JPSS

SCIENCE SEMINAR ANNUAL DIGEST 2019

ARTICLES + FEATURES

from the Nation's new generation polar-orbiting operational environmental satellite system

JOINT POLAR SATELLITE SYSTEM PROGRAM · NOAA · NASA · JPSS

2019

JPSS SCIENCE SEMINAR ANNUAL DIGEST

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WEB FEATURES

ANNUAL DIGEST CONTRIBUTIONS

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FROM THE PROGRAM DIRECTOR

As 2019 draws to a close, and as we look toward 2020 and beyond, we have so much to be thankful for here at JPSS.

Six years ago, the Government Accountability Office (GAO) pointed to a potential gap in weather satellite coverage that could have threatened the accuracy and integrity of the nation's weather forecasts. Earlier this year, on March 6, 2019, the GAO removed mitigating gaps in weather satellite data from the high-risk list because of the launch of JPSS-1 (now NOAA-20) and the significant progress in reducing and mitigating risk for our future launches.

The JPSS satellites were built on the success of their predecessor programs, and they continue to represent the significant technological and scientific advances in observations used for severe weather prediction and environmental monitoring. After more than two years in orbit for NOAA-20 and more than eight for the Suomi National Polar-orbiting Partnership (Suomi NPP), both satellites continue to provide global state-of–the art atmospheric, oceanographic, and environmental data. The combination of these two satellites in the afternoon orbit flying 50 minutes apart is a great opportunity to provide even more data and products to users as they respond to changing environmental conditions. It has allowed for lower latency data and increased global coverage both for numerical weather, forecast applications, and emergency response.

The JPSS baseline continues to consist of four instruments: advanced microwave and infrared sounders (CrIS, ATMS) which are critical for weather forecasting; a leading-edge visible and infrared imager (VIIRS) critical to data sparse areas such as Alaska and needed for environmental assessments such as snow/ice cover, volcanic ash, forest fires, droughts and surface temperature; and an ozone sensor (OMPS) primarily used for global monitoring of ozone and input to weather and climate models. The accuracy of the nation's short and medium-range weather forecasts have significantly improved with data from CrIS and ATMS.

JPSS-2 is scheduled to launch in 2022. The spacecraft is mostly complete, awaiting deliveries of the flight Antenna Pointing Assembly (APA) for the KA-Band antenna and the flight Payload Interface Electronics (PIE). The spacecraft completed initial electrical power systems and propulsion functional tests. Comprehensive performance test dry-runs have started. And Spacecraft Instrument Interface Simulator (SIIS) testing has been completed with the VIIRS and OMPS engineering model instruments, which successfully tested both the 1553 and spacewire databus interfaces.

The VIIRS instrument for JPSS-2 is ready for shipment to the spacecraft and is in safe storage with periodic aliveness testing performed to exercise components and distribute mechanism lubrication. Raytheon held schedules and completed the JPSS-2 VIIRS instrument 33 days earlier than its April 30, 2018, contractual date.

The JPSS-2 ATMS completed thermal vacuum testing on December 2, 2019, and is on track for delivery in February 2020. The spacecraft's CrIS instrument is in thermal vacuum testing that should be completed in January 2020 and remains on track for delivery in March 2020. OMPS completed Pre-Shipment Review in June 2019 and is safely in storage at Ball Aerospace and Electronics Corporation.

JPSS-3 and -4 spacecraft subsystem procurements are underway as are the builds of the ATMS, CrIS, OMPS, and VIIRS instruments for each spacecraft. The VIIRS for JPSS-3 is well along in its build cycle and is expected to be ready for the start of environmental testing in April 2020. The JPSS-3 spacecraft harness has been completed and is ready for bakeout cleaning prior to integration onto the JPSS-3 structure, which is also completed. The spacecraft have planning launch readiness dates of September 2024 and December 2026 respectively.

Global collaboration is vital to JPSS. As a result, the program continues to maintain 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.

For the first time, the Joint Satellite Conference (JSC) merged three unique satellite conferences—the NOAA Satellite Conference (NSC), the American Meteorological Society's (AMS) Conference on Satellite Meteorology, Oceanography and Climatology, and the Meteorological Satellite Conference of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)—into one major event in Boston, from Sept. 30–Oct. 4, 2019.

The theme aptly titled: Shaping the Future Together—Providing Observations for the Coupled Earth System embodies the importance of working together to accomplish a global mission.

JPSS also works closely with its user community through the Proving Ground and Risk Reduction (PGRR) Program to identify opportunities to maximize the operational application of current JPSS capabilities. The Program remains robust, and the articles in this digest capture examples of how our users are putting these capabilities to use. For every example provided here, there are many more that have yet to be documented.

I offer my thanks for the many contributions in this digest, and to our JPSS science team and community for their outstanding contributions to this program. I hope you enjoy the 2019 Science Digest. As we celebrate the achievements of JPSS, we are not resting on our laurels. There is plenty more tough work ahead to ensure that our successes assure a bright future for our support to stakeholders, the nation and the world. The best is yet to come!

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FROM THE SENIOR PROGRAM SCIENTIST

The most important function of polar orbiting weather satellites is to feed Numerical Weather Prediction (NWP) models with three-dimensional structures of atmospheric temperature and moisture. These measurements inform three- to seven-day weather forecasts and provide important information on severe weather, which is critical to the protection of life and property.

Almost 90 percent of all the input data used in NWP models comes from polar orbiting satellites. These satellites also provide visible, infrared, and microwave imagery. In high latitude areas like Alaska and other regions near the poles, overlapping imagery swaths provide additional views for situational awareness. Moreover, for data-sparse areas, particularly oceans and the polar regions, polar orbiting satellites continue to be the most important source of information. The polar orbiters also tell us about ozone, aerosols, ice, volcanic ash, wildfires, floods, droughts, vegetation health, algal blooms, and sea surface temperature.

The 2019 JPSS Science Digest brings you a compilation of feature stories inspired by talks from our monthly science seminars, along with news items and highlights from our website that underscore the importance of JPSS for key applications. For more information on our web features please visit http://www.jpss.noaa.gov/.

Weather forecasting is considered a public good and is critical to protecting lives and property, and enhancing the national economy—helping build a Weather-Ready Nation—so it is vital for JPSS to continue to provide the most up-to-date and accurate forecasts possible in the years to come. JPSS has two hard-working next generation satellites in orbit, which have been providing operational continuity and improved capability via critical datasets needed for both weather forecasting and environmental assessments.

To maintain this public good, it is necessary to integrate data globally, from multiple observations, platforms and nations. We already are doing this in the Proving Ground and Risk Reduction program (PGRR), which now contains key data products and applications from other observing systems, including those in the geostationary orbit, such as GOES-R. Consider flooding, for example—one of the most frequent natural disasters, which severely impacts communities worldwide. Next generation satellites, including JPSS, GOES-R and HIMAWARI (Japan) for the very first time have spectral bands for inundation mapping covering large geographic areas with excellent temporal coverage. These satellites also have real-time distribution capabilities through direct broadcast and/or cloud services allowing fast generation and utilization of disaster products for timely critical decision making. We have leveraged these groundbreaking technologies to create products that have enabled the expansion of existing activities and initiation of new activities in new markets. While the higher spatial resolution (375m) and daily global data coverage imagery from JPSS remains critical for flood mapping, the latency is 90 minutes and visible imagers are easily affected by clouds and cloud shadows due to the data availability once a day in mid to low latitudes. Conversely, imagery from the new-generation geostationary satellites such as the GOES-16/Advanced Baseline Imager (ABI) and Himawari-8/AHI are available every 5 to 15 minutes. The high temporal resolution allows more clear-sky views for flood mapping, although the spatial resolution is relatively low at 1km. Our Visible Infrared Imaging Radiometer Suite (VIIRS) flood mapping application area now integrates data from the GOES-R series ABI to provide users with integrated JPSS and GOES-R flood maps.

This combined product enables us to provide flood maps in near real time to emergency managers on their timescale. This new integrated LEO-GEO flood mapping (inundation) service is available through the University of Wisconsin (UW)'s RealEarth webpage and IPhone/Android app. The service is also provided using the NOAA/UW Community Satellite Processing Package (CSPP) installed at X-band direct readout sites collecting data from JPSS polar orbiting satellites in real-time. In the United States, our major users include the National Weather Service (NWS) and the Federal Emergency Management Agency (FEMA). Internationally, NOAA provides flood maps when the International Disaster Charter is activated.

Having two satellites in the same orbit ensures that data for forecasting and environmental monitoring will still be available should one of the satellites experience a partial or total failure. In March, radiation damaged the midwave infrared signal processor on the Cross-track Infrared Sounder (CrIS). To avoid a data gap, our scientists' fast-tracked similar data to the National Weather Service (NWS) from the NOAA-20 satellite, which flies 50 minutes ahead of Suomi NPP, and has an identical CrIS instrument. Like all of the JPSS instruments and much of the spacecraft, CrIS has redundant parts. It contains a "Side 2," a fully functional backup set of electronics. A switch from the damaged side of the sensor to Side-2 returned the instrument to full capability.

For years, we took pride in our ability to provide data and products according to the detailed level-one requirements defined early in the program acquisition. And we still do. However, our data and products are useful only as far as they meet our users' needs. In 2014, we shifted the paradigm when our Proving Ground and Risk Reduction (PGRR) Program transitioned from individual project management to "User Initiatives." This shift meant moving from meeting the defined user requirements to helping users tailor JPSS capabilities to their unique mission needs. It also redefined program success based on the effectiveness of the operational application of JPSS data and products by its key stakeholders.

The impacts of two JPSS satellites in the same orbit, separated by 50 minutes, with equator crossing times of the ascending nodes at 13:30, have enabled better monitoring of the changing environment. In data sparse areas such as the polar regions, in addition to monitoring features such as ice and detecting wildfires, forecasters are now better able to view the weather in motion. The ocean covers more than 70 percent of our planet, yet it is one of the most sparsely observed parts of the globe for weather forecasting purposes. Global sampling of the ocean is feasible only from earth-observation satellites. They provide more data over oceans than would be possible to obtain solely from conventional sources. The Oceans and Coasts initiative user community identified needs for multi-sensor data sets, long-term time series datasets and higher level, value-added products for both near real-time and long-term time series to support a broad range of scales from small local watersheds to ocean basins. Data from the JPSS satellites are helping scientists' asses ocean temperature and biological productivity, sea levels, ocean currents and waves, monitor the health of ecosystems and coastal habitats, and detect harmful algae blooms.

In another highlight, we are this year marking the 60th anniversary of TIROS-1, the first civilian weather satellite, with a special anniversary series. This includes a series of seminars, which focus on the legacy of weather satellites. The goal of these seminars is to show how the first weather satellites paved the way for todays' satellite generation, and how JPSS carries on that powerful legacy. This year's program included the history of:

- Atmospheric sounding.
- Satellite microwave sounding, from its beginnings on early research satellites through its transition to operational satellites, to today's central role in numerical weather prediction and climate studies, as well as a peek at the future of microwave sounding.

- Ocean remote sensing in the U.S., and the long journey to operational satellite oceanography.
- Satellite observations of clouds, including the integration of high temporal resolution animations from geostationary satellites, the calibration with high spectral resolution IR.

The presentations attracted large crowds and generated many questions and healthy discussions among attendees.

In other highlights, a validated maturity review meeting for the JPSS reprocessed sensor data record (SDR) was held in September at the NOAA Center for Weather and Climate Prediction (NCWCP). This review meeting was a major milestone for releasing the reprocessed SDR data from Suomi NPP for use in a variety of applications in support of NOAA's weather and climate mission goals. The reprocessing allows scientists to quantify the SDR quality in the time dimension, and also allows for their use in environmental applications including developing climate data records, identifying NWP model errors, improving climate re-analyses as input datasets, and supporting the programs which define satellite reference standards such as Calibration/Validation (Cal/Val) and the Global Space-based Inter-Calibration System (GSICS).

Following a request from forecasters at the National Weather Service (NWS), we created the JPSS Advocacy Channel with a goal to provide timely and short training videos that are accessible to all. The channel contains a catalog of training materials relative to polar orbiters under two umbrellas: A YouTube Channel that contains videos describing different JPSS topics (NUCAPS Soundings, VIIRS, Total Precipitable Water, etc.), and a website with links to other training materials and data sources. The channel provides in mostly video format easy-to-follow instructions on how to access data from polar orbiters, and how those data can be used and understood.

The examples above are just a few of the many achievements we celebrated this past year. As we move into 2020 and toward our next mission spacecraft we will continue reporting our accomplishments, challenges and opportunities and hope that they spur dialog on new applications that leverage JPSS capabilities.

I would like to acknowledge all the hard work that has gone into making this digest possible. Thank you to our federal and private sector support staff, and numerous partners whose contributions and dedicated efforts make these digests a big success. I want to acknowledge Julie Price for the science seminar articles, Jenny Marder for the feature articles included in this document, and Joshua Brady, our expert graphic designer, for always giving us a distinct and bold product. I would also like to give special thanks to my Program Science staff, JPSS Communications, and the entire JPSS staff, for their ongoing support in the development of this digest; and to the sources of material. Most importantly, thank you to our readers. It is through our collective efforts that we can present this information to you. I hope you enjoy reading this digest and that you find it useful.

The entire Program Science efforts would not be possible without the outstanding interactions between the JPSS Program, STAR, NASA, the NOAA cooperative institutes, government and international partners, government contractors, and of course the user community.

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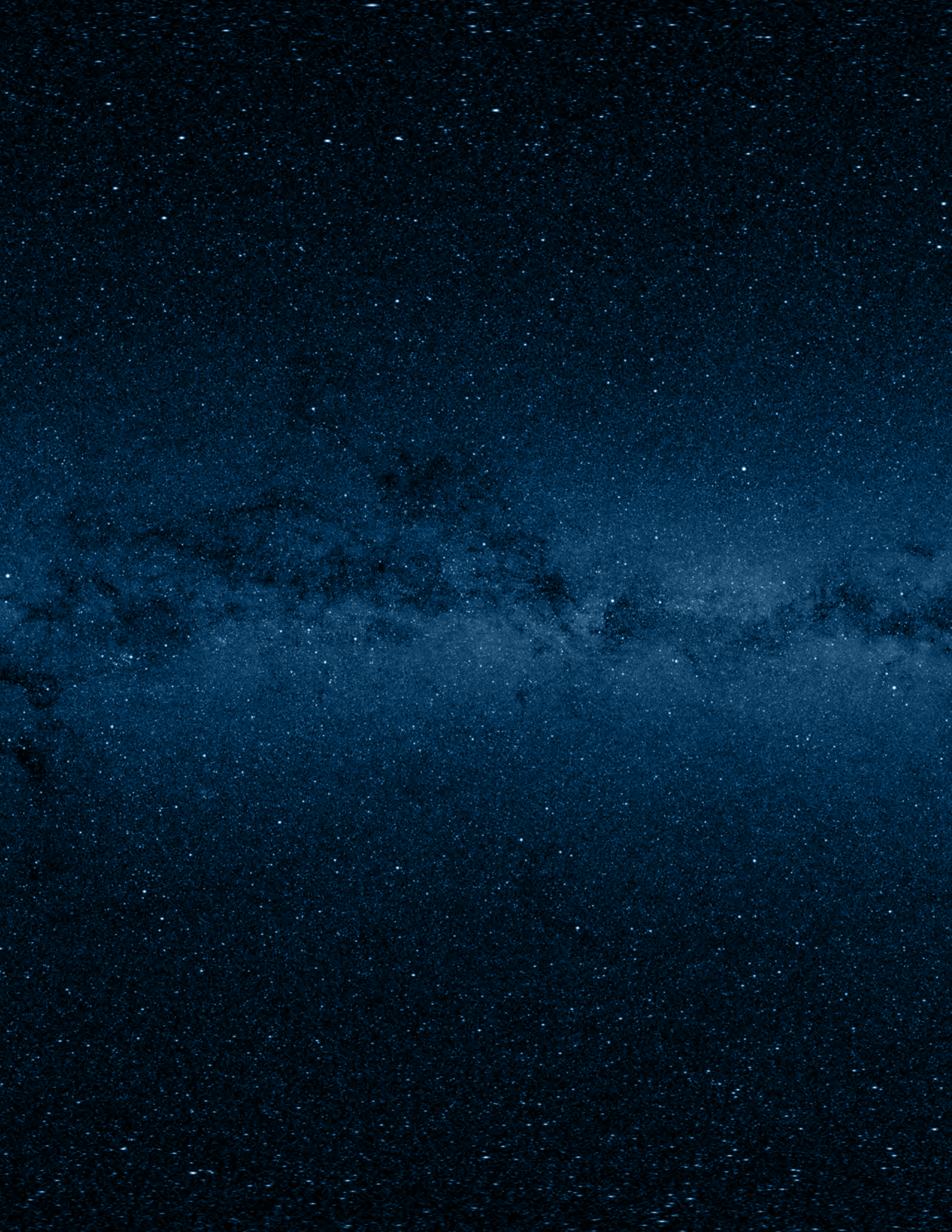
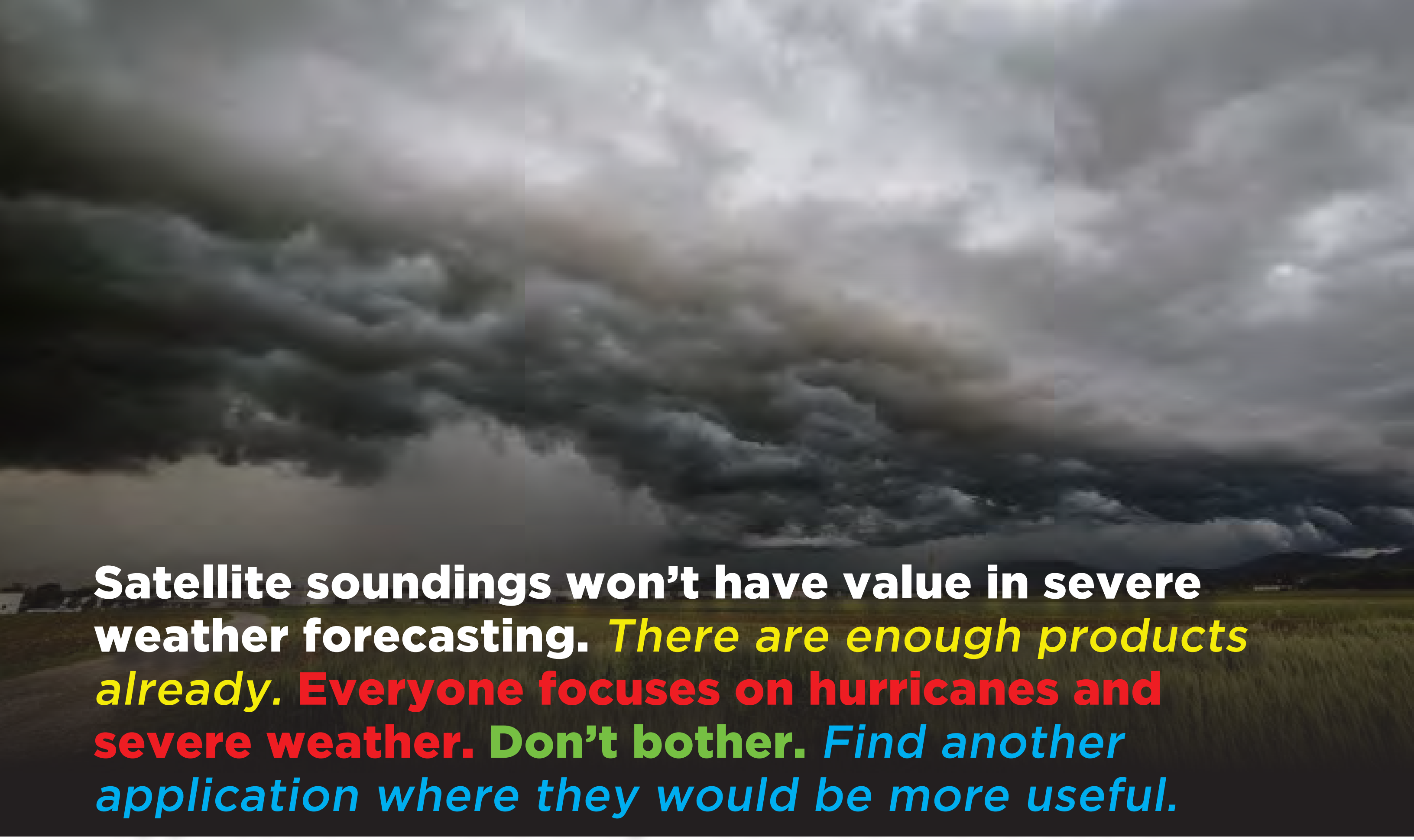


FEATURED ARTICLES

A PLACE FOR SATELLITE SOUNDINGS IN SEVERE WEATHER FORECASTING

The information in this article is based, in part, on the October 15, 2018 JPSS science seminar presented by Nadia Smith, Science and Technology Corporation, Columbia Maryland. It features work being done by Emily Berndt, Kris White, Jack Dostalek, and Chris Barnet.



Satellite soundings won't have value in severe weather forecasting. *There are enough products already.* Everyone focuses on hurricanes and severe weather. Don't bother. *Find another application where they would be more useful.*

The term "atmospheric soundings" refers to vertical profiles of atmospheric features such as temperature and moisture as well as wind and some trace gases. For the greater part of the 20th century, the primary source of such soundings was radiosondes, which are instruments tied to weather balloons that make and transmit measurements as the balloon ascends, resulting in a vertical profile. In recent decades, Numerical Weather Prediction (NWP) models have routinely used atmospheric soundings retrieved from infrared and microwave instruments on Earth-orbiting satellites.

Modern-era space-borne sounding instruments on polar-orbiting platforms, such as the Cross-track Infrared Sounder (CrIS) on satellites in the Joint Polar Satellite System (JPSS)[1], provide radiance measurements from which profiles of atmospheric temperature and moisture can be retrieved. These measurements are taken with very high spectral resolution in thousands of spectral channels, two orders of magnitude higher than the number of channels on the Advanced Baseline Imager (ABI) of the Geostationary Operational Environmental Satellite system (GOES) series of satellites. The higher the spectral resolution, the greater the sensitivity to atmospheric parameters along the vertical column from the earth's surface to the top of the atmosphere. Hyperspectral sounders facilitate the accurate retrieval of atmospheric profiles at multiple pressure layers. At first, these hyperspectral radiance measurements were heralded exclusively for their breakthrough impact on the quality and accuracy of global assimilation and NWP models, but now they are increasingly valued for their retrieved sounding observations in nowcasting scenarios. In 2006, NOAA implemented the NOAA-Unique Combined Atmospheric Processing System (NUCAPS) to retrieve high vertical resolution satellite soundings from the Infrared Atmospheric Sounding Interferometer (IASI) instrument on NOAA's European partner, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) polar orbiting spacecraft Meteorological Operational-A (MetOp-A). Today, NUCAPS generates wide swaths of soundings with near global coverage twice a day (night- and daytime orbits) from instruments on four platforms, Suomi-NPP, NOAA-20, MetOp-A and MetOp-B. NUCAPS retrieves vertical profiles of temperature, moisture, ozone and other trace gases, as well as clouds and surface properties, from spaceborne infrared and microwave instruments. It is based on the NASA AIRS science team algorithm and epitomizes the strength that comes from a partnership between NASA and NOAA. The availability of NUCAPS soundings within sufficient timelines is facilitating their use in mesoscale weather and nowcasting applications, such as aviation and severe weather forecasting. But this wasn't always the case. For years, forecasters were skeptical of satellite soundings because they expected them to look like radiosondes.

This feature story will briefly describe how atmospheric measurements from hyperspectral sounders onboard low-Earth orbiting satellites such as NOAA-20 and Suomi NPP can add value to severe weather forecasting. It will focus on how collaborative efforts in the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) Program's Sounding initiative led to a breakthrough in how satellite soundings are both perceived and used within the National Weather Service. The PGRR Sounding Initiative brings researchers, developers and forecasters together to clarify product requirements, refine product design and study their application in complex weather scenarios. Fostering interdisciplinary collaborative partnerships between research and operational communities, the PGRR Sounding Initiative plays a key role in building a knowledgeable user base and developing robust operational applications with satellite sounding products that address real-world requirements. Without such partnerships, new products might have remained abstract concepts that never bridged the gap between development and useful application.

IS THERE A PLACE FOR SATELLITE SOUNDINGS IN SEVERE WEATHER FORECASTING?

Hyperspectral infrared sounding instruments measure emitted radiance at the top of the atmosphere with several thousand spectral channels, from short-wave to long-wave infrared. These measurements contain information about temperature, cloud amount and cloud height as well as concentrations of water vapor and other trace gas molecules at multiple pressure levels. With 2,200 km wide swaths of measurements from pole-to-pole, the retrieved NUCAPS soundings not only contain information about the vertical atmospheric state within each footprint, but visualized together, they depict horizontal and vertical gradients. This observing capability is unique to satellite soundings. Radiosondes measure localized conditions, which is the atmospheric state in direct contact with the instruments, while satellite soundings observe the atmospheric state in kilometer-wide columns from the top of the atmosphere to the surface. Even though there is a global effort to standardize the launch time and format of radiosondes in a coherent network of observations, this network is limited to land, and too sparse to be visualized as horizontal maps of thermodynamic conditions. It is here that satellite soundings add unique capability. Forecasters can use NUCAPS sounding observations to verify NWP models.

In 2014, NUCAPS soundings became available within the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS). AWIPS gives forecasters real-time access to most of the data they need for accurate weather forecasts. With NUCAPS in AWIPS, forecasters gained real-time operational access to satellite soundings for the first time. AWIPS allows forecasters to visualize NUCAPS sounding observations as either individual skew-T diagrams or as horizontal and vertical cross-sections of the atmosphere to improve their situational awareness of the three-dimensional atmosphere. Despite the perceived value of satellite soundings, forecasters were initially hesitant to adopt them into their decision-making processes. This is partly because they expected these sounding observations to capture the fine-scale vertical structure they were used to seeing in radiosondes. NUCAPS was a new type of observation and not known or trusted yet. The opinions captured in the introductory image reflect the thinking of that time. Members of the Sounding initiative were able to overcome some of these adoption barriers by building a new understanding of satellite soundings in applications that exploit their unique observing capability to complement traditional sounding sources.

THE SOUNDING INITIATIVE: UNCOVERING AND FOSTERING A NICHE FOR SATELLITE SOUNDINGS IN SEVERE WEATHER FORECASTING

Retrieved atmospheric sounding products have always had the potential to meet forecaster needs, but initially failed to live up to their potential mainly due to a large gap in their perceived versus their real value. It was only when product developers and operational forecasters came together within the PGRR Sounding Initiative that they realized they were talking past each other. To overcome the misunderstandings in the PGRR Sounding Initiative, researchers focused on addressing a few basic questions: "What type of information do you need?" and "What exactly do we measure from space?" Today the Sounding initiative is a productive collaboration between many stakeholders including forecasters, data product experts, as well as research and operational scientists. According to Dr. Nadia Smith, a Subject Matter Expert (SME) in satellite sounding observations, members of the Sounding Initiative "talk with each other about what is needed, where something is needed, if sounding products are suitable, and how products or data flows could be improved to better serve the weather community."

A WINDOW OF OPPORTUNITY FOR NUCAPS

Forecasters have difficult jobs in a fast-paced and stressful environment that requires products be delivered in the simplest, most efficient way, while still providing the maximum information content.

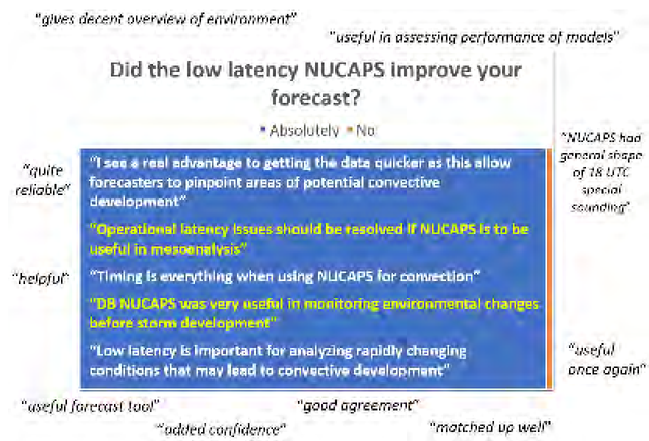
Forecasters assess the pre-convection environment to determine potential for severe storm development. The sooner they can pinpoint when and where a storm may develop, the sooner they can issue weather watches and warnings. There are certain indicators in the thermodynamic environment, such as lapse rates and Convective Available Potential Energy (CAPE) that characterize atmospheric convective instability and serve as early indicators of storm potential. AWIPS derive such indices from in-situ (radiosondes), modelled (NWP), and satellite soundings (NUCAPS). Each of these sources contribute unique capabilities that complement each other and help complete forecasters' conceptual models about evolving weather. Radiosondes are accurate, localized estimates, NWP are model forecasts and NUCAPS observations depict gradients of instability that help pinpoint where storms could develop.

The 12-hour time difference between conventional radiosonde soundings sometimes requires gap filling information such as special launches. Suomi-NPP NUCAPS arrives on a forecaster's desk between 1800–2000 UTC, providing supplementary information about severe weather potential between the 0000 UTC and 1200 UTC radiosonde launches. With NUCAPS now in its native forecasting and display toolkit, or AWIPS-II environment, "it is like having hundreds of 1800 UTC radiosondes" (Smith and Nietfeld, 2018). As 2,200 km wide swaths from pole-to-pole, NUCAPS soundings also capture spatial gradients. Based on feedback from forecasters, a new visualization mode was developed to display NUCAPS sounding information as horizontal gridded surfaces at multiple pressure levels from the surface to the tropopause. Convective parameterization is used in NWP to calculate the collective effects of sub-grid scale convective clouds as a function of larger scale processes. NUCAPS differs from NWP models in that its soundings are not constrained by convective parameterization and have low spatial correlation, so they can observe sudden sharp gradients typically smoothed over in NWP models.

"What we start to see now is that **NUCAPS observations help forecasters determine what is about to happen next** by greatly improving their situational awareness of instantaneous conditions and localized feedbacks often not captured by NWP systems in real-time," Smith says. For example, a biomass burning plume may change the local atmospheric state and only real-time observations could capture this change.

STAKEHOLDER BUY IN

The afternoon overpass of Suomi-NPP is valuable to forecasters because it occurs at 1800–2000 UTC and falls between the standard 0000 UTC and 1200 UTC time when radiosondes are launched. It is also the time when convective initiation typically occurs in Spring and Summertime. Taking measurements from space at a useful time is one thing, getting the data products to forecasters desks fast enough to maintain relevance is another. Data from Suomi NPP downlinks to the JPSS ground system antenna once per orbit at Svalbard, Norway (near the North Pole). This means that the satellite completes a full orbit, which takes about 90 minutes, before its measurements are downlinked and distributed to NOAA processing centers. Following the centralized operational NOAA pathway that distributes data to AWIPS via the Satellite Broadcast Network, NUCAPS becomes available to forecasters anywhere between two and four hours after the measurements were made from space. This is too late! Forecasters need NUCAPS soundings to help characterize the pre-convective environment, to fill data gaps in the sparse radiosonde network and pinpoint where severe storms may develop. Radiosondes typically make it into AWIPS within an hour of the balloon launch, irrespective of its site location. NUCAPS being 2-4 hours late rendered it effectively useless in operations because by that time storms were well under way and forecasters monitor their development with high temporal frequency using geostationary imagery and data products. The inability to deliver NUCAPS data from Suomi NPP in time to contribute to pre-convective forecasting had been a steady drawback to its operational utilization. NOAA-20 launched in November 2017. The latency from NOAA-20 is better because the data is downlinked twice per orbit, at Svalbard and at the McMurdo Station in Antarctica (near the South Pole). Smith says latency is critically important if NUCAPS products are to be useful in nowcasting applications[2]. The figure below contains some excerpts from forecasters responding to a question on whether the low latency NUCAPS improved their forecast.



CONFRONTING THE BARRIERS TO ADOPTION

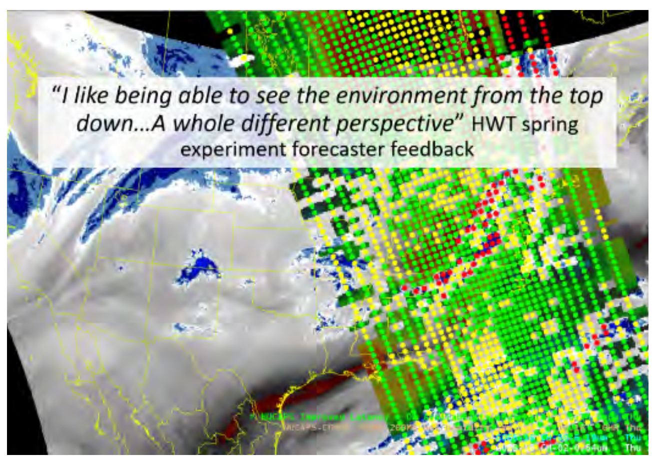
Leveraging the Hazardous Weather Testbed

The continued improvement of NUCAPS products in AWIPS is driven by forecaster needs and feedback. Much of this feedback comes from interactions between product developers and users at NOAA's Hazardous Weather Testbed (HWT)—where new and experimental products are tested and evaluated in simulated National Weather Service (NWS) operations. In 2018, researchers from the Sounding initiative decided to develop and test an alternative pathway for NUCAPS into AWIPS. They planned to demonstrate that radiosonde data latency could be matched and also that they could get NUCAPS into AWIPS within an hour after a satellite overpass. Their goal was to test whether this improvement in NUCAPS latency would improve the value of its soundings in forecasting operations.

The HWT Spring Experiment runs in Spring each year for 4–6 weeks. Each week, a team of three to five NWS forecasters and one U.S. broadcaster gather to evaluate experimental and new products within operations. The main focus is to test how products are used in decision making. For example, do the products provide novel/unique information, do they enhance understanding, how can they be improved and so on. At the end of each week, the team of forecasters deliver a briefing on their main conclusions. Weaver et al. (2018) discusses this experiment in more detail and give links to where these briefings can be found online.

NUCAPS has been evaluated and tested at the HWT since 2015. For three years, forecasters identified latency as one of the main drawbacks of NUCAPS—it arrived too late to contribute to pre-convective forecasting. Product latency is critically important in nowcasting. The period between when an observation is made and when it becomes available to forecasters largely determines its usefulness. Forecasters maintained that a reduced latency would make NUCAPS products much more useful in severe weather forecasting. Smith says "in May 2018, at the HWT Spring Experiment we tested if this were true. We implemented a low latency pathway for NUCAPS into AWIPS by making use of the Community Satellite Processing Package (CSPP; http://cimss.ssec.wisc.edu/cspp/)." CSPP packages and distributes NOAA operational algorithms, such as NUCAPS, to the meteorological and environmental satellite user community that they can run on their local servers. This is specifically useful for direct-broadcast (DB) stations across the world. The unencrypted Suomi-NPP (or NOAA-20) data can be downlinked at any of DB station and processed with CSPP software to generate NOAA operational quality data products in real-time. DB stations offer a faster data pathway because data starts to downlink the moment the satellite is within view of the DB antennae. From horizon to horizon, each DB station antennae has a regional domain and receives a subset of the satellite data. When combined, a network of DB stations can cover the whole U.S. domain. It is this network of DB station data that is employed to generate NUCAPS products in real-time, and then streamed into AWIPS-II at the HWT using a Local Data Manager (LDM). A huge accomplishment in 2018 was a radiosonde-like latency for NUCAPS products, i.e., less than 60 min from space measurement to sounding product in AWIPS.

Demonstrating the availability of satellite soundings in less than an hour of a satellite overpass was "a game changer for the Sounding initiative," Smith said. Where feedback from the 2017 HWT evaluation was a "we can see its value but it arrives too late so has limited value", the 2018 HWT feedback was a resounding "we find it useful and would like greater awareness at all WFOs".



Building Competencies

The real test of any training occurs when the meteorologists return to their weather forecast offices, which unlike the more controlled environment at the HWT, are characterized by uncertainty and complexity. Operational meteorologists on forecast duty have to depend on numerous datasets to guide their decisions in issuing weather watches and warnings. Things can get complicated for the meteorologist when model forecasts suggest divergent outcomes or when modeled conditions differ from real conditions. They need observations to verify numerical weather prediction models in real time and improve their situational awareness of what is actually happening as opposed to what is forecasted to happen (Smith et al. 2018). NUCAPS provides forecasters with observations that uniquely characterize the pre-convective environment ahead of storms. These observations help forecasters verify conditions on the ground and guide them toward more accurate and timely watches and warnings.

Iterative Communication

Beyond data latency, challenges such as the sheer volume of data and little knowledge of satellite soundings have also been stumbling blocks in the satellite sounding community's ability to draw in operational users. However, members of the JPSS PGRR Sounding initiative are helping overcome many of these challenges. One of the biggest breakthroughs for the Sounding initiative, Smith says, is the outcome of iterative communication between product developers and the user community (Smith, Barnet and Shontz, 2018).

SUMMARY AND CONCLUSIONS

For decades, the only well-characterized and trusted observation forecasters had of the vertical atmospheric state came from radiosondes, whereby a single radiosonde would be used to verify conditions spanning hundreds of miles. NUCAPS soundings have the potential to bridge these data gaps and improve nowcasting in ways not anticipated before.

No single NWP system generates forecasts so well that human meteorologists have become obsolete. In fact, no single NWP system models the complex atmosphere with an accuracy and consistency that outperforms all others on a daily basis. Operational meteorologists on forecast duty at a local weather forecast office thus employ multiple NWP datasets in their decision-making toward issuing weather watches and warnings. While forecasters may gain a more robust view of atmospheric processes with this ensemble approach, they often face cross roads where model forecasts suggest divergent outcomes or where modeled conditions differ from real conditions. They need observations to verify model accuracy and highlight shortcomings in their own conceptual models. ❖

Footnotes

[1]Currently the National Oceanic and Atmospheric Administration (NOAA)-20, and the NOAA- NASA Suomi National Polar-orbiting Partnership (Suomi NPP), which is a bridge between NOAA's legacy polar-orbiting satellites and the JPSS generation.

[2]At the time of this writing NOAA-20 data was still being validated.

Story Source

Materials obtained from JPSS October 2018 Science Seminar titled "A place for satellite soundings in severe weather forecasting."

Further Reading

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SATELLITE-BASED TROPICAL CYCLONE INTENSITY ESTIMATION WITH A NEW SATELLITE GENERATION

The information in this article is based, in part, on the November 28, 2018 JPSS science seminar presented by Derrick Herndon, Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison, WI.

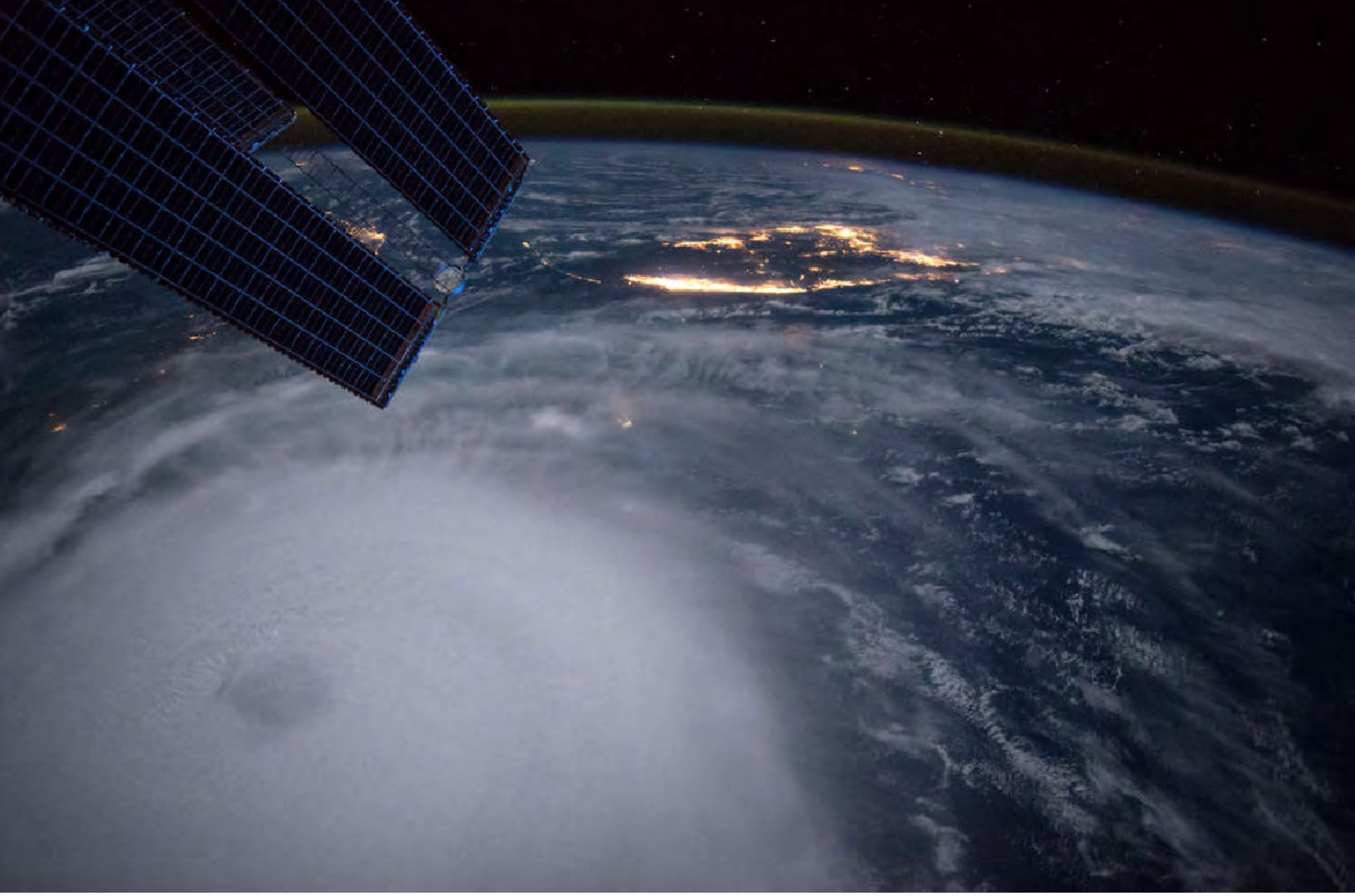


Photo credit: Daniel Brown, National Hurricane Center. https://www.nhc.noaa.gov/outreach/presentations/NHC2017_IntensityChallenges.pdf

Tropical cyclones are warm-core, large-scale systems with organized deep convection and a closed surface wind circulation around a well-defined center, which originate over tropical or subtropical waters. They are high-impact weather events that come in a variety of sizes, intensities, and structures, and they can be dangerous and disruptive to those in their path. The U.S. National Hurricane Center (NHC) is responsible for all tropical cyclone forecasts in the Atlantic and Eastern Pacific basins around North America. As such, the hurricane center gathers measurements that help characterize tropical cyclone features such as size, structure, strength, speed and track.

Accurate estimates of a tropical cyclone's current intensity and its exact location are vital for developing accurate forecasts throughout the life of the storm. A tropical cyclone's intensity is also important for model initialization to help establish short-term trends. What the storm has been doing in the past (persistence forecast), enables forecasters to evaluate previous forecast accuracy and make any adjustments as needed.

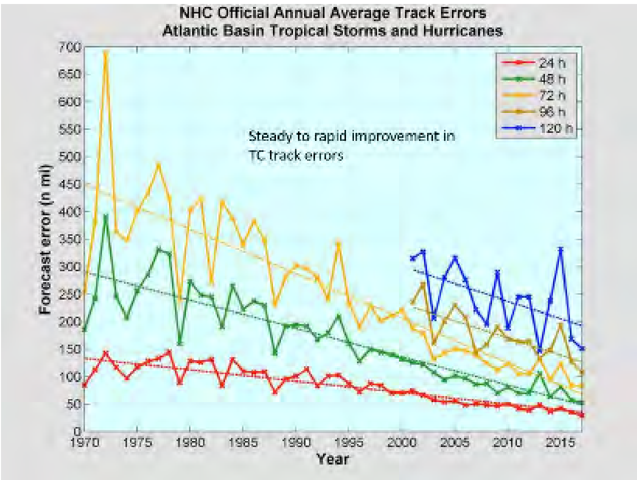
The NHC relies on data from multiple platforms to develop tropical cyclone forecasts. These include satellites, ships, aircraft, buoys and radar, as well as ground measurements. For over two decades, tailored tropical cyclone models have played a critical role in the improvement of track forecasts. Advances in data assimilation over this period have allowed for increased use of satellite data. However, accurately predicting changes in intensity has largely remained a challenging area of research. And getting measurements over the open ocean is especially challenging, due to scarce conventional data acquisition methods, such as upper-air and surface observations, ship reports, or buoy data. In the absence of these methods, satellites are sometimes the only data source available.

Geostationary satellites have served as the primary tool for monitoring high-impact weather events like hurricanes in real time. A new generation of satellites, which include the Geostationary Operational Environmental Satellite (GOES) - East and -West come equipped with some of the most sophisticated technology, including the Advanced Baseline Imager (ABI) that has three times as many channels and four times better resolution than previous weather imagers. Their higher spatial resolution and impressive temporal resolution provide advanced imaging with faster coverage for more accurate forecasts and real-time mapping of weather events. In addition, a new generation of polar orbiting satellites, which includes the National Oceanic and Atmospheric Administration's, NOAA-20, its precursor, the NOAA-NASA Suomi National Polar-orbiting Partnership (Suomi NPP), and the Global Change Observation Mission (GCOM) come with some of the highest spatial resolution sensors, and have generated many microwave sensor driven products that allow forecasters to see key features within the hurricane. Spotting and tracking these features can provide valuable insight during key phases of the hurricane development. Among the instruments used to estimate inner core winds are dropsondes. Dropsondes are tubes filled with sensors, dropped by parachutes from aircraft, which send weather data as they glide down. It should be noted that dropsondes are only one component of estimating the inner core winds. Often these values conflict with the other three sources: flight level winds, winds measured by the Stepped Frequency Microwave Radiometer (SFMR) and the central pressure determined by dropsondes in the center and the extrapolated pressure from the aircraft. Still, in the modern era, direct observations of the strongest winds in the inner core of the storm are difficult to obtain, which can lead to "surprises" in changes in a storm's intensity. Such was the case in October 2015 with hurricane Patricia, during which it was especially challenging to determine the strongest surface winds as the eye was very small.

HURRICANE PATRICIA PROMPTS AN ON-THE-FLY ADJUSTMENT

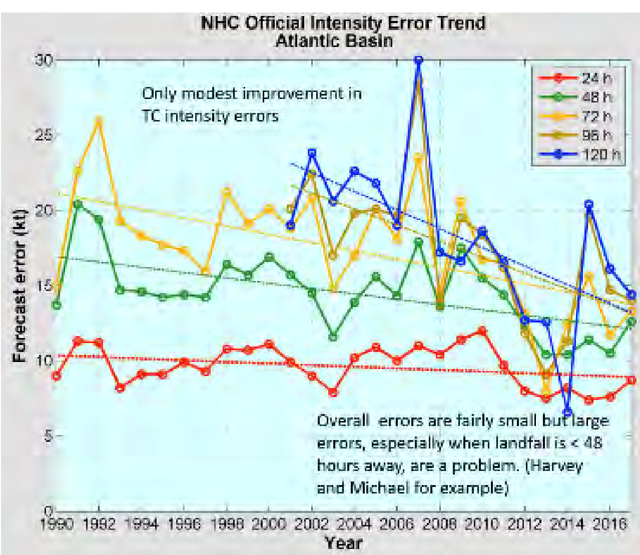
In October 2015, Hurricane Patricia, a powerful Category-5 storm churned in the eastern Pacific. Hurricane Patricia began as a tropical depression on October 20. While, its development was slow, it showed modest signs of strengthening within the first day of its classification. Up until the early hours of October 22, what had been a mere tropical storm intensified rapidly into a Category 5 hurricane. The official NHC forecast showed the cyclone "peaking at 135 knots in 12 hours, followed by a little weakening prior to landfall" (Brennan, 2015). On October 23, as the U.S. Air Force (USAF) hurricane hunter aircraft took measurements during a pass through the eye of the storm, they found Patricia had intensified into an extremely powerful hurricane with maximum sustained winds of 180 knots and a minimum central pressure of around 879 mb. Forecasters at the NHC determined that their previous forecast was running well behind, which resulted in the issuance of a special advisory (captured below) with the forecast adjusted upward based on the USAF hurricane hunter aircraft measurements.

> **HURRICANE PATRICIA SPECIAL DISCUSSION NUMBER 13 NWS NATIONAL HURRICANE CENTER MIAMI FL EP202015 1230 AM CDT FRI OCT 23 2015**
>
> The purpose of this special advisory is to update for a significant increase in the intensity of the hurricane. Reports from the Air Force Hurricane Hunters indicate that Patricia has intensified at an incredible rate since yesterday. The plane measured peak 700-mb flight level winds of 179 kt in the northeastern eyewall, and this may be an unprecedented value for a tropical cyclone.



The figure shown above helps highlight the progress made toward forecasting tropical cyclone track errors over the last couple of decades. Meanwhile, the ability to forecast intensity changes has only seen modest improvements, particularly for short-term forecasts (see figure shown below). Given the significant role that a tropical cyclone's current intensity plays in its forecasts, and particularly for those in the short term, i.e., the 24-hour forecasts, more research is being done to improve model initial conditions so as to improve this aspect of the forecasts going forward.

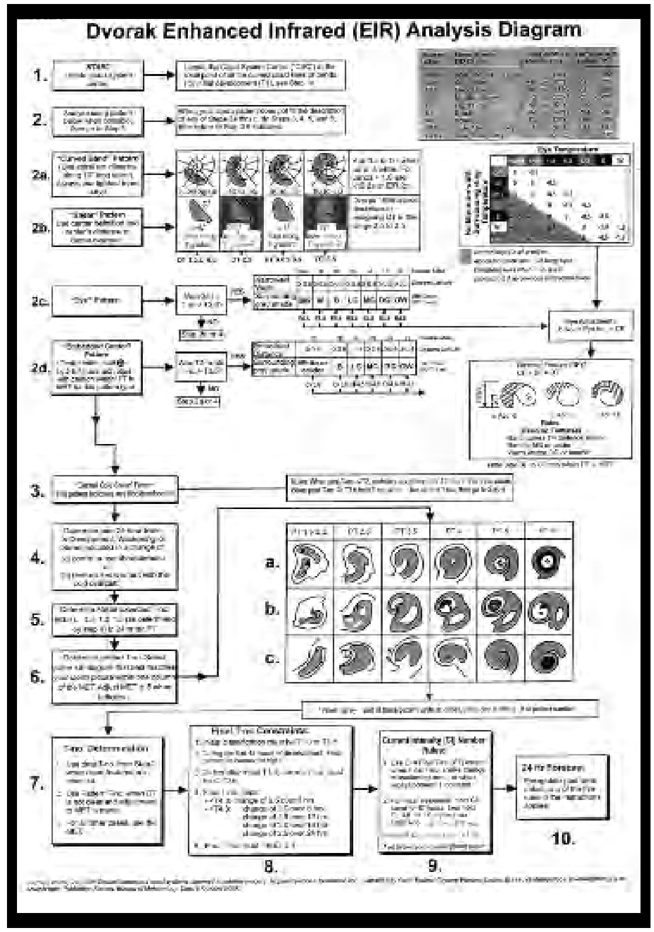
Where conventional observation platforms are scarce, data from environmental satellites often serve as the primary means of estimating a tropical cyclone's current intensity. The most widely used method is called the Dvorak Technique (DT), developed by Vern Dvorak in



the 1970's. The technique relies primarily on infrared imagery derived from geostationary satellites, although it exploits both visible and infrared satellite imagery.

THE DVORAK TECHNIQUE

The Dvorak Technique is a subjective, rules-based analysis method that relates the organization and strength of convective features in geostationary satellite imagery to the tropical cyclone's current intensity. Infrared imagery is used primarily, however the method can also be applied to visible imagery. The analysis process begins by locating the center of the tropical cyclone and measuring the relative distance to the convective features. The analyst then selects the best representation of the current image from four cloud pattern types: eye, curved band, shear, or embedded center (figure shown on the next page). The storm's intensity from 24 hours prior is taken into consideration. For example, the intensity 24 hours prior must have been stronger than 30 knots in order to use the "eye" type. Other deciding factors include the temperature of the coldest cloud tops (using a specially designed enhancement scale), the amount of curvature in the cloud features, or the distance that the storm center is embedded into the central cloud feature. During this initial intensity estimation, values are called T numbers. T numbers ascend in 0.5 increments from 1.0 to 8.5. For example, the colder the cloud tops in the central cloud region, the higher the T number assigned for the initial intensity. Additional adjustments up or down are made depending on the cloud pattern determination. If the tropical cyclone has an identifiable eye feature, the temperature of the eye is determined along with the surrounding cloud top temperatures to make an adjustment to the T number. Eye scenes are generally the easiest and most objective of the DT cloud scene types because the temperature difference between the eye and the surrounding cloud tops is more directly related to the tropical cyclone intensity due to the warm core nature of the tropical cyclone. Finally, analysts must determine how much of the T number has changed in the previous 6, 12, 18 and 24 hours. Limitations are placed on the rate of intensity change for both strengthening and weakening. This was done to prevent rapid intensity changes for cloud features that may be transient in nature and to also fall within the climatological rate of change in the intensity. After all the rules have been applied, the T number is compared to a model of expected intensity resulting in the final Current Intensity (CI) number. This CI number is converted to a maximum sustained wind value using a standard table. Different conversion tables may be used at different tropical cyclone warning agencies to account for deviations noted in different ocean basins based on past verification data.

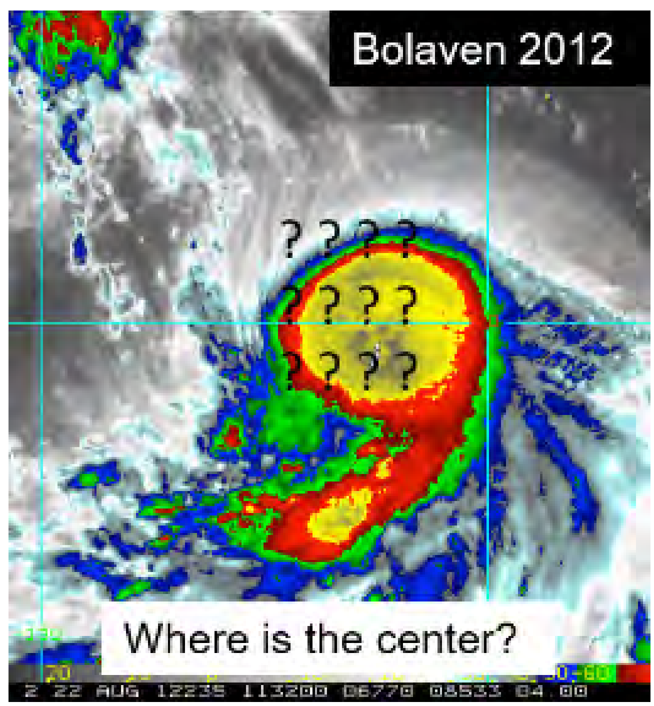


LIMITATIONS

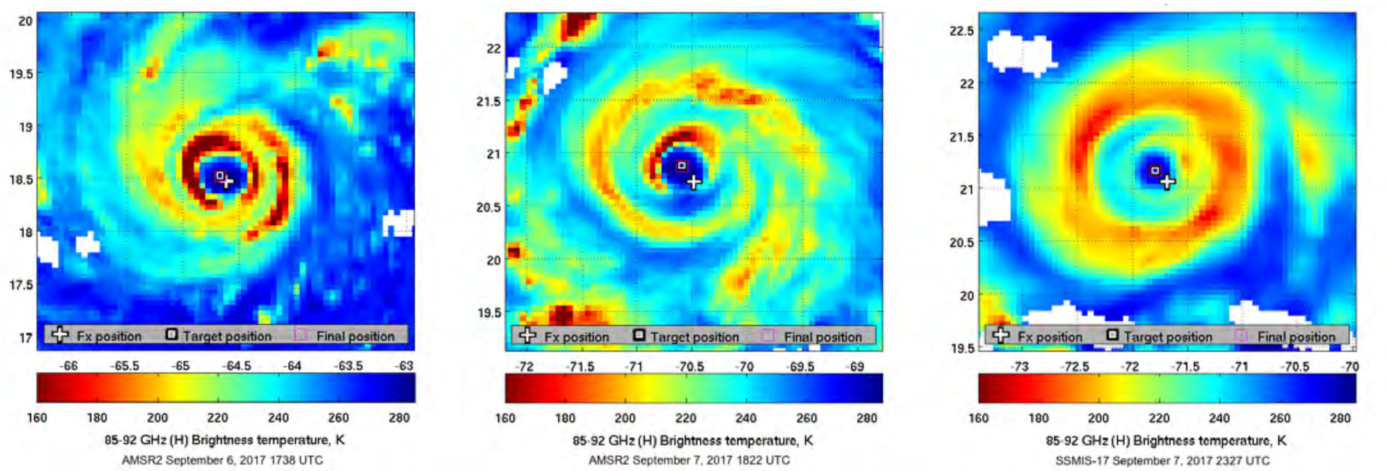
One challenge with the Dvorak Technique is the amount of time it takes to become proficient. While a basic knowledge can be learned in a few months, it can take years to become fluent in the technique. While the method has stood the test of time and shown itself to be skillful, it may, at times, lag during rapid intensification, or be too slow to show storms that are rapidly weakening. In addition, tropical cyclones can pose challenges that lead to uncertainties in intensity estimates. A common complication stems from the structure of a tropical cyclone, which, due to its varied nature can impact intensity estimates, especially when using IR-based methods such as the Dvorak Technique.

COLD DENSE OVERCAST STRUCTURES

Prior to the emergence of an eye, cold dense overcast cloud tops can develop, making it difficult to locate the tropical cyclone's center. This can create huge problems for an analyst because the position of a storm's center relative to a convective feature is extremely important for analyzing its intensity. When the spread of uncertainty is large, it can lead to uncertainty in the short term forecast. In the image to the right of Typhoon Bolaven in 2012, the intensity estimate could be 45 knots or 90 knots, depending on the intensity estimated previously (6–24 hours ago), and where the center of the tropical cyclone is located. In such cases, an



analyst can rely on imagery from microwave imagers that are able to "see" through clouds. But in the absence of microwave imagery, an analyst is left to make guesses based on IR data. And although measurements from IR sensors



Hurricane Irma weakens from 160 knots to 130 knots. Polar orbiting sensors operating in the 85-92 GHz range reveal the inner core structure evolution and ERC of Irma. These images are produced using the CIMSS ARCHER algorithm.

can at times be less accurate than those from microwave sensors, those on board geostationary satellites provide a more complete representation of precipitation with a considerable higher temporal resolution. More and more satellite data products are being developed using a combination of the excellent space/time resolution from geostationary estimates with the better accuracy of microwave estimates. A detailed analysis highlighting the different sensors is presented in the SATCON section.

NON-CLASSICAL STRUCTURES

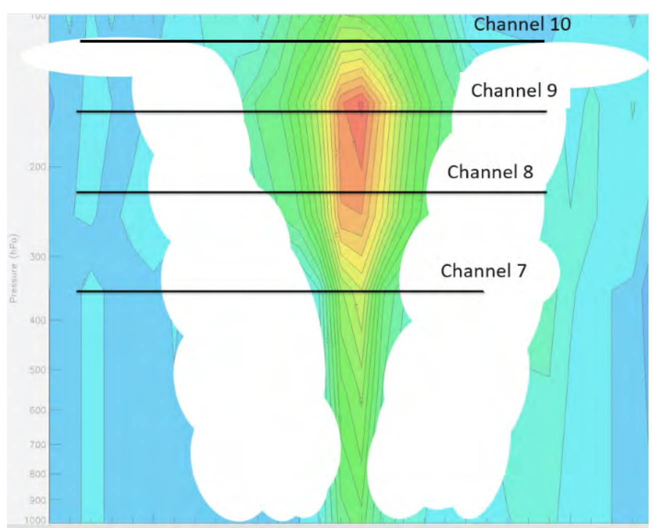
There are also cases where the Dvorak Technique has difficulty handling a storm's transition phase to an extratropical system, or representing some storm types, such as monsoon depressions that are hybrid in nature. A technique similar to the DT was developed by Hebert-Poteat to determine the intensity of subtropical cyclones that fall outside of the classical tropical cyclone structures for which the DT was designed (Hebert and Poteat, 1975).

EYEWALL REPLACEMENT CYCLE

Tropical cyclones undergoing eyewall replacement cycles (ERCs) are handled poorly by traditional methods such as the Dvorak Technique. In the short term, these methods tend to miss the fluctuations in intensity during storm transition phases because the DT rules prevent temporal fluctuations in the intensity on short time scales.

Tropical cyclones undergoing an ERC tend to weaken as an outer eyewall surrounds the inner eyewall, weakening the inner core convection. Eventually the inner eyewall is "replaced" by the outer eyewall, forming a new primary eyewall and the storm may re-intensify. Intensity changes of a full Saffir-Simpson category (more than 30 knots) may occur during this process. An example of an eyewall replacement cycle viewed by microwave imagery for Hurricane Ivan in 2004 can be viewed at this link: http://tropic.ssec.wisc.edu/real-time/mimtc/gallery/galleryivan1.html.

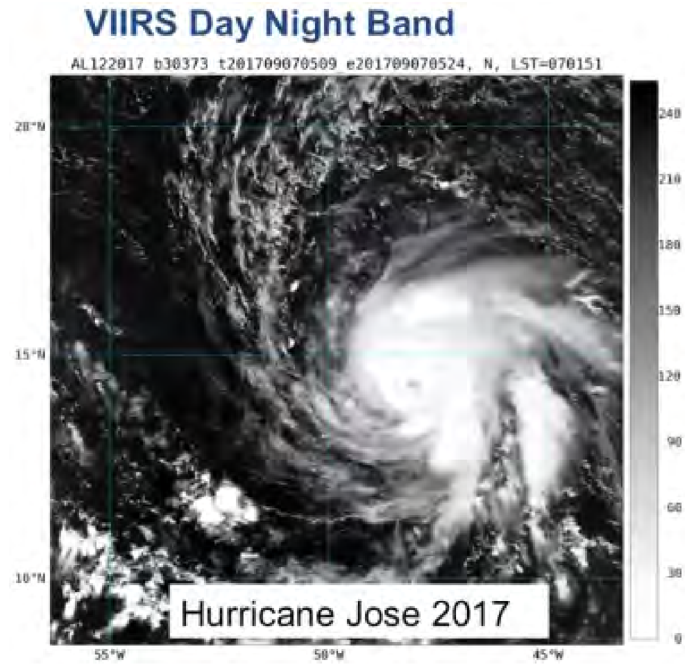
To mitigate some of the challenges associated with intensity analysis, analysts typically look to other technologies to complement the Dvorak.

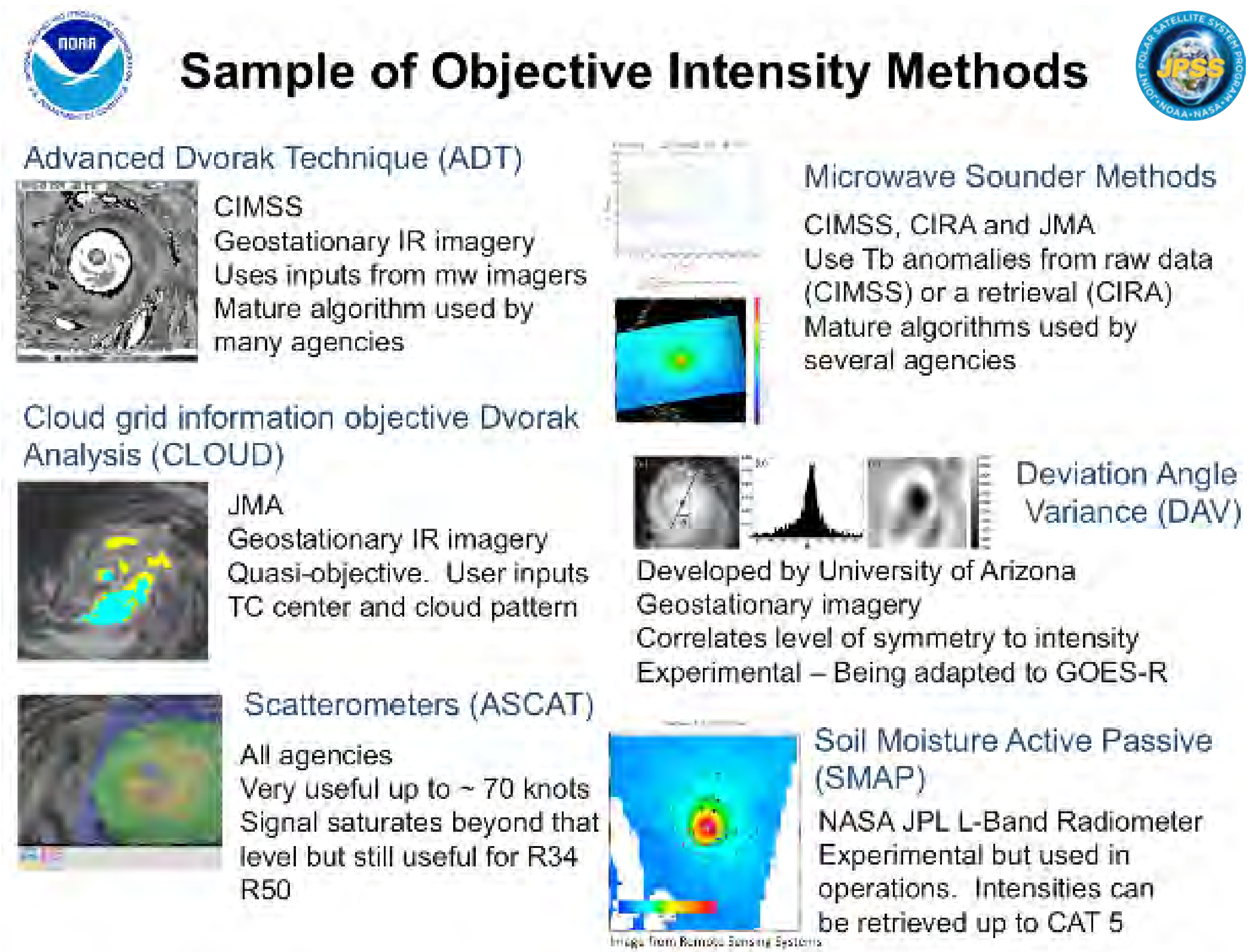


The warm core anomaly in the figure is visible between channels 7 and 9. It features prominently near channel 9, with a peak close to 200 hPa.

These include microwave sounding instruments, which capture details of vertical temperature and moisture throughout the atmospheric column. They also have the ability to penetrate through deep, non-precipitating clouds and therefore can provide vertical soundings under most weather conditions. The temperature sounders on microwave instruments (shown in the ATMS vertical cross section of Typhoon Lekima on the bottom of the previous page) are used to measure a tropical cyclone's warm core, which is an indicator of its strength.

Another complementary tool is the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument's Day Night Band (DNB) sensor, which is sensitive enough to provide storm information even under limited moonlight conditions. The DNB imagery can be helpful for Dvorak analysts as it can help them locate a tropical cyclone's center relative to central convection, and it can also help them identify the eye of a storm. There are also several objective methods that may be used to estimate intensity. These include the Advanced Dvorak Technique (ADT), Cloud Grid Information objective Dvorak analysis (CLOUD), which is the operational tropical cyclone analysis developed by the Japan Meteorological Agency; scatterometers such as the Advanced Scatterometer (ASCAT); microwave sounders; the Deviation Angle Variance (DAV) technique; as well as the Soil Moisture Active Passive (SMAP) radiometer which can measure ocean surface winds. The ADT, microwave sounder methods and scatterometers are widely used in operations while the DAV and SMAP methods remain experimental. The ADT, developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), is an objective algorithm based on the general approach of the subjective Dvorak Technique and has been used since the 1990s. A fully automated and objective center technique locates the tropical cyclone center using digital infrared geostationary imagery. The intensity is then determined by evaluating the cloud pattern type, similar to Dvorak, and assigning a T number. The final intensity is based on averaging three to six hours of estimates (depending on the system type) and applying rules for weakening/strengthening. Passive microwave imagery in the 89 GHz range is also used to guide the intensity logic when a tropical cyclone eye emerges in the microwave imagery but has not yet developed in the infrared imagery. Intensity estimates are produced every 30 minutes. The microwave sounder methods have a heritage dating back to the Scanning Microwave Spectrometer (SCAMS) launched in 1975 (Kidder 1978). These methods relate the temperature anomaly measured by various channels on the instrument to the tropical cyclone current intensity. Microwave sounder methods, which are limited by the instrument resolution, only became skillful with the launch of the Advanced Microwave Sounding Unit (AMSU) aboard the NOAA satellite series in 1998. More recent sounders, both with much improved resolution, include the Special Sensor Microwave Imager/Sounder (SSMIS) and the Advanced Temperature Microwave Sounder (ATMS) flown aboard the Suomi-NPP and JPSS satellites. Sounder tropical cyclone intensity techniques have been developed by CIMSS, the Cooperative Institute for Research in the Atmosphere (CIRA) and JMA. In addition to intensity, some of these techniques, such as the CIRA sounder method, ADT and ASCAT, can be used to estimate tropical cyclone structure parameters such as the radius of gales (R34), storm (R50), and hurricane force winds (R64).





Some of the current tropical cyclone intensity methods being used by warning agencies across the globe. Estimates from several algorithms are used in routine operations while some listed above and others such as deep learning artificial intelligence approaches are still experimental.

In order to account for storms with different structures, an approach that makes optimal use of satellites in the geostationary and low Earth orbit platforms would be a valuable asset in the forecast environment. Moreover, given an overwhelming number of algorithms and sensors for forecasters to sift through in a short amount of time, a simplified approach that can help them move the forecast forward would be beneficial as well. Such an approach has been explored by scientists from the Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin–Madison (UW-CIMSS). The approach, known as SATellite CONsensus (SATCON) is an objective method which makes optimal use of various satellite sensors to account for the different structures.

SATCON

The SATCON algorithm combines tropical cyclone intensity estimates analyzed from multiple satellite sources, i.e., infrared and microwave-based methods, to produce a weighted consensus estimate, which is more accurate than estimates based on an individual satellite source or straight averaging.

SATCON is a comparative guidance tool for evaluating various tropical cyclone intensity estimates that, as shown from the sample of comments from some members of the end user community, enables a tropical cyclone analyst to reconcile differences in objective intensity methods quickly.

Current members in the SATCON algorithm include the CIRA ATMS algorithm, the CIMSS

Tropical Storm Ophelia Discussion Number 5
NWS National Hurricane Center Miami FL AL172017
500 AM AST Tue Oct 10 2017

NHC

Although the intensity of Ophelia's deep convection has decreased during the past several hours, the cloud pattern has improved and become more symmetric with banding features now better established around the center. The initial intensity is held at 45 kt, in agreement with a Dvorak classification from SAB and the latest satellite consensus estimate from CIMSS at the University of Wisconsin.

TROPICAL CYCLONE TECHNICAL BULLETIN: AUSTRALIA Issued by PERTH TROPICAL CYCLONE WARNING CENTRE
at: 0716 UTC 01/12/2017
Name: Tropical Cyclone Dahlia
Identifier: 03U
Data At: 0600 UTC
Latitude: 10.2S
Longitude: 109.6E
Maximum 10-Minute Wind: 50 knots [95 km/h]
Maximum 3-Second Wind Gust: 70 knots [130 km/h]
Central Pressure: 987 hPa
Intensity now at 50kn [category 2] determined from: Dvorak analysis: FT/CI=3.5 based on shear pattern and MET [slight development over 24hours]. ASCAT at 0230UTC has maximum of 45kn to the northeast. SATCON also is 45kn [10min average].

ABoM

Tropical Storm Ophelia Discussion Number 5
WDPN31 PGTW 030900
MSGID/GENADMIN/JOINT TYPHOON WRNCEN PEARL HARBOR HI//
SUBJ/PROGNOSTIC REASONING FOR TYPHOON 28W (DAMREY) WARNING NR 07//RMKS/
1. FOR METEOROLOGISTS.
2. 6 HOUR SUMMARY AND ANALYSIS.
TYPHOON 28W (DAMREY), LOCATED APPROXIMATELY 328 NM SOUTHEAST OF DA NANG, VIETNAM, HAS TRACKED WESTWARD AT 08 KNOTS OVER THE PAST SIX HOURS. ANIMATED MULTI-SPECTRAL SATELLITE IMAGERY DEPICTS DEEP CONVECTIVE BANDING WRAPPING INTO A WELL ORGANIZED LOW LEVEL CIRCULATION CENTER (LLCC) THAT AT TIMES, SHOWS A FORMATIVE EYE FEATURE. THE INITIAL POSITION IS PLACED WITH HIGH CONFIDENCE BASED ON THE FORMATIVE EYE FEATURE VISIBLE IN THE MULTI-SPECTRAL LOOP. THE INITIAL INTENSITY OF 75 KNOTS IS BASED ON DVORAK INTENSITY ESTIMATES OF T4.5 (77 KNOTS) FROM BOTH PGTW AND RJTD. THE INTENSITY IS ALSO SUPPORTED BY A SATCON ESTIMATE OF 72 KNOTS.

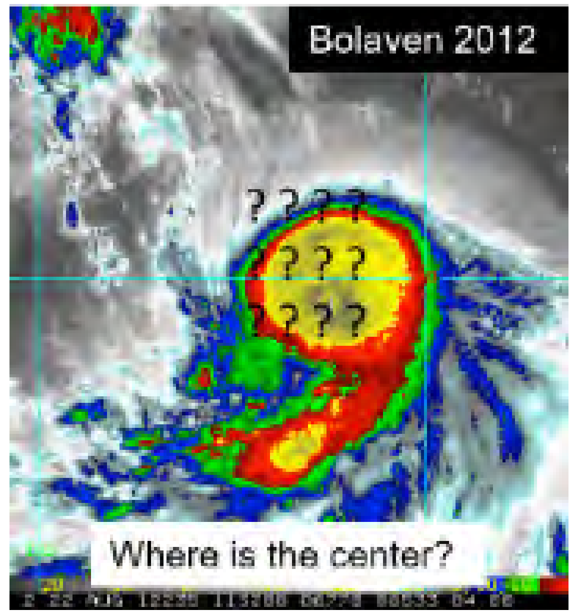
JTWC

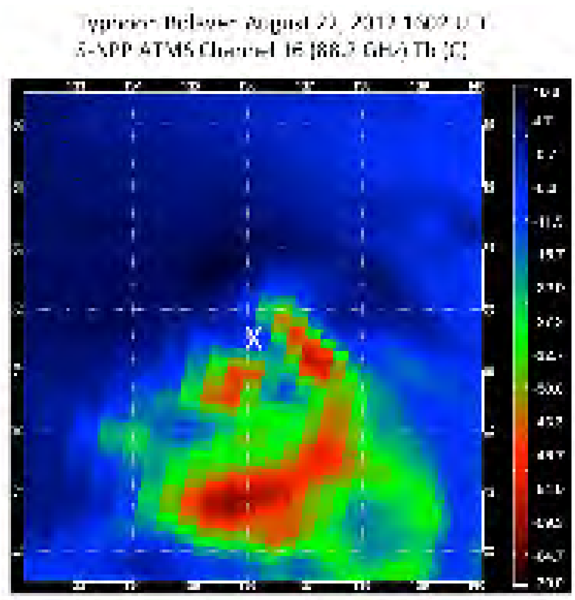
ADT, AMSU, SSMIS, and ATMS sounder methods. Statistical performance of each algorithm is stratified based on criteria that are related to the algorithm. The RMSE for each algorithm in these stratifications defines the weights used in SATCON. For example, the ADT tends to perform best when the infrared image is an eye scene. For the sounder algorithms, the primary source of error is the size of the tropical cyclone eye relative to the instrument resolution for the field of view that is closest to the tropical cyclone center. The weighting equation for SATCON is shown below:

$$\text{SATCON}= \frac{(W_1W_2\,(W_1+W_2\,)\,E_3 + W_1W_3\,(W_1+W_3\,)\,E_2 + W_3W_2\,(W_3+W_2)\,E_1\,)}{(W_1W_2\,(W_1+W_2)+W_1W_3\,(W_1+W_3)+ W_3W_2\,(W_3+W_2)}$$

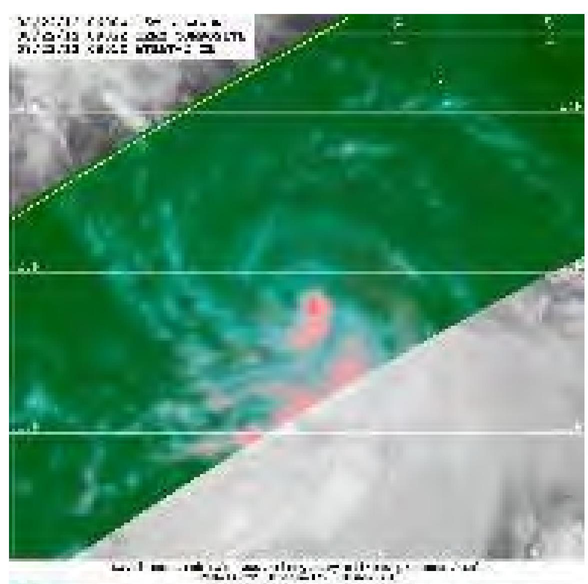
Where W is the member weight and E is the member intensity estimate.

Unique weights exist for both minimum sea level pressure and Maximum Sustained Winds (MSW). A fourth pseudo-member of SATCON is the pressure-wind estimate of MSW which is derived using the SATCON estimated pressure anomaly. The pressure-wind component is included since this information includes adjustments for storm motion, tropical cyclone size and latitude. The final SATCON MSW includes bias corrections for tropical cyclone eye size and eyewall strength obtained from the CIMSS Automated Rotational Center Hurricane Eye Retrieval (ARCHER) algorithm. An example plot for SATCON MSW estimates for Super Typhoon Bolaven is shown on the next page. The plot includes all member estimates along with the best track intensity from the warning agency(the Joint Typhoon Warning Center in this example) and Dvorak estimates from all agencies performing Dvorak intensity fixes (black dots). Light red lines denote the two standard deviation bounds for the SATCON estimates. These provide the forecaster a quick assessment of the best track intensity estimates that significantly deviate from the SATCON estimates. In the Bolaven example, the best track and Dvorak estimates exceed the SATCON two standard deviation bounds on August 22. As noted earlier, the Bolaven case is interesting because cold, dense clouds obscure the tropical cyclone center, making Dvorak estimates more challenging. In many cases where modest differences occur for intensity estimate, an average of all estimates (both subjective and objective) tend to be closest to the true intensity (verified using aircraft data). However in cases such as Bolaven on August 22–23 a large bifurcation in estimates informs the forecaster that something has gone amiss in one of the groups of estimates. This may require the forecaster to find additional satellite imagery to help rectify the differences.





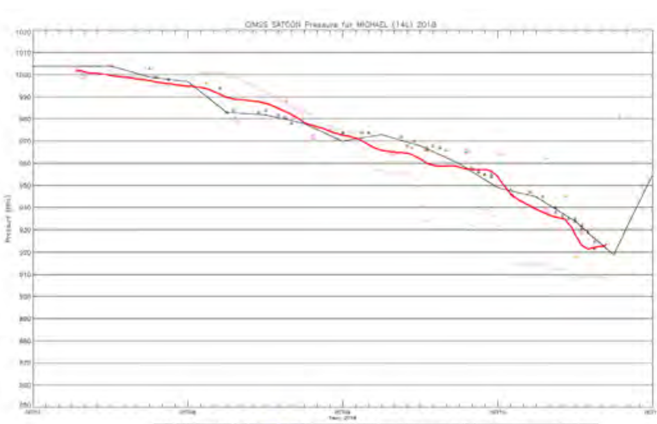
Returning to the infrared image of Bolaven, it was noted that the position of the storm's center relative to the cold deep cloud tops was uncertain. Passive microwave imagery can be used to determine the storm center when cold cloud tops in geostationary infrared imagery mask the center location. A Suomi-NPP ATMS pass a few hours after the infrared image (center) suggests that much of the deep convection (cold brightness temperatures at 88.2 GHz) is located south and east of the center. A TRMM 37 GHz image (courtesy of the Naval Research Laboratory tropical cyclone page) also indicates that the storm's center is at least partially exposed and located to the west of central deep convection. This would place the center on the western edge of the infrared image and also indicates that intensity estimates



that were based on the center location farther east into the deep convection may be too high. The corresponding sounder-based intensity estimate for the ATMS image above is 64 knots, 26 knots weaker than the best track intensity of 90 knots (solid black line in the above SATCON plot). This value is in good agreement with the ADT and SSMIS intensity estimates as well as the previous ATMS estimate 12 hours prior. The best track intensity of 90 knots was based primarily on the Dvorak intensity estimates. A multi-spectral analysis of the intensity indicates the best track value may be too high. In addition, the SATCON plot provides two standard deviation error bounds (light red lines) and the best track values fall well outside of these bounds, and this is statistically unlikely.

If aircraft observations are available, they are included in the SATCON plot of MSLP as seen below for Hurricane Michael in 2018 (black triangles). Hurricane Michael was a rapidly intensifying hurricane that made landfall in the Florida Panhandle near Panama City as a strong Category 4 storm. There is very good agreement between the SATCON estimated pressures and those measured by aircraft. It can be seen that though the individual members exhibit substantial fluctuations over time, the averaging and weighting approach of SATCON decreases these variations and shows a steady trend.

SATCON performance can be measured against the Dvorak estimates for a homogenous sample of storms to determine how the algorithm compares. Using independent data from 2016–2017 (N=310), this comparison yields a RMSE of 8.4 knots compared to an RMSE of 10.6 knots



for Dvorak. It should be noted that SATCON also outperforms all individual members and a simple average of the members for this sample. SATCON estimates for current and past storms can be viewed at: http://tropic.ssec.wisc.edu/real-time/satcon/.

FUTURE PLANS

Additional members are being evaluated for inclusion in SATCON including the Deviation Angle Variance technique and the Soil Moisture Active Passive (SMAP) estimates. SMAP estimates are currently being included in SATCON MSW plots for comparison purposes but are not currently a weighted member of SATCON. Blending both groups of objective and subjective intensity estimates has shown promise in reducing the overall estimate error. A separate product that includes weighted Dvorak members is being considered.

SUMMARY

Tropical cyclone current intensity is an important part of the forecast process. JPSS has improved tropical cyclone forecasting capability with ATMS microwave soundings providing more detail of the warm core, which helps indicate the strength of the cyclone. As ATMS provides higher spatial coverage and its higher spatial resolution increases our ability to observe the warm core, we are able to eliminate gaps. Moreover the VIIRS DNB allows us to observe in great detail a cyclone's overall structure at night, which generally is more difficult with only infrared observations. The SATCON algorithm incorporates information from ATMS and other sources to provide forecasters with a quick way to assess the tropical cyclone current intensity by combining multiple intensity estimates into a single estimate. SATCON displays multiple satellite sensors from both geostationary and polar orbiting platforms to provide multispectral information to the hurricane forecaster. The weighting methodology in SATCON removes some of the challenges in tropical cyclone intensity analysis by accounting for the idiosyncrasies of individual members. By decreasing the amount of time spent on intensity analysis, more time can be invested in the forecast process. SATCON also helps mitigate some of the challenges associated with storm structures where the traditional Dvorak Technique may provide uncertain estimates. Future algorithms currently under development along with new satellite sensors such as the Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission will further reduce estimate uncertainty and improve temporal resolution. ❖

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SATELLITE FOUNDATIONAL COURSE FOR THE JOINT POLAR SATELLITE SYSTEM (SATFC-J): EMPOWERING OPERATIONAL FORECASTERS

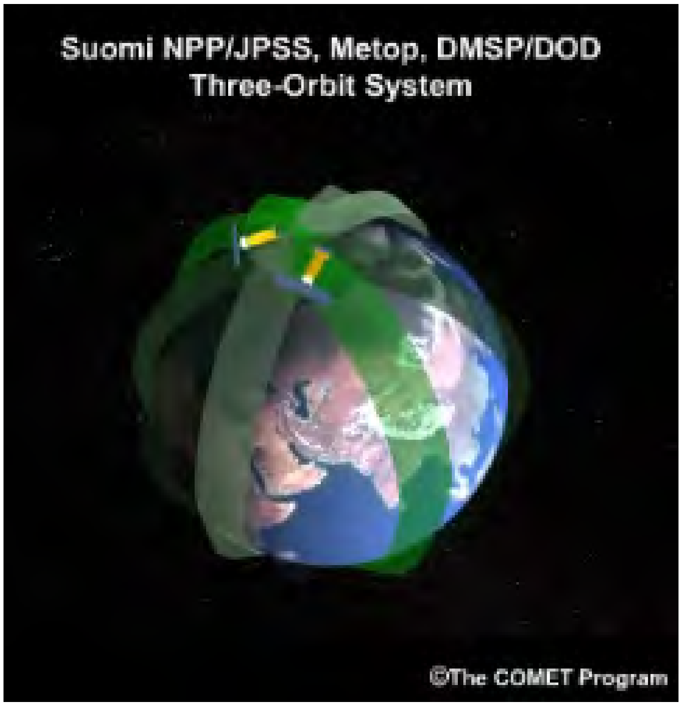
The information in this article is based, in part, on the December 21, 2018 JPSS science seminar presented by Jorel Torres, Cooperative Institute for Research in the Atmosphere (CIRA) / Colorado State University (CSU), Fort Collins, CO. It features work being done by the JPSS Satellite Training Advisory Team (STAT).

Jorel Torres (CIRA) speaking about JPSS products to National Weather Service (NWS) Science and Operations Officers (SOO) at the SOO Development Course in Norman, Oklahoma. Image credit: Courtesy of Jorel Torres.

Earth-observing environmental satellites contribute a significant percentage of the data used in various operational applications. As part of the asset portfolio used by the United States National Weather Service (NWS) to observe the atmosphere, satellites play a vital role in collecting data over remote or isolated regions of the Earth and its vast ocean basins.

Data from polar-orbiting satellites is available over the entire globe daily. It helps fill in gaps where ground-based environmental observations are limited, such as the ocean-surrounded Antarctic continent. Satellite data and imagery can help forecasters monitor features such as tropical storms, smoke from wildfires, cloud cover, and precipitation. With their global reach, polar orbiting satellites provide nearly 90 percent of the data assimilated into Numerical Weather Prediction (NWP) models.

The Joint Polar Satellite System (JPSS) is an essential part of the nation's commitment to its worldwide partners to provide frequent global



coverage for a broader range of observations of atmospheric terrestrial and oceanic conditions, including sea and land surface temperatures, water vapor, snow and ice cover, vegetation, clouds, and rainfall. It also carries NOAA's primary satellites in the afternoon orbit. The JPSS program has two next-generation satellites in orbit. NOAA-20, launched on November 18, 2017, and Suomi National Polar-orbiting Partnership (Suomi NPP), launched on October 28, 2011. Also in orbit some 22,000 miles above the Earth are two advanced Geostationary Operational Environmental Satellite (GOES). GOES-East monitors the eastern United States, much of South America, the Caribbean region and the Atlantic Ocean. GOES-West observes North America and the Pacific Ocean to the west of Hawaii. These satellites introduce a variety of new and improved capabilities over their predecessors.

To ensure that NOAA and the external satellite user community is prepared to make the most of the imagery and data available from the nation's environmental satellites, the NWS has worked with several groups to develop and deliver foundational training for JPSS and GOES. It describes the satellite programs, the satellites, and their sensors, imagery and applications. It is also available to diverse end-user communities in and outside of NOAA such as international users and institutes of higher learning that encompass researchers and student users.

THE NEED FOR SATELLITE TRAINING

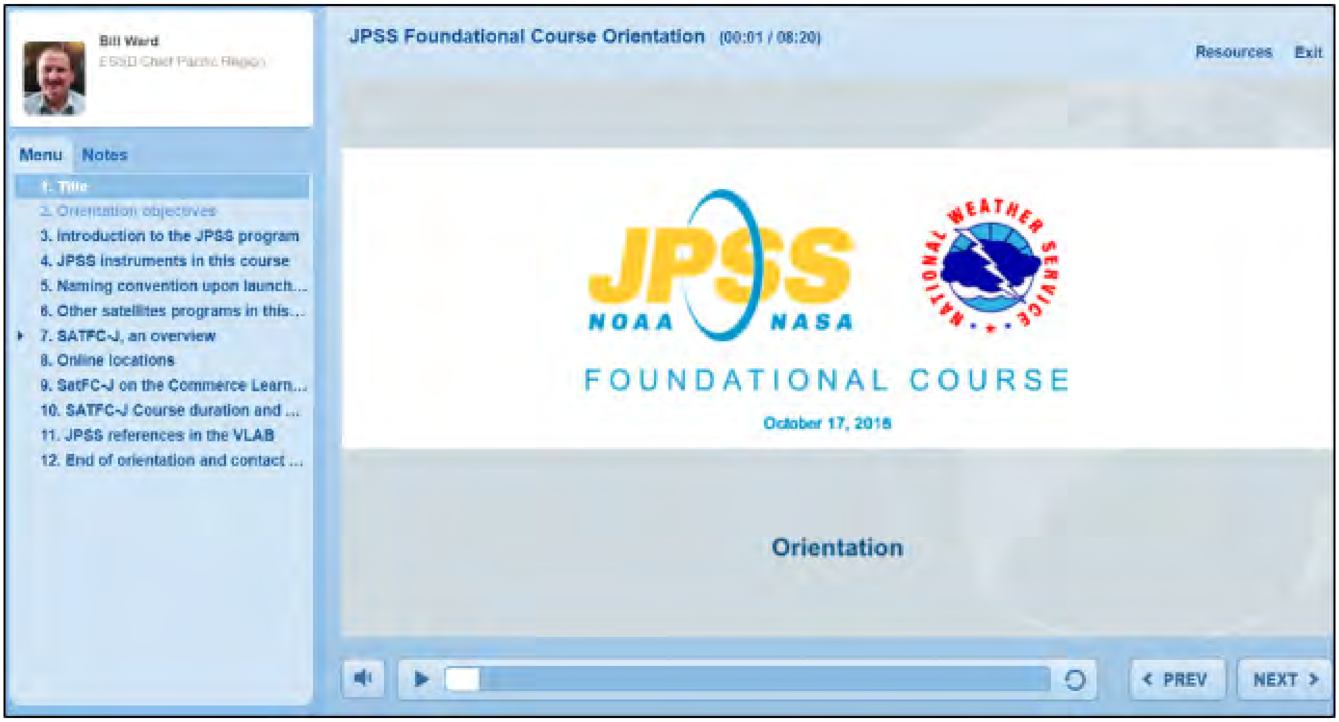
Unfamiliarity with data from polar-orbiting satellites, especially with end users such as NWS operational forecasters, can be an impediment to its application in operations. If forecasters have insufficient knowledge of satellite sensors and derived products, and don't understand how to use satellite observations, they won't be able to leverage this dynamic technology for their benefit. Training is one of the key ways to help forecasters understand how satellite products, such as those from JPSS, add observational value to the forecast process. With this understanding comes increased usage of data from NOAA's satellite constellation in operational applications.

The JPSS Program has worked closely with its NOAA stakeholders to provide detailed information on the JPSS data and products, and vital training resources on their applications to meet a wide range of mission requirements.

JPSS training describes the new and improved capabilities of polar-orbiting satellites that benefit forecasters in the forecast process and daily operations. Additional training can focus on the following: the JPSS series instruments (such as the Advanced Technology Microwave Sounder (ATMS), Cross-track Infrared Sounder (CrIS), and Visible Infrared Imaging Radiometer Suite (VIIRS)) along with their products and applications, polar-orbiting satellites and their impact on NWP models, polar-orbiting satellites from other countries and their corresponding imagery and applications, and details regarding satellite training resources and how to quickly access these resources.

JPSS SATELLITE FOUNDATIONAL COURSE

The training includes a Satellite Foundational Course for JPSS (SatFC-J), which is comprised of modules that aim to address the training needs associated with the capabilities of the advanced instruments onboard JPSS spacecraft. The instruments, which include VIIRS, ATMS, CrIS, the Ozone Mapping Profiler Suite (OMPS), and the Clouds and Earth's Radiant Energy System (CERES), are a significant upgrade from those on legacy polar-orbiting satellites. One of the driving factors for this course is to ensure that operational forecasters have a comprehensive understanding of the added value of JPSS satellites. The material emphasizes the capabilities of JPSS in applications where GOES can be of limited use, or where polar data can be used in complement to GOES in the forecast process. Forecasting applications range from detecting and monitoring severe weather, ice, clouds, snow, fog, fire, vegetation health, smoke, aerosols and so forth. The VIIRS Day/Night Band (DNB), which uses reflected moonlight and emitted natural and anthropogenic light at night has become an essential part of nighttime applications including hurricane forecasting, identifying sea ice in the arctic, and wildfire detection.



SatFC-J

JPSS Orientation

Objective 1: Introduction to Microwave Remote Sensing

Objective 2: Introducing Suomi-NPP, JPSS, GCOM, GPM

Objective 3: Basic Forecast Applications

Follow on Section: Additional SNPP/JPSS Applications

Proof of Concept Videos

The course can be viewed in the NOAA Commerce Learning Center (NOAA CLC) while the reference materials can be viewed in the Satellite Training and Operations Resources (STOR) within the NOAA Virtual Lab (NOAA VLab) for NWS users. For non-NOAA users, training materials can be accessed via Virtual Institute of Satellite Integration Training (VISIT) webpages.

The course, which holds approximately six hours of content, is the outcome of collaborative input from the JPSS Satellite Training Advisory Team (STAT), which is comprised of NWS Science Operations Officers (SOOs) from five regions, satellite liaisons, cooperative institutes (CIs), the Warning Decision Training Division (WDTD) and representatives from the NWS Office of the Chief Learning Officer (OCLO) and NWS Operational Advisory Team (NOAT). Training and 'reference material' developers include representatives from the Cooperative Institute for Research in the Atmosphere (CIRA), the Cooperative Institute for Meteorological Satellite Studies (CIMSS), COMET, the Short-term Prediction Research and Transition Center (SPoRT), University of Alaska-Fairbanks (UAF), and the Geographic Information Network of Alaska (GINA).
The JPSS STAT monitors available training resources, schedules, deliverables, and provides comprehensive information on course content.
It is open to the NOAA end user community, as well as external communities such as educational institutions and international communities.

The orientation component presents a brief summary on what to expect from the course, which includes a description of the objectives, along with highlights of resources and strategies for taking the course.

TRAINING MODULES

Topic	Title	Expected Completion Time	Contributor	Developed
Introduction to Microwave Remote Sensing	Introduction to Microwave Remote Sensing	20	CIRA	2018
Introduction to Microwave Remote Sensing	Oxygen and Water Vapor Absorption Bands	30	CIRA	2018
Introduction to Microwave Remote Sensing	Microwave Surface Emissivity	20	CIRA	2018
Introduction to Microwave Remote Sensing	Influence of Clouds and Precipitation	20	CIRA	2018
Introducing Suomi NPP, JPSS, GCOM and GPM	Orbits and Data Availability	20	Dills (COMET)	2018
Introducing Suomi NPP, JPSS, GCOM and GPM	The VIIRS Imager	30	Lee and Dills (COMET)	2018
Introducing Suomi NPP, JPSS, GCOM and GPM	The CrIS and ATMS Sounders	35	Dills (COMET)	2018
Introducing Suomi NPP, JPSS, GCOM and GPM	The AMSR2 Microwave Imager	25	Lee and Dills (COMET)	2018
Introducing Suomi NPP, JPSS, GCOM and GPM	NASA GPM Overview	20	SPoRT	2018
Beneficial Products and their Applications	Uses of VIIRS Imagery	20	Lindstrom (CIMSS)	2018
Beneficial Products and their Applications	The VIIRS Day / Night Band	20	Lee and Dills (COMET)	2018
Beneficial Products and their Applications	NUCAPS Soundings	15	Lindstrom (CIMSS)	2018
Beneficial Products and their Applications	Impact of Satellite Observations on NWP	20	COMET	2017

SatFC-J contains short training modules along with section quizzes covering three main overarching objectives: microwave remote sensing, satellite constellations and instrumentation, and forecast applications that demonstrate the utility of JPSS data and products in operational forecasting. The following sections describe some of these modules and their contents.

INTRODUCTION TO MICROWAVE REMOTE SENSING

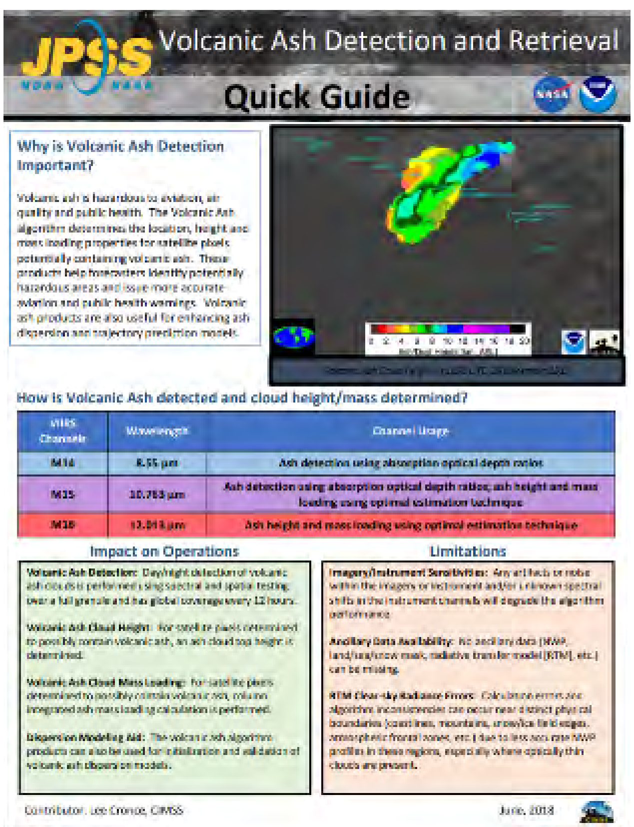
The first module under this topic area covers passive sensing, along with perspectives on how microwave remote sensing complements observations derived from the visible and infrared sensors. The second module provides course participants a brief overview of the oxygen and water vapor absorption regions in the microwave spectrum. The third module describes differences in microwave emissivity that aid in the characterization of land surfaces, snow and ice cover, and water surfaces. The last module focuses on the influence of clouds and precipitation on microwave remote sensing and how microwave sensors provide atmospheric moisture and precipitation information against different surface backgrounds (land vs. ocean).

INTRODUCTION TO SATELLITE CONSTELLATIONS

The first module under this theme presents an overview of NOAA's operational polar-orbiting satellites, focusing on how their orbits define observational coverage and how ground receiving capabilities impact data latency from the observation time to product availability. A following module introduces the VIIRS imager, coupled with highlights of its capabilities and improvements, as well as applications in operational meteorology. A subsequent module introduces next-generation infrared and microwave sounders, CrIS and ATMS. The CrIS instrument is designed to produce high vertical resolution water vapor and temperature profiles of the atmosphere in clear to partly cloudy conditions. Clouds are largely transparent at microwave frequencies, thus when CrIS works in complement with ATMS, they make it possible to cover a broader range of weather conditions. Another module under this topic area, focuses on the Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument, on-board the Japan Aerospace Exploration Agency (JAXA) GCOM-W1 satellite. AMSR2 measures the microwave energy emitted from the Earth's atmosphere and its surface. This module also highlights AMSR2's real-time imagery and product applications, along with its orbital, frequency and footprint size characteristics. The final lesson in this topic area is focused on the Global Precipitation Measurement (GPM), an international mission between NASA and JAXA which provides global observation of rain and snow. The GPM is a key contributor of information on the Earth's water cycle. This lesson describes key features, which include data products and an explanation of their potential impact on forecast operations.

BASIC FORECAST APPLICATIONS

The Basic Forecast Applications topic area has four lessons. The first lesson aims to help users understand the various applications of VIIRS imagery. The VIIRS DNB views reflected moonlight from clouds and the Earth's surface. It images surface light emissions from various natural sources (such as fires) and anthropogenic sources (such as city lights and gas flares), and finally it views certain atmospheric light emissions such as the auroras, airglow, and lightning flashes. The following DNB module


Volcanic Ash Detection and Retrieval

Quick Guide

Why is Volcanic Ash Detection Important?

Volcanic ash is hazardous to aviation, air quality and public health. The Volcanic Ash algorithm determines the location, height and mass loading properties for satellite pixels potentially containing volcanic ash. These products help forecasters identify potentially hazardous areas and issue more accurate aviation and public health warnings. Volcanic ash products are also useful for enhancing ash dispersion and trajectory prediction models.

How is Volcanic Ash detected and cloud height/mass determined?

VIIRS Channels	Wavelength	Channel Usage
M14	8.55 μm	Ash detection using absorption optical depth ratios
M15	10.763 μm	Ash detection using absorption optical depth ratios; ash height and mass loading using optimal estimation technique
M16	12.013 μm	Ash height and mass loading using optimal estimation technique

Impact on Operations

Volcanic Ash Detection: Day/night detection of volcanic ash clouds is performed using spectral and spatial testing over a full granule and has global coverage every 12 hours.

Volcanic Ash Cloud Height: For satellite pixels determined to possibly contain volcanic ash, an ash cloud top height is determined.

Volcanic Ash Cloud Mass Loading: For satellite pixels determined to possibly contain volcanic ash, column integrated ash mass loading calculation is performed.

Dispersion Modeling Aid: The volcanic ash algorithm products can also be used for initialization and validation of volcanic ash dispersion models.

Limitations

Imagery/Instrument Sensitivities: Any artifacts or noise within the imagery or instrument and/or unknown spectral shifts in the instrument channels will degrade the algorithm performance.

Ancillary Data Availability: No ancillary data (NWP, land/sea/snow mask, radiative transfer model [RTM], etc.) can be missing.

RTM Clear-sky Radiance Errors: Calculation errors and algorithm inconsistencies can occur near distinct physical boundaries (coastlines, mountains, snow/ice field edges, atmospheric frontal zones, etc.) due to less accurate NWP profiles in these regions, especially where optically thin clouds are present.

Contributor: Lee Cronce, CIMSS

June, 2018

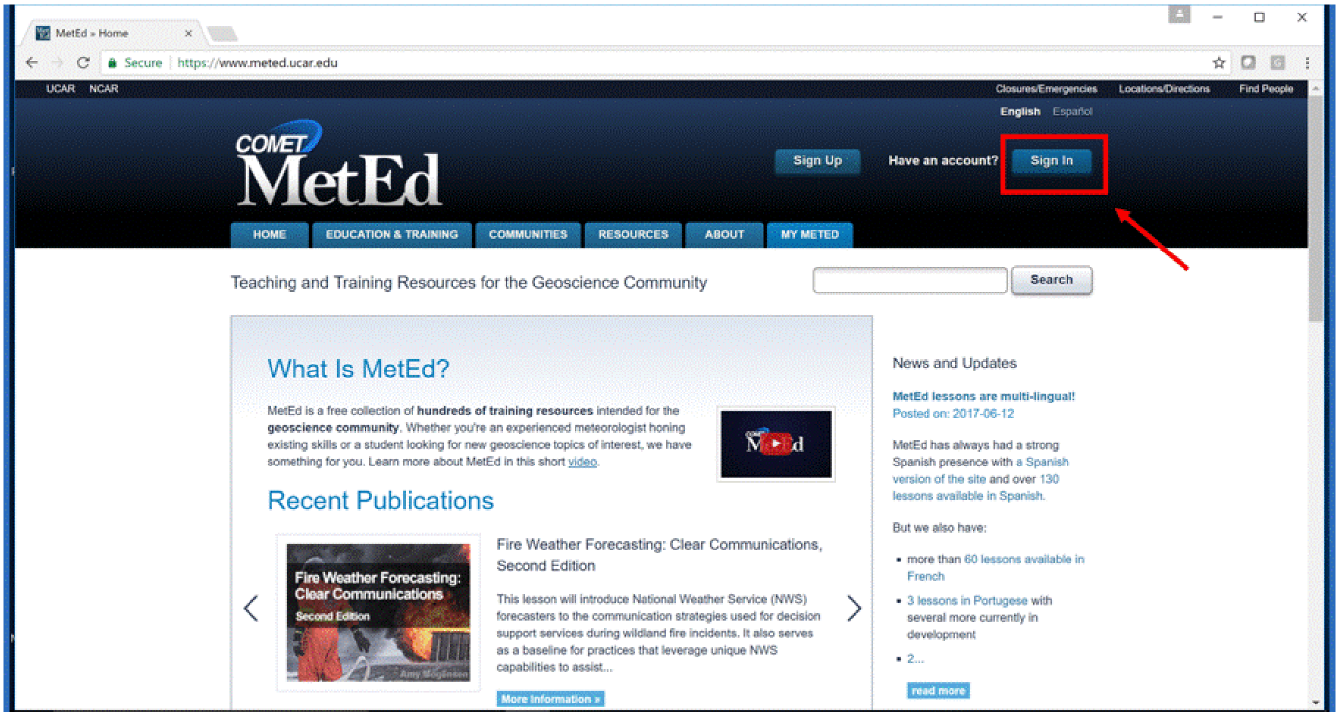
https://vlab.ncep.noaa.gov/group/stor/polar2

discusses the utility of this type of imagery in locating features such as low-level circulation centers at night and near-infrared data in providing river flooding estimates. The lessons also cover the detection of features like fog, smoke, fires, snow cover, ice, and volcanic eruptions, as well as manmade features such as gas flares, city lights and so forth using VIIRS. A lesson on soundings from the NOAA Unique Combined Atmospheric Processing System (NUCAPS) takes the participant from their creation from VIIRS Infrared and ATMS Microwave imagery on Suomi NPP and NOAA-20, to their delivery into the Advanced Weather Interactive Processing System (AWIPS), the NWS toolkit for communicating, displaying and analyzing weather data. Several examples of how the data can be used to assist Decision Support Systems (DSS) are also included. The last module in this section focuses on how satellite observations inform NWP models. It begins with a basic overview of what satellite data types are assimilated, and ends with an overview of how data from new instruments may make it into a model.

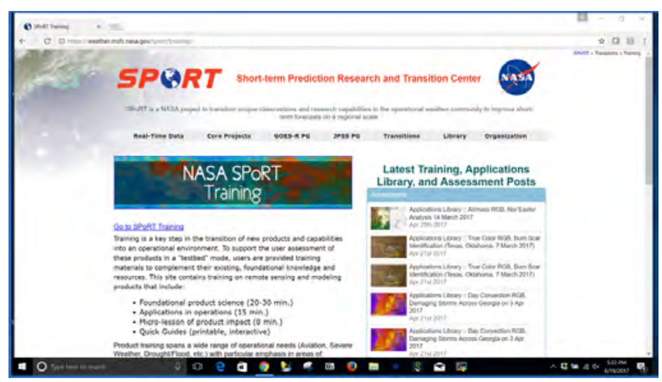
Quick Guides are product reference materials that supplement SatFC-J. The guides are one-to-two page documents that address a specific imagery product or a technical aspect of the various satellites and their instruments. These guides emphasize real-world applications and often provide details on the limitations of the operational use of these products. Quick Guides were pioneered by NASA's Short-term Prediction Research and Transition (SPoRT) Center, and are concise enough to be used quickly during a busy forecast shift. Another training resource are 'Quick Briefs', which are short (3–5 minute) training videos designed to introduce various imagery and product applications. They can be accessed from several sites including http://rammb.cira.colostate.edu/training/visit/quick_briefs/, https://vlab.ncep.noaa.gov/group/stor/polar3, and https://www.youtube.com/watch?v=IL4ptEZrQaY. Finally additional aids include short proof-of-concept videos, which demonstrate the utility of JPSS data and products in the operational forecast environment.

ADDITIONAL TRAINING PARTNERS

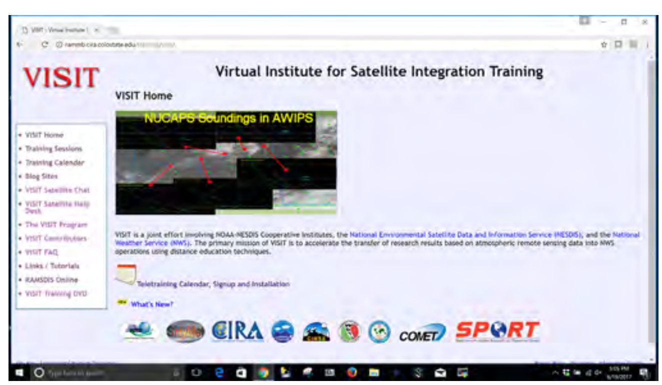
Training from JPSS Stakeholders have become a core part of user readiness. For years, JPSS has worked with the Cooperative Program for Operational Meteorology, Education, and Training (COMET), which is part of the University Corporation for Atmospheric Research's (UCAR's) Community Programs (UCP). COMET offers foundational and satellite applications training in weather and related sciences. Through its MetEd website, www.meted.ucar.edu, COMET offers free self-paced training modules on the application of data derived from geostationary and polar-orbiting satellite instruments in operational environments as well as in forecast processes.

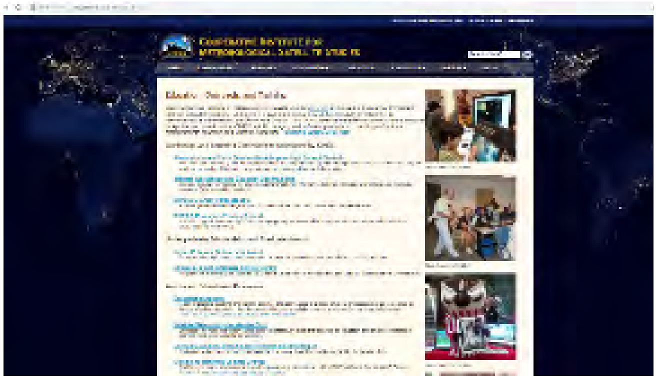


Training is also offered by the NASA Short-term Prediction Research and Transition (SPoRT) Center, https://weather.msfc.nasa.gov/sport/training, which focuses on the transition of unique NASA and NOAA observations and research capabilities into operational environments to improve short-term weather forecasts on a local and regional scale. SPoRT matches specific research and experimental products and derived technologies from NOAA and NASA satellite observations to user-identified forecast challenges.



The Virtual Institute for Satellite Integration Training (VISIT) (http://rammb.cira.colostate.edu/training/visit/), offers training sessions from multiple NOAA CIs including CIRA and CIMSS. VISIT combines the use of the Internet and audio conferencing to connect trainers with forecast offices remotely. The method is employed to help accelerate the transfer of research results





based on atmospheric remote sensing data into NOAA/NWS operations. CIMSS (https://cimss.ssec.wisc.edu/dbs/) additionally has formal and informal courses offered as classes or workshops at the University of Wisconsin-Madison. Many of these courses are tailored toward users who employ data from polar orbiting satellites via non-AWIPS platforms.

POLAR SLIDER[1]

The Polar 'Satellite Loop Interactive Data Explorer in Real-Time' (SLIDER) is an interactive website that users can explore JPSS satellite data over the Northern and Southern Hemispheres. Data consists of SNPP and NOAA-20 satellite imagery and products in real time, and provides archived data for training-related purposes. SLIDER also encapsulates real-time data from GOES-16, GOES-17 and Himawari-8.

SUMMARY

Satellite training courses have gained traction as key avenues for exposing forecast offices and national centers to new imagery and products from NOAA polar-orbiting and geostationary satellite platforms. Training activities such as SatFC-J have been established to help the NOAA satellite user community stay engaged and up to date with the imagery and data available from JPSS as well as affiliated satellite programs. These training resources are formulated to assist NOAA's diverse user community in effectively utilizing satellite data and derived products to meet their mission needs. A comprehensive set of training tools are critical to the response to challenges in aviation operations, ocean services, tropical cyclones forecasting, severe convective storms, fire weather, and others. Users and developers will continue to tailor these training resources to new mission requirements for years to come. ❖

Footnotes

[1]Polar SLIDER can be accessed from the following link: https://col.st/cubT2.

Story Source

Materials obtained from JPSS 21 December 2018 Science Seminar titled "JPSS Training: Satellite Foundational Course for JPSS (SatFC-J)."

WILDLAND FIRES AND REMOTE SENSING— AN OPPORTUNITY FOR CAPACITY BUILDING AND EXAMINATION

The information in this article is based, in part, on the January 28, 2019 JPSS science seminar presented by Evan Ellicott, Department of Geographical Sciences, University of Maryland (UMD). It features contributions from the efforts of the US Forest Service: Matt Dickinson, Nick Skowronski, David Weise, Tom Waldrop, Joe O'Brien, Mark Dietenberger, Michael Gallagher, Joey Chong; and UMD: Heather Levine, Louis Giglio, Kris Lasko, Colin Miller.

Main image: Camp fire, CA, 2018. Inset image: Whitewater-Baldy fire, NM, 2012.

Wildfires are a natural occurrence in many regions of the world. They typically occur in vegetated areas, such as dry forests and grasslands. They can be ignited naturally by heat from the sun or lightning as was the case in the summer of 2012 with the Whitewater-Baldy Complex, which burned in New Mexico's National Forest and wilderness designated land. The complex (upper left image), which burned over 290,000 acres on the Gila National Forest[1], became the largest fire on record in New Mexico. Areas such as this which feature a dry mixed conifer forest, a matrix of fuel types, and dry conditions make for a ripe environment for a wildfire.

Fire report data from the National Interagency Fire Center (NIFC) dates back nearly four decades, and shows an upward trend in area burned and a longer- lasting fire season. According to a U.S. Forest Service (USFS) research data archive (Short, 2017), roughly 85 percent of wildland fires in the United States are ignited by humans, making them the leading source of wildland fires, particularly in the Southeast. The USFS data also contains statistics on lightning and human -caused fires, compiled by the National Interagency Coordination Center (NICC) from 2001 to 2018. Humans cause an average of 61,375 fires each year, far surpassing the 9,941 lightning-caused fires.

Figure generated using historical wildland fire information on human-caused wildfires. https://www.nifc.gov/fireInfo/fireInfo_stats_human.html

The new normal is that intense, massive wildfires are burning through urban areas; sprawling towns built on land situated in and near forests and other wildlands, also known as the Wildland-Urban Interface (WUI). Experts add that with temperatures predicted to continue rising, extreme heat, and drier forests and vegetation will make wildfires more frequent and intense.

The figure below shows statistics compiled by the National Interagency Fire Center (NIFC) of wildfires nationwide. One can infer from the table (right) that the increase in fires is occurring on non-federal land (e.g. California state land).

	2013	2014	2015	2016	2017
Number of Fires (thousands)					
Federal	14.2	13.0	13.8	12.6	15.2
FS	*7.1*	*6.8*	*7.1*	*5.7*	*6.6*
DOI	*6.7*	*6.1*	*6.6*	*6.8*	*7.3*
Nonfederal	33.4	50.6	54.4	55.2	56.4
Total	**47.6**	**63.6**	**68.2**	**67.7**	**71.5**
Acres Burned (millions)					
Federal	3.08	2.15	7.41	3.00	6.3
FS	*1.37*	*0.87*	*1.92*	*1.25*	*2.9*
DOI	*1.59*	*1.24*	*5.47*	*1.70*	*3.3*
Nonfederal	1.23	1.4	2.72	2.51	3.7
Total	**4.32**	**3.60**	**10.13**	**5.51**	**10.0**

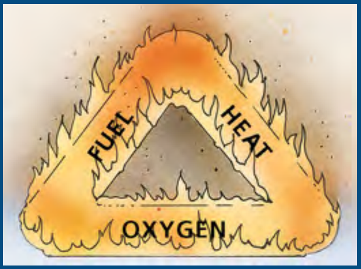
Source: National Interagency Fire Center (NIFC).

Annual Wildfires and Acres Burned, https://fas.org/sgp/crs/misc/IF10244.pdf

URBAN WILDLAND JUXTAPOSITION

Several studies—including one from the USFS, which details the spread of human settlements into forested areas (Radeloff et al.)—indicate that the wildland-urban interface in the United States grew rapidly from 1990 to 2010 with a 41 percent growth in new houses, and 33 percent growth in land areas, making it the fastest-growing land use type in the nation. According to a wildfire risk analysis by Verisk in 2017, nearly 4.5 million homes nationwide were found to be in high or extreme risk areas, and almost half (more than 2 million) of these were in California.

DID YOU KNOW?



According to the National Park Service, there are three elements that must be present for a fire to exist. **HEAT. FUEL. OXYGEN.** Absent any of these elements, a fire will not burn.

Heat comes from a natural ignition source such as lightning or a manmade source such as a lighter.

Fuels include any flammable material such as dead trees, leaves, needles and grasses. Dry vegetation burns faster and hotter.

At least 16 percent oxygen must present for a fire to start. At 21 percent, the oxygen contained in the Earth's atmosphere is more than enough.

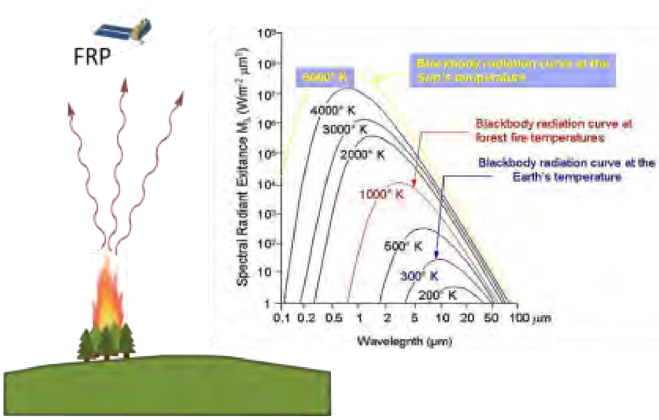
https://www.nps.gov/articles/wildlandfire-facts-fuel-heat-oxygen.htm

A NEED FOR SPACEBORNE ASSETS

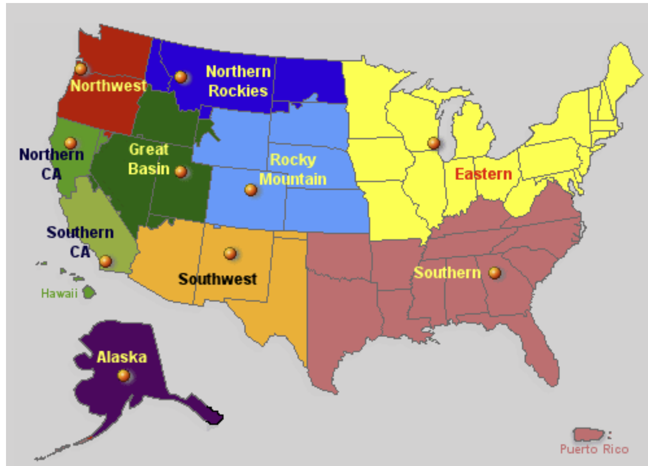
Much of the information about the Earth's physical, chemical, and biological systems comes from ground instruments, aircraft, weather balloons, or instruments floating in the ocean. While they represent major contributors to atmospheric data, ground-based observations tend to be specific to their location, and they are severely limited in time and space. Earth observation satellites, in contrast, provide continuous and consistent coverage of various features on the Earth's surface, including fires. An example of these is a new generation of spacecraft from the Joint Polar Satellite System (JPSS). The National Oceanic and Atmospheric Administration's NOAA-20 satellite launched in November 2017 while its precursor, a bridge between the legacy NOAA polar-orbiting satellites and the JPSS generation, the NOAA-NASA Suomi National Polar-orbiting Partnership (Suomi NPP) satellite, launched in 2011. NOAA-20 and Suomi NPP carry five instruments including the Visible Infrared Imaging Radiometer Suite (VIIRS), which has the capability to provide not only the location of fires, but also an indication of their intensity through the parameter called Fire Radiative Power (FRP). This information can help identify the most intense burning along extensive fire fronts, which might not be evident from other ground-based or airborne observations.

The increasing number of WUIs calls for timely and accurate data for operations to develop improved models for wildfire prediction and near-real time situational awareness. For those communities residing in areas prone to wildfires, accurate and timely knowledge of potential weather threats is essential to reducing risk to damage and loss. Moreover, it is helpful for responders on the ground to get a handle on a fire's perimeter as well as future expansion, since fires often spread rapidly. Remote sensing instruments, such as VIIRS, have demonstrated their capability to provide synoptic and timely information that enables scientists to detect, monitor and assess fires in different phases including pre and post-fire event. Combustion releases the heat energy through several pathways including conduction, convection, vaporization, and radiation.

The radiant component is emitted as electromagnetic waves traveling at the speed of light in all directions and is proportional to the absolute temperature of the fire (assumed to be a black body) raised to the fourth power. It is the radiative component that is estimated from Earth-observing satellite sensors.



A NEED FOR CAPACITY BUILDING: THE VIIRS ACTIVE FIRE PROJECT



The VIIRS Active Fire project was established in 2012 with a goal to maximize the benefits of the VIIRS fire data and products for downstream operational and research users through product evaluation, improvement, outreach and education to support fire management and NOAA operations. The goal of this project is to leverage the VIIRS AF products for active and post-fire management and NOAA operations to improve research and decision-making. The project focuses on the use of remotely sensed data and products in wildland firefighting operations, leveraging existing relationships with the NWS, the National Interagency Fire Center (NIFC) and their regional centers, and international partners.

Active Fire is one of the operational environmental data products generated from the VIIRS instrument. This product, especially the Imagery band (I-band, 375 meter) hot spots, is used by operational users for improving fire detections. It is also used for situational awareness by operational groups such as Geographical Area Coordination Centers (GACCs). These interagency centers are focal points for coordinating and mobilizing wildland fire incidents. Initially, the product was expected to be used for real-time resource and disaster management, and more specifically for wildland fires. However, the product turned out to be better than expected due to saturation levels in the VIIRS channel from which it is derived,

Opportunity Calls: Reaching Beyond the Target Audience

Evan Ellicott, an Associate Research Professor at the University of Maryland's department of Geographical Sciences, and member of the VIIRS AF product development and evaluation team, works with research and operational personnel to evaluate and improve the delivery of a stable, timely, and useful product. He works closely with various members of the NWS user community, such as Incident Meteorologists (IMETs), to improve situational awareness and decision-making. Ellicott's first opportunity to get his boots on the ground came in June 2013 when there was an outbreak of fires in Colorado. It was the goal of this team to see if one of their members could spend time at the command post of a forest fire to interact directly with users of satellite data on the frontline.

The West Fork Complex fire, which was spreading fast and furious in southern Colorado, presented an opportunity for Evan to get a first-hand view of operation activities on the fire line. Initially, his goal was to meet with IMETs to assess how they utilized remotely sensed data in operations, but as he observed and interacted with the different personnel on the incident, it became apparent that he had missed a key audience, which included Fire Behavior Analysts (FBANs), Long Term Analysts (LTANs) and other personnel who were keenly interested in AF products such as fire location, intensity, and vegetation products as well.

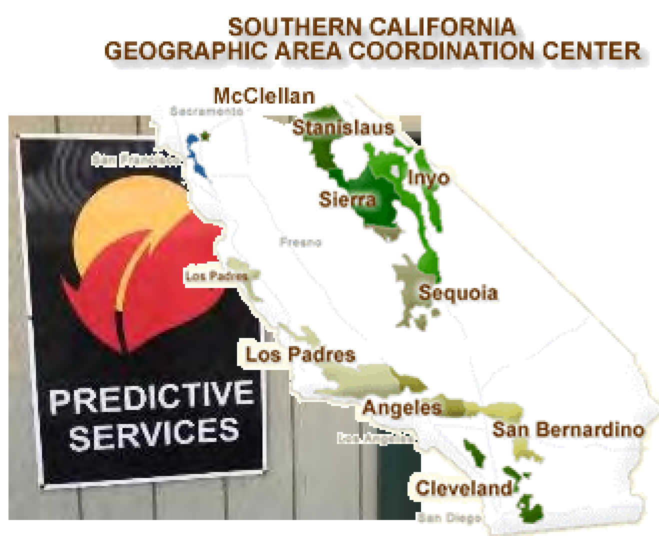
Lessons learned from this site visit included broader education to wildfire operations personnel, decreased latency of products, and user-friendly data formats.

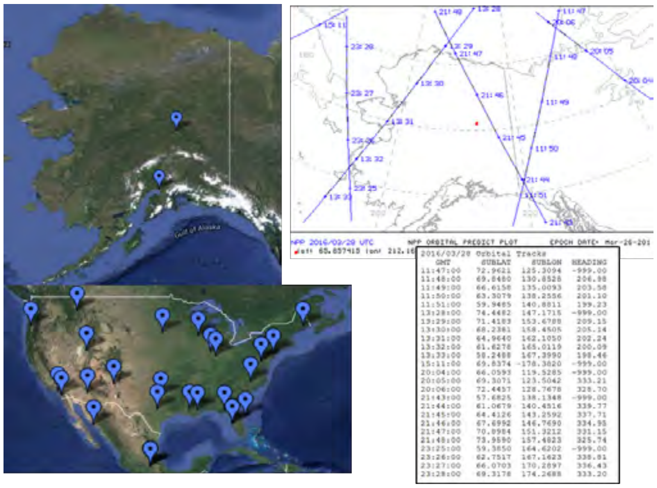
leading to expanded application in areas such as air quality monitoring, ecosystem monitoring, and climate studies.

As part of the JPSS PGRR Fire and Smoke Initiative, members of the VIIRS Active Fire Project implemented capacity building support efforts, which target user communities of the National Weather Service (NWS), U.S. Department of Agriculture (USDA), and local fire management agencies such as CalFire and the Alaska Fire Service. The efforts include capacity building through education and outreach, product evaluations through field campaigns, and participatory activities with embeds from the Visiting Scientist Program (VSP).

VISITING SCIENTIST PROGRAM

Evan Ellicott took part in a visiting scientist program in which researchers embed themselves in regional wildland fire operations centers (GACCs). The visits offer a detailed and thorough exchange of knowledge and examination of operations. They also provide a greater understanding of the day-to-day operations and duties, as well as applications of remote sensing data, and help reduce knowledge gaps about the data and address potential uncertainties and misuse of the data. Over the years, Ellicott's visits have taken him to five GACCs. From these visits he has learned that each center is unique in that they cater their operations to, among other things, their environment, fire situation, and resource availability. For example, the resources used by wildland fire crews in the Operations Southern California (OSCC) GACC include social media, which would not be practical in a region like Alaska, which presents challenging terrain to include its remoteness and vast size as well as limited road networks. As a result the Alaska Interagency Coordination Center (AICC) wildland fire crews depend on aircraft, which are critical not only for operations but for transportation of personnel and supplies as well.





Ellicott has also been struck by other stark differences between the areas he has visited. For example, it is more likely for a human to be the ignition source of a wildland fire in a western state like California, whereas in Alaska a wildfire is more likely associated with lightning. Due to Alaska's remoteness, understanding environmental conditions, such as the timing of snowmelt and subsequent green-up of vegetation, is critical to developing temporal and spatial trajectories of where and when fires might start.

In addition, due to its high latitude, Alaska has an abundance of observations from polar-orbiting satellites which offer frequent information about fire locations. The Geographic Information Network of Alaska (GINA) is located at the University of Alaska-Fairbanks. It is a conduit for geospatial data—to the university, Alaska Fire Service, and AICC—from its direct-readout satellite receiving antennas.

Despite the regional differences, Ellicott notes that common problems exist, notably that there are many sources for obtaining fire-related satellite data, but these are often redundant and either lack information about what is being displayed or the information is not presented clearly. This redundancy and ambiguity can lead to confusion. For example, differences between nominal and actual spatial resolution, a function of satellite scan angle, is not immediately evident. He notes that reducing redundancy and/or improving data access and metadata to clarify differences in sensor data, spatial, and temporal resolutions is important, especially for decision making. In other words, fire detections are more than just dots on the screen. They hold actionable information that's pertinent to Decision Support Systems and as such, they need to be understood.

Ellicott notes that many users have become familiar and comfortable with using satellite data, but cautions that as the application increases so does the potential for misinterpretation, or even misuse, of the data. And there are still many operations personnel who are uncomfortable with using satellite data because of these knowledge gaps.

Redundancy in sources of geospatial information, uncertainty in the application and interpretation of data, and a wealth of sensors and associated products suggests that capacity building is needed to reach out to end users, especially for time-sensitive decision making. In addition, such efforts offer opportunities to solicit user feedback to help ongoing improvement and VIIRS evaluation.

Operational personnel and first responders need fire data, and the quicker they get it, the better! Reducing data latency, especially for personnel deployment to an incident, is a necessary step forward. With a growing number of incidents of wildfires igniting close to residential areas, and quickly spreading, getting closer to "real-time" data availability would improve situational awareness and decision making. At least that's the hope.

LOOKING OVER THE HORIZON

Multi-sensor, blended products is the future. Merging the spatial resolution of polar-orbiting satellites with temporal frequency from geostationary sensors may seem a little strange, but a no brainer for some, like Ellicott, who contends that marrying this with optimized data processing and greater bandwidths and situational awareness truly approaches real-time.

EVALUATION

Members of the VIIRS AF PGRR team have been evaluating and validating the VIIRS AF product since sensor checkout in early 2012. Prescribed fire has offered numerous opportunities to validate the VIIRS AF detection envelope as well as FRP estimates. Ellicott and his research team have conducted such field efforts in South Africa, Brazil, and throughout the United States. These managed fires also provide a chance for outreach and education while getting feedback. For example, the VIIRS AF PGRR team regularly partners with the Maryland Department of Natural Resources (DNR) to time prescribed fires with overpasses from Suomi NPP and NOAA-20 while collecting in-situ measurements.

SUMMARY

As fire seasons expand and the proximity of fire activity and wildland urban interface shortens, there is a growing need for faster and better informed responses. The information that can aid in this endeavor has increasingly come from remote sensing, whether this be from aircraft, satellite, or more recently unmanned aerial systems (UAS). Engaging end-users to facilitate dialogue around sensor data/product applications and experiences provides crucial feedback to improve development of such data. At the same time, these interactions are educational for operational (and research) personnel about best practices and uncertainties to be aware of. Looking forward, the partnerships between R2O will likely strengthen and result in better products, response, and situational awareness for natural disasters, such as fire. ❖

Footnotes

[1]USDA Forest Service, June 2013. Whitewater-Baldy Complex Fire Review, Gila National Forests, https://www.wildfirelessons.net/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=c49b9cd9-e0cf-4dee-8055-d6d0225444d7

Story Source

Materials obtained from JPSS January Science Seminar titled "Wildland Fires and Remote Sensing."

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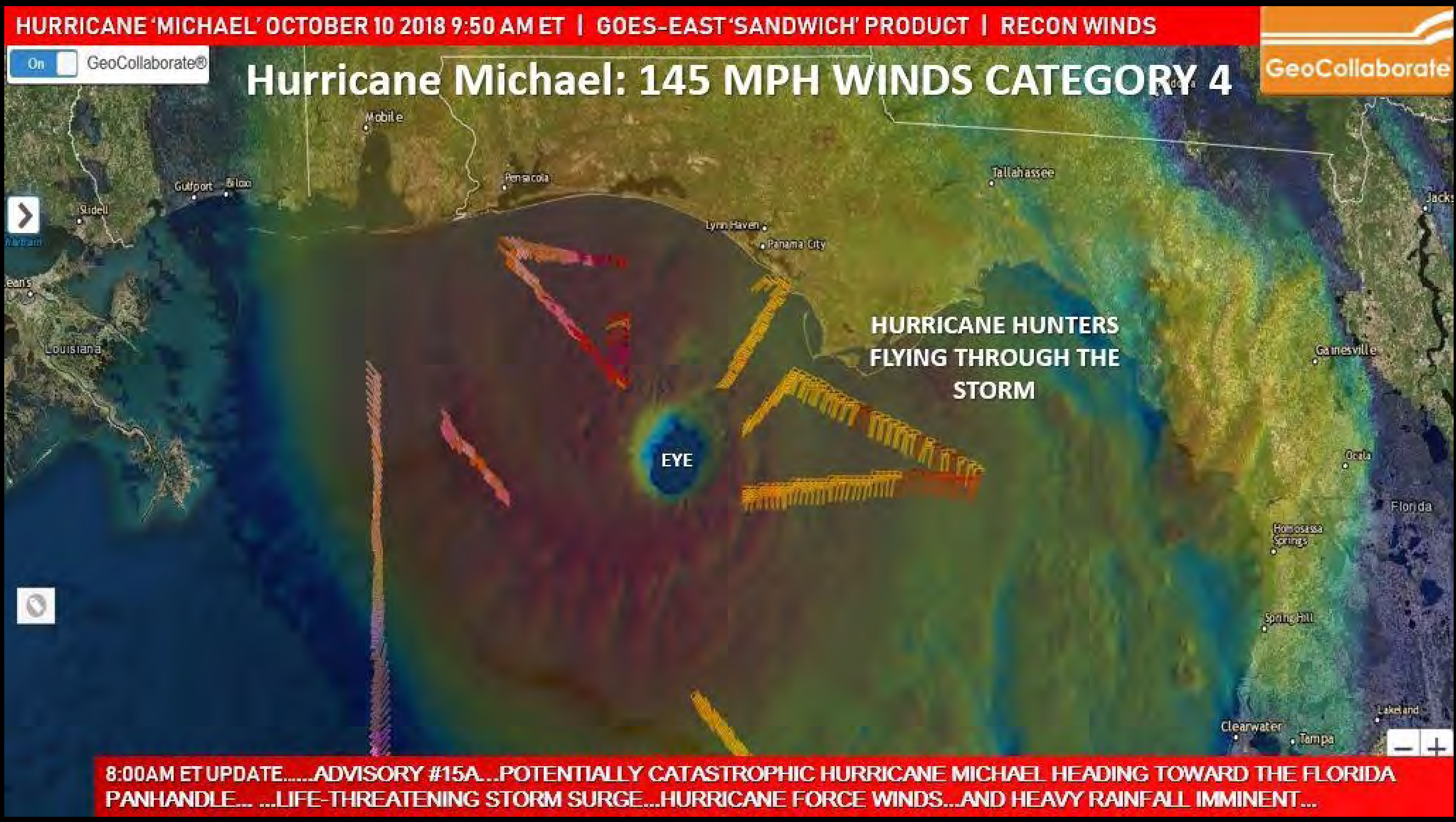
The activities featured in this paper are follow-ups on stories previously featured in the 2013 and 2014 Science Digests.

EXPANDING ACCESS TO AND USE OF SATELLITE DATA THROUGH GEOCOLLABORATE®

IMPROVING SITUATIONAL AWARENESS AND DECISION MAKING IN DIVERSE, MULTI-SECTOR ENVIRONMENTS

The information in this article is based, in part, on the February 25, 2019 JPSS science seminar presented by Dave Jones, Founder & CEO StormCenter Communications, Inc. It features work being done by StormCenter with support from the JPSS Fire & Smoke and River, Ice & Flooding Initiatives. It also features work being performed in partnership with the All Hazards Consortium (AHC) to leverage trusted data sources from federal, state and private sector organizations.



Category 4 (CAT 5 at landfall) Hurricane Michael approaches the Florida Panhandle with its destructive winds, devastating storm surge and intense rainfall. NOAA GOES-East data channels are combined in a 'sandwich' product from CIMSS RealEarth combined with NOAA Recon reports from the NOAA P-3 hurricane hunter aircraft, accessed and shared across multiple platforms to decision makers for improved situational awareness via GeoCollaborate. More NOAA data is now available for GeoCollaborate to share putting more NOAA data in the hands of real users who can begin to assess threats, response, damage assessments and recovery.

We are exposed to a wide variety of extreme weather events, such as wildfires, floods, earthquakes, severe storms, and volcanic eruptions. Natural hazards turn into disasters when lives are lost and livelihoods are damaged or destroyed. Some hazards, whether manmade or natural, become catastrophic disasters or large scale mass casualty events, which bring entire regions to a standstill. When these incidents occur, all those involved in responding and making decisions need to collaborate on the same map at the same time with accurate geospatial data in real time across multiple platforms. Personnel on the ground need critical information to assist in responding and making damage assessments, whether it's wildfires spreading in shifting winds, intense flooding that requires evacuations and rescue, or a hazardous chemical spill, while those in other support capacities provide resources and information, while keeping the big picture in mind.

In 2017, a trifecta of storms—Hurricanes Harvey, Irma and Maria—rolled ashore bringing storm surge, heavy rainfall, and violent wind to portions of the United States, Puerto Rico, and the Caribbean Islands. Harvey made landfall along the Texas coast on August 25, 2017. Its slow movement and record-setting rainfall over the Houston metro area led to widespread flooding over multiple days. Irma crossed over the Caribbean Islands and Florida, and moved into the southeastern United States. Hurricane Irma's landfall on the U.S. coastline roughly two weeks after Harvey marked the first time in a century that two storms rated Category 4 or stronger struck the U.S. mainland in the same year. These storms left significant trails of damage and destruction in their wake, including coastal and inland flooding, extensive wind damage, and numerous power outages. The long-lasting impacts to the electrical infrastructure of Puerto Rico from Maria resulted in thousands of residents being without power for months.

As with any disaster, communities came together, and in their various capacities assisted those impacted. Federal, state and local agencies deployed units including first responders who navigated various conditions to perform operations on the ground. Without communications, many of the ongoing efforts would be extremely risky or futile.

COLLABORATIVE DECISION-MAKING

Sharing of real-time geospatial data in a collaborative environment is not only useful in emergency situations. Activities such as monitoring ports and dams, coordinating mass transit activities on roads, rails, air and waterways, and large-scale outdoor events such as concerts and football games, are examples where shared geospatial and other data help facilitate operations. It is referred to as disparate system interoperability or cross-platform communication.

Many organizations including federal, state and local agencies as well as those in the private sector employ a Common Operating Picture (COP) to share information. The term, which is widely used in armed forces and law enforcement, refers to displays of identical information—from a single unit—to multiple parties to achieve situational awareness or facilitate decision making. The idea behind a COP is to have many people sharing the same information at the same time, for example at meeting or conference events where many participants congregating at the same physical location can view data in real time from one screen, and/or enable other participants to view the same data remotely through web screen-sharing services.

Some organizations employ screen-sharing technologies that enable them to reach multiple parties outside the constraints of being in the same physical location. The National Weather Service (NWS) uses PowerPoint and screen sharing technology to provide briefings to emergency managers.

Constraints, such as inadequate system resources, bandwidth or administrative privileges needed to share screens can serve as barriers to critical information dissemination when most needed.

Moreover, screen-sharing technologies do not necessarily provide collaborative environments that allow the participants to incorporate the information shown in the presenter's desktop video stream. Remote participants can only view the information being broadcast on the presenter's desktop, and when the screen-sharing session ends, so does the remote user's access to the information.

Superstorm Sandy was one of the worst storms to ever hit the U.S. East Coast. The storm, which impacted a wide swath of the nation's Atlantic coastline in late October 2012, completely decimated some of the neighborhoods in its path. Unlike typical coastal storms that move north along the east coast, Sandy made an extremely rare hard left (westward) turn that put it in on a direct collision course with heavily populated regions along the Atlantic coastline. According to an information pamphlet detailing lessons learned from the Federal Emergency Management Agency's (FEMA) Hurricane Sandy response deployment procedures (www.hsdl.org/?view&did=784026), one of the biggest challenges for agencies was the inability to gather accurate, real-time information to match resources and capabilities to these needs and requirements. Superstorm Sandy demonstrated firsthand the challenges of not having access to critical data in time to inform their situational awareness. The pamphlet further states that a "lack of clear information" was an impediment to decision making as well as to reducing the severity of impacts or making improvements.

TRUSTED INFORMATION (TI)

TI is information that is from a reputable/reliable source. It can be combined with disparate TI sources from multi-agencies and private sector.

Each trusted data source is a separate data layer.

EXAMPLES

Weather Observations

NOAA satellite data

Pictures

Soil conditions in burn scars

Remote Sensing

Declarations, Waivers, Guidance

Critical Infrastructure

Drone Data

Cameras

Federal Open Datasets

State Datasets

Municipality Datasets

Taken as a whole, COPs enable data integration from multiple sources into one spatial data platform, and therefore help create a unified approach to situational awareness and decision making. Most COPs, however, are characterized as 'cylinders of excellence' as they typically operate in their own domain, and the information they provide is often restricted to authorized users. No other technology can perform cross-function operations or share their data in real-time into disparate platforms. During events where multiple parties need to respond and coordinate, as is in the case of disaster response, it can be a challenge for all those providing support to be on the same map. Many federal, state and local agencies use their own mapping environment to access data, but their systems cannot share those trusted data sources with each other. In some cases, they do not even have access to the same type of information.

Having a capability that allows for the different players in the field to access and share information in real time, including base layers and data from remote sites, is vital. And a system that improves situational awareness and enables data-driven decision-making through the sharing of trusted information among all stakeholders can save lives and protect property.

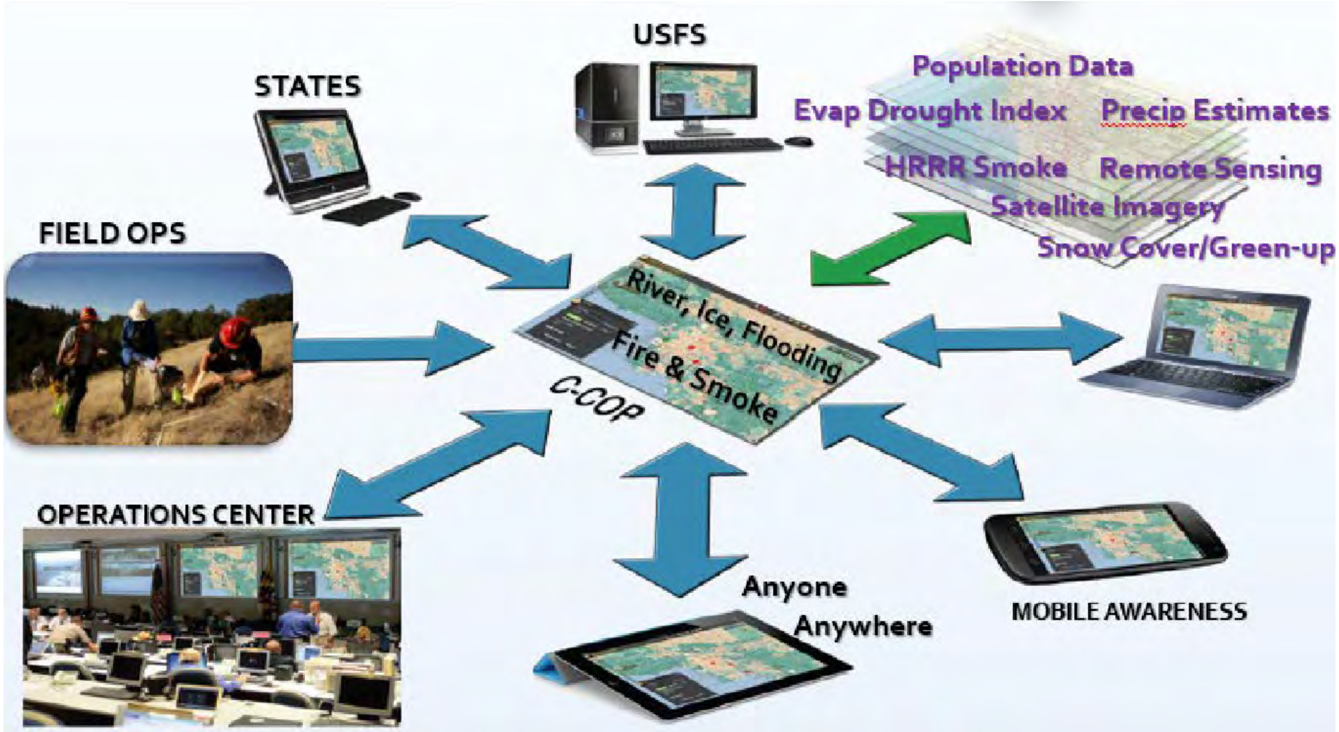
STORMCENTER COMMUNICATIONS

StormCenter Communications was launched in 2001 to help expand access to and use of science data to improve situational awareness and decision making. It has been working to access and deliver high resolution data from NOAA's polar orbiting satellites for broadcast use and improved situational awareness and decision making.

The company created GeoCollaborate®, a technology that allows for real-time sharing of data, such as weather, critical infrastructure and emergency management information, across multiple platforms.

GEOCOLLABORATE

GeoCollaborate is a patented multi-platform and device data sharing cloud-based service, developed through the Small Business Innovation Research (SBIR) program under a NASA grand challenge. It enables data to be accessed and shared in real time simply through a web browser or integrated into multiple disparate web maps to create a collaborative environment. After years of development, GeoCollaborate has now obtained the highly-sought, and rare, SBIR Phase III status, and is the U.S. Federal Government's 'preferred provider' for geospatial data sharing and collaboration.

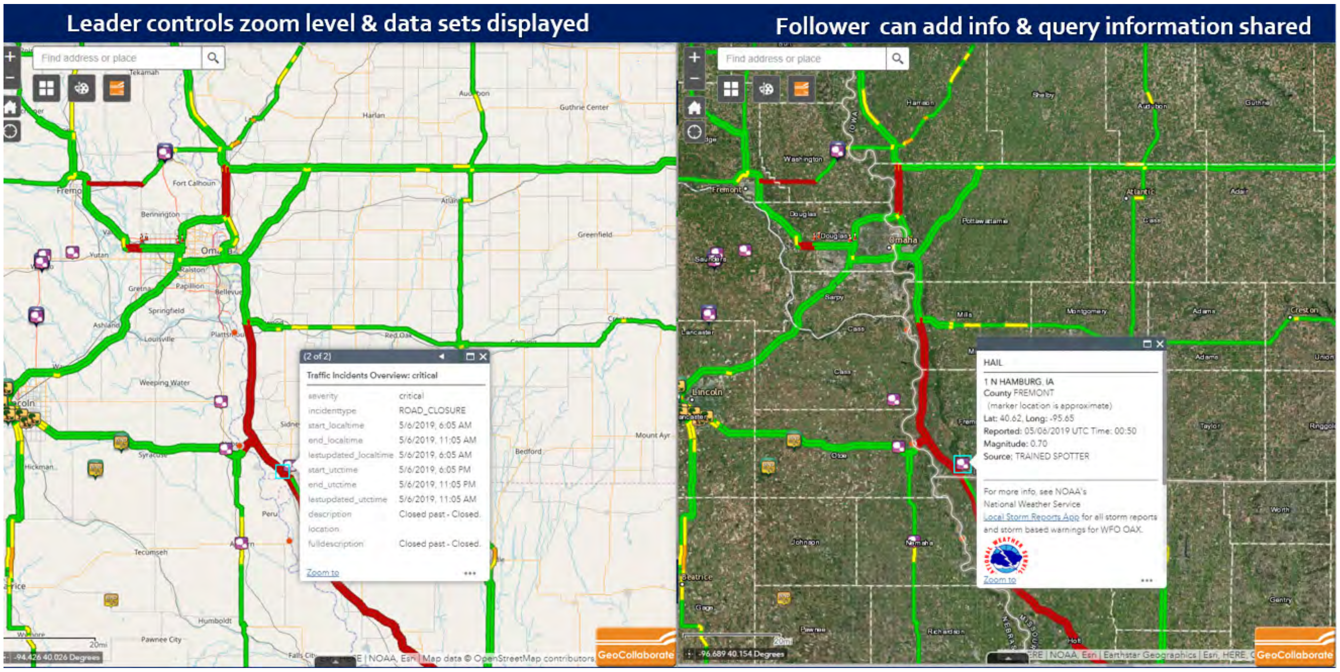


Data sharing and collaboration use case for fighting wildfires. GeoCollaborate can introduce a cross-agency coordination capability that leverages low bandwidth environments and open government data such as NOAA JPSS and GOES satellite imagery to any device in the field or operations center enabling decision makers to see NOAA data in combination with their own.

This means that as a " sole source" provider of this technology, StormCenter Communications, Inc. can easily and quickly be contracted for licensing, customizing, training, professional services and workshops on the topics of data sharing, collaboration, cross-platform interoperability, collaborative decision making, virtual globe data sharing, training and more.

The concept behind GeoCollaborate is simple: allow anyone to author the content of a lead web map, share that content, and collaborate with others in real time on follower web maps. GeoCollaborate is available on the cloud as a hosted web map and a data sharing and collaborative service that meshes data feeds from various sources including satellites, in-situ observations, crowdsourced information, critical infrastructure and even socio-economic analytics to create map displays, imagery, critical infrastructure, real-time vehicle location visualizations and more. Datasets can be easily downloaded through low-bandwidth cell phone and wireless networks and combined with other geospatial information on-site, to ease collaboration across all stakeholders including those who interpret the data (authors, analysts, and subject matter experts) and those who make decisions based on that data (managers and team leaders), which can lead to effective and valuable decision support services.

Besides sharing and visualizing data on the go, GeoCollaborate can also accelerate the ability for the delivery of Impact-based Decision Support Services (IDSS) to a wide variety of NOAA partners. Any product visualized within the Advanced Weather Interactive Processing System (AWIPS) can be exported for rapid inclusion into the data-sharing environment. GeoCollaborate also leverages the expanding GIS services offered by NWS. As more and more products produced by NOAA are offered via the NWS' Information Dissemination Portal (IDP) and NOAA nowCOAST, GeoCollaborate can access and share these services across multiple platforms so everyone can be on the same map at the same time. This significantly improves situational awareness and accelerates decision making that can save millions of dollars in wasted efforts.



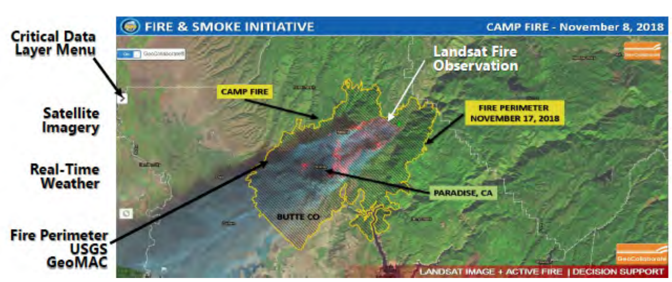
Disparate system interoperability is demonstrated here with two different instances of GeoCollaborate sharing data between them. This powerful capability can enable existing mapping environments to become collaborative and lower the training curve because no-one has to change their existing mapping system or switch to another vendor. This opens the doors to enabling each agency, organization or nation to accelerate their situational awareness and approach to decision making and is a breakthrough for placing more NOAA data to work serving decision makers.

APPLICATION EXAMPLES

Task orders under two JPSS initiatives—Fire and Smoke, and River, Ice and Flooding—have helped demonstrate how various datasets can be accessed and incorporated into decision-making environments. Flooding and power restoration after a severe weather event have been popular use-cases for GeoCollaborate with many others beginning to surface as more utilities and emergency managers realize the powerful benefits that real-time data sharing offers.

Wildfires

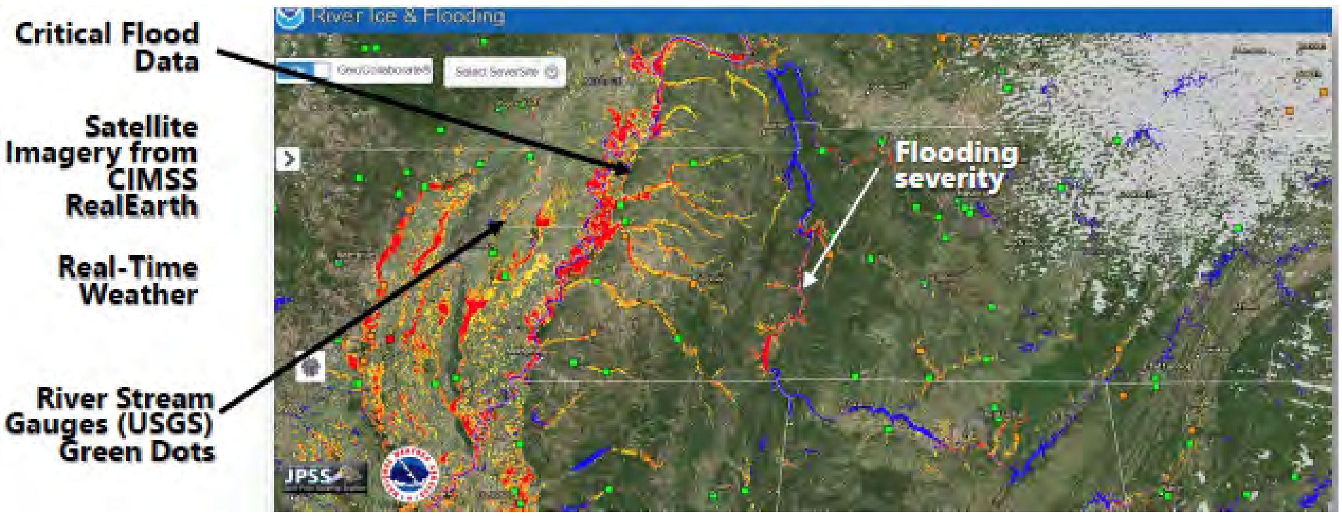
Wildfires can pose serious hazards to the environment. Meanwhile, long range transport of smoke emissions can adversely impact air quality, and exposure can lead to health complications for sensitive members of the population. Some population groups, particularly those living in the urban-wildland interface, are at considerably higher risk of the dangers wildfires pose to life and property. The following is an example of how a GeoCollaborate Dashboard delivers critical information for data driven decision making (3DM) during a wildfire event in Northern CA. This example from 2018 shows several data layers including satellite imagery marked with fire perimeters of the Camp fire in Butte County, California. All of the data layers originate from trusted sources such as NOAA, USGS GeoMAC (a multiagency coordination information source), USGS Landsat imagery and critical infrastructure datasets from utilities and the private sector. This information is useful for immediate situational awareness and coordination because all decision makers can be on the same map looking at the same data at any moment providing local, state or federal partners with access to unique datasets.



The JPSS Fire & Smoke Initiative GeoCollaborate session depicts the latest fire perimeter data layer from USGS GeoMAC overlaid onto a timely Landsat image during the Camp Fire in Northern CA. Introducing this capability can enable a unified multi-agency approach to situational awareness and decision making.

Floods

Flooding along rivers causes billions of dollars of damage every year. Extreme rainfall, snowmelt and jams caused by the breakup of river ice happens frequently, putting lives and livelihoods at risk. The following is an example of a dashboard for data-driven decision making (3DM) during a flooding event. A product like the one below can help officials on the ground and at FEMA determine the extent of the flooding and think about who else may be at risk. These steps can aid evacuations, planning and closing of businesses so inventories can be saved and properties protected.

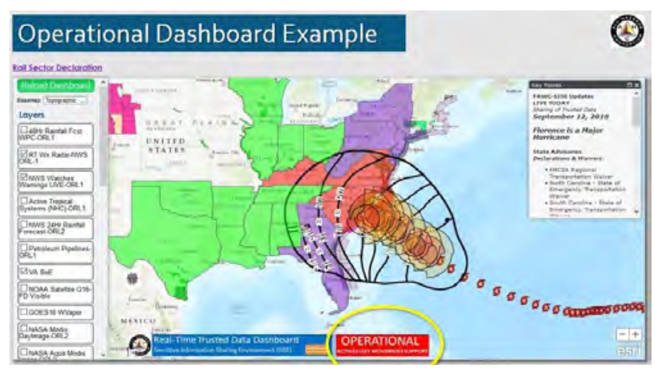


This example shows flooding along the Mississippi River as a combination of snow melt and heavy rains from severe thunderstorms and heavy downpours impacted Missouri, Arkansas and Tennessee. Rapid response algorithms from the JPSS River, Ice and Flooding Initiative. Can identify where flooding is occurring and provide decision makers such as local officials and FEMA with a broad understanding of the flooding extent. This helps plan the extent of evacuations and in preparing businesses with information so they can save their inventory before the flood arrives.

Hurricanes and Power Restoration

When hurricanes hit, power often goes out. Lives are threatened and those who rely on power to sustain life-support functions need assistance right away. The All Hazards Consortium's (AHC) Fleet Response Working Group (FRWG) Sensitive Information Sharing Environment (SISE) GeoCollaborate® Dashboard was used to provide sensitive information to fleet utility vehicles responding to requests for mutual assistance in the Carolinas and Virginia as a result of the impacts from Hurricane Florence.

The All Hazard Consortium (AHC) Fleet Response Working Group includes both private and public sector individuals from energy companies, state emergency management agencies and logistics coordinators to engage in the important operational efforts to expedite the restoration of power, supply chains and other critical infrastructures that businesses and communities rely upon such as power, fuel, water, food, shelter, communications, transportation, etc.



The GeoCollaborate Dashboard is being used to coordinate the movement of fleet utility vehicles across state lines to get to disaster areas so power can be restored as quickly as possible. The green states represent 'pass-through' states for utility vehicles while purple states are states covered by transportation waivers from the Federal Motor Carriers Services Administration (FMCSA) and the red states are where declarations of emergency have been issued by the governors. NWS data layers are visible such as NHC hurricane wind field prediction, best track and time of arrival for tropical storm force winds. Key points point out specific information to support decision makers.

Critical to the process of moving utility vehicles into the right locations at the right times is accurate damage assessments after a disaster. GeoCollaborate brings together disparate data sources across all decision-making lines of authority to save money by improving

GeoCollaborate enables collaborative damage assessment activities, such as rapid labeling and drawing, across platforms so decision makers can determine how many power poles are down, destroyed or damaged. Critical infrastructure can be overlaid to provide an assessment of how much pipeline needs to be ordered to get communities back up and running with water, sewer and other services. By collecting imagery right after disasters, NOAA is enabling decisions to be made rapidly, saving millions of dollars.

efficiencies and leveraging data sources such as NOAA's rapid response Office of Marine and Aviation Operations (OMAO) high resolution imagery collections when tasked by FEMA.

The FRWG supports joint public/private 'integrated' planning, education and training, joint information sharing, and annual exercises to improve power restoration efforts and supply chain resiliency. GeoCollaborate has become a critical capability to enable improved efficiencies.

FUTURE PLANS

As more agencies and organizations at the state and federal levels as well as the private sector learn about the unique capabilities that GeoCollaborate brings to situational awareness and decision making, many doors will open for how NOAA data can support these efforts. For years, producers of science-based datasets and information sources have struggled to understand how research results can transition to operational implementation. GeoCollaborate can bridge that gap and place research products in front of decision makers rapidly and provide the capability to deliver feedback to those researchers.

GeoCollaborate can also improve efficiencies for quality-controlling datasets against in-situ measurements by bringing those disparate observations together. It is the hope of Dave Jones, Founder and CEO of StormCenter Communications, Inc. that GeoCollaborate can transform how researchers and operational decision makers work together to accelerate R2O and O2R and enable the sharing of research findings that can benefit innovation, decision makers and the private sector. Training can be accelerated and the connection between training center and operations can be maintained indefinitely. This has direct economic impacts and benefits to be gained as more people understand the power of real-time data sharing across platforms.

For NOAA, the invention of GeoCollaborate means that there is now a vehicle available to deliver trusted NOAA and other open government data sources into decision making environments efficiently and effectively, saving time and money. This means a host of new users is just around the corner with every use case that gets identified. As weather events become more intense and climate change impacts more and more people around the world, GeoCollaborate can provide the environment for domestic and international collaboration from any computer, tablet or mobile device.

SUMMARY AND CONCLUSIONS

GeoCollaborate allows many users including federal, state and local agencies as well as private sector organizations to share trusted data in real time across any platform or device to enable collaboration and sharing of data when it's most needed. This is a capability that has been needed for decades and is still being identified as a need within agencies and the private sector to accelerate data access and sharing. Now that a data sharing and collaboration platform exists, more attention can be applied toward applications and applied benefits of NOAA data in both operational and research environments. This will benefit other agencies at the federal, state and local levels as well as the private sector and NGOs. ❖

Story Source

Materials obtained from JPSS February Science Seminar titled "Delivering JPSS Data to Improve Situational Awareness and Decision Making."

Additional Resources

How GeoCollaborate® works: https://www.youtube.com/watch?v=O20gjnti4Qk&index=3&list=PLEXjtR48sZXE881KLsXlcOr0X-LhpS-3u&t=0s

Member Highlight: StormCenter Communications, Inc. https://www.esipfed.org/member-highlights/member-highlight-stormcenter-communications-inc

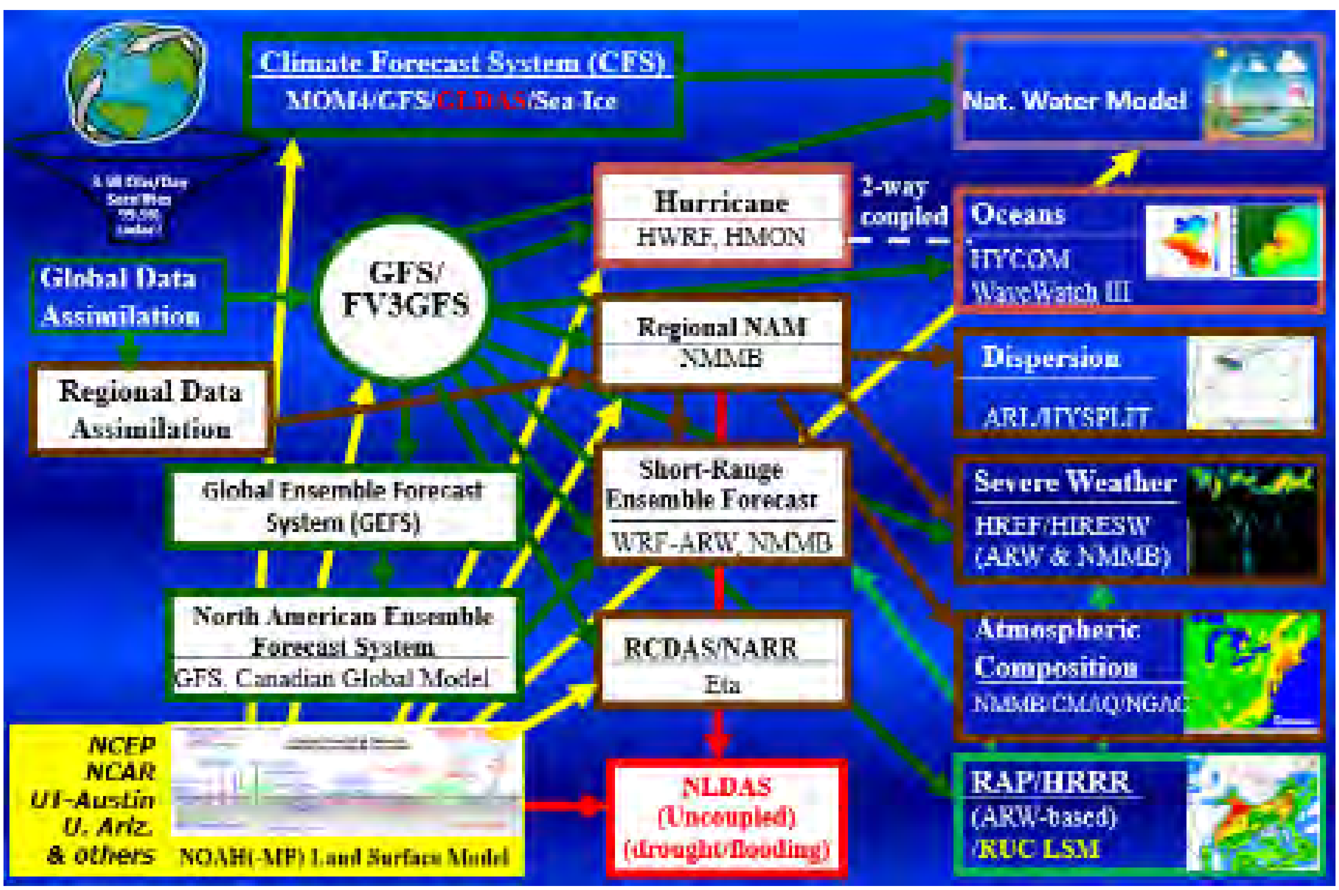
The Promise of JPSS, Storm Center Communications. https://youtu.be/eulPPfwexaE

SATELLITE SOIL MOISTURE DATA PRODUCTS AND THEIR POTENTIAL CONTRIBUTIONS TO NOAA RESEARCH AND OPERATIONS

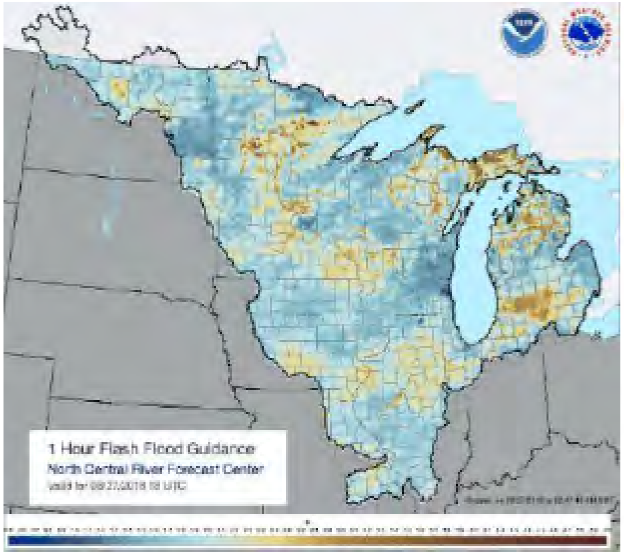
The information in this article is based, in part, on the March 18, 2019 JPSS science seminar presented by Xiwu Zhan, NESDIS/STAR. It features work being done by Jicheng Liu, Jifu Yin, Li Fang, Nai-Yu Wang, Mitch Schull, Cooperative Institute for Climate Studies (CICS), University of Maryland, Weizhong Zheng, Jiarui Dong, Daryl Kleist, NWS/NCEP.

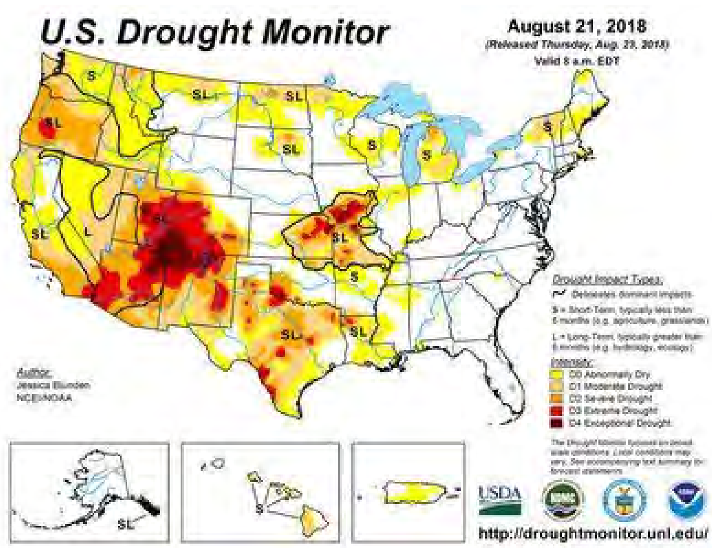
Water is essential for sustaining life on Earth. According to the National Ocean Service (NOS) roughly 97 percent of the Earth's water is contained in the ocean; the remaining three percent is distributed in many different places, including the layers of soil at the Earth's surface. The water content held in these soil layers is referred to as soil moisture. Soil moisture is an important component of the water cycle, which, in turn is one of the most important processes of the weather and climate system. Soil moisture is also an essential element in many hydrological, biological and biogeochemical processes including precipitation—the process that allows water vapor to fall from the sky and onto the soil surface in liquid form as rainfall or in solid form as snow, sleet or ice. Soil moisture controls the exchange of water and heat energy between the land surface and the atmosphere through processes such as evapotranspiration and runoff, and the carbon cycle through plant/crop photosynthesis and respiration.

Because soil moisture plays a key role in the development of weather patterns, it is of interest to agencies such as the National Oceanic and Atmospheric Administration (NOAA), whose operations are based on scientific insights that extend from the surface of the sun to the depths of the ocean floor.



Noah (-MP) Land Model Connections in NOAA's NWS Model Production Suite. Courtesy of Yihua Wu, NCEP





Soil moisture measurements are ingested into multiple numerical weather, climate and hydrological prediction models at NOAA. These models, which include the Global forecast System (GFS), are at the core of National Weather Service (NWS) operations. They provide guidance which is informed by forecasts produced by Weather Forecast Offices (WFOs), and service centers within the National Centers for Environmental Prediction (NCEP).

Numerical weather and climate prediction models require soil moisture data to initialize their forecasts. Estimates of how much water and energy the atmosphere will exchange with the land surface play a major role in these forecasts. For these estimates to be made, the current land surface properties, including soil moisture, have to be known and input into these models. This process is called forecast model initialization. Currently, these initial soil moisture value estimates are calculated using rainfall data and a land surface model. Given potential errors in rainfall data and the land surface model physics or parameters, there is some uncertainty in soil moisture estimates.

Satellite soil moisture retrievals are observed values that could be treated as surface soil moisture truth, and thus are expected to improve the initialization of numerical weather and climate prediction models and in turn improve the weather and climate forecasts.

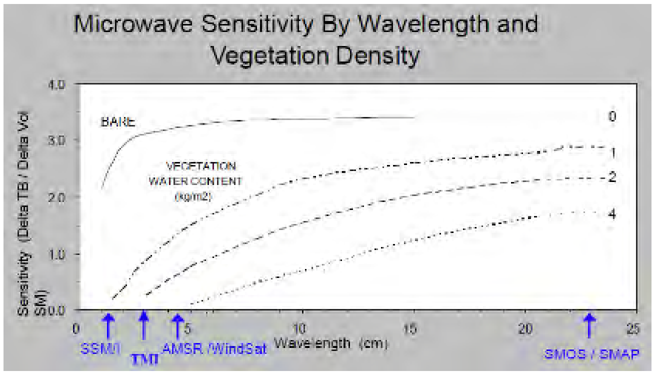
Soil moisture information can be used in various applications and practices including drought monitoring and prediction, erosion prediction, wildfire risk assessment, flood monitoring, and crop yield forecasting.

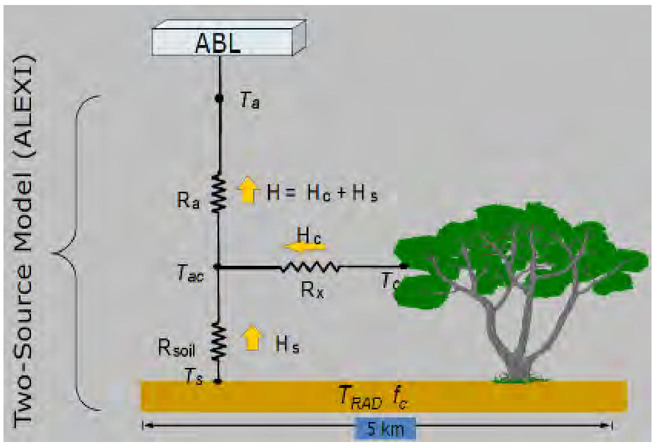
Soil moisture observational data can replace model data or be used to improve model estimates. Shown on the left above is an example of the NWS Operational Flash Flood Guidance (FFG), which is based on modeled soil moisture deficit and on the right is an example of a NOAA and National Drought Mitigation Center (NDMC) operational drought index, which is based on modeled soil moisture data.

REMOTE SENSING OF SOIL MOISTURE

Satellite observations provide the only means to measure and analyze key features of droughts routinely with relatively high repetition rates, synoptic coverage and increased spatial detail of vegetation conditions compared to information provided by ground-based monitoring systems.

There are two ways to retrieve soil moisture from satellites. One is a physical method based on microwave observations whereby the observed microwave brightness temperature depends on the dielectric constant of soil, which is the physical property being very sensitive on water content. The strength of this method lies in higher reliability based on direct physical relationships. However, the same relationships are impacted by many factors including land surface roughness, land surface vegetation water



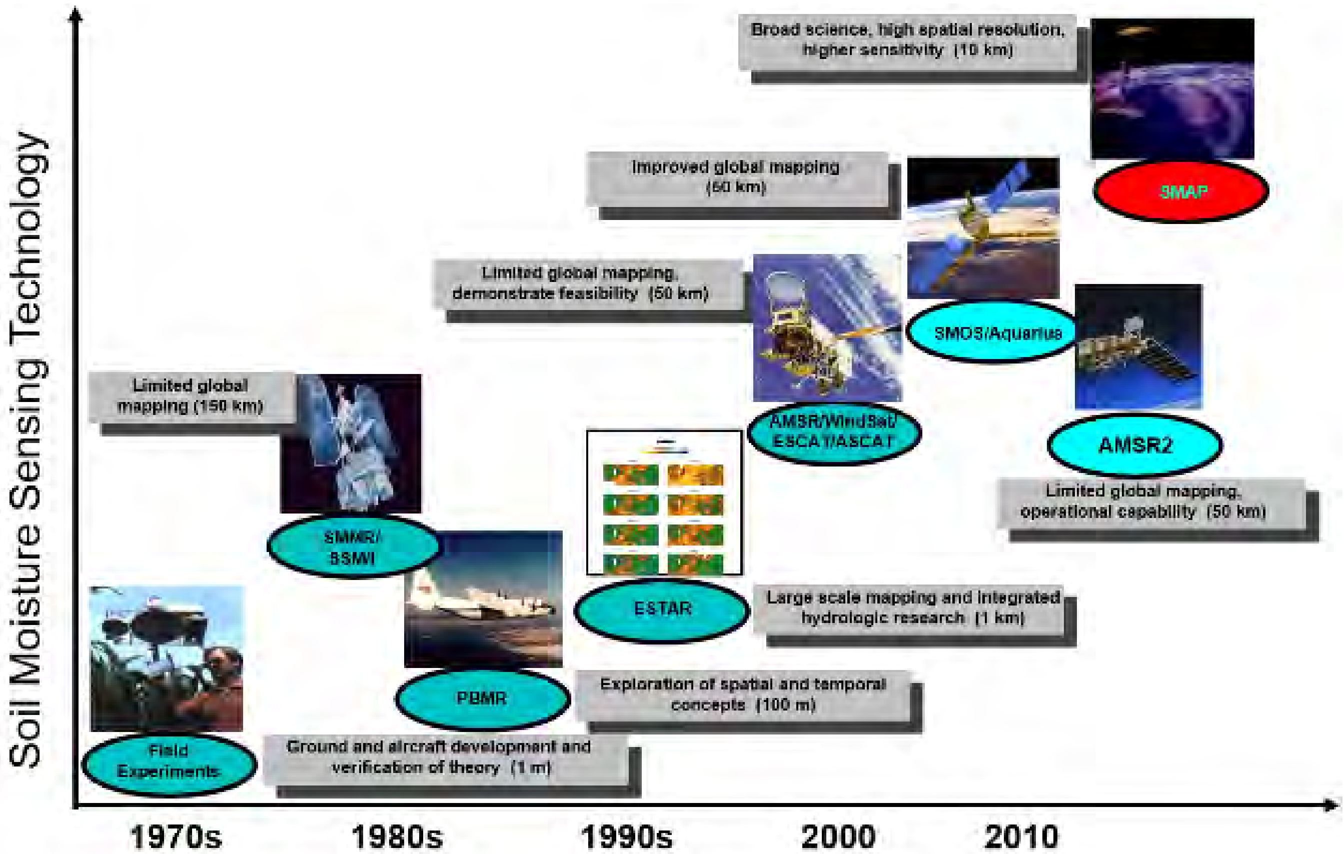


content and spatial resolution that are limited by antenna technology. The other approach is to use the Thermal Infrared (TIR) to observe changes in surface temperature. This approach exploits the empirical connections between soil and water whereby the surface energy balance is dependent on soil moisture. Put simply, wet soil will appear darker than dry soil. Moreover dark soil is warmer than light soil. Thermal and/or optical sensors such as the Visible Infrared Imaging Radiometer Suite (VIIRS) on current and future satellites in the Joint Polar Satellite System (JPSS) can be used in this way to infer soil moisture. Using the Atmosphere-Land Exchange Inversion (ALEXI) model, NOAA scientists have successfully derived a soil moisture proxy product, called Evaporative Stress Index (ESI) from the TIR sensed land surface temperature. The two approaches are quite complementary. Thermal infrared sensors provide much higher spatial resolution than the microwave sensors, but cloud cover can obscure the views, which impacts their ability to extract any useful information under these areas. Conversely, microwave sensors provide relatively low spatial and high temporal resolution given their ability to penetrate through cloud cover.

EVOLUTION OF SOIL MOISTURE MAPPING SENSORS

Satellite instruments have been contributing soil moisture observations for decades beginning with the launch of the Scanning Multi-channel Microwave Radiometer (SMMR) on the National Aeronautics and Space Agency (NASA) Nimbus-7 satellite in 1978. Since then, many satellite soil moisture data products have been made available for research and applications in various fields including weather and climate. In the past, soil moisture measurements have been retrieved from channels that are sensitive to soil moisture (typically Ka and X band) on space-based instruments.

NOAA and other national and international space agencies have continued to develop satellite sensors to acquire near real-time soil moisture observations from space. Technological advancements, particularly those that have taken place in the last decade, have uncovered more ways to obtain estimates from even more channels. For example, channels in the C, L, and X bands have been found to be better suited for the detection of soil moisture. One of the earliest instruments to unveil these new capabilities was NASA's Advanced Microwave Scanning Radiometer for Earth Observing System (EOS) missions (AMSR-E) onboard the Aqua spacecraft, which launched on May 4, 2002, and operated until October 4, 2011. AMSR-E observations were soon boosted by the European Space Agency's (ESA) Soil Moisture and Ocean Salinity (SMOS) mission which launched on November 2, 2009. NASA launched another L-band radiometer instrument, Aquarius, on June 10, 2011. While it was designed to measure ocean salinity, Aquarius could also map over land albeit at a coarse spatial resolution of 150 km. In January 2015, NASA launched the Soil Moisture Active Passive (SMAP) spacecraft designed with a radar which could provide active microwave observations at a much higher spatial resolution up to one kilometer, as well as a radiometer for passive observations. In September, NASA announced that the radar had failed leaving only the passive radiometer to return data. The



Japan Aerospace Exploration Agency (JAXA) launched the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the Global Change Observation Mission-Water (GCOM-W or "SHIZUKU") satellite to provide observations of water cycle related land and ocean surface properties. Its C/X-band microwave observations are used to retrieve land surface soil moisture.

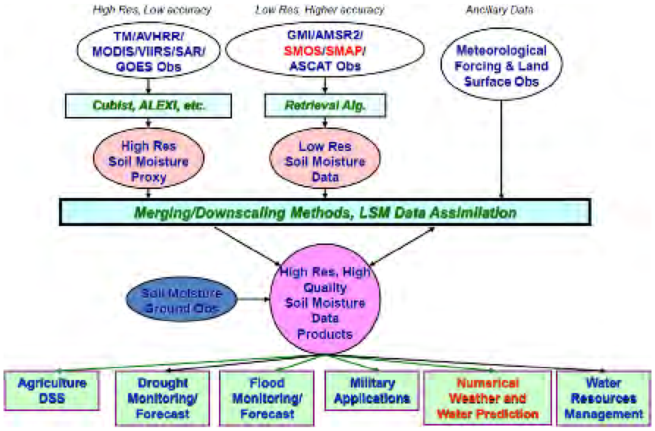
THE NEED FOR ONE STOP SHOPPING

How do scientists convert soil moisture observations into physical variables? Dr. Xiwu Zhan, a scientist in NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Meteorology and Climatology Division (SMCD) specializes in creating soil moisture products for use in NWS operational applications. He leads several research teams in the development of satellite data products such as soil moisture, soil surface type, as well as satellite and drought product systems. Dr. Zhan's research interests include developing land remote sensing data products and applying them in numerical weather prediction models, along with models that deal with climate, hydrology and ecology to advance atmospheric sciences and meet societal needs.

As indicated earlier, high resolution measurements such as those from MODIS, VIIRS, radar instruments, as well as from Geostationary Operational Environmental Satellite (GOES) missions rely on empirical methods to derive soil moisture. Low resolution measurements are generated through physical means using microwave instruments such as GMI, AMSR2, SMOS, SMAP, and ASCAT. To support their efforts to promote high resolution, high quality soil moisture data products, Dr. Zhan and his team merged observations from various satellites including AMSR-E, AMSR-2, and SMAP to develop a one-stop shop system that creates a blended global map with more spatial and temporal coverage.

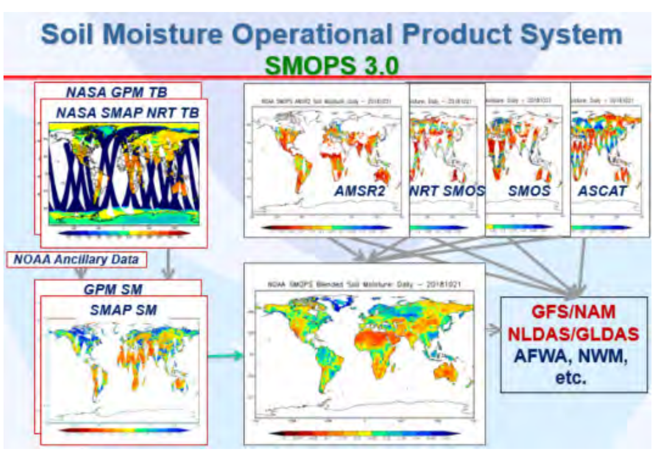
SOIL MOISTURE OPERATIONAL PRODUCTS SYSTEM (SMOPS)

In 2007, Zhan and his team at SMCD developed the Soil Moisture Operational Products System



(SMOPS) from a merged dataset of all current available satellite soil moisture retrievals. Currently, SMOPS ingests observations from NASA's SMAP, Advanced Scatterometers (ASCAT-A and B) on EUMETSAT MetOp-A & -B satellites, ESA's SMOS, and JAXA's AMSR2 on GCOM-W1. The global soil moisture data from SMOPS include six-hour and daily data files of each individual satellite retrieval along with an equally weighted blended product (figure shown on the following page).

The data files have been available to operational users since 2013. SMOPS products have been used or tested in NWP at NCEP and DoD Air Force Weather Agency (AFWA), drought and flood monitoring users, world crop productivity forecasts at the USDA Foreign Agricultural Service, as well as in water predictions at the NWC (Zhan et al, 2014).



Sample data layers from Soil Moisture Operational Product System (SMOPS) of NOAA NESDIS

SUPPORTING NCEP NWP AND DROUGHT MONITORING

Although the satellite soil moisture data products have been tested for numerical weather prediction models, it's possible that the benefits of assimilating the soil moisture data into numerical weather prediction models has not been fully realized, due to the possible shortcomings of the data assimilation algorithms currently used (Nearing et al, 2018). To improve the effectiveness and efficiency of land data assimilation algorithms currently used in NWP models, a dual-pass approach is being tested. According to the study team, "the preliminary results seemed to be promising."

The U.S. Drought Monitor is developed with inputs from many data sources including the land surface model estimates of soil moisture from the North America Land Data Assimilation System (NLDAS). The negative anomalies of the soil moisture estimates indicate droughts. Assimilating satellite soil moisture observations into the land surface models could improve the soil moisture estimates for use in drought monitoring. Operationally assimilating the satellite soil moisture into NLDAS is planned.

SUPPORTING NWC NWM (JPSS PGRR)

In a project funded by the JPSS Proving Ground Risk Reduction (JPSS PGRR) program, experiments were performed in collaboration with scientists from the National Water Center, to compare SMOPS soil moisture data products with the simulations of the national water model (NWM). Preliminary intercomparison results show that satellite soil moisture observations could agree better with in situ soil moisture measurements than the national water model simulations, which indicates the satellite soil moisture observations could be used to improve the national water model simulations and in turn to enhance national water model forecasts.

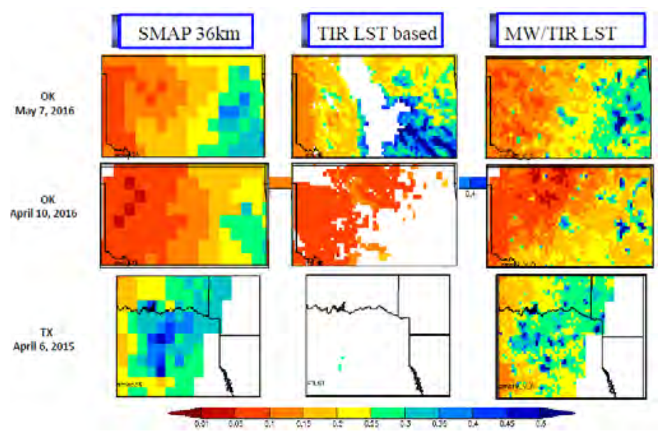
Current SMOPS satellite soil moisture observations are all at resolutions as coarse

Data Source	Type	Input	Examples	Reference
	Active microwave	Radar backscatters	SMAP L2-SM-A/P product	Entekhabi et al (2014, ATBD) Wagner et al, 2007; Sabel et al, 2007
	Optical	Vegetation Index, albedo	VIIRS SM product	Zhan et al., 2002
	Thermal Infrared	LST	R LST changes and SM; "universal triangle"	Fang et al. 2013; Carlson, 2007; Petropoulos et al., 2009; Zhan et al., 2002
	Microwave BT	Ka-band BT	AMSR-E or AMSR2	

Down-Scaling Approach	Type	Examples	Reference
	Liner Regression	1. Relationship between backscatter and SM 2. linear regression relationships between daily LST changes and SM	Entekhabi et al (2014, ATBD) Fang et al. 2013
	Change detection	Relationship between changes in radar backscatter and SM	Njoku et al., 2002; Narayan et al., 2006; Das et al., 2011
	Regression Tree (RT)	RT, a data mining technique, is used to sharpen coarse resolution satellite imageries using fine resolution optical products	F. Gao, et al. 2012
	Neural network (NN)	NN is trained with samples of AMSR-E BT matched to SMOS L3m which is then applied retrospectively or future observations	Rodriguez-Fernandez et al., 2015, 2016
	Bayesian merging	Using the tau-omega equation and a radar backscatter model from the Observing System Simulation Experiment (OSSE) of the SMAP mission (formerly called Hydros), Zhan et al (2006) implemented a Bayesian merging method to combine the observations of 36km radiometer and 3km radar	Zhan et al (2006, TGARS)
	Combined modeling and RS	Models are used in the downscaling DISPATCH method	Merlin et al. 2005,2006,2008 Fang et al. 2013
	Deterministic	Using fine-scale SM obtained from a hydrologic model	Ines et al. 2013 Merlin et al (2008, RSE)

as 25km while the national water model's resolution is 1km. As part of the JPSS PGRR supported project, an effort to downscale the coarse resolution data product to resolution as high as 1km is in progress. Various downscaling algorithms are being tested. Main data sources of high resolution include the thermal infrared observations of land surface temperature and vegetation indices from JPSS VIIRS or GOES imagers. Results using the 4km land surface temperature from GOES imager is demonstrated to improve the scale of satellite soil moisture products in order to meet the data needs of National Water Model.

In some instances the thermal infrared based land surface temperature observations used in the downscaling algorithms can be corrupted by clouds. For these cloud contaminated areas, the Ka-band microwave observations are used. The following figure demonstrates the advantage of the Ka-band observations for downscaling coarse resolution microwave soil moisture data products.



PATH FORWARD

To meet the satellite soil moisture data needs in NOAA's numerical weather and water prediction operations, the best downscaling, merging algorithms are being further tested and validated for a soil moisture data product with high spatial and temporal resolutions and high quality. Applications of this satellite soil moisture data product in drought and flood forecasting and agricultural production monitoring are to be explored.

SUMMARY AND CONCLUSIONS

Since 2013, SMOPS has produced land surface soil moisture data products from satellite observations which have been utilized in various operational applications including assimilation in NOAA's numerical weather and water prediction models for weather and water predictions. SMOPS soil moisture products have also been used in AFWA and USDA FAS operations and tested in NCEP GFS and WRF models. Moreover satellite soil moisture is explored to improve drought monitoring research and operations. ❖

Story Source

Materials obtained from the JPSS March Science Seminar titled "Satellite Soil Moisture Data Products and Their Potential Contributions to NOAA Research and Operations."

Further Reading

Nearing, G., Yatheendradas, S., Crow, W., Zhan, X., Liu, J., & Chen, F. (2018). The efficiency of data assimilation. Water Resources Research, 54. https://doi.org/10.1029/2017WR020991

Zhan X, J Liu, W Zheng, M.B. EK, 2014, Soil Moisture Operational Product System (SMOPS) for NCEP GFS Soil Moisture Data Assimilation. 94 American Meteorological Society (AMS) Annual Meeting—2nd Symposium on the Joint Center for Satellite Data Assimilation, Atlanta GA, USA.

I GET THE PICTURE!

DISSEMINATING WEATHER INFORMATION OVER THE AIRWAVES

The information in this article is based, in part, on the April 15, 2019 JPSS science seminar presented by Dan Satterfield, Chief Meteorologist, WBOC-TV (Salisbury, Maryland).

Dan Satterfield, Chief Meteorologist WBOC TV in Salisbury, Maryland uses satellite imagery to present updates during a severe weather event.

In the Earth's atmosphere, temperature, moisture and moving air currents, which are always in flux, interact to form weather. The Earth's surface is so diverse that weather varies dramatically from location to location. Chances are that at any given moment, an interesting weather event is taking place somewhere on the planet.

Accurate descriptions of the atmosphere and predictions of its future state are important for societies, economies, and the environment. They are indispensable to first responders and pilots, but also event planners and school principals. Weather forecasts inform us of dangers related to heat index or wind chill. They alert people to severe weather and related hazards such as lightning, tornadoes and hurricanes. They help farmers plan for factors that could impact their crops and livestock; and they help people with health issues, such as allergies or asthma, plan according to the air quality reading that day.

Throughout history, humans have scrutinized features in the atmosphere in attempts to predict its state. Long ago, people relied on weather wisdom acquired by happenstance or experience. The Babylonians, for example, studied cloud features[1] to help predict the weather. Some watched animal behavior, believing that animals foreshadowed the weather. In fact, some societies relied on animals as storm detectors. It was not uncommon to find people—especially those with outdoor occupations—with animals on hand to alert them of approaching storm systems. Fast forward to today, and people still plan their lives around the weather forecast. Today's era of free information offers up plenty of weather sources. These include mobile platforms such as cell phones, online sources and apps, the local news, newspapers and the radio. Still, when a storm rolls in, people often turn to their local television weathercasters, possibly the most visible members of the weather team, for guidance. A vital link to the public, they play an important role in communicating the official watches and warnings for hazardous weather from the National Weather Service (NWS) to help keep people safe.

> “When the eye and ear compete, the eye wins.

WHEN EYES AND EARS COMPETE

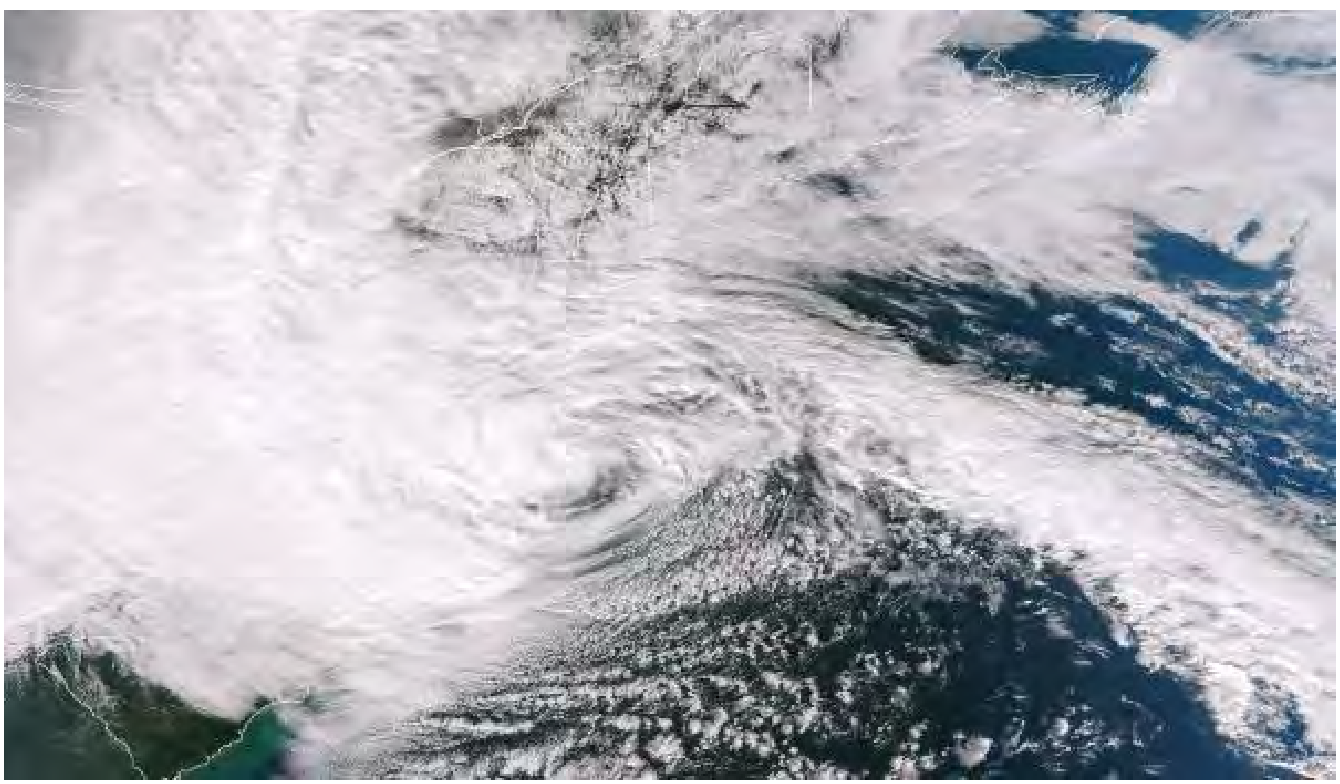
You know the saying: “A picture’s worth a thousand words.” Dan Satterfield (image on previous page) Chief Meteorologist at WBOC-TV, a local television station in Salisbury, Maryland, knows the power of a good image. It comes, he says, from four decades of explaining science and disseminating weather information on television.

“When the eye and ear compete, the eye always wins,” he says.

In a recent seminar, Satterfield recounted a story of a young, ambitious reporter who worked at a Houston TV station named Dan Rather. Rather, relatively unknown at the time, was sent to Corpus Christi in 1961 to cover a powerful storm heading toward the Gulf Coast of Texas.

When he showed up at the local weather bureau office, he saw an image of Hurricane Carla on the Galveston WSR 57 radar, which having been installed just the year before, was relatively modern technology. Rather felt there wasn’t enough time to describe what was ahead, and he wanted the public to benefit from this new insight. But, an image of a storm had never been shown on air.

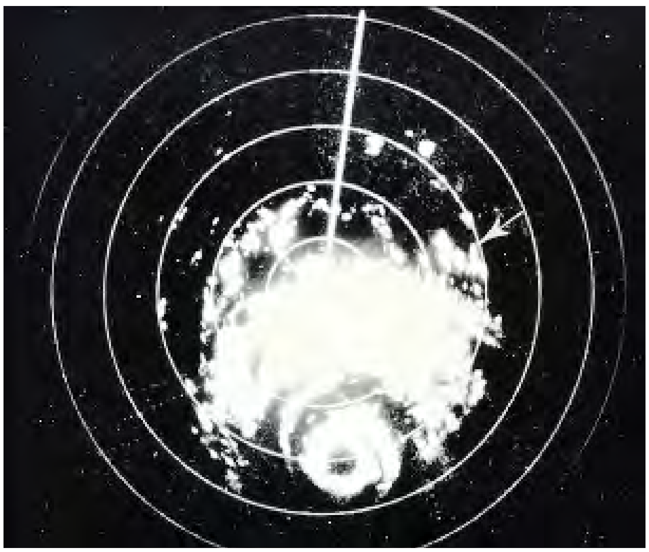
Nonetheless, creativity kicked in, and during the broadcast, the young Rather placed an impromptu doodle of a hurricane headed towards the Texas coast. The doodle, which consisted of a transparent sheet of plastic with a map outlining the Gulf of Mexico, superimposed over the computer’s black-and-white radar display, is said to have given his audience a better perspective of the storm’s size and eye location. The visualization worked. It motivated people to evacuate—and made Dan Rather a household name. Rather’s innovation would



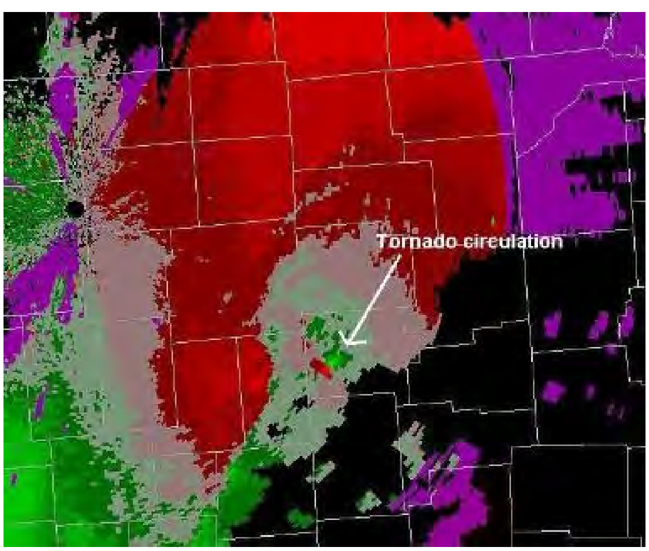
The Suomi NPP satellite VIIRS instrument shows Hurricane Sandy as it makes its way to landfall in New Jersey. The image above was taken during the satellite pass around 1735Z on October 29, 2012. Source: NOAA National Environmental Satellite, Data, and Information Service (NESDIS).

be widely adopted in broadcast media and revolutionize how the NWS communicates hazardous weather warnings on television. The image above shows Hurricane Carla on its way towards Galveston Island in Texas.

It would take over five decades for another hurricane matching Carla's intensity to make landfall in Texas. On August 25, 2017, Hurricane Harvey, the first Category-4 hurricane to affect Texas since Hurricane Carla, made landfall in Texas. By this time though, weather radar had seen several transformations including a huge revolution in the early 90s with the introduction



Radar image of Hurricane Carla in September 1961. The eye is visible on the Galveston WSR 57 radar. (Credit Dan Satterfield, Digitized by the NOAA Photo library. Originally published in Monthly Weather Review, December 1962)



Advancements in Doppler radar made it easier to isolate tornadic features. This enabled meteorologists to better detect tornadoes, especially the F4s and F5s. Source: NWS, www.weather.gov/dtx/beecherradar

of NexRad Doppler radar. This evolution of radar imagery is illustrated in the image on the right of the Doppler velocity product from the NWS Northern Indiana WSR-88D, which captures the dramatic signature of a tornado over Van Wert County, Ohio.

Elsewhere, more advances were on the horizon. In addition to supercomputing capabilities, a new generation of weather forecasting tools were entering the scene. Chief among them were polar orbiting and geostationary weather satellites from the National Oceanic and Atmospheric Administration (NOAA) which would rapidly enhance the nation's ability to make better predictions, faster than ever before.

NEXT-GENERATION WEATHER FORECASTING TOOLS

Weather satellites are ideal for observing the planet's dynamic environment as they can detect features or events that go beyond the reach of conventional observational methods or human vision. They provide data that help convey information on current and future weather conditions and phenomena.

NOAA's satellite fleet includes the Polar Operational Environmental Satellites (POES), Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellites (GOES). JPSS satellites, including the now operational NOAA-20 and its predecessor and pathfinder satellite, the Suomi National Polar-orbiting Partnership (Suomi NPP), come fitted with five state-of-the-art instruments, all featuring significant enhancements over legacy instruments. These next-generation instruments include the Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), Ozone Mapping and Profiler Suite (OMPS), and the Clouds and the Earth's Radiant Energy System (CERES). They gather global measurements of atmospheric, terrestrial and oceanic conditions, including sea and land surface temperatures, vegetation, clouds, rainfall, snow and ice cover, fire locations and smoke plumes, atmospheric temperature, water vapor and ozone. Close to 90 percent of the data used in NOAA's numerical weather prediction (NWP) models come from polar-orbiting spacecraft. These data provide insight to global weather patterns and help meteorologists generate forecasts out to seven days in the future.

THE SATELLITE PROBLEM

Satellite data is vital for weather forecasts and warnings. Without it, weather forecast accuracy would be seriously degraded, and severe weather warning lead times would increase. Also of note is that some information about the Earth's atmosphere can only be gleaned from the gaze of satellites. Unlike conventional observation instruments, such as radars, satellites provide a complete picture of the atmosphere. Moreover, continuous improvements in instruments and technology have opened up an even wider range of possibilities to communicate science about our changing planet. But, according to Satterfield, this value is often not readily apparent to the viewers. It wasn't until the 1970s that satellite imagery was incorporated into television weathercasts, albeit only once a day. As it happens, satellites have improved our ability to forecast weather. And even with technological advances that enable data from the different platforms—satellite, radar, and even forecast models—to be broadcast over airwaves, the use of weather satellite imagery in nightly broadcasts is much less frequent compared to radar. Hurricanes are amongst the most dangerous forces in nature. They form in the ocean. And while radar, along with reconnaissance aircraft, ships, buoys, and other conventional meteorological platforms are important tools used in hurricane tracking and prediction, satellites provide the only practical means to obtain measurements over the open ocean.

The satellite images shown on television are usually from geostationary satellites, which are located some 22,000 miles above the Earth's surface. Polar-orbiting satellites view the Earth from a lower altitude, just a few hundred miles above its surface. They have instruments that can measure winds, temperatures and moisture at many different levels as they fly over the poles. Without them 5–7 day long range forecasts would not be possible.

Hurricane Sandy

In 2012 a superstorm named Sandy became one of the most destructive hurricanes in history to hit the United States. Superstorm Sandy made a rare maneuver, a left turn that propelled it toward a wide swath of the Atlantic, and put almost 60 million people along the US east coast in its path. A study done by the European Centre for Medium-range Weather Forecasts (ECMWF) highlighted the importance of data from polar-orbiting satellites in numerical forecast models. According to the study—which ran experiments that excluded polar-orbiting satellite data from their numerical weather models and re-ran their forecasts for Hurricane Sandy—NOAA forecasts of the hurricane's track could have been hundreds of miles off without information from polar-orbiting satellites. Moreover, they would have shown Sandy remaining at sea. Instead, five days before impact, NWP models correctly projected the storm's path and strength.

> "Without data from polar orbiting satellites, weather models would have provided a severely degraded forecast for Hurricane Sandy.
>
> **Accurate forecasts save lives!**

There are three types of satellite imagery available: visible, which can only be viewed during the day; infrared (IR), which works both day and night; and water vapor, which indicates how much moisture is present in the upper atmosphere. Television weathercasts typically show visible (daylight) and/or IR. Satterfield contends that despite an abundance and availability of satellite imagery, radar continues to be the platform of choice when it comes to weather coverage on television. Data from polar orbiting satellites is not delivered by vendors. Moreover the process required to get data from polar-orbiting satellites on air takes considerable time and effort to facilitate, which makes it a less attractive option to radar. But even with brand new instrumentation, additional spectral information including 16 channels of imagery (two visible, four near IR, and 10 IR) as opposed to five on the previous GOES generation; improved resolution; and faster scanning ability from the GOES-16 and -17 satellites, their imagery is not updated at the same frequency as radar data. While the resolution and detail enable better discernment of features like smoke, ice, dust, volcanic ash and water vapor, it can be more complex to explain. More importantly, time constraints play a huge role in on-air presentations, thus satellite imagery can only be incorporated when time allows.

Adding to these factors is a lack of training. According to Satterfield, to interpret satellite imagery one needs highly specialized training, and even though weathercasters experience high levels of audience credibility, they are not necessarily well-trained nor well-informed experts.

Aside from the severe weather outlooks and hurricane forecasts from the NWS Storm Prediction and National Hurricane centers, weathercasts tend to be hyperlocal. Stations tend to focus on weather content that is specific to their specific geographical location or viewing area. One of the advantages of radar is its ability to measure precipitation from one single installation within a 250-mile radius. Other advantages include the ability to work under conditions of poor visibility and in adverse weather such as fog, hail, and, most importantly, under cloud cover. Thus, as many stations have their own radars, it makes sense that they would use these along with data feeds from the NWS network of Doppler weather radars to develop their local forecasts.

SLOW BUT SURE SIGNS OF ESTABLISHMENT

While there's plenty of sources for weather information available today, from mobile platforms to newspapers to radio, for many, television remains one of the most popular sources. Earth observation satellites are vital sources of information for weather forecasts and warnings, which some broadcasters have made moves to embrace and synthesize into their operations and analysis. But, as a whole, it has been a slow embrace, and data feeds from radar instruments remain the dominant source of weather information on television.

Still, there are some things, besides a global view of weather events that only satellites can provide. For example, at WBOC-TV 16, Satterfield employs a "V NOTCH"—a severe storm signature from satellites—that he uses daily for sea breeze and outflow boundary location. He also uses the now available, one minute GOES data, as it has a higher temporal resolution than the NEXRAD's now.

Part of his repertoire for severe weather situations includes the Prob Severe model using satellite and radar data along with data from the Geostationary Lightning Mapper (GLM). The GLM is a single-channel, near-infrared optical transient detector that can detect the momentary changes in an optical scene, indicating the presence of lightning. It is the first operational lightning mapper flown in geostationary orbit. Information from the GLM alerts forecasters of developing severe storms much earlier and before these storms produce damaging winds, hail or even tornadoes.

SUMMARY AND CONCLUSIONS

Weather technology has changed a lot since Dan Rather took his doodle on air in 1961. The early 90s gave rise to Doppler radar, which provided even better views of severe events such as tornadoes.

Elsewhere, a new space age has dawned as a new generation of earth observation satellites have come on line and advanced weather detection. Their data are widely applied in weather analysis, numerical weather and climate prediction models, as well as in environment and disaster monitoring. Now, global observations from satellites, such as Suomi NPP and NOAA-20, account for more than 90 percent of the input used in the nation's weather forecasting models. They are critical for generating the three-to-seven-day forecasts used in the nightly weather broadcasts. More than that, Earth-observing satellites have shrunk the Earth into a global village, and are providing data that enables television stations to expand their audiences to new continents. They are also producing images that are helping scientists communicate to broader audiences about our changing planet. Compared to imagers on previous GOES satellites, the GOES-16 and -17 Advanced Baseline Imager (ABI) provides three times more spectral information to discern cloud properties and the near-storm environment, four times the resolution to resolve finer detail, and has a scanning ability that's five times faster, providing earlier indications of evolving and intensifying severe storms, and before these storms produce damaging winds, hail or even tornadoes.

Although, radar remains the star of local stations as well as national television networks, satellite data is vital. ❖

Footnotes

[1]NASA. "Weather Forecasting Through the Ages". https://earthobservatory.nasa.gov/features/WxForecasting/wx2.php. Archived content. Retrieved 2019-08-08.

Story Source

Materials obtained from JPSS April Science Seminar titled "Communicating Science in the Age of Crazy: Things I've Learned (Mostly the Hard Way)."

Further Reading

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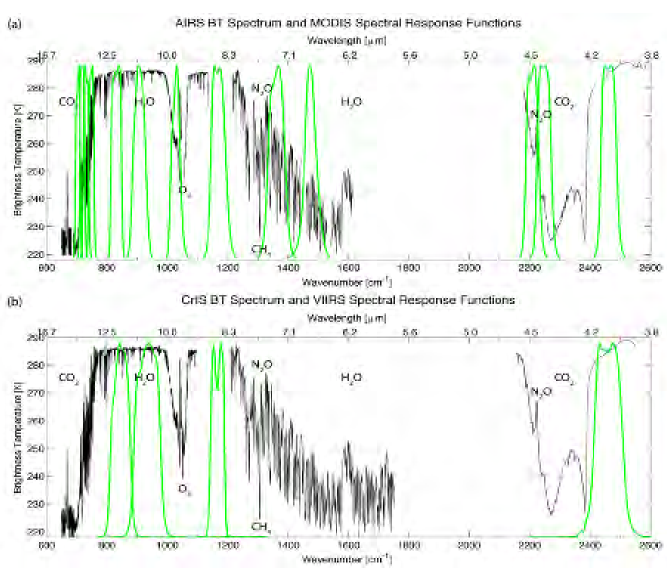
GENERATING HYPERSPECTRAL SOUNDER RETRIEVAL PRODUCTS AT LEO AND GEO IMAGER SPATIAL RESOLUTION

The information in this article is based, in part, on the May 13, 2019 JPSS science seminar presented by Elisabeth Weisz, Associate Scientist, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison). It also features work by Paul Menzel, Eva Borbas, Richard Frey, Chris Moeller, Szu-Chia Moeller, and James Anheuser.

Polar-orbiting weather satellite platforms, operating in the low earth orbit at approximately 800 km altitude, carry both a high spatial resolution imager with pixel spatial resolution on the order of 1 km, and a high spectral resolution (or hyperspectral) infrared (IR) sounder, with fields of view (FOVs) of about 14 km. The imagers are designed to take measurements for a limited set of narrow wavelength bands at visible through IR wavelengths. The imager data are used, for example, to develop operational aerosol, moisture, and cloud properties. The sounder measurements are used to infer profiles at high vertical resolution of temperature, water vapor, and ozone and also to infer surface, trace gas, and cloud properties.

Imagers of interest include the Visible Infrared Imaging Radiometer Suite (VIIRS) on the National Oceanic and Atmospheric Administration's (NOAA)/National Aeronautics and Space Administration's (NASA) Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellites, which is similar to the MODerate resolution Imaging Spectroradiometer (MODIS) on the NASA Terra and Aqua satellites. These were preceded by the Advanced Very High Resolution Radiometer (AVHRR) on both NOAA and the European Metop satellites. AVHRR and VIIRS lack absorbing IR bands (carbon dioxide and water vapor) that are essential for accurately deriving atmospheric variables such as total column precipitable water vapor and cloud properties (e.g., cloud top height, thermodynamic cloud phase). This makes it extremely challenging to develop consistent atmospheric products that can be used across multiple platforms.

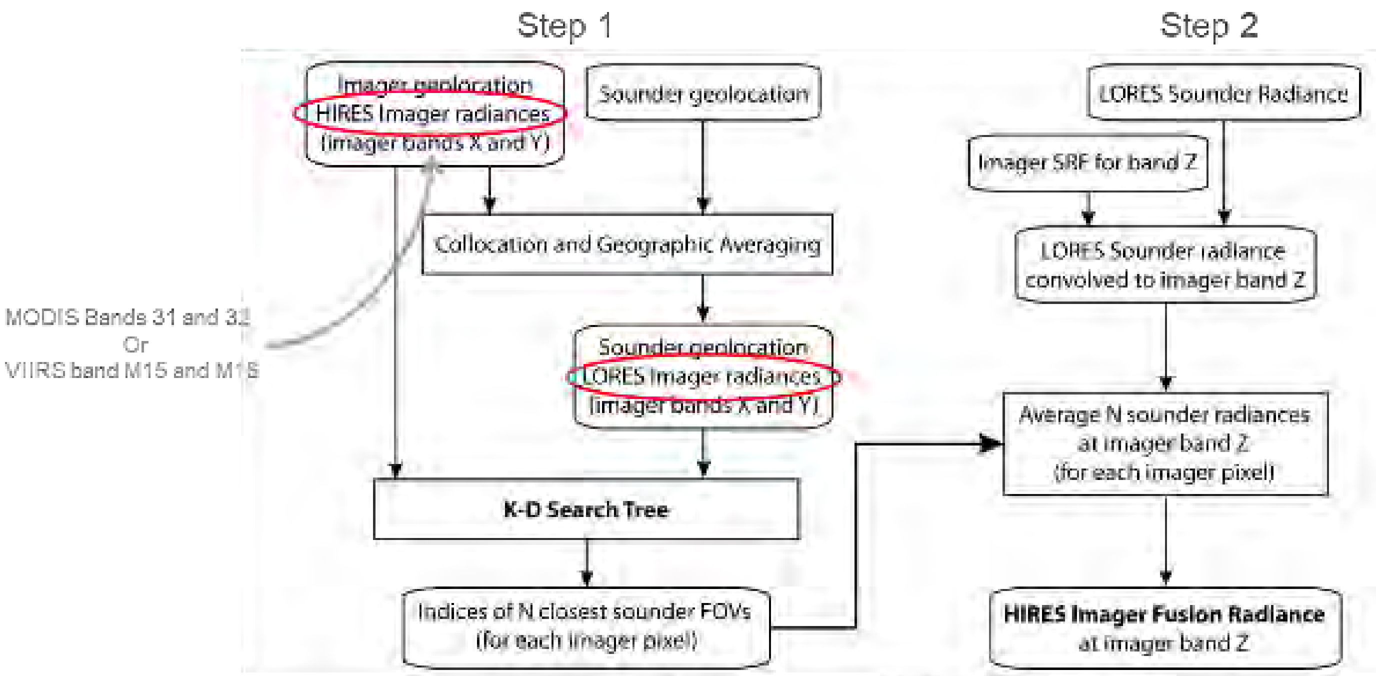


Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Construction of high spatial resolution narrowband infrared radiances from satellite-based imager and sounder data fusion. J. Appl. Remote Sens. 11 (3), 036022, doi: 10.1117/1.JRS.11.036022.

On the bottom left is an illustration of the different imager/sounder spectral coverages. It shows the high spectral resolution brightness temperatures from the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua satellite and the Cross-track Infrared Sounder (CrIS) with the spectral response function of the corresponding imager overlaid, MODIS and VIIRS respectively.

PROJECT CONCEPT: CONSTRUCTING THE MISSING PORTION OF THE SPECTRUM

These differences are very important to scientists like Elisabeth Weisz, an Associate Scientist at the University of Wisconsin-Madison (UW) Cooperative Institute for Meteorological Satellite Studies / Space Science and Engineering Center (CIMSS/SSEC), whose research focuses on the development of atmospheric sounding retrieval algorithms using satellite-based high-spectral resolution infrared radiance measurements. This includes investigations of the impact of the sounding and cloud products obtained from high-spectral radiance measurements on weather forecasting, numerical weather prediction, and the development of future instruments. Dr. Weisz's research is useful to users of satellite-derived products including NOAA organizations such as the National Weather Service (NWS). Its potential to deliver enhanced products for use in operational applications is among the reasons the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) program funded an innovative study by Dr. Weisz and her science team to develop a data fusion methodology to transfer the missing portion of the spectrum from the sounder to the imager, which will establish imagers with fusion spectral bands that can be used to derive more consistent atmospheric products. Moreover, the derivation of cloud products and other products that require IR absorption bands can be sustained over generations of polar-orbiting satellites.



Note, HIRES and LORES refer to high and low spatial resolution.

IMAGER AND SOUNDER RADIANCE FUSION

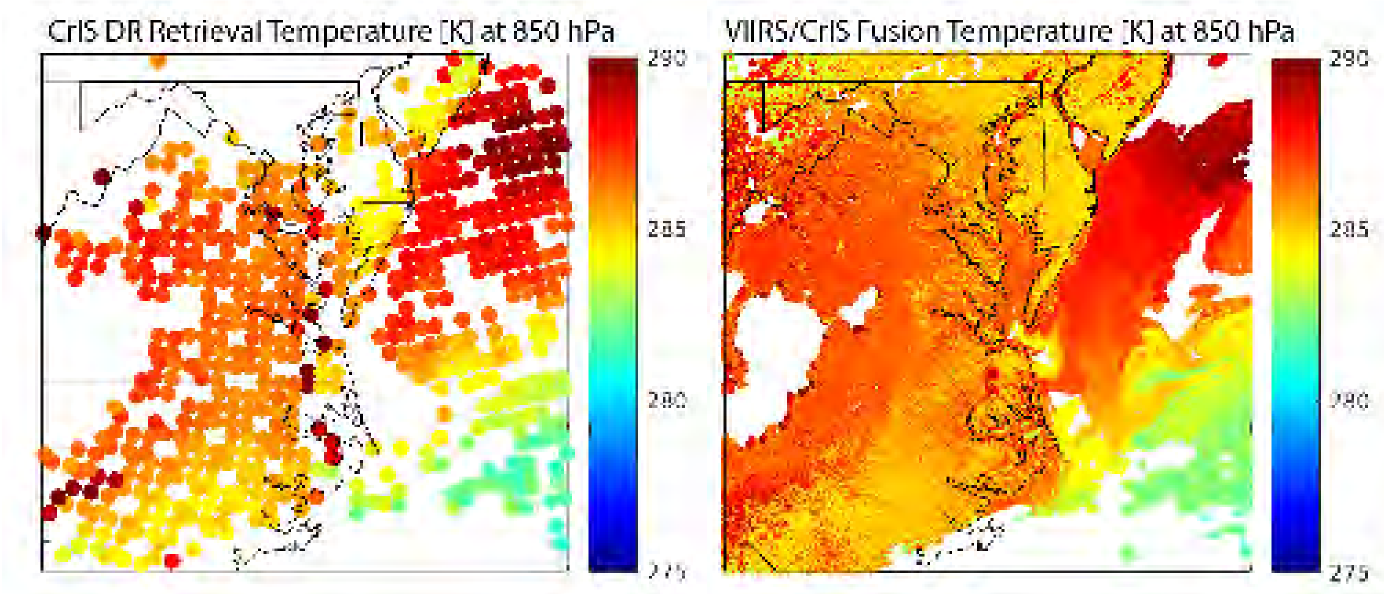
At the core of this research, which has been published in the Journal of Applied Remote Sensing (Weisz, 2017), is a fast and efficient nearest neighbor search, a k-d tree algorithm, which provides the N closest—in radiance space—matching FOVs in the low spatial resolution imager data to each pixel in the high spatial resolution imager data (step 1 in the diagram above).

Low spatial resolution imager data refers to imager radiance data co-located to the sounder FOVs and then geographically averaged. In the VIIRS/CrIS radiance fusion approach, the inputs to the k-d tree are the split window (11 and 12 µm) imager radiances. The corresponding imager and sounder latitude and longitude values are used as additional predictors. In step 2, the sounder radiances are reduced to narrowband radiances by applying the spectral response function (SRF) for the band to be constructed. For the VIIRS/CrIS fusion application, the Aqua MODIS SRFs are used to provide MODIS-like bands for VIIRS. Then the mean of these convolved radiances for the N neighbors from the first step is computed for each of the imager pixels. It has been shown in Weisz et al. (2017) that radiance fusion increases the spatial resolution of IR window radiances by an order of magnitude at the cost of adding some noise to the brightness temperatures. For carbon dioxide and water vapor sensitive bands, the noise increases by about 0.7K and 1K, respectively, since the split-window search emphasizes surface and total column moisture features but not mid- and upper tropospheric CO2 and H2O absorption properties.

IMAGER AND SOUNDER PRODUCT FUSION

(a) VIIRS/CrIS Product Fusion

Initially, Weisz and her colleagues focused on the fusion of radiance data to construct additional high spatial resolution IR absorption bands. In their next study, they considered “product fusion”, where retrievals are constructed directly from imager and sounder data (i.e., skipping the intermediate step of generating fusion radiances). That is, high vertical resolution sounder temperature and humidity profile retrievals (or derived products such as lifted index) are constructed directly at imager high spatial resolution. The same input (i.e., imager split-window radiances) to step 1 is used as in the radiance fusion, but instead

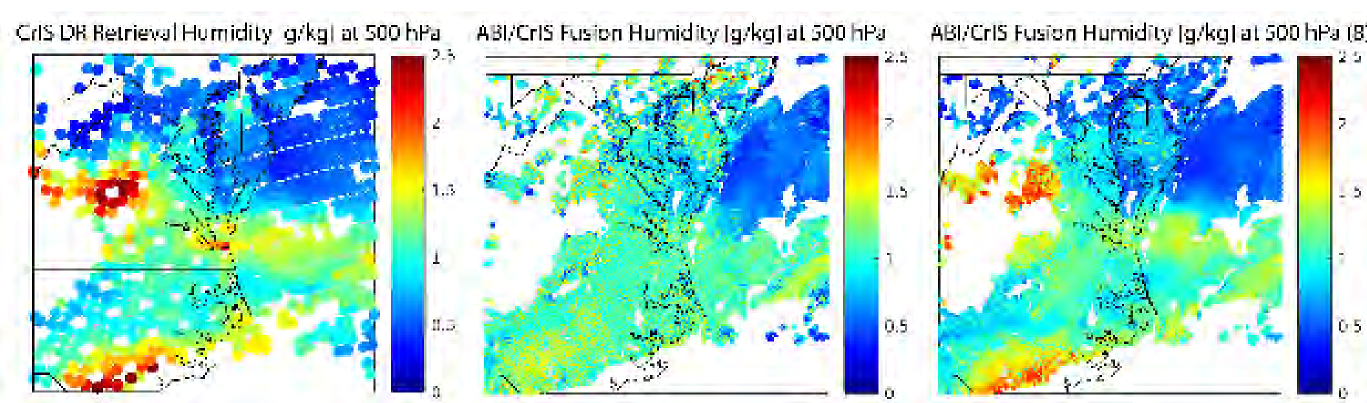


of averaging convolved radiances the mean of hyperspectral retrieval products is computed in step 2. Here CrIS retrieval profiles are derived using the UW hyperspectral retrieval system, which is based on the Dual-Regression method (Smith et al., 2012), although any other retrieval algorithm can be used.

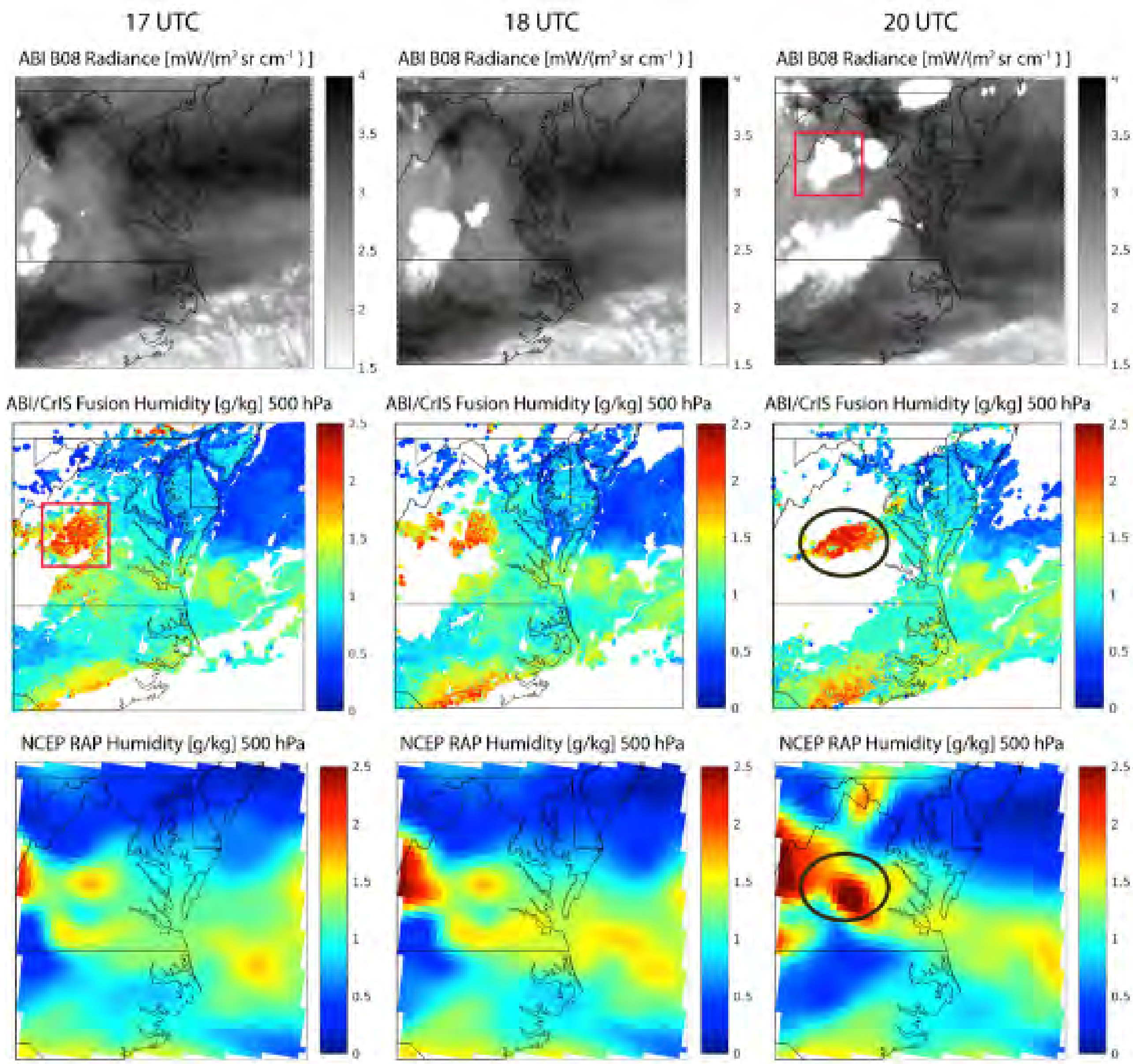
With the direct product fusion approach, CrIS retrieval products can be now provided at high spatial (imager) resolution while maintaining fine-scale vertical information. This is illustrated in the figure above showing 850 hPa temperature sounder retrievals (left) at coarse sounder resolution and the fusion results at high spatial resolution (right); the latter provides increased coverage as well as improved spatial detail.

(b) ABI/CrIS Product Fusion

It is also possible to enhance the retrieval products with high temporal resolution by combining data from the Advanced Baseline Imager (ABI) onboard NOAA's Geostationary Operational Environmental Satellite (GOES) with the polar-orbiting hyperspectral sounder (CrIS) data. Weisz and her team were able to demonstrate the capability of the GEO/LEO fusion method to benefit severe weather monitoring and forecasting in a case study of moisture transport, cloud top changes and convective stability during severe weather development. They also discovered that expanding beyond the split-window bands (in k-d tree search) can improve the fusion mid- and high level moisture products. Adding water vapor sensitive channels (e.g., ABI bands 8-10, centered between 6 and 8 µm) improved the results significantly as depicted in the figure below where humidity at 500 hPa provided by the dual-regression CrIS retrieval, the ABI/CrIS split-window fusion and the ABI/CrIS 8-band fusion are shown. For the latter, all ABI bands except the short-wave and the ozone absorption band are used in the nearest neighbor search.



Results shown in the previous figure were derived when the CrIS measurements were taken at approximately the same time as the ABI data (i.e., at 18 UTC). But since ABI data is available at high frequency (e.g., every 15 minutes) the more interesting aspect of their investigation focused on whether the fusion method can be used to project sounder products (which are available only twice per day per location) forward in time and how far this projection can be extended. For example, to create sounder products an hour past the sounder overpass, the k-d tree results from current ABI radiance measurements are used. The image below shows ABI band 8 (6.3 µm) radiances (top row), the 500 hPa water vapor ABI/CrIS fusion results (middle row) as well as the NCEP Rapid-Refresh (RAP) 500 hPa water vapor model analysis (bottom row) at 17, 18 and 20 UTC. Note that the SNPP overpass occurred around 18 UTC. The moisture pocket over central Virginia and visible in the left and right panels of the previous image has intensified at 20 UTC and is confirmed by the RAP (marked as black ovals). Furthermore, (outlined as red squares) the fusion suggests moisture intensification at 17 UTC that is then followed by convective activity as seen in the ABI band 8 radiances at 20 UTC. The eastern region adjacent the red box at 17 UTC contains mid-level dry features but shows moistening at lower levels (e.g., at 850 hPa, not shown here), indicative of pre-convective conditions with strong updrafts and a high likelihood of severe thunderstorms.



CONCLUSIONS AND OUTLOOK

Dr. Weisz's present efforts are concentrated on developing and improving retrieval algorithms for the different satellite sensors and increasing the synergistic utility between various instruments. In this study, Dr. Weisz and her team demonstrated that the synergistic use of high spatial resolution imager data with high spectral resolution infrared sounder data has advantages over the use of individual data sets alone. The radiance fusion approach provides missing imager bands (e.g., MODIS-like H_2O absorption bands for VIIRS) to be able to continue applications, which require infrared CO_2, H_2O, and O_3 absorptions bands (such as cloud climate records). To take this a step further, the product fusion provides hyper-spectral retrieval products at high spatial resolution while maintaining the high vertical resolution contained in hyperspectral temperature and moisture profile retrievals. Furthermore, temporal resolution can be increased when the fusion technique is applied to GEO/LEO imager/sounder pairs (e.g., ABI/CrIS). The same synoptic situation is highlighted from comparison of the fusion moisture gradients with model analysis, although the imager sounder fusion provides more small-scale features that are consistent with developing weather events. Overall, the featured research and the case study suggest the possibility to successfully transfer high vertical resolution sounder retrieval products to imager high spatial and temporal resolution. Besides performing additional fusion product validation studies, current and ongoing work includes the investigation of fusion water vapor to track polar winds and fusion trace gases like SO_2 to detect volcanic plumes. ❖

Story Source

Materials obtained from JPSS May Science Seminar titled "Generating Hyperspectral Sounder Retrieval Products at LEO and GEO Imager Spatial Resolution."

Further Reading

Weisz, E., B. A. Baum, W. P. Menzel (2017), Fusion of Satellite-Based Imager and Sounder Data to Construct Supplementary High Spatial Resolution Narrowband IR Radiances. J. of Applied Remote Sensing, 11(3), doi:10.1117/1.JRS.11.036022.

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NUCAPS BOUNDARY LAYER MODIFICATIONS IN PRE-CONVECTIVE ENVIRONMENTS:

DEVELOPMENT OF A TIMELY AND MORE ACCURATE PRODUCT TO ASSIST FORECASTERS IN MAKING SEVERE WEATHER FORECASTS

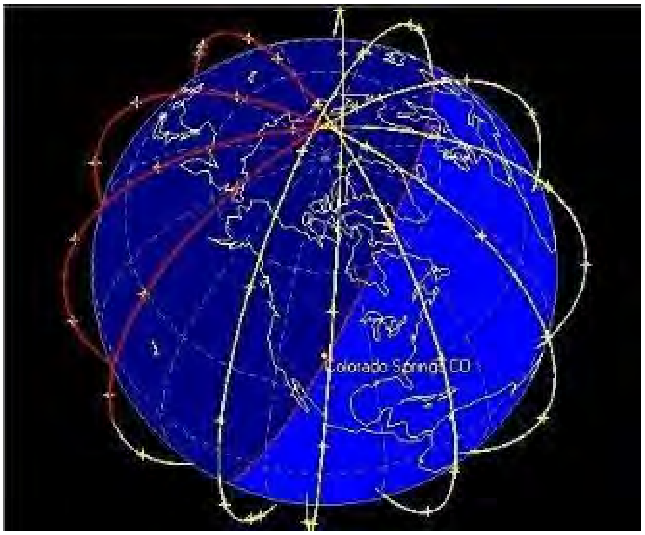
The information in this article is based, in part, on the June 19, 2019 JPSS science seminar presented by Jack Dostalek, Cooperative Institute for Research in the Atmosphere. It also features efforts by John Haynes-Cooperative Institute for Research in the Atmosphere (CIRA); Dan Lindsey–NESDIS/STAR/Regional and Mesoscale Meteorology Branch; Chris Barnet–Science and Technology Corporation (STC), Antonia Gambacorta–STC, Nadia Smith–STC, Kris White–NWS Huntsville, AL; Emily Berndt–NASA Short-term Prediction Research and Transition Center, Rebekah Esmaili–STC, Michael Bowlan–Cooperative Institute for Mesoscale Meteorology Studies (CIMMS), Brandon Smith–CIMMS, Jason Burks–CIRA, Tiffany Meyer–CIMMS, Darrel Kingfield–Cooperative Institute for Research in the Environmental Sciences, and Deb Molenar–NESDIS/STAR/Regional and Mesoscale Meteorology Branch.

The National Oceanic and Atmospheric Administration (NOAA) Storm Prediction Center (SPC), located in Norman, OK, is responsible for issuing all severe thunderstorm and tornado watches nationwide. As thunderstorms and other severe weather develops, the local National Weather Service Forecast Offices (NWSFOs) issue severe thunderstorm and tornado warnings. To prepare these forecasts, meteorologists use a number of observational tools that measure atmospheric conditions both at the surface and aloft.

Operational radiosondes are the principal means by which forecasters receive observations concerning the structure of atmospheric temperature and moisture. Although unparalleled in vertical resolution, the temporal and spatial resolution of this dataset is rather limited. Balloons are launched only twice daily, at 0000 and 1200 UTC. The network over the continental United States consists of 70 roughly evenly spaced stations, resulting in coverage every 400km or so. When severe weather is imminent, SPC can request that one or more stations launch an additional balloon, typically around 1800 UTC. The ability to request additional balloon launches underscores the demand that exists among severe weather forecasters to possess up-to-date knowledge concerning the vertical structure of temperature and moisture.

SOUNDING THE ATMOSPHERE FROM SPACE

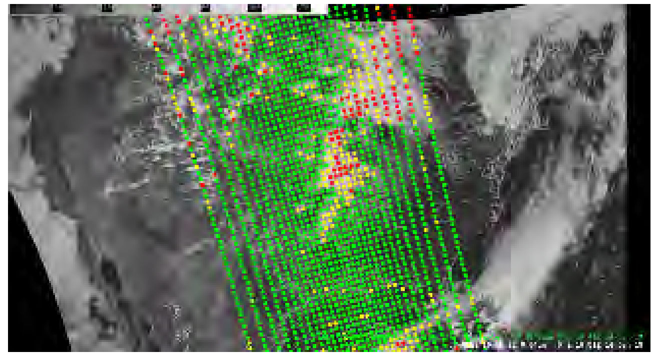
In an attempt to complement the information received from balloon launches, scientists have developed methods to retrieve vertical profiles of temperature and moisture from satellite measurements (Kidder and Vonder Haar 1995). Such methods have been developed for both infrared and microwave radiation, and



have been used by both geostationary and polar-orbiting satellites. Two of the newest polar-orbiting satellites capable of sounding the atmosphere are part of the Joint Polar Satellite System (JPSS), a partnership between NOAA and NASA. The Suomi National Polar-orbiting Partnership (S-NPP) satellite was launched in November 2011, and the NOAA-20 satellite was launched in November 2017. Both satellites generate temperature and moisture retrievals using the NOAA Unique Combined Atmospheric Processing System (NUCAPS), one of NOAA's operational retrieval packages.

WHAT IS NUCAPS AND HOW DOES IT WORK?

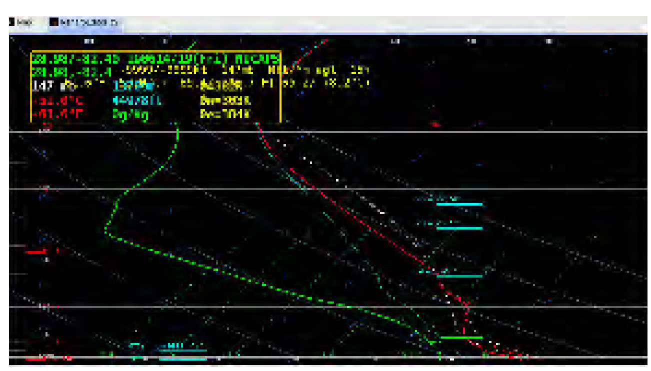
NUCAPS is a passive retrieval algorithm, which combines input from infrared and microwave instruments. It produces vertical profiles of temperature and moisture from the Earth's surface to the top of the atmosphere, as well as several trace gas profiles. NUCAPS is currently being run using data from SNPP and NOAA-20, which carry the Cross-track Infrared Sounder and the Advanced Technology Microwave Sounder, and data from the MetOp series satellites, which carry the Infrared Atmospheric Sounding Interferometer and the Advanced Microwave Sounding Unit. Each scan line contains 30 footprints, nominally 50 km at nadir, but increasing in size away from the sub-satellite point. In addition to the combined infrared/microwave retrieval (which will be referred to as the NUCAPS retrieval), the NUCAPS package



also generates a retrieval based on microwave data only (which will be referred to as the microwave-only retrieval).

Above is an example of a swath from a NUCAPS pass as seen in the NWS' primary forecasting tool, the Advanced Weather Interactive Processing System (AWIPS). Each dot represents a retrieval and is color coded according to the quality control. A green dot indicates that both the NUCAPS retrieval and the microwave-only retrieval have passed the quality control. A yellow dot indicates that the NUCAPS retrieval failed, but the microwave-only retrieval passed. A red dot indicates the failure of both the combined NUCAPS and microwave-only retrievals. As is evident on the figure, the green dots generally correspond to clear and partly cloudy areas, whereas the yellow and red dots occur in areas of full cloud cover, and where precipitation is likely to be falling.

The image below shows a NUCAPS temperature and moisture retrieval over Florida as seen from the AWIPS workstation. Because of the coarse vertical resolution of the satellite instruments, the temperature and moisture profiles appear smooth when compared to measurements from a radiosonde. The lack of detail in the vertical is somewhat mitigated by



the much greater number of NUCAPS retrievals compared to radiosonde launches. Seeing that the NUCAPS retrievals are available on polar-orbiting satellites only, they are generally used to monitor events occurring across large spatial areas and over long time scales. Data and imagery from polar-orbiting satellites also have immediate application over the Arctic and Antarctic, where geostationary data are limited but the polar-orbiting satellites pass over several times a day.

MOTIVATION FOR SEVERE WEATHER APPLICATIONS

Although intended to monitor primarily global features, polar-orbiting satellites can be of use in monitoring weather phenomenon on small spatial and short time scales, such as severe convection. In this regard, the JPSS satellites are particularly useful because they pass over the northern hemisphere middle latitudes in the early (local) afternoon on their ascending node. This timing allows the NUCAPS retrievals to sample the atmosphere an hour or two before the typical time of convective initiation, thus adding to the information provided by the 1200 UTC radiosonde launches. The additional information is similar to the early afternoon radiosonde launches requested by the SPC to assist in the issuances of severe weather watches. Two parameters derived from temperature and moisture profiles that are of particular interest are Convective Inhibition (CIN) and Convectively Available Potential Energy (CAPE). CIN is a measure of the likelihood for convection to develop, and CAPE is a measure of the potential severity of the convection. In order to undergo testing for the applicability to severe weather forecasting, the NUCAPS retrievals is being evaluated at NOAA's Hazardous Weather Testbed.

HAZARDOUS WEATHER TESTBED

NOAA's Hazardous Weather Testbed (HWT) provides a forum in which severe weather forecast and warning techniques

and applications are developed, tested and evaluated for use by the NWS. The HWT is located at the National Weather Center in Norman, Oklahoma. It is jointly managed by the NWS and the National Severe Storms Laboratory. Each spring, the NOAA HWT hosts multiple rounds of experiments, typically over a four to six week period, to test new or enhanced products and techniques. Each week four to six NWS forecasters, broadcast meteorologists, and scientists get an opportunity to participate in experimental forecast and warning generation exercises using the new products. It is also an opportunity for participants to critique and suggest improvements for algorithms in different stages of their development.

NUCAPS was first evaluated at the 2015 HWT. It was also the first-ever demonstration of an algorithm from JPSS at this event. Forecasters spent time comparing the NUCAPS profiles with other data sources such as radiosonde soundings, NWP-based soundings, and the SPC meso-analysis. Forecasters' reception to the NUCAPS product in 2015 was mixed. Some forecasters conveyed that it was not a bad product, although it was not always accurate at low levels. Some stated that the surface temperature and dewpoint temperature were not always consistent with nearby surface observations, while others indicated that they had problems calculating CAPE and CIN. Such critiques may not have been altogether unanticipated, as satellite retrieval algorithms typically struggle near the surface. NUCAPS retrievals may be modified manually on AWIPS using NSHARP (National Center Sounding and

Hodograph Analysis and Research Program). By replacing the surface temperature and dewpoint temperature retrieved from NUCAPS with data from a nearby surface observing station, a forecaster can produce a profile with more accurate values of CIN and CAPE. This process can be time consuming, however, especially if several profiles are in need of modification.

Following feedback from the 2015 HWT experiment, a JPSS-PGRR (Proving Ground Risk Reduction) project was undertaken to provide to forecasters NUCAPS retrievals that have already been modified at the lower levels. These retrievals are called modified NUCAPS retrievals.

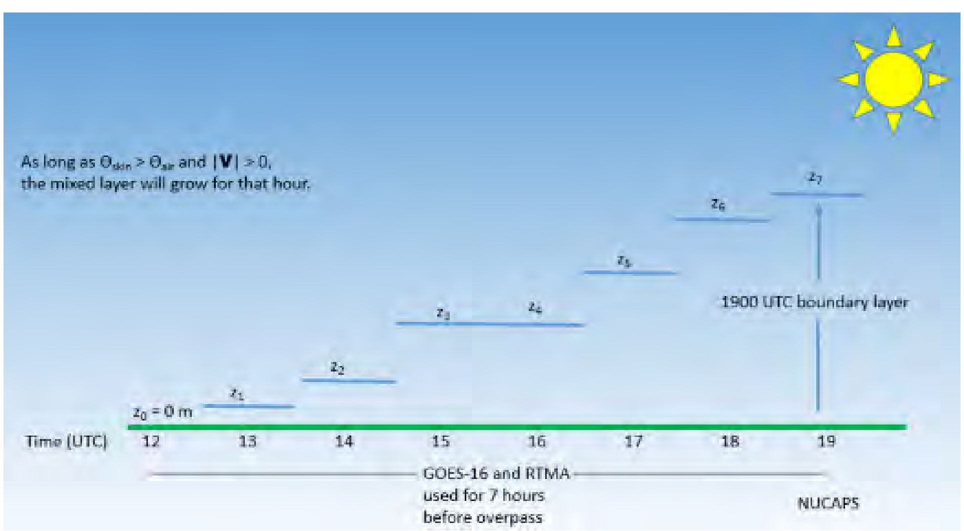
MODIFIED NUCAPS RETRIEVALS

The modified NUCAPS retrievals were first evaluated at the 2017 HWT. The automated algorithm was based on what a forecaster would likely do at an AWIPS station—replace the surface temperature and the dewpoint temperature of the NUCAPS retrieval with more representative values. In the algorithm these values come from the Real Time Mesoscale Analysis (RTMA) fields. Merely replacing the surface temperature and dewpoint temperature is useful for computing surface-based CIN and CAPE, but would likely still give erroneous values of mixed-layer CIN and CAPE. Additionally, replacing only the surface values may result in a low-level profile that is not particularly realistic. The algorithm, therefore, not only changes the surface values of temperature and dewpoint temperature, but the temperature and dewpoint temperature throughout the entire boundary layer.

The first step in creating the modified profile is to calculate the height of the boundary layer at the time of the satellite overpass using an equation found in Stull (1988):

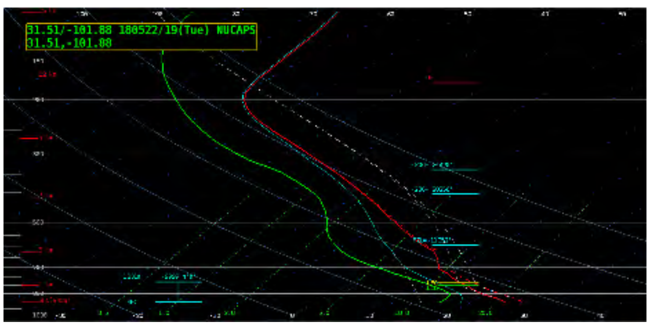
The dependent variable z is the height of the mixed layer at time step i. The independent variables are: |V|, the wind speed; Θskin, the potential temperature of the surface skin; Θair, the potential temperature of the surface air; Δt, the time increment. C_H is the bulk heat transfer coefficient, and γ is the lapse rate of the free atmosphere.

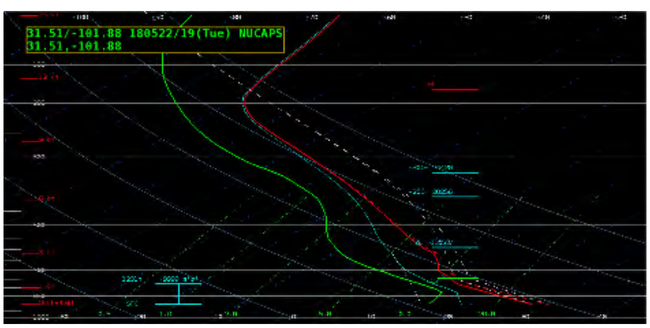
C_H is given a constant value of 0.005, and the value for γ is measured from the NUCAPS temperature profile at the time of overpass. The boundary layer grows from sunrise to the time of the satellite overpass according to the windspeed and the difference in the potential temperature of the surface and the air. The wind speed and the potential temperature of the air are determined from the RTMA data, and the potential temperature of the skin is determined by the GOES-16 data using a simple formula involving the brightness temperatures at 11.2 µm and 12.3 µm. As long as there is at least some wind and the potential temperature of the skin exceeds that of the air, the boundary layer will grow during the time increment Δt, for which 1 hour is used. The figure below gives a pictorial example of the growth of the boundary layer according to this method.



At the time of the satellite overpass, the temperature and the dewpoint temperature are given by the RTMA, and the height of the boundary layer has been determined using GOES-16 and RTMA data. The profile of the temperature and dewpoint temperature within the boundary layer were assumed to follow the lapse rate of constant potential temperature and constant water vapor mixing ratio. That is, the boundary layer was assumed to be well mixed.

For the 2018 HWT, the assumption of a well-mixed boundary layer was relaxed. The degree of mixing was dependent on how often Θ_{skin} exceeded Θ_{air} in the hours leading up to the satellite overpass. If that was always the case, then the boundary layer in the modified NUCAPS would be well mixed. If not, the lapse rate deviated from well mixed in both potential temperature and water vapor mixing ratio. A comparison between the operational (unmodified) NUCAPS on the top, and the modified NUCAPS on the bottom, demonstrates the result of applying the algorithm to a retrieval over west Texas at 1900 UTC on 22 May 2018.





In 2019 a further alteration to the algorithm was made. Instead of a constant bulk transfer coefficient of heat, C_H, the value was allowed to vary according to the leaf area index of the surface (Abdolghafoorian et al. 2017). Unfortunately, it became apparent that the change did not work as planned, and that more research into a varying C_H was needed. The modified NUCAPS processing returned to the 2018 algorithm.

Overall, the modified NUCAPS product has been well received at HWT. During the experiment, forecasters are expected to comment on the products they are evaluating in the form of blog posts, as well as daily and weekly surveys. Here are some comments from forecasters:

"The NUCAPS data allow for a detailed analysis of the resulting profile and can be a useful alternative to model soundings, especially the modified products as they attempt to more accurately represent the boundary layer based upon RTMA data."

"The modified NUCAPS sounding over Brewster Co TX was more representative of the actual conditions at 20Z versus the regular NUCAPS."

But, it is a work in progress and the feedback wasn't always positive:

"The modified sounding didn't capture the moist boundary layer."

However, whether positive or negative, this feedback is informative and critical for identifying improvements needed for products and applications.

MODIFIED NUCAPS AT NWS FORECAST OFFICES

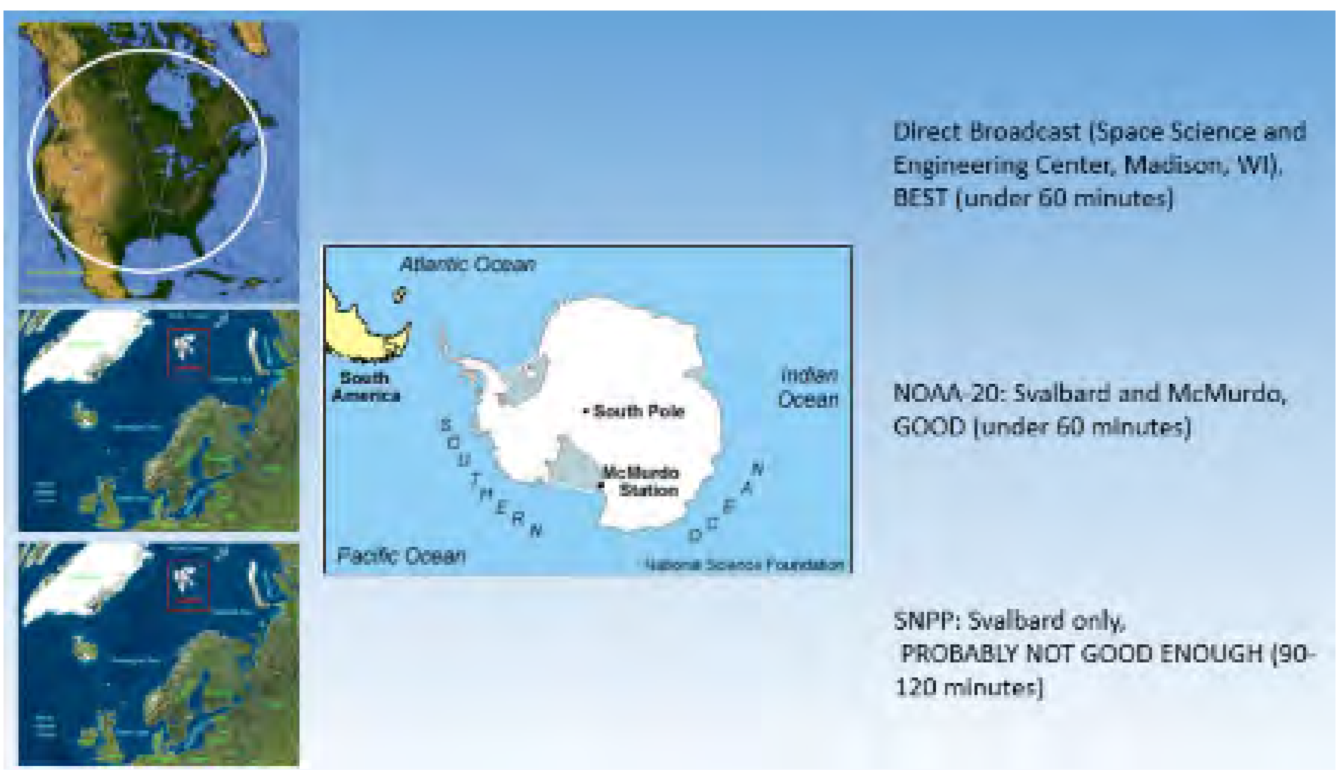
In addition to the ongoing evaluation at the HWT, the modified NUCAPS product is currently available through a special AWIPS ingest arrangement at 4 NWSFOs: Cheyenne, WY; Grand Rapids, MI; Newport/Morehead City, NC; and Rapid City, SD. During their day-to-day operations forecasters can provide not only additional feedback, but also may come up with additional applications for both the operational and modified NUCAPS. In addition to the four offices at which the product is running, several other offices are also in the process of receiving the modified NUCAPS product.

PRODUCT LATENCY

Apart from the performance of the algorithm to modify NUCAPS in a way that leads to a more correct view of the atmosphere, a second issue was evident at the HWT. S-NPP NUCAPS files can be downloaded only at the Svalbard receiving station in Norway. This single point of download can result in product latencies of up to 2 hours. Such high latency prohibits full implementation of both the operational and modified NUCAPS because the product likely will be available to the forecasters only after convection has already begun. The retrievals could still find use in monitoring the atmosphere ahead of an already developed line of thunderstorms, but the general consensus among the forecasters is that without an improvement in latency, NUCAPS products would not be used in the forecast offices. Some improvement is available from NOAA-20, whose files can be downloaded not only at Svalbard, but also at McMurdo Station in Antarctica. The second downlink station allows for a latency reduction by a factor of two, or 60 minutes latent. This timing was better received by the forecasters, enough so they generally agreed that it might be considered as a forecast tool. The best solution is to use the direct broadcast sites over the continental United States at Madison, WI and Wallops Island, VA. Direct broadcast latency is generally 30 minutes or less. This solution would require additional configuration changes to AWIPS, however.

ADDITIONAL APPLICATIONS OF NUCAPS/MODIFIED NUCAPS

Aside from its application in computing CIN and CAPE, forecasters are discovering other applications where the modified NUCAPS product has shown promise. For example, forecasters are demonstrating the use of the retrievals in radar interrogation to help identify freezing levels, or hail and lightning potential. The NWSFO in Grand Junction, CO anticipates utilizing NUCAPS in fire weather applications.



NEXT STEPS

The positive responses to the modified NUCAPS product are encouraging. While much progress has been made to the algorithm, there is still a lot to be done, beginning with quantitative validation of the modified NUCAPS retrievals in comparison to the operational retrievals, as well as to temperature and moisture profiles from the High Resolution Rapid Refresh model. Ground truth will come from early afternoon, "special" radiosondes launched by the NWS at the request of SPC, as well as from data sets such as the Atmospheric Radiation Measurement-Southern Great Plains launches.

Finishing the implementation of the next version of the algorithm, which includes the bulk heat transfer coefficient that varies with surface type is also a priority. Other improvements include automatically filling any gaps in GOES or RTMA data, and using the operational GOES-16 Land Surface Temperature product instead of the currently used skin temperature computation. Finally, the modified NUCAPS from both SNPP and NOAA-20 can be combined to see whether the 50-minute orbital separation adds more information regarding the atmospheric stability for forecasting convection.

As these steps are taken, interaction with the NWS in the form of participation in future HWTs as well as coordination with individual forecast offices will continue. This collaboration is key to producing the best satellite products possible for use in forecasting severe weather. ❖

MEET THE TEAM

Jack Dostalek, a research scientist at the Cooperative Institute for Research in the Atmosphere (CIRA), and JPSS PGRR principal investigator is leading the project on modifying NUCAPS soundings for application to severe weather forecasting. The team consists of both algorithm developers and IT specialists. The principal members of the algorithm development are John Haynes of CIRA and Dan Lindsey of NESDIS/STAR, who initially proposed the idea of modifying the low levels of NUCAPS retrievals.

Quite a bit of IT effort was needed to configure AWIPS to display the modified NUCAPS. Help in that area came from Tiffany Meyer of the Cooperative Institute for Mesoscale Meteorology Studies, Darrel Kingfield of the Cooperative Institute for Research in the Environmental Sciences, Deb Molenar (NESDIS/STAR), and Jason Burks (CIRA).

Dostalek also works in partnership with NUCAPS developers Chris Barnet, Rebekah Esmaili, Antonia Gambacorta, and Nadia Smith, all scientists at the Science and Technology Corporation, Kris White at the Huntsville AL NWSFO, and with Emily Berndt of NASA's Short-term Prediction Research and Transition Center.

Story Source

Materials obtained from JPSS June Science Seminar titled "NUCAPS Boundary Layer Modifications in Pre-Convective Environments."

Further Reading

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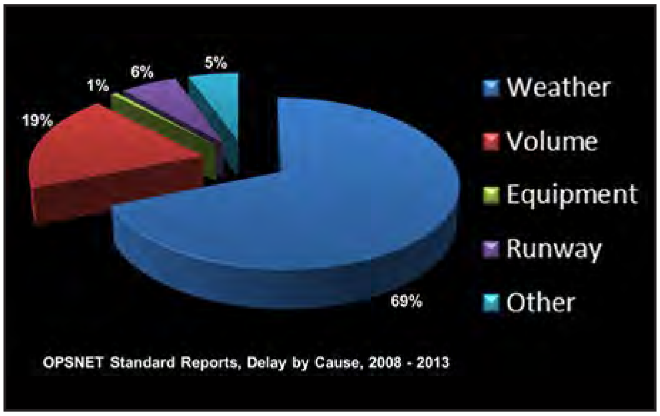
THE JOINT POLAR SATELLITE SYSTEM (JPSS) PROVING GROUND AND RISK REDUCTION (PGRR) AVIATION INITIATIVE

The information in this article is based, in part, on the July 25, 2019 JPSS science seminar presented by Jeff Weinrich, Science and Technology Corporation (STC). The seminar featured contributions from Gail Weaver (NWS), Emily Berndt (NASA/SPoRT), Kris White (NWS, and NASA/SPoRT), Jack Dostalek (CIRA), Brad Zavodskey (NASA/SPoRT) and Nadia Smith (STC), Andy Heidinger, YJ Noh, and the Cloud Team, Carl Dierking (GINA), Carrie Haisley (CWSU), Tom George (AOPA), Arron Layns (JPSS), Becca Mazur (Arctic Test Bed), Andrew McClure (FAA), Jeff Osiensky (AAWU), Bonnie Reed (JPSS/STC), Jorel Torres (CIRA) and Adam White.

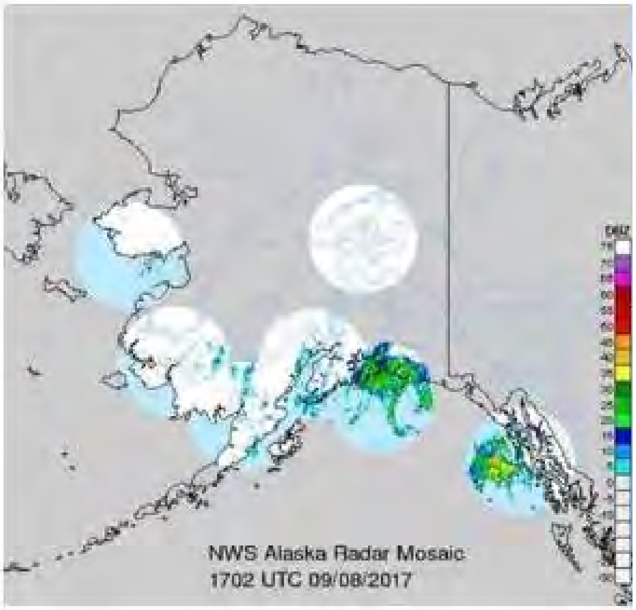
An aircraft takes flight over a snow covered landscape dotted by trees and distant mountains with peaks hidden in low clouds. Photo credit, Adam White, Alaska Airmen Association.

With more than 570,000[1] square miles of land, Alaska is the largest state in the U.S., yet the least densely populated, with a resident population of 738,432, and only 1.3 people per square mile.[2] Much of it is virtually inaccessible to humans except through remote means such as unmanned aerial vehicles (UAV) or drones, and earth observation satellites. In fact, just 20 percent of Alaska is accessible by road. That makes other forms of transportation, such as aircrafts, especially important. For many remote towns, air travel is the only way to get about, which means it has woven its way into all aspects of life in this vast state.

According to the U.S. Federal Aviation Administration (FAA), the largest traffic delay in the National Airspace System is caused by weather (FAA 2017). And there are times when weather conditions can deteriorate to an extent that it becomes dangerous for planes to fly. Accurate weather information is critical to pilots and aviation safety. And in Alaska, landings and takeoffs must be performed in a complex environment with varied topography and harsh weather conditions that pose hazards in almost every season. For example, wildfires, a common occurrence in the summer in Alaska, can limit flight operations due to reduced visibility. This happened during the Swan Lake Fire in August 2019[3]. In the winter, weather hazards from cold, ice and snow, coupled with minimal hours of daylight, present treacherous flying conditions.



Causes of air traffic delay in the National Airspace System.
Credit FAA. https://www.faa.gov/nextgen/programs/weather/faq/

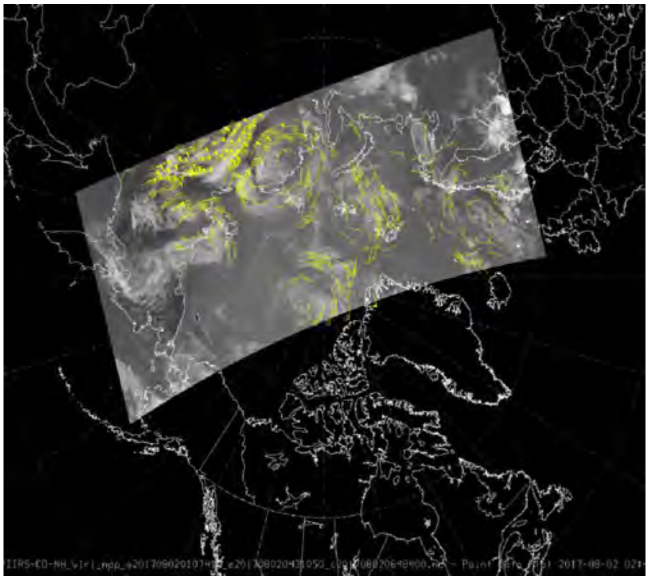


The challenge of surveilling weather in Alaska is that it is a comparatively large, remote, topographically complex landscape with prominent microclimates. Part of the data that is used to generate aviation weather forecasts comes from surface weather observations derived from ground stations or provided by human observers. The radar network (shown right) is limited in coverage and located mainly along coastlines, leaving much of Alaska's interior bare of this data. Moreover, these limited observation platforms cannot accurately represent large areas, as radar beams are often blocked by steep topography. According to the FAA's surface weather observation stations website, Alaska has 133 AWOS or ASOS weather station locations—a small number when compared to over 1,800 similar sites in the "contiguous 48 states". And, while the number of surface observing weather stations surpass those of radar networks, large portions of Alaska's interior remain relatively uncovered.

THE HIGH LATITUDE ADVANTAGE

Alaska's sparsity in surface weather observations is compensated by those from another source, Earth observation satellites, and chiefly, those operating in the polar orbit. Due to overlapping coverage from passes, Alaska, more than any other state in the nation, receives frequent coverage from polar orbiting satellites. Among them are NOAA-20 and NOAA/ National Aeronautics and Space Administration (NASA) demonstration satellite, Suomi National Polar-orbiting Partnership (Suomi NPP) in the Joint Polar Satellite System (JPSS). These satellites have an excellent view of Alaska because of its latitude and proximity to the North Pole, as opposed to geostationary satellites which are centered more on the equator, and therefore have a larger viewing angle at high latitudes due to the curvature of the Earth.

Polar orbiting satellites are also referred to as the "backbone" of global weather forecasting. They provide as much as 85 percent of the data used by numerical weather models, making them vital for 3- to 7-day global forecasts In Alaska and the polar regions, JPSS serves as the primary weather observation satellite system for and is also used as a 'nowcasting' tool for predicting weather in locations that are not visible to geostationary satellites.



Clouds and winds over the North Polar Region as observed from space.

When weather conditions rapidly deteriorate, travel can become difficult, even impossible. To get the information needed for weather forecasts applications, operational forecasters in Alaska rely on the same tools as their counterparts across the lower 48: ground-level data from weather stations, radar, radiosondes, and imagery and data from earth-observing satellites. The difference is that Alaska forecasters are limited to a sparse network of observations from conventional sources, thus gaps in coverage can have an adverse effect on forecast skill.

The FAA operates 21 air route traffic control centers (ARTCC), which monitor aircraft flights all over the United States. The Anchorage Center Weather Service Unit (ZAN CWSU) provides aviation hazard forecasts for Flight Information Regions (FIR) covering more than 2 million square miles of airspace from the North Pole to Russia, Japan, Canada, and Oakland, California—which is roughly the area covered by 13 of the 20 CWSUs in the Lower 48 states. It is co-located with the Anchorage ARTCC.

According to the National Institute for Occupational Safety and Health (NIOSH), about a fifth of fatal aviation crashes in the U.S. occur in Alaska. Since 1992, the Bureau of Labor Statistics (BLS) has been collecting nationwide information on work-related fatal injuries in its Census of Fatal Occupational Injuries (CFOI). This census, along with data from the NIOSH, ranked aviation as one of the most deadly occupations in the United States—a list on which aviation has appeared consistently since 1992. Alaska's commercial airline pilots have low on-the-job fatality rates, with bush, charter and air taxi pilots, according to industry statistics, at the greatest risk of death or injury. In 2019, researchers from 24/7 Wall St. conducted a study to determine the 25 occupations with the highest fatality rates. Their study, which was based on numbers from a 2017 BLS Census of Fatal Occupational Injuries report, ranked aircraft pilots third after logging and fisheries workers (Sauter and Stockdale, 2019).

Federal Aviation Administration officials and Hageland leaders testifying under oath before the board stressed throughout the intense, nine-hour day of inquiry that two age-old Alaska themes are often at the root of CFIT crashes in the state: **much of rural Alaska still lacks needed infrastructure to give pilots the information they need — in this case for weather reporting and communications —and the daring, "bush pilot culture" is still pervasive amongst the state's aviators.**

https://jdasolutions.aero/blog/alaska-aviation-safety/

THE AVIATION INITIATIVE CLEARS FOR TAKEOFF TO ALASKA

Created in 2017 in response to a need for satellite products in the aviation community, the JPSS Aviation Initiative is one of the newest in the PGRR Program.

The data extracted from weather satellites can derive features such as the three-dimensional structure of clouds, which is helpful in aviation weather applications. Among these products are VIIRS Cloud Vertical Cross-sections, Cloud

Base Altitude, Cloud Top Altitude, and Cloud Cover Layers (CCL). These products, which are described in the next section, have been demonstrated to pilots and forecasters in the Alaska region to showcase their potential in addressing forecast challenges related to aviation hazards such as clouds, icing, turbulence, and cold air aloft (CAA). There are now several user communities including the FAA; NWS Alaska Aviation Weather Unit, Aviation Weather Center and Weather Forecast Offices (WFOs) in Anchorage, Fairbanks, Juneau and Phoenix; private pilots, professional associations; international users such as the German Weather Service, Iceland Weather Service, and Environment Canada. Other new users include the National Transportation Safety Board (NTSB), Southwest Airlines, and the National Center for Atmospheric Research (NCAR).

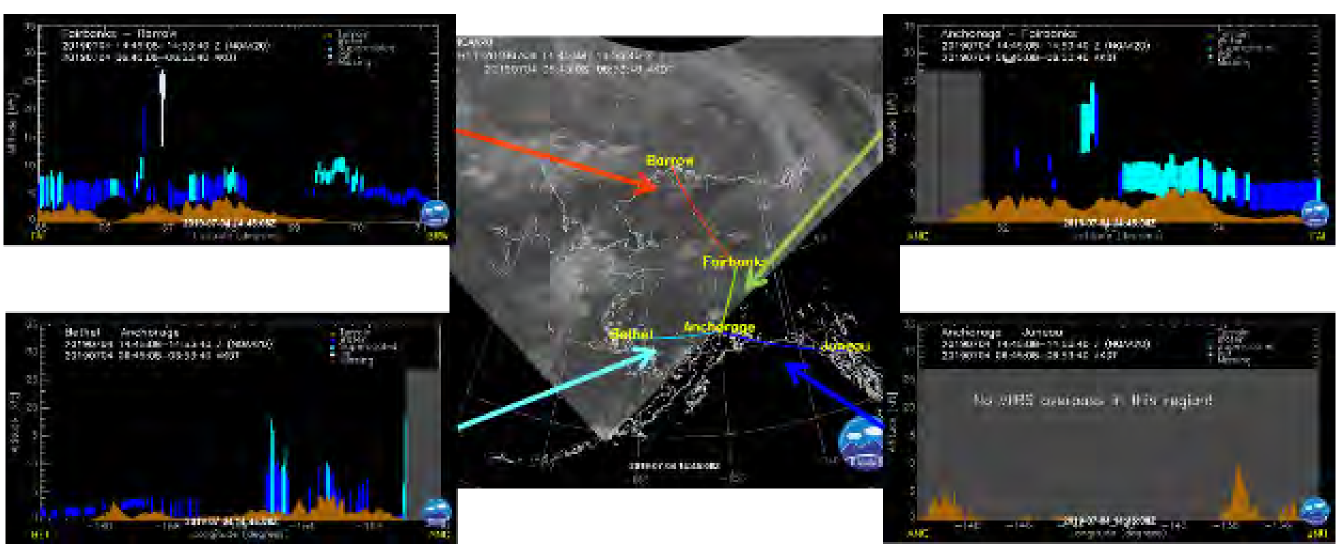
Beyond Alaska, the initiative is looking to expand its products in the Continental United States (CONUS) as well as internationally. Presently, the majority of the demonstrations focus on JPSS/VIIRS cloud products, however, the initiative is looking to collaborate with other satellite programs, such as the NOAA Geostationary Operational Environmental Satellite system (GOES).

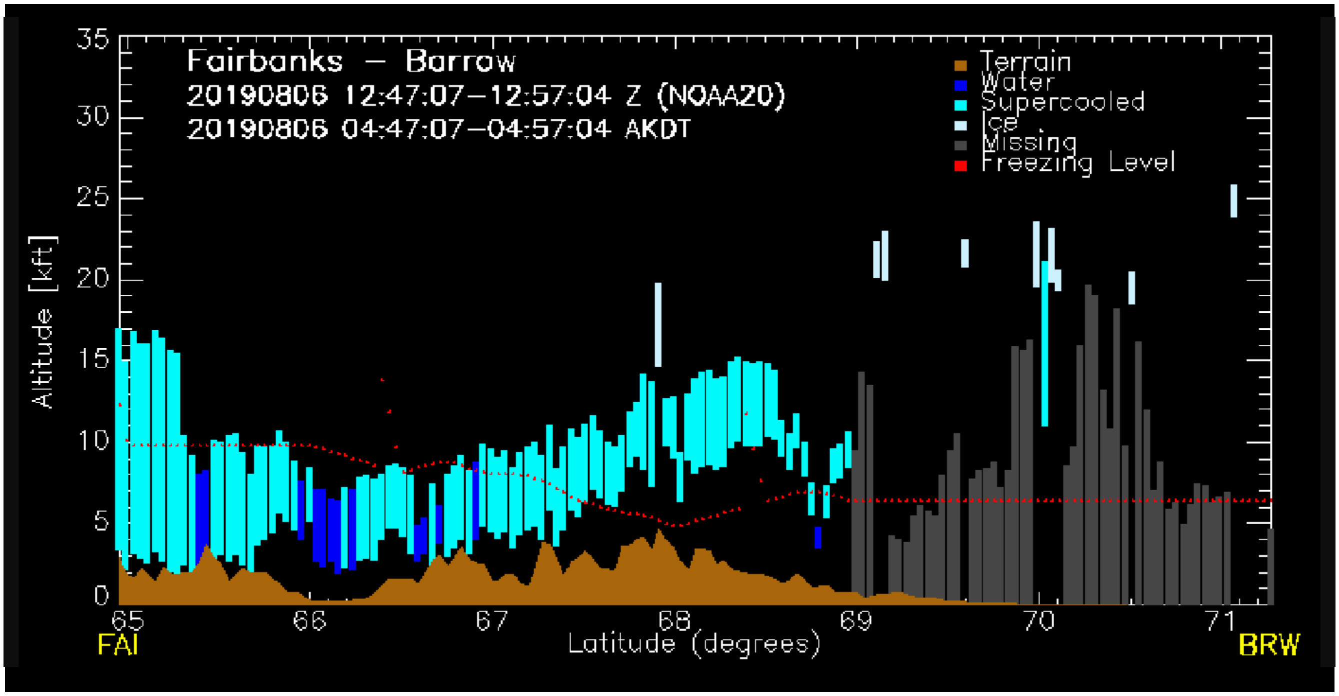
DEMONSTRATIONS

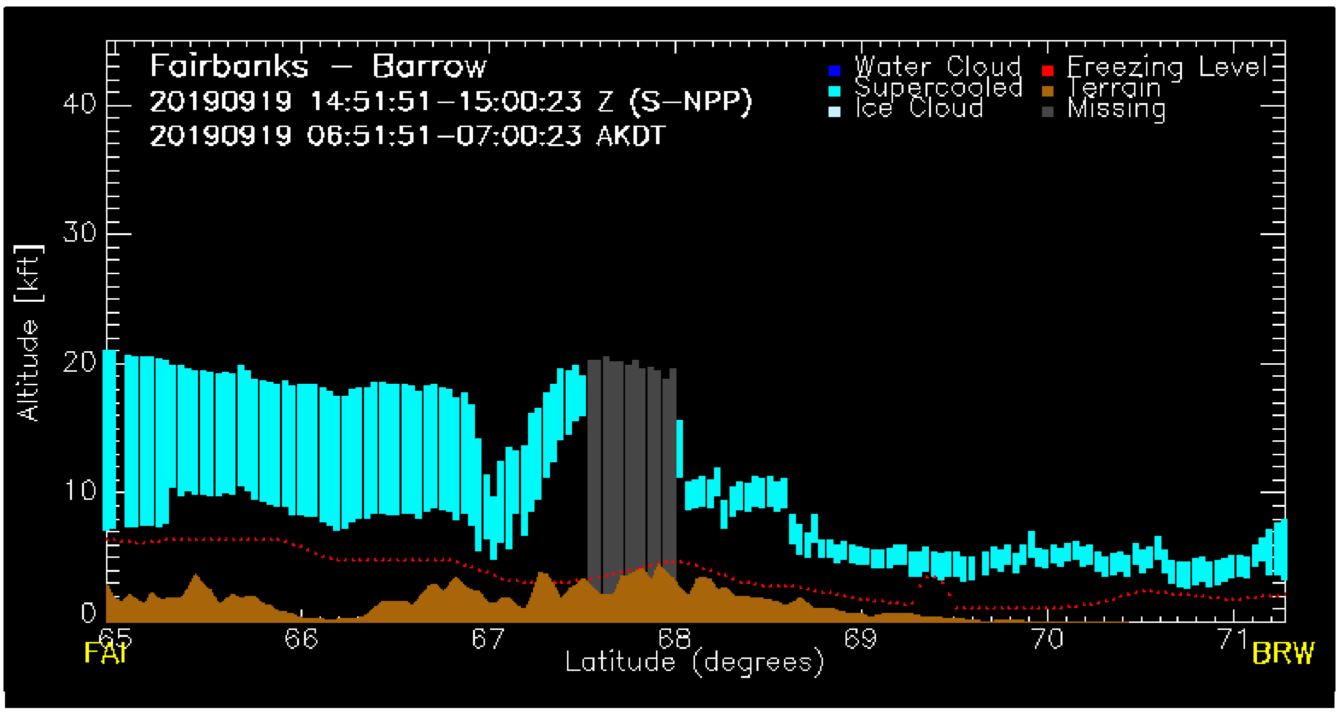
Demonstrations play a vital role in helping the initiative determine how polar satellite data improves the diagnosis and forecast of aviation hazards. The following are brief descriptions of some of the products that were demonstrated to showcase their potential in determining the presence of clouds and cloud-specific hazards in the atmosphere. General aviation mostly occurs in the lower cloud layers, which are typically hidden under cloud top. Thus, for better application in general aviation, the products were enhanced to display more levels of clouds at the lower layers.

VIIRS Cloud Vertical Cross-section

The VIIRS Cloud Vertical Cross-section (CVC) is an experimental product that estimates cloud conditions over a given area. The example shown on the next page shows four prototype routes between the cities of Fairbanks and Barrow, Anchorage and Fairbanks, Bethel and Anchorage, and Anchorage and Juneau, which were demonstrated in the 2019 fall season. The CVC along flight routes over Alaska are obtained by extracting VIIRS Cloud Top Height (CTH) and Base Height (CBH) data from Suomi NPP and NOAA-20. Each cross section displays the type of cloud thought to be present, for example ice, water, or supercooled liquid, as well as terrain along each route, which is indicated in the brown color with heights are in the vertical axis. The missing values denote areas of no satellite overpass or where both VIIRS and NWP models provide invalid cloud water path (CWP) input which leads to a failure to predict CBH.





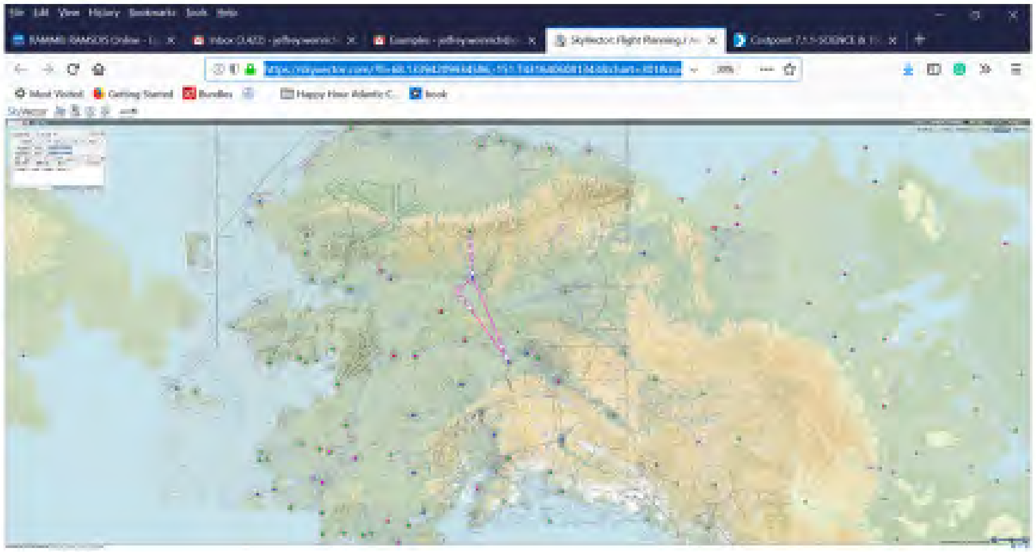


The Anchorage CWSU used JPSS Cross Sections above to verify a Pilot Report (PIREP) that had indicated icing was present to the north of Fairbanks. In Alaska, icing can occur anywhere and in any season, albeit more predominantly along the state's higher terrain areas which border the Gulf, over its Peninsula and in the Southeast (NOAA, 2006). The CVC values were within the range of temperatures where icing occurs, and they also displayed areas along the edge of supercooled liquid water—indicators that icing was present, thus verifying the PIREP.

In the example above, the JPSS Cross Sections indicated hazardous flight conditions, including supercooled liquid water along with sub-freezing temperatures. Based on this information, Adam White, a private pilot, determined that it was not safe to fly the planned route. Addition hazards included the presence of cloud along the flight route as well as a possible danger of icing.

- While there is some weather reporting at these airports and a weather observer at Bettles there is still a lot of distance between these locations with no data and very hostile terrain features.

- The test product was helpful to get an idea what I might encounter, especially in the PABT-PAKP-PFAL section of the trip as I was in the Brooks Range.
- Adam White Pilot



Cloud Base Altitude

Cloud Base Altitude (CBA) is an estimation of the base altitude of the uppermost cloud layer in each column of the atmosphere as viewed from above by a satellite (Noh, 2017). If there are multiple cloud layers only the highest base is displayed. In general aviation, CBA helps pilots in Visual Flight Rules (VFR) aircraft determine whether to fly their route, find an alternate route, or not take off at all.

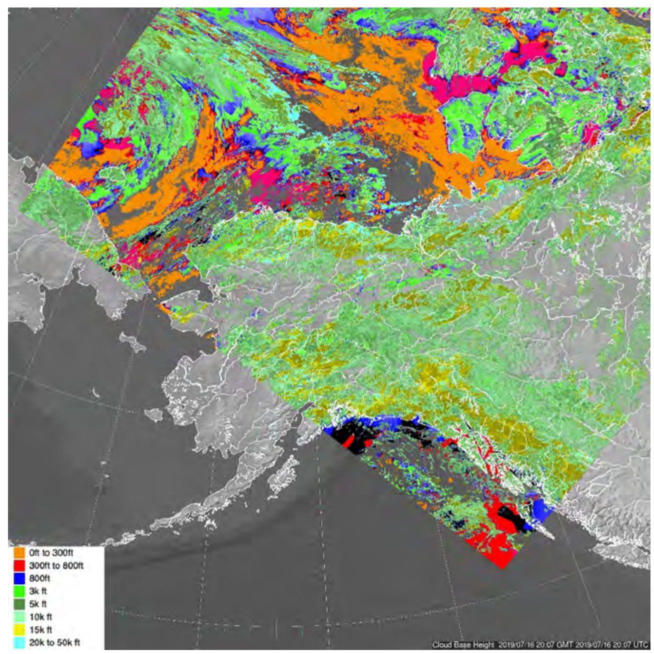
Cloud Top Altitude

Another product under evaluation that has been demonstrated in Alaska is the cloud-top altitude product displayed in kilo-feet. Cloud top altitude is the highest cloud top. The product is used in general aviation to determine where the cloud tops are and whether the presence of clouds may pose hazards to flying.

Cloud Cover Layers (CCL)

Layer #	Cloud Alt (kft)
1	0–5
2	5–10
3	10–18
4	18–24
5	24–100

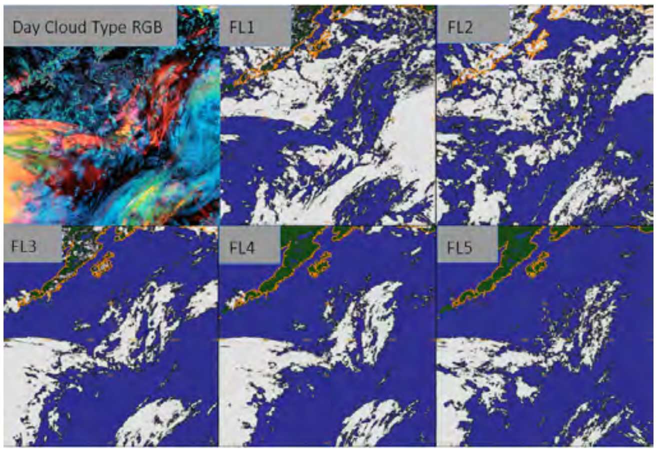
The Cloud Cover Layers (CCL) product provides cloud fraction in five layers defined by flight levels. It uses the cloud base to extend cloud



into lower layers. The color red indicates the highest two layers; green indicates the middle three layers and blue is the lowest two layers.

The RGB gives the user a general picture of where the area clouds are and at which layers. The meteorologist or pilot can look at the flight levels to determine where the cloud areas exist at the different levels.

For the general aviation pilot, Flight Level 1 and 2 may be the most useful to determine whether a flight is possible or not due to the presence of clouds. Other Flight levels may be more useful to commercial airlines and meteorologist to guide bigger jets though the air traffic control system.



Courtesy: Andrew Heidinger (NOAA/ Center for Satellite Applications and Research (STAR)

VIIRS Day Night Band

The VIIRS DNB has also been instrumental in many winter time operational applications in Alaska. The DNB flies the Arctic skies, capturing highly detailed imagery even under low light levels. The DNB becomes particularly important when polar darkness prevails as visible channels are typically rendered unusable during these times.

An example of how important the DNB has become in aviation include the Air Algérie commercial flight disaster in 2014 in Mali. According to various press reports, the crash was caused by high altitude stall in icing conditions. Suomi NPP was flying over Mali and Burkina Faso at 0152 UTC on 24 July and provided high-resolution infrared and DNB imagery showing light flare from the crash impact.

CONCLUSION

Of all the factors that can influence flight safety, the weather, due to its uncertainty, is perhaps the most significant. As a result, safe flying depends on accurate and up-to-date weather information. In Alaska, the need for timely data is considerable given (1) a heavy dependence on air transportation, which in some parts of the state, is the only mode available; and (2) a limited number of conventional resources, including radar that are by and large partially blocked by mountains, to collect weather information. In addition, much of the state's interior includes remote areas with no data for hundreds of miles. Thus, on long routes with inadequate access to weather information, there is always the possibility of encountering hazardous weather conditions.

Weather satellites play a vital role in Alaska, given its sparse network of radars, surface observations, and balloon launches. In addition,

Changes to the distribution 'stable lights' provides a means to locating crash sites and assisting in search & rescue efforts. Satellite imagery courtesy of William Straka, UW CIMSS).

the forecast area of responsibility for the Alaska Region is vast and includes large ocean areas. Because of its unique high latitude location Alaska receives multiple passes per day from polar-orbiting satellites, including NOAA-20 and Suomi NPP. The information they provide is helping generate products that are contributing to many forecast operations, including aviation weather. In fact, the VIIRS instrument is now a key contributor to the satellite data products that provide critical data to Alaska's aviation community. Products derived from VIIRS, such as the Cloud Cross Sections, have helped fill a void in areas that previously lacked weather data. Moreover, the product displays of the estimated extent of cloud cover along a route, and information that enables pilots and forecasters to determine the presence of water clouds, ice clouds, and supercooled liquid water, is helping members of the aviation community anticipate the weather along their flight routes.

The Initiative, which grew out of a need for accurate and up-to-date aviation weather information in Alaska has demonstrated several cloud products to the region's NWS operational forecasters along with members of the aviation community including general aviation pilots and the FAA. The initiative is working closely with its user community to determine how these products are helping to improve the diagnosis and forecast of aviation hazards. Counted in the initiative's list achievement is the creation of JPSS Cloud Cross Sections which can be utilized by general aviation pilots to determine whether or not to fly along paths impacted by clouds. In addition, the initiative now has 17 new user groups that did not use JPSS Cloud Products before.

And there's more, including several Cloud Product demonstrations in 2020. These will feature enhancements including a dynamic global cross section capability where a user can point and click and get a cross section created on demand. But that's not all!

According to the Alaska Volcano Observatory (AVO), the state is home to more than 130 volcanoes and volcanic fields. This includes more than 75 percent of active U.S. volcanoes in the last two hundred years[2]. Volcanic ash is extremely harmful to jet engines, and can melt and congeal within turbines and other parts, causing rapid engine failure. For this reason, it is vital that the height and extent of volcanic ash be accurately forecast. JPSS derived volcanic ash detection products are constantly in development to assist Volcanic Ash Advisory Centers (VAAC). Already, the aviation initiative is taking steps to partner with a newly formed Volcanic Hazards Initiative to further support the needs of Alaska's user communities. ❖

Footnotes

[1]National Atlas of the United States at https://nationalmap.gov/small_scale/

[2]https://state.1keydata.com/state-population-density.php

[3]Alaska Division of Forestry. Swan Lake Fire. https://inciweb.nwcg.gov/incident/6387/

[4]INTRODUCTION- HOW MANY VOLCANOES IN ALASKA? https://avo.alaska.edu/volcanoes/about.php. Accessed Oct 24, 2019.

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Further Reading

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THE JOINT POLAR SATELLITE SYSTEM AND THE INTERNATIONAL CONSTELLATION

SUPPORTING ENVIRONMENTAL APPLICATIONS ACROSS THE GLOBE

The information in this article is based, in part, on the August 29, 2019 JPSS science seminar presented by Dr. Mitch Goldberg, NOAA/NESDIS/JPSS. It also features activities taking place in the Satellite Proving Ground User Initiatives.

Illustration of the World Meteorological Organization's Global Observing System, including space, weather and environmental satellites. Credit NOAA.

In 1960, the first weather satellite launched into space. The Television Infra-Red Observation Satellite, or TIROS 1, heralded an era in weather observation where cloud systems could be viewed from space. TIROS 1 offered early insights into cloud formation as it followed the movement of clouds across the globe. Since then, weather satellites, from their unique vantage points, have become vital tools for monitoring the global environment. While recognized for their extraordinary ability to track and monitor weather phenomenon across the planet, the capabilities of weather satellites have expanded to include non-meteorological applications (NMAs) such as floods, fires, volcanic eruptions, trace gases, droughts and many more. In addition, information from weather satellites have also provided benefits in the areas of wildlife and forest conservation, land use planning, water supply management, crop management, and so forth.

The unrivaled perspective that satellites provide help inform the lives of communities worldwide, and alert people to prepare for approaching weather events. Satellites are especially vital over the oceans, where conventional observations are sparse. Without satellite observations, storm systems brewing in the ocean would be missed. Thus, predicting weather at any location depends on good observations around the Earth.

COLLABORATION AS A GLOBAL PUBLIC GOOD

The provision of national and international meteorological services are examples of pure public goods. According to economic text book terminology (Stiglitz, 2000), pure public goods are those which are non-rivalrous, whereby one person's use does not diminish or affect the amount available to others; and non-excludable, which means that one cannot be denied the opportunity to consume the good. The provision of weather forecasts and warnings fall into this category. Public goods are typically produced by governments because the private sector cannot provide the information efficiently (Freebairn and Zillman, 2002b). Weather doesn't stop at borders; local, regional or national. A weather system can form in one region, and inflict damage in an entirely different region. Some weather systems, especially those which are extreme in nature, are often harbingers of hazards, and cause for concern across the globe. For example, weather conditions that spawn events like tropical cyclones, dust storms, droughts, and floods can cause property damage, impacts to health and well-being, displacement of populations, or loss of life and property. When it comes to monitoring developing weather events across the globe, ensuring that this particular public good is available and accessible to all is increasingly important. It is one of the most critical justifications for cooperation among weather satellite operators. Cooperation involves the creation, adaptation, transfer and sharing of knowledge and experiences, while leveraging existing resources and capacities. It can be an effective tool to help confront the global challenges posed by weather through shared knowledge and best practices to attain local solutions (Ostrom 1990).

To meet the level of coverage needed, NOAA works with the international community, sharing the Earth observation data required for weather and environmental prediction on a full, free, and open basis. Following a pattern that was established many years ago, European polar orbiting satellites operated by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) provide coverage in the mid-morning, while the U.S. polar-orbiting satellites provide coverage in the afternoon. This arrangement ensures a continuity of measurements from the polar orbits.

Data from NOAA and EUMETSAT's "Joint Polar System" form the backbone of all medium range weather forecasts in the U.S. and Europe and make up the majority of the data used by the U.S. weather model (GFS) and the major European weather model (ECMWF). Credit: EUMETSAT

A THREAT IN ONE CORNER OF THE WORLD IS A THREAT TO ANYWHERE ELSE

Most of the tropical cyclones that hit the United States Atlantic Coast and the Caribbean originate half a world away, off the western coast of Africa. In addition, massive dust storms can journey from the deserts of Northeast Africa and cross the Atlantic Ocean, impacting communities thousands of miles away. NESDIS provides timely access to global environmental data and information from satellites and other sources to promote and protect the nation's environment, security, economy, and quality of life. But its reach extends well beyond the United States and its territories to encompass the globe through international coordination activities administered through agencies such as the United Nations (UN) World Meteorological Organization (WMO)—a specialized UN agency that provides a framework for international cooperation by facilitating activities among providers of meteorological observations to monitor and protect the environment.

The ubiquitous nature of the weather and the call for collective action is encapsulated in the organization's mandate that "as weather, climate and the water cycle know no national boundaries, international cooperation at a global scale is essential for the development of meteorology, climatology and operational hydrology as well as to reap the benefits from their application."[1] Best practices for calibration and traceability, as described in the Annex VIII to the WMO Technical Regulations "Manual on the WMO Integrated Global Observing System," include a call for satellite operators to execute

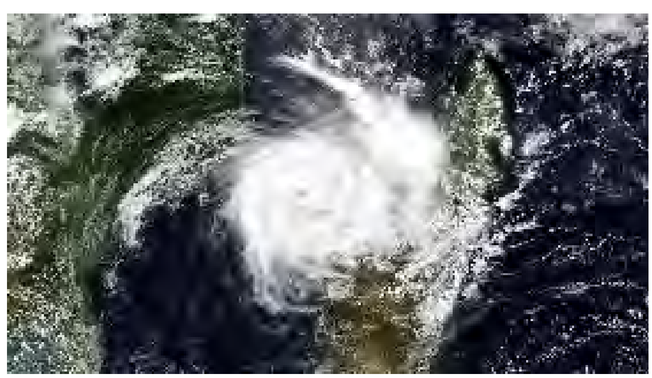
detailed instrument characterization prior to launch. This enables standardization and data interoperability. It is based on a paradigm of establishing best practices that will enable the global community to detect and respond to weather events. How so? By providing data to support weather forecast applications in other parts of the world, especially where weather data are limited.

During a lively hurricane season in the Atlantic Ocean, satellite images of major Tropical Cyclones (TCs) headed for the U.S. coast become some of the most familiar and recognizable items in the media. In 2019, this scene, familiar to U.S. residents became all too real a world away in Mozambique as Kenneth, an intense TC came ashore in April in the northern part of the country. Surveillance of this TC by operators of environmental satellites is an example of how their cooperation works to implement the requirements of the WMO. TC Kenneth, equivalent to a Category-4 storm on the Saffir-Simpson scale, had gust wind speeds reaching a maximum of 270kph and average wind speeds of 185kph (WMO, 2019), making it the strongest storm on record to hit the area. In addition, TC Kenneth hit Mozambique just weeks after another powerful cyclone, Idai had made landfall. This was the first time in the nation's recorded history that two powerful cyclones had hit back to back.

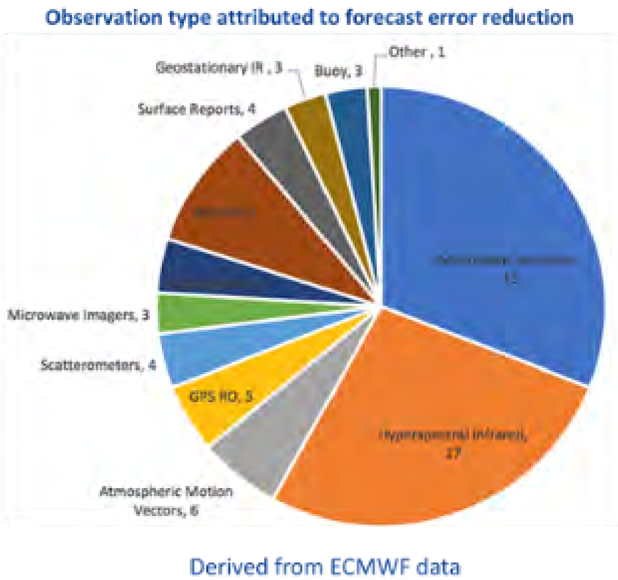
On March 10, 2019, the VIIRS instrument on NOAA-20 captured Idai brushing the island of Madagascar before moving south and west toward the coast of central and southern Mozambique.

According to the United Nations Office for Disaster Risk Reduction (UNISDR), roughly 90 percent of major disasters are triggered by weather related events, including floods, storms, and heatwaves (CRED, UNISDR, 2015). Over a span of two decades, 1995-2015, the UNISDR noted that while weather-related disasters were on the rise, the number of deaths caused by them were going down.

Data from satellite instruments can help improve forecasts and aid in recovery efforts. For example, the JPSS payload includes the Advanced Technology Microwave Sounder

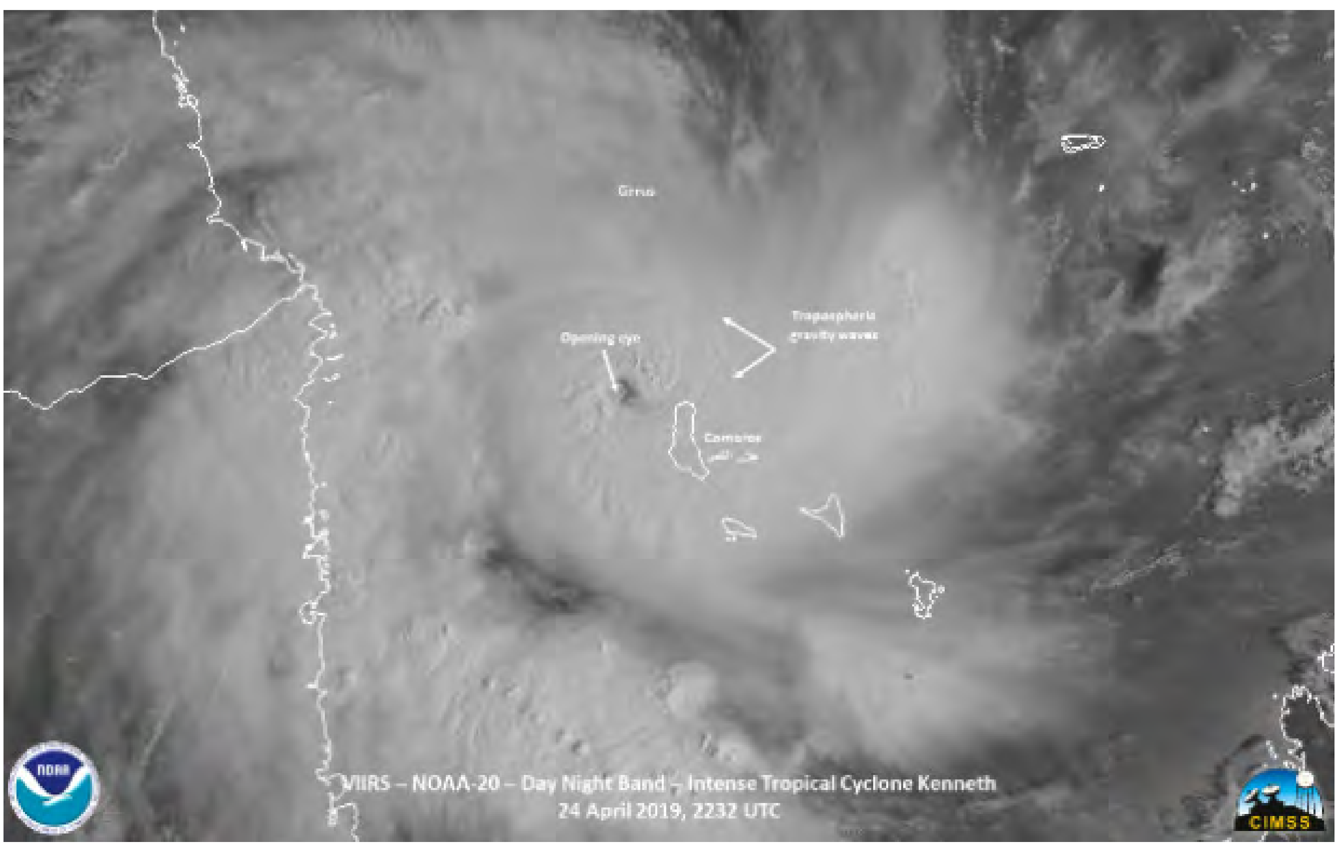


Tropical Cyclone Idai is seen moving through the Mozambique Channel. Image credit: NOAA



(ATMS), which provides atmospheric temperature and moisture profiles for operational weather and climate applications. ATMS collects microwave radiation from the Earth's atmosphere and surface all day and all night—even through clouds. Another sensor, the Cross-track Infrared Sounder (CrIS) is an advanced operational sounder that provides more accurate, detailed atmospheric temperature and moisture observations for weather and climate applications. These sensors are core components of the weather forecasts enterprise. Close to 90 percent of the data used in forecast models are from polar-orbiting satellites and attribute to nearly 60 percent of the reduction in forecast error. As illustrated in the pie chart showing the different observation types that can be attributed to forecast error reduction, the largest contributions come from microwave and hyperspectral infrared sounders. These error reductions have resulted in more accurate forecasts allowing the public to better prepare for impacts from weather events.

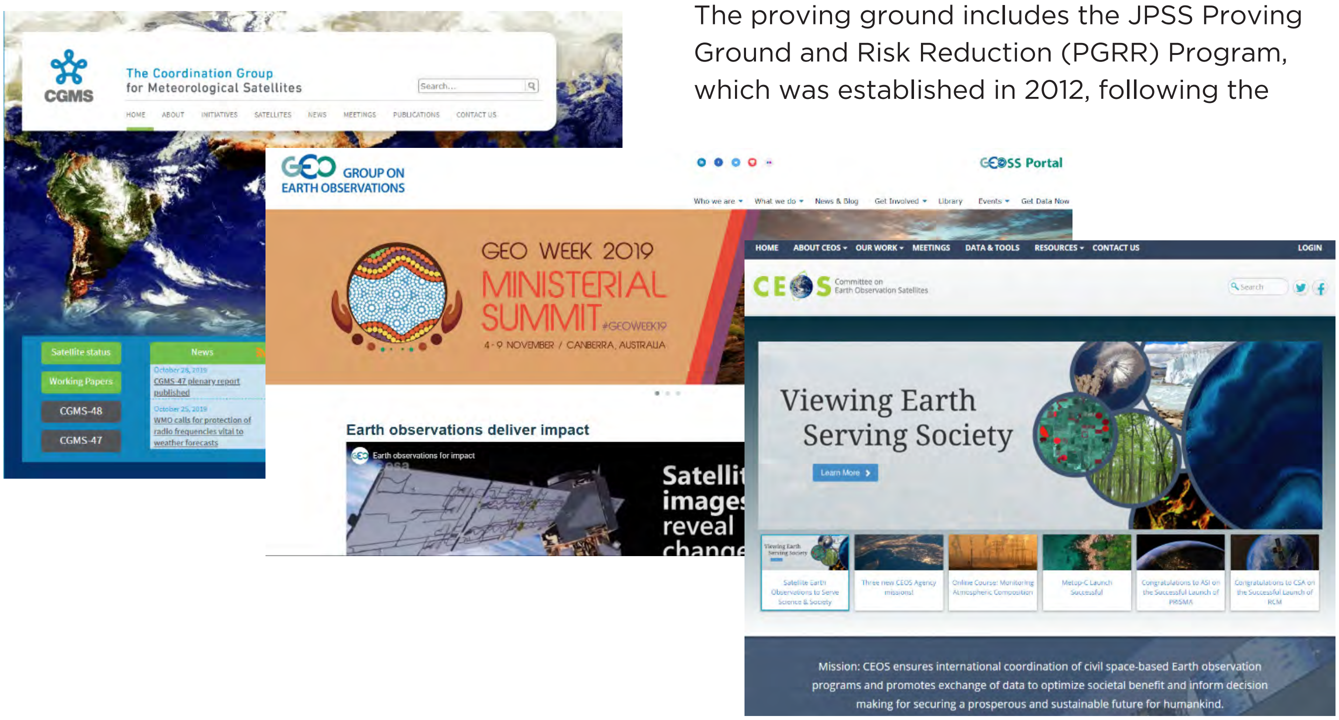
On the night of April 24, TC Kenneth was observed by Suomi NPP, NOAA-20 and GCOM-W1, each contributing unique points of view of the storm. Kenneth was first observed by Suomi NPP at 2142Z on the edge of the pass as it was to the northwest of Comoros. The IR imagery showed features that are typical of an intense tropical system with overshooting tops and convectively driven tropospheric gravity waves. With the Waning Gibbous moon (Illumination: 73%), one could see the similar



Credit: NOAA/ University Of Wisconsin - Madison, SSES-CIMSS, William Straka III features in the VIIRS Day Night Band (DNB) along with a lone lightning streak in the south of the storm. The DNB is sensitive to low levels of visible light at night. It can detect the light from a single ship at sea and even the glow of Earth's atmosphere. Fifty minutes later, at roughly 2232Z, NOAA-20 provided a near nadir pass of the storm showing similar features (next page), but with a notable difference—the eye appeared to have opened up between the two passes.

The near-nadir pass also allowed the ATMS instrument on NOAA-20 to provide a look at the inner structure of the storm. The ATMS microwave brightness temperatures also made it much easier to see in detail the convection surrounding the eye of the storm. Roughly four minutes later, another microwave instrument, the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the JAXA satellite GCOM-W1, also observed Kenneth and also showed the cold cloud tops completely surrounding the well-defined circulation. The utilization of microwave imagery is key to knowing where the center of the storms are located.

NOAA also responds to WMO requirements through engagements with multilateral organizations such as the Coordination Group for Meteorological Satellites (CGMS), the Group on Earth Observations (GEO), and the Committee on Earth Observation Satellites (CEOS). The purpose of international coordination groups is to ensure that satellite data providers establish requirements for best practices in activities such as calibration/validation so that the data become interoperable. This is achieved through various activities including the provision of data in a standard format, which ensures that all members of the global community are able to communicate with each other as well as leverage the resources available in the entire global satellite constellation.

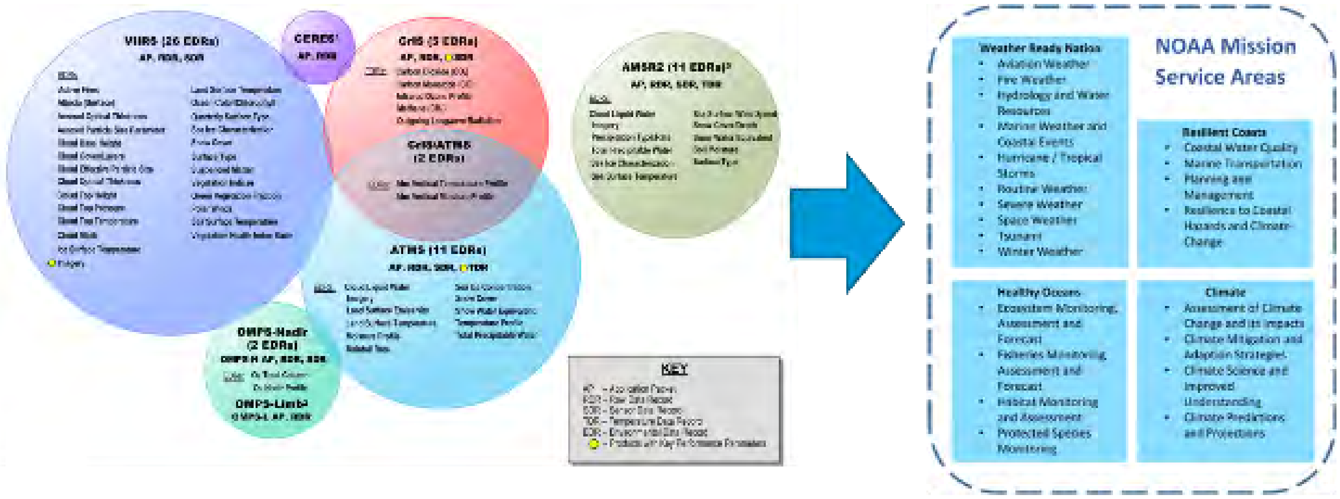


NOAA SATELLITE PROVING GROUND

The following section will focus on NOAA's satellite Proving Grounds, and present examples from User Initiatives in the JPSS Proving Ground and Risk Reduction (PGRR) Program to show how they connect to the WMO's global observing system.

The goal of NOAA's Satellite Proving Ground is to improve NOAA Services through optimizing the use of satellite data along with other sources of data and information. It leverages satellite **observations** to feed into **services** and provide benefits to **stakeholders**.

The proving ground includes the JPSS Proving Ground and Risk Reduction (PGRR) Program, which was established in 2012, following the

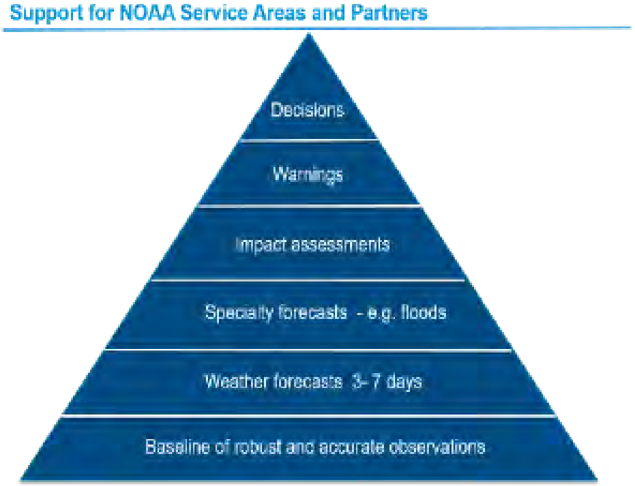


Addressing needs across NOAA

launch of the Suomi NPP satellite, to facilitate Operations to Operations (O2O) through demonstrations of JPSS derived data and products in user environments. It provides resources and support to research activities which demonstrate improved operational application of JPSS data and products to assist NOAA and other agencies in meeting their mission requirements.

Satellite data has become a vital part of decision-making systems all over the world, which many—from resource planners, policy makers, ecosystem managers, farmers, first responders, to the general public—have come to rely upon. Satellite data produces information such as: (1) where the hurricane is going. (2) Is there an air quality issue? (3) How is the fire spreading? (4) Where is the ice? And so forth. This information "requires a baseline of robust and accurate observations," says JPSS Program Scientist, Dr. Mitch Goldberg. Dr. Goldberg says that these are provided through JPSS as well as other observing systems, including the GOES-R series. As shown in the pyramid above, these observations feed into the three to seven day weather forecasts. In fact, it is because of shared data access that accurate weather forecasting out to seven days is available.

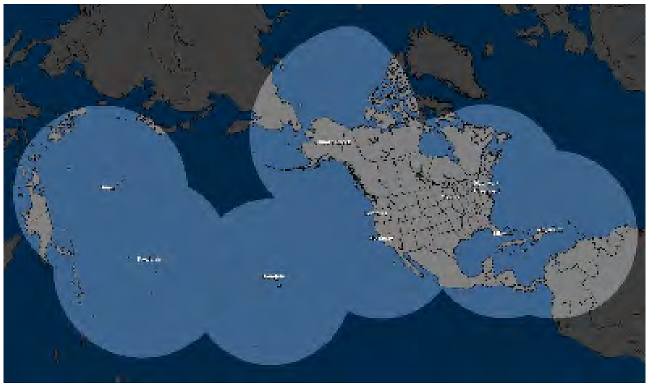
Proving Ground User Initiatives focus on Applications and Decision Support for NOAA Service Areas and Partners



NESDIS Strategic Metric "The utilization of NESDIS developed science by internal and external partners and stakeholders through enhanced coordination with partners and the user community"

In 2014, the JPSS PGRR Program developed a project management recipe to enable more collaboration and synergy between projects through "User Initiatives." The program engages users and service providers to better understand their needs, with the goal of ensuring that the. The model shown above lays out the mission of the JPSS Proving Ground: to help qualify, quantify and compare the relative impact of its science applications on society; demonstrate the value to those who contribute to, and benefit from, JPSS products and services; and also to generate the information needed to improve what it produces. Beyond JPSS data, the initiatives also exploit data from instruments operated by national and international partners, such as NASA, EUMETSAT, Japan, and the European Space Agency (ESA), and that complement JPSS by gap filling or are innovative.

This is also the case with direct broadcast (DB), which is one of the keystone mission



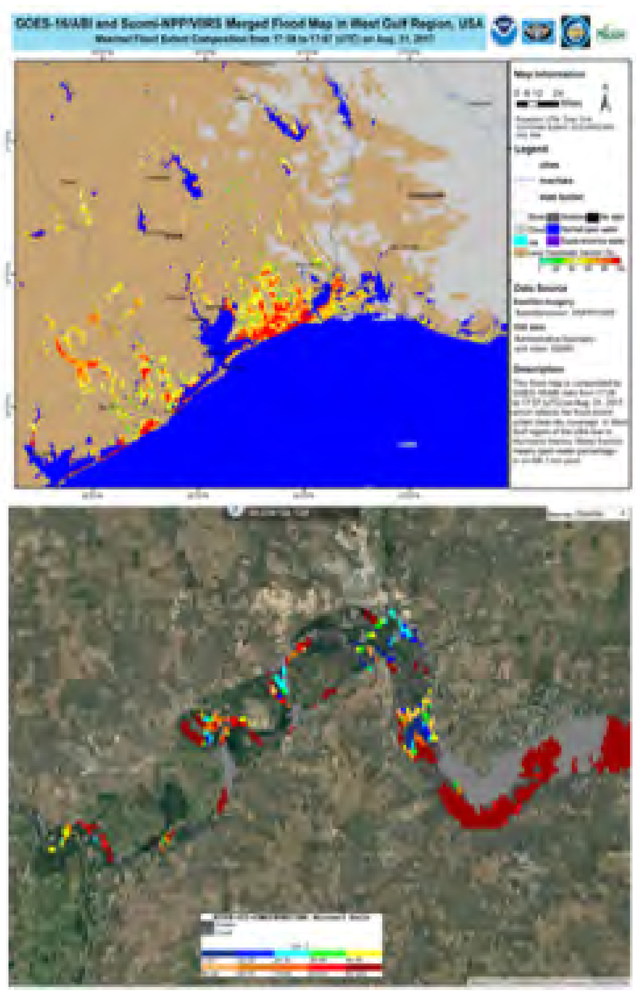
elements of JPSS. As specified in the Program's Level 1 Requirements Document (L1RD) "JPSS-1 shall provide a real-time X-band direct broadcast of instrument data to the direct readout community." The development of the Community Satellite Processing Package (CSPP) for direct readout capabilities has become a cornerstone of a number of PGRR Projects. CSPP uses open source science software to package and distribute meteorological and environmental satellite data through DB. CSPP transforms data —from instruments on NOAA-20 and Suomi NPP, as well as from instruments on other NOAA POES and domestic and international partner agency satellites—into optimal formats for real-time processing and regional applications. The use of CSPP enables demonstrations of new capabilities or algorithms without having to impact the ground segment. In addition, CSPP provides very low latency data, typically within 20 minutes, which enables much faster delivery of real-time imagery and selected derived products to forecasters, thereby accelerating their forecasting capabilities.

NEAR REAL TIME WEATHER PREDICTION APPLICATIONS

The following section presents examples from initiatives to illustrate the ways the JPSS PGRR matches the needs of user communities with its data products—a move that has led to a rapid utilization of JPSS data in key applications impacting life and property and economic resiliency. This move has also seen collaborations extending out to the international community as well as the International Charter on Space and Major Disasters (ICSMD) in the area of floods, fires and volcanoes. The Charter is a collaborative effort between space agencies which provides satellite-derived information and products to support disaster monitoring and response efforts worldwide. Following are just four of many examples in a diverse and important set of proving ground initiatives.

FLOODS AND RIVER ICE

In May 2013, Galena became a focal point of action when an ice jam restricted the flow of water along the Yukon River. This caused severe flooding, which not only posed a hazard to the local communities and damaged property, but also disrupted activities in the region. This became an opportunity for the JPSS PGRR to demonstrate ice and flood detection capabilities. In response to a request for assistance from the National Weather Service (NWS) River Forecast Centers (RFC) in Alaska, two product expert

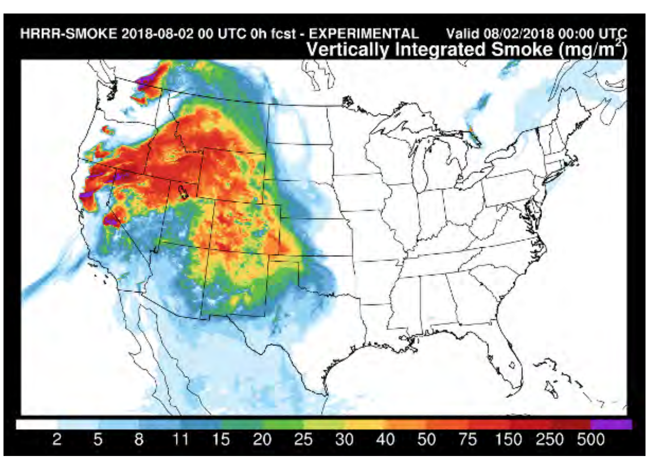


Top image: Integrated JPSS/GOES-R flood maps: Harvey
Lower image: JPSS VIIRS ice map: Missouri and Yellowstone River: 3/27/18

teams from the JPSS PGRR created near real-time satellite-derived flood maps to support the RFC's monitoring efforts. The flood product was developed by a team from the George Mason University (GMU), and helped to define river flooding, while the River ice product, which was developed by a team from the City College of New York (CCNY) helped to designate the extent of river ice formation and breakup. The products showed immediate potential, although it was slightly cumbersome to use given issues such as cloud shadows, which distort an image since they tend to look like water. Since then, and through continuous feedback, the products have undergone significant improvements including delivery in formats to fit diverse user requirements; zooming features that enable VIIRS data be scaled down to 30 meters; as well as integration with data from sensors on geostationary satellites which allows for better areal extent while preserving the better spatial resolution available from the LEO platform. This initiative has also spurred a number of global flood mapping pilot activities in CGMS and CEOS.

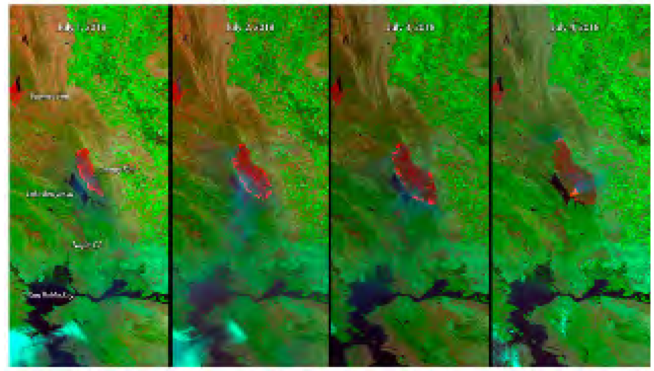
FIRE AND SMOKE

One of the activities of the Fire and Smoke initiative is to provide high-resolution fire information, or fire radiative power (FRP) into the High-Resolution Rapid Refresh (HRRR) smoke model. The result has been highly detailed products that help predict fire spread and forecast smoke, detect small fires in remote areas, or estimate the radiative power of fires. Its goal is to help improve warnings of wildfires as well as their impacts such as poor air quality.



At close to 375 meters, JPSS (below on the left) provides high spatial resolution that is used for identifying fire perimeters and it is also ingested into smoke forecast models, while GOES-R (below on the right) provides nearly continuous observations of fires at a 2–3 km resolution (function of latitude ~ 6 km in central Alaska).

The Expanding County Fire in Northern California



In August 2018, as thick smoke from wildfires choked northern and central California, emergency responders relied on various data including the experimental HRRR-smoke model to inform their operational decisions. The NOAA Smoke Forecasting System was built to provide guidance to air quality forecasters and the public for fine particulate matter emitted from large wildfires and agricultural burning which can elevate particulate concentrations to dangerous levels. For example, California's Department of Transportation scheduled changes to AMTRAK bus and train routes through northern and central California where it was predicted that adverse effects such as poor visibility and air quality would impact the areas. In addition, the National Park Service decided to close Yosemite National Park based on forecast guidance.

This closure became the longest in nearly two decades and had a devastating effect on tourism in the region.

SOUNDINGS—PART OF THE HAZARDOUS WEATHER TESTBED

Another area where JPSS data has demonstrated utility has been in the use of soundings in various weather scenarios. Soundings have been used to investigate the pre-convective environment, which is helpful for forecasters because the sooner they can determine, with accuracy, where and when severe storms will develop, the sooner they can issue warnings and watches. Satellite soundings are also being used to investigate cold air aloft, an important aviation safety concern. The Federal Aviation Administration (FAA) uses JPSS Temperature Soundings to warn pilots of Cold Air Aloft (CAA) conditions, which occur when air temperatures decrease to minus 65°C and below and cause jet fuel to thicken and crystallize and adversely impact the operation of jet engines.

AVIATION APPLICATIONS

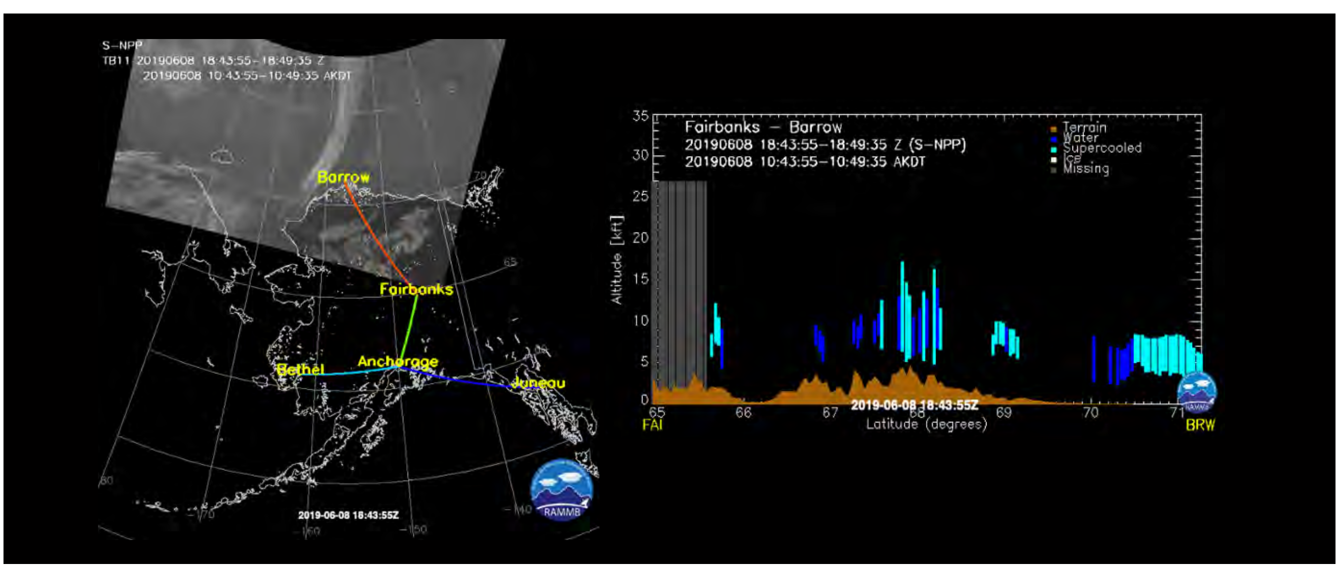
Alaska is more dependent on general aviation and small aircraft commercial aviation than any other state in the nation. In May 2018, JPSS held a summit in Alaska that included a newly created Aviation Initiative, the NWS Weather Forecast Offices (WFOs), the FAA, members of the general aviation community, and international partners. This was the first meeting with the aviation community that the JPSS had held.

The influence of low-level clouds and fog poses a strong threat to aviation throughout Alaska. VIIRS imagery is one of the primary tools used in detecting low-visibility conditions throughout data-sparse Alaska. Subsequent to feedback from the summit, JPSS is working with the NWS to demonstrate cloud products for pilots which will be made available through the NWS.

The left image shows a VIIRS image laid over an image showing four typical flight paths, and the right image shows the vertical extent of clouds along the Fairbanks to Barrow flight path as well as their type, i.e., water, supercooled, and ice.

CONCLUSION: TOWARD A WEATHER READY PLANET

Since 1960, when the first weather satellite launched to provide views of cloud systems, more have followed suit to observe the Earth from vantage points in space, which enable them to uncover and track phenomenon worldwide. Weather satellites continue to be the key contributors to the global observing system, providing data that is used to deliver essential predictions and warnings, and to save lives. Space agencies have for years recognized the importance of sharing remotely sensed data for weather analysis and forecasting, climate analysis, and monitoring hazards worldwide. As



a result, they operate under a policy of freely shared data. JPSS provides the sustained robust and accurate set of key observables that are crucial to obtaining continuity, global coverage, and filling data gaps. JPSS data is shared and accessed by the global community through the WMO, which enables its utilization in various critical applications and decisions impacting lives, property in the US and across the globe. JPSS collaborates with national and international partners through the WMO and engages with multilateral organizations such as CGMS, GEO, and CEOS to develop requirements, establish best practices for combining measurements from multiple satellite sensors, and develop capabilities that enable communities worldwide to develop local solutions to address the challenges related to global atmospheric processes and their complex interactions. ❖

Footnotes

[1]https://public.wmo.int/en/our-mandate/what-we-do

Story Source

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VISIBLE APPLICATIONS IN DARK ENVIRONMENTS, REVISITED (VADER)

The information in this article is based, in part, on the September 18, 2019 JPSS science seminar presented by Steve Miller, Cooperative Institute for Research in the Atmosphere. It also features contributions from William Straka, III (UW-CIMSS), Curtis Seaman, Yoo-Jeong Noh, and Louie Grasso.

Polar-orbiting satellites are considered the backbone of the global environmental observing system. Their data feed into numerical weather prediction (NWP) models, contributing to the best possible warnings, forecasts, and monitoring of the ever-changing global environment. Imaging radiometers on board satellites flying in sun-synchronous polar orbits (configured to provide a fixed local overpass time throughout the year) observe any given location on the Earth roughly twice daily; once during the day and once at night. Except for the polar region and high latitudes, where overlapping imagery swaths provide additional views, the low temporal resolution limits the ability of polar orbiting satellites to monitor changing conditions, and in particular, to view the weather in motion.

Visible (VIS; typically regarded as light between wavelengths of 380 to 740 nanometers) satellite imagery is a longstanding staple for situational awareness in daytime operational weather forecasting. VIS provides an excellent ability to measure and distinguish between many meteorological and surface parameters owing to differences in their reflective properties. The lack of visible imagery at night has meant a sole reliance on thermal infrared (IR) imagery, a kind of longer wavelength measurement that is available both day and night, to provide this information. While IR imagery offers important, complementary information to VIS, it also has many limitations. For example, it is limited in its ability to detect aerosol, low-clouds and surface properties.

The traditional paradigm of "IR-only observations at night" shifted dramatically with the new generation of NOAA's operational polar-orbiting satellites. The Visible/Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB; Miller et al., 2013) was introduced to the world on October 28, 2011 with the launch of the Suomi National Polar-orbiting Partnership (Suomi NPP)—the first of a series of next-generation spacecraft in the Joint Polar Satellite System[1] (JPSS)—from California's

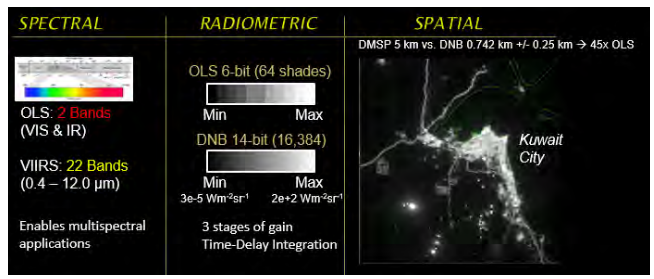
Vandenberg Air Force Base. True to its name, the DNB brings a kind of daytime image quality to nighttime images—offering a capability to sense the environment using very weak-light visible signals that are present at night, and to do so at unprecedented quality. Forecasters are taking notice, and beginning to see the advantages of "the dark side" with the help of these revolutionary new observations.

The DNB introduced a powerful new asset to nighttime environmental characterization. It is the only sensor on VIIRS with low light sensitivity which enables it to pick up many diverse signals at night. In particular, the DNB is uniquely qualified to detect sources ranging from moonlight to light emissions from anthropogenic and atmospheric sources. In other words, we can see ourselves in the DNB.

Nocturnal awareness of parameters key to commerce and transportation (surface, aviation, and maritime), infrastructure (e.g., power consumption), and major components of the climate system (clouds, cryosphere, aerosol, land, and ocean), are now capable thanks to the DNB's unique sensitivity to artificial (ships, cities, gas flares; Elvidge et al., 2017) and natural (e.g., lunar reflection, active fires, airglow; Miller et al., 2013) sources of nocturnal light.

THE NEW ORDER OF LOW-LIGHT IMAGING

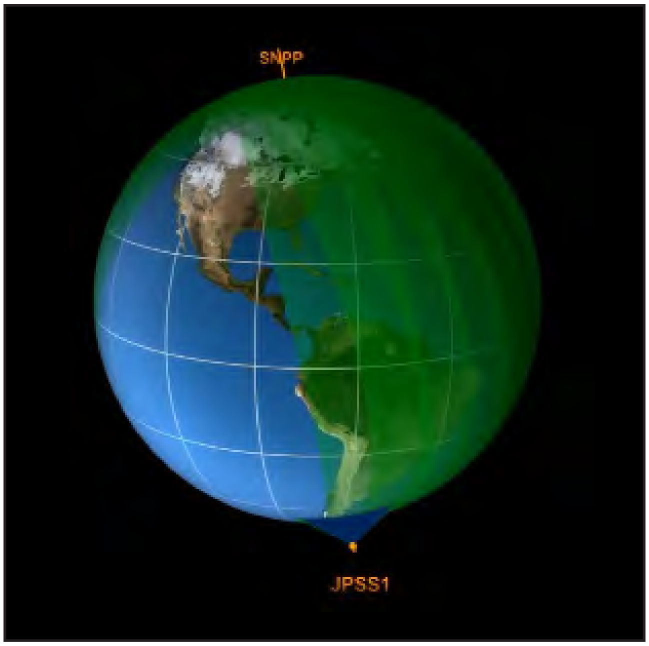
The DNB sensor builds upon the low-light visible technology from the Defense Meteorological Satellite Program's (DMSP) Operational Linescan System (OLS), which was developed in the late 1960s. The generation transfer from the OLS to the DNB came with some impressive upgrades: significantly higher spatial and radiometric resolution, and some improvement to sensitivity. This DNB has effectively 45 times better spatial resolution than the OLS, provides 14 bit depth (16,348 levels of information) compared to 6 bit depth (64 levels), and on-orbit performance has demonstrated a higher signal-to-noise ratio (a measure of image quality) over the darkest nighttime scenes. Importantly, the DNB is calibrated (unlike the OLS) and accompanied by numerous other IR bands on VIIRS that allow for multi-spectral applications (in contrast to the OLS which offered only one accompanying IR window band).



WHY VADER?

It takes roughly 100 minutes for each of the JPSS satellites to complete one orbit around Earth. While observing environmental changes at this cadence of sampling is useful at higher latitudes (where imagery swath overlaps provide multi-hour blocks of time with 100 min revisit from a given satellite), the lower latitudes do not enjoy these overlaps. At these lower latitudes, the coarse temporal resolution of ~2-3 samples per 24-hr period hinders their ability to make any meaningful impacts in real-time environmental situational awareness. For the unique benefit of low-light sensitivity to the high latitude winter season, when visible imagery is unavailable, the Key Performance Parameter for DNB imagery (represented by Near-Constant Contrast; NCC) is currently relegated to latitudes poleward of 60 N. However, the DNB holds complementary capabilities to other VIIRS bands at all latitudes.

The insertion of NOAA-20 into the 1330 sun-synchronous orbit has introduced a new ability to make use of temporal resolution—doubling the revisit rate at high latitudes while introducing the first multi-pass "looping capability" to the middle and lower latitudes.

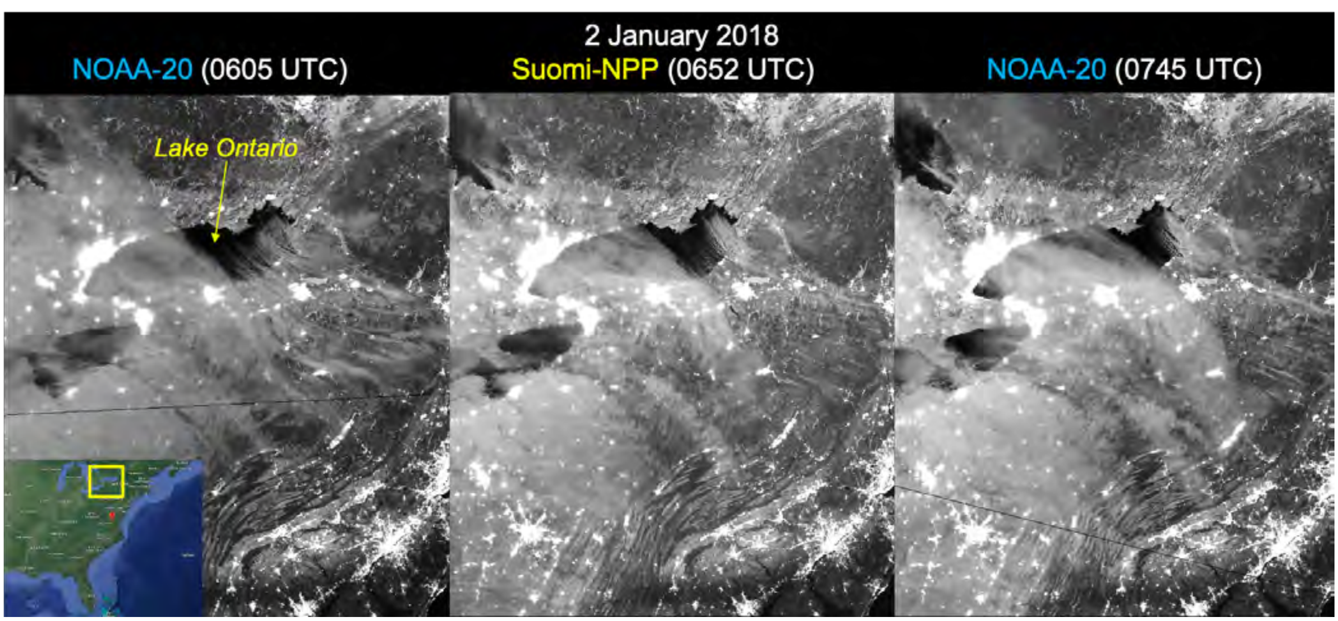


Specifically, the half-orbit separation between NOAA-20 and Suomi NPP enables a ~50 min sampling about the nominal local crossing time of 0130. The revisit enables improved detection and monitoring of environmental parameters at the lower latitudes—at least for a couple of passes. In addition, it has increased the chances for cloud-free views of the surface, improving the ability of the DNB to detect power outages.

This new ability to explore the temporal dimension of DNB imagery motivates the Visible Applications in Dark Environments, Revisited (VADER)—a JPSS Program project, led by Senior Research Scientist and Deputy Director of the Cooperative Institute for Research in the Atmosphere (CIRA), Dr. Steven Miller, which aims to socialize and capitalize on the potential of the expanded dual-VIIRS/DNB observing system for the benefit of the research and operational communities. "Revisited" in the VADER acronym refers to the revisit offered by the dual-satellite DNB observing system Some of these attributes, along with selected examples of general DNB utility to nighttime sensing, are considered here to whet the appetite for this truly revolutionary measurement.

THE HIGHLIGHTS OF LOW-LIGHT

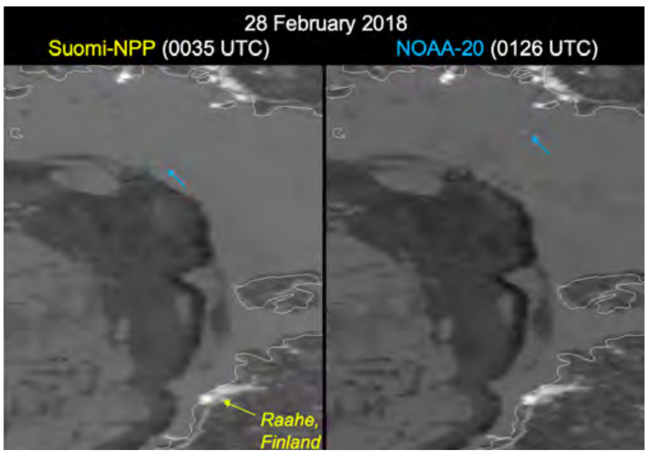
VADER seeks to illustrate the advantages of a dual-satellite (Suomi NPP + NOAA-20) DNB observing system. The potential of this pairing was revealed shortly after the launch of NOAA-20, via a three-image "loop." The loop (static graphic shown below) was constructed from NOAA-20 and Suomi NPP DNB passes on 2 January, 2018, over areas of interest in the Eastern U.S. The image loop from NOAA-20 at ~0605 UTC, Suomi NPP at ~0652 UTC, and NOAA-20 at ~0745 UTC is the first example ~50-min low-light visible feature motion at mid-latitudes.



Cloud motions over and around Lake Ontario revealed in DNB moonlight-reflectance imagery, provided at ~50 min resolution by the pairing of NOAA-20 and Suomi NPP.

A NEW PERSPECTIVE ON SHIPS PASSING IN THE NIGHT

Sea ice, one of the key parameters of DNB sensing at high latitudes, moves slowly over time, and consecutive-night images are typically adequate for many sea ice motions. But now the higher time refresh from two satellites is expanding the capabilities of seeing the motion of rapidly changing features in the ice, such as sea vessels (Straka et al., 2014). The example on the right shows one such vessel, identified readily by the DNB as a lone point source of light, making its way across sea ice (reflecting moonlight) in the Bay of Bothnia.

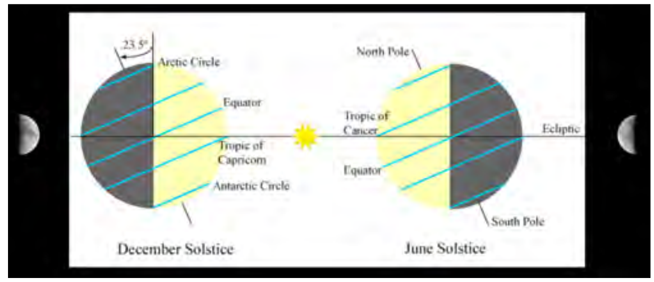


The pairing of Suomi NPP and NOAA-20 captures a ship (revealed by its light; blue arrows) moving across an ice channel in the in the Gulf of Bothnia, between Sweden and Finland.

WORKING WITH MOONLIGHT

When it comes to visible sources of light at night, one of the main advantages is the ability to work with moonlight. Fortunately, at mid- to high latitudes, when moonlight is needed the most during the longer nights of winter, it is literally at its best! It turns out that the moon's orbit around the Earth aligns more closely with the ecliptic plane–which defines the Earth's path around the Sun—than it does with Earth's equator.

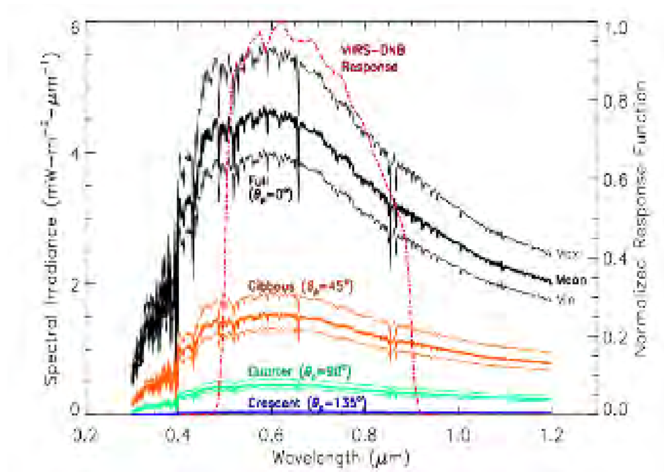
The geometry is shown in the figure below, which illustrates how the Full Moon's nadir point approaches the Tropic of Cancer at the December Solstice, and the Tropic of Capricorn at the June Solstice. Thus, wintertime moons are higher in the sky than they are during the summer, providing stronger illumination exactly when it is most useful to the higher latitudes.



But, unlike the Sun, lunar brightness varies with the phase angle over the ~29.5 day lunar cycle (Miller and Turner, 2009), from zero during a new moon to its maximum of a few milliwatts per square meter as the moon approaches Full.

To account for those variations, a lunar irradiance model Miller and Turner, 2009, was developed and applied to the DNB. It is applicable to astronomically dark conditions only, and is useful for both qualitative and quantitative applications, since the DNB is a calibrated measurement.

The lunar model takes into account the sun, moon, and earth geometry to correct images for lunar elevation angle and phase, turning a difficult to interpret image—for example one taken during



Selected spectra of lunar irradiance for different lunar phases. Mean values in bold, and min/max ranges shown. DNB spectral response function is superimposed (red-dash).

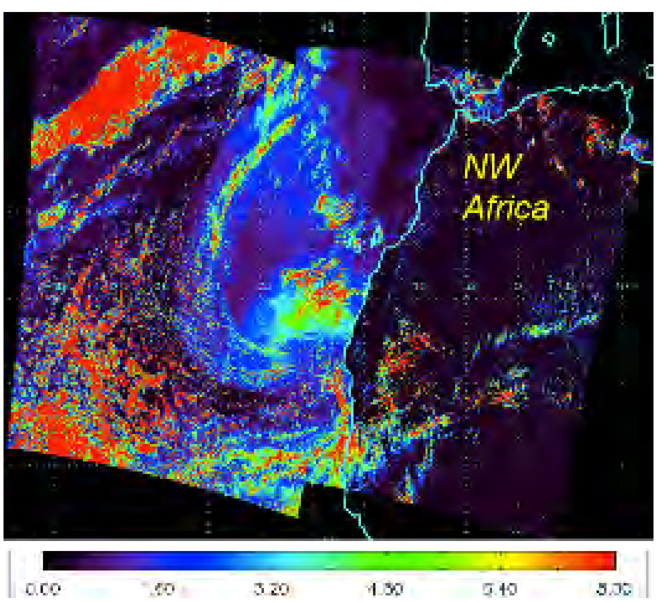
the Quarter moon phase and at a low elevation angle—into a vivid bright useful image, thereby dramatically increasing the level of detail.

More specifically, the model calculates the lunar irradiance spectra at one nanometer resolution coming down at the top of the atmosphere, for a specified night (which defines the current) moon-sun-earth geometry. Next the DNB response function, φ(λ), is convolved with the model to yield in-band irradiance (W/m^2).

$$E(\theta_p)_{DNB} = \int_\lambda E_{TOA}(\lambda,\theta_p)\varphi(\lambda)d\lambda \Big/ \int_\lambda \varphi(\lambda)d\lambda$$

Model Irradiance (E) enables calculation of Lunar Reflectance (R) from the measured DNB Radiance (L) as follows: $R = \pi L / (\cos(\theta_m) E)$ (where θ_m is the lunar zenith angle). This computation provides an equivalent reflectance which, when presented as imagery, brightens and improves the quality of images. These reflectance values are also useful for quantifying certain properties of the atmosphere which could not be done for many clouds at night due to sensitivity limitations of the IR.

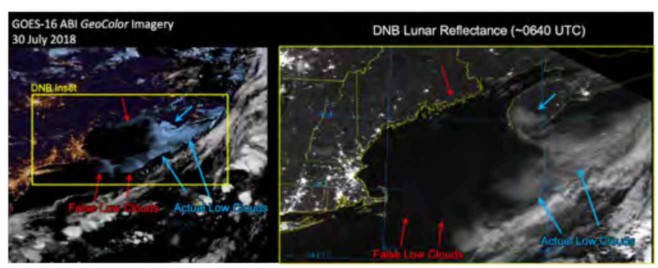
Already, several new products are incorporating the lunar model to provide more detailed and quantitatively useful descriptions of nighttime properties. For example, use of the model in cloud products is enabling the quantitative characterization of properties at night such as cloud and mineral dust aerosol optical depth, which is shown in the figure on the right. In short, the DNB's sensitivity, coupled with tools to exploit this sensitivity, is enabling new ways to not only visualize the night, but also to quantify it.



Courtesy of Andy Heidinger (NOAA/NESDIS) and Andi Walther (UW/CIMSS)

SHEDDING LIGHT ON FALSE LOW CLOUDS

The DNB is not only helping us see more clouds at night—it's also giving us a better picture of where they *aren't*. There are several techniques that are used to detect low clouds at night from IR. The GOES *GeoColor* product—a 10.4-3.9 μm BTD whose ability to detect nighttime low clouds is tied to spectral emissivity differences—displays these detections in a light-blue color. The figure below shows an example of GOES-16 *GeoColor* imagery (left panel) collected on the night of 30 July 2018, compared with time-matched VIIRS DNB lunar reflectance imagery (right panel) collected on the same night. Close inspection reveals that *GeoColor* depicts a field of apparent low cloud signals offshore from the U.S. East Coast (e.g., near Cape Cod) and other coastal zones, corresponding to locations where the VIIRS DNB lunar reflectance indicates clear sky (dark ocean).



The general understanding for the false signals is that there are situations where low-level water vapor combined with cold ocean surface temperatures can 'confuse' the standard 10.4-3.9 μm difference technique, making it think there are low clouds present when in fact there are not. Comparisons between the weighting functions, which describe the sensitivity of these bands to atmospheric emissions, show enhanced sensitivity to the boundary layer at 10.4 μm compared to the more 'transparent' 3.9 μm band. In cases where the atmosphere is warmer than the surface (called 'inversions') the positive 10.4-3.9 μm difference typically associated with low cloud behavior can be produced, masquerading as a low cloud.

The DNB moonlight observations help to flag these problematic areas of false low cloud at night, and potentially, enable better descriptions of sea surface temperature at night by identifying more clear-sky scenes than we currently 'think' we have based on IR information alone.

WORKING WITH TERRESTRIAL LIGHT SOURCES

Wildland Fires

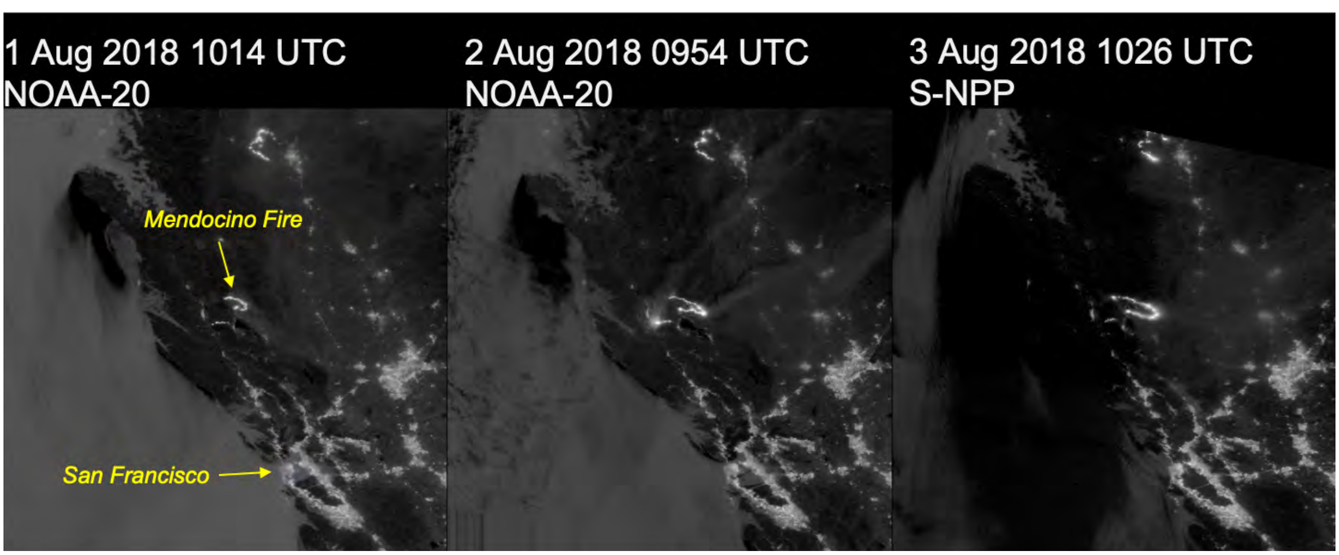
The light emission from wildland fires as well as lunar reflection of biomass smoke also provide an opportunity to examine the value of temporal refresh for DNB imagery. The growth of the Mendocino Complex fire (July 2018; northern California) illustrates how the light from fires is readily detectable.

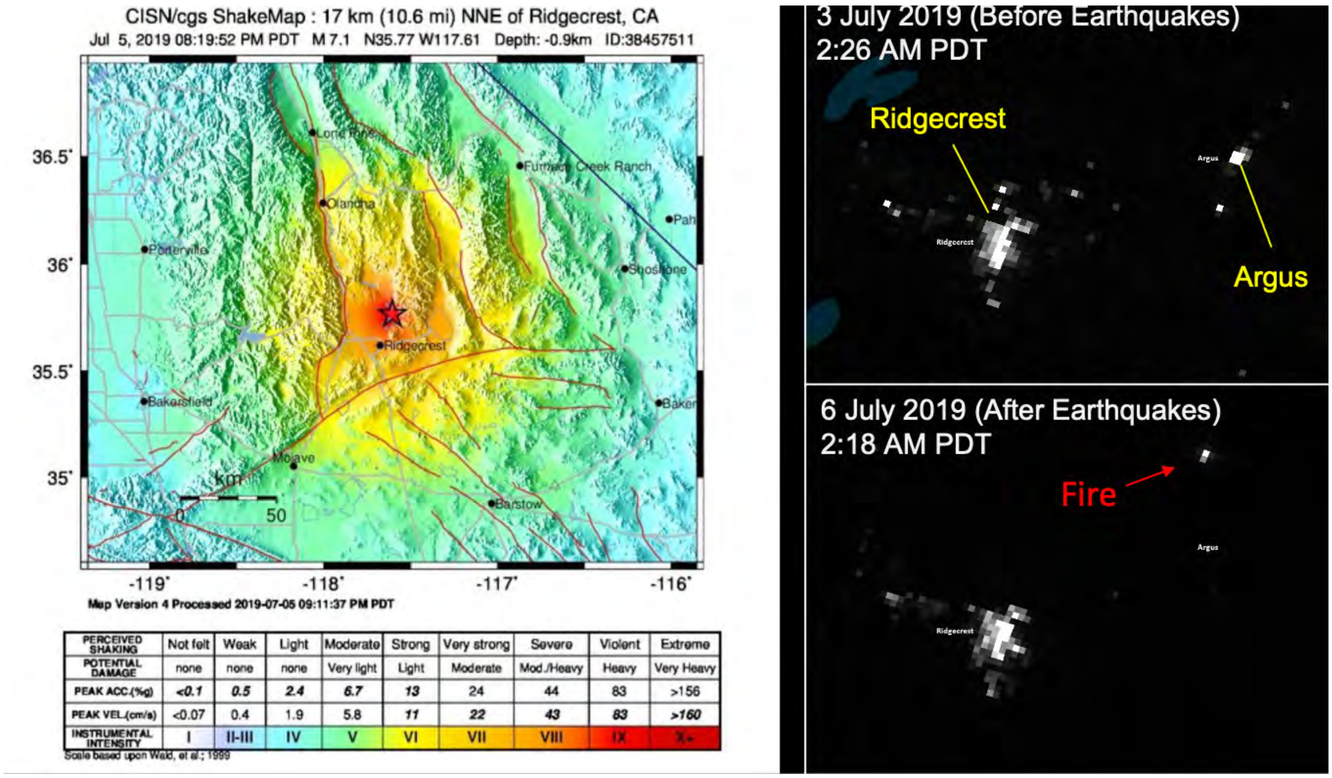
The DNB also has the capacity to detect smaller fires, which are typically harder to detect using conventional near- and thermal-infrared bands. In addition, the DNB's sensitivity to smoke plumes (when moonlight is available) makes details like nocturnal fire behavior and fine-scale circulation more discernable. Here, a 50-min revisit can provide incident meteorologists an ability to examine short-term changes in the fire line and associated visibility, which can be relayed to those responsible for strategizing, allocating resources and dispatching firefighters.

Disaster-Related Power Outages

The unique ability of the DNB to observe anthropogenic lights, and changes to them, opens the door to a large cadre of applications—especially with the additional time resolution from the Suomi NPP/ NOAA-20 pairing. With addition temporal resolution, the sudden impacts of disasters can be caught and characterized in real time.

One such example occurred at 10:33 AM PDT on 4 July, 2019, when a magnitude 6.4 earthquake struck ~100 miles north of Los Angeles, California. The following day, at 8:20 pm PDT a magnitude 7.1 earthquake occurred along the same fault location, causing significant power outages in areas north and east of Ridgecrest, CA. DNB imagery, shown in the right panels of the figure on the next page, was found to be consistent with independent information from public utilities. Since the satellite information





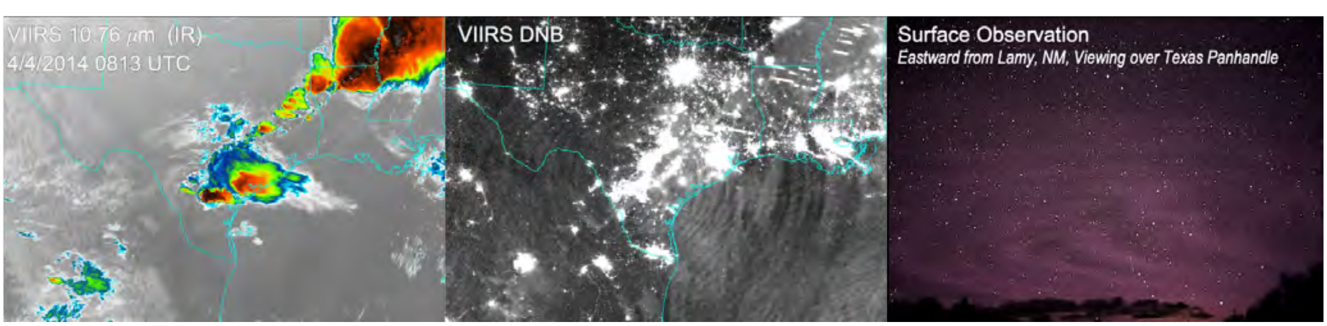
The 2019 Ridgecrest Earthquake intensity map (left), with DNB imagery showing both power outages around Ridgecrest and Argus (completely out),, and a 'new light' from a fire.

is available in real-time, it can be relayed to disaster managers to help interpret dynamic situations as they unfold, and DNB has in fact been used in this manner by the Federal Emergency Management Agency (FEMA) for disasters ranging from earthquakes to hurricanes on the East Coast (Miller et al., 2018). Even when the power stays on, the study of city lights for a range of applications (e.g., Duriscoe et al., 2014; Levin et al., 2019) makes the DNB a game changer for understanding our own unique role within the climatological biosphere.

AN UNFATHOMED CAPABILITY

Shortly after first-light imagery came streaming in from Suomi NPP, it became apparent that the DNB was seeing something special, and completely unanticipated. Imagery collected on moonless nights over the open ocean—scenes that were presumed to be completely dark and being collected for noise characterization—were instead revealing cloud structures, being lit by a source that was not considered at the time of the DNB's design (Miller et al. 2012). Researchers determined that the source of the illumination was atmospheric airglow, a signal that is 100–1000 times fainter than moonlit nights, but still detectable (albeit, with significant noise) by the highly sensitive DNB. The notion of a form of visible imagery on all nights, with or without the Moon as a surrogate for the Sun—is now seen to be possible.

More remarkable still, says Miller, "the direct upward emissions of airglow contain



modulations in brightness that are related to the passage of gravity waves, which are an important form of energy transfer in the atmosphere" (Miller et al., 2015; Yue et al., 2014). The DNB imagery in the example above show these modulations as "concentric ripples of light," reminiscent of a rock dropped into a pond, formed by the upwelling gravity waves of a strong thunderstorm over Texas. The left panel shows the cloud field (with deep/cold storms in red), the middle panel shows the DNB (noting ring structure centered upon the deepest storms in southern Texas), and the right panel is an example of what such rings appear as when viewed from the surface with special low-light camera systems.

By these revelations, the DNB has found yet another utility—high resolution sensing of gravity waves that are key to seasonal and climate scale processes. For lack of direct observations, current numerical models must parameterize the effects of these waves in terms of their impact to the temperature, chemistry, and circulation of the middle and upper atmosphere. Miller and his team have been making incredible breakthroughs with the DNB for a while now. But this new found utility has led Miller and his team to ask a question even they had not fathomed: Can the DNB, and particularly, constellations of satellites carrying low-light sensors that are optimally-tuned for airglow gravity wave detection, allow us to 'put the waves into motion' (via temporal resolution) and thereby begin to fill this critical observational gap, ultimately improving our seasonal forecasts and getting a better handle on climate feedback processes?

LIGHT ON THE HORIZON: TOWARD AUGMENTING OUR CURRENT CAPABILITIES

Despite its tremendous potential, the utility of VIIRS to forecasters over the mid- to low-latitudes is limited. Overcoming the infrequency of observations is the key. But, what if it was possible to provide high time refresh at the lower latitudes? Miller and his team are now considering the potential of future observing systems to begin filling the temporal gap. Whether that solution entails additional polar orbiting satellites enabled in a smaller/faster/cheaper way through CubeSat/SmallSat resources, or deploying a DNB measurement on a geostationary satellite—the end goal is the same: to enable the same DNB-quality measurement throughout the night. Even now, NOAA is supporting the exploration of such options for its next-generation polar-orbiting and geostationary satellites, and scientists continue to propose research-grade concepts to push the envelope of technology and demonstrate proof of concepts to the NASA Earth Ventures program, Miller says.

The DNB has already provided strong testimony to the value of such measurements, and the research and operational communities have begun to weigh in. After only eight years of on-orbit performance, the cited literature related to DNB usage has surpassed the ~50 year compendium of DMSP/OLS heritage publications. With such momentum, it would appear that low-light visible measurements are here to stay.

SUMMARY

For all the reasons that daytime visible information is useful as a staple form of imagery, the DNB extends this relevancy to the night. Its incredible sensitivity opens the door to exploiting a plethora of visible light signals of the night. DNB applications are far reaching, ranging from its ability to see through overriding cirrus to reveal underlying low clouds and fog, to the ability to detect atmospheric aerosol (e.g., smoke, pollution, dust, volcanic ash) and quantify aerosol/cloud optical properties at night. It can also detect snow cover and sea ice. Coupled with this is he unique ability to measure city lights, gas flares, and ship traffic. With the DNB, all these capabilities are offered at higher spatial resolution than the previous generation DMSP/OLS, and coupled with the other spectral bands of VIIRS, this makes for a highly capable observing system for NOAA's new-generation polar satellite program.

And now, with Suomi NPP and NOAA-20 offering dual DNB observations at 50 minutes separation, all these capabilities are available at two-to-three image sequences at low-mid latitudes worldwide.

The added information enables a new and powerful way to characterize features through their motion/change—applicable to artificial lights (ship motion, light pollution studies, and disaster-related power outages) and natural lights (e.g., fire lines, lightning, features seen in moon glint, and gravity waves in nightglow) alike.

Might there be other visible light sources, lurking like denizens of the deep in the furthest recesses of night, yet to be discovered? These exciting pursuits on the frontiers of science have drawn many users to work with the DNB—and to join the ranks of The Dark Side! ❖

Footnotes

[1]Currently the National Oceanic and Atmospheric Administration (NOAA)-20, and the NOAA- NASA Suomi National Polar-orbiting Partnership (Suomi NPP), which is a bridge between NOAA's legacy polar-orbiting satellites and the JPSS generation.

Story Source

Materials obtained from JPSS June Science Seminar titled "The Power of the Dark Side: Visible Applications in Dark Environments, Revisited (VADER)."

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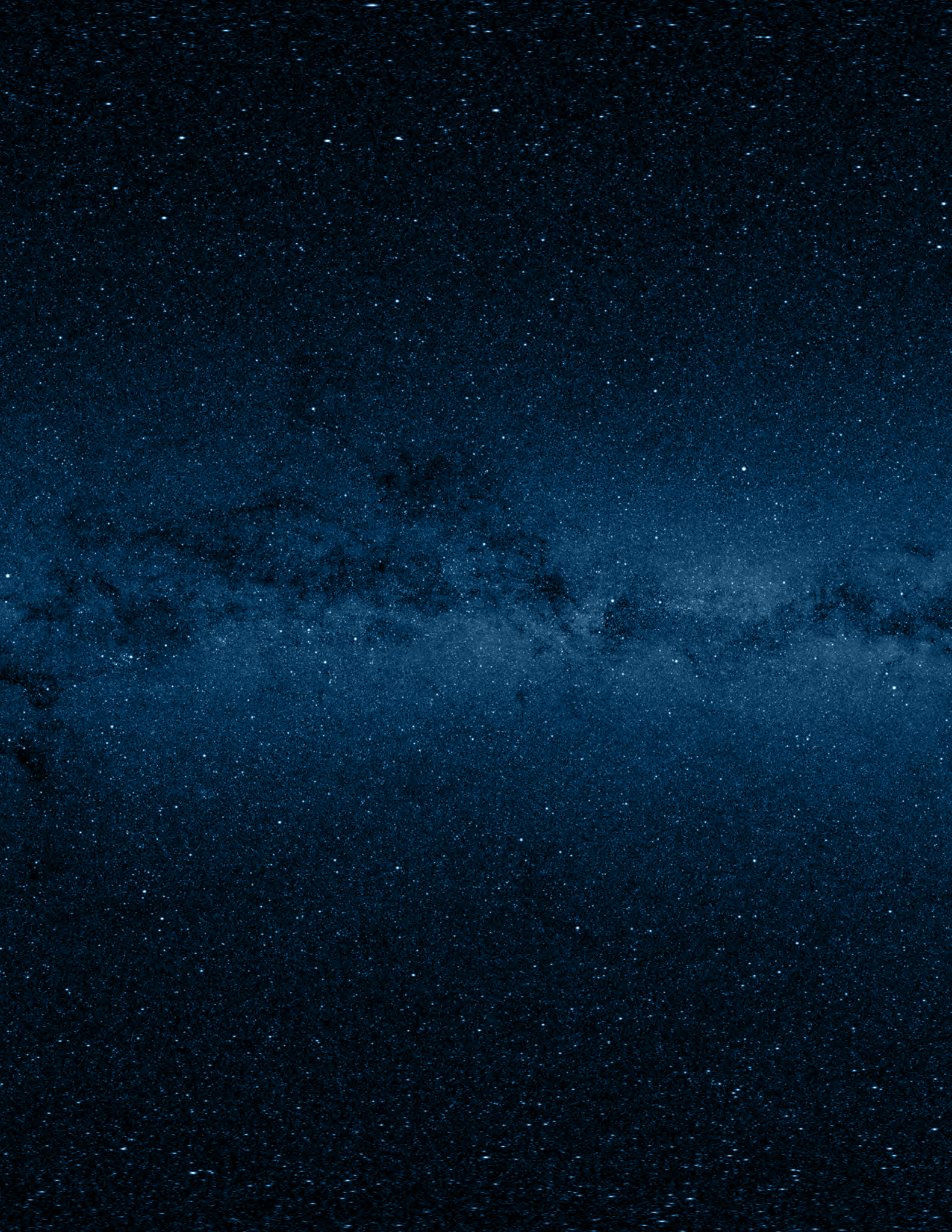


WEB FEATURES

WEB FEATURE: DECEMBER 17, 2018

METOP-C LAUNCH CLOSES FINAL CHAPTER ON HISTORIC POES PROGRAM

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

Metop-C launched on a Soyuz rocket from Europe's Spaceport in French Guiana on Nov. 7, carrying four POES-legacy instruments.
Image by ESA-CNES-Arianespace/Optique du CSG—JM. Guillon

The Polar-orbiting Operational Environmental Satellite (POES) project can claim a number of firsts in its 40-year history. It was the nation's first to provide global search and rescue capabilities from space. Its NOAA-10 and NOAA-11 satellites captured the first cloudless photograph of the entire planet Earth, pieced together using thousands of images. And its advanced data collection system, which pulled environmental data from buoys, balloons, tagged sea animals and streams, inspired a major citizen science effort on the ground and in classrooms around the country.

As the Metop-C satellite lifted off from the launchpad on Nov. 7, the last of the legacy POES mission instruments were sent into space, closing a final chapter on the historic program. The NASA Goddard Space Flight Center (GSFC) is responsible for the construction, integration and launch of NOAA-series satellites.

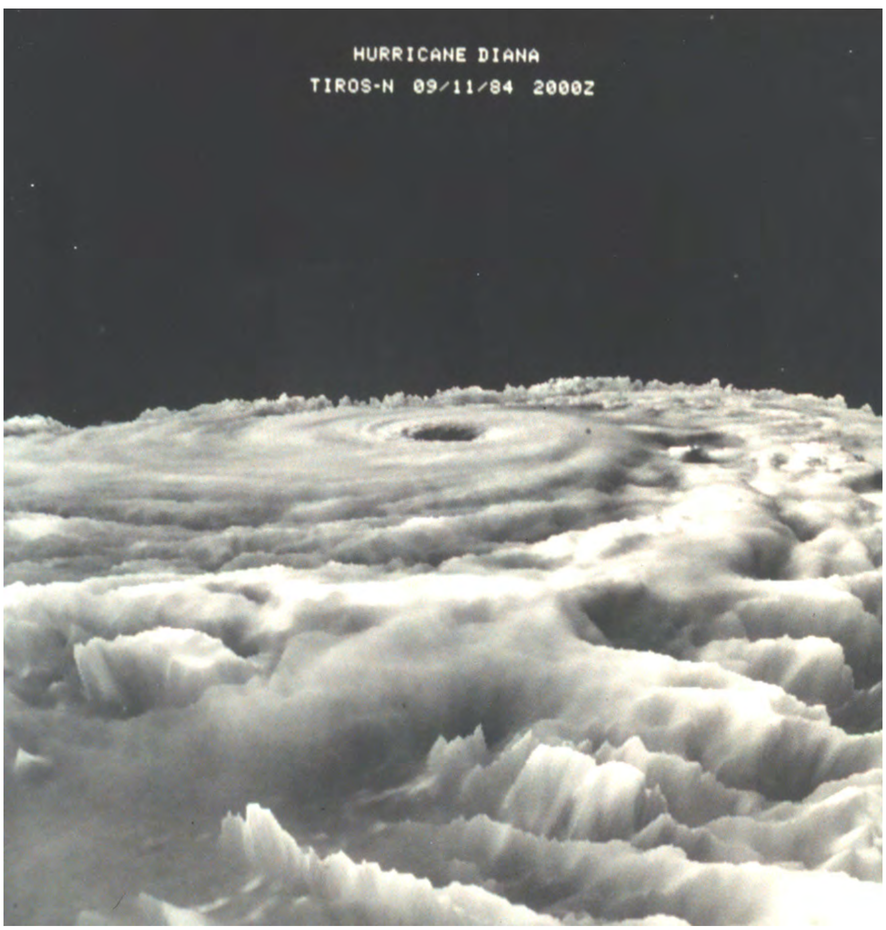
Metop-C is the successor to Metop-B and Metop-A, and it carries four POES-legacy instruments: The Advanced Very High-Resolution Radiometer (AVHRR), the Advanced Microwave Sounding Units, AMSU-A1 and AMSU-A2, and the Space Environment Monitor, SEM-2. AVHRR captures visible and infrared imagery of clouds, oceans, the atmosphere, ice, and land surfaces. AMSU-A1 and AMSU-A2 measure global atmospheric temperature, humidity, precipitation and snow and ice cover in all weather conditions. And the Space Environment Monitor studies energetic particles in the upper atmosphere.

Weather satellites date back to 1960, when TIROS 1 first launched from Cape Canaveral. The early satellite carried two TV cameras and two video recorders, and for the first time, gave forecasters a fuzzy picture of cloud formations moving across the planet.

"Finally, you could see what a hurricane looked like, or a line of thunderstorms," said Mitch Goldberg, NOAA program scientist for the Joint Polar Satellite System.

The POES program began 18 years later with the launch of TIROS-N. In the years since, it has launched 16 satellites, provided decades of critical climate and weather data and contributed to saving more than 28,000 lives with its search and rescue instruments.

Beginning with TIROS-N, the satellites had microwave sounding instruments that could see through the clouds.



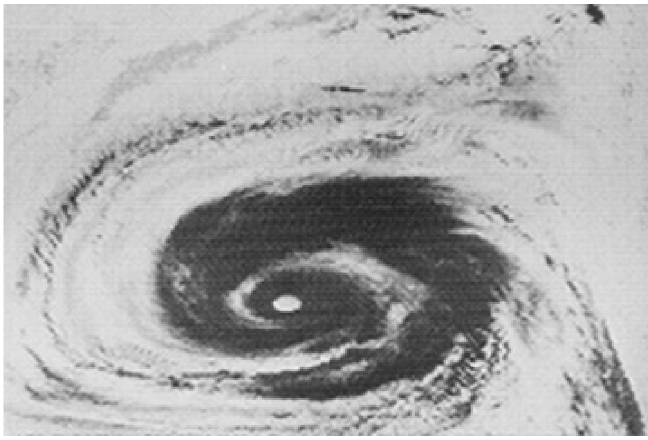
This cloud-top image of Hurricane Diana captured by TIROS N on Sept. 11, 1984, was one of the earliest three-dimensional images of a hurricane from data obtained from a satellite. It shows the hurricane as it was strengthening from a Category-3 to a Category-4 storm.
Image Courtesy NOAA In Space Collection

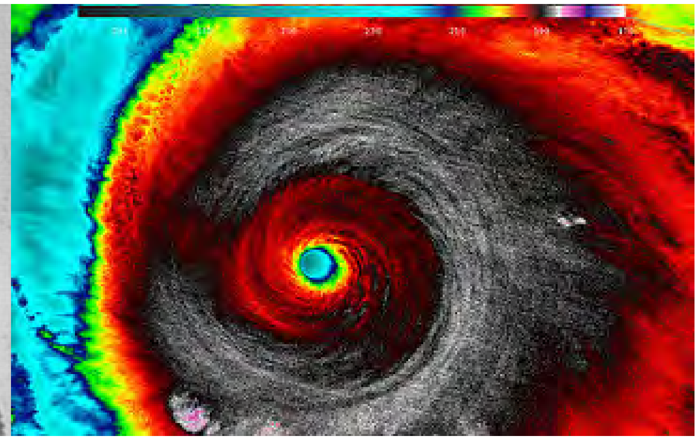
"Microwave data allowed knowledge of whether it is snowing or raining and what rain rates and humidity levels were," said Tom Wrublewski, a NOAA scientist with the Joint Polar Satellite System flight project. "It even allowed us to know whether snow and ice melted during the day and refroze at night."

The global sea surface temperature data provided by the AVHRR instruments on the POES satellites also played a key role in tracking El Niño, the climate pattern that causes warm water to slosh across the Pacific Ocean, influencing all kinds of weird weather and fishing anomalies.

We didn't know much about El Niño until the early 1980s, primarily because we didn't know what was going on in the ocean across the equator," said Joe Witte, a climate outreach specialist with Aquent, a contractor at NASA's Jet Propulsion Laboratory and a longtime broadcast meteorologist. The sea surface temperatures measured by the AVHRR instruments, along with underwater measurements from ocean buoys gave scientists a three-dimensional view of how the ocean worked, providing vastly more information on these global climate shifts.

In 1971, Witte was working as a meteorologist for Seattle's King TV station. At the time, satellite images would arrive by fax, and Witte would snap a polaroid of the grainy picture, tape it onto the studio wall, and during forecasts, point to it with a





pencil, as the cameras zoomed in on a tight shot. He reflects on how much the quality and distribution of the satellite images have evolved since then.

"That was just really hi-tech at the time," Witte said, "Black and white photograph, pencil and all. It's amazing now that people can have the images on their phone almost in real time."

The Suomi-NPP and NOAA-20 polar-orbiting weather satellites are the successors to POES. Jim Gleason, NASA project scientist for JPSS, calls them the generational change. JPSS program satellites have advanced from the POES era in instrument technology, sensitivity and their ability to transmit information.

"You have a whole class of spacecraft and instruments that are used for decades," Gleason said, referencing POES, "and then you make the shift to much more advanced instruments and different spacecraft. AVHRR had six channels. VIIRS has 22. The microwave instruments were in three boxes on the satellite; now they're in one."

But today's weather satellites have been shaped by the decades of rich history and lessons learned from their polar-orbiting ancestors.

The POES program, Wrublewski said, "saved countless lives over the decades, in terms of search and rescue, input to the weather service modeling and how you plan your day. There are some countries that don't have their own weather service, but they could get our imagery for free."

Metop-C is part of a collaboration between EUMETSAT, the European Organization for the Exploitation of Meteorological Satellites, and NOAA, with contributions from NASA and the European Space Agency. ❖

WEB FEATURE: JANUARY 31, 2019

VIIRS TRACKS A MASSIVE ICE STORM

Curtis Seaman
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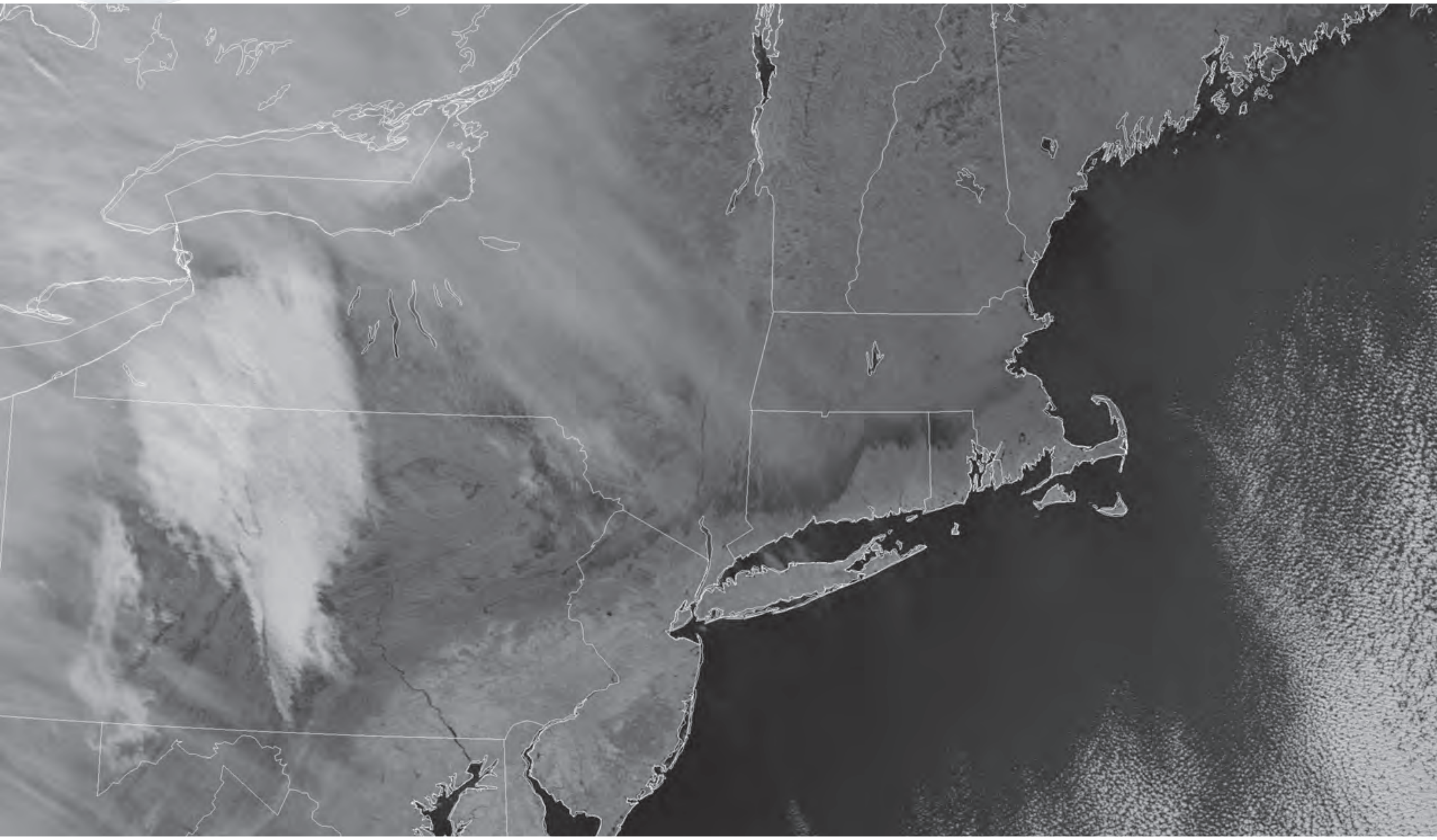
Member of the JPSS Imagery and Visualization Team



VIIRS channel I-3 image from NOAA-20, 17:09 UTC 22 January 2019. Image courtesy Curtis Seaman (CIRA/Colorado State University)

As a winter storm moved through the Northeast U.S. the weekend of Jan. 21-22, some 40 million residents watched the forecasts, wondering who would get the rain, who would get the snow, and who would get the "wintry mix."

This Nor'easter was a tricky one to forecast. Temperatures near the coast were expected to be near (or above) freezing. Temperatures inland were expected to be much colder. "Liquid-equivalent precipitation," according to the Global Forecast System, was predicted in the 1-3 inch (25-75 mm) range. (Liquid-equivalent precipitation is the amount that would fall if it were liquid, though it is often sleet or snow.) This could easily convert to 1-2 feet (30-60 cm) of snow. It was the kind of situation that meteorologists live for.

While the difference between 71 and 74 degrees Fahrenheit is virtually meaningless, the difference between 31 and 34 degrees Fahrenheit (with heavy precipitation, at least) is the difference between closing schools, bringing out the plows, and shutting down public transportation—or life as usual.

Of course, the obvious follow-up question is what will the "wintry mix" be? Rain mixed with snow? Sleet? Freezing rain? It doesn't take much to change from one to the other, but what ultimately falls from the sky can make a big difference to the people below.

So in the case of this storm, what happened? Here's an article that explains it well. And here are PDF files of the storm reports from National Weather Service forecast offices in Albany, Norton, Mass., and Upton, N.Y. The synopsis: some places received 1.5 inches (~38 mm) of rain, some places received 11 inches (30 cm) of snow, and some places were coated in up to 0.6 inches (15 mm) of ice.

Consider the locations that received the ice. Plotted on a map, areas with more than 0.1 inches of ice match up quite well with storm-related power outages. Scroll down in this article to see a map of outages in Connecticut during this time period.

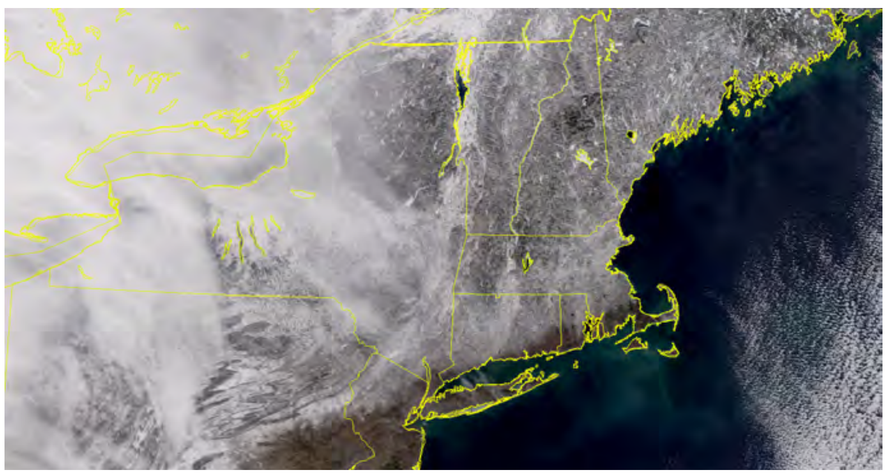
Now, compare that map with this NOAA-20 VIIRS image (previous page) from January 22 (captured after the clouds cleared).

You can click on the image to bring up the full resolution version. This is the high-resolution imagery band, I-3, centered at 1.6 Qm from the NOAA-20 satellite. Notice that very dark band stretching from northern New Jersey into northern Rhode Island? That is the area of greatest ice accumulation. And notice how well it corresponds with the known power outages across Connecticut!

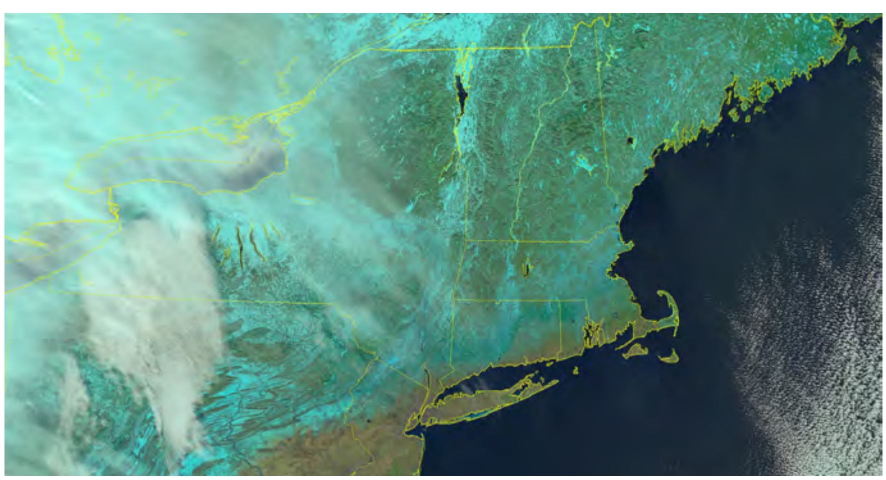
The ice-covered region appears dark at 1.6 Qm because ice is very absorbing at this wavelength and, hence, not very reflective. And, since it is cold, it doesn't emit radiation at this wavelength either (at least, not in any significant amount). This is especially true for pure ice, as was observed here (particularly in the second image), since there aren't any impurities in the ice to reflect radiation back to the satellite. The absorbing nature of snow and ice compared with the reflective nature of liquid clouds is what earned this channel the nickname "Snow/Ice Band" (PDF).

At shorter wavelengths (less than ~ 1 Qm), ice and snow are reflective. (Note how a coating of ice makes everything sparkle in the sunlight.) This makes it nearly impossible to identify ice accumulation in True Color images.

The Natural Color RGB (which the National Weather Service forecasters know as the Day Land Cloud RGB (PDF file)) includes the 1.6 Qm band, which is useful for distinguishing clouds from snow and ice. And, as expected, the region of ice accumulation does show up here (although it is tempered by the highly reflective nature of snow and ice in the visible and "veggie" bands that make up the other components of the RGB).

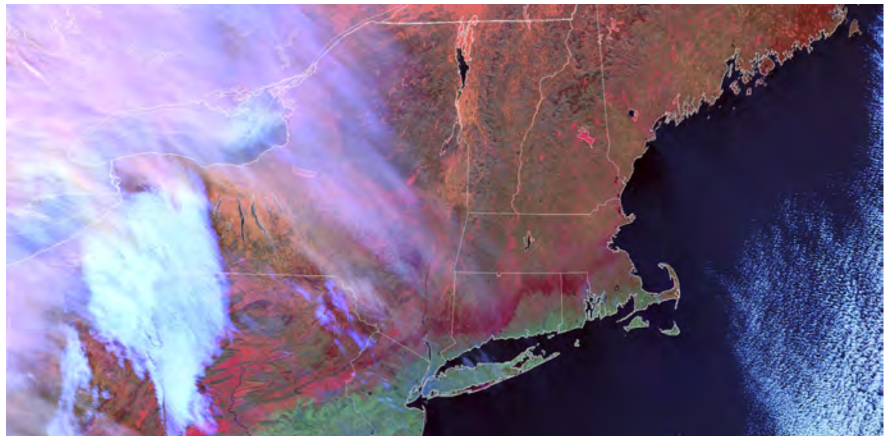


VIIRS True Color RGB composite of channels M-3, M-4 and M-5 from NOAA-20, 17:09 UTC 22 January 2019. Image courtesy Curtis Seaman (CIRA/Colorado State University)



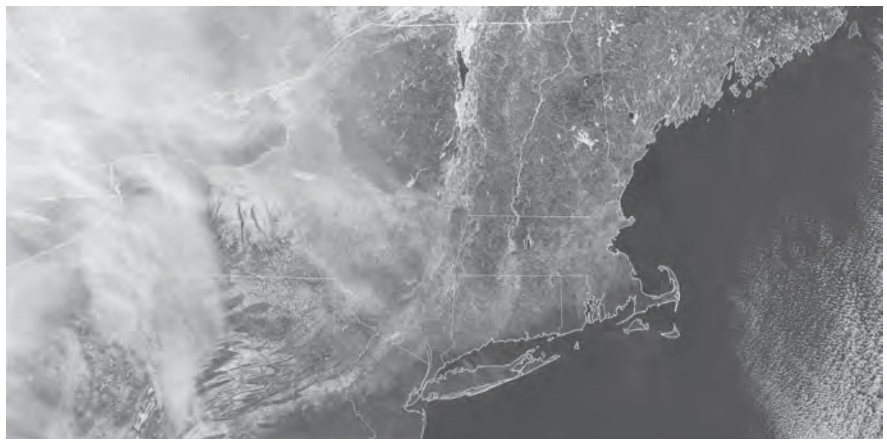
VIIRS Natural Color RGB composite of channels, I-1, I-2 and I-3 from NOAA-20 (17:09 UTC, 22 January 2019). Image courtesy Curtis Seaman (CIRA/Colorado State University)

Another RGB composite popular with forecasters is the Day Snow/Fog RGB (PDF file), where blue is related to the brightness temperature difference between 10.7 Qm and 3.9 Qm, green is the 1.6 Qm reflectance, and red is the reflectance at 0.86 Qm (the “veggie” band). This shows the region of ice even more clearly than the Natural Color RGB:



VIIRS Day Snow/Fog RGB composite of channels (I-5 minus I-4), I-3 and I-2 from NOAA-20 (17:09 UTC, 22 January 2019).

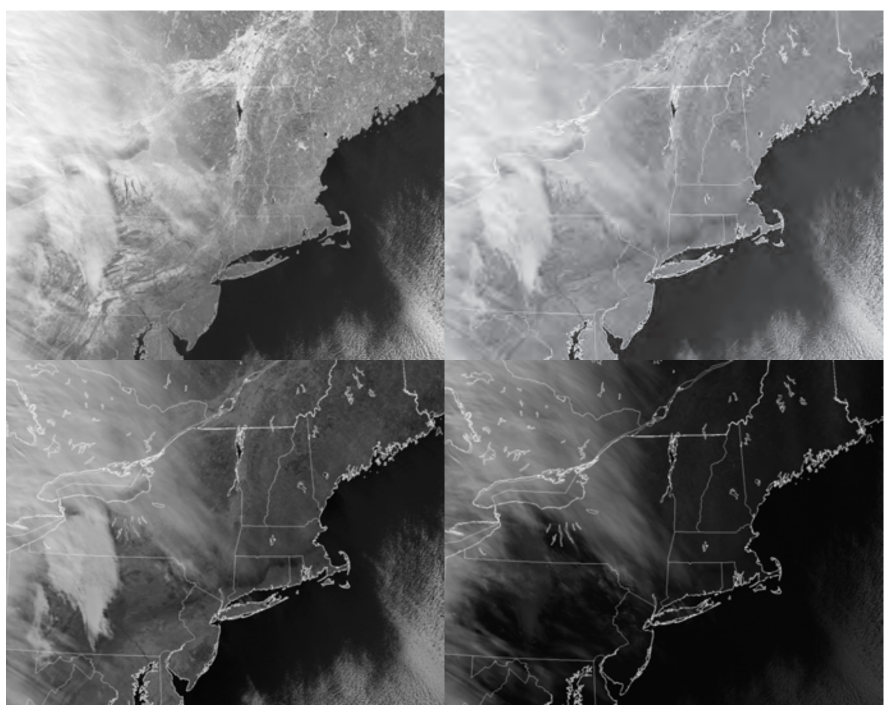
You can see how the ice transitions from being reflective in the visible and near-infrared (near-IR) to absorbing in the shortwave-IR.



VIIRS high-resolution visible channel, I-1 (0.64 Qm), from NOAA-20 (17:09 UTC, 22 January 2019).

If you squint, you can even see a hint of the ice signature at 1.38 µm, the "Cirrus Band," where most of the surface signal is blocked by water vapor absorption in the atmosphere.

If the ice had accumulated in southern New Jersey or Pennsylvania, it would not have shown up in this channel, since the moisture in the air would have blocked the view of the surface. But you can see in this image why they call it the cirrus band.



Top left: VIIRS high-resolution “veggie” channel, I-2 (0.86 Qm), from NOAA-20 (17:09 UTC, 22 January 2019). Top right: VIIRS channel M-8 (1.24 Qm) from NOAA-20 (17:09 UTC, 22 January 2019). Bottom left: VIIRS channel M-11 (2.25 Qm) from NOAA-20 (17:09 UTC, 22 January 2019). Bottom right: VIIRS “cirrus” channel, M-9 (1.38 Qm), from NOAA-20 (17:09 UTC 22 January 2019). All images on this page courtesy Curtis Seaman (CIRA/Colorado State University)

So mark this down as another use for VIIRS: detecting areas impacted by ice storms. And remember, even though ice storms may have a certain beauty, they are dangerous. And, not just for the obvious reasons. During this storm, drivers in Connecticut reported a large number of “ice missiles,” chunks of snow and ice flying from the tops of vehicles. So, for the love of everyone else on the road, scrape your car clean of ice before attempting to drive. ❖

WEB FEATURE: FEBRUARY 27, 2019

NOAA SATELLITE IMAGES SHOW MAJOR FLOODING ALONG RIVERS IN THE SOUTHEAST U.S.

NOAA/NASA/JPSS

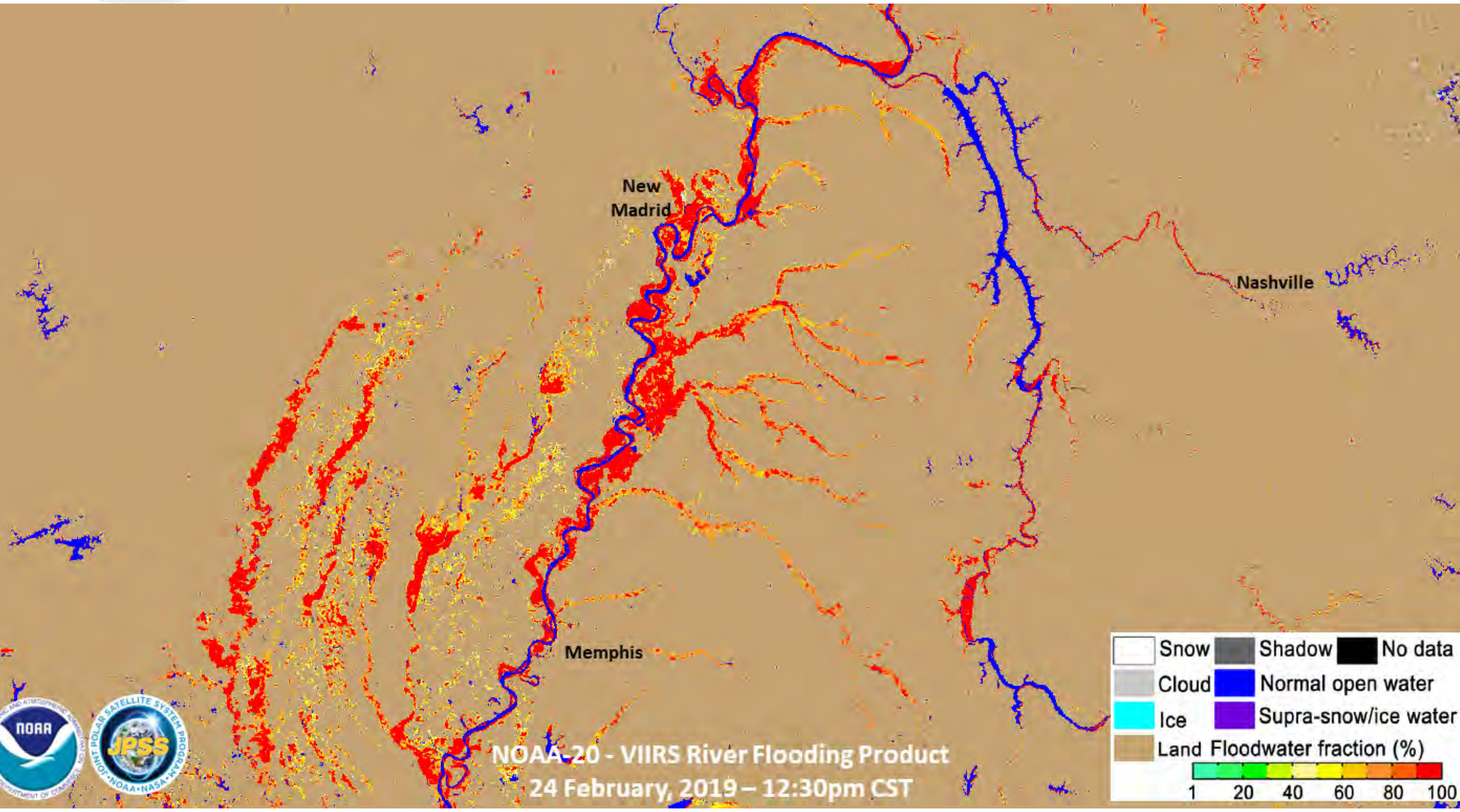


Image by NOAA/NASA/Joint Polar Satellite System

The severe storms that brought tornadoes, damaging winds, rain, and hail to the Southeast over the weekend, leaving tens of thousands without power, were the result of a "meteorological battle zone" between warm and cold air, said Walt Zaleski, warning coordination meteorologist for NOAA's National Weather Service Regional Headquarters in Fort Worth, Texas. A low-pressure system over the Southern Plains pushed warm, moist air from the Gulf of Mexico over the southeastern United States, while cold, drier air dropped from Canada into the Northern and Central Plains and the Midwest and Great Lakes regions.

The result was record rainfall that caused flooding in the Mississippi, Ohio and Tennessee River valleys, along with the Green and Wabash rivers in Kentucky and Indiana.

This convergence of cold and warm air "creates a traffic jam in the atmosphere, and the air has nowhere to go but up," Zaleski said. "It's like someone taking a sponge full of moisture, twisting it and wringing out all that moisture...It just sets up the perfect cycle of above-normal precipitation to fall over the Southeast United States."

Over a 30-day period ending February 26, Tennessee, northern Alabama, northern Mississippi, eastern Arkansas and most of Kentucky received 10 to 15 inches of rain, five to eight inches above the normal amount of rainfall during that period, according to Zaleski.

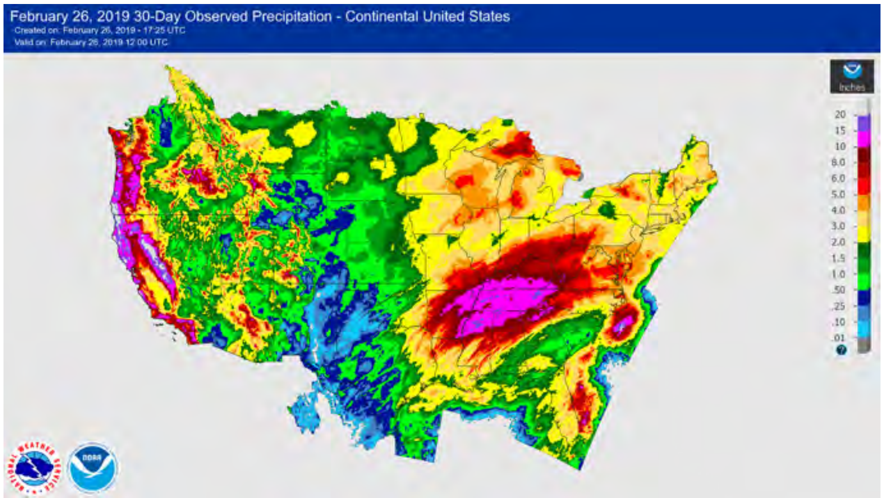


Image by National Weather Service/NOAA

The flood map below, generated using images taken by the VIIRS instrument on the NOAA-20 satellite on Sunday afternoon, captures the scope of flooding in this region with blue showing normal water and red indicating the most severe flooding, said Dr. Sanmei Li, assistant research professor at George Mason University and one of the developers of the flood product.

Li has developed algorithms that can produce flood maps using visible, near-infrared and short-wave infrared channels from the polar-orbiting VIIRS instrument as well as the ABI sensor on the new NOAA GOES satellites.

The image at the top of the previous page is a zoomed-in shot that shows flooding along the Mississippi, Ohio and Tennessee Rivers near Evansville, Indiana, New Madrid, Missouri, and Nashville. VIIRS provides high spatial resolution, which is especially important for forecast centers," said William Straka III, researcher for the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison. "You want to know what's going on with the little creeks and rivers and streams, because people live along those."

This NOAA-20 true color image below shows the same region, as seen from space. You can see how it's difficult, especially in winter when even the rivers look brown, to distinguish flooded areas.

"This is why you need to have the algorithm to pull out that information and translate it into a product that can be used by the forecasters and emergency managers," Straka said. "They can use these to issue warnings and say, 'There's lots of flooding over here, but not so much over here. Let's direct the resources to people who really need it.'" ❖

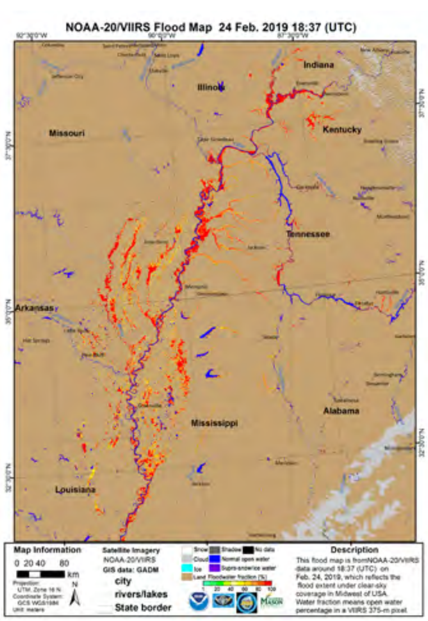
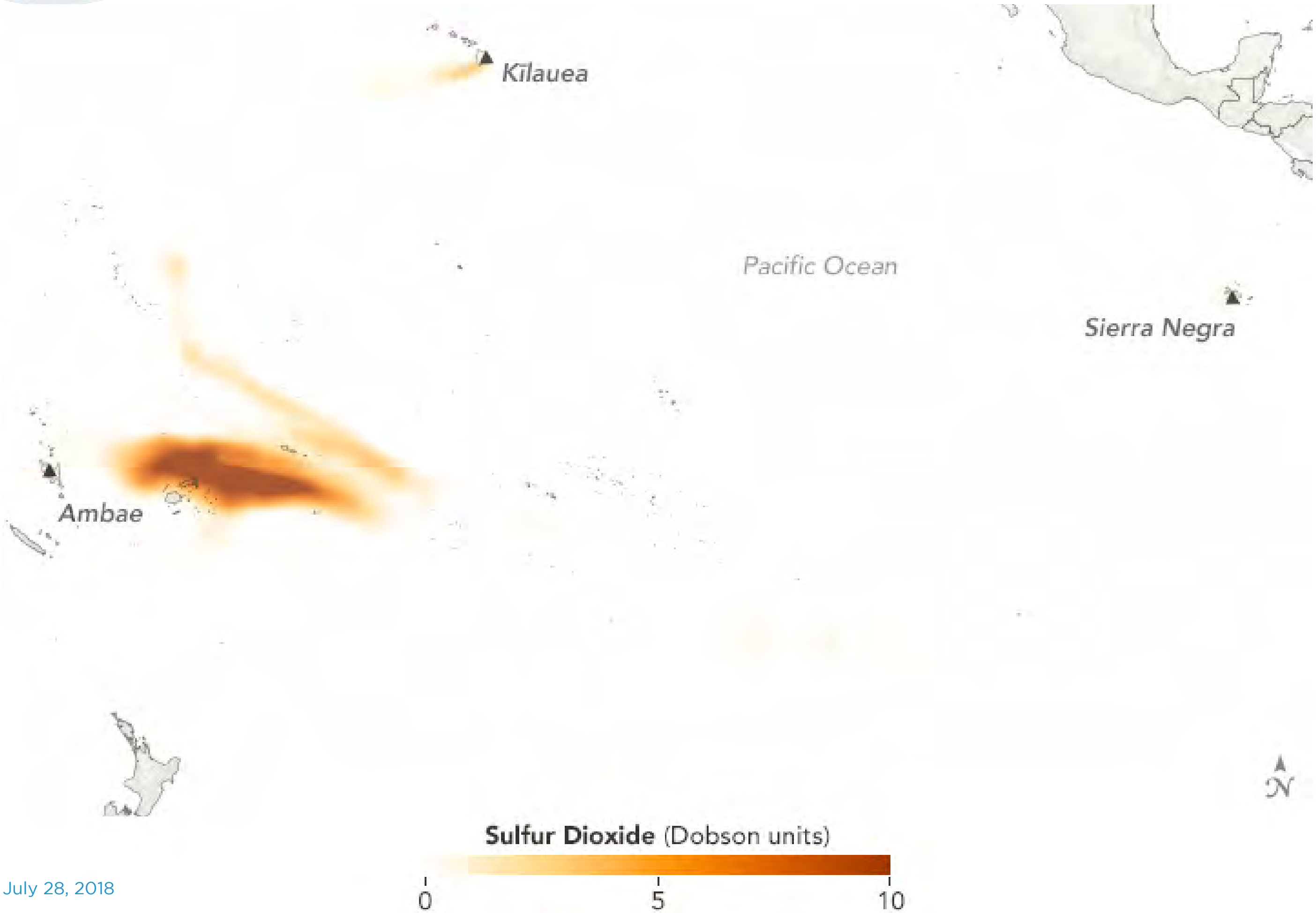


Image by NASA/ NOAA/Joint Polar Satellite System

WEB FEATURE: FEBRUARY 28, 2019

THE BIGGEST ERUPTION OF 2018 WAS NOT WHERE YOU THINK

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



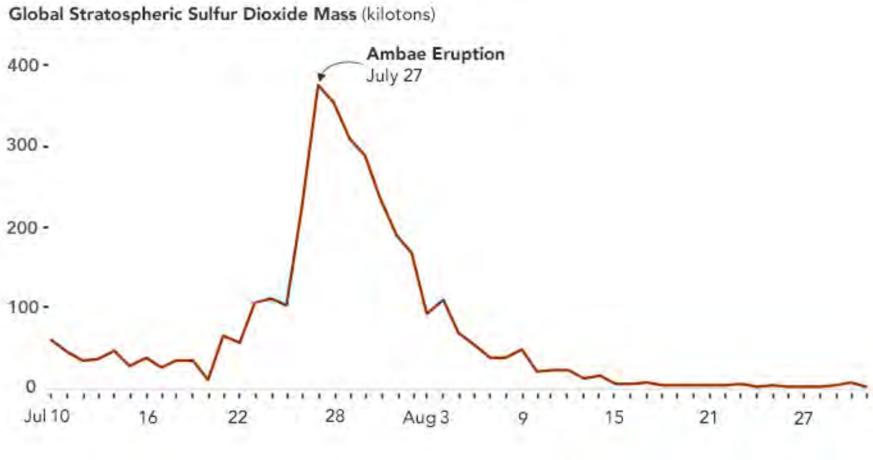
July 28, 2018

While Kilauea dominated headlines last year, the largest explosive eruption of 2018 occurred 5,600 kilometers (3,500 miles) to the southwest on Ambae, a volcanic island in Vanuatu. The Manaro Voui volcano spewed at least 400,000 tons of sulfur dioxide into the upper troposphere and stratosphere during its most active phase in July, and a total of 600,000 tons in 2018. That was three times the amount released from all combined eruptions in 2017.

The map above shows stratospheric sulfur dioxide concentrations on July 28, 2018, as detected by the Ozone Mapping Profiler Suite (OMPS) on the Suomi-NPP satellite. The volcano on Ambae (also known as Aoba) was near the peak of its sulfur emissions at the time. For perspective, emissions from Hawaii's Kilauea and the Sierra Negra volcano in the Galapagos are shown on the same day. The plot below shows the July–August spike in emissions from Ambae.

"With the Kilauea and Galapagos volcanoes, you had continuous emissions of sulfur dioxide over time, but Ambae was more explosive," said Simon Carn, professor of volcanology at Michigan Tech. "There was a giant pulse in late July, and then it dispersed."

During a series of eruptions at Ambae in 2018, volcanic ash blackened the sky, buried crops, and destroyed homes. Acid rain turned the rainwater—the island's main source of drinking water—

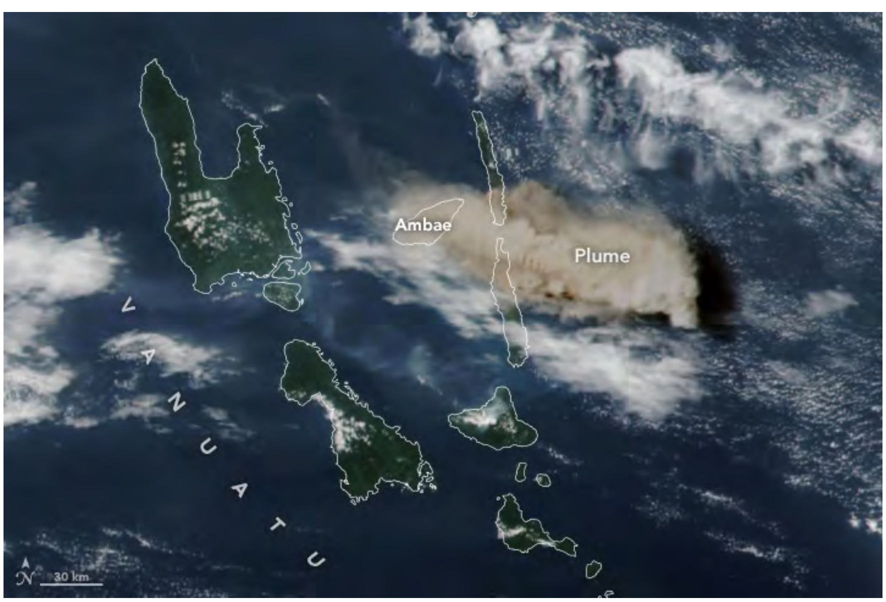


July 10–August 31, 2018

cloudy and "metallic, like sour lemon juice," said New Zealand volcanologist Brad Scott. Over the course of the year, the island's population of 11,000 was forced to evacuate several times.

The OMPS instruments on the Suomi-NPP and NOAA-20 satellites contain downward-looking sensors, which can map volcanic clouds and measure sulfur dioxide (SO2) emissions by observing reflected ultraviolet light. SO2 and other gases (such as ozone) each have a spectral absorption signature, or unique fingerprint, that OMPS can measure and quantify.

"Once we know the SO2 amount, we put it on a map and monitor where that cloud moves," said Nickolay Krotkov, a atmospheric scientist at NASA's Goddard Space Flight Center. The maps, which are produced within three hours of a satellite overpass, are used by volcanic ash advisory centers to predict the movement of volcanic clouds and to reroute aircraft, if necessary.



July 27, 2018

At the peak of the Ambae eruption, a powerful burst of energy pushed gas and ash into the upper troposphere and stratosphere. The natural-color image above was acquired on July 27, 2018, by the the Visible Infrared Imaging Radiometer Suite (VIIRS) on Suomi NPP.

SO2 is short lived in the atmosphere, but once it penetrates the stratosphere, it can combine with water vapor to make sulfuric acid aerosols. Such particles can last much longer—weeks, months or even years—depending on the altitude and latitude of injection, Carn said.

In extreme cases, like the 1991 eruption of Mount Pinatubo, the tiny aerosol particles can scatter so much sunlight that they cool Earth's surface below. "We think to have a measurable climate impact, the eruption needs to produce 5 to 10 million tons of SO2," Carn said. The Ambae eruption was too small to cause such cooling.

"This wasn't huge, it wasn't Pinatubo," Carn said. "But it was the biggest one of the year." ❖

NASA Earth Observatory images by Lauren Dauphin, using OMPS data from the Goddard Earth Sciences Data and Information Services Center (GES DISC), sulfur dioxide mass data courtesy of Simon Carn, and VIIRS data from the Suomi National Polar-orbiting Partnership. Story by Jenny Marder.

WEB FEATURE: MAY 2, 2019

HOW ATMOSPHERIC SOUNDING TRANSFORMED WEATHER PREDICTION

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

Artist's rendering of the Nimbus-3 spacecraft. Credits: NASA

In the late 1950s, a scientist named Lewis Kaplan divined a new and groundbreaking way to calculate temperature in the atmosphere for weather forecasting: by measuring the vibration of molecules at different altitudes. The hope was to do this using a brand-new technology, an Earth-observing satellite.

At the time, the only way to get a reading on atmospheric temperature was to dispatch high-altitude weather balloons, or radiosondes. Weather balloons collected critical information for weather forecasting. They still do today. But they required a lot of manpower; someone needed to fill each balloon with helium and release it, and they were sparse over the ocean. Hours often passed between measurements.

"Once you got out over the oceans, where there aren't people to launch balloons, you were essentially in the dark, and weather forecasts weren't very good," said William Smith, professor emeritus at the University of Wisconsin, Madison, a distinguished professor at Hampton University in Hampton, Virginia, and a longtime leader in the field. "The satellite data was urgently needed to fill the gap over the oceans, and to fill in some of the time gaps."

Kaplan, who worked at NASA's Goddard Space Flight Center in Greenbelt, Maryland and Jet Propulsion Lab in California, as well as the Massachusetts Institute of Technology, before he died in 1999, published his early ideas in a landmark 1959 paper entitled, "Inference of Atmospheric Structure from Remote Radiation Measurements." It transformed the field of weather forecasting, and arguably, the world.

Fast forward 60 years, and the ideas that Kaplan laid out in that paper remain at the heart of atmospheric sounding, the process by which instruments called sounders probe the sky vertically for details on temperature, moisture and water vapor, revealing subtle changes in the Earth's atmosphere. NASA and NOAA have led the way in developing the technology for the sounders.

Weather satellites now take hundreds of thousands of soundings a day. They play a vital role in early storm warnings. The data they gather are used for wildly diverse applications, from forecasting snowfall in New Jersey and sea ice in Alaska to tracking toxic ammonia hotspots in California's San Joaquin Valley. Unlike the radiosondes, they reveal the full scope of the planet.

"You've got one instrument that measures everywhere on the globe, every day, for many years, and we calibrate it very, very well," said Chris Barnet, a senior research scientist for Science and Technology Corporation, who serves as the sounder discipline lead for NASA's Suomi-NPP satellite and a senior advisor for atmospheric sounding for the NASA/NOAA Joint Polar Satellite System.

THE PIONEERS

On March 26, Barnet delivered a presentation at the JPSS headquarters in which he laid out the history of sounders and the scientists who helped create them.

There was Rudy Hanel of NASA's Goddard Space Flight Center, who in the early 1980s used a TI-59 calculator to compute how light interacts with Saturn's ring particles and atmospheric gases, avoiding the crowded keypunch machine and card readers at the computer center. There was David Staelin of MIT, who'd become annoyed with people interrupting him, so he gave his talks in reverse, conclusion first. And David Wark of NOAA's National Environmental Satellite, Data, and Information Service, known for his gruff, no-nonsense style and perpetual cigar.

"Is it real data?" Wark once asked a young Barnet during a presentation on simulated moisture and temperature results. "Come back when you have some real data."

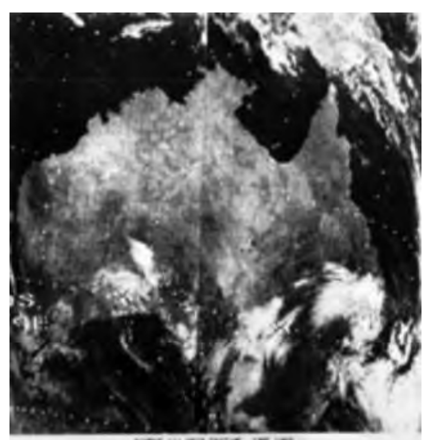
"I was new to the community, a newbie, and he just blasted me," Barnet recalls now. "It was a wake-up call. He was saying, 'It's not as simple as you think.'"

And it wasn't simple. Kaplan had concluded his seminal paper by noting that two factors would be key to making his idea work: "Our technical ability to produce an adequate optical system," he wrote, "and our knowledge of the atmospheric infrared spectrum."

By "adequate optical system," he meant the pointing and detector technology that could take the precise measurements needed to track temperature and moisture in the atmosphere. The second factor, knowledge of the atmospheric infrared spectrum, gets squarely at how satellites measure the weather.

HOW ATMOSPHERIC SOUNDERS WORK

Everything that has a temperature radiates. We radiate. Snow cones and swimming pools and pine trees radiate. So do the molecules of all the gases that make up the atmosphere. If scientists know where in the



Nimbus-3 view of Australia from 1969.
Credits: NASA

electromagnetic spectrum to look, they can measure the radiation of different molecules at different altitudes: water, carbon dioxide and ozone, for example. With a knowledge of how these different molecules vibrate or rotate, which has been determined in the lab, plus the use of modern infrared and microwave instruments to secure these measurements, scientists can provide temperature, along with moisture, or gas composition, at those altitudes.

Kaplan had tapped into the idea that temperature, simply, is a measure of the kinetic motion of molecules. Infrared sounders, which "see" in the infrared part of the electromagnetic spectrum, are highly sensitive to the vibration and rotation of certain molecules as they absorb and emit radiation, which means that temperature can be determined by recording that kinetic motion with great precision. The only problem is infrared sounders cannot see through thick clouds.

Microwave sounders operate in the microwave region of the spectrum. And they have an important advantage when it comes to understanding weather: they can see through clouds. Temperature readings from microwave sounders also play an important role in the global climate record: the measurements that show global temperature trends over time.

"When we combine the infrared and microwave instruments, we get a more complete story," Barnet said. "The sum is greater than the parts. The two instruments complement each other such that we gain insight to clouds, surfaces, temperature from the surface all the way to the mesosphere, and water vapor in the troposphere."

'THE KAPLAN EXPERIMENT'

The first satellite to take soundings of the Earth from orbit was Nimbus-3, which launched on April 14, 1969, carrying two spectrometers: the Satellite Infrared Spectrometer (SIRS) and the Infrared Interferometer spectrometer (IRIS), developed by NASA Goddard's Rudy Hanel. This was known at the time as "the Kaplan experiment." On launch day, Smith and his colleague, Harold Woolf, stayed up all night processing and hand-plotting a day's worth of global data and delivered their analysis the following morning to the National Meteorological Center.

"Oh my god, this is incredible," Smith recalls the head of operations saying, when he looked at the data.

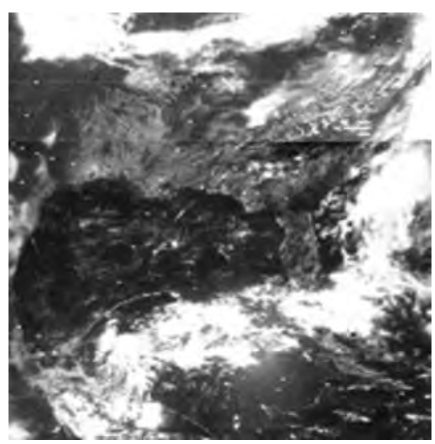
That same morning, in a blow to the airlines, weather forecasts had missed strong headwinds in the Western Pacific. It was the kind of miscalculation that could result in travel delays, added expense to the airlines, and even force planes flying from U.S. to Tokyo to stop and refuel. A meteorologist can determine the direction and intensity of wind by looking at temperature patterns. And temperature data from the brand-new satellite clearly showed the jetstream that forecasts had missed.

People would come to rely on the Nimbus fleet of satellites for forecasts on daily weather and extreme storms, along with search and rescue. And the sounding technology quickly outgrew Earth when planetary scientists realized its value in understanding the climates of far-off worlds. Sounders that flew on the Mariner, Voyager and Cassini missions gave scientists insight into the temperature and composition of Mars and the outer planets.

60 YEARS OF SOUNDERS

In his seminal paper, Kaplan had predicted that "Earth satellites hold the promise of continuous and truly global sounding of the atmosphere." Sixty years later, they've achieved just that.

Over the years, atmospheric soundings have become increasingly more sensitive and precise at measuring wavelengths. In the mid-1980s, scientists developed a new



Nimbus-3 image showing clouds over the southeastern U.S. Credits: NASA way of seeing the Earth from space called "hyperspectral sounding." Spectral resolution refers to the ability of a satellite instrument to distinguish features at various wavelengths with high precision. The spectral resolution of the newer operational weather instruments was orders of magnitude higher.

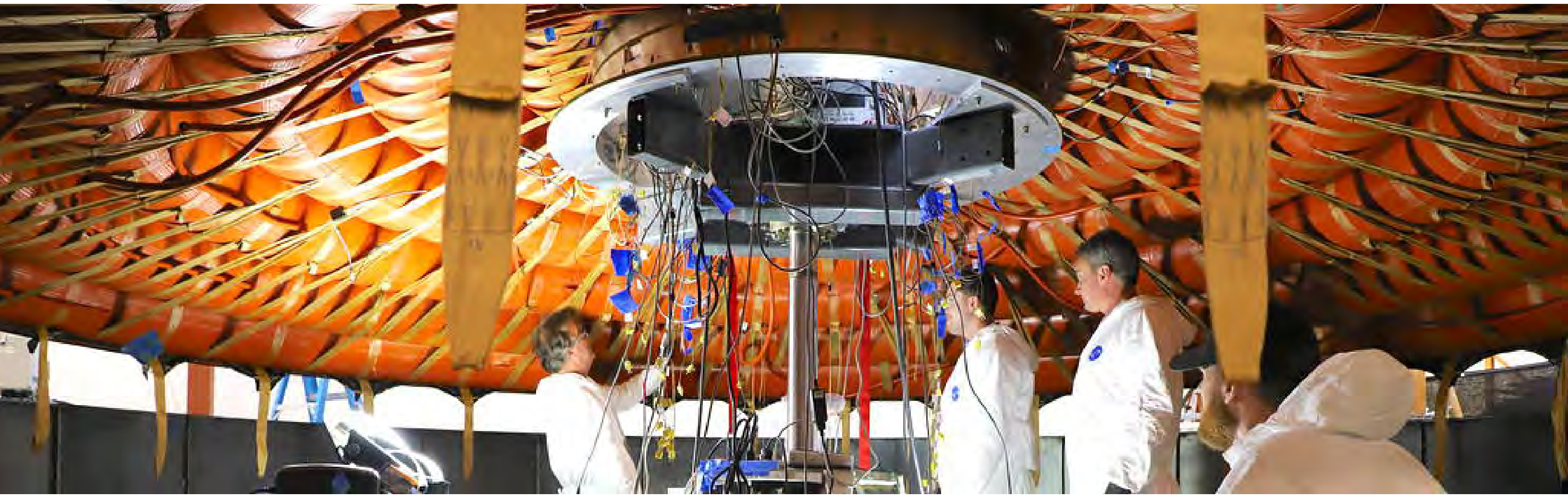
While the Nimbus-3 SIRS instrument, for example, had eight spectral channels for sounding the atmosphere, the Atmospheric Infrared Sounder (AIRS), a hyperspectral instrument that launched in May 2002, has 2,378 channels in the infrared range. The Suomi-NPP and NOAA-20 satellites, which orbit the Earth from pole to pole, each crossing the equator 14 times a day, have two advanced hyperspectral sounders on board: the Cross-Track Infrared Sounder (CrIS), which has 2,211 channels, and the Advanced Technology Microwave Sounder (ATMS), which has 22 channels.

"This led to a dramatic improvement in weather forecasting," Smith said in a presentation delivered for the Nimbus 50th Anniversary Celebration in 2014. "The microwave sounding systems and the hyperspectral infrared are the biggest contributors to the weather forecasts now, much greater than the radiosonde. In other words, the forecast accuracy degrades the most if you exclude these instruments." ❖

WEB FEATURE: JULY 1, 2019

INFLATABLE DECELERATOR WILL HITCH A RIDE ON THE JPSS-2 SATELLITE

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



Engineers prepare for the flexible heat shield installation on the inflatable structure. The view is from bottom side, heat shield is on top. The gold straps hanging from the black triangles will be attached to the inflatable structure strapping and tensioned. Credit: NASA's Langley Research Center.

An inflatable decelerator technology that could one day help humans land on Mars will fly on the same Atlas V rocket as the JPSS-2 satellite.

The Apollo lunar landers fired retro rockets to land humans on the Moon. The space shuttle relied on drag from the atmosphere to act like a brake during re-entry to Earth. But firing rockets requires hauling lots of fuel. And the Martian atmosphere, which is roughly 100 times thinner than our own, is too thin to produce enough drag to slow a spacecraft as easily as we can on Earth.

The 2,000-pound Curiosity Rover, which landed on Mars in 2012, is the biggest thing we've ever sent to the Red Planet, and close to the weight limit for existing deceleration technology.

"Right now, heat shields are rigid, and the maximum size is constrained by the size of the launch vehicle," said Barry Bryant, project manager for the Low-Earth Orbit Flight Test of an Inflatable Decelerator, or LOFTID, at NASA's Langley Research Center.

Delivering humans and their cargo to Mars will require much bigger payloads. Humans need lots of food, water, air, insulation, radiation protection and life support systems - rovers don't.

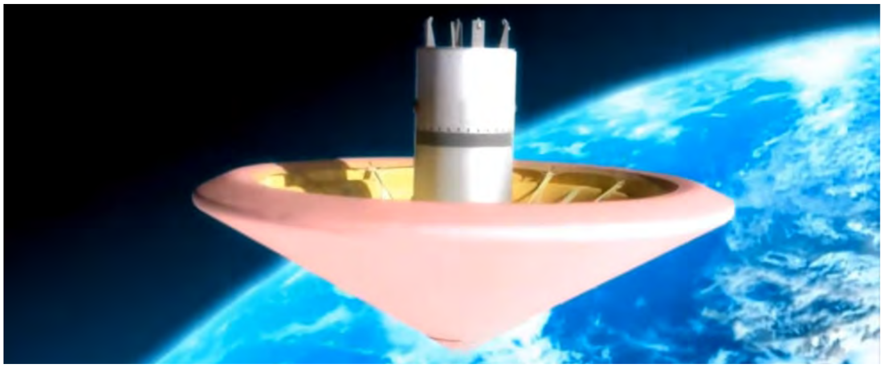
"To take humans to Mars, we have to deliver a small house," said Neil Cheatwood, senior engineer for planetary entry, descent and landing at NASA's Langley Research Center. "You need an aeroshell much larger than you can fit inside a rocket."

But in order to one day deliver that payload, engineers need to first demonstrate that the decelerator can survive the incredible heat and speeds of re-entry.

Enter LOFTID, a partnership between NASA's Space Technology Mission Directorate and United Launch Alliance. It's the latest step in a kind of technology known as Hypersonic Inflatable Aerodynamic Decelerator.

LOFTID will fly as a rideshare with the JPSS-2 polar-orbiting satellite in March 2022.

This flight will not carry a payload, but will test the vehicle's ability to survive re-entry to Earth from space, produce the desired atmospheric drag and, Cheatwood said, "exhibit



Low-Earth Orbit Flight Test of an Inflatable Decelerator, or LOFTID, is the next flight mission of the HIAD (inflatable heat shields) technology. HIAD is on the cutting-edge cusp of heat shields and NASA Langley researchers recently tested the LOFTID HIAD by doing a blow down test to measure gas intake. Credits: NASA

adequate aerodynamic stability to keep us pointed forward and not just come in tumbling."

JPSS-2, to be renamed NOAA-21 after entering orbit, is a continuation of the Joint Polar Satellite System series of satellites, which provide data that inform seven-day forecasts and extreme weather events. Instruments from the JPSS satellites also tell us about wildfires, volcanoes, atmospheric ozone, ice loss and ocean health.

"Our JPSS-2 mission is literally focused on the Earth," said Greg Mandt, director of the JPSS Program. "To think that we could share some of the excess capacity from our Atlas launch vehicle to test technologies that will support human exploration of Mars is a tremendous bonus."

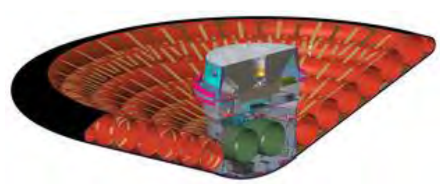
LOFTID will get folded and packed down tight during launch and then inflated just before re-entry. The inflatable structure is made of synthetic fibers, braided into tubes that are 15 times stronger than steel. The tubes are coiled so that when they're inflated, they form the shape of a blunt cone. The thermal protection system that covers the inflatable structure is designed to survive searing entry temperatures and able to withstand 2,900 degrees Fahrenheit. The aeroshell built for the flight demonstration will reach 20 feet in diameter when deployed, nearly five times its size when stowed and the length of a mini school bus. Engineers believe it can be scaled up to accommodate large payloads.

"If you look at fuel efficient cars, they're streamlined to minimize drag," said Cheatwood, who is also the principal investigator for LOFTID. "Part of their efficiency is coming from low mass, and part is the aerodynamic shape. We're looking for the opposite. We want to maximize the drag."

After the JPSS-2 satellite is delivered to its orbit, the Centaur, the rocket's second stage, will do a deorbit maneuver to a lower orbit. The Centaur will point the LOFTID vehicle toward its desired atmospheric entry point and allow the aeroshell to inflate. The Centaur then will spin the vehicle up to give it gyroscopic stability, eject it, and then perform a divert maneuver. As LOFTID re-enters the Earth's atmosphere, it will slow from hypersonic to subsonic speeds, deploy a parachute and then land, likely in the Pacific Ocean near Hawaii. It is expected to reach speeds as fast as 5 miles per second.

Getting humans to the surface of Mars is just one of many possible applications for LOFTID. United Launch Alliance is interested in its potential to recover booster engines after launch. The technology could also be used to haul equipment back from the International Space Station or to return materials like fiber optic cables manufactured in space.

"ULA is excited to work with NOAA and NASA to demonstrate this critical technology," said Michael Holguin, senior program manager for the LOFTID mission for United Launch Alliance. "Not only for recovery of engines for the Vulcan Centaur program engine reuse, but also for the entire space program, re-entry of space vehicles to Earth as well as other planetary bodies." ❖

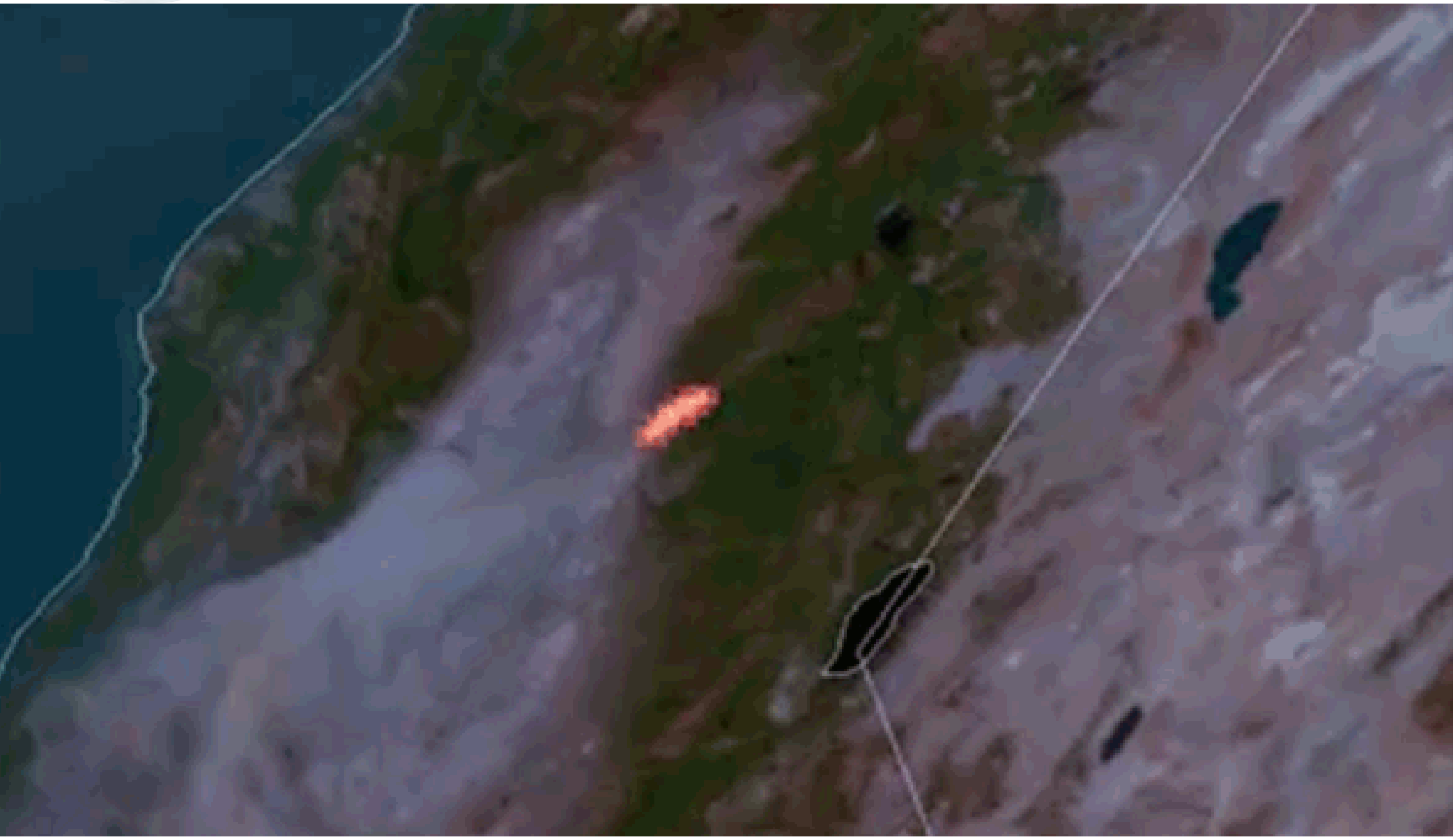


Artist rendering of the LOFTID aeroshell and payload. For this flight experiment, the payload consists of the inflation system (large green tanks), instrumentation throughout the flexible heat shield and inflatable structure, data handling, internal data recorder, ejectable data recorder and parachute. Credits: NASA's Langley Research Center.

WEB FEATURE: JULY 30, 2019

WILDFIRES FROM SPACE: HOW THE VIEW FROM ABOVE HELPS FIREFIGHTERS ON THE GROUND

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



Smoke from California wildfires is seen making its way over the Pacific Ocean in this GOES East loop from Nov. 12, 2018. Credit: (NESDIS)

Every evening from late spring to early fall, two planes lift off from airports in the western United States and fly through the sunset, each headed for an active wildfire, and then another, and another. From 10,000 feet above ground, the pilots can spot the glow of a fire, and occasionally the smoke enters the cabin, burning the eyes and throat.

The pilots fly a straight line over the flames, then U-turn and fly back in an adjacent but overlapping path, like they're mowing a lawn. When fire activity is at its peak, it's not uncommon for the crew to map 30 fires in one night. The resulting aerial view of the country's most dangerous wildfires helps establish the edges of those fires and identify areas thick with flames, scattered fires and isolated hotspots.

The aircraft are part of a small fleet of planes operated by the U.S. Forest Service and a larger constellation of NASA and NOAA satellites that help detect and map forest fires. As technology has advanced, so has the value of remote sensing, the science of scanning the Earth from a distance using satellites and high-flying airplanes.

The most immediate, life-or-death decisions—sending smokejumpers to a ridge, for example, or calling an evacuation order when flames jump a river—are made by

Frontline responders do the heavy lifting when it comes to fighting and managing wildfires, but they're often helped by the view from higher up. Each year, a coordinated effort from the U.S. Forest Service aircraft teams and satellite teams from NASA and NOAA provide valuable information that help fire management teams on the ground make the best decisions possible. Satellite observations and data from new NASA airborne field campaigns also help us understand the role, frequency, and intensity of fires in a changing world. Credits: NASA's Goddard Space Flight Center

firefighters and chiefs in command centers and on the fire line. Data from satellites and aircraft provide a strategic, big-picture view used in making these decisions.

"We use the satellites to inform decisions on where to stage assets across the country," said Brad Quayle of the Forest Service's Geospatial Technology and Applications Center, which plays a key role in providing remote-sensing data for active wildfire suppression. "When there's high competition for firefighters, tankers and aircraft, decisions have to be made on how to distribute those assets."

It's not uncommon for an Earth-observing satellite to be the first to detect a wildfire, especially in remote regions like the Alaskan wilderness. And at the height of the fire season, when there are more fires than planes to map them, data from satellites are used to estimate the fire's perimeter, like in the case of Montana's Howe Ridge Fire, which burned for nearly two months in Glacier National Park last summer.

GLOBAL FIRE PICTURE FROM SPACE

In January 1980, two scientists, Michael Matson and Jeff Dozier, who were working at NOAA's National Weather Service building in Camp Springs, Maryland, detected tiny bright spots on a satellite image of the Persian Gulf. The image had been captured by the Advanced Very High Resolution Radiometer (AVHRR) instrument on the NOAA-6 satellite, and the spots, they discovered, were campfire-sized flares caused by the burning of methane in oil wells. It marked the first time that such a small fire had been seen from space. Dozier, who went on to become the founding dean of the Bren School of Environmental Science and Management at the University of California at Santa Barbara, was "intrigued by the possibilities," and he went on to develop, within a year, a mathematical method to distinguish small fires from other sources of heat. This method would become

On the left is an imager of a cockpit of a National Infrared Operations plane. On the right is a night vision picture of a fire. Credit: NIROPS the foundation for nearly all subsequent satellite fire-detection algorithms.

What was learned from AVHRR informed the design of the first instrument with spectral bands explicitly designed to detect fires, NASA's Moderate Resolution Imaging Spectroradiometer, or MODIS, launched on the Terra satellite in 1999, and a second MODIS instrument on Aqua in 2002. MODIS in turn informed the design of the Visible Infrared Imaging Radiometer Suite, VIIRS, which flies on the Joint Polar Satellite System's NOAA/NASA Suomi-NPP and NOAA-20 satellites. Each new instrument represented a major step forward in fire detection technology.

"Without MODIS, we wouldn't have the VIIRS algorithm," said Ivan Csiszar, active fire product lead for NOAA's Joint Polar Satellite System calibration validation team. "We built on that heritage."

The instruments on polar-orbiting satellites, like Terra, Aqua, Suomi-NPP and NOAA-20, typically observe a wildfire at a given location a few times a day as they orbit the Earth from pole to pole. Meanwhile, NOAA's GOES East and GOES West geostationary satellites provide continuous updates, though at a coarser resolution and for fixed portions of the planet.

"You can't get a global picture with an aircraft, you can't do it from a ground station," said Ralph Kahn, a senior research scientist at NASA's Goddard Space Flight Center. "To get a global picture, you need satellites."

The MODIS instrument mapped fires and burn scars with an accuracy that far surpassed AVHRR. And after nearly 20 years in orbit, the optical and thermal bands on MODIS, which detect reflected and radiated energy, continue to provide daytime visible imagery and night-time information on active fires.

VIIRS has some improved fire detection capabilities. Unlike MODIS, the VIIRS imager band has higher spatial resolution, at 375 meters per pixel. This allows it to detect smaller, lower temperature fires. VIIRS also provides nighttime fire detection capabilities through its Day-Night Band, which can measure low-intensity visible light emitted by small and fledgling fires.

The first moments after a fire ignites are critical, said Everett Hinkley, National Remote Sensing Program Manager for the U.S. Forest Service. In California, for example, when intense winds combine with dry fuel conditions, the response time can mean the difference between a catastrophic fire, like the Camp Fire that consumed nearly the entire town of Paradise, and one that is quickly contained.

"Those firefighters who are first responders don't always know the precise location of the fire, how fast it's moving or in what direction," Hinkley said. "We're working to try to give them real-time or near-real-time information to help them better understand the fire behavior in those early critical hours."

Responders increasingly turn to the GOES satellites for early, precise geolocation of fires in remote areas. On July 2, 2018, for example, after smoke was reported in a wooded area near Central Colorado's Custer County, GOES East detected a hotspot there. Forecasters in Pueblo visually inspected the data and provided the exact coordinates of what would become the Adobe Fire, and crews were sent quickly to the scene. The fire detection and characterization algorithm, the latest version of NOAA's operational fire detection algorithm, is in the process of being updated and is expected to further improve early fire detection and reduce false positives.

"The holy grail is that firefighters want to be able to get on a fire in the first few hours or even within the first hour so they can take action to put it out," said Vince Ambrosia, a wildfires remote-sensing scientist at NASA's Ames Research Center in Moffett Field, California. "So it's critical to have repeatable coverage."

WHERE THERE'S FIRE, THERE'S SMOKE

Of course, where there's fire, there's smoke, and knowing how wildfire smoke travels through the atmosphere is important for air quality, visibility and human health.

Like other particulate matter in the atmosphere, smoke from wildfires can penetrate deep into the lungs and cause a range of health problems. Satellites can give us important information on the movement and thickness of that smoke.

Terra carries the MISR instrument, a sensor that uses nine fixed cameras, each viewing Earth at a different angle. MISR measures the motion and height of a fire's smoke plume, as well as the amount of smoke particles coming from that fire, and gives some clues about the plume's composition. For example, during the Camp Fire, MISR measurements showed a plume made of large, non-spherical particles over Paradise, California, an indication that buildings were burning. Smoke particles from the burning of the surrounding forest, on the other hand, were smaller and mostly spherical. Measurements also showed that the fire had lofted smoke nearly 2 miles into the atmosphere and carried it about 180 miles downwind, toward the Pacific Ocean.

Scientists also closely monitor whether the height of the smoke has exceeded the "near surface boundary layer," where pollution tends to concentrate. Wildfires with the most energy, such as boreal forest fires, are the most likely to produce smoke that goes above the boundary layer. At that height, "smoke can typically travel farther, stay in the atmosphere longer, and have an impact further downwind," Kahn said.

VIIRS and MODIS data also feed into NOAA's HRRR-Smoke, a model whose use is increasing among responders, government agencies, and even elementary schools and high school football coaches. HRRR-Smoke provides a forecast of the amount of smoke produced by a fire, the direction it will likely travel, and its plume height. It predicts both "near surface smoke," the kind responsible for burning eyes and asthma, and "vertically integrated smoke," which includes smoke high in Earth's atmosphere.

The satellites have limitations. Among them, the heat signatures the instruments detect are averaged over pixels, which makes it difficult to precisely pinpoint fire location and size. Interpreting data from satellites has additional challenges. Although thermal signals give an indication of fire intensity, smoke above the fire can diminish that signal, and smoldering fires might not radiate as much energy as flaming fires at the observed spectral bands.

UP CLOSE WITH AIRBORNE 'HEAT' SENSORS

That's where the instruments on the Forest Service National Infrared Operations Program (NIROPS) aircraft come in.

Each NIROPS plane is equipped with an infrared sensor that sees a six-mile swath of land below and can map 300,000 acres of terrain per hour. From an altitude of 10,000 feet, the sensor can detect a hotspot just 6 inches across, and place it within 12.5 feet on a map. The data from each pass is recorded, compressed and immediately downlinked to an FTP site, where analysts create maps that firefighters can access directly on a phone or tablet in the field. They fly

The USDA Forest Service's National Infrared Operations King Air B200 plane, which holds the Phoenix scanner. Credit: NIROP at night when there's no sun glint to compromise their measurements, the background is cooler, and the fires are less aggressive.

"Every time we're scanning, we're 'truthing' that fire," says Charles "Kaz" Kazimir, an infrared technician with NIROPS, who has flown fires with the program for 10 years. "On the ground, they may have ideas of how that fire is behaving, but when they get the image, that's the truth. It either validates or invalidates their assumption since the last time they had intel."

The infrared aircraft instruments fill some of the gaps in the satellite data, and field campaigns, such as the NOAA-NASA FIREX-AQ, now underway, are designed to address these issues. But scientists are also looking to new technology to fill the gaps. In 2003, representatives from NASA and the Forest Service formed a "tactical fire remote sensing advisory committee," which meets twice annually to discuss ways to harness new and existing remote sensing technology as it relates to wildfires. For example, a new infrared sensor is being developed that scans a swath three times wider than the existing system. That would mean fewer flight lines and less time spent over an individual fire, Hinkley said.

"The takeaway really is that we are actively investigating and developing capabilities that will aid decision-makers on the ground, especially in the early phases of dynamic fires," Hinkley said. "We're not just resting on our laurels here. We understand that we need to better leverage new technologies to help keep people safe." ❖

WEB FEATURE: SEPTEMBER 9, 2019

SUOMI-NPP SATELLITE INSTRUMENT RESTORED AFTER RADIATION DAMAGE

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

An engineer works on the CrIS instrument for the JPSS-2 satellite, which is slated to launch in March 2022. The CrIS instrument also flies on the Suomi-NPP satellite, and was recently restored to full capability after getting damaged while on orbit. Credits: L3Harris Technologies.

A team of engineers, scientists, and satellite operators recently restored a damaged satellite instrument that is used to measure temperature and water vapor in the Earth's atmosphere.

After the instrument, the Cross-track Infrared Sounder (CrIS), was damaged by radiation as it flew on the Suomi-NPP satellite, the team made a successful switch to the sensor's electronic B-side, returning the instrument to full capability.

Meanwhile, to fill the data gap created by the event, scientists from the Joint Polar Satellite System fast-tracked similar data from Suomi-NPP's cousin, the NOAA-20 satellite, to the National Weather Service (NWS).

The CrIS instrument probes the sky vertically for details on temperature and water vapor—using a process is known as sounding. These observations provide important information on our planet's atmospheric chemistry and composition, which inform weather forecast centers, environmental data records and field campaign experiments. CrIS can also quantify the distributions of trace gases in the atmosphere, such as carbon dioxide and methane.

CrIS sees in three spectral bands within the infrared part of the spectrum: shortwave, midwave and longwave. Analysts first detected the anomaly in the midwave data on Saturday, March 23. By Monday, things weren't looking good, said Flavio Iturbide-Sanchez the CrIS instrument's calibration validation lead for NOAA/NESDIS/STAR.

The midwave band, which includes channels sensitive to water vapor, had stopped reading properly. The next day, measurements from that band had disappeared completely.

"Midwave is particularly focused on moisture," said Clayton Buttles, the CrIS chief engineer for L3Harris Technologies, the instrument's contractor. "Losing that creates a hole in the data products used to generate weather forecast predictions. Ideally, you want to combine all three bands into a comprehensive unit that allows for better forecast and prediction."

An algorithm called the NOAA Unique Combined Atmospheric Processing System, or NUCAPS, provides the only satellite soundings available to National Weather Service's weather forecast offices, said Bill Sjoberg, a senior systems engineer with NOAA and JPSS. NUCAPS combines infrared and microwave observations to produce atmospheric profiles of temperature and water vapor, and it relies on CrIS data. Without the CrIS soundings, forecasters would have risked losing the ability to derive an important set of measurements during afternoon hours when severe convection is most common.

But NOAA-20, which flies 50 minutes ahead, has its own identical CrIS instrument.

Accelerating access to NOAA-20 satellite soundings for the National Weather Service "helped reestablish the ability to track changes in severe weather conditions," Sjoberg said.

Meanwhile, after months of analyzing what went wrong in March, the team determined that the problem with the instrument was likely caused by radiation damage to its midwave infrared signal processor, said David Johnson, NASA's CrIS instrument scientist. Raw data from the detectors goes through the signal processor, where the data rate gets greatly reduced in size so that it can be efficiently delivered to the ground stations.

Fortunately, like all of the JPSS instruments and much of the spacecraft, CrIS has redundant parts. It was designed with this threat in mind. It contains a "Side 2," a fully functional backup set of electronics, which the team hoped had not been damaged.

"But we wouldn't know without making the switch," Iturbide-Sanchez said.

For three months, the team studied the instrument. They ran a "reliability analysis." They weighed the risks. They "located and verified all configuration files for Side 2," Johnson said.

On June 21, the team made the official decision to switch to Side 2, and three days later, they executed the switch. The turn-on process involved tuning the instrument and checking settings. But Iturbide-Sanchez knew almost immediately that the three bands were working.

The plan was to complete the turn-on in two weeks. They did it in five days, a result of working long hours and frequent communication with ground station command. And by early July, satellite soundings had been recovered and the product was good enough to be used in weather models.

It was very much a team effort, Iturbide-Sanchez and Johnson both said: The Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin and the Joint Center for Earth System's Technology at the University of Maryland, Baltimore County, worked with the team during both phases, contributing to the preparation of a configuration file before the side switch, and evaluating data quality after.

"NOAA invests in redundant systems to maximize the useful life of the instruments," said Jim Gleason, NASA project scientist for JPSS. "This is a story of the system working as designed."

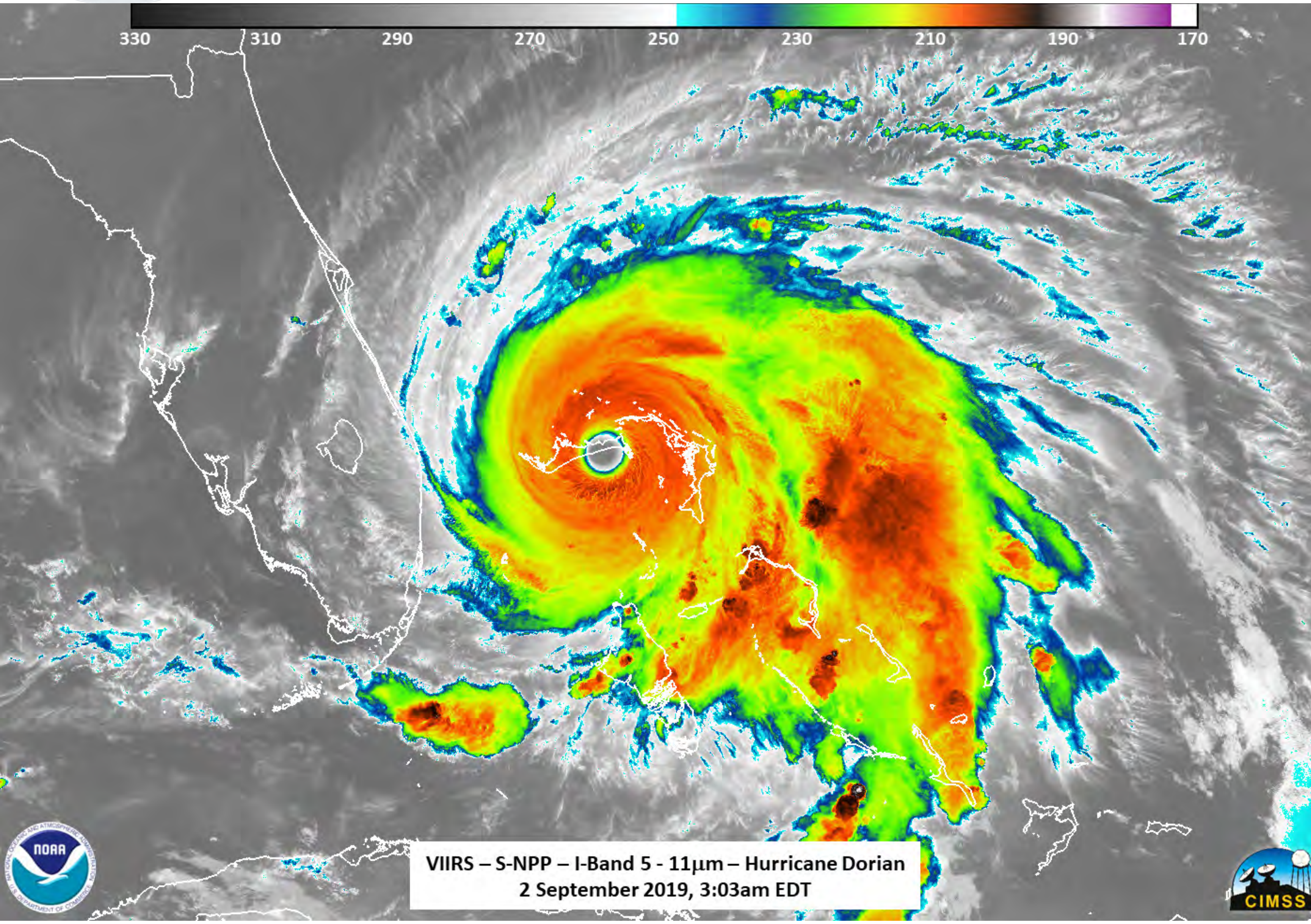
Making the successful switch from Side 1 to Side 2 also allows for National Weather Service products that provide early warnings for events like hurricanes, Buttles said:

"We would all be worse off if we didn't have that data." ❖

WEB FEATURE: OCTOBER 10, 2019

A GUIDE TO UNDERSTANDING SATELLITE IMAGES OF HURRICANES

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



On the morning of September 2, 2019, as a devastating Hurricane Dorian made landfall over three islands in the Bahamas, delivering torrential rain and sustained winds of 185 miles per hour, the VIIRS instruments on the NOAA-20 and NASA-NOAA Suomi-NPP (S-NPP) satellites captured infrared pictures from above. These images, caught at 2:13 am ET and 3:03 am ET respectively, showed a circular eye inside a nearly perfectly symmetrical Category-5 storm.

The world watched that week as Dorian slammed into the Bahamas and then stalled for more than 36 hours, leaving at least 61 people dead and 70,000 homeless. It was the strongest storm on record to hit the island nation.

During a hurricane, instruments on NOAA-20 and S-NPP capture data twice a day. These data are converted into brightly colored pictures that reveal the structure, intensity and temperature of a storm, along with other features, such as lightning and gravity waves.

NOAA's GOES East and West satellites also show the storm's evolution by measuring infrared and visible radiation from the atmosphere and surface in real-time. These measurements tell us about wind at various levels in the atmosphere, sea surface temperatures and cloud properties.

"The imagery is fundamental to locating where the storm is, knowing what direction it's moving and estimating its strength," said Mark DeMaria, technology and science branch chief at NOAA's National Hurricane Center in Miami, Fla.

During major storms, it's common for these images to circulate on social media and surface in news articles and on television reports. But without the trained eye of a meteorologist, it can be a challenge for most people to know what to make of them. Using a series of images from Hurricane Dorian, we've created this guide.

HURRICANE 101

First, some basics on hurricanes.

A tropical cyclone, known as a hurricane in the Atlantic, a typhoon in the Pacific and a cyclone in the southern hemisphere and Indian Oceans, typically begins as a cluster of thunderstorms that form over the ocean. As it strengthens, drawing energy from warm ocean water and warm, moist air, it begins to organize and rotate. The warm air rises high into the atmosphere, where it condenses into liquid and freezes to ice, forming giant rain-producing clouds. When winds form a closed circle with speeds exceeding 39 miles per hour, the cluster of storms becomes a tropical storm. At 74 mph, it officially becomes a hurricane, one of the most violent storms on Earth.

A hurricane's eye is its clear center, and the calmest part of the storm. The eye is surrounded by a wall of deep clouds and deadly winds.

Rotation around a central core corresponds with the eye wall and spiral rain bands, said William Straka III, a researcher for the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin-Madison. "So essentially, the convection surrounding the circulation acts as the engine that sustains a hurricane."

THE SHAPE

The first thing that Rob Gutro, meteorologist and deputy news chief at NASA, looks at is the hurricane's shape. The most powerful hurricanes, like Dorian on Sept. 2 above, have a round, almost circular shape.

Think of a storm as a rotating stack of tires in the atmosphere, spun by winds, said Gutro, who also maintains the "Hurricanes and Tropical Storms" section of NASA's website. If wind shear —that's a change in wind speed with height—pushes harder against the top of the tire stack than the bottom, that's going to upset the stack of tires, causing it to lean over and wobble.

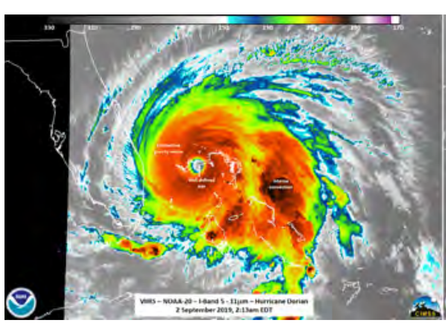
"When wind shear affects a storm, it distorts the storm, and the storm can start to weaken," Gutro said.

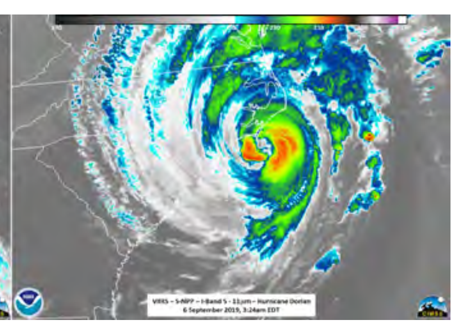
When wind shear is minimal, storms tend to be more symmetric, said Scott Braun, a research meteorologist with NASA's Goddard Space Flight Center in Greenbelt, Md. But when wind shear increases and the storm starts to tilt, thunderstorm activity gets pushed to one side.

Compare, for example, these side-by-side images of Dorian from Sept 2 (bottom left) and Sept. 6 (bottom right.)

"If you start to see that more uniform "donut shape" in the clouds suddenly shift to being sort of a crescent shape, that's usually an indication that the wind shear is increasing," Braun said.

At the time the Sept. 6 image above was taken, the storm was experiencing an increase in wind shear and crossing into cooler waters, Straka said. You can see a ragged eye and a





drop in symmetry compared to the earlier image.

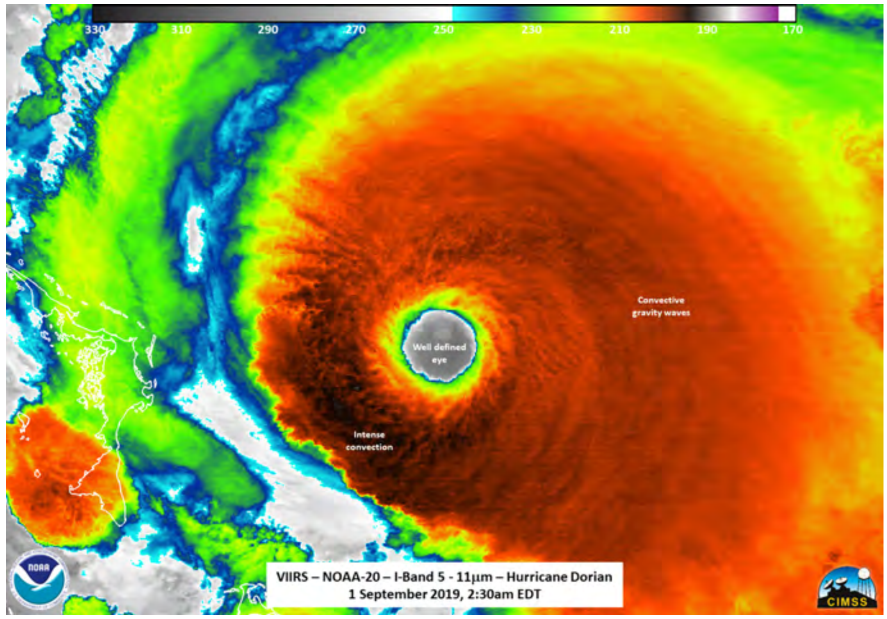
A hurricane that encounters strong shear can drop in intensity by as much as 35 mph or more in the span of a day. This is known as rapid weakening. That decrease can be equivalent to one or more categories on the Saffir-Simpson hurricane intensity scale, Braun said.

But the opposite is also true. A jump in 35 mph or more in less than 24 hours is considered rapid intensification. “What most often leads to rapid intensification is movement of a storm over a deep layer of warm waters, and a decrease in wind shear,” Braun said.

With Dorian, rapid intensification occurred twice: Once between Aug 30 and 31, when winds jumped from 105 mph to 140 mph. And then it happened again the next day. On Sept 1, the same day the storm made landfall on Grand Bahama Island, winds surged from 150 mph to 185 mph in only nine hours.

One of the most surprising aspects of Dorian, DeMaria said, was its ability to maintain its strength while stalled over the Bahamas.

“That is very unusual because stationary or very slow moving tropical cyclones usually mix with the upper ocean, cooling the sea surface temperature, which leads to weakening,” he said. “Dorian was able to maintain category 5 intensity while it was stationary.”



THE EYE

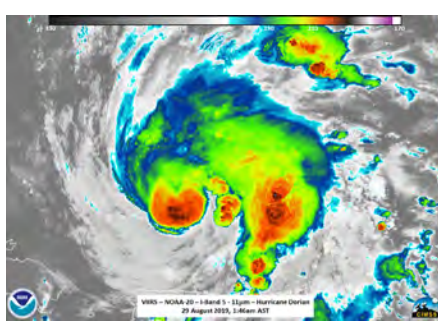
Braun also pays close attention to the formation of a well-defined eye, another indicator of the storm’s power. See the unmistakable eye of Dorian below, on Sept 1.

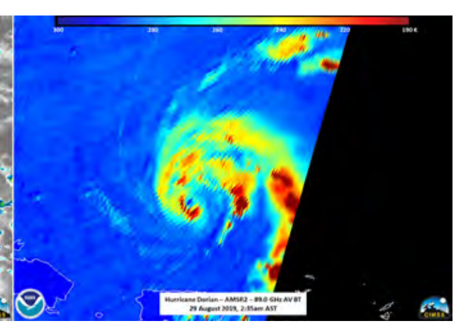
In its early stages, a storm is less defined, consisting mostly of cloud cover and no obvious eye. But as wind speeds rise, you start getting a stronger, rising motion in the growing wall of clouds that forms around the eye.

In the lower atmosphere, known as the troposphere, air gets colder with height until it reaches the stratosphere, where the trend reverses and air begins warming with height. Inside a thunderstorm, air rises, as long as it is warmer than the colder, denser air around it, until it reaches an equilibrium and then begins spreading outward.

That outward-spreading air causes surrounding air to sink, both inside and outside of the eye wall. And as the air inside the eye sinks, it dries and warms, evaporating the clouds and clearing out the center.

“So it becomes this loop, where the air coming in near the surface accelerates the spinning winds, drives a stronger vertical circulation, increases the sinking motion in the eye, increases the warming, and further clears out the eye,” Braun said. “When you get a major storm like Dorian, eventually you get to the point where it’s so strong and it’s

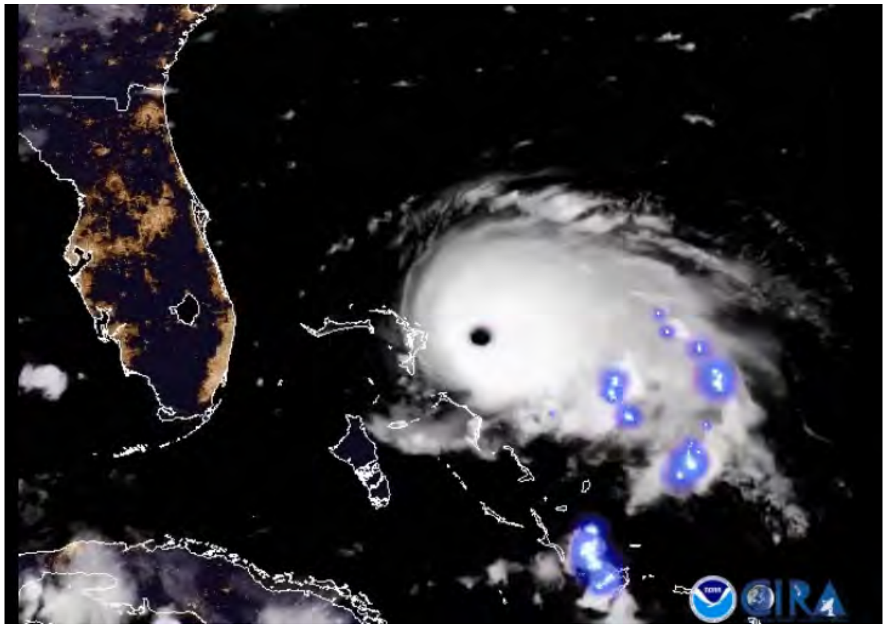


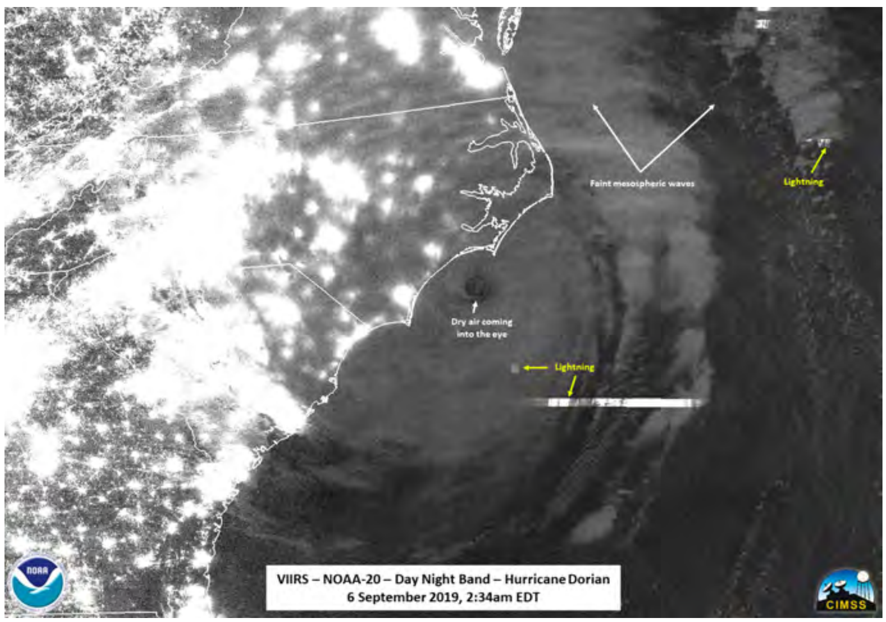


driving such strong, sinking motion in the eye, that you get the really well-defined eye in satellite imagery.

Since circulation surrounding the eye is an indicator of the storm's strength, Straka said it's also important to pay attention to whether the eye is exposed. "If it's exposed, that means there's dry air in it, and it could be weakening," Straka said. Dry air saps the storm of the moisture it needs to thrive.

When a storm's eye is obscured by clouds, meteorologists use microwave imagery to see the eye, because the microwave can penetrate the clouds. See, for example, this image, captured from the Advanced Microwave Scanning Radiometer, or AMSR2 instrument, aboard JAXA's GCOM-W1 satellite. "Microwave imagery is very important because it provides early information on whether a tropical storm is intensifying," said Mitch Goldberg, NOAA program scientist for the Joint Polar Satellite System.





LIGHTNING AND GRAVITY WAVES

The GOES satellites have a Geostationary Lightning Mapper (GLM), the first of its kind, which maps lightning activity in hurricanes. This device provides continuous observations of total lightning, both inside and below clouds, and can help forecasters predict rapid intensification of hurricanes as far as 24 hours ahead of time. See, for example, this loop from GOES East, captured on the morning of Sept 1.

VIIRS has a channel, known as the "Day/Night Band," which provides a snapshot of night lights, as well as lightning and gravity waves from various altitudes.

Gravity waves, (not to be confused with ripples in space-time known as "gravitational waves") distribute energy and momentum throughout the atmosphere. The more intense the storm, the greater the amount of energy that is transferred. These waves exist all the time, even on clear days, and waves in the troposphere can often be seen in the infrared and visible imagery. However, strong convection from storms can cause a bunch of energy to be released, which is then transferred to the upper atmosphere.

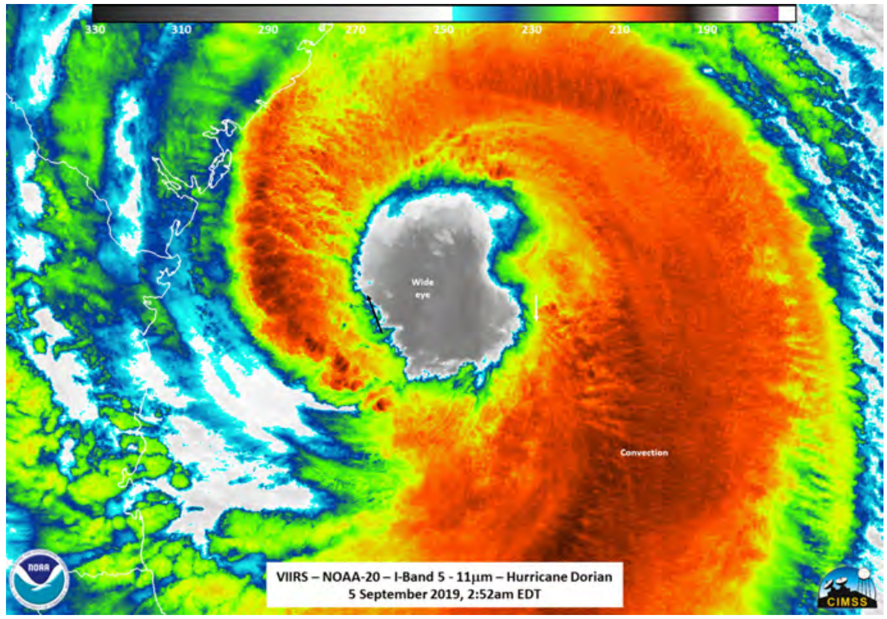
The most intense storms (as well as violent volcanic eruptions) have enough force to generate mesospheric gravity waves, noted in the image above. These are gravity waves near the mesopause, the boundary between the mesosphere and the thermosphere, where Earth's atmosphere meets space.

Strong storms with a well-defined eye can easily be tracked in the GOES visible imagery during the day and infrared imagery at night. However, weaker storms don't always have an eye and are more difficult to track, especially at night, when the visible imagery from GOES is not available. The Day/Night band can detect very small amounts of visible radiation, such as that reflected from moonlight at night. Thus, VIIRS can also help forecasters determine the storm's center at night for these weaker storms, DeMaria said.

"Knowing where the center is, that's the starting point for our forecast," he said.

COLOR AND TEMPERATURE

Color in these images is an indicator of the temperature at the very top of the clouds. The colors are a little counterintuitive, since we typically associate red with hot and blue with cold. If you look at the key on top of this Sept. 5 image of Dorian below, you can see that blue is warmest; red is cooler, black is coldest.



Colder cloud-top temperatures often indicate that the clouds are deep and that the thunderstorm is intense. It's typical to see colder temperatures in the eye wall and warmer temperatures around the edges of the storm.

Color, like shape, also often corresponds with wind speeds. It can provide clues about the health of the storm's convection, Straka said. Black and red, marked above, means the clouds are cold and the convection runs deep. In other words, these colors indicate more intense thunderstorms.

STORM EVOLUTION

Knowing how the storm changes over time is another critical component to understanding it. And that's something you need geostationary satellites like GOES to observe. See, for example, this timelapse video from GOES East that begins on Aug. 29, 2019—the day after Dorian became a hurricane—and continues through Sept. 3, 2019. That is when the dangerous storm began to pull away from the Bahamas and head for the U.S. mainland.

Of everything that he monitors, Braun says he especially pays attention to this trend in temperatures as the storm evolves.

"If the temperatures are getting colder over time, you know those thunderstorms are getting stronger and deeper," Braun said. "And if they're warming over time, it might indicate that they're starting to dissipate. That tells us what might be going on in terms of the behavior of the storm." ❖

For NOAA's National Hurricane Center page, visit: https://www.nhc.noaa.gov/

For NASA's Hurricane and Tropical Cyclones page, visit: www.nasa.gov/hurricane

Image credits: William Straka/CIMSS

Videos by NOAA Satellites

WEB FEATURE: OCTOBER 17, 2019

JOINT POLAR SATELLITE SYSTEM'S MICROWAVE INSTRUMENT FULLY ASSEMBLED

Ashley Hume
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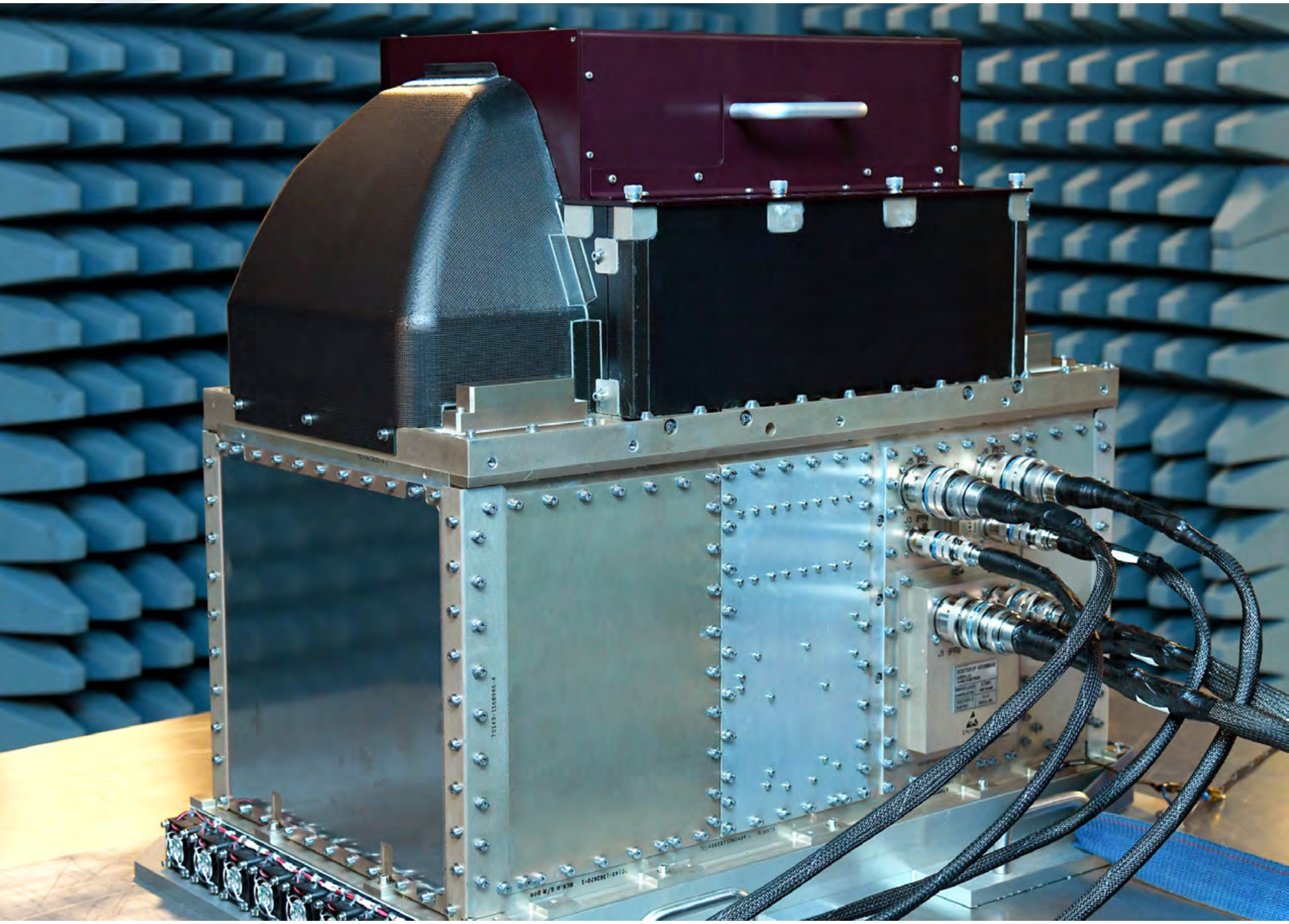

The Joint Polar Satellite System-2's fully assembled Advanced Technology Microwave Sounder instrument undergoes electromagnetic interference testing at the Northrop Grumman Aerospace Systems facility in Azusa, California. Credit: Northrop Grumman Aerospace Systems.

The Advanced Technology Microwave Sounder (ATMS) for the National Oceanic and Atmospheric Administration's Joint Polar Satellite System-2 spacecraft, scheduled to launch in 2022, has been fully assembled and has begun environmental testing.

A next-generation instrument that detects microwave radiation from the Earth's atmosphere and surface, ATMS provides atmospheric temperature and moisture data that is critical for weather forecasting and global climate trends.

"Data from ATMS instruments on the JPSS satellites—including NOAA-20 and its predecessor Suomi-NPP—have significantly improved the accuracy of U.S. short and medium range weather forecasts," said Greg Mandt, program director for the Joint Polar Satellite System

(JPSS) Program. “After it is launched in 2022, the JPSS-2 ATMS instrument will be used to ensure continuity for these improvements for years to come.”

Northrop Grumman, headquartered in Falls Church, Virginia, is responsible for the manufacturing, test and delivery of the ATMS instrument for JPSS-2. The instrument has been in development since 2016, and environmental testing marks the final step before the instrument gets delivered for integration into the JPSS-2 spacecraft early next year. The rigorous testing will ensure the instrument can successfully withstand launch and the harsh environment of space.

“Every detail matters in ATMS’s environmental test campaign. This is the most rigorous, thorough assessment the instrument will see, until it is on orbit,” said Bob Mehltretter, vice president, military and civil space, Northrop Grumman. “Our close collaboration with NASA and NOAA throughout the testing ensures that ATMS will provide quality data for our weather forecasts.”

Northrop Grumman is also responsible for the design, production and integration of the JPSS-2 spacecraft. The satellite is under construction at the company’s Gilbert, Arizona, satellite manufacturing facility.

ATMS currently flies on the NOAA-20 and Suomi National Polar-orbiting Partnership satellite missions. JPSS-2 will become NOAA-21 upon successful launch and on-orbit check-out.

The Joint Polar Satellite System (JPSS) is the nation’s advanced series of polar-orbiting environmental satellites. JPSS represents significant technological and scientific advancements in observations used 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. JPSS is a collaborative effort between NOAA and NASA.

NOAA’s National Weather Service uses JPSS data as critical input for numerical forecast models, providing the basis for mid-range forecasts. These forecasts enable emergency managers to make timely decisions to protect American lives and property, including early warnings and evacuations.

For more information about JPSS, visit: https://www.jpss.noaa.gov. ❖

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DOI: 10.25923/ta5d-a382

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