JPSS 2016

JOINT POLAR SATELLITE SYSTEM

SCIENCE SEMINAR ANNUAL DIGEST

Front and back cover: Composite imagery from the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi NPP satellite acquired in August 2016 showing paths almost bare of ice in the Northwest Passage. The Northwest Passage is a sea route connecting the northern Atlantic and Pacific Oceans through the Arctic Ocean, in the high latitudes, along the northern coast of North America through channels of water in the Canadian Arctic Archipelago.

Image by Jeff Schmaltz, LANCE/EOSDIS Rapid Response, generated from the NOAA/NASA Suomi NPP VIIRS instrument.

Inset (left): Map of North America highlighting the geographic location of the Northwest Passage.

Cover and inset designed by Joshua Brady, GAMA-1 Technologies.

Joint Polar Satellite System Science Seminar Annual Digest

2016

From the Senior Program Scientist

I am pleased to present our 2016 Joint Polar Satellite System (JPSS) Science Seminar Digest. This digest, like its predecessors, features a collection of articles generated from our monthly science seminars. These articles profile the operational capabilities of space crafts within the Nation's next generation of polar-orbiting environmental satellites in the JPSS constellation.

Considered the backbone of the global observing system, data from polar-orbiting satellites are critical for forecasting weather three to seven days in advance and monitoring the global environment. NOAA's JPSS provides critical environmental observations to support NOAA's overarching mission to "understand and predict changes in weather, climate, oceans, and coasts".

Within NOAA JPSS, Program Science provides guidance for the science quality of the JPSS sensor's data and derived products. The Proving Ground and Risk Reduction (PGRR) Program—managed by Program Science—supports user demonstration by stimulating interactions between technical experts from the JPSS Program, university partners, and key user stakeholders. Established in 2012, the PGRR program aims to test, learn and share ways to strengthen the use of data and products from the JPSS. It is through the PGRR that Program Science receives user feedback on the impact of Suomi NPP/JPSS data, which is helpful for identifying the improvements needed for products and applications. The information received by the PGRR is fed back to the Center for Satellite and Applications (STAR) calibration and validation (Cal/Val) teams who then use it to build and/or improve the products. This feedback provides a valuable loop between the product user and developer or researcher. The entire Program Science efforts would not be possible without the outstanding interactions between the JPSS Program, STAR, the NOAA cooperative institutes, government and international partners, government contractors, and of course the user community.

The year 2016 was significant for the PGRR Program, and especially for a number of our Initiatives. These Initiatives were launched to help our projects tackle the challenges affecting the utilization of JPSS products in operations. They are now hallmarks of the PGRR landscape. Our first Initiative, launched in 2013, was a project-led response to severe flooding along the

Yukon River—deep in the interior of Alaska. The capabilities demonstrated by the highly successful inaugural River Ice and Flood Initiative paved the way for other Initiatives, beginning with Fire and Smoke, and Atmospheric Soundings in 2014. These were soon followed by another wave of Initiatives in 2016, which focused on hydrological applications, ocean and coastal issues, the Arctic and numerical weather predication (NWP) and data assimilation. To add to our growing number of Initiatives, we witnessed the user community assimilate a significant number of JPSS PGRR products into their operational applications—a reflection of our success in tackling the challenges affecting product utilization.

Some tangible benefits derived from our PGRR Initiatives this year included:

The assimilation of real- time fire detection and characterization data derived from VIIRS in the High Resolution Rapid Refresh (HRRR) Forecast model to simulate emissions as well as smoke trajectories. Team members from our Fire and Smoke Initiative had an opportunity to perform a real-time test for the experimental model during the wildfires that scorched the Western parts of the U.S. in July. Smoke associated with these wildfires resulted in poor air quality across portions greater San Francisco Bay Area and Monterey Bay Region. Currently the HRRR-Smoke is run in real time by NOAA/ESRL/GSD for the CONUS domain at a horizontal grid resolution of three kilometers. In addition, an Alaskan sector was created and run to support forecasters during their fire season. It showed such success that the Alaska Region will be used again next year. The runs are initialized every 6 hours at 00, 06, 12 and 18UTC to produce 36 hour forecasts. For more information please visit: http://rapidrefresh.noaa.gov/HRRRsmoke/.

The use of soundings from the NOAA-Unique Combined Atmospheric Sounding System (NUCAPS) was demonstrated during the Hazardous Weather Testbed Spring Experiment in Norman, OK from April 18th–22nd 2016. Forecasters used the vertical temperature and moisture soundings to great effect in high impact weather regimes. A vertical plan view of sounding capabilities was also tested successfully during the Spring Experiment. Being able to evaluate soundings between ground-based rawinsonde launches just as convection was beginning to break proved to be very valuable to the forecasters. Their daily feedback captured specific examples of NUCAPS successes, especially over poorly sampled regions.

In northern Alaska, overflows of water along the Sagavanirktok River or Sag River from January through May 2016 threatened the safety of Dalton Highway. This highway is the main supply route for the Prudhoe Bay oilfields. During this period, VIIRS flood maps were extensively used by Alaska-Pacific River Forecast Center to provide support and service to Alaska Department of Transportation & Public Facilities. These maps provided dynamic information on the overflow water and helped river forecasters with situational awareness during the forecasting process.

During the August 2016's Louisiana flood, VIIRS flood maps were sent to FEMA, NASA and NWS. Downscaled VIIRS high-resolution flood maps attracted great interest from FEMA. The downscaling model enhances the spatial resolution of the current VIIRS flood product by pushing the resolution from 375 meters down to 30 meters or even 10 meters. The better resolution enables the VIIRS flood products to contain 3-D inundation information, and allows the product to address much more detailed spatial distribution of flooding water. The downscaling model has greatly enhanced the capability of moderate-to-course resolution satellite sensors.

This year was also notable for the advances made in the installation and use of Direct Broadcast antennas. Prior to the use of direct broadcast, the time needed to retrieve satellite data for time sensitive applications took more than 100 minutes. The antenna network has cut the process down to less than 20 minutes, making it a critical aspect of enhanced operational applications. Initiatives such as the Fire and Smoke are employing direct readout as a proving ground testbed to demonstrate new products and applications, and more importantly to improve product latency. Timely delivery and acquisition of global observations facilitates faster forecasting of local weather events.

Funding from the JPSS Program supported the installation of “Sandy Dog”—a new direct broadcast antenna to complement the legacy “Big Dog” antenna in Alaska. This expanded the capacity of the Geographic Information Network of Alaska’s (GINA) to receive and process direct broadcast data from Suomi NPP and other polar-orbiting weather satellites. Polar-orbiting satellites provide Alaska with the much needed imagery and products useful for both research and operations. More importantly, the spatially comprehensive and nearly continuous coverage they provide makes them effective and essential systems for monitoring rapidly changing environmental conditions in the region.

In addition, a direct broadcast antenna, designed to receive data from polar-orbiting weather satellites including Suomi NPP, was installed in Mayaguez, Puerto Rico. Originally intended to mitigate potential loss of primary global stored mission data, the antenna is providing overall enhancement to the forecast enterprise. Today, forecasters at the National Weather Forecast Office in the capital city of San Juan and the wider Caribbean and South Florida area have access to advanced data such as high resolution imagery and data products from VIIRS, refreshed at least every three hours. Along with the global environmental data, this expedited access has enhanced opportunities to obtain a comprehensive picture of rapidly changing weather conditions. Next year, the direct readout network will be expanded to include data from Guam and Japan, allowing coverage from western Pacific region and data from EUMETSAT’s regional network to cover Greenland and the remaining Northern Atlantic where the data takes an extended length of time to process.

The need for training has been recognized as an essential ingredient in successfully transitioning products into operations and in NOAA’s vision for a world-class workforce to support NOAA’s mission of "Science, Service, and Stewardship". One of the thrusts in our Training Initiative is to improve the user community’s utilization of JPSS products and applications. Another is to promote the access, display, and use of JPSS derived products and applications to a wide reaching user community. The PGRR is collaborating with the NWS to identify a unique JPSS applications training using various training aids including quick guides, virtual classrooms, and short event focused training sessions. We also continued our outreach to NOAA’s operational Ocean user community through the annual Ocean Satellite Course. This course has become a cornerstone in demonstrating how to access satellite data using the tools and services generated at the Environmental Research Division (ERD) at

NOAA's Southwest Fisheries Science Center (SWFSC). It has proven to be an effective method of bringing satellite data, such as that from VIIRS to end-users at the NMFS and NOS.

The program's vision for innovative uses of JPSS data has led to the evaluation and testing of new products and better application of current products. I selected a few examples to show that our Initiatives are having an impact in many areas including critical ones like transport and forecasting of local severe weather events. Indeed there's a wide range of applications from JPSS data and products, and many are exemplified by the success stories presented in this digest. Thank you for your interest in our activities.

I would like to thank each of the contributors and editors, and numerous partners for their dedicated efforts to provide you these digests. I would also like to give special thanks to my Program Science staff, JPSS Communications, and the NOAA JPSS Program Office, for their ongoing support in the development of this digest; and to the authors and editors. 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 to be a worthwhile resource.

Mitch Goldberg
Senior Program Scientist, Joint Polar Satellite System (JPSS)
Satellite and Information Services
National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Commerce

From the Director

2016 marked a year of many achievements for the Joint Polar Satellite System (JPSS) Program. Among them was the fifth anniversary of the NOAA/NASA Suomi-National Polar Partnership (NPP) mission. Through the Suomi NPP mission, the JPSS team and its partners have contributed to the continued outstanding success supporting the missions of both Agencies and partners across the U.S. Government and around the world. Environmental observations and data products from Suomi NPP have led to better forecasts and situational awareness for the nation and users worldwide. Suomi-NPP has exceeded user expectations, and has been the Nation's primary polar satellite for weather since May of 2014. Data produced by Suomi NPP are derived from a new generation of instruments that will also fly on future JPSS satellites: Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), Ozone Mapping and Profiler Suite-Nadir (OMPS-N). Suomi-NPP also hosts the fifth flight model of the Cloud and Earth Radiant Energy System (CERES). Its successor, the JPSS-1 spacecraft is scheduled to launch in 2017. After launch and commissioning are complete JPSS-1 will be known as NOAA 20 and become the primary, and Suomi-NPP will continue operations as secondary.

Observations from Suomi NPP are among the most important and largest volume sources of data for weather forecasts beyond 48 hours and increase the consistency and accuracy of forecasts three to seven days in advance of a severe weather event for NOAA's National Weather Service (NWS). In addition, data from Suomi NPP are provided fully and openly to other federal, state and local users; commercial weather sector; and international partners. In-turn, we receive data from our international and inter-agency partners that greatly increase the benefits received from our own satellites.

The JPSS is part of the U.S. Department of Commerce infrastructure dedicated to supporting NOAA's missions to enable a weather ready nation; healthy oceans; climate adaptation and mitigation; and resilient coastal communities and economies. As such, JPSS is set to play a key role in fulfilling the promise of the Joint Polar System Agreement reached in 2016 between NOAA and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) to continue to share the burden of operating polar orbiting weather satellites in two orbits for the next twenty years. The 2016 Agreement builds on the obligations under the long-term cooperative agreement signed on 27 August 2013—with the first Generation MetOp satellites, the U.S. POES satellites, Suomi-NPP and JPSS-1. The JPS Agreement also extends to NOAA's planned JPSS-2, -3, and -4 satellites and EUMETSAT's planned second-generation Metop satellites, ensuring that the U.S., Europe, and the world will have the data required for modern weather forecasting through the late 2030s.

As we celebrate the five-year anniversary of Suomi NPP and prepare to deploy the next mission in the series, JPSS-1, I want to thank the NOAA / NASA Government / Industry / Academia team and partners for their contributions to the program.

This Digest covers issues as diverse as air pollution from various sources including smoke emissions, biological productivity in the oceans, and prediction of tropical cyclones. It ranges from recognizing global trends to specific local events. To mention a few, you'll read on how polar-orbiting satellites provide Alaska with the much needed imagery and products useful for both research and operations. As well as see some examples of improved products from our PGRR, specifically from Suomi NPP that were delivered to the National Weather Service in Alaska. From our Proving Ground Risk Reduction (PGRR) project with NOAA's Earth System Research Laboratory (ESRL), you'll read on efforts being made to better understand emissions, particularly, methane (CH_4) and carbon monoxide (CO), and their impacts on air quality and climate.

The Digest also presents some examples from the PGRR Programs for JPSS and the Geostationary Operational Environmental Satellite-R Series (GOES-R), to show how they are working to introduce and promote the use of satellite data within the NWS, focusing on the service centers at the National Centers for Environmental Prediction (NCEP). Other examples include approaches taken by the Environmental Research Division (ERD) at NOAA's Southwest Fisheries Science Center (SWFSC) to facilitate the oceanographic community's access to satellite data, and to increase the utilization of environmental satellite data within NOAA's NMFS and NOS.

I offer my thanks for the many contributors to this digest, and to our JPSS science team and community for their outstanding contributions to JPSS. I hope you enjoy the 2016 Digest and learning about the achievements of our many team members who work hard to ensure the JPSS Program delivers on its commitments. We welcome any opportunity for our Digests to be more widely shared and disseminated. To learn more about past JPSS achievements, you can access previous digests from our science publications page online at: http://www.jpss.noaa.gov/science_publications.html.

Harry Cikanek
Director, Joint Polar Satellite System (JPSS)
Satellite and Information Services
National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Commerce

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JPSS USER PERSPECTIVE

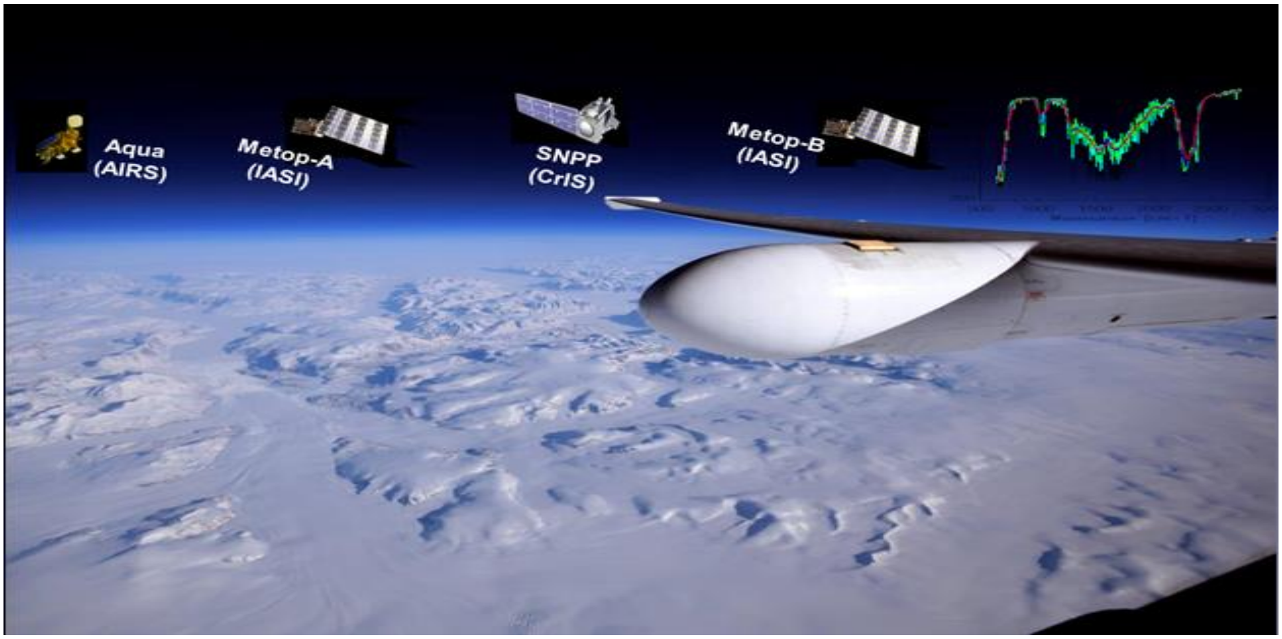
What the users are telling us about JPSS

Validating Suomi National Polar-orbiting Partnership (Suomi NPP) Instruments and Data from the Arctic Skies

*This article is based in part on the **October 26, 2015** JPSS science seminar presented by Allen Larar, NASA Langley Research Center, and Dave Tobin, University of Wisconsin-Madison.*

Contributing editor: Joe Taylor: University of Wisconsin-Madison.

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg



Credits: The icy expanse of land observed from the cockpit of NASA ER-2 flight to Iceland in March. NASA Photo/ ER-2 pilot

Since the 1960s, measurements from environmental satellites have enabled us to obtain global scenes of the Earth's dynamic environment. The high temporal and spatial resolution of satellite data, their continuity, and global coverage have made it easier to detect and quantify changes in the Earth's environment, and also increased our understanding of climate processes. Moreover, satellite-derived measurements have generated global data products that have proven valuable in diverse applications ranging from weather forecasting, the deployment of firefighters and the routing of aircraft to tracking vector-borne diseases. But, as with any remotely sensed data, for these measurements to be meaningful, their accuracy must be verified. For the observations retrieved by satellite-flown instruments, this involves comparing them against other measurements from sensors on ships, and instruments on airborne, ground- and balloon-based, and laboratory platforms. These "remote" and "in-situ" measurements provide data with levels of accuracy, precision, a short traceability chain to absolute standards, and resolution that are unavailable from satellite-flown sensors. Without validation the accuracy of satellite-derived data cannot be verified nor guaranteed. Validation therefore builds confidence in and increases subsequent utility and usage of the satellite dataset.

Validation Campaigns

Satellite instruments and corresponding data can degrade and change over time. This degradation can occur from a number of sources. Like any mechanical piece of equipment, sensors can start to show wear, electronic impulses can be disrupted; and outside influences such as solar interference or impact with space debris can cause sensor problems. Therefore, when analyzing measurements from satellites, it is important to assess the performance of their instruments over time. To assess the quality of satellite-derived data and/or changes in satellite instrumentation, independent measurements of the same quantity from one or more instruments (airborne-, balloon-, and ground-based) are used.

Benefits of Airborne Validation Campigns

Aircraft validation campaigns have unique benefits. Using aircraft platforms makes it possible to perform long flights over large areas. Adding or removing sensors on aircraft makes it easy to configure or reconfigure an aircraft to meet the unique needs of a particular satellite system. Also, aircraft can operate out of airfields ideally suited to underfly satellite passes when and where needed. Aircraft also possess high flexibility to achieve close temporal and spatial coincidence with satellite overpasses almost everywhere on the globe and under most weather conditions. Aircraft validation is also the crucial link between ground-based measurements and satellite measurements at moderate resolution.

Aircraft measurements are accurately calibrated and can be used under different types of scenes to make careful comparisons of how well they match up with satellite data. By employing its sensors and flight patterns, an aircraft can produce measurement perspectives that bear resemblance to those obtained by satellite sensors when the same spatial and temporal features are measured directly coincident to the satellite of interest's sensors and flight path. This enables parameters that are alike to be compared. An "apples to apples-like" comparison as the same instrument types can be compared using the same scenes albeit at higher spectral and spatial resolutions. In addition, aircraft under-flights of multiple satellites during a single campaign allows for validation across the different platforms. Multiple campaigns spaced over the years can be an important element in long term monitoring of system performance.

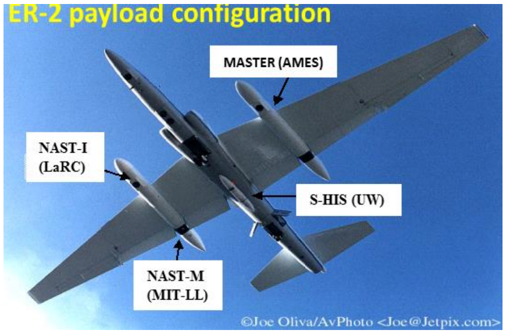
The Suomi National Polar-orbiting Partnership (Suomi NPP)

The Suomi National Polar-orbiting Partnership (Suomi NPP) is the first next generation satellite in the Joint Polar Satellite System (JPSS) series. It is also NOAA's primary weather satellite. JPSS is equipped with five state-of-the-art instruments: the Visible Infrared Imaging Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS), the Ozone Mapping and Profiler Suite (OMPS), and the Clouds and the Earth's Radiant Energy System (CERES) FM5. The CrIS is the operational counterpart to the Atmospheric Infrared Sounder (AIRS) on the NASA EOS Aqua Platform. It is an infrared Fourier transform spectrometer that produces high-resolution, three-dimensional temperature, pressure, and moisture profiles for weather and climate applications. This refined information on the Earth's atmosphere from CrIS has helped improve our weather forecast capabilities and understanding of climate.

The Suomi NPP Arctic Validation Mission

As part of the Suomi NPP Arctic Validation Mission, NOAA and NASA jointly sponsored a series of science flights, out of Keflavik, Iceland during March 2015. Using a complement of remote sensing and in-situ instruments, the Suomi NPP Arctic Validation Mission sought to reconcile the radiance differences between the cold scene observations from CrIS on Suomi NPP, the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua satellite, and the Infrared Atmospheric Sounding Interferometer (IASI) on the European MetOp-A and MetOp-B satellites. It also sought to provide data for improving understanding and methodologies for the challenging EDR retrievals associated with polar conditions. The basic goal was to help benchmark or prove the data quality for research and operational data applications. To meet the mission goals, the ER-2 flights were timed to fly directly under the paths of the Suomi NPP, Metop-A and -B, and Aqua satellites.

The NASA high altitude (20-km) Earth resources aircraft, ER-2, is a flying laboratory in the Airborne Science Program under the agency's Science Mission Directorate. Its payload for the Suomi NPP Arctic Validation Mission consisted of the Scanning High Resolution Interferometer Sounder (S-HIS), the National Airborne Sounding Testbed Interferometer (NAST-I), the National Airborne Sounding Testbed Microwave (NAST-M), and the MODIS/ASTER Airborne Simulator (MASTER) which was developed for NASA's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and Moderate Resolution Imaging Spectroradiometer (MODIS) projects.



The NASA ER-2 research aircraft equipped with NAST-I, NAST-M, S-HIS and MASTER

Influence of the Weather on Airborne Campaigns

Performing validation procedures in the field is often at the mercy of the weather. As weather affects conditions on the ground and in the air, it can impose substantial logistical challenges! This is especially true within the icy realm of the Arctic region. Due to a number of reasons including complex terrain and surfaces, Arctic weather brings the potential for operational difficulties; be it with instruments, infrastructure, and even to the operators themselves. To say that conducting a validation campaign in the Arctic can be complicated would be an understatement. Often, extra planning is required for working outdoors in the extremely low Artic temperatures.

Local weather delays start of science flights

Strong winds disrupt flights out of Iceland

Weather subsides and the ER-2 crew performs preflight activities. Photo Credits: NASA / ER-2

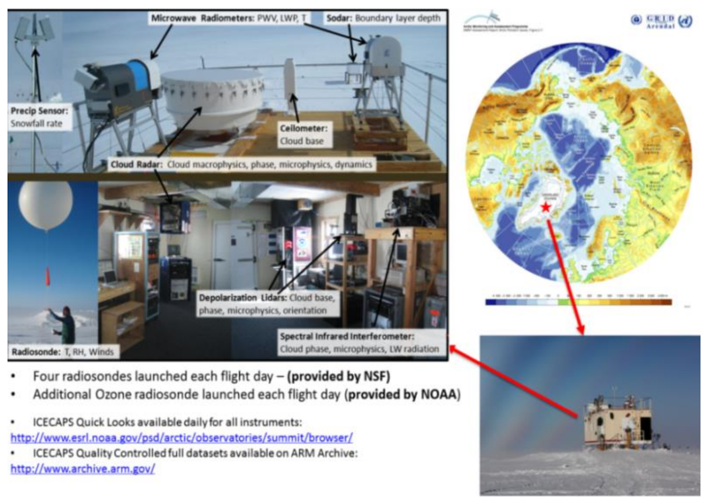
Before the science team could even take to the skies, strong storms—which extended over a number of days—brought gale-force winds to Iceland, which disrupted all air traffic in the region. Faced with challenging local weather conditions, the science flight team members soon learned to fly sorties whenever the local weather permitted.

Advancing Earth Observation through Science Flights

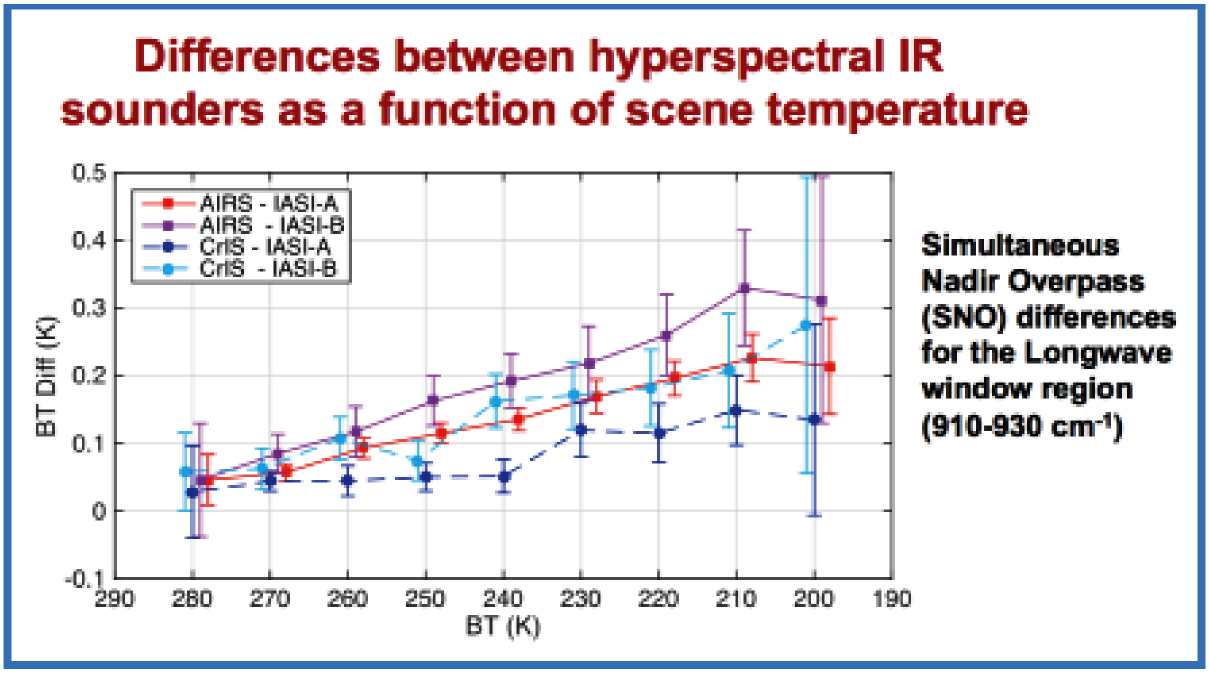
In total seven mission sorties were implemented during the campaign. Each flight captured multiple assets for cross-validation. There was repeated coincidence with the Suomi NPP, Aqua, Metop-A, and Metop-B satellites, the Summit Station, and the British Aerospace 146 (BAe 146)—a heavily instrumented Atmospheric Research Aircraft (ARA). Although final processing and analysis is still in progress preliminary results are very encouraging, showing campaign cold scene radiance differences to be less than those derived from Simultaneous Nadir Overpasses (SNO).

ER-2 flight				S/C				GROUND	A/C
GMT Date	Duration (hrs)	TO	RTB	SNPP	AQUA	METOP-A	METOP-B	Summit	BAE146
3/15/15	5.9	1151	1746	1331, 1511			1424		
3/19/15	4.6	1411	1846	1356				4x	
3/23/15	6.3	1142	1757	1420	1452	1403	1458	2x	
3/24/15	4.2	1103	1510	1401				2x	
3/25/15	7.5	1017	1744	1343	1441	1322	1416	4x	
3/28/15	7.4	1016	1738	1246, 1426	1333	1401	1454	2x	
3/29/15	6.1	1115	1720	1407	1416	1339	1433	2x	

In addition, radiosondes launched from the Summit ground site augmented the flights each campaign day. Each day, four radiosondes were provided by the National Science Foundation (NSF) while an additional Ozone radiosonde was provided by NOAA. Daily datasets for all instruments were also available from the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) instrument suite. The ICECAPS instrument suite takes focused measurements of the cloud, atmosphere, precipitation, and radiation properties over the Greenland Ice Sheet (GIS).



Aircraft data enable same-same (measurement, scene, space, time) observations to best inter-compare satellite sensors. The diagram that follows shows some systematic differences between the AIRS, IASI and CrIS sensors from Simultaneous Nadir Overpasses (SNOs)—which primarily occur at the Polar Regions—for the Longwave window region in the 910 to 930 wavenumbers. Because Suomi NPP and EOS Aqua are in similar orbits, there are many SNOs distributed over a wide range of latitude and longitude. However, due to different orbits between Suomi NPP and MetOp-A, the CrIS and IASI SNO collocations only occur at high latitudes. The smallest observed differences are between the CrIS and IASI on the MetOp-A spacecraft while the biggest differences are between the AIRS and IASI on the MetOp-B spacecraft. These differences merit further investigation into whether they are characteristic of the calibration; the assessment can be made using other methods, and can help determine if there is a possibility for improvement.

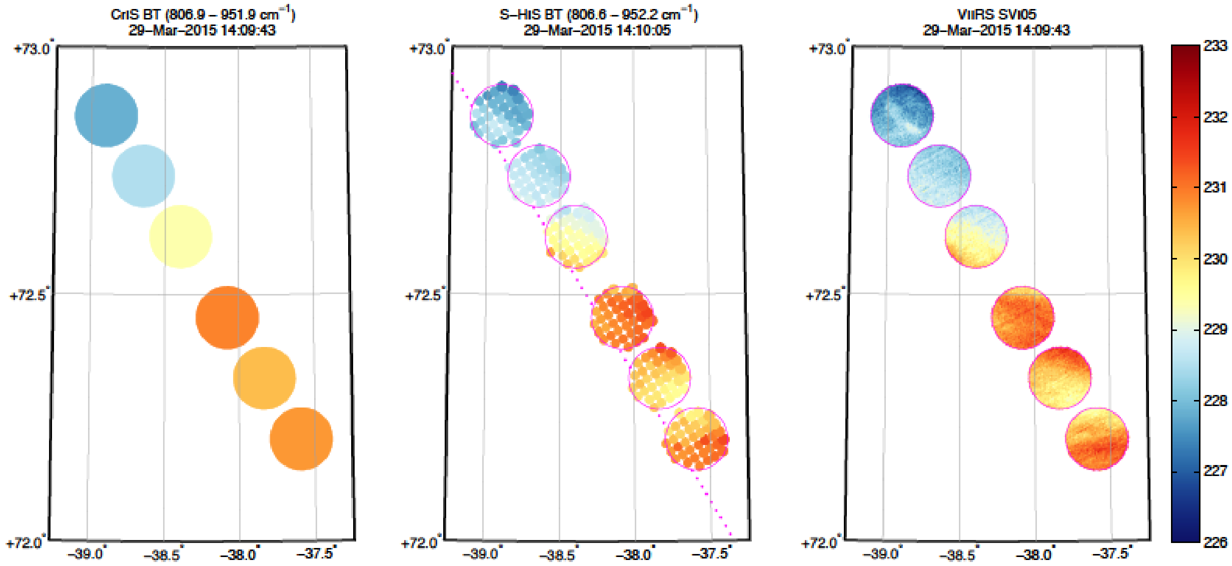


This is where aircraft campaigns—or methods which can examine or compare one or more parameters at the same time—come into play. Sensors with similar design or measurement capability as the satellite sensors are flown on high altitude aircraft for validation of the satellite products. The primary advantage offered by the aircraft sensors is that, unlike the current satellite sensors, their performance and measurement accuracy can be verified before and after each campaign under flight like conditions. This includes periodic verification with traceability to reference standards provided by the National Institute of Standards and Technology (NIST), therefore providing a robust and traceable uncertainty chain for the validation findings. An example is the accurately calibrated airborne reference instrument, the Scanning High-resolution Interferometer Sounder (S-HIS). S-HIS is an advanced version of the High-resolution Interferometer Sounder (HIS) NASA ER-2 instrument, which, over the last 20 years has proven to be extremely dependable with a 99.8 percent reliability rate.

Some Preliminary Results from the S-HIS

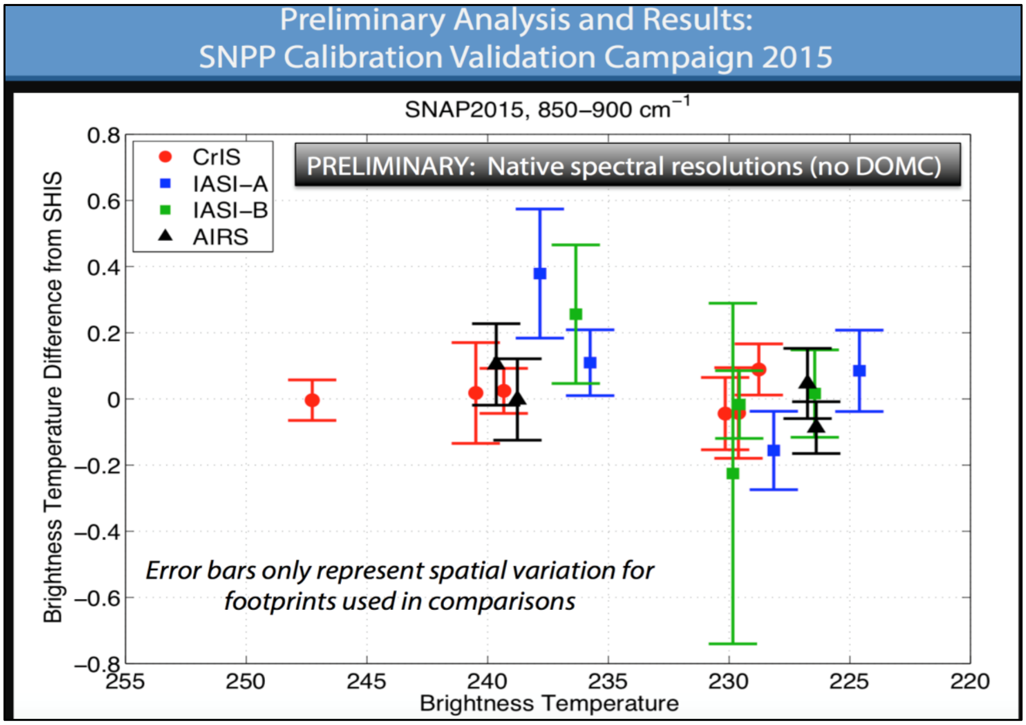
Refined Footprint Selection Completed for CrIS Cases

The validation process begins with identifying the right flight plan, then flying the flight tracks so that the aircraft is at nadir when the satellite passes. Next in the path to validation is identifying the footprints which are collocated in space and time as shown in the example below from the March 29, 2015 flight. On this day, nadir measurement coincidence was achieved for multiple satellite overpasses including Suomi NPP, Aqua, and Metop-A and –B; in addition to two overflights of the Summit ground site.



CrIS Mean BT (806.9 – 951.9 cm-1) | S-HIS Mean BT (806.6 – 952.2 cm-1) within selected CrIS FOVs | VIIRS SVI05 BT within selected CrIS FOVs

The image above shows the measured scene brightness temperature within the 6 near-nadir CrIS footprints used in the CrIS to S-HIS comparison (left), along with the S-HIS (middle) and VIIRS I-5 band (right) data collocated within the selected CrIS footprints. The S-HIS and CrIS data have been spectrally averaged over the VIIRS I-5 spectral band for this figure. The S-HIS footprint size is approximately 2 km at nadir, for an aircraft altitude of 20 km. For non-uniform cloudy scenes, footprint selection becomes increasingly important due to temporal variability between the satellite and aircraft overpasses, as well as potentially incomplete spatial coverage of the satellite footprint by the aircraft measurements due to high clouds. It is useful to use the satellite IR imager, with its higher spatial resolution, to evaluate and refine the CrIS and S-HIS footprint selection for the calibration validation data. The collocated VIIRS data can be used to evaluate the spatial coverage of the CrIS footprints by the S-HIS footprints, as well as the scene uniformity within the CrIS and S-HIS footprints. Furthermore, the VIIRS imager data can also be used to evaluate temporal variability in the scene between the times of the satellite and the aircraft observations. While the satellite will take only seconds to cover the spatial scale represented by the 6 CrIS footprints, it will take the ER-2 approximately ten minutes to pass over the same area. We can see from the image that for this case the spatial structure of the satellite and S-HIS observations are very similar, indicating good spatial and temporal coincidence between the satellite and aircraft observations.



Credit: Dave Tobin

The figure above shows an intercomparison of satellite and aircraft sensors. Of note, albeit preliminary, is the excellent agreement between CrIS and S-HIS. Because S-HIS is tied to a NIST traceable calibration source, this NIST-traceable validation is critical for uncertainty analysis needed to fully assess data quality of the CrIS sensor.

Summary and Way Forward

Airborne platforms, particularly high altitude aircraft such as NASA's ER-2 have the unique capability to validate satellite data such as that from the JPSS series of polar-orbiting satellites. As a result, post-launch validation activities, including airborne field campaigns, play a critical role in verifying the quality of satellite measurement systems (sensor, algorithms, and data products).

Many valuable satellite underflight datasets were collected during this field campaign. The Suomi NPP-2 campaign datasets remain to be finalized. In the meantime, they continue to provide benefits through data products, algorithm validation and other science, assimilation studies, and further refinement of methodologies for future advanced sounder validation. These datasets are not only beneficial to the new sensors on Suomi NPP or those that will be carried on the other satellites in the JPSS constellation. They cross over to heritage sensors such as the Atmospheric InfraRed Sounder (AIRS) and the Infrared Atmospheric Sounding Interferometer (IASI) on the Aqua and Metop-A satellites thus ensuring data continuity which is vital for climate and other environmental applications as well.

Field campaigns employing airborne sensors play a vital role in assessing the health of our space-borne assets and the accuracy of their measurements since they provide the best means of comparison with spatially- and temporally-coincident direct measurements, along with independently-retrieved geophysical measurements for comparison with like satellite-derived measurements. Results from field experiments such as the Arctic Validation Campaign provide information and insight into weather, climate, and other aspects of Earth's global environment. The corresponding instrument development that is involved in field experiments such as the Arctic Validation Campaign further add to our measuring capabilities, thereby advancing our understanding of our environment and creating new opportunities for scientific exploration through new instrument technology such as that available from Suomi NPP.

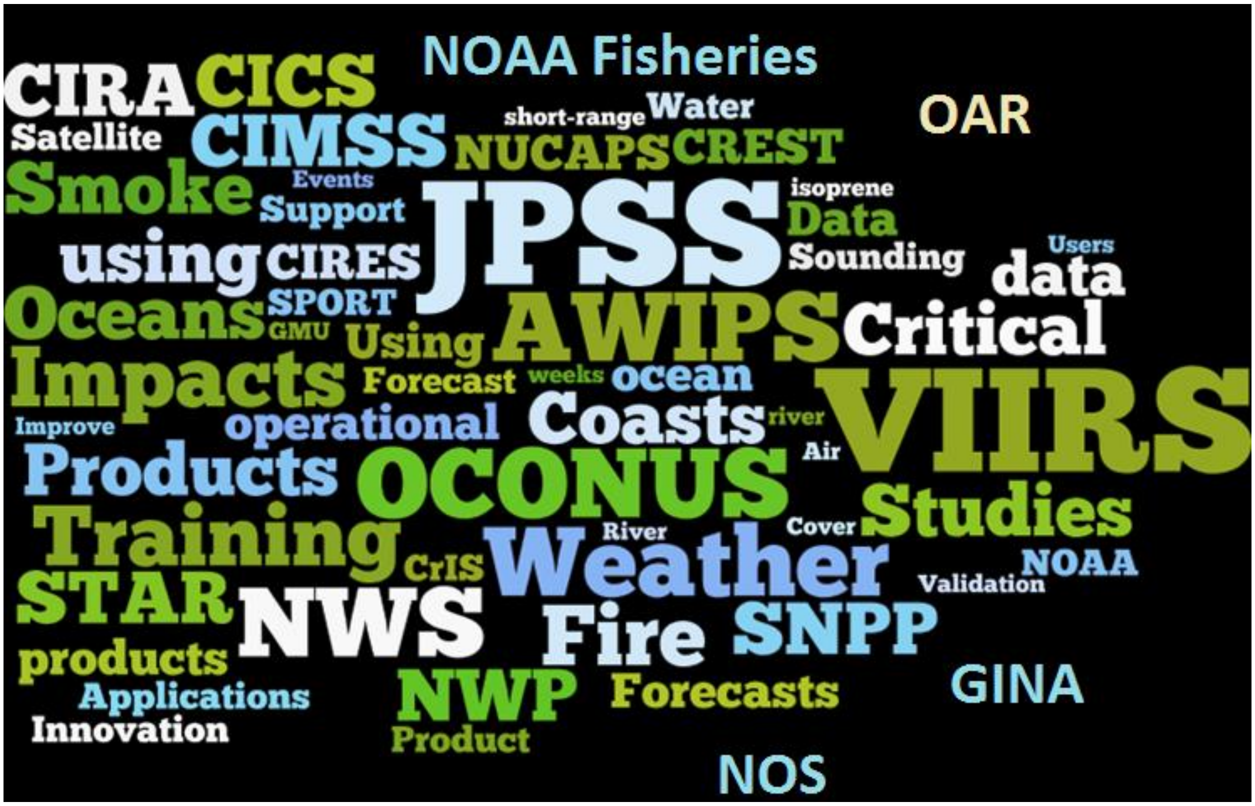
JPSS USER PERSPECTIVE

What the users are telling us about JPSS

JPSS Proving Ground and Risk Reduction Program Priorities

*This article is based in part on the **November 23, 2015** JPSS science seminar presented by Arron L. Layns, NOAA, JPSS.*

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg



Polar-orbiting environmental satellites are considered the backbone of the global observing system as they provide full global coverage of the Earth's ocean, land and atmosphere. They also contribute to numerical weather prediction (NWP) models some of the most valuable inputs needed to generate forecasts beyond 48 hours. And, to a greater degree, data from polar orbiters is increasing the consistency and accuracy of forecasts of severe weather events three to seven days in advance. The Suomi National Polar-orbiting Partnership (Suomi NPP) is the first next-generation polar-orbiting satellite in the Joint Polar Satellite System (JPSS) constellation, and is NOAA's primary polar-orbiting satellite. Suomi NPP circles the Earth from pole-to-pole and crosses the equator 14 times daily in the afternoon orbit—providing full global coverage twice a day, in which approximately 3.5 terabytes of data are produced. Its follow-on, JPSS-1, is expected to generate 4.5 terabytes of data each day. This data is spurring new products and applications to emerge constantly! Forecasters are also receiving a lot more data from other sources including model runs, ensembles, new radar technologies, aircrafts, surface observations, different satellites systems and so forth. In addition to the wide array of products and applications, forecasters have to contend with new science as a result of these technological innovations. For the average forecaster inundated with a lot of data, this can lead to information overload. Even the most organized decision-maker can be overwhelmed by the myriad of data sources pumping terabytes of data at ever increasing rates.

Shortly after the launch of Suomi NPP, the Proving Ground and Risk Reduction (PGRR) Program was established to identify the most promising new satellite capabilities and establish the best paths to transition these capabilities from research to operations. The PGRR Program helps identify more optimal ways of using current data, and future capabilities that show promise for operational applications. The JPSS PGRR contributes to the NOAA's mission goal to understand and predict changes in all facets of the Earth's environment including weather, climate, oceans, and coasts.

JPSS PGRR Background

Since 2012, the PGRR Program has supported demonstrations of user capabilities by stimulating interactions between technical experts from the JPSS program, university partners, and key NOAA stakeholders. This user engagement has helped to enhance or improve applications through the optimal utilization of JPSS data. The PGRR Program is made up of two components. The Proving Ground component focuses on the demonstration and utilization of data products by an end-user operational unit, such as a National Weather Service (NWS) Weather Forecast Office (WFO). It is also a key element of JPSS user readiness (risk reduction), which is achieved through testing of all the baseline products from Suomi NPP. The Risk Reduction Component facilitates the transition of improved algorithms to operations. Moreover, it is through the PGRR that Program Science receives user feedback on the impact of Suomi NPP/JPSS data, which is helpful for identifying the improvements needed for products and applications. The information received by the PGRR is fed back to its calibration and validation (Cal/Val) teams who then use it to build and/or improve the products. This feedback provides a valuable loop between the product user and developer or researcher. For the PGRR delivering "the last mile"—the operational implementation of a product—is a vital element that has contributed to the overall success of the program. It is also in these proving grounds where products based on future satellites are demonstrated.

The PGRR has strategically invested in multiple projects to maximize the application of current JPSS capabilities and identify new ways of using JPSS data operationally. The applications from these data exploitation projects have produced numerous documented successes. The projects involve key users within NWS, National Ocean Service (NOS), National Marine Fisheries Service (NMFS) and Office of Oceanic and Atmospheric Research (OAR). A major strength of the JPSS PGRR is the ability of project leads to quickly engage users during rapidly changing environmental events to determine the best ways to leverage the JPSS observations/capabilities to their forecast problems. Projects were able to provide data from Suomi NPP that proved vital in several high impact events including Super Storm Sandy, the Colorado Rim Fire, the Yukon River Flooding in Alaska, and the South Platte River flooding in Colorado.

The JPSS PG Program's leveraging of the Community Satellite Processing Package (CSPP) for direct readout capabilities has become a cornerstone of many of the PG Projects. In Alaska, the use of direct broadcast and the CSPP algorithms are crucial to reducing latency as it gives forecasters access to JPSS products allowing them to quickly evaluate environmental conditions and rapidly disseminate information. Alaska's northern latitude is an added advantage allowing it to receive multiple, overlapping, passes of Suomi NPP every day. Due to this ready access, imagery from the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi NPP spacecraft has become critical to Alaska's operations. Alaska's WFOs, its River Forecast Office, its Aviation Weather Center, and even its Volcanic Ash Advisory Center have put VIIRS to use to respond to its extreme weather events. In support of other NOAA Line

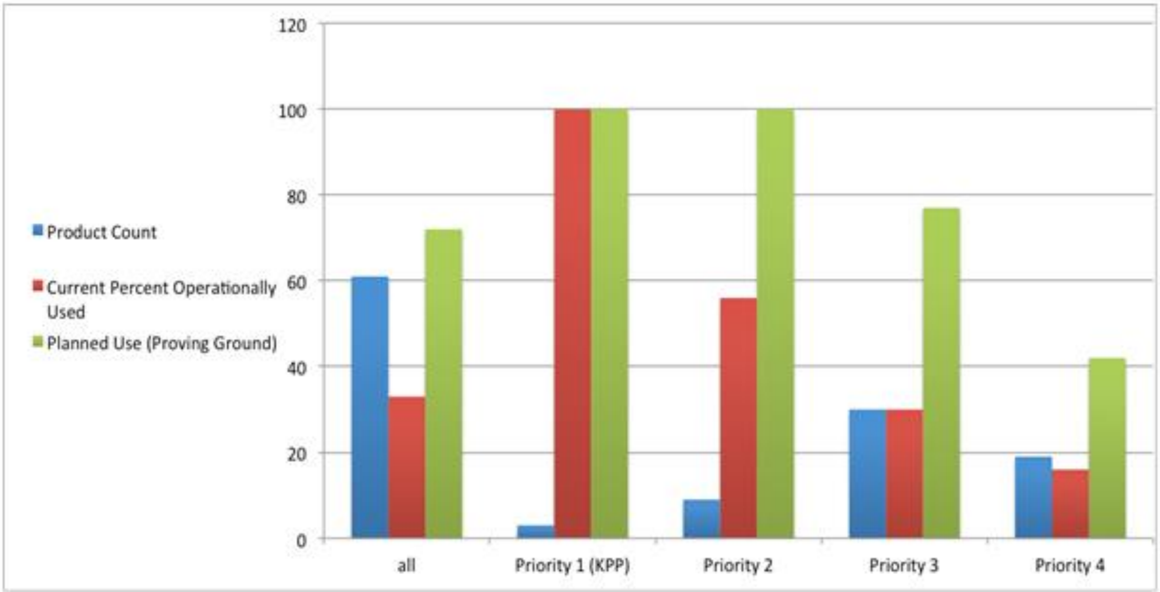
Offices, VIIRS ocean color data are being used in the NOS to monitor coastal water quality. VIIRS data are being used to detect and monitor forest fires. Projects exploiting the VIIRS Day Night Band (DNB) resulted in new discoveries, including demonstrations of the VIIRS DNB in determining tropical storm structure at night for improved short term forecasting.

Call for Proposals (CFPs)

The first JPSS PGRR Call for Proposals was made in 2012. This call drew 90 responses. A selection committee established the criteria for evaluating and selecting the applications to be funded. The result was 28 proposals that demonstrated the use and value of Suomi NPP data in various science and risk reduction applications ranging from regional and global weather forecasting; tropical cyclones; hazards such as smoke, fire, volcanic ash, air quality; Ocean/Coastal; hydrological; to data assimilation, and imagery/visualization. The weather data produced by Suomi NPP is derived from the Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), and Ozone Mapping and Profiler Suite (OMPS). Suomi NPP also flies the 5th flight model of the Cloud and Earth Radiant Energy System (CERES). However, a majority of the selected projects were based on the capabilities of the VIIRS, CrIS and ATMS sensors.

A new JPSS PGRR CFP was released in December 2014. This call was motivated by a big challenge facing the PGRR, i.e., getting the products in the hands of the operational user and ensuring their use in operations. The call garnered over 130 letters of intent. Unlike the previous call which heavily promoted the innovative use of science applications and products from JPSS, this CFP focused on maximizing the use of existing Suomi NPP products and applications in operations. Thus, in 2015, particular emphasis was placed on those products that are used to improve forecasts and warnings of fire and air quality, warnings and prediction of poor water quality in coastal regions, and drought, precipitation, snow and ice assessments and predictions.

Statistics of Operational Use and Expectation by JPSS-1 Launch (as of October 2015)



With the PGRR Program underway for over three years, the JPSS Program began looking for ways to evaluate the program's effectiveness. JPSS Products have been prioritized by the NOAA user community with the most important products being defined as Key Performance Parameters (KPPs). The remaining products are grouped into priority 2 through 4. The chart shown above gives a breakdown (based on priority level) of the operational usage of products from the PGRR. It shows that one hundred percent of the KPPs are currently used operationally. With the priority 2-4 products, the operational usage gets lower and lower. Using this evaluation method, the JPSS Program can work with the PGRR Projects and their user stakeholders to identify actions that can be taken to increase the usage of these products. The PGRR Program has a goal to double the number of JPSS data products that are used operationally within 4 years (indicated by green bars in the chart above).

Early Successes in the PGRR

The VIIRS DNB capability got a lot of attention during Super Storm Sandy in late October, 2012. With assistance of a JPSS PG representative the NWS Hurricane Center (NHC) was able to evaluate the VIIRS DNB's ability to provide a nighttime continuity with daytime visible imagery. With this capability NHC forecasters could track tropical cyclone features as the storm strengthened. The successful application of the DNB capability during Super Storm Sandy led to the DNB becoming a critical element in the forecasting of tropical cyclones in the Atlantic and Pacific Regions in all phases of their development.

More opportunities to showcase the innovations from the PGRR came in 2013, when the VIIRS Active Fire Team was able to send a participant to one of the largest wildfires in Colorado history, the West Fork Complex. The team member was able to meet with the Fire Incident Command cadre, NWS Incident Meteorologists, and other US Forest Service and National Park Service fire managers and planners. He was able to provide one-on-one briefings of Suomi NPP

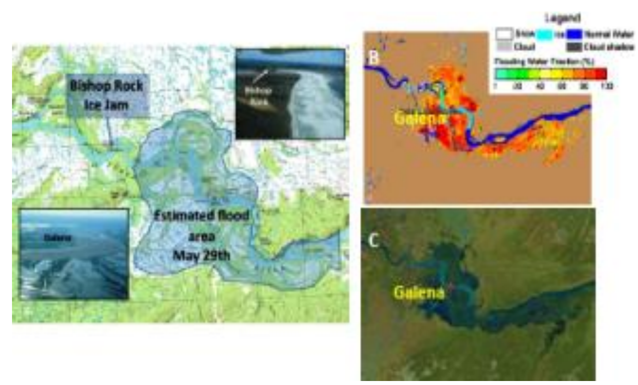
VIIRS capabilities to support the fire weather mission and receive their feedback on how satellite weather can be used more effectively. This interaction served as a model for visits to additional high visibility fires and has guided decisions on the application of the VIIRS Active Fire product.

In May 2013, two PG teams responded to a request to support severe flooding situations along the Yukon River in Alaska. One team helped designate the extent of River Ice formation and breakup using VIIRS and the other team used VIIRS to define river flooding. Both products provided critical decision making information to NWS forecasters responsible for issuing flood warnings for the region. This event prompted the development of the River Ice Flooding initiative by the JPSS PGRR in conjunction with PGRR Projects being managed by research teams at George Mason University (GMU) and the City College of Ney York (CCNY). The flood detection product from GMU is used to monitor ice jams and snowmelt, and forecast floods events, while the river Ice product from CCNY provides enhanced river ice maps with detailed information on ice location, extent, and concentration. VIIRS data for river ice and flood detection is now routinely used by NWS River Forecast Centers (RFCs), and will soon follow the path to operations.

PGRR Initiatives

Following on these successes, the PGRR Program formalized this initiative approach for all of its PGRR Projects. Two additional Initiatives, Fire and Smoke and Atmospheric Soundings were established. By 2014, all of the projects had been grouped into initiatives. In late 2014, the initiatives were then used to prepare the second JPSS PGRR CFPs. This call used the following initiatives to guide research teams in their response: Numerical Weather Prediction, Advanced Weather Information Processing System (AWIPS) Operational Demonstrations in the OCONUS and at NCEP Centers, Arctic and Cryosphere, Land Data Assimilation, Oceans and Coasts, Atmospheric Chemistry, Hydrology, Aerosol Data Assimilation, Innovation, and Training. Each initiative sets its own goals and objectives, all with the overarching goal of increasing the usage and function of Suomi-NPP and JPSS data products in operations, particularly for NOAA users. In 2015, the PGRR program selected more than 40 projects for funding under the initiatives. The following sections discuss these initiatives in more detail.

The River Ice and Flooding Initiative



A) West Interior AK map of Yukon River ice jam at Galena. B) River Ice and Flood detection products on May 29, 2013 at 1330 UTC. C) Suomi NPP VIIRS false-color satellite imagery generated at the same time.

River Flooding caused by rain, snow/ice melt and ice jams is a common hazard in the U.S. River flooding poses a serious year round threat to U.S. coasts and its territories. Coastal regions in particular, which are home to more than 8 million people, are most at risk to flooding events. This initiative initially focused on flooding due to River Ice jams in Alaska. With its early success, it expanded to river flooding due to ice jams across the northern tier of the US. The initiative then pushed its support further by providing River Flooding Products throughout NWS operational areas year round. This helped forecasters to respond to environmental events like heavy rain and coastal undulation due to tropical storms.

Over the last three winters, this Initiative has tested river ice and flood products in operational NWS RFC environments. Because of bandwidth limitations as well as the latency of getting data to WFOs through conventional ground system distribution methods, direct readout became very attractive for these applications. Data is taken from direct broadcast antennas and then processed in near-real time into the river ice and flooding products. These products are then made available to RFC forecasters on their workstations in a user-ready format. Each year, more RFCs requested to participate in this initiative. The feedback from these forecasters will greatly influence the design of and application of these River Ice and Flooding Products in the future.

Numerous large wildfires burn across sections of northern Baja and southern California, producing plumes of moderate to dense smoke that combine with blowing dust/sand move west off the coast and well into the Pacific Ocean. May 15, 2014 image, captured by the VIIRS instrument on the Suomi NPP satellite. Credit: NOAA Visualization Lab

The Fire and Smoke Initiative

Wildfires have detrimental effect on human health and economy. The societal impacts from fire and smoke include the destruction of forest and rangeland vegetation, wildlife habitat, adverse impacts on recreation, tourism, and water quality. Smoke emissions are a major source of Greenhouse Gases. In addition, they affect air quality and are a major health hazard. As an example, in May 2014 a swarm of 14 wildfires erupted in San Diego County, California. By the time the last blaze was extinguished, approximately 26,000 acres of land had burned and an estimated 65 structures had been destroyed. Private property owners incurred an estimated $29.8 million in damages.

Those responsible to support the response to these fires are searching for capabilities that, among other things, can successfully use models to predict fire spread and forecast smoke, detect small fires in remote areas, or estimate the radiative power of fires. Success in these areas will help determine the short and long-term impacts of fire and are essential for effective risk assessment, policy formation, and disaster and resource management.

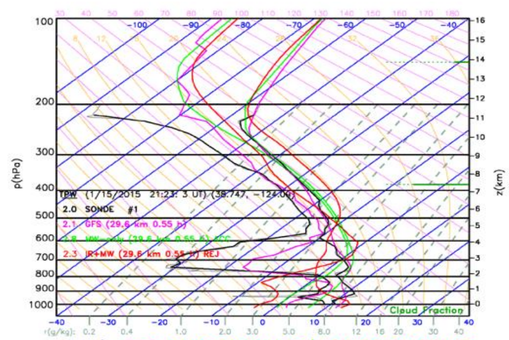
The Fire and Smoke (F&S) Initiative was established in 2014. This initiative evaluates a variety of fire, aerosol and smoke products from polar-orbiting and geostationary satellites in support of the U.S. Fire and Smoke mission. Tasks under the F&S initiative include evaluating the operational use of the VIIRS Active Fire Product in the NWS Advanced Weather Interactive Processing System (AWIPS). Projects in this initiative are researching how best to track smoke and aerosol movement from fires, identify where this smoke may stay aloft or stay close to the ground. The JPSS fire radiative power will be assimilated into the High Resolution Rapid Refresh (HRRR)

Model to generate better forecasts for air quality purposes. This initiative has begun to look at a Blended Fire and Smoke Product. A beta version of this product will be demonstrated to NWS Incident Meteorologists to get their feedback on how this product could be used operationally.

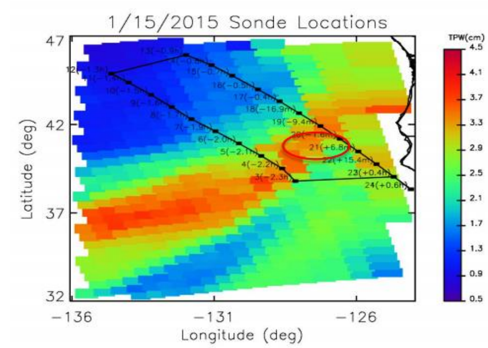
The Sounding Initiative

Modern sounders such as ATMS and CrIS contain a wealth of information about atmospheric temperature, humidity, and composition of trace gases. Hyperspectral infrared instruments have been shown to have the largest single instrument impact on global forecast models even though only the cloud-free portions of atmosphere have been used. The projects within this initiative mainly focus on the NOAA-Unique Combined Atmospheric Processing System (NUCAPS), which combines both the microwave (e.g. ATMS) and infrared (e.g. CrIS) sounding measurements to exploit the full information content of these space-borne assets. NUCAPS is based on the NASA AIRS algorithm and leverages two decades of algorithm research and validation. NUCAPS relies on a technique called 'cloud clearing' to remove the effect of clouds so that atmospheric information can be obtained all the way to the surface, the region that is most relevant for most weather applications, also in presence of clouds. The primary goal of this initiative is to promote new applications, with a secondary goal to encourage interaction between developers and users to tailor NUCAPS to applications.

When the NUCAPS initiative was established in July 2014, the initial work focused on the use of NUCAPS soundings in Alaskan winters, in convective environments, and to help support Atmospheric River research. NUCAPS soundings gave great insight into cold air aloft where temperature less than -65 degrees impacted the viscosity of fuel in passenger and cargo aircraft. Less efficient fuel usage causes increased cost and longer flight times. Aviation forecasters found these soundings were able to identify these key cold areas in their most data sparse regions. Forecasters evaluated NUCAPS in convective environments during the Spring Experiment in 2015. Their feedback highlighted the value of these soundings to bridge the gap between rawinsonde launches every 12 hours. NUCAPS Soundings (right) were used as input to aircraft flight time and route decisions during CalWater 2015, a research field campaign studying Atmospheric Rivers. The successful application of NUCAPS soundings led to the decision to use them in future field campaigns, such as the 2016 El Nino Rapid Response Campaign and the 2016 Hazardous Weather Experiment. Furthermore, this led to additional projects being funded to study the operational applications of this important capability.



Sonde, GFS, NUCAPS MW-Only, NUCAPS MW+IR
(GFS interpolated at NUCAPS location)

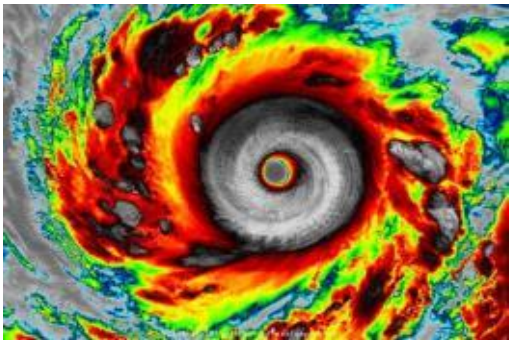


Near Real time NUCAPS TPW snapshot using NPP 2230UT overpass, overlapped with the G-IV flight track. Dots indicate drop sonde locations. Point 20: closest NUCAPS-drop sonde match (1.6 minutes apart)

Figures courtesy of Gambacorta et al., CSPP/IMAPP Meeting, 2015.

http://www.ssec.wisc.edu/meetings/cspp/2015/Agenda%20PDF/Thursday/Gambacorta_NUCAPS.pdf

The NWP Impact Studies and Critical Weather Applications Initiative

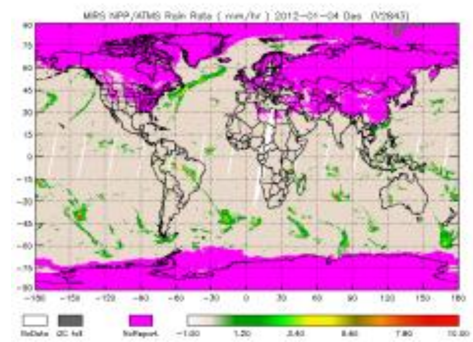


Infrared VIIRS image, October 7, 2014

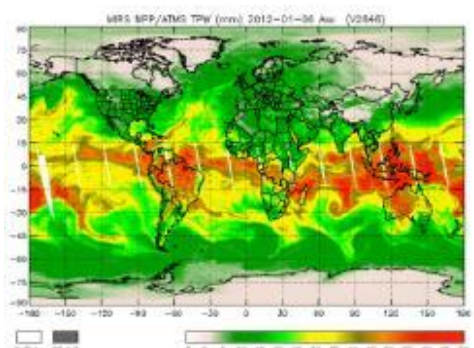
In order to provide feedback on the capabilities of next generation instruments such as CrIS and ATMS, studies on their impact on the Global Forecast System (GFS), the HRRR and other operational models are needed to evaluate their performance in context with legacy sounders. In addition, studies are needed to demonstrate the value of lower latency. The focus of projects within this initiative range from, the use of sounder data products for improving tropical cyclones and other severe weather events and estimating the intensity of hurricanes, to the use of a proactive quality control (PQC) in ensemble data assimilation.

The OCONUS and NCEP AWIPS Initiative

The Outside CONtiguous United States (OCONUS) region includes Alaska, Hawaii, United States unincorporated territories (e.g., Puerto Rico), and adjacent coastal waters, as well as portions of the Pacific Ocean and Atlantic Ocean that are of interest to the United States for safe aviation and maritime shipping. Due to limited observation networks relative to the contiguous United States, these areas are dependent on satellite imagery and products and primarily use data through direct readout. The projects within this initiative seek new and innovative applications for satellite imagery, products, and derivatives which exploit the information from polar-orbiting satellites. The goal is to improve the analysis and forecast of weather phenomena, using data from Suomi NPP and the Japan Aerospace Exploration Agency (JAXA) Global Change Observation Mission. The capabilities of the CrIS and ATMS sensors on Suomi NPP and the Advanced Microwave Scanning Radiometer-2 (AMSR-2) sensor onboard GCOM-W1 satellite provide more detailed atmospheric thermal structures, and have a direct impact on the improvement of tropical cyclone forecasting. Priority applications under this initiative, include techniques that limit the impact of space and time gaps between polar-orbiting satellite passes; improvements to current satellite products and imagery that make them more useful in data sparse regions; concepts that apply satellite data to address longstanding forecast concerns (e.g., ice, very cold tropospheric temperatures, fog, etc.), and innovations for displaying and interacting qualitative and quantitative data.



Rain Rates

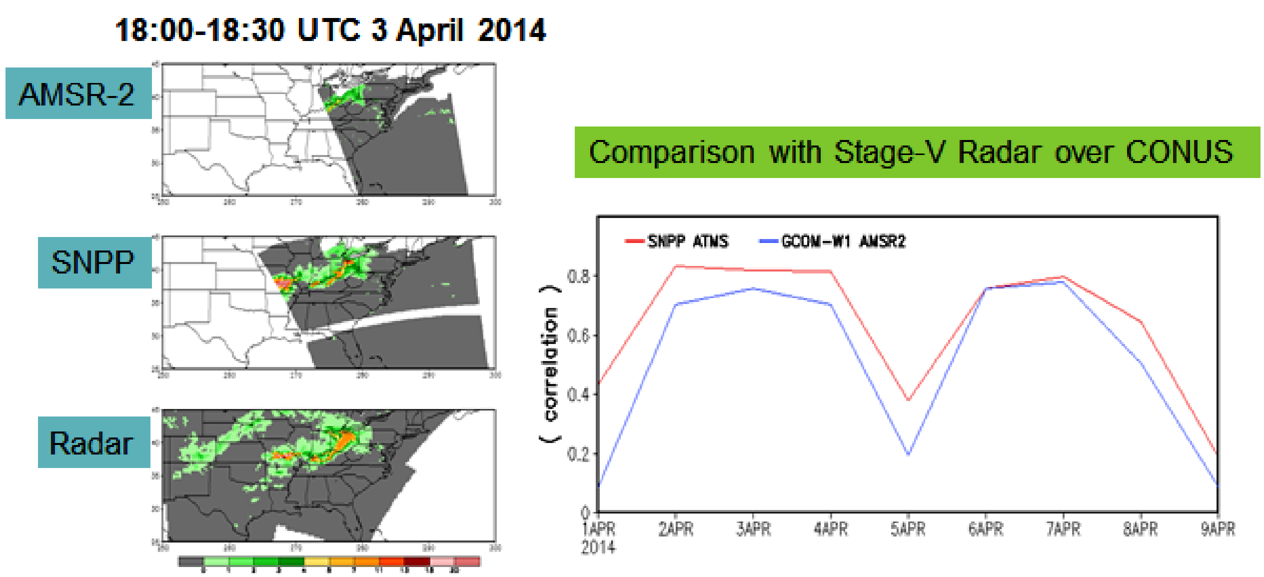


Total Precipitable Water

The Hydrology Initiative

Precipitation is a crucial link in the hydrologic cycle, and its large spatial and temporal variations are drivers for regional hydrology and global fresh water balance. Accurate knowledge of the timing and spatial distributions and amount of regional rainfall is essential to make accurate, short-term forecasts. Rainfall also drives the hydrological cycle, and to improve weather and climate predictions, an accurate global coverage of rainfall records is necessary. The projects within this initiative generate precipitation products from Suomi-NPP and GCOM-AMSR to improve NOAA precipitation and related hydrological applications. These include improvements to precipitation retrievals under conditions of orographic forcing, where conventional retrieval algorithms are known to break down; activities that employ synergistic uses of VIIRS with ATMS or AMSR-2 to improve rainfall and snowfall retrieval; and regional algorithm development and application to exploit direct broadcast data. They also use similar products from the DMSP SSMIS, MetOp MHS and GPM DPR/GMI.

The figure below (left) shows a heavy precipitation event associated with a large-scale synoptic system that was captured by the Suomi NPP/ATMS based retrievals, with a wider spatial coverage than that for the retrievals from AMSR-2. Further quantitative comparisons against the Stage-V radar estimates over CONUS (the figure on the right side) demonstrate the superior quantitative accuracy of the NESDIS Microwave Integrated Retrieval System (MIRS) ATMS retrievals compared to that of the AMSR-2.

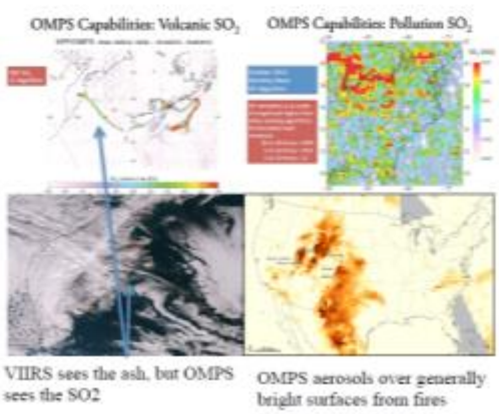


The Oceans and Coasts Initiative

The JPSS program ensures that ocean satellite data are available for meeting the ocean and coastal service areas of NOAA. VIIRS Sea Surface Temperature (SST), Ocean Color Radiometry (OCR), and VIIRS Imagery environmental data is integral to the missions of the NMFS, NOS, NWS, and OAR. This Initiative's overarching goal is to support the activities that provide users with fit-for-purpose, accurate, consistent and timely ocean data and derived products from VIIRS. Given the diversity of users, efforts under this initiative incorporate and tailor data to meet their requirements. Such efforts may include (but are not limited to):

optimizing data scenes in time and space (e.g. resolution needs, gap filling issues, cloud/feature detection); generating consistent and accurate time series; integrating data from multiple sources; characterizing uncertainties; identifying why, when, where and how global approaches are underperforming (e.g. coastal and inland water); ensuring routine, sustained and easy access to and utilization of the best quality ocean satellite data, in appropriate formats and map projections, and including both near-real time products and retrospective data (e.g., for anomaly and trend detection). Activities under this initiative include the development of a new technique for VIIRS Detection of Harmful Algal Blooms (HABS), facilitating the use of VIIRS ocean color data, developing algorithms and user services for near real time (NRT) reporting of VIIRS boat detections (VBDs), and evaluating approaches and developing a prototype foundational global biogeochemical modeling capability for NOAA's operational Real-Time Ocean Forecast System (RTOFS).

VIIRS coastal true color image of Lake Erie, August 3, 2014 depicting the large bloom of the cyanobacterium, Microcystis sp. threatened the water supply of Toledo, OH

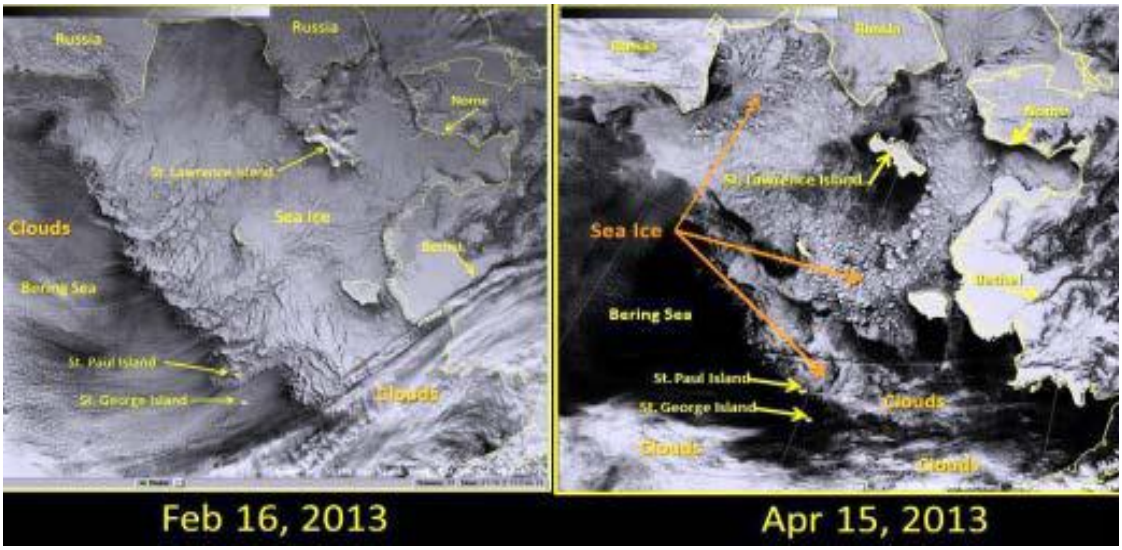


The Atmospheric Chemistry Initiative

The OMPS Nadir instrument makes measurements with high information content on atmospheric SO2 and UV absorbing aerosols (including volcanic ash). The goal of this initiative is to increase the utilization of the JPSS atmospheric chemistry products, including improved SO2 and aerosol products. Projects in this initiative will use models to interpolate sparse aircraft observations to the satellite temporal, spatial, and vertical sampling characteristics for detailed validation.

The Cryosphere Initiative

Due to the remoteness of most snow- and ice-covered areas, satellite remote sensing is essential for delivering sustained, consistent observations that can be used for weather forecasting, ice operations, climate prediction, research, and engineering. While many satellite-derived snow and ice products have been developed, they are underutilized in weather, hydrology, and climate models and applications. The projects within this initiative mainly focus on improving the utilization of JPSS and other snow and ice products in numerical weather prediction, hydrological analysis and forecasting, climate reanalyses, and ice operations.



VIIRS image comparison between February 16th and April 15th, 2013 shows sea ice melt, especially near St. Lawrence Island and south of Nunivak Island. (Image courtesy of NWS Alaska)

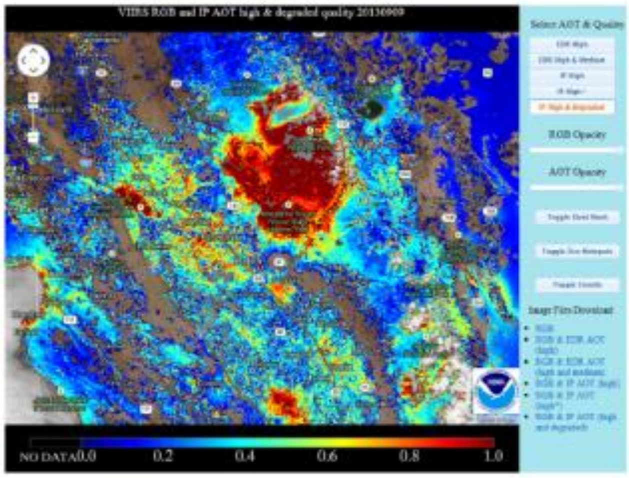
The Training Initiative

Not a complete photo – 9 people missing

The need for training has been recognized as an essential ingredient in successfully transitioning products into operational use and in NOAA's vision for a world-class workforce to support NOAA's mission of "Science, Service, and Stewardship". The projects within this initiative focus on improving the user community's utilization of JPSS products and applications. For example, one project plans to make VIIRS datasets easily available on a server commonly used by the NMFS and the NOS. In addition, training sessions that demonstrate the easy accessibility of these datasets will be given. Another project plans to utilize the international virtual lab training activities, which aims to promote the access, display, and use of JPSS images and products in the international community.

The Innovation Initiative

Innovation is critical to keep NOAA science fresh and cutting edge. This Initiative is designed to proactively meet the diverse and evolving needs of NOAA's user communities by generating much-needed "out-of-the-box" ideas and concepts and applying them toward societal benefits. The information content from the Suomi NPP sensors holds the potential to develop new applications that were not envisioned as part of the original scope of any particular sensor. Some concepts being explored include the use of soil moisture products for flood monitoring, and leveraging high-resolution VIIRS imager data and using it to develop new remote sensing products for planetary boundary layer (PBL) convective clouds.



The Aerosol Data Assimilation Initiative

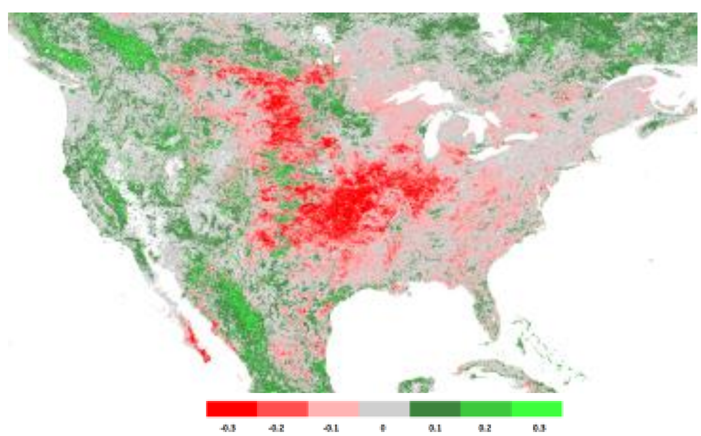
Numerical prediction of aerosols using regional and global prognostic models has become a critical activity at operational and research weather prediction centers to meet various stakeholder needs such as weather, UV Index, air quality, ocean productivity, visibility, and sea surface temperature forecasting and warnings.

The accuracy of numerical aerosol predictions hinges on the correct representation of aerosol sources and sinks in the models. Near real time observations of aerosols including optical depth and composition from satellites can be assimilated to account for deficiencies in sources and sinks in the models and to improve the accuracy of predictions. The projects within this initiative make use and demonstrate the value of VIIRS aerosol optical depth, aerosol (smoke, dust, volcanic ash) detection, and OMPS UV Aerosol Index products in improving forecasts.

The Land Data Assimilation Initiative

Proper characterization of land surface conditions is critical to accurately describe and model land atmosphere interactions in numerical environmental modeling. Various satellite-based data products provide large-scale, continuous information on vegetation amount, condition and functioning, soil moisture, radiative properties, hydrological conditions including snow cover and disturbances that affect exchanges of momentum, energy and moisture. Accurate characterization and modeling of land-atmosphere interactions lead to more accurate weather forecasts, in particular, over areas and during time periods with anomalous conditions such as droughts.

The overarching goal of this initiative is to maximize the utilization of JPSS land surface environmental data products by the NOAA NWP community. Top priority is given and initial efforts will focus on the utilization of Green Vegetation Fraction (GVF) and Land Surface Temperature (LST), and the soil moisture products from the Suomi NPP or GCOM satellites.



VIIRS GVF difference (15 Aug 2012 minus 15 Aug 2014)

Summary

The JPSS PGRR Program helps forecasters become familiar with the new products and applications derived from Suomi NPP observations. It also allows for feedback from forecasters that will help produce the most useful products for operations. As a result, researchers in the

PGRR are constantly developing new applications for and products from Suomi NPP as well as for the advanced instruments as they come online. Part of the Program's success stems from its Cal/Val program which utilizes the feedback given to the PGRR by the user community to identify improvements needed for data products.

The JPSS PGRR Program has provided key pathways for the effective transition of current and future capabilities from research to operations. The program's vision for innovative uses of Suomi NPP data has led to the evaluation and testing of new products and the better application of current products. The JPSS stakeholder can then determine how best to fully integrate these capabilities into their support toolkit. There are numerous success stories. For example, the use of VIIRS for cloud imagery, fire/smoke monitoring, fog detection, and ice detection are now routine. The VIIRS ocean color and SST products are now fully leveraged by the NMFS and the NOS to meet their users' needs. The JPSS PGRR Program initiatives continue to further promote the use of Suomi NPP data for operational use by engaging NOAA users in even more activities. These activities range from the assimilation of VIIRS aerosols and land products in NCEP global models; assimilation of VIIRS snow fraction and ATMS snow information in hydrological models; better utilization of CrIS/ATMS soundings by forecasters; improved use of VIIRS, ATMS and AMSR-2 for nowcasting imagery; better assimilation of CrIS in NCEP models; and the use of CrIS and ATMS in regional models via direct broadcast.

As user communities' needs continue to grow and change, particularly as the volumes of data generated are only get bigger, the PGRR Program is committed to providing the highest quality data products and applications. Following the PGRR Initiative approach, even more successes can be anticipated as the NOAA Line Offices and its customers prepare for the JPSS-1 products after its launch in 2017.

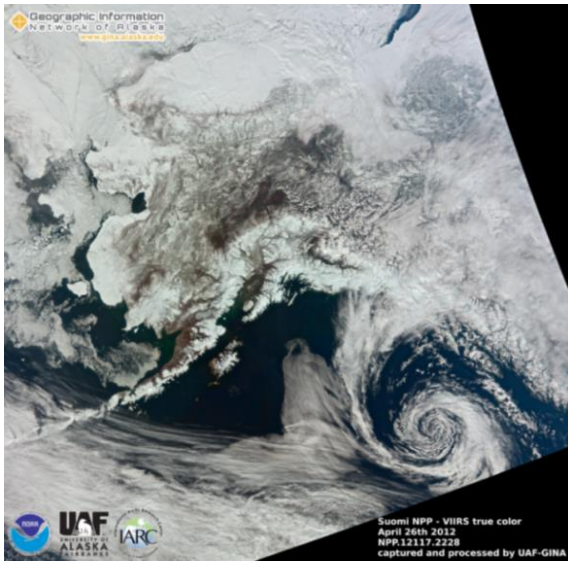
JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Faster, Better, More: Upgraded Support For NWS Alaska Courtesy of The Geographic Information Network of Alaska's (GINA) "Sandy Dog" Antenna

This article is based in part on the ***December 7, 2016*** *JPSS science seminar presented by Eric Stevens, Geographic Information Network of Alaska (GINA), University of Alaska Fairbanks.*

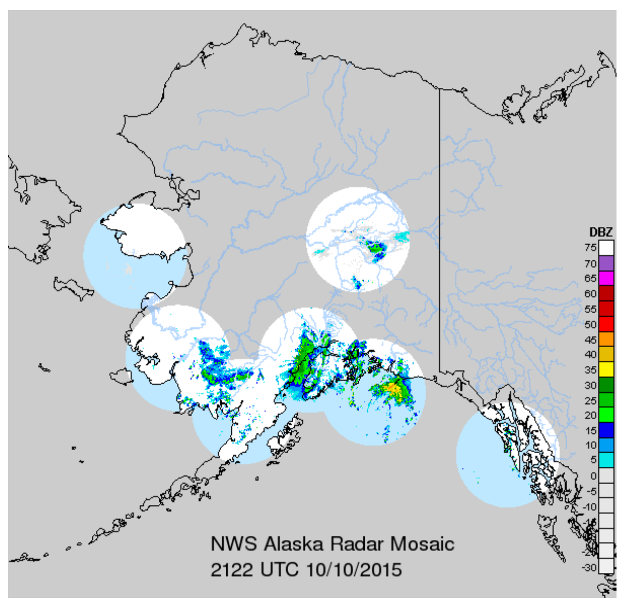
Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg



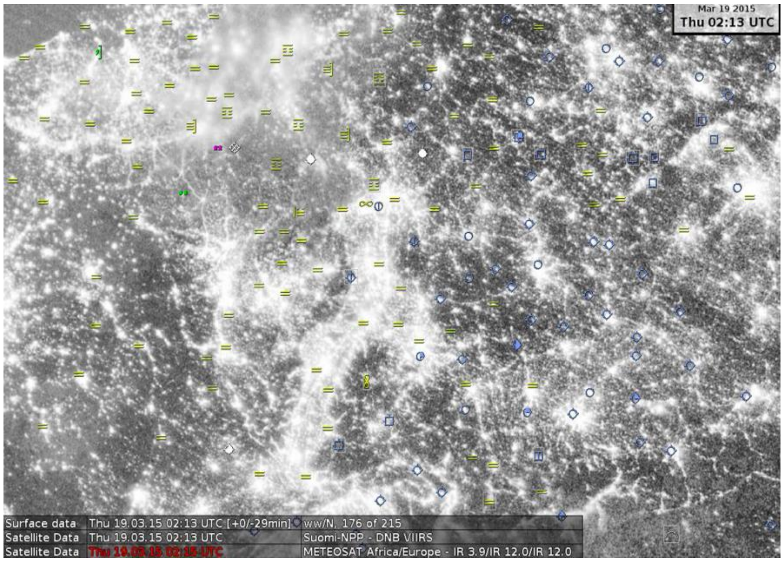
Weather satellites give forecasters vital information about the current state of the atmosphere. Knowing what the weather is doing now is the first critical step in accurately forecasting what the weather will do in the future. The image shown left was captured in April 2012 by the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor aboard NOAA's primary polar-orbiting satellite, the Suomi National Polar-orbiting Partnership (Suomi NPP). This satellite is also the first next-generation polar-orbiting satellite in the Joint Polar Satellite System (JPSS) constellation. This VIIRS image provides incredible detail including a storm in the southeastern Gulf of Alaska, sea ice in the Bering Sea and over the Arctic Ocean, as well as areas of bare ground emerging over lower elevations in Alaska's Interior as the winter snowpack begins to melt.

The Alaskan Challenge

In the 'Lower' 48 contiguous States, or CONUS, geostationary satellites are the mainstay of short-range forecasting. Polar-orbiting satellites feed data into numerical weather prediction (NWP) models to generate forecasts one to seven days in advance. So, simply stated, geostationary satellites are used predominately for weather surveillance, while polar orbiters are used mainly to drive NWP models. While this arrangement is true for the CONUS, things are slightly different in Alaska. Why? ***Because Alaska is different!*** In some respects, this difference is a disadvantage. Alaska lags behind the Lower 48 in the density of National Weather Service (NWS) radar stations (see right figure) and other observing systems like weather balloons and surface observations. Geostationary satellites orbit the earth above the equator. Due to the curvature of the Earth, geostationary satellites looking at Alaska suffer from a large viewing angle and associated problems such as parallax and degraded spatial resolution.

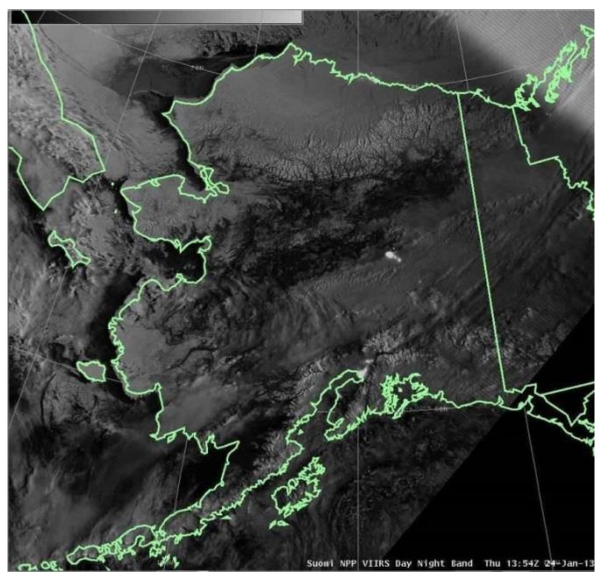


But the upside of "Alaska is different" is that, thanks to its high latitude, Alaska enjoys more frequent passes from polar-orbiting satellites than any other part of the United States. This includes multiple overlapping daily passes from Suomi NPP. In fact, polar orbiters fly over Alaska so frequently that, in addition to supplying data to the NWP models, they are a viable tool for weather surveillance. Since the launch of Suomi NPP in 2011, imagery from the VIIRS has become critical to Alaska's operations. NWS WFOs in Alaska, the River Forecast Center (RFC), the Aviation Weather Center (AWC), and even the Volcanic Ash Advisory Center (VAAC) are employing VIIRS to respond to extreme weather events.



From November to January Fairbanks receives less than four hours of daylight, and areas north of Fairbanks get literally no sunlight. During this extended darkness, the VIIRS day-night-band (DNB) provides visible-like imagery at a sharpness that has never been available before. Another upside of "Alaska is different" is that, thanks to Alaska's very low population (only 700,000 people in a state more than two times the size of Texas) there is very little light pollution in the DNB to obscure the weather and terrain features.

Above left is a VIIRS DNB image taken over the densely populated areas of North Eastern France, Belgium and Western Germany. Because of these dense populations, there is a lot of lighting from anthropogenic sources. These anthropogenic light sources can obscure the meteorological signal and detract forecasters from using the DNB. In comparison, the image on the right, also from the DNB, was captured during a pass over Alaska. As much of Alaska is devoid of light pollution, it is much easier for satellites to capture meteorological features.



GINA Supporting Alaskan Weather Forecast Operations

The Geographic Information Network of Alaska (GINA) is part of the Geophysical Institute (GI) at the University of Alaska Fairbanks (UAF). GINA's mission is to "promote collaboration at the local, state, and federal levels by increasing community-wide participation in the discovery and use of geospatial data[1]." Its strong partnership with the NWS in Alaska and long history of leading-edge research in Alaskan weather and other environmental issues made it an ideal fit for working with this initiative.

GINA receives data from a number of polar-orbiting satellites via these direct broadcast antennas. These data are then processed in near-real time into imagery at GINA via the University of Wisconsin's Community Satellite Processing Package (CSPP) and other software, and then distributed within minutes through the High Latitude Proving Ground (HLPG)[2] to users such as the NWS. This arrangement delivers satellite imagery to NWS Alaska at lower latency than any other method. This is a significant advantage, as the best satellite product does a meteorologist no good if it arrives too late to be used in making a forecast.

Demonstrating the Value of Polar Data: Superstorm Sandy

Hyperspectral sounders such as the Cross-track Infrared Sounder (CrIS) and microwave sounders such as the Advanced Technology Microwave Sounder (ATMS) on Suomi NPP supply temperature and moisture information throughout the atmosphere. The importance of soundings in predicting the future state of the atmosphere was demonstrated in late October 2012, during one of the worst storms to ever hit the East Coast—Superstorm Sandy. Sandy impacted more than a dozen states and completely decimated some of the neighborhoods in its path. One of the few bright spots in the Sandy event was the accuracy of NWP models in predicting its track. A post-event analysis revealed that without sounder data from polar orbiting satellites the predicted track of Sandy would have been hundreds of miles off.

In the aftermath of Sandy, the U.S. Congress allocated funds to various agencies, including the National Oceanic and Atmospheric Administration (NOAA), to improve and streamline disaster assistance. One of NOAA's objectives for the use of Sandy funds was to ensure continuity of polar-orbiting data in the NWS Alaska Region, where it plays an outsize role in successful operations. To achieve this objective, NOAA funded a Sandy Supplemental project managed by the Geographic Information Network of Alaska that oversaw the installation of a new, 3.0 meter, X, L, and S band antenna at NOAA's Fairbanks Command and Data Acquisition Station (FCDAS). In addition to new direct broadcast antenna, GINA used its Sandy Supplemental funds to also acquire associated processing hardware, which significantly upgraded its ability to receive and deliver satellite imagery. These upgrades allow GINA to track more weather

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[1] http://www.gina.alaska.edu/

[2] Supported by the JPSS and GOES-R program offices

satellites, and each of its two antennas provides a redundancy that ensures there is no interruption in the flow of this vital data.

The Sandy Project Serves Alaska a New Dish

Stemming from collaborative efforts between NOAA via the JPSS Proving Ground and Risk Reduction (PGRR) Program, the NWS, and GINA, a new 3.0 meter X, L, and S band antenna from Orbital Systems was installed in April 2015 at FCDAS. This installation ran concurrent with NWS communication upgrades.

The addition of this antenna dubbed "Sandy Dog" now complements GINA's legacy antenna, the 3.6m X-band "Big Dog", to allow the tracking of more satellites with fewer conflicts, and also increase robustness and improve reliability in the delivery of satellite data. In addition to Sandy Dog, computer processors at GINA were upgraded, and new hardware was installed at the NOAA/NESDIS operation at Gilmore Creek and the NWS Alaska Region's Arctic Testbed. To accommodate the increased volume of satellite data, a direct communications link to the NWS was established. This provided a significant increase in bandwidth between the NWS Alaska Region Headquarters and the WFOs at Fairbanks, Juneau, and Anchorage; a high-speed network presence at the 24/7 NESDIS FCDAS satellite reception facility; and faster and more reliable delivery of satellite products via the Local Data Manager (LDM) feed into the Advanced Weather Interactive Processing System (AWIPS). The new processing hardware and software have further minimized the latency in delivering vital imagery to NWS forecasters in Alaska.

GINA, NWS, and NESDIS are working actively to transition these systems from research to operations. One of the primary benefits of having the new Sandy Dog antenna sited at FCDAS is the availability of 24/7 operations monitoring staff. Over the coming years, the systems at FCDAS built out through the Sandy funds will be transitioned to NWS ownership and shared operations among GINA, NWS, and NESDIS. This will be a significant research to operations (R2O) success story that benefits the NWS and its stakeholders through reliable, low latency access to polar orbiting satellite data.

More Channels and New Products Bring New Opportunities for Alaska

NWS forecasters in Alaska now have more products available in less time. Comparing the "before Sandy" and "after Sandy" VIIRS menus shows there are now more than twice as many products available to forecasters.

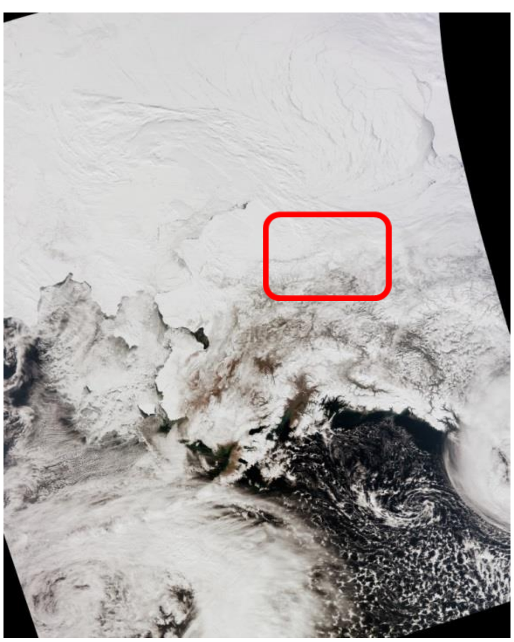
VIIRS menu before Sandy

VIIRS menu after Sandy

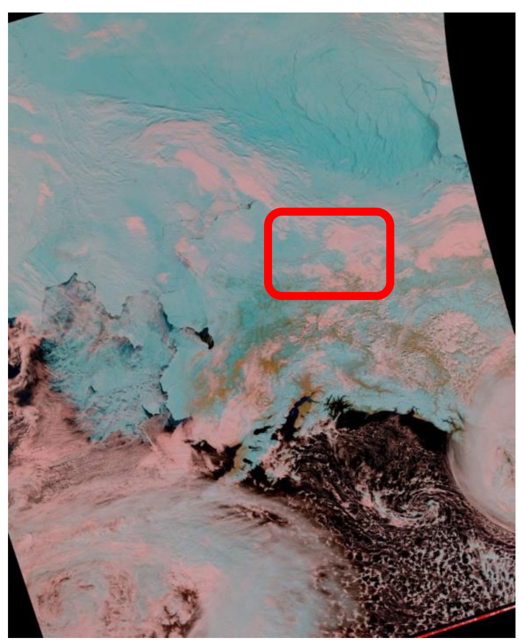
Each of the channels shown in the above menu can be interrogated on its own. Additionally, a number of these individual channels can be combined into multispectral images or "RGBs" which stands for red, green, and blue. Multispectral imagery reveals atmospheric and surface features that are hard to distinguish with single channel images alone and also offer a savings in time since RGBs let forecasters interrogate several satellite channels by looking at just one product.

RGBs address specific needs such as detecting snow cover, volcanic ash, fire hotspots/smoke, and flooding due to river ice break up. In conventional "true color" imagery, clouds and snow both appear white, and it can be very difficult to differentiate cloudy areas from areas that are free of clouds but covered by snow or ice. The two images below are from the same VIIRS pass in April of 2015. The conventional true color image is at left, and the "Natural Color RGB" is at right.

True Color:
0.49um to 0.67um

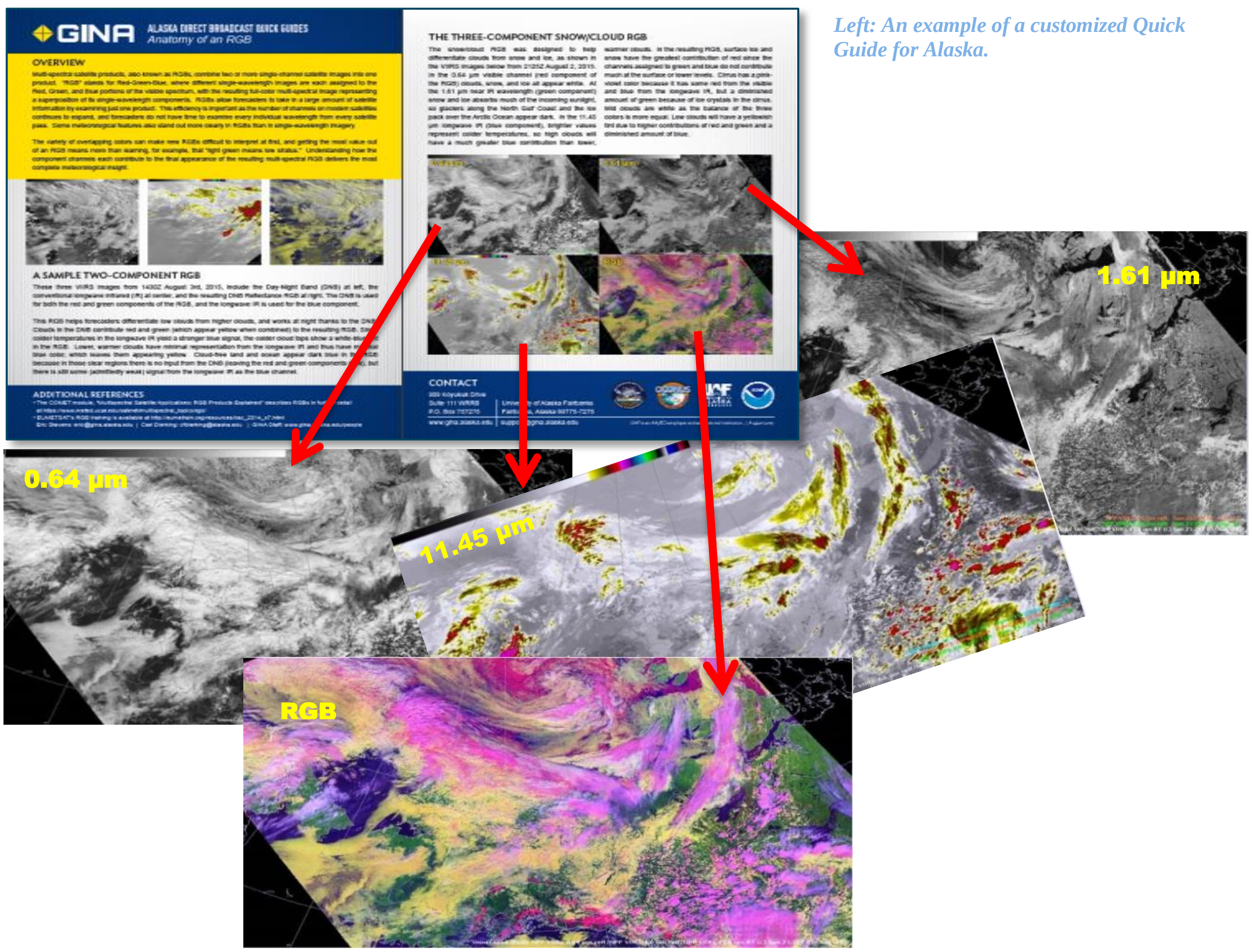


Natural Color:
0.64um to 1.61um



The strength of the Natural Color RGB is that it combines different VIIRS channels such that liquid-phase clouds appear pink, while snow-covered ground and ice-covered ocean appear blue. Consider the area within the red box: in the True Color image it is near impossible to identify the patches of clouds, while such identification is easy using the Natural Color RGB. Pilots need accurate forecasts of clouds in complex terrain, and tools like the Natural Color RGB allow the NWS to give pilots such forecasts.

To accelerate the integration of these new products into NWS operations in Alaska, GINA developed a series of "quick guides" such as the "Anatomy of an RGB" Quick Guide shown below, as references for NWS meteorologists. The intent was to familiarize operational forecasters with the basic characteristics of these resources and how they address the region's forecast challenges. These Quick Guides were modelled after similar Quick Guides produced by NASA's Short-term Prediction Research and Transition Center and are concise enough to be used quickly during a busy forecast shift. Each Quick Guide is a single double-sided document that addresses a specific imagery product or technical aspect of the various satellites and their instruments, with an emphasis on its real-world application in an Alaskan forecasting context.



Left: An example of a customized Quick Guide for Alaska.

The zoomed–in images from the Quick Guide example above were captured by the VIIRS sensor from 2125Z August 2, 2015. On the left is the 0.64µm visible channel (red component of the RGB) in which clouds, snow and ice all appear white, which can make it challenging to distinguish between these features. On the right is the 1.61µm near infrared (IR) wavelength (green component in the RGB) which absorbs much of the incoming sunlight, thus glaciers along the North Gulf Coast and the ice pack over the Arctic Ocean appear dark. In the center is the VIIRS 11.45µm longwave IR band, which is the blue component in the RGB. In this channel brighter values represent colder temperatures, so high clouds will have a much greater blue contribution than lower, warmer clouds.

More Resources

Besides timely delivery of JPSS products to the operational user, the PGRR works with NOAA's operational forecasters to ensure their access to the full portfolio of JPSS satellite data, products and services. The PGRR also ensures that forecasters are able to transition these capabilities into their operational missions as quickly and effectively as possible. Consequently, the GINA HLPG is planning a multi-faceted approach to integrating these products into the NWS forecast process in Alaska. Future plans to familiarize the operational forecasters in the region with JPSS data products include developing additional Quick Guides, with the goal that every GINA satellite product available in AWIPS at Alaska's NWS field offices will have its corresponding Quick Guide; collaborating with the NWS Arctic Testbed in Anchorage to develop new products relevant to Alaska; customizing existing products to better suit Alaska; and obtaining feedback that will help determine how to best use these satellite products in the NWS' forecast process.

SUMMARY

National Weather Service forecasters in Alaska face a difficult challenge. Their areas of responsibility are huge and topographically complex, and the observing systems that monitor current weather are not up to the standards of those in the CONUS. However, Alaska does have an advantage with polar orbiting weather satellites. Due to its high latitude, Alaska gets very frequent coverage from polar orbiters including the Suomi NPP satellite. Polar-orbiting satellites provide Alaska with the much needed imagery and products useful for both research and operations. More than that, the spatially comprehensive and nearly continuous coverage they provide makes them effective and essential systems for monitoring rapidly changing environmental conditions in the region.

With funding from the JPSS PGRR program, a new direct broadcast antenna was installed outside Fairbanks, Alaska. The acquisition of “Sandy Dog” complements the legacy “Big Dog” antenna and has expanded GINA's capacity to receive and process direct broadcast data from Suomi NPP and other polar-orbiting weather satellites. These systems will make the leap from research to operations in the coming years. This project has led to improvements in the number of channels available, near-real time processing, and system redundancy/availability. With the benefit of the HLPG, operational forecasters in Alaska now have a wide variety of products, including multispectral RGBs, which are helping address forecast needs such as detecting snow cover, volcanic ash, fire hotspots/smoke, and flooding due to river ice break up. Efforts taking place in the HLPG represent a continuation of innovative research that has lead, and will continue to lead, to improvements in operational weather applications.

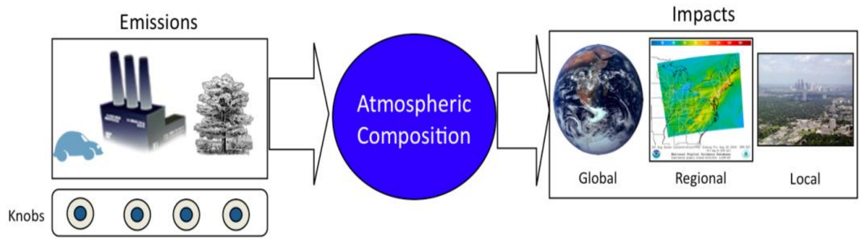
Through funding from the JPSS PGRR, GINA is now able to offer the Alaska region NWS "faster, better and more" environmental products and services that will ensure that the forecasters are better equipped to wrestle with the region's complex weather patterns and provide the best possible weather forecasts and warnings to the Alaska public.

Understanding Emissions and Tropospheric Chemistry using Observations from the Joint Polar Satellite System

This article is based in part on the ***January 28, 2016*** *JPSS science seminar presented by Gregory Frost, NOAA OAR ESRL.*
Project Contributors: ESRL: S. McKeen, R. Ahmadov, S.-W. Kim, M. Trainer, Y. Cui, W. Angevine, B. McDonald, T. Ryerson, J. Peischl, J. Roberts, J. Gilman, J. deGouw, C. Warneke, C. Granier, K. Rosenlof, J. Brioude
Science and Technology Corporation (STC): C. Barnet, A. Gambacorta, and N. Smith
NOAA NESDIS STAR: R. B. Pierce
NOAA NESDIS NCEI OGSSD: C. Elvidge

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg

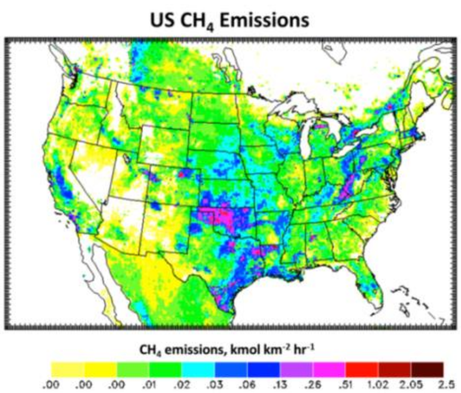
Emissions are releases of gases and particles into the atmosphere from natural or anthropogenic sources, and even though all emitted substances are not air pollutants, many can cause significant health and environmental problems. To understand and make decisions about addressing poor air quality and a changing climate, the amount of pollutants emitted into the air must be quantified. Emissions inventories prepared by regulatory agencies and other entities incorporate detailed understanding of pollutant sources and serve as inputs to computer models that simulate the past, present and future state of the atmosphere. Given the complexity of inventory datasets, atmospheric observations of pollutants in the atmosphere offer opportunities for evaluation of these important model inputs.



To better understand emissions, particularly, methane (CH_4) and carbon monoxide (CO), and their impacts on air quality and climate, a Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) project with NOAA's Earth System Research Laboratory (ESRL) is using NOAA aircraft field measurements along with atmospheric chemical-transport models to characterize the quality of NUCAPS trace gas retrievals. NUCAPS, or the NOAA Unique Combined Atmospheric Processing System, is the operational retrieval system for sounding products from the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) pair on the JPSS; NOAA's operational weather satellite in polar orbit. JPSS' first flight mission began with the launch of the Suomi National Polar-orbiting Partnership, or Suomi NPP in October of 2011. While the focus here is on the Suomi NPP instruments, it is important to note that NUCAPS can generate retrieval products for sounder pairs on any of the polar-orbiting platforms, including the operational European MetOp as well as follow-on JPSS spacecraft. This platform independence allows the combination of NUCAPS sounder products from different times of the day (as determined by the overpass time of the various spacecraft), thus making it ideal for use in environmental monitoring. The NUCAPS sounder products include profiles of temperature, water vapor and trace gases in addition to cloud and surface properties. The work in this JPSS PGRR project seeks to evaluate NUCAPS trace gas retrievals, specifically, using the ESRL measurements with state of the art chemical models. The NUCAPS trace gas products, along with Visible Infrared Imaging Radiometer Suite (VIIRS) data for source identification, will then be examined to see if they can be used to constrain chemical models that map the emissions and transport of pollutant species and thus lead to improved understanding of their impact on air quality and climate.

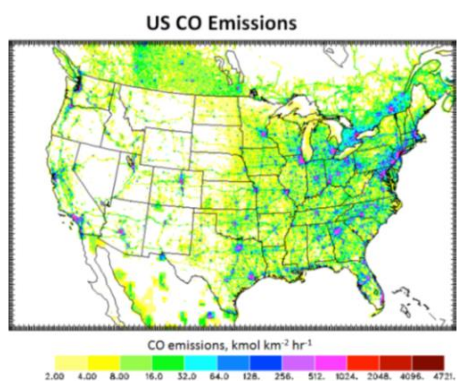
A Tale of Two Pollutants

Recent assessments in the United States and globally using field and satellite data demonstrate significant knowledge gaps in the magnitude, trends, and source locations of pollutant emissions such as CH_4 and CO. CH_4 is the second most important anthropogenic greenhouse gas after carbon dioxide (CO_2). According to the U.S. Environmental Protection Agency (EPA), significant anthropogenic sources of CH_4 include energy exploration and distribution, food production as well as waste disposal.



The map on the left shows CH_4 emissions across the U.S. High CH_4 methane emissions in the south central U.S. can be attributed to a heavy presence of oil and gas extraction basins in Texas, Oklahoma, Louisiana, and Arkansas. In California, CH_4 emissions are notably high in areas of agricultural and livestock management such as the Central Valley. Recent studies are shedding light on the accuracy of emission estimates supplied by national and global level inventories. According to some findings, U.S. emissions of CH_4 have been underestimated by 50 to 70 percent in current inventories[3].

Another pollutant of concern is carbon monoxide (CO), produced by incomplete combustion of fossil fuels, agricultural burning and wildfires. A precursor of near-surface ozone, CO is itself a toxic air pollutant regulated under the Clean Air Act (CAA). It can cause harmful health effects by reducing oxygen delivery to organs and tissues, and at extremely high levels, can cause death. The map at right shows emissions of CO across the U.S. Urban areas and highway networks stand out, since motor vehicles are a particularly significant source of CO.



Motor vehicles and energy development are important sources of volatile organic compounds (VOCs), a group of carbon-containing chemicals that contribute to the formation of ground-level ozone (O_3). At ground level, O_3 is a pollutant with negative impacts on human health and vegetation that is also regulated under the CAA. Many VOCs from motor vehicles co-emit with CO, while the oil and gas industry emits CH_4 along with a number of other VOCs. So observations and inventories of CO and CH_4 can be used to infer the emissions of many VOC compounds.

While CH_4 and CO are currently measured by a variety of monitoring approaches nationally and globally, there is a need for additional observations of CH_4 and CO to understand emissions

[3] Miller et al. PNAS | December 10, 2013 | vol. 110 | no. 50 | 20021

from different source types, quantify temporal variability in these sources, evaluate and improve the accuracy of emission inventories, and quickly identify problematic high-emitting sources.

Towards Improved Air Chemistry Applications of Suomi NPP

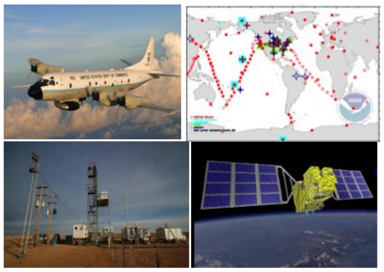
Earth-observing satellites provide information on atmospheric conditions over regional and global scales. With the launch of Suomi NPP, next generation sensors such as CrIS and VIIRS together with robust and accurate retrieval systems such as NUCAPS stepped forward to meet this need for additional and reliable measurements of atmospheric structure and composition.

While temperature and moisture are the primary sounder products of NUCAPS, the algorithm also retrieves a number of trace gases, including O_3, CO, CH_4, carbon dioxide (CO_2), nitric acid (HNO_3), nitrous oxide (N_2O), and sulfur dioxide (SO_2). Knowledge of these gases improves the primary products (temperature, moisture, surface temperature, and cloud fractions), because many of the trace gas have absorption features that interfere with the primary sounding channels. Thus, the intent of this PGRR project is to test and improve the accuracy of trace gas profiles retrieved from NUCAPS, particularly the daily global measurements of CH_4 and CO. In so doing, their usefulness to air quality and climate modeling studies will be determined.

The atmospheric sounding channels are located in parts of the infrared (IR) and microwave spectrum for which the atmosphere is the main contributor to the measured radiance. NUCAPS relies on the ATMS instrument and a technique called "cloud clearing" to remove the effect of clouds so that information can be obtained all the way to the surface, the region that is most relevant for most weather applications. Cloud clearing uses multiple scenes to remove the effect of the clouds. Therefore, cloud clearing sacrifices spatial resolution so that CrIS and ATMS can provide soundings in nearly 70 percent of scenes; however, this significantly increases the number of channels and scenes in which CrIS IR products have value to forecasters. ATMS can see through non-precipitating clouds, therefore in the Suomi NPP application, it virtually offers an all-weather capability, although at reduced vertical resolution compared to the CrIS. Cloudy scenes are also more likely to include interesting weather and these scenes are more likely to be useful to forecasters. The high-resolution imagery gleaned from VIIRS are ideally suited to detect and identify the location and strength of emissions sources such as wildfires. VIIRS can help determine how much burning resulted in the emission of gases and particulate matter into the atmosphere.

Satellite observations are providing valuable insight on trace gas concentrations and emissions both on regional and global scales. For example, using satellite data collected from 2003 to 2009, by the European Space Agency's (ESA) Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument, scientists[4] noted that the biggest hotspots in CH_4 anomalies in the U.S. were in the Four Corners region, located at the intersection of New Mexico, Arizona, Colorado, and Utah. This area is home to a basin where oil, natural gas, and coal are produced. These findings showed correlations between the basin's emissions and increases in the CH_4 column. To get a better understanding of the sources of these emissions, researchers are using independent samples from aircraft measurements to evaluate the satellite data.

[4] Kort et al., Four corners: The largest U.S. methane anomaly viewed from space, Geophysical Research Letters, doi:10.1002/2014GL061503, 2014



NOAA ESRL: Observing, Understanding and Predicting the Earth System

NOAA ESRL carries out research and long-term monitoring of atmospheric constituents. ESRL uses a unique combination of observational platforms, analysis approaches, and human expertise for its research endeavors. ESRL research projects seek to understand emissions, chemical processes, dynamics, and removal of atmosphere constituents. ESRL scientists then apply that knowledge to national and global environmental issues, such as air quality, climate change, stratospheric O_3 depletion, and their interactions.

Understanding Emissions and Impacts: An ESRL Case Study in a Utah Oil and Gas Basin

High amounts of ground level O_3 are typically considered a summer time problem. In the summer, intense sunlight, warm temperatures, and humid conditions can trigger chemical reactions involving nitrogen oxides (NOx) and VOCs that create O_3 pollution. In contrast, the Uintah Basin, an oil and natural gas basin in Utah, experiences high levels of O_3 in the wintertime, when sunlight, temperatures, and humidity are lower. A series of studies in the Uintah Basin starting in 2012 illustrates ESRL's approach to understand the causes for this phenomenon and to provide scientific information that can help environmental regulators and decision-makers.

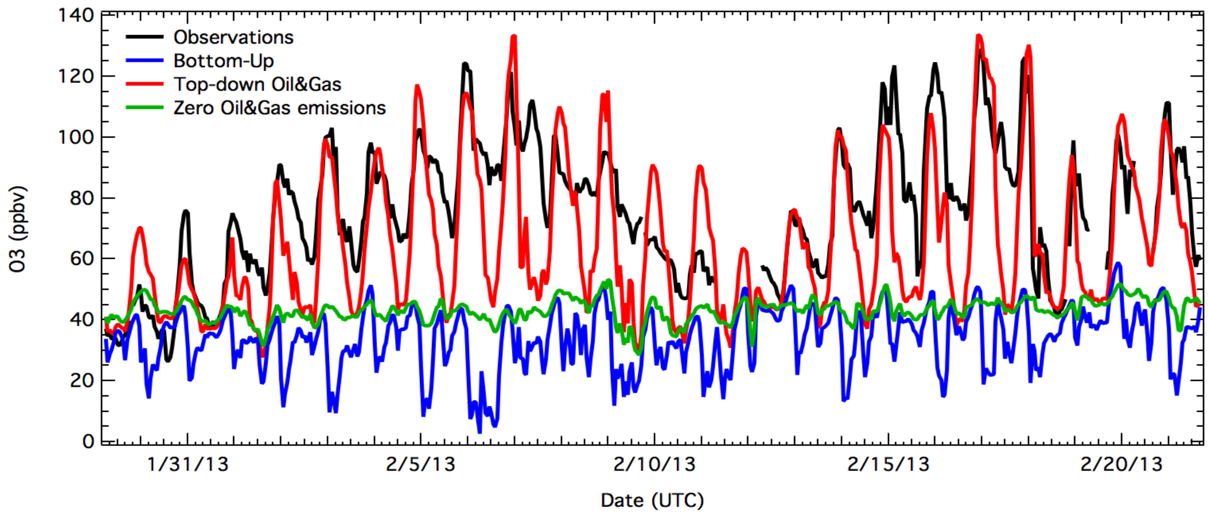
Wintertime cold air causes the gases released from oil and gas operations to be trapped near the ground in the shallow Uintah Basin. The presence of snow increases light reflection, which in turn accelerates ozone production. O_3 deposits to vegetation and soils and reacts with organic material in these media. O_3 levels can remain high in winter in the basin because the snow cover suppresses deposition. Cold, stagnant conditions and snowfall can persist for several days in the basin, allowing O_3 levels to remain high during these periods.

However, what was not clear before the NOAA field campaigns was the precise amount of NOx and VOCs emitted in the Uintah Basin, whether oil and gas operations are the main source of these O_3 precursors, and if existing understanding of photochemistry explained the observed O_3 formation. So a team of researchers from NOAA ESRL and several other institutions conducted a study[5] in which they fed the Weather Research and Forecasting with Chemistry (WRF-Chem) model with two different sets of emissions data (see following figure). Using data from the EPA National Emission Inventory (NEI) as input to the WRF-Chem model, the research team could not reproduce the observed high O_3 episodes seen in the basin. Moreover, WRF-Chem simulations using the NEI could not capture the observed levels of CH_4, NOx and VOCs. So the team adjusted the emissions inventory, using their own observations of these compounds from NOAA's highly instrumented ground site and aircraft measurements in the Uintah Basin. They found that the model using these observationally constrained emissions was able to accurately

[5] Ahmadov et al., Understanding high wintertime ozone pollution events in an oil and natural gas producing region of the western U.S., Atmospheric Chemistry and Physics, doi:10.5194/acp-15-411-2015, 2015.

simulate the high ozone events in the basin. The chemistry leading to high O_3 in the basin was similar to that causing O_3 to form in other regions in the summer. The critical finding from the study was the accurate quantification of the emissions of NOx and VOCs in the basin based on NOAA's observations.

Using the "chemical fingerprint" of CH_4 and different VOCs measured in the basin, the ESRL team showed that the oil/gas sector is the main contributor to emissions in the Uintah Basin. So another key result from the NOAA study was that these oil/gas emissions are the main drivers of the high O_3 levels measured in the wintertime basin. This research demonstrates that atmospheric measurements can significantly improve emission inventories for CH_4 and ozone precursors for the oil/gas sector in the Uintah Basin.



Observed and modeled ozone time series at the Uintah Basin surface site during winter of 2013

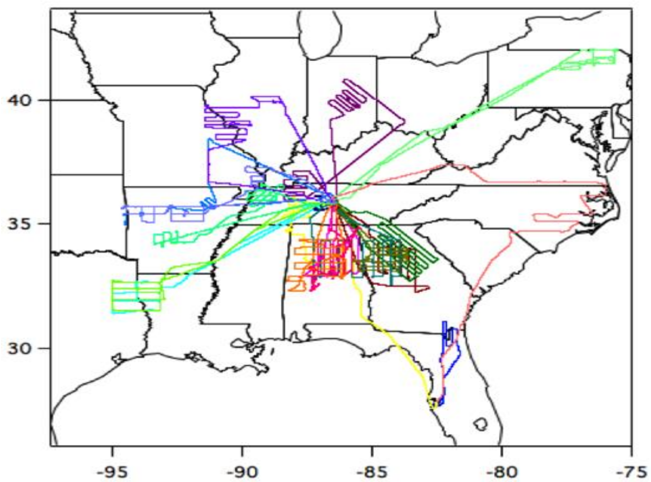
ESRL's Aircraft Observations

Instrumented research aircraft provide reliable and quantitative platforms for estimating emissions from source regions. With their high accuracy and precision, high spatial resolution, and repeated sampling, aircraft are ideal for establishing vertical profiles that can be used for satellite sounder validation. Aircraft measurements also provide a crucial link between ground-based measurements and satellite measurements at moderate resolution.

NOAA's WP-3 aircraft. (Photo credit: NOAA)

NOAA's premier aircraft platform is the WP-3. The primary mission of NOAA's 2 WP-3 aircraft is weather research and forecasting, including flying into hurricanes to collect data to inform weather models. Approximately every year or two, ESRL has the opportunity to use one of these WP-3's to conduct air quality and climate research.

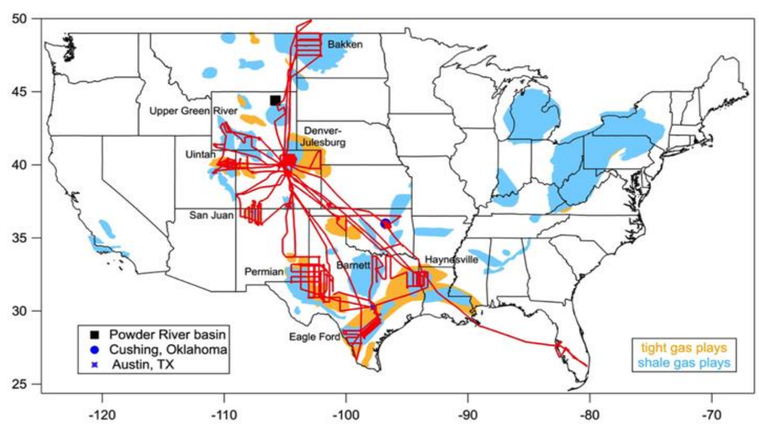
ESRL scientists, along with colleagues from many U.S. institutions, outfit the plane with a large number of instruments to measure the composition and properties of trace gases and aerosols, along with detailed meteorological measurements. The instrument suite on the WP-3 contains state-of-the-art observing techniques that are considered the gold standard in the community. The large number of gas and aerosol species measured also allows ESRL scientists to establish the chemical fingerprints of different types of sources. This type of identification approach is critical for quantifying the amount of a targeted pollutant, such as CH_4 or CO that can be attributed to a particular type of source.



Flight tracks of NOAA's WP-3 aircraft during the 2013 SENEX campaign

During two dedicated field campaigns, NOAA WP-3 aircraft measurements of pollutant gases were collected over regions with different types of emissions sources. The Southeast Nexus campaign (SENEX) (http://esrl.noaa.gov/csd/projects/senex/) took place in the summer of 2013. The WP-3 sampled trace gases and aerosols in air masses with different mixtures of anthropogenic, biogenic and fire emissions sources over the eastern and southeastern U.S.

The 2015 Shale Oil and Natural Gas Nexus (SONGNEX) campaign (http://esrl.noaa.gov/csd/projects/songnex/) focused on trace gas emissions, specifically CH_4 and CO, and fine particles from oil and gas basins in the western and south central U.S., as well as wildfire activity. Combined, these campaigns provided high quality profile measurements with which to characterize trace gas retrievals from satellite radiance measurements.



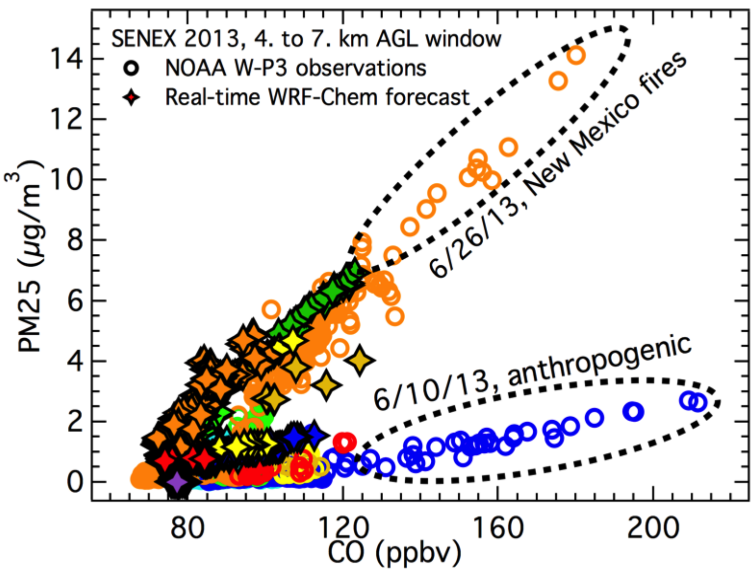
Flight tracks of NOAA's WP-3 aircraft during the 2015 SONGNEX campaign

ESRL's Model and Satellite Validation Approaches

Despite the extensive atmospheric sampling carried out by the NOAA WP-3 during SENEX and SONGNEX, there are relatively few opportunities for direct comparisons with NUCAPS soundings. The WP-3 flights tend to focus on boundary layer sampling, with significantly less time spent in the mid-troposphere where thermal IR sensors like CrIS have their maximum sensitivity. The WP-3 does not fly much above 7 km in altitude, so it does not fully probe the high sensitivity region of CrIS. The WP-3's periodic vertical profiles generally do not coincide in time and space with the Suomi NPP overpasses. Finally, there is a short time window of only a few minutes when the satellite is actually scanning the same area where the aircraft is flying.

So instead ESRL uses their field campaigns' observations from aircraft and ground-based sensors to validate their atmospheric chemical transport models. ESRL scientists then use their observationally validated models to simulate the much broader spatial and temporal coverage that is available from Suomi NPP. The model output provides a detailed evaluation of the spatial and temporal behavior of NUCAPS meteorological products and soundings of trace gases, including CH_4 and CO. In this way, the model acts as a transfer standard between the aircraft and satellite data.

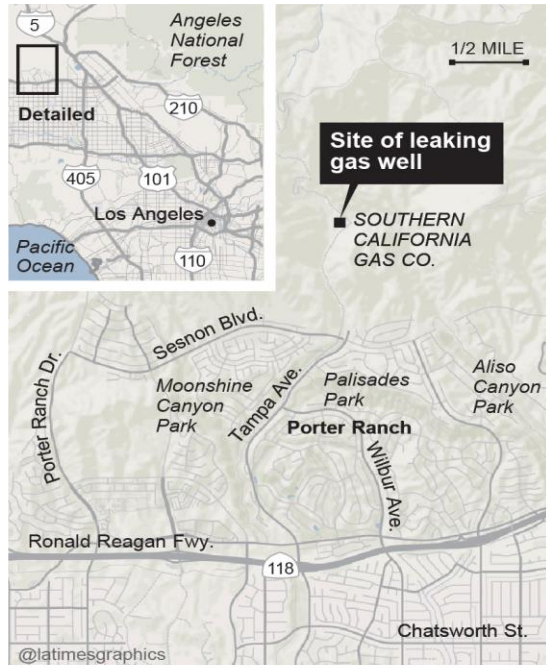
In a preliminary example of this approach, data for $PM_{2.5}$ and CO from the SENEX field campaign are shown in the figure at right. The NOAA P-3 aircraft sampled air masses influenced by anthropogenic, biogenic and fire sources. Aircraft observations in the height range of 4 to 7 km above ground are shown alongside preliminary WRF-Chem model results for the same times and locations as the aircraft data. The aircraft detects distinct chemical signatures of urban areas and wildfires at altitudes where CrIS has high sensitivity. Furthermore, the model qualitatively predicts the plume enhancements seen by the aircraft, giving confidence in the model's ability to track pollution plumes as they are transported both horizontally and vertically.

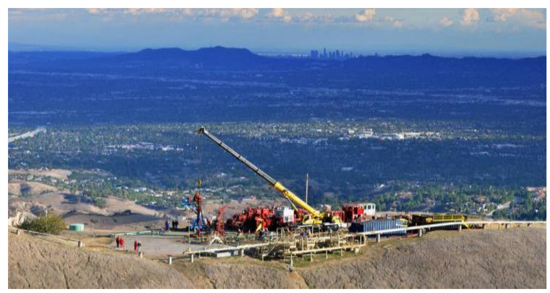


Measurements by NOAA's WP-3 aircraft during high altitude portions of 2013 SENEX flights compared with WRF-Chem model output at the same times and locations.

More quantitative agreement between the aircraft observations and model simulations will be the focus of the project's efforts to improve the WRF-Chem model's treatment of emissions, transport, and chemistry. The model will then be used to generate CH_4 and CO fields that can be compared to the NUCAPS products.

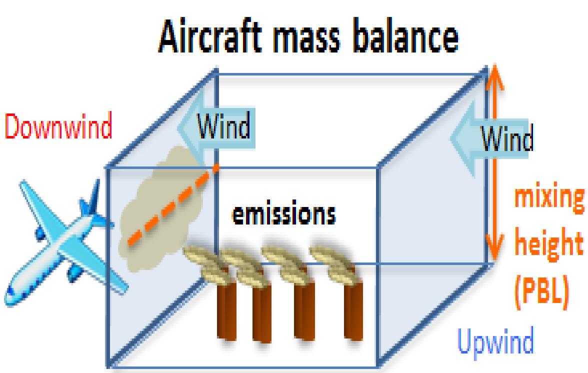
An Assessment at the Local Level: Southern California Natural Gas Leak





On 23 October 2015, there was a blowout of a well connected to a Southern California Gas (SoCalGas) underground storage facility for natural gas on the edge of the densely populated San Fernando Valley near Los Angeles, CA. Similar reservoirs are located next to many metropolitan areas to ensure a stable supply of natural gas to nearby customers. This blowout was caused by a breached metal pipe connected to a well that had been drilled in 1953. The continuous leakage of natural gas into the atmosphere created high levels of methane, which could have led to an explosion, and of sulfur-containing odorants typically added to the odorless natural gas so that leaks can be readily identified. The dangerous and smelly conditions forced hundreds of families in the area to relocate for nearly four months.

In response to this blowout, NOAA scientists rapidly deployed a research aircraft to sample emissions from the well and determine air quality impacts. The aircraft arrived about a week after the leak began and continued to provide support until the leak was stopped.



During aircraft operations ESRL applied a mass balance approach to characterize emissions using the aircraft's data. The aircraft would fly upwind and downwind of the well site. Under the right flow conditions, ESRL researchers were able to estimate the emissions of a targeted pollutant, such as CH_4, by measuring a relatively small number of parameters, including the enhancement of species in the plume, the wind speed, and the height of the boundary layer.

These periodic measurements allowed NOAA researchers to provide the only accurate assessment of the CH_4 leak rate from the SoCalGas facility[6]. This airborne chemical response delivered time-critical and actionable information to SoCalGas and local air quality managers. The success of this support reinforced the value of a capability already well proven during other

[6] Conley et al., Methane emissions from the 2015 Aliso Canyon blowout in Los Angeles, CA, *Science*, doi:10.1126/science.aaf2348, 2016

high profile incidents, including the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. This capability also encourages additional work to assess the ability of satellite measurements such as NUCAPS to develop methane emissions estimates during these types of events

Future work and milestones

Quantifying emissions is essential for scientific understanding and environmental regulation of air quality and climate. However, a number of research studies based on atmospheric observations demonstrate that emissions of air pollutants, including CH_4 and CO, are not well quantified by national and global inventories. Because of the potential of these emissions to adversely impact the environment and society, it is critical to develop methods that can accurately quantify these emissions. These findings are an impetus for the JPSS PGRR to test some of its most advanced and innovative products, including NUCAPS, to help researchers understand atmospheric trace gas composition. Results from experiments inaugurated in the SENEX and SONGNEX campaigns, and from real life examples such as the Southern California gas leak, could provide opportunities for more comprehensive evaluations of CH_4 and CO measurements from NUCAPS.

Aircraft are capable of sampling pollutants both upwind and downwind of industrial and urban sources, and can detect more chemical species than are typically measured at surface sites. However, these samplings are infrequent, and cover a limited geographic area. The CrIS and ATMS sensors on the Suomi NPP spacecraft contain a wealth of information about the composition of trace gases. The JPSS Sounding Initiative has been critical to the effort to provide NUCAPS soundings to NOAA operational users to help with all types of applications. NUCAPS data helps fill the spatial and temporal gaps between aircraft measurements. It provides high spectral (and high spatial) resolution soundings derived from the CrIS and ATMS that help depict various atmospheric conditions. VIIRS can aid in these studies, by identifying the location and strength of emissions sources such as wildfires. PGRR program support of projects like this one ensures that NUCAPS data will help provide a clearer picture of “what is in our air” for years to come.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

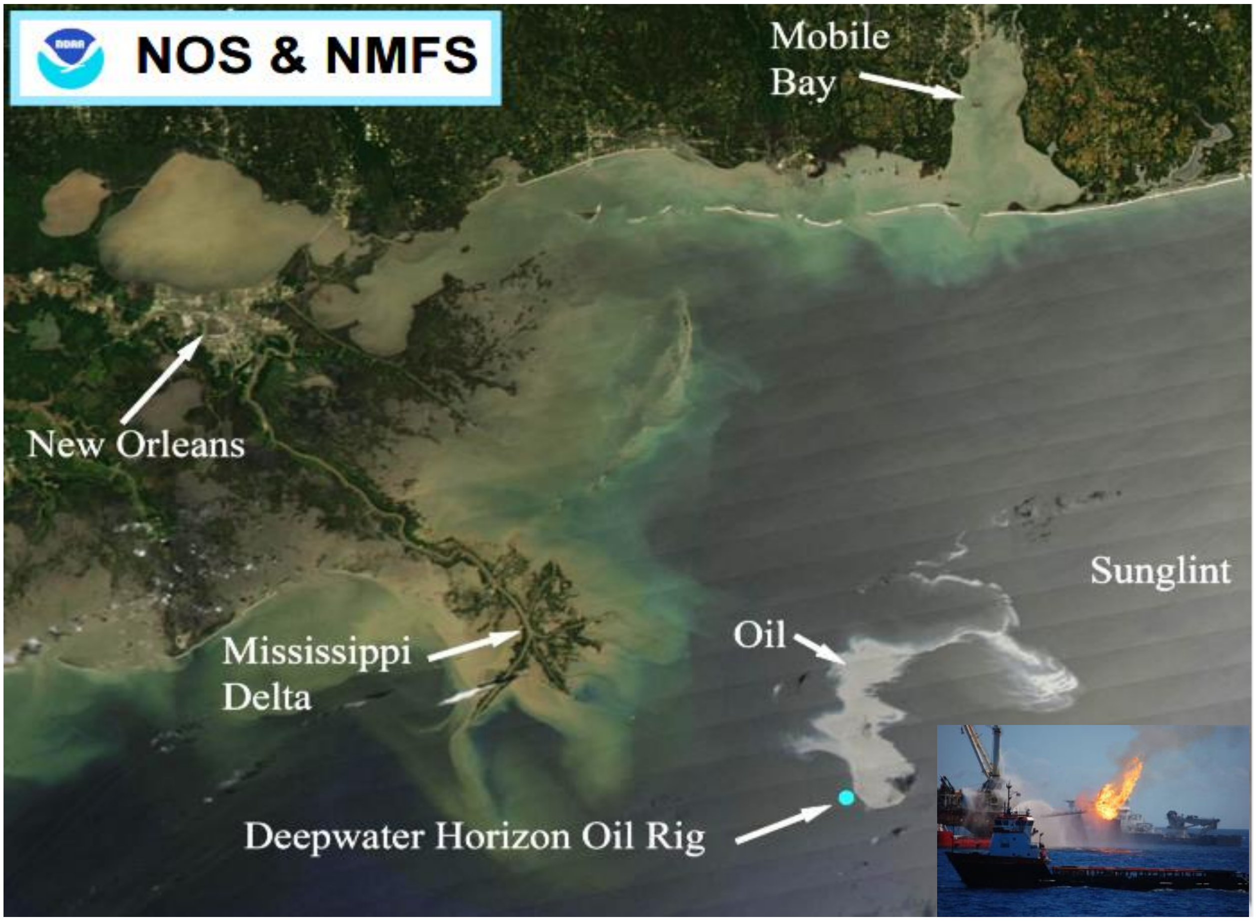
NOAA's Environmental Research Division: Emerging Leader in Designing and Delivering Ocean Satellite Training Programs to the NMFS and NOS

Helping Increase the Utilization of Data from the Joint Polar Satellite System

*This article is based in part on the **February 18, 2016** JPSS science seminar given by presented by Cara Wilson, NOAA Southwest Fisheries Science Center, Environmental Research Division (SWFSC/ERD).*

Additional project contributors: Roy Mendelssohn, Dale Robinson and Elliot Hazen, NMFS/SWFSC/ERD

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg



Instruments on the JPSS Satellite series will offer a continuity of observations to enable oil spill trajectory forecasts, such as this one, generated on 4/25/2010 with imagery from NASA's MODIS instrument during the Deepwater Horizon spill. Credit: NASA Goddard MODIS Rapid Response Team. Inset photo: The Deepwater Horizon site. Credit: NOAA

The oceans cover more than 70 percent of the Earth's surface, and they play an essential role in shaping global weather patterns, regulating climate, shipping and navigation, and harboring natural and living marine resources. Yet, oceans remain the most complex and challenging environments on Earth to explore, monitor and study. For centuries these efforts have been undertaken primarily by collecting data from ships and, more recently, from automated platforms such as buoys. Important as these measurements are for our understanding of the oceans, their limited spatial and temporal coverage cannot adequately capture the dynamic features of the oceans on local, regional, and global scales. In these instances, when conventional data are sparse or unavailable, the important role that satellite data play cannot be overemphasized. A prominent example is Alaska, a region where polar-orbiting satellites provide the data needed to fill-in the gaps from a sparse network of conventional observing systems. This is especially true for fishery centers which conduct limited data collection or field surveys and run the risk of missing key data.

Alaska's high latitude gives the region a distinct advantage because it receives more frequent passes from polar-orbiting satellites than any other part of the United States. This includes multiple overlapping daily passes from Suomi NPP. In fact, polar orbiters fly over Alaska so frequently that they are a viable tool for environmental applications and have become critical to operations in the region. These satellites have helped capture features such as ocean fronts, eddies, convergence zones, river plumes, which are important to ecosystems, and can be adequately resolved only with observations made from satellites.

National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) and the National Ocean Service (NOS) are tasked with the gathering of intelligence about and managing the nation's living marine resources and the environments they inhabit. To accomplish these tasks, NOAA and NMFS have come to depend on observations provided by a fleet of satellites that continually monitor environmental conditions within the world's ocean.

Two of the most important satellite measurements for monitoring the oceans are sea surface-temperature (SST) and ocean color data. Temperature changes influence the behavior of fish, can cause the bleaching of corals, and affects weather along the coast, and the spatial variations in SST are used to observe and monitor patterns of water circulation. Satellite ocean color data is particularly important to fisheries, since it is the only remotely sensed parameter that measures a biological component of the ecosystem, and allows for the monitoring of harmful algal blooms. Since the 1980s NOAA's polar-orbiting and geostationary satellites have been collecting global SST data. With the United States Joint Polar Satellite System (JPSS) NOAA is now collecting ocean color data for the first time (in the past it was collected from NASA satellites). The first satellite in the JPSS constellation, the Suomi National Polar-orbiting Partnership (Suomi NPP), was launched in October 2011. Ocean color and sea surface temperature (SST) measurements from the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor on board Suomi NPP are providing vital information on the biological productivity in the oceans and have become invaluable resources for oceanographic research and marine resource management.

Using VIIRS Data for Fisheries and Ecosystems Science

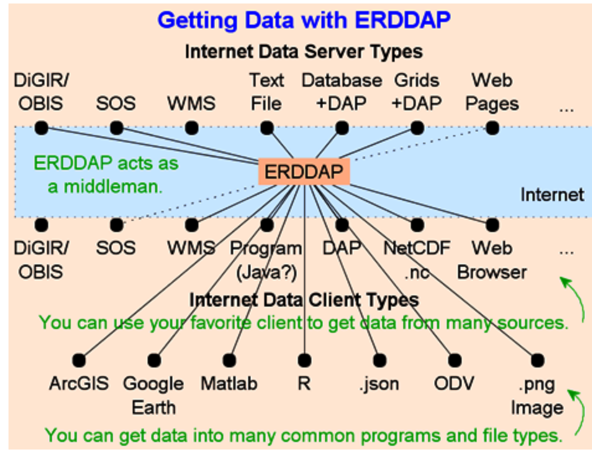
To be most useful for fisheries and ecosystems science, environmental datasets typically meet a few general criteria. First, fisheries and ecosystems studies often require long time series, on the order of years to decades. Many satellite data time series are now sufficiently long-term to meet this criterion. For example, SST satellite data are available from the 1980s to the present and chlorophyll satellite data are available since the late 1990s. VIIRS, launched in 2011, provides a five-year record of SST and ocean color data, as of this writing. Intercalibration of the VIIRS instrument with legacy satellite sensors will allow VIIRS data to extend the long-term datasets well into the future. A second criterion is that satellite datasets must be discoverable and usable to fisheries and ecosystems scientists who often do not have experience with the databases, tools and data formats typically used to work with satellite data. This criterion is cited as a reason for the apparent underutilization of satellite data in fisheries and ecosystems studies. The Environmental Research Division (ERD) at NOAA's Southwest Fisheries Science Center (SWFSC) has taken a lead role in addressing this second criterion and in working towards increasing the utilization of environmental satellite data within NMFS and NOS[7]. ERD has done this by developing a variety of data services and tools that make accessing and

[7] This material was presented in the 2014 JPSS Science Seminar Annual Digest article titled "The Visible Infrared Imaging Radiometer Suite (VIIRS) Ushers in a New Era of Support to the NOAA Oceanographic Mission". http://www.jpss.noaa.gov/pdf/2014_science_seminar_digest.pdf

analyzing satellite data easier. In addition, since 2006 ERD has conducted an annual satellite course for NMFS and NOS scientists where these data services and tools are highlighted. These data services and tools and the annual satellite course are described in further detail below.

ERDDAP

ERDDAP, a data server developed at SWFSC/ERD, gives users a simple, consistent way to download data at the spatial and temporal coverage that they want and in the format that they are most comfortable working with. It does this by acting as a data "middleman," tapping into its own datasets and those on remote servers, subsetting according to user instructions, and translating the data into a user-selected format. Furthermore, ERDDAP can act both as a web application, with an interface for people to use and a web service, which allows data access directly from any computer program (e.g. Matlab, R, or webpages).



ERDDAP
Easier access to scientific data

ERDDAP has been installed by over 50 organizations worldwide, including:

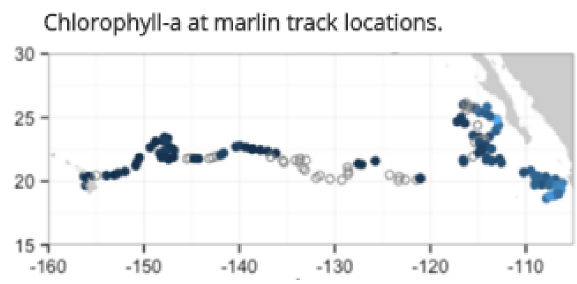
CSIRO and IMOS, Australia
IPSC JRC, European Commission
IRD (Institut de Recherche pour le Développement), France
CNRS (Centre National de la Recherche Scientifique), France
UPMC (Université Pierre et Marie CURIE), Paris, France
IPSL (Institut Pierre Simon Laplace des sciences de l'environnement), Paris, France
UCAD (Université Cheikh Anta Diop de Dakar), Sénégal
UGB (Université Gaston Berger - Saint-Louis), Sénégal
UFHB (Université Félix HOUPHOUËT-BOIGNY), Abidjan, Côte d'Ivoire
The Marine Institute, Ireland
Marine Instruments S.A., Spain
Ocean Networks Canada
Stanford University, Hopkins Marine Station
University of California at Davis, Bodega Marine Laboratory
USGS Coastal and Marine Geology Program
UW APL

Serving over 7,000 datasets, the ERDDAP servers (operated by ERD) function as a "one-stop shopping" mart for environmental data. Holding more than satellite data, ERDDAP also contains underway data from NOAA ships and National Science Foundation) research vessels, and fish-catch landing data from California, the World Ocean Atlas, and other sources. Within NOAA, ERDDAP servers have been installed by several organizations including the National Centers for Environmental Information (NCEI), the CoastWatch West Coast Node, and the CoastWatch Caribbean/Gulf of Mexico Node. The NOAA's Data Access Procedural Directive which declares "all NOAA environmental data (with limited exceptions) shall be made discoverable through the NOAA Data Catalog and accessible via the Internet," includes ERDDAP in its list of recommended data servers for use by groups within NOAA.

ERDDAP has gained recognition outside of NOAA and has now been installed by over 50 organizations worldwide, including Australia's Commonwealth Scientific and Industrial Research Organisation, the Integrated Marine Observing System, and the Maritime Affairs Unit, Institute for the Protection and Security of the Citizen/Joint Research Centre of the European Commission. Information about ERDDAP can be found on the CoastWatch West Coast Regional Node (WCRN) website (coastwatch.pfeg.noaa.gov/erddapinfo).

The Environmental Data Connector

ArcGIS is a mapping and spatial analysis software used within both NMFS and NOS for identifying Essential Fish Habitat, planning and executing living marine resource surveys, developing integrated ecosystem assessments, habitat restoration and many more applications. Traditionally, importing satellite data into ArcGIS had been challenging, since importing multiple HDF files into ArcGIS can be quite cumbersome. To alleviate this issue, ERD had the Environmental Data Connector (EDC) developed by Applied Science Associates in 2008. The EDC is a Java-based Graphical User Interface that allows for easy access to distributed data from directly within ArcGIS, Matlab, R and, for Windows only, Excel. The EDC can access data served by OPeNDAP, THREDDS, ERDDAP, IOOS SOS and also local files. Users can search for and graphically select custom temporal and spatial data subsets, and then automatically download the subsets into the software application. The EDC can also extract data from within a user drawn polygon and along ship or animal tracks. Information about the EDC can be found on the CoastWatch WCRN website (coastwatch.pfeg.noaa.gov/EDC).



Chlorophyll-a concentrations for a marlin track that were extracted from a MODIS satellite dataset served by ERDDAP.

Xtractomatic scripts

Xtractomatic scripts are a set of free tools, written in Matlab and in R, that allows client-side access of environmental data served on the ERD/CoastWatch ERDDAP Server. The xtractomatic tools were originally developed for the marine biology tagging community to extract satellite data coincident to the tracks from tagged animals. The packages have been extended to extract a 3D cube of data and time series from the region defined by the polygon. Xtractomatic scripts are available on GitHub, extract satellite data coincident to the tracks from tagged animals. For more information please visit the CoastWatch WCRN website (coastwatch.pfeg.noaa.gov/xtracto).

NOAA Ocean Satellite Course: Stimulating Research with Satellite Data

Since 2006 the SWFSC ERD has been conducting 3-day short courses in oceanographic satellite data[8]. These courses are geared towards NMFS and NOS scientists, but are also open to non-NOAA participants. These training courses offer up a two-way, reciprocal learning experience in which the instructors and participants get to share knowledge, ideas and experiences. The participants get an introduction to the different types of environmental satellite data, including sea surface temperature, ocean color, salinity, sea surface height, and ocean surface winds. They also receive information on where and how to access these data into the platform that is most efficient and appropriate for their needs. Meanwhile, the instructors get a better idea of users' needs and wants, and are better placed to understand any subtleties and/or ambiguities, and address those needs. In fact, the EDC was developed out these courses, when the instructors identified the challenges associated with importing satellite data into ArcGIS.

[8] http://www.pfel.noaa.gov/events/NOAASatCourses/

A unique aspect of this course is that the instructors focus on the software platforms used by the participants, generally ArcGIS, Matlab and R. In addition, the courses emphasize hands-on, scenario-based training to reinforce skills proficiency. Participants are encouraged to come to the course with a specific project to work on during the lab component.

In 2013, the SST and ocean color data provided by the VIIRS became integral part of the course material. There is evidence that this inclusion could expand the use of VIIRS data within NMFS and NOS. Survey results revealed that although the majority of the participants were unaware of VIIRS data before the course, most planned to continue using VIIRS data for their research after completing the course.

The course will once again be offered in August of 2016, and will introduce PolarWatch, a new CoastWatch initiative which will provide environmental satellite data for both the northern and southern polar regions. Since 2011, travel funds provided by the JPSS Program have helped encourage new and returning attendees, as well as support projects demonstrating the usages of environmental satellite data within NOAA. With 32 participants signed up, the 2016 course is gearing up to be one of the biggest class sizes ever. For information about the course, please visit the CoastWatch West Coast Regional Node website (coastwatch.pfeg.noaa.gov/courses/). In addition, a 5-day satellite training session is planned to take place before the 2016 Pan Ocean Remote Sensing Conference (PORSEC) meeting in Brazil.

Case studies from the 2014 and 2015 satellite data courses

Participants of the NOAA satellite data courses work on specific projects during the course, which span a broad range of topics and methodologies. Below are examples of projects that explored the use of VIIRS during the course. They reflect the breadth of coverage in the course and also give a flavor of the innovative science taking place in NOAA.

Salmon Survival in 2011—What Happened?

Brian J. Burke
Fish Ecology Division
NWFSC, NOAA Fisheries

Chinook Salmon

Photo: NOAA

http://www.nmfs.noaa.gov/pr/species/fish/chi

Chinook salmon (*Oncorhynchus tshawytscha*) is the largest species in the Pacific salmon genus *Oncorhynchus*. Juvenile Chinook spend anywhere from three months to two years in freshwater before migrating to estuarine areas and then into the ocean to feed and mature. Pacific salmon abundance has been highly variable over the last few decades and most forecasting models have proven inadequate, primarily because of a lack of understanding of the processes affecting variability in survival.

In 2011, less than 90,000 adult spring-run Chinook salmon returned to the Columbia River. These numbers were far below the returns of over 200,000 fish projected from previous relationships between various ocean ecosystem indicators (http://www.nwfsc.noaa.gov/oceanconditions) and adult salmon returns[9]. Ground-based surveys provide a way to track the status or abundance of fish populations.

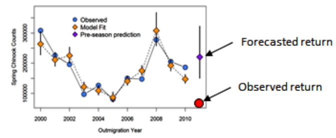


Figure 1. Observed and fitted adult spring Chinook salmon returns, with the forecasted and observed returns for fish entering the ocean in 2011.

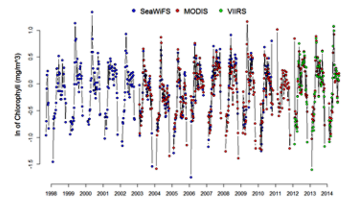


Figure 3. Time series of 8-day composite chlorophyll concentrations.

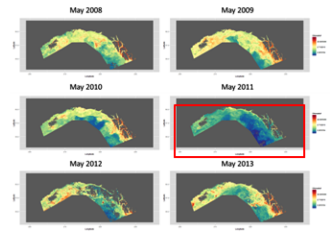


Figure 2. Chlorophyll concentration in May (2008-2013) in coastal Gulf of Alaska.

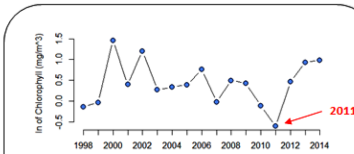


Figure 4. Time series of average April-May chlorophyll concentrations in coastal Gulf of Alaska. The lowest value (2011) suggests that low productivity could have negatively influenced salmon survival that year.

But these platforms are limited in time and spatial coverage. During the course, Brian Burke used satellite ocean color data, including VIIRS, to examine whether environmental conditions could explain the lower than expected return. While no definitive conclusions were reached, satellite ocean color data will help shed some light on the interannual variability in chlorophyll levels during the spring phytoplankton bloom in coastal Gulf of Alaska. This data may potentially explain whether chlorophyll levels contributed to the low observed salmon returns as well.

Satellite Data May Help Improve Understanding of Age-0 Pollock Recruitment in the Southeastern Bering Sea

Jeanette Gann
NMFS/AFSC

Alaska or Walleye pollock is an important economic species that also plays a vital ecologic role in the Bering Sea ecosystem as prey for fish, sea birds and other marine animals.[10] Although broadly distributed throughout the North Pacific, the largest concentrations are found in the Eastern Bering Sea. They dominate the Alaska groundfish fishery, one of the largest in the world. Pollock are on the move throughout their lives, migrating to feeding areas during spring and summer and moving to spawning areas during winter. Because of their economic and ecological importance, it is necessary to understand the factors affecting their movement patterns and recruitment.

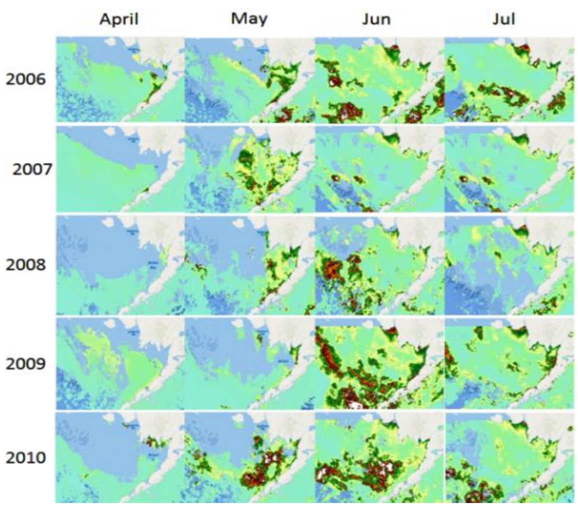
Recruitment strength in pollock is particularly sensitive to events that occur during the early life phases (spawning to age-1 juveniles), because high abundances of small-sized offspring are

[9] Burke BJ, Peterson WT, Beckman BR, Morgan C, Daly EA, Litz M (2013) Multivariate Models of Adult Pacific Salmon Returns. PLoS ONE 8(1): e54134. doi:10.1371/journal.pone.0054134 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0054134#s4

[10] Ianelli, J.N., *et al.*, 2012. *Assessment of the walleye pollock stock in the Eastern Bering Sea*, Alaska Fisheries Science Center National Marine Fisheries Service, http://www.afsc.noaa.gov/refm/docs/2012/EBSpollock.pdf

more vulnerable to mortality than older, more established life stages. Survey datasets for the Alaska Fisheries Science Center (AFSC) Ecosystem Monitoring and Analysis (EMA) and Recruitment Processes (RP) groups are restricted to spring and late summer/ early fall, which misses much of the in-between summer production. Center scientists sometimes rely upon satellite data to fill in these data gaps.

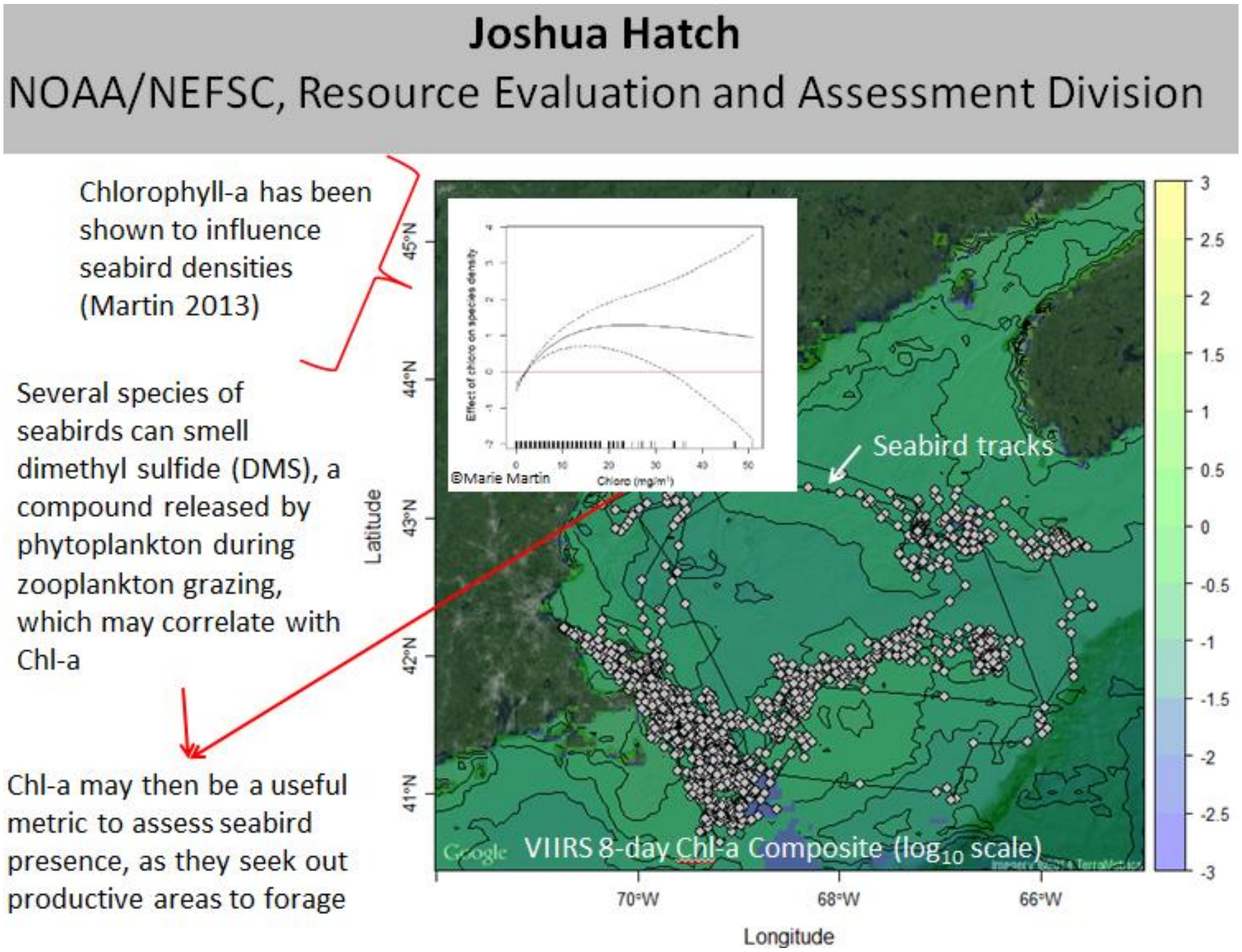
The year 2007 was anomalous for primary production, low nutrients, and low recruitment for pollock from age-0 to age-1 juveniles (an important 1st year metric for the fishery)[11]. Surface chlorophyll concentration data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the NASA Aqua polar orbiting platform was used to fill in gaps for missing data between field surveys. It also helped Jeanette Gann from the Alaska Fisheries Science Center (AFSC) better understand what factors influenced Pollock recruitment in 2007. Surveys for the EMA group at Auke Bay Labs in Juneau, AK, are restricted to late summer/early fall, so understanding the progression of chlorophyll concentrations throughout summer is very helpful to gain an understanding of total productivity during the primary growing season. As the legacy of previous sensors such as the Advanced Very High Resolution Radiometer (AVHRR) flown on NOAA's Polar Orbiting Environmental Satellites (POES) and MODIS continues with VIIRS, it ensures that the ocean data stream from satellites remains in place to support the NOS and NMFS research and operational applications.

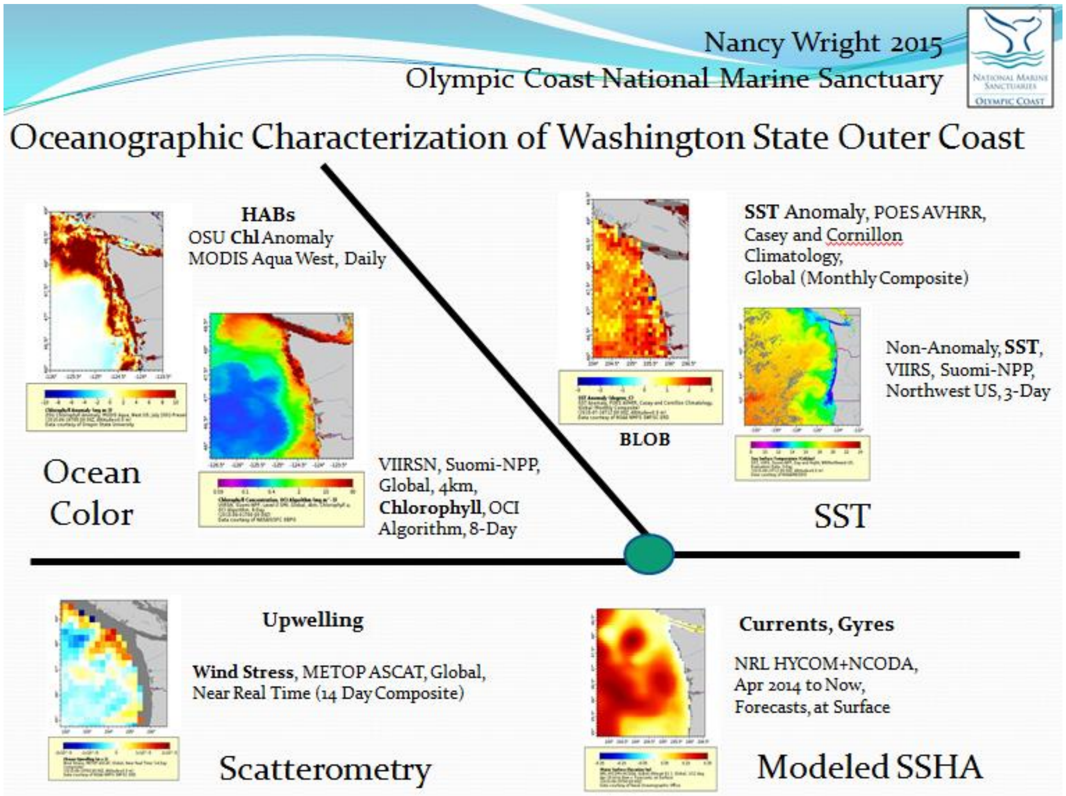


Aqua MODIS satellite data showing monthly average (April-May) variations by year (2006-2010) of surface chlorophyll-a concentrations during summer in the southeastern Bering Sea.

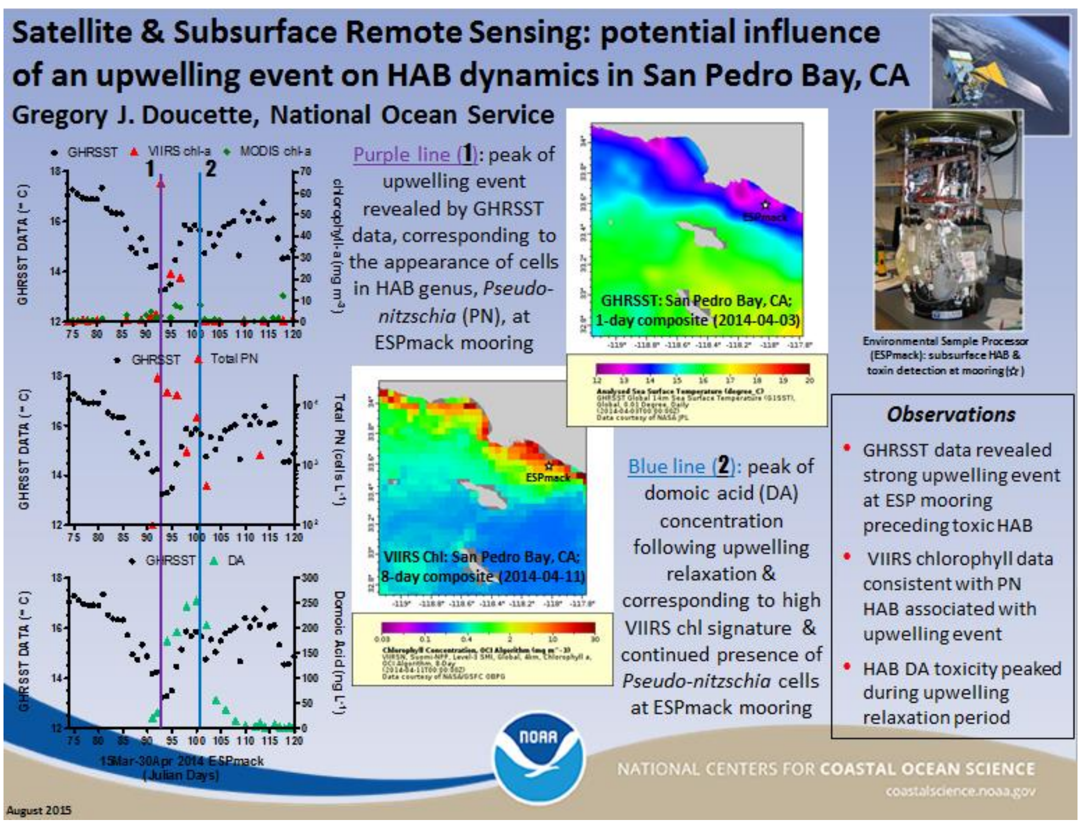
[11] Gann, J.C., et al., 2015. Possible mechanism linking ocean conditions to low body weight and poor recruitment of age-0 walleye pollock (Gadus chalcogrammus) in the southeast Bering Sea during 2007, Deep Sea Research Part II: Topical Studies in Oceanography, doi:10.1016/j.dsr2.2015.07.010.

The following are further examples of how course participants incorporated satellite data in their projects. These direct screen captures provide content summaries from participants' projects.





Nancy Wright 2015
Olympic Coast National Marine Sanctuary
Oceanographic Characterization of Washington State Outer Coast
HABs
OSU Chl Anomaly
MODIS Aqua West, Daily
SST Anomaly, POES AVHRR,
Casey and Cornillon
Climatology,
Global (Monthly Composite)
Non-Anomaly, SST,
VIIRