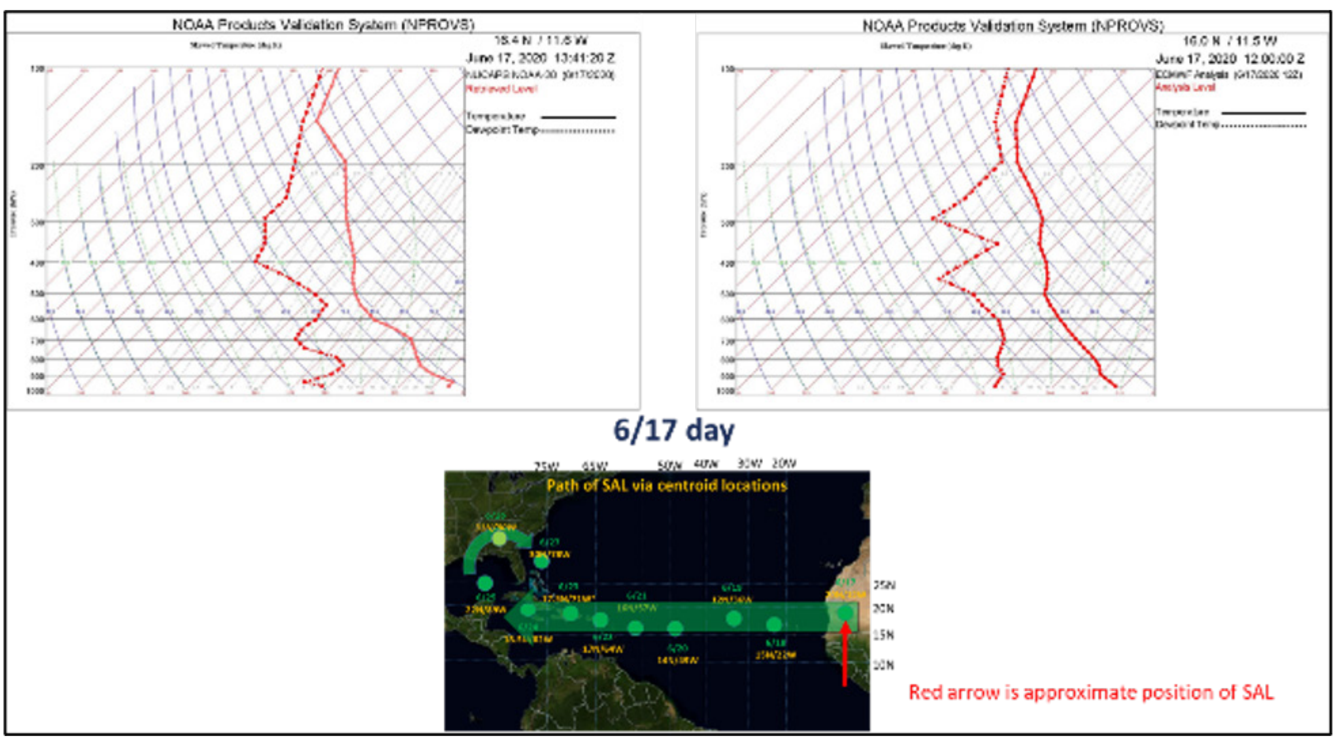
NOAA-20 NUCAPS Retrieved WV at 695 mb. Red ovals indicate the position of the SAL on each of the days.

A SAL'S JOURNEY: AS TOLD BY ATMOSPHERIC SOUNDINGS

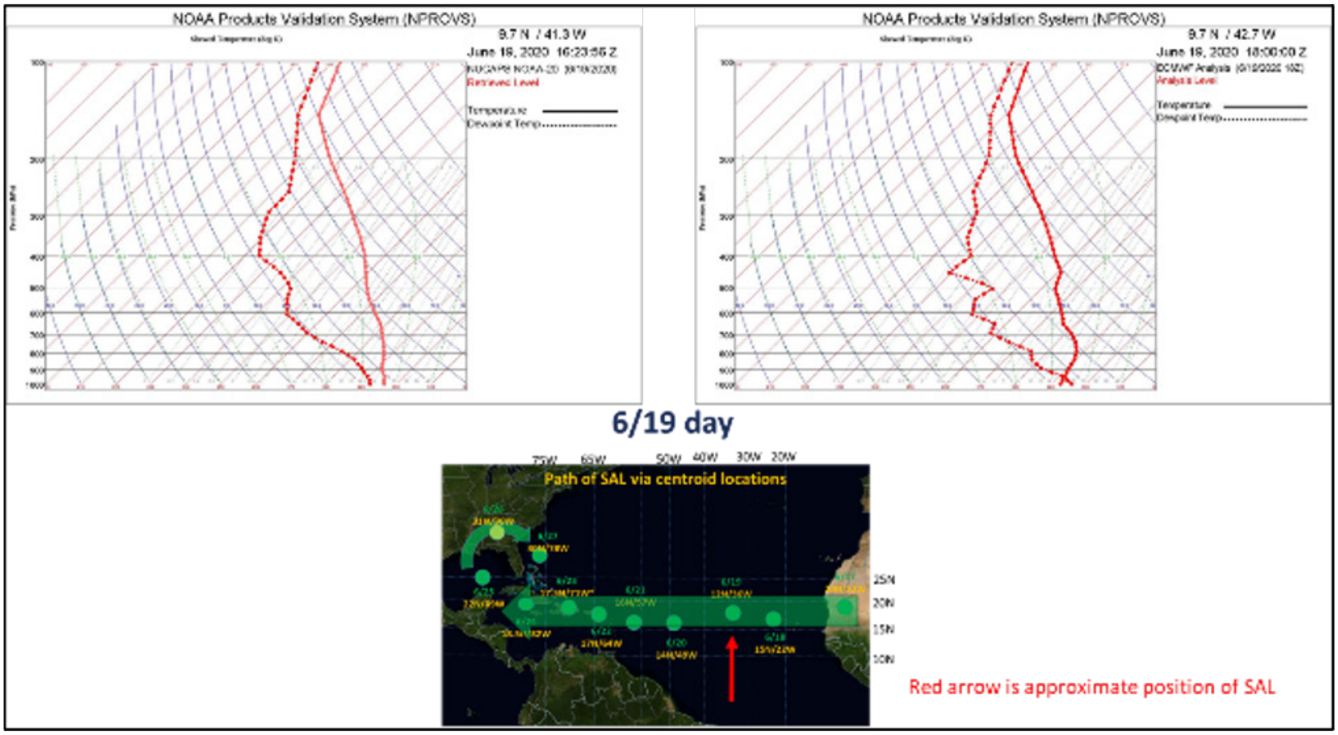
While the SAL air mass was over Africa, data from Suomi NPP NUCAPS (below on the left,) soundings and ECMWF model (below on the right) analysis showed the characteristic constant theta profile at the low levels with hot and very dry conditions at the surface.



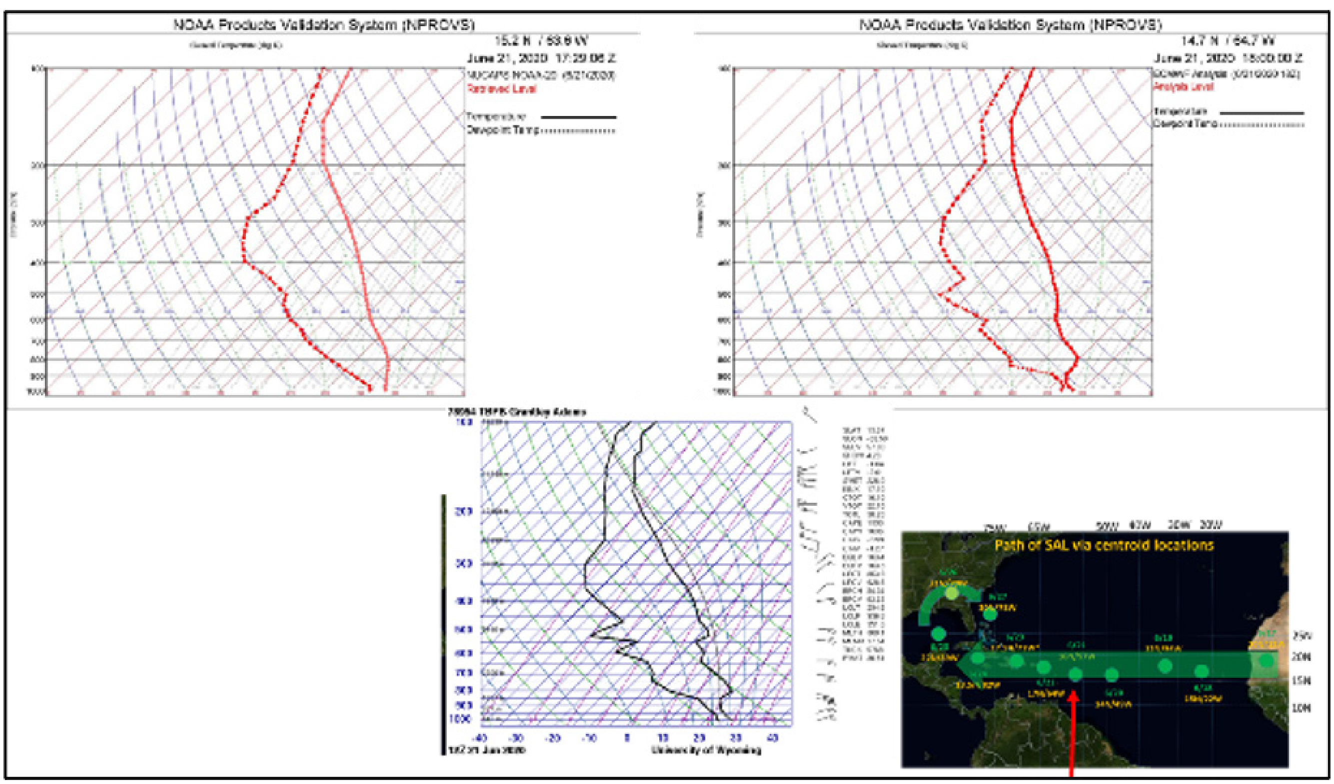
Approximately 12 hours later the air mass transitioned from land to maritime conditions as it moved over the coast. However, it still exhibited the same characteristics as it did when inland.



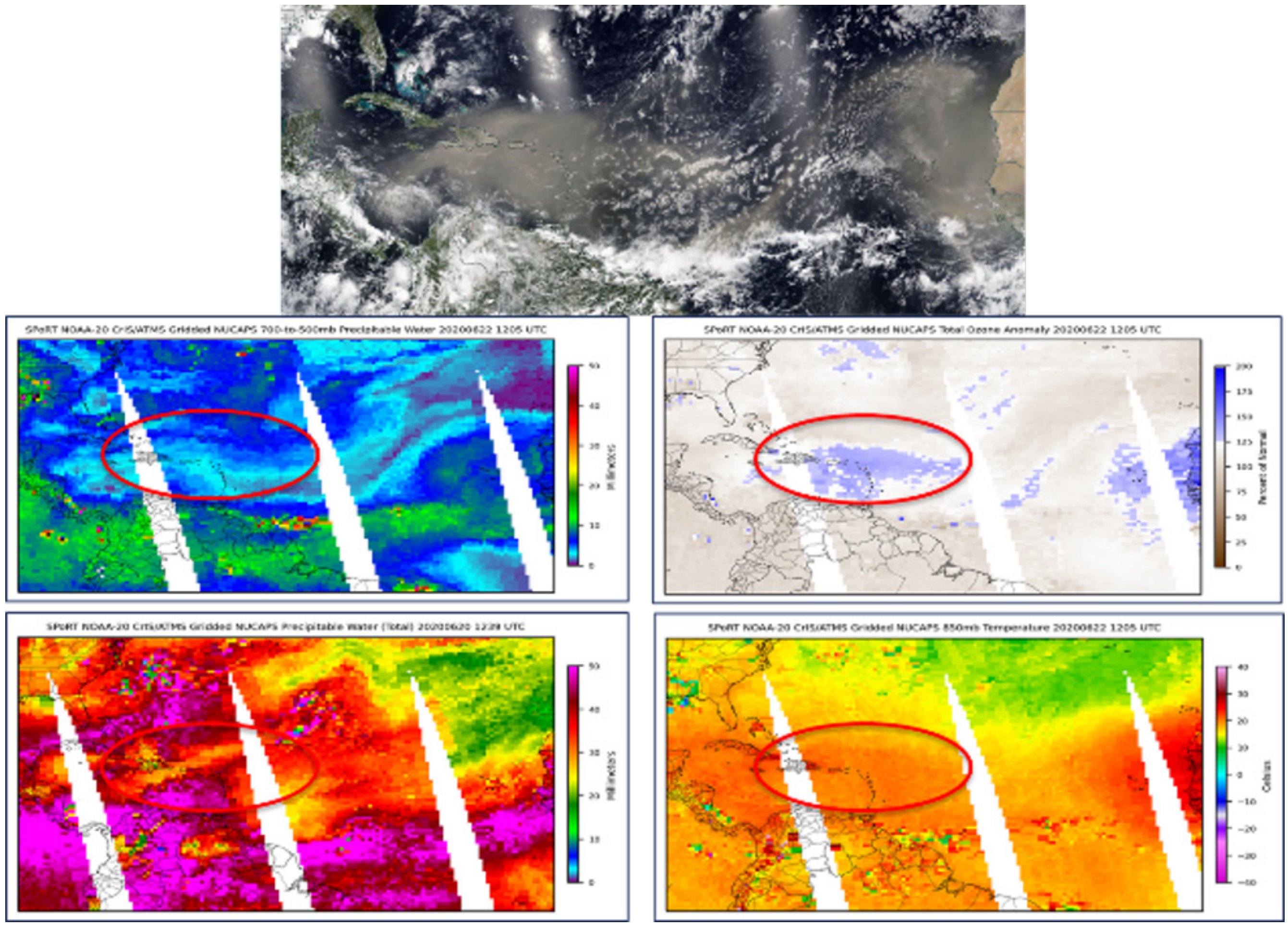
On the 19, the NUCAPS (below on the left) showed a broad drying up until the 600mb level whereas the ECMWF analysis (below on the right) showed more layer of dryness.



On the 21, as the SAL moved further downstream, some differences between the NUCAPS (below on the left) and ECMWF (below on the right) profiles were noted. The SAL, as would be expected, was becoming more diffuse as it moved. The ECMWF picked up the intricacies, while NUCAPS showed some difficulty in picking up the layers. The Grantley Adams, Barbados rawinsonde site at 12Z (bottom center figure) matched up with ECMWF, where ECMWF showed the low level inversion, whereas NUCAPS seemed to try profiling the moisture layer from the surface to 500mb.



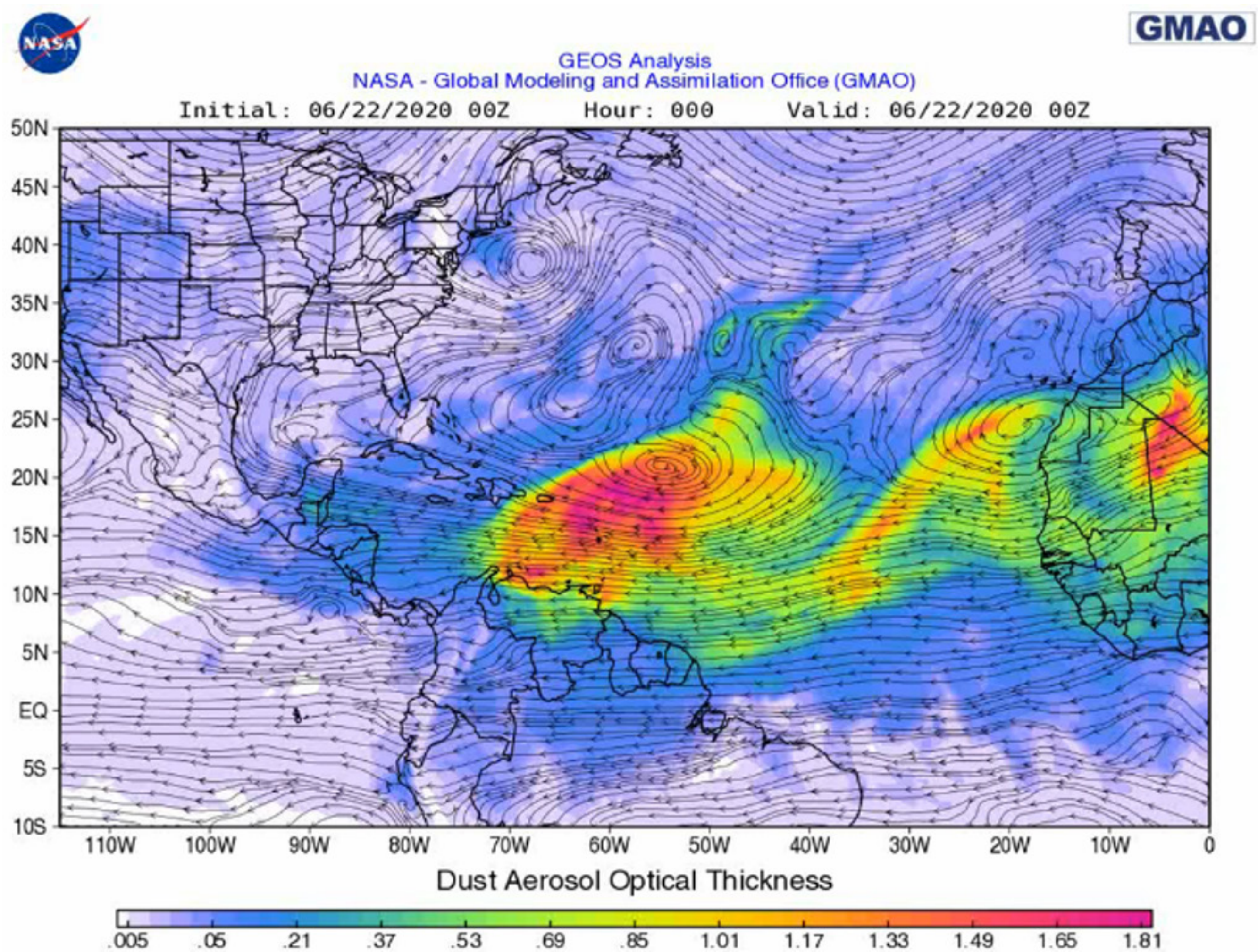
CrIS has many bands that are sensitive to Water Vapor. Using the top as a reference point shows how well gridded NUCAPS products matched up with model data. Gridded NUCAPS is the capability to view plan-view and cross-section displays. The 700mb to 500mb precipitable water in the top left panel matches up with the total Ozone anomaly on the upper right panel. The red circle in the precipitable water figure in the lower left panel indicates very dry conditions. The lower right panel shows the temperature at 850mb from the gridded NUCAPS derived from NOAA-20.



Gridded NUCAPS products, Courtesy: Emily Berndt NASA-SPoRT.

IT'S NOT OVER TILL IT'S OVER

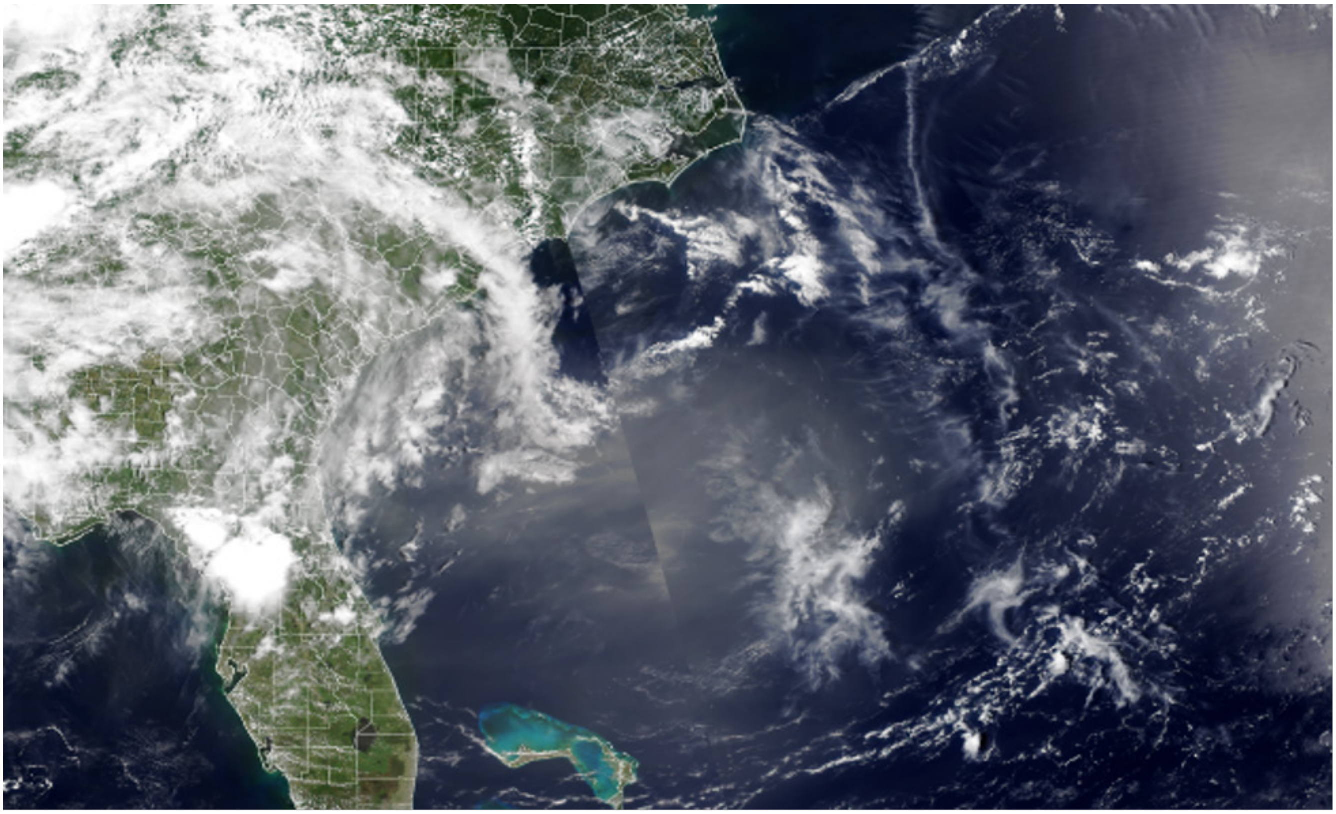
What was most striking in this SAL episode was its strong signature that prevailed throughout its 6,000+ mile journey from Northwest Africa, westward across the Atlantic, through the Caribbean countries, into the Gulf of Mexico, northward into Southcentral U.S., and exiting the Southeast U.S. and back out into the Atlantic. Shown on the following page is the GEOS model analysis on June 22, illustrating the path of the high aerosol content following the streamlines.



The Saharan air layer continued to move across the Atlantic into the Gulf of Mexico and impacted the weather in Corpus Christi, Texas on June 26.

Image credit: Official Twitter account for the National Weather Service Forecast Office Corpus Christi, TX. NWS Corpus Christi @NWSCorpus http://weather.gov/twitter

The upper level flow over the United States caught the SAL movement along the Southeastern coast and then eastward back into the Atlantic where it finally dissipated.



NOAA-20 image showing the SAL on June 27, 2020.

To summarize, for the case just described, NUCAPS appears to show reasonable skill in identifying and tracking the vertical profile of the SAL. NUCAPS captured the over-land theta structure but eventually lost it further downstream. NUCAPS profiles provided a good vertical structure consistent with various analysis and radiosondes. For the moisture profiles, NUCAPS captured multiple layers of dust until it reached the greater Caribbean where it smoothed out.

With a lack of weather observations and sounding information over the data sparse Atlantic, NUCAPS can provide the necessary gap-filling information that can prove invaluable in supporting SAL forecast operations in the greater Caribbean region.

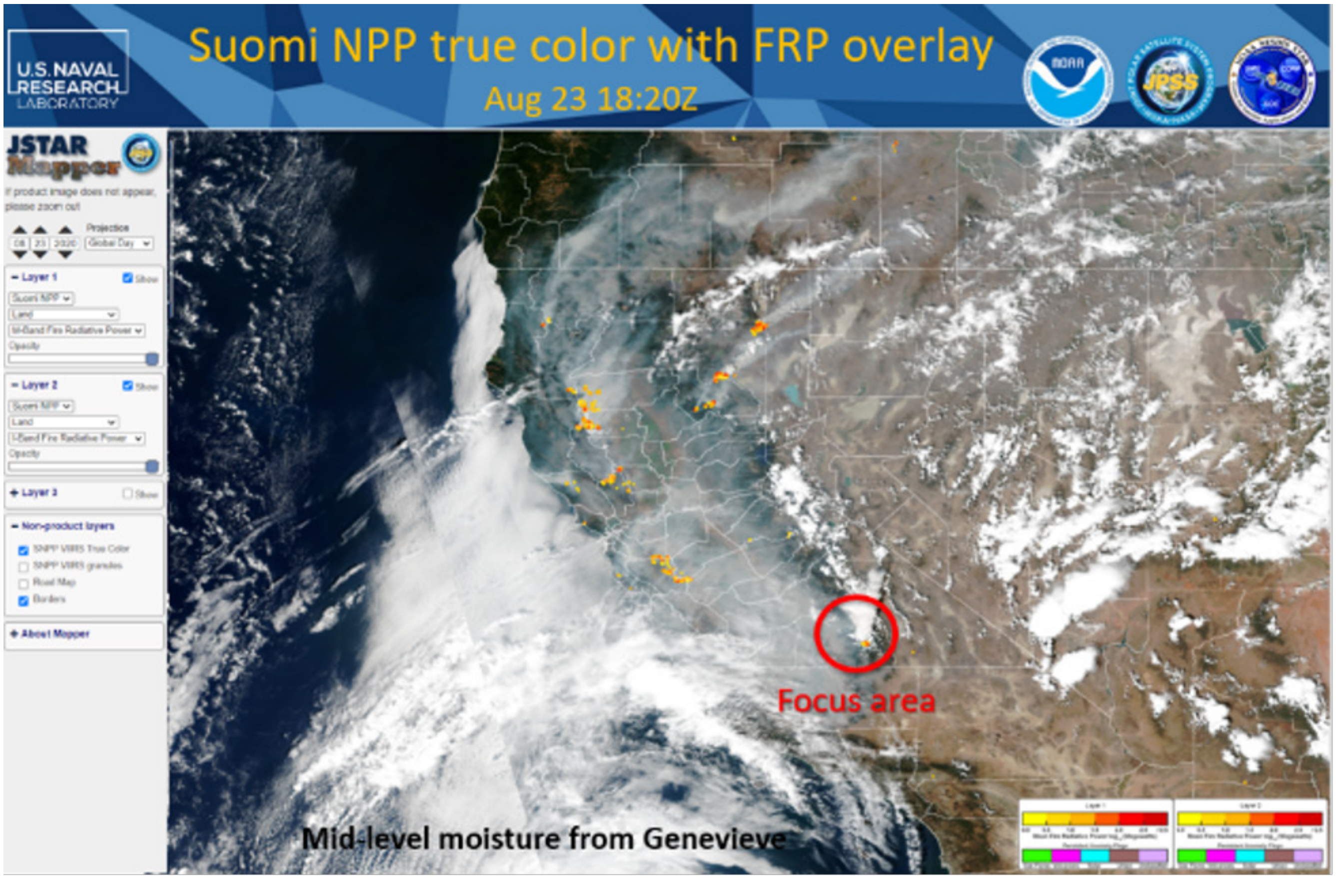
CASE STUDY TWO

California Fire Weather

The monsoon weather in California occurs around late summer and the early fall season (close to the end of August and the beginning of September). This time period is also active for wildfires due to heatwaves, strong high-pressure systems over the eastern Pacific, offshore winds, and associated low humidity throughout the state. Altogether these conditions create the perfect environment for PyroCbs—massive thunderstorm clouds that can ignite wildfires.

Pyrocumulonimbus (PyroCb) eruptions in Northern California

During late August in 2020, there were several weather events that helped contribute to the deadliest and costliest series of fires in northern California. Much of this started on 13 August as the combination of mid-level moisture and hot over land conditions, resulted in thousands of lightning strikes within Central California. The next several weeks showed sustaining wildfires where some erupted into PyroCbs as shown in the Suomi NPP true color product with an overlay of numerous high levels of fire radiative power (FRP = wildfires) below (on June 23). The annotated red circle detected an ongoing hot spot that eventually grew to a huge PyroCb, as evidenced by the bright convective stream of clouds.

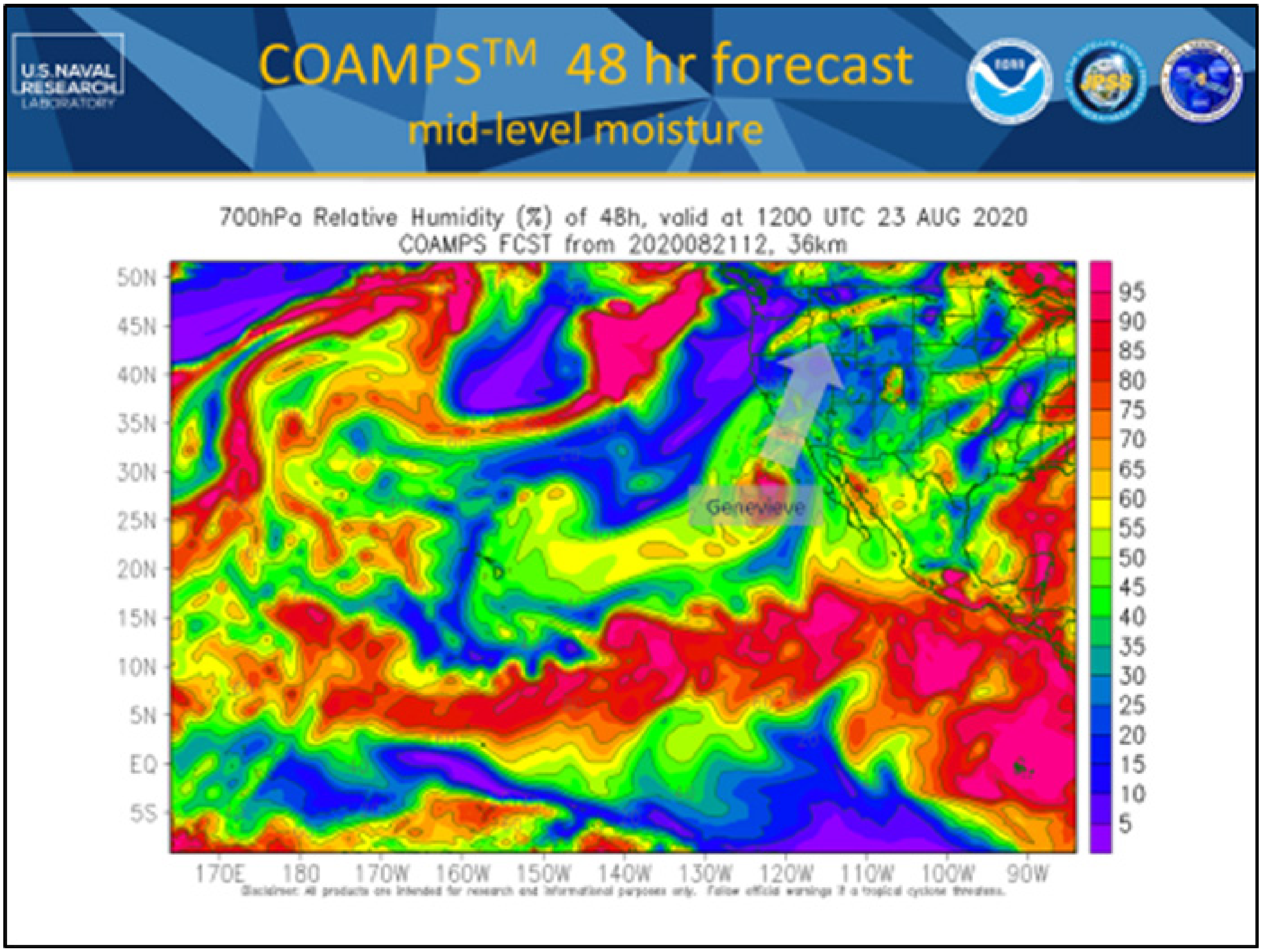


M and I-band FRP.

WHAT NRL BRINGS TO THE TABLE

COAMPS

The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) is a regional weather prediction model developed and maintained by the Marine Meteorology Division (MMD) of the Naval Research Laboratory (NRL). During August 22 and 23, COAMPS predicted the midlevel moisture and stability components necessary for igniting the various 'Lightning Complex' wildfires mechanisms that greatly enhanced the already record setting wildfire season throughout the state. The figure at the top of the next page illustrates how the moisture pattern within the dying stages of tropical storm "Genevieve" managed to flow northeastward through Central and Northern California. With existing unstable conditions in the area, an intensive and far reaching lightning array triggered numerous small wildfires that continued to grow to several very intensive and deadly outbreaks, some with imbedded PyroCb outbreaks, which continued well into October. Studies are underway to determine whether NUCAPS would have been an instrumental nowcast tool to forecasters in determining pre- and post-convective signatures leading to the dry lightning storms that occurred.


U.S. NAVAL RESEARCH LABORATORY
COAMPSTM 48 hr forecast
mid-level moisture
700hPa Relative Humidity (%) of 48h, valid at 1200 UTC 23 AUG 2020
COAMPS FCST from 2020082112, 36km
50N
45N
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25N
20N
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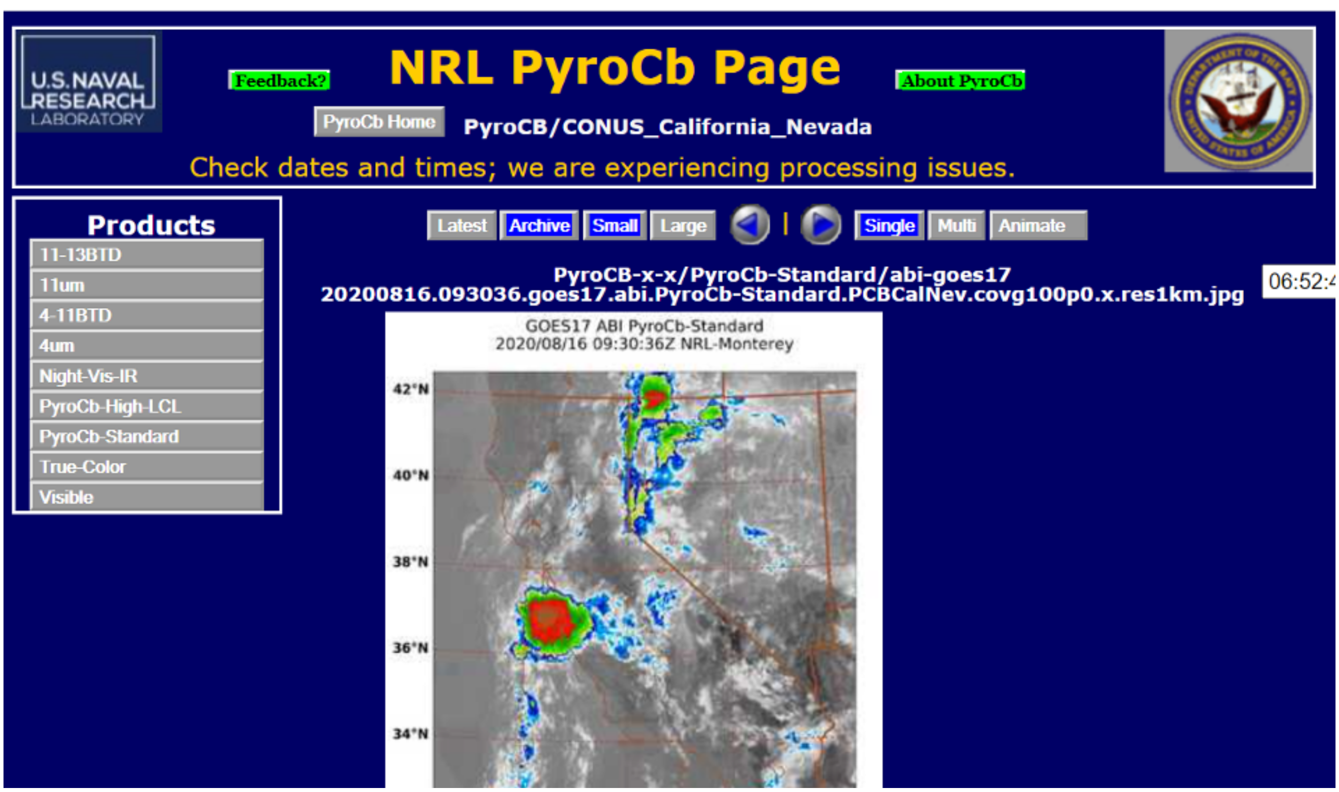
NexSat


U.S. NAVAL RESEARCH LABORATORY
Feedback?
NRL PyroCb Page
About PyroCb
PyroCb Home
PyroCB/CONUS_California_Nevada
Check dates and times; we are experiencing processing issues.
Products
11-13BTD
11um
4-11BTD
4um
Night-Vis-IR
PyroCb-High-LCL
PyroCb-Standard
True-Color
Visible
Latest
Archive
Small
Large
Single
Multi
Animate
PyroCB-x-x/PyroCb-Standard/abi-goes17
20200816.093036.goes17.abi.PyroCb-Standard.PCBCalNev.covg100p0.x.res1km.jpg
GOES17 ABI PyroCb-Standard
2020/08/16 09:30:36Z NRL-Monterey
42°N
40°N
38°N
36°N
34°N

The NRL 'NexSat' is a public-access website that provides a dedicated PyroCb page. The PyroCb products feature GOES-16 and 17, Suomi NPP and NOAA-20 channels (4 and 11 microns) sensitive to fire, smoke and cloud removals. Both of these 'fire channels' are contained in both GOES and VIIRS sensors. Where the VIIRS products provide fine radiometric detail, GOES products provide detailed temporal viewing. A standard PyroCb product captured the large northward moving convective cell that impacted Central California with thousands of associated dry lightning strikes that eventually generated numerous wildfires throughout the day. The product display within NexSat is shown at the bottom of the previous page.

WHAT NUCAPS BRINGS TO THE TABLE

For both SAL and PyroCb events, NUCAPS provides forecasters and researchers with gap-filling information both temporally and spatially. Rawinsondes provide twice daily vertical assessments of atmospheric conditions, at 00 and 12 UTC. PyroCb development often occurs outside of effective time periods, where pre-convection or convection. From a temporal perspective, NUCAPS coverage provides the necessary information in between these times. From a spatial perspective, NUCAPS provides continuous information which is especially useful within areas far removed from RAOB sites. Fires occur in remote areas. Over the CONUS region, this information comes during vast opportunities to exploit convective conditions, both prior to and during PyroCb development, particularly in remote areas, where most wildfires occur. The ability to add this information to the matrices of fire predictions.

SUMMARY AND FUTURE WORK

"The focus is to continue collecting cases for SAL studies that will allow NRL to provide NUCAPS updates to both the NWS and Caribbean forecasting agencies," says Arunas. For the latter group, the NUCAPS demonstrations will be offered on several websites outside of the AWIPS-2 platform. NRL also plans to utilize existing results from recent FIRE-X field campaigns to study pre and post-convective conditions leading to strong PyroCb outbreaks. NRL also plans to leverage several ongoing PyroCb projects that advertise NUCAPS to the U.S. Navy and Air Force throughout FY21. ❖

Story Source

Materials obtained from JPSS August Science Seminar titled "Applying NUCAPS During Recent Saharan Air Layer and Wildfire Events"

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Kuciauskas, A. P., P. Xian, E. J. Hyer, M. I. Oyola, and J. R. Campbell, 2018: Supporting Weather Forecasters in Predicting and Monitoring Saharan Air Layer Dust Events as They Impact the Greater Caribbean. Bull. Amer. Meteor. Soc., 99, 259–268, https://doi.org/10.1175/BAMS-D-16-0212.1.

A WHEEL IN MOTION

A MODEL FOR SERVICE DELIVERY AND DECISION SUPPORT FOR THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The information in this article is based, in part, on the September 21, 2020 JPSS science seminar presented by Ellen Mecray, Regional Climate Services Director, Eastern Region, NOAA/NESDIS/National Centers for Environmental Information and the NOAA Water Team paper titled "A Model of Service Delivery for the NOAA Water Initiative: A Proven Method for Integrating Decision Support and Service Delivery."

Models are useful tools, which can help in several ways including to make predictions, explain concepts or ideas, provide visual representations of abstract concepts, and provide important information. For the past few years, a multi-line office team consisting of members from all service entities across line offices of the National Oceanic and Atmospheric Administration (NOAA) has been drafting a strategy to develop and deliver a model for NOAA service delivery. The idea behind the model is to develop products and services through co-production and continuous engagement with user communities. Its notable feature is a wheel (see figure above), which provides a simple way to visualize the process through which continuous engagement (through and around the wheel) with NOAA user communities facilitates the delivery of NOAA products and services.

A September 21, 2020 seminar organized by the Joint Polar Satellite System (JPSS) featured Ellen Mecray, the Regional Climate Services Director-Eastern Region in the National Centers for Environmental Information (NCEI), who gave a talk about the model. In her talk, Mecray described the process beginning with building trusted relationships, and moving through and around the wheel to the delivery and measurement of effectiveness with the end-user. Mecray, who is also the team's service delivery lead, said the model builds on efforts that began in the NOAA Water Initiative (NWI), which was established in 2016 to provide better access to water information.

Service Delivery/Decision Support Objective Team Members

Ellen Mecray, NESDIS* (Service Delivery Lead)
Miki Schmidt, NOS* (Decision Support Lead)

Katherine Hawley, NESDIS*
David Helms, NESDIS
Doug Kluck, NESDIS
Thanh Vo Dinh, NESDIS*
Colette Cairns, NMFS
Nate Mantua, NMFS
Cayla Dean, NOS
Ginger Hinchcliff, NOS*
Donna Johnson, NOS
Audra Luscher, NOS
Brenna Sweetman, NOS*

Kate Abshire, NWS*
Karen Bareford, OAR/SG*
Jocelyn Burston, NWS
Margaret Hurwitz, NWS
Mary Mullusky, NWS
Jen Sprague, NWS
Michelle Stokes, NWS/ReCo
Nancy Beller-Simms, OAR*
Veva Deheza, OAR
Kola Garber, OAR
Meredith Muth, OAR
Claudia Nierenburg, OAR*
Elizabeth Rohring, OAR
Chris Lauer, Chief Economist's Office

Members include engagement specialists, physical scientists, social scientists, as well as specialists in academia and practitioners with the knowledge and skills needed for this type of undertaking.

WHAT IS THE SERVICE DELIVERY MODEL FOR NOAA?

The service delivery model as described in "A Model of Service Delivery for the NOAA Water Initiative: A Proven Method for Integrating Decision Support and Service Delivery" (NOAA Water Team, 2020) "describes a consistent approach that will enhance NOAA's delivery of water-related services, and could also be applied to other NOAA initiatives that cite the need to understand and apply user needs to guide product and service development (e.g., subseasonal-to-seasonal predictions, climate services, Blue Economy, and Weather-Ready Nation)." The model articulates the creation of a culture of continuous engagement and describes what service delivery is and why it's important that the agency move in this direction.

The vision for the model is for users to "understand and use the breadth of NOAA's information for their decisions." The idea is that the vision can be achieved using multiple avenues including continuous engagement (its core), trusted relationships; information gathering; translating; assessing product and service development; addressing user needs; product delivery; and evaluating user satisfaction. These avenues are outlined in the box on the next page (NOAA Water Team, 2020).

Figure 1. To achieve this vision, NOAA's service providers must (1) continue to build trusted relationships with NOAA's internal and external users and partners; (2) understand the decisions of those users, their use of NOAA information, and be able to gather the user's information needs; (3) evaluate user needs (that cannot be quickly satisfied) through a lens of both NOAA and its partners' capacity; (4) review and prioritize NOAA's products and services to meet the needs; (5) respond to user needs by developing new, or refining existing, products and services across NOAA; (6) deliver these products and services to users; and (7) evaluate user impact of NOAA's tools and services. These elements represent a process. It is imperative that as each element is conducted, interaction occurs between the trusted NOAA entity, end users, and various partners. It is also likely that elements will co-evolve and loop forward, across, and behind in the diagram to verify needs and capabilities, and ensure the provision of the best products and services.

AN OPPORTUNITY FOR A NEW TOOL

Several reasons motivated the decision to build the model. One related to a question on product use. "NOAA's niche lies in its ability to build products and services that are useful, useable and used" (NOAA Water Team, 2020). While it's evident that the products and services are useful and useable, it's far less clear whether they are being used by the public. The other motivation came from transformations in NOAA "from science and technology needed to create products and services, to understanding the value of user needs that inform the building new technologies, new products and new services" (NOAA Water Team, 2020).

As part of defining, implementing and subsequently using the service delivery model, the team has created a glossary of terms which provides a common definition for words – like "user," "stakeholder", "customer," and key concepts such "user engagement" – that are associated with NOAA's work. Creating this glossary became necessary in the process of trying to describe and articulate a strategy that would lay out a vision, mission, and plan for the model. The team realized that definitions varied across Line Offices. In some instances, Line Offices used different terms to describe essentially the same thing, and in other instances common words had different interpretations. It therefore became apparent to the team that clear definitions of terms like users, stakeholders, and customers needed to be established before anything else could be done. In addition, they discovered and made distinctions between users internal and external to NOAA.

THE MODEL IS BUILT, WHAT'S NEXT?

The next step in the process is the drafting of an implementation approach that will provide knowledge of who already does this kind of work, and how the results of user engagement outcomes (needs) will be built into discussions within NOAA in order to respond with products and services. Stay tuned.

SUMMARY

For the past few years, a multi-line office effort from all service entities across NOAA has been drafting a strategy to articulate a model for service delivery for the agency. The model's roots can be traced back to the NWI, which lay the groundwork to provide better access to water information. The goal of the service delivery model is to help NOAA prioritize new and existing product lines; develop new and refine existing products and services informed by user needs; and transmit and translate actionable information, be it the delivery or the technical assistance provided with the delivery. The timing, it seems, could not have been better, given the shift from science and technology to an appreciation of user needs throughout the process of creating products and services. ❖

Story Source

Materials obtained from JPSS September Science Seminar titled "A Model for Service Delivery and Decision Support for NOAA" and the NOAA Water Team paper titled "A Model of Service Delivery for the NOAA Water Initiative: A Proven Method for Integrating Decision Support and Service Delivery."

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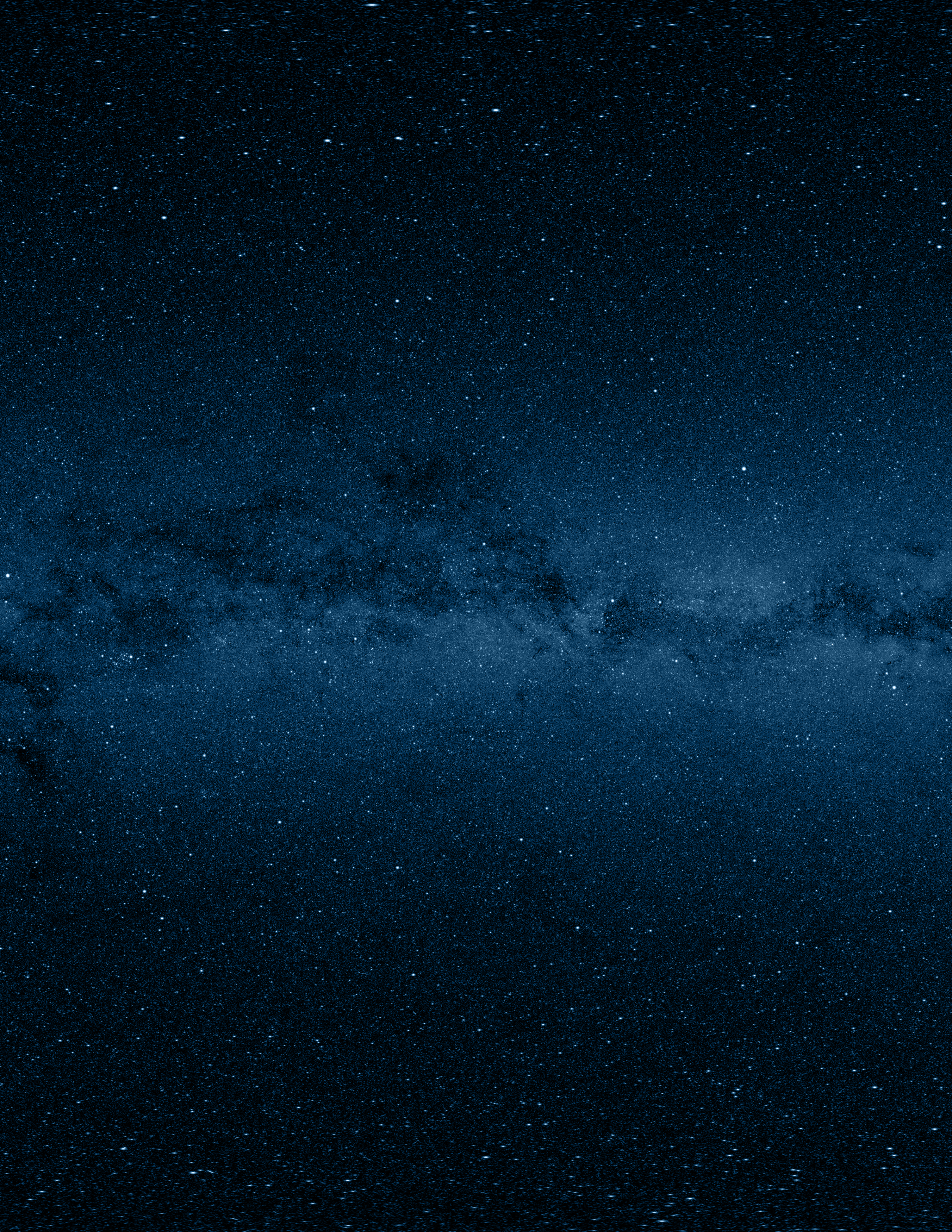
Water Initiative. 2020. "A Model of Service Delivery for the NOAA Water Initiative: A Proven Method for Integrating Decision Support and Service Delivery." Authored by the NOAA Water Team.



WEB FEATURES

WEB FEATURE: APRIL 6, 2020

HOW WEATHER SATELLITES CHANGED THE WORLD

Jenny Marder
Science Writer, Joint Polar Satellite System
NASA Goddard Space Flight Center

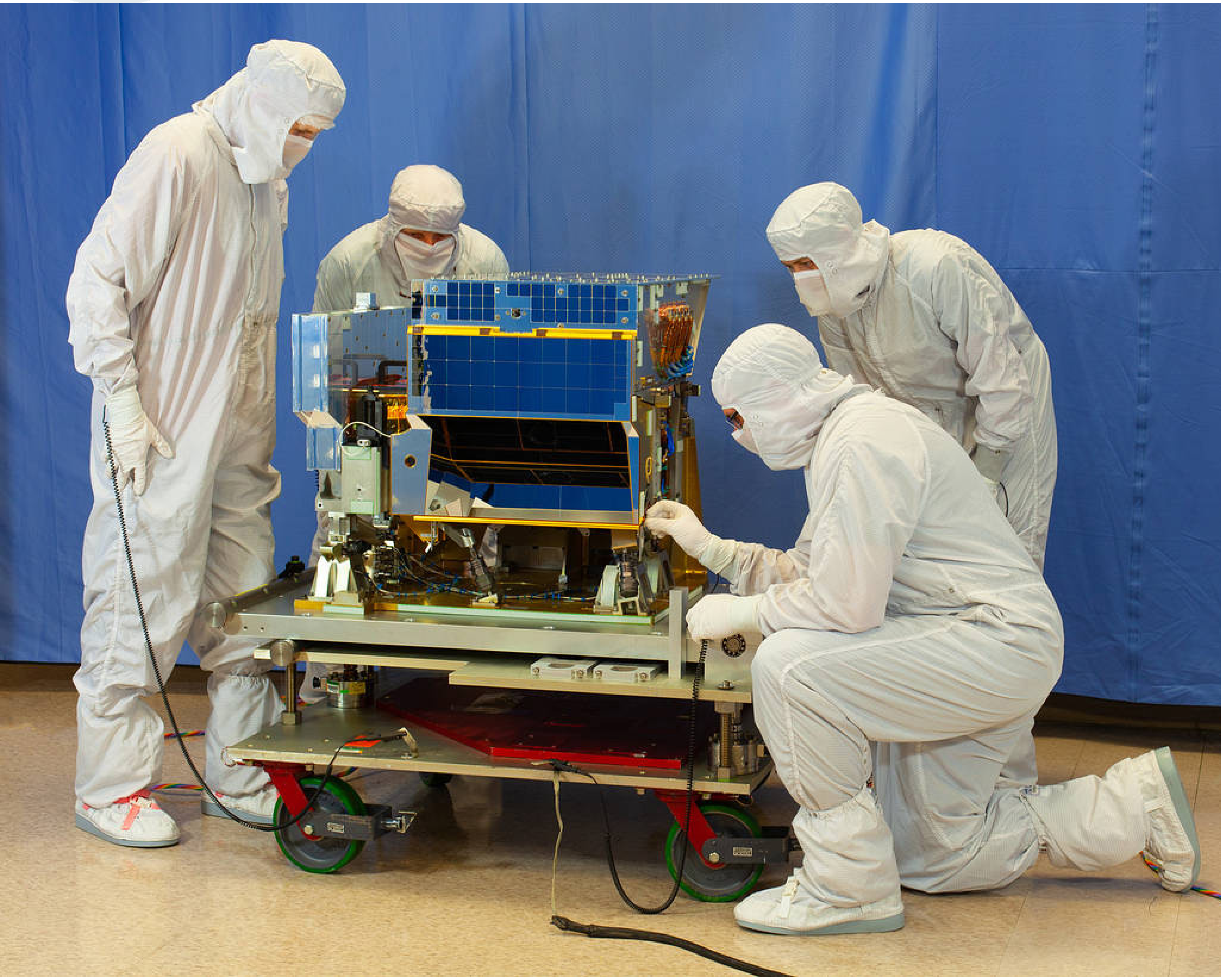
Click here for Story Map.

Credit: NASA/NOAA

On April 1, 1960, NASA’s first operational weather satellite, TIROS-1, launched from Cape Canaveral. This multimedia story map looks at the value and importance of the nation's weather satellites and game-changing moments in their 60-year history. ❖

FINAL JPSS-2 SATELLITE INSTRUMENT PASSES READINESS TEST

Jenny Marder
Science Writer, Joint Polar Satellite System
NASA Goddard Space Flight Center



Credit: NASA/NOAA

The Cross-Track Infrared Sounder (CrIS) instrument built to fly on the Joint Polar Satellite System (JPSS)-2 satellite is ready to ship to the spacecraft. CrIS has passed all of its readiness tests, completing its pre-ship review. Pre-ship review is the final step before instruments are shipped to and integrated onto the spacecraft. CrIS is the future satellite's final instrument to be ready for spacecraft integration.

The CrIS instrument is an advanced operational sounder that provides more accurate, detailed atmospheric temperature and moisture observations for weather and climate applications.

CrIS is a key instrument currently flying on the NASA-NOAA Suomi NPP and NOAA-20 (or JPSS-1) satellites, the first two in the Joint Polar Satellite System's series of polar-orbiting satellites. CrIS represents a significant enhancement over NOAA's legacy infrared sounder—the High-Resolution Infrared Radiation Sounder (HIRS).

Data from the JPSS satellites feed daily weather models and tell us about atmospheric conditions needed to provide extreme weather forecasts several days in advance. CrIS will be among the instruments on the JPSS-2, -3 and -4 satellite missions.

The CrIS instrument was developed and built by L3Harris Technologies.

The Joint Polar Satellite System (JPSS) is the nation's new generation polar-orbiting operational environmental satellite system. JPSS is a collaborative program between the National Oceanic and Atmospheric Administration (NOAA) and its acquisition agent, National Aeronautics and Space Administration (NASA). This interagency effort is the latest generation of U.S. polar-orbiting, non-geosynchronous environmental satellites. ❖

WEB FEATURE: MAY 6, 2020

NOAA SATELLITES PROVIDE DETAILED IMAGERY OF MICHIGAN FLOODS

Jenny Marder
Science Writer, Joint Polar Satellite System
NASA Goddard Space Flight Center

William Straka III
SSEC/CIMSS/UW Madison

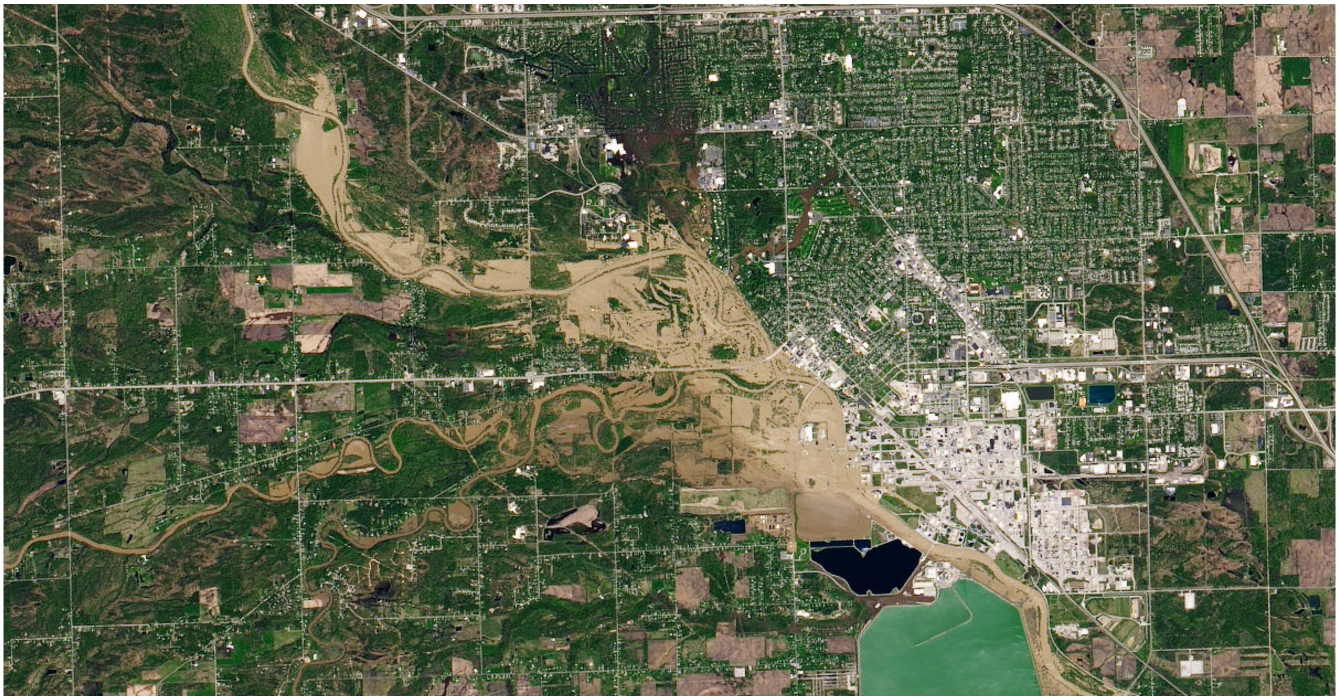
Downtown Midland, Mich., is flooded May 20. Credit: Kelly Jordan and Junfu Han, Detroit Free Press

On May 19, after three days of heavy rain and flooding in Michigan, two dams failed, flooding roads, engulfing homes and bridges, and forcing nearly 11,000 people in nearby towns to evacuate.

The Edenville Dam collapsed that Tuesday afternoon, unleashing the Wixom Lake into the Tittabawassee River. Later that day, floodwater began gushing over the Sanford Dam downstream. By Wednesday evening, the Tittabawassee River had peaked at 35.05 feet, 10 feet above flood levels, beating the previous record of 33.9 feet set in 1986, according to the National Weather Service, which called the flooding "catastrophic."

During a major flooding event, local forecasters and first responders rely on satellite data, along with other tools like aerial mapping, to understand the extent of damage.

In this case, the Operational Land Imager (or OLI, below) on the Landsat 8 satellite provided a detailed view of the Tittabawassee River and surrounding area. But Landsat, which captures a narrow swath just 180 km, or 111 miles wide on each pass, revisits a single spot in the U.S. about once every 16 days, and is therefore not always available to capture flooded areas when they happen.



NASA Earth Observatory image of the flooding in Midland, Mich. (light brown areas), as seen from the U.S. Geological Survey satellite, LandSat. Credit: Joshua Stevens

On the night the dams breached, the NOAA-20 and Suomi-NPP satellites of the Joint Polar Satellite System (JPSS) also observed the floods, allowing scientists to reveal the capabilities of an improved flood product.

Scientists at George Mason University have been working to create a product that gets daily measurements of the entire United States at a similar resolution to Landsat, using the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the NOAA-20 and Suomi NPP satellites. This is especially important now, as the NOAA Climate Prediction Center in March forecast widespread river flooding this spring, due to expected above-average temperatures and rainfall.

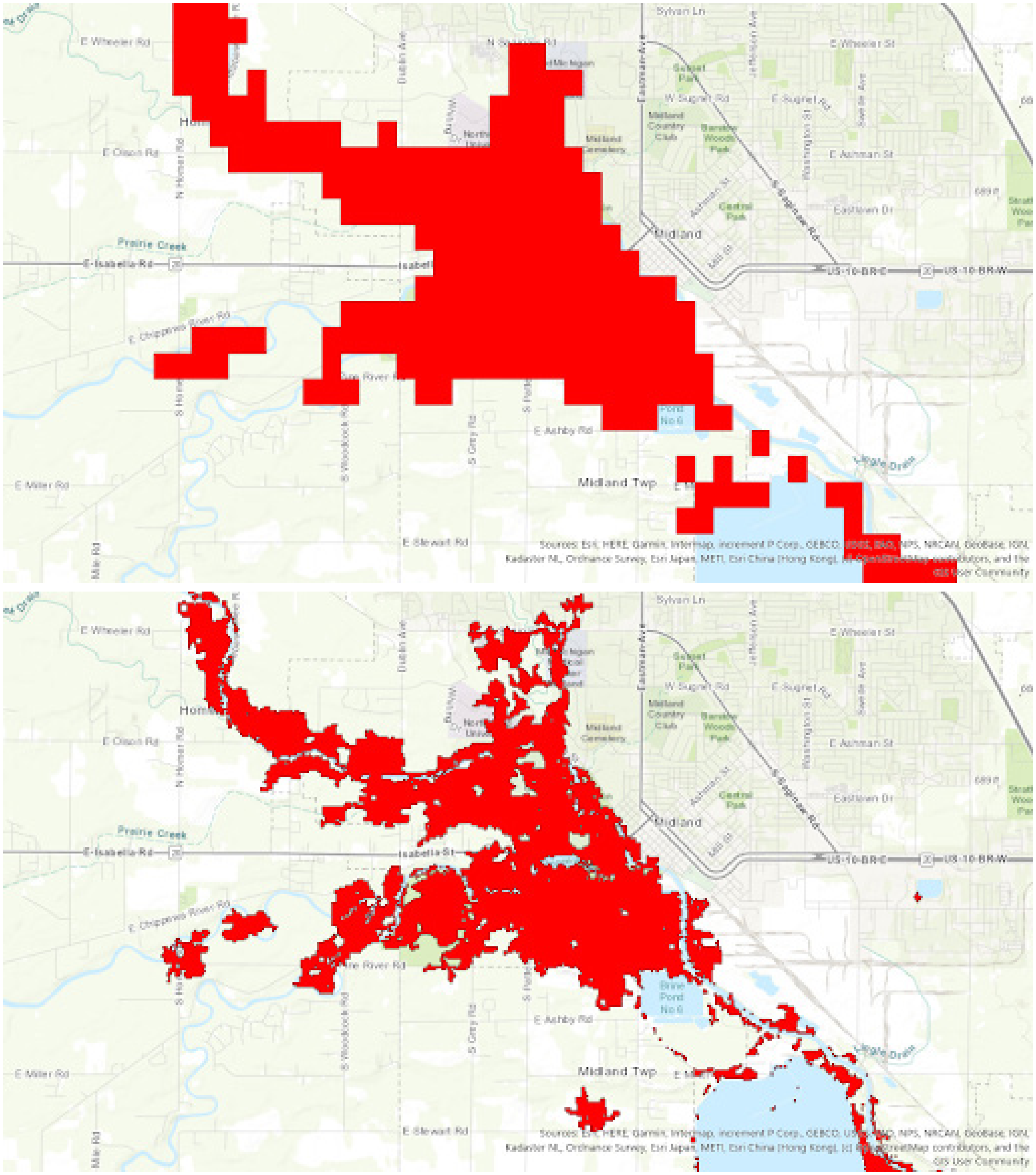
JPSS polar-orbiting satellites observe a width of 1,901 miles at every pass, which allows each to image the entire globe twice a day. And recent improvements to the flood algorithm mean the satellites can now see flooded regions at a resolution of 30 meters, or about 98 feet—that's 12 times sharper than the previous VIIRS flood product.

"We're demonstrating the new improvements by looking at the dam," JPSS Chief Scientist Mitch Goldberg said. "And we're showing that the new algorithm compares really well against Landsat."

In 2016, when this technology first debuted during a joint JPSS/George Mason University seminar, the model could only produce preliminary unsteady results in specific regions. "In recent months, we've made great progress," said Sanmei Li, the algorithm developer at George Mason University. "Now, the model can be used to generate 30-meter flood maps from VIIRS in the continental United States with pretty robust performance."

In the map below, you can see Michigan's Midland County and the Tittabawassee River, with flooding shown in red. The images show the original VIIRS flood product at a coarse 375-meter resolution (top) and the improved flood product at a 30-meter resolution (bottom), with much more detail on impacted areas.

The new flood product, funded by the JPSS Proving Ground initiative, relies on an algorithm that takes the satellite data of floodwater at a 375-meter resolution, and, using an understanding of terrain and surface elevations, gives a higher resolution (30m) estimate of flood extent within each satellite image pixel.



"VIIRS has such a large swath, and Landsat's swath is much more narrow," Goldberg said. "It takes 16 days for the whole world to be covered by the smaller Landsat swaths which is only 115 miles wide, versus VIIRS at 1,901 miles. This new technique allows us to improve resolution in flood mapping and still maintain global coverage."

Lyric Prince contributed to this report. ❖

WEB FEATURE: JULY 17, 2020

FIRES NEAR THE HOTTEST CITY IN THE ARCTIC

Curtis Seaman
Research Scientist
Cooperative Institute for Research in the Atmosphere, Colorado State University

Something incredible happened in the Arctic on June 20. The temperature record reached 100.4 degrees Fahrenheit, or 38 degrees Celsius. More in this video from the World Meteorological Organization (WMO).

In case you're wondering where Verkhoyansk is, you can look it up on Google Maps.

If that temperature is verified, it would be the hottest temperature ever recorded north of the Arctic Circle. To put that 100.4 degrees Fahrenheit (38 degrees Celsius) into perspective, that was only 4 degrees Fahrenheit off from the high temperature in Phoenix, AZ that same day—a place where 104 wdegrees is normal in the summer. It's also worth reiterating how unusual it is for any location to average 15 to 20 degrees above normal for an entire month. Russia as a whole—by far the largest country on Earth—has averaged 15 degrees above normal for the entire first half of 2020!

If you clicked that last link, you saw an excerpt of the video above, plus more information on the unusual impacts of this heatwave. The clouds of mosquitoes. The collapsing buildings due to melting permafrost. (One of the largest oil spills ever in the Arctic happened in May, caused by melting permafrost.) And, an even more alarmist impact of the heat: "zombie fires".

That's right—if you didn't have enough with the coronavirus or the murder hornets or the melting Arctic, you can now panic about zombie fires. In all seriousness, the silly name has been applied to the phenomenon of fires in peat bogs never really being fully extinguished, and continuing to smolder deep down below the ice and snow that covered it up all winter. Then, when a heatwave happens the next summer, the smoldering turns to re-ignition of the fire, and it once again appears on the surface.

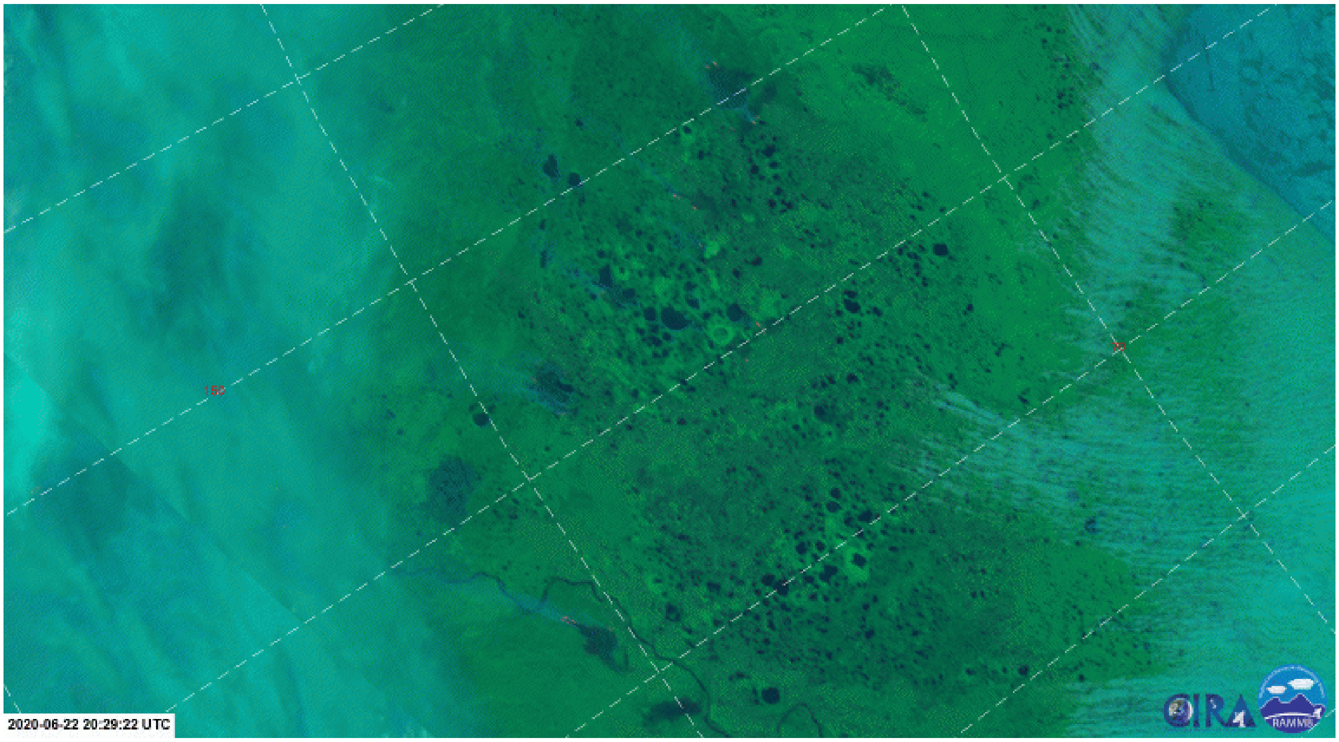
Fires have been happening on a massive scale throughout Siberia this summer (and they're probably not all zombie fires). But, we have a tool to observe them from satellite: Polar SLIDER.

Polar SLIDER is designed to show the most recent imagery from VIIRS, the Visible Infrared Imaging Radiometer Suite, available anywhere on Earth in as close to real-time as possible. Images from individual orbits from both the Suomi-NPP and NOAA-20 satellites are stitched together to create hemispheric composites that always feature the most recent imagery on top. The way the orbits work, when Suomi-NPP is crossing over into the Southern Hemisphere, NOAA-20 is crossing into the Northern Hemisphere (and vice versa). By combining imagery from both satellites, there is a ~50 minute refresh over the poles, giving a quasi-geostationary satellite view of each pole. Imagery is available at six different zoom levels, separated by factors of two, so you can zoom in to see full resolution VIIRS imagery anywhere on Earth.

Here's an example of Polar SLIDER (next page), reduced in size to play well with this blog software, showing our GeoColor product (True Color imagery during the day, blended with the Day/Night Band and a low cloud detection algorithm at night) over Siberia on June 23 and June 24, 2020:

How much smoke can you see? Did you count the plumes? Did you see the swirl in the smoke at about 70°N, 140°E? (For reference, Verkhoyansk is near 67°N, 133°E.)

That loop covers approximately 30 hours in the Arctic and, since we're so close to the



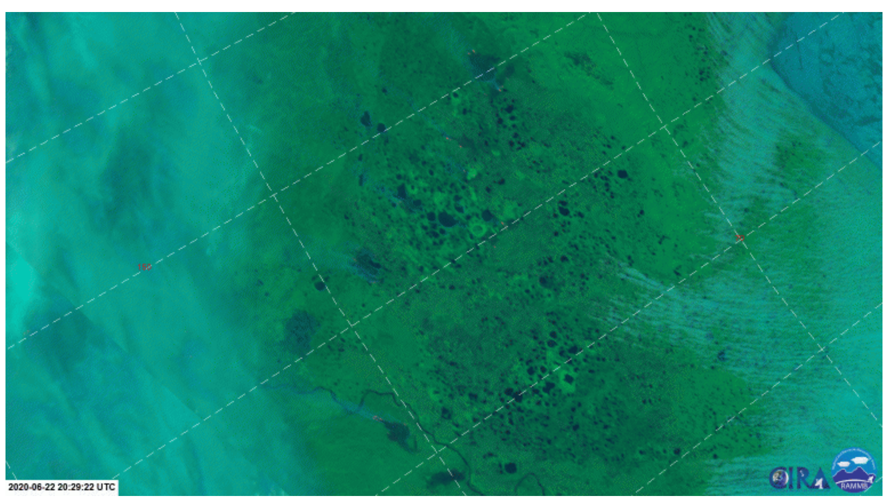
VIIRS GeoColor animation (23-24 June 2020)

summer solstice, you can estimate the location of the Arctic Circle, even though it isn't plotted.

Even those of you who have heard of (or seen) Polar SLIDER before might not be aware of the recent upgrades made in May 2020. For the first 18 months of its existence, Polar SLIDER had all 22 VIIRS channels (DNB, 16 M-bands, 5 I-bands) plus GeoColor (as shown in the loop above) and, occasionally, the I-band Natural Color (aka Day Land Cloud RGB) product. Now, we have added 10 new products, including the most popular RGB composites (the ones that are available from VIIRS, anyway) and two new RGBs for snow monitoring that utilize the 1.24 µm band that are not available on any geostationary satellite. (More information on those is available here.) We've also fixed the issues with the Natural Color RGB, making it a permanent fixture, rather than an anomaly.

Among the new products available on Polar SLIDER is what we call Natural Fire Color (and the National Weather Service calls "Day Land Cloud Fire RGB"), made from VIIRS bands I-1 (0.64 Qm, blue), I-2 (0.86 Qm, green) and I-4 (3.7 Qm, red). As it is made from VIIRS I-bands, it is available at 375 m resolution around the globe. Here's what it shows from 22–23 June 2020 over this part of Siberia:

This animation is too large for WordPress. You have to click on it to get it to play. But, I couldn't resist showing the full resolution imagery. Also, a note about the timestamps on Polar SLIDER: it takes about 50 min for each satellite to



VIIRS Day Land Cloud Fire RGB animation (22-23 June 2020) cover each hemisphere, and the image times displayed on Polar SLIDER represent the Equator-crossing time as the satellite leaves the hemisphere, which is most likely not the time the satellite was viewing the area you're looking at.

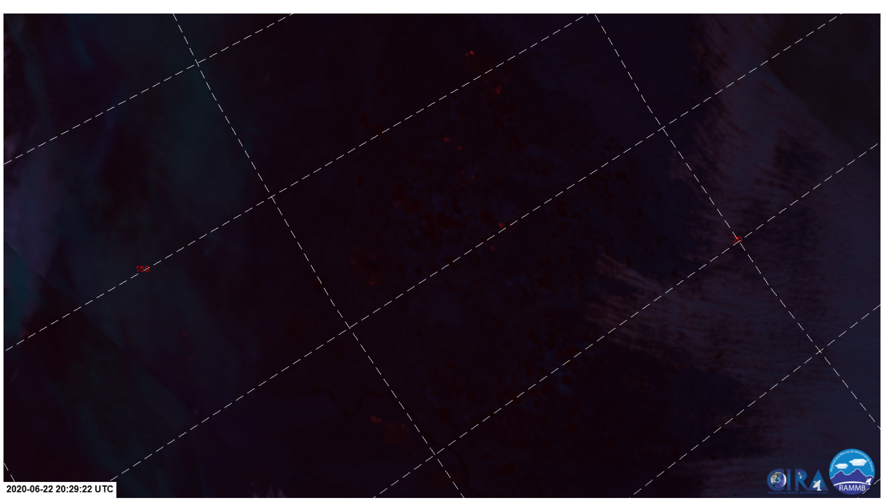
The Natural Fire Color/Day Land Cloud Fire loop covers a 10-hour period from about 8:00 AM to 6:00 PM local time (depending on where you are in the scene, it might be 7:00 AM to 5:00 PM), during which time there were 11 consecutive VIIRS overpasses over this region between the two satellites. This is a textbook example of how fires typically die down at night (or, at least, when the sun is hovering over the horizon) and intensify during the the day.

Of course, you can get a better idea of the intensity of the fires by looking at the Fire Temperature RGB, which is also now on Polar SLIDER:

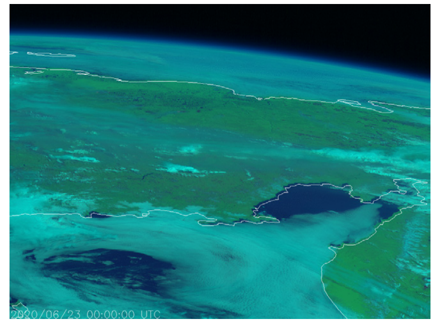
The Fire Temperature RGB is made with VIIRS M-bands (750 m resolution), so the fires don't look as crisp when viewed at the 375 m zoom level. But, since it uses more information from fire-sensitive bands in the shortwave IR, it provides a qualitative estimate of fire intensity, not just the locations of the active hot spots. (As fires become more intense, their color changes from red to orange to yellow to white in the Fire Temperature RGB.)

Other differences to note between the two loops are: the Natural Fire Color RGB shows the reddish-brown burn scars more clearly against a background of green vegetation; it shows the bluish smoke more clearly; and it shows ice in the Arctic Ocean, which appears nearly black in the Fire Temperature RGB. We've covered all of this before, both here and elsewhere. We've also covered the importance of VIIRS' high resolution (compared to geostationary satellites) when it comes to fires. But, it's worth looking at again. Compare the loops above with the view from the Advanced Himawari Imager (AHI) on Himawari-8:

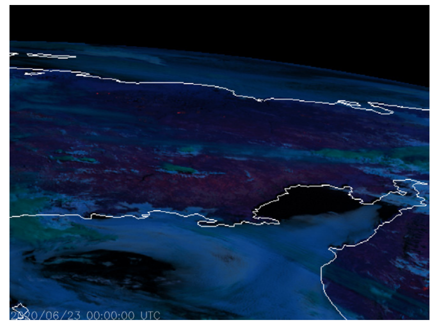
You can find a loop of the AHI GeoColor showing the smoke plumes here.



VIIRS Fire Temperature RGB animation (22-23 June 2020)



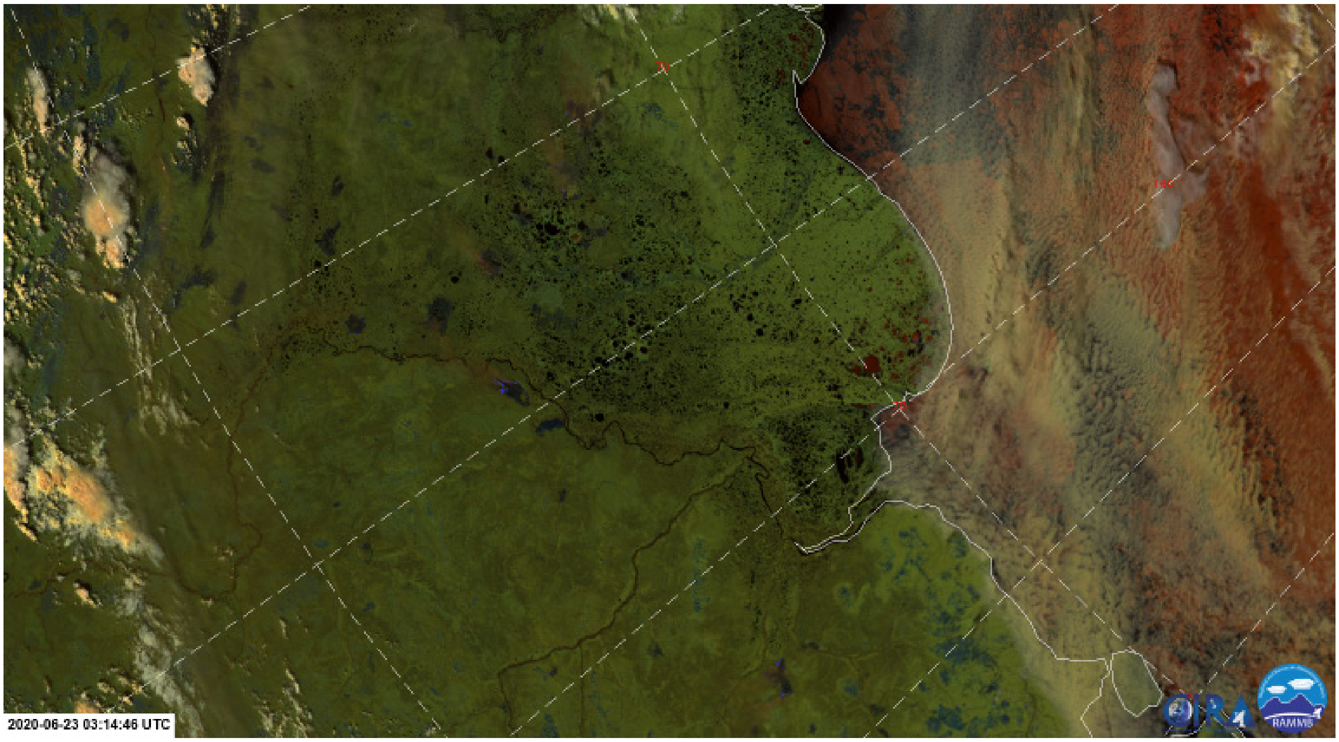
AHI Day Land Cloud Fire RGB animation (23 June 2020)



AHI Day Land Cloud Fire RGB animation (23 June 2020)

It's difficult to identify any fires in the AHI Natural Fire Color/ Day Land Cloud Fire RGB, given the resolution of the 3.9 μm channel is 2 km at the Equator (more like 3-6 km in this part of the world)—not 375 m like the VIIRS version. Hot spots show up better in the AHI Fire Temperature RGB this far north, because this combination of channels makes the background surface appear darker relative to the pixels with active fires in them, whereas the background is brighter in the Natural Fire Color RGB.

Finally, because I mentioned new RGBs for snow on Polar SLIDER, one of them has an interesting artifact when it comes to fires. The Snow RGB originally developed by MétéoFrance utilizes the 2.25 μm band as the blue component, making hot spots appear blue:



VIIRS MeteoFrance Snow RGB composite of channels M-11, M-8 and M-7 (23 June 2020)

Of course, if you're looking for fires, don't reach for the Snow RGB. But, someone, somewhere is going to be looking at the Snow RGB when they spot a couple of bright blue pixels and wonder, "What's going on here?" And, I'm here to say, "Those are moderately intense fires." ❖

WEB FEATURE: AUGUST 19, 2020

NEW DATA PRODUCT WARNS ALASKA PILOTS OF CLOUDS, DANGEROUSLY COLD WEATHER

Jenny Marder
Science Writer, Joint Polar Satellite System
NASA Goddard Space Flight Center

This Maule M7-235B plane is on the Yukon River between the villages of Tanana and Ruby, about 50 miles from the nearest village and weather reporting station. Credits: Copyright Adam White, used with permission.

A new product that alerts pilots to clouds, icy conditions and dangerously cold temperatures is tapping into NOAA's Joint Polar Satellite System's satellites for the critical data it needs.

Starting next month, scientists will start the first round of testing of this product on flight paths over Alaska. The product, which combines cloud measurements from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the Suomi-National Polar-Orbiting Partnership (NPP) and NOAA-20 satellites with atmospheric sounding data from the Advanced Technology Microwave Sounder (ATMS) instrument and pilot reports, is designed to help pilots understand the extent of clouds and hazardous icing conditions on a given flight route.

This product, which is funded by the NOAA Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University, was developed in response to specific needs from the aviation community and a demand for satellite cloud products for aviation weather applications, said Yoo-Jeong Noh, a research scientist with CIRA and one of the product's developers.

"Before this approach, we usually just provided a two-dimensional view of the cloud tops," she said. "But aviation users are always interested in the vertical structure of clouds."

Adam White is one of those users. White is a pilot who lives in interior Alaska and flies to remote areas across the state to deliver supplies to radio stations and to work with youth camps. He flies a Cessna 206, which "stays on wheels," and a Maule M-7 bush plane, which he equips with skis in the winter and floats in the summer.

This Maule M7-235B plane is on the Yukon River between the villages of Tanana and Ruby, about 50 miles from the nearest village and weather reporting station.

"While the tops of clouds are important, I need to know what the clouds are made of, and I need to know how far down they go and how close they are to the ground," he said. "And this is the first time we've had a product that helps us answer these questions."

In some clouds, supercooled droplets turn to ice and accumulate on the windshield, nose, propeller and wings of the plane, changing the shape of the airfoil and the weight of the aircraft, said Tom George, a pilot and the Alaska regional manager for the Aircraft Owners and Pilots Association.

"Ice is a serious issue for pilots, so they either need to avoid it or have the proper equipment to deal with it," George said.

Icy conditions makes pilots of small planes especially nervous, White said.

"The shape of the wings is critical for an aircraft to fly," he said. "If you change that shape, it's not generating lift in the same way. And you can get to the point where they can't generate lift at all. That's a severe case, but it can happen frighteningly quick."

In the lower 48, more information is available on flight conditions, especially on busy flight routes. But in Alaska, where colder conditions persist throughout the year, and where there are fewer weather radars and limited surface observation data, satellite data are especially useful. Especially from satellites like Suomi-NPP and NOAA-20, which, because of their polar orbit, cross over Alaska multiple times in a day with a 50-minute delay between the two.

The product has been in development for about two years, but recent updates were made that include an expanded temperature range, adaptations for users with color blindness, and an updated user guide.

The next step is a demonstration phase, which involves sending the product to a large group of pilots for testing and feedback.

In the meantime, White, a government liaison for the Alaska Airmen's Association and a participant in the JPSS program's aviation initiative, said he's already using the product to inform flight decisions.

"I've made decisions not to fly on a particular day because of what this product has shown me, even in the testing phase," he said. "It's saved me from potential problems, whether it's icing or clouds down to the ground that I wouldn't be able to navigate."

The Joint Polar Satellite System (JPSS) series of satellites enable forecasters and scientists to monitor and predict weather patterns with greater accuracy and to study long-term climate trends by extending the more than 30-year satellite data record. JPSS is a collaborative program between the National Oceanic and Atmospheric Administration (NOAA) and its acquisition agent, the National Aeronautics and Space Administration (NASA). The Suomi NPP satellite served as the bridge between NASA's Earth Observing System of satellites and JPSS. For the JPSS-2, -3 and -4 satellites, NOAA is responsible for managing and operating the JPSS program, and developing the ground segment, while NASA is responsible for developing and building the JPSS instruments, spacecraft, and providing launch services. ❖

WEB FEATURE: AUGUST 27, 2020

JPSS SATELLITES PROVIDE UNIQUE PERSPECTIVE OF HURRICANE LAURA

Jenny Marder
Science Writer, Joint Polar Satellite System
NASA Goddard Space Flight Center

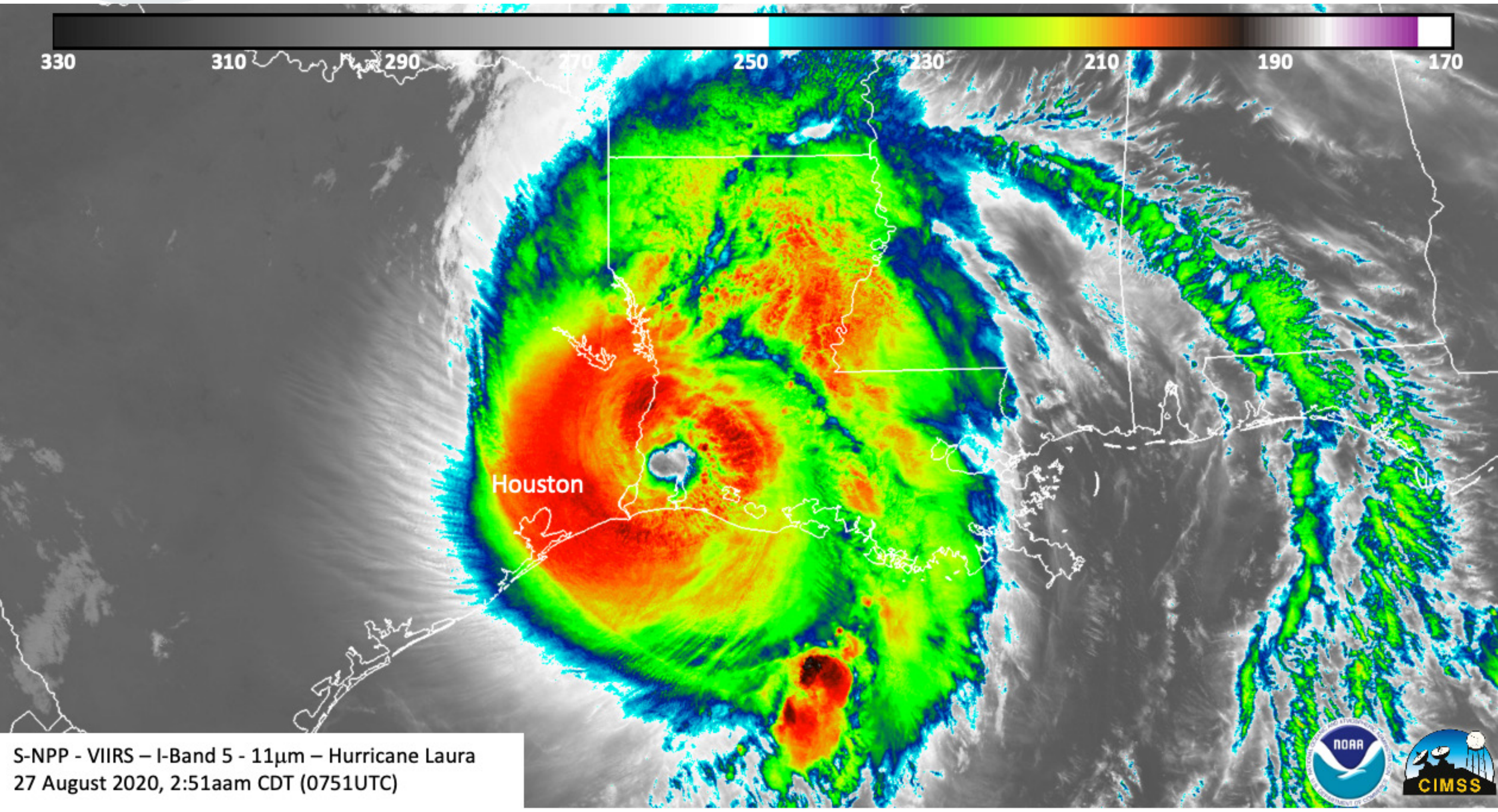
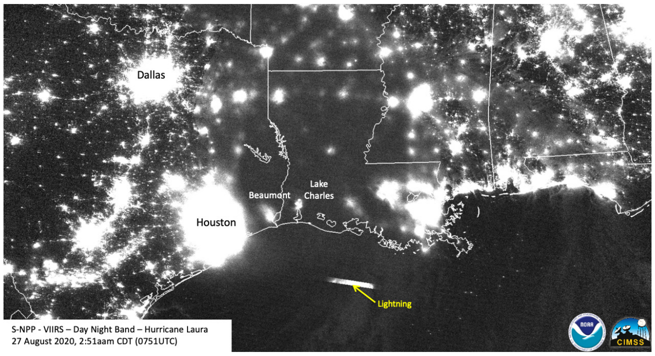


Image Credit: CIMSS/NOAA

About two hours after Hurricane Laura made landfall Thursday morning, hammering the Louisiana and Texas coasts with 150 mile-per-hour winds and an "unsurvivable" storm surge, the VIIRS instrument on the Suomi-NPP satellite captured this image of the storm. The infrared image shows intense circulation and a clearly defined eye just north of the Gulf coastline and east of the Texas border.

This corresponding nighttime Day-Night Band image below, also captured by VIIRS at 2:51 am CDT, shows a lightning streak in the Gulf and some lights still on in parts of Lake Charles, LA., and Beaumont, TX. But more than half a million people in Louisiana and Texas were without power Thursday afternoon, according to PowerOutage.us, which tracks outages across the United States from various power utility companies.



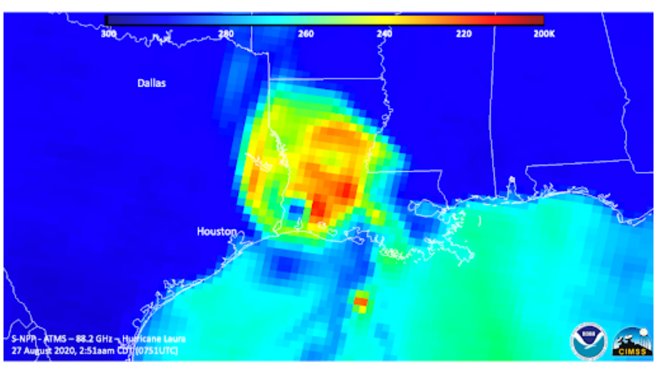
By 1 PM, Laura had been downgraded by the National Hurricane Center to a tropical storm, with maximum sustained winds at 65 miles per

hour and water levels still elevated along the Gulf Coast. It was marching northward at 15 miles per hour across Northern Louisiana, expected to weaken to a tropical depression this evening and move across Arkansas tonight.

Since slamming into the coast, the storm has destroyed buildings, blown windows out from high rises, downed trees and power lines, and ripped the top off a bridge. At least four people have died, all related to falling trees, said Louisiana Gov. John Bel Edwards of Louisiana during an afternoon press conference.

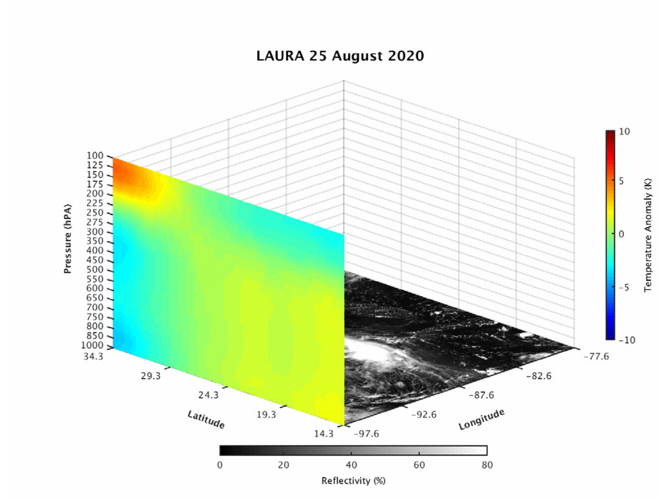
Firefighters are battling a chemical fire caused by storm damage at a facility in Westlake, La., and the NEXRAD Doppler radar at the National Weather Service office in Lake Charles is down, according to images shared on social media, which showed that the dome and radar had been torn from the tower.

The Advanced Technology Microwave Sounder (ATMS) on Suomi-NPP, provided "a glimpse into the inner structure of the storm Thursday morning, showing well-defined circulation with convection completely surrounding it, with the coldest cloud temperatures centered on the northeast side of the eye," according to William Straka III, a researcher for the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison.



This is also where the most intense rain rates were found by the Microwave Integrated Retrieval System (MiRS) Rain Rate product, which is derived from ATMS, and part of the Climate Prediction Center morphing method (CMORPH2), a NOAA product that provides precipitation estimates from satellites.

The following animation shows the temperature differences between the core of the hurricane and its surrounding atmosphere, as observed by ATMS on the Suomi-NPP and NOAA-20 satellites as the storm gathered strength and intensified. This kind of warm core is typical to the structure of a hurricane, as described in this article from the journal Geophysical Research Letters. The larger the area of the core and the higher the temperature difference between the warm core and the area surrounding it, the more precipitation is produced.



The storm surge was not as severe as anticipated, but its outer band is still powerful and pushing into Corpus Christi, Texas, said Gov. Edwards during the press conference.

"We are getting reports now that water continues to rise," he said. "Not as quickly as we had feared. But what I'm trying to tell people is, in your particular area, you might not have seen the water at its highest yet, so be cognizant of that." ❖

WEB FEATURE: SEPTEMBER 3, 2020

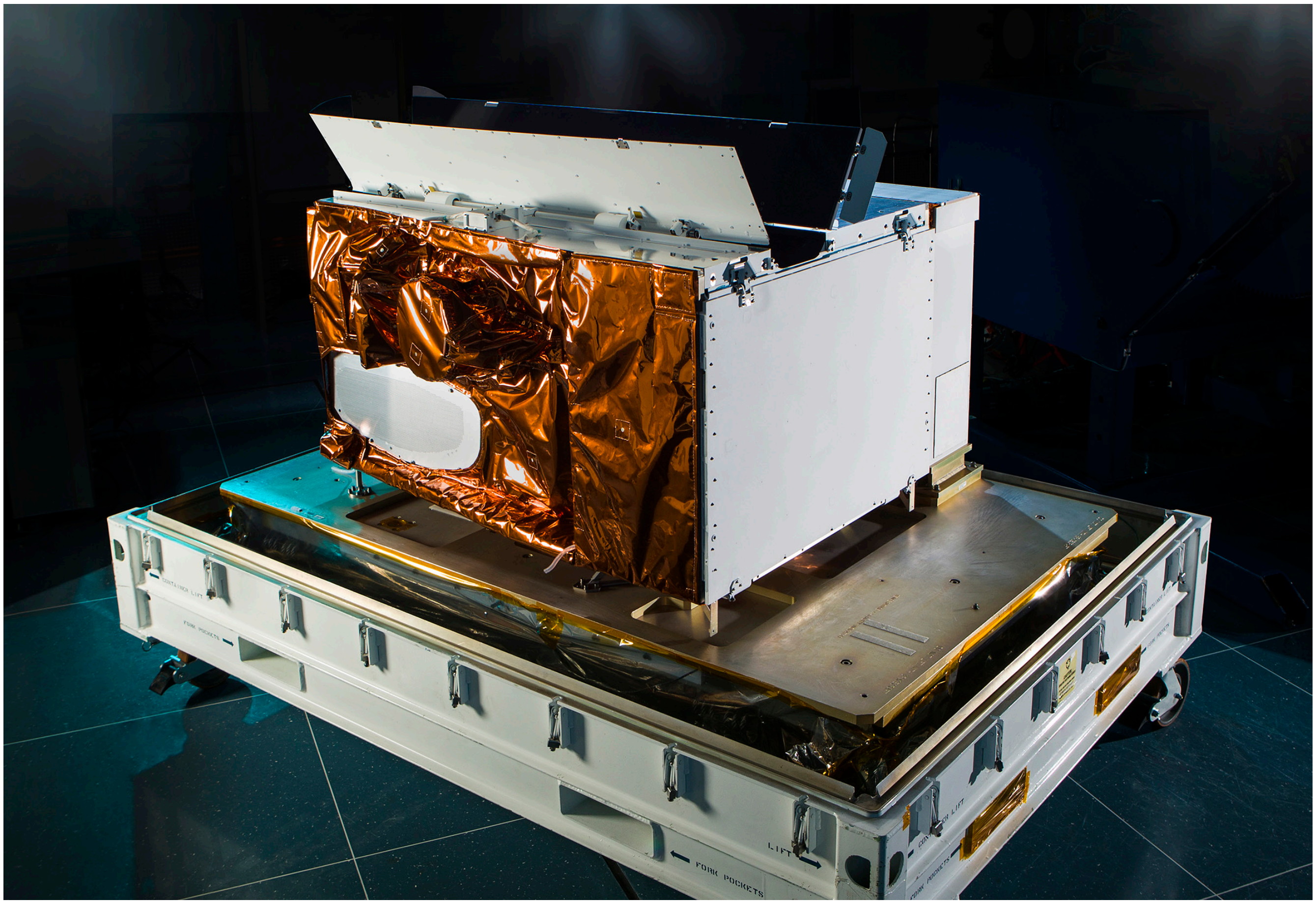
FIRST INSTRUMENT FOR JPSS-2 SATELLITE ARRIVES FOR INTEGRATION & TEST

Ashley Hume
Joint Polar Satellite System Program
NASA Goddard Space Flight Center

Engineers unpack the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument from its protective shipping container at Northrop Grumman's spacecraft facility in Gilbert, Arizona. Credit: Northrop Grumman.

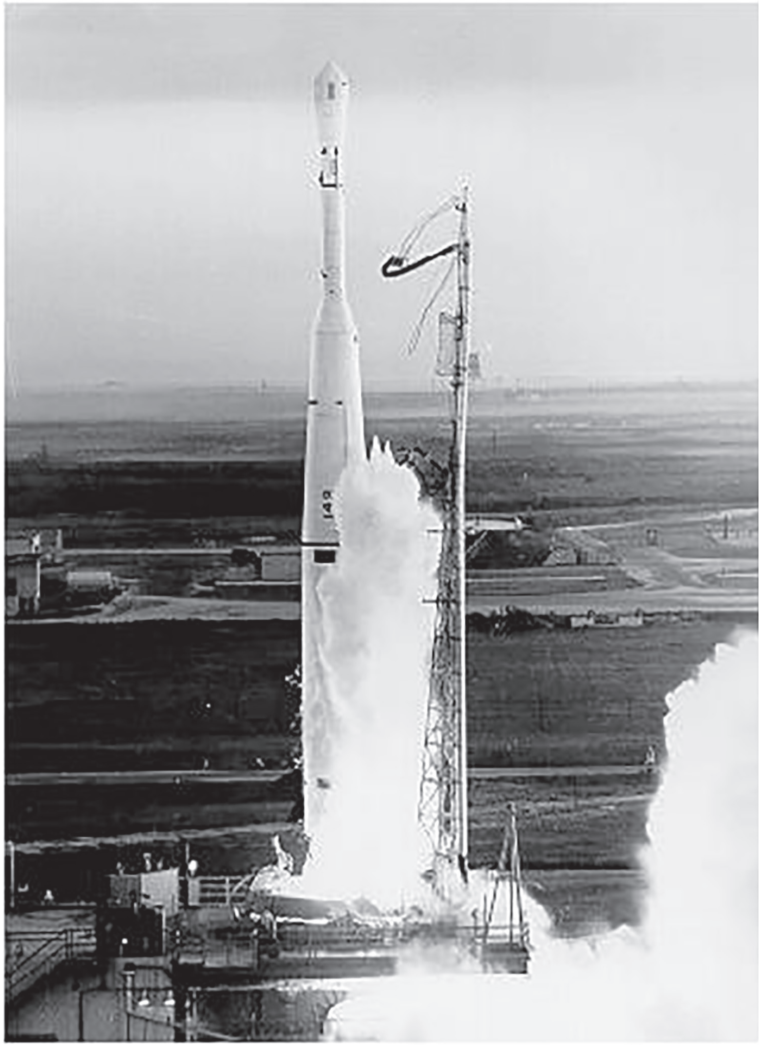
The Visible Infrared Imaging Radiometer Suite (VIIRS), the first instrument for NOAA's next polar-orbiting weather satellite, arrived at Northrop Grumman's spacecraft facility in Gilbert, Arizona, last week to be integrated with Joint Polar Satellite System 2 (JPSS-2).

The third satellite of the JPSS series, NOAA's JPSS-2 is preparing for launch in 2022 to continue the critical flow of weather and environmental data to users like the National Weather Service, the National Hurricane Center and more. The VIIRS instrument is the eyes of JPSS. It produces infrared images of hurricanes; identifies snow and ice cover, clouds, fog and dust; and helps locate and map wildfires. Its Day-Night Band, the satellite's eyes at night, can distinguish between city lights, moonlight, lightning, and auroras.



The VIIRS instrument photographed prior to shipping. Credit: Raytheon Intelligence & Space

A collaboration between NOAA and NASA, JPSS is the United States' most advanced series of polar-orbiting environmental satellites. It provides significant technological and scientific advancements for severe weather prediction and environmental monitoring. These data are critical to the timeliness and accuracy of forecasts three to seven days in advance of a severe weather event. ❖



Front: A collage of historic photographs and images from Polar Orbiting Environmental Satellites beginning with the first image from the Television Infrared Observation Satellite (TIROS) in 1960.

Back: Images of low-Earth orbit weather satellite launches. On the left, TIROS-1 lifts off from Cape Canaveral Space Launch Complex 17 on April 1, 1960 (credit: NASA), and on the right, NOAA-20 lifts off from Vandenberg Air Force Base on November 18, 2017 (credit: JPSS).

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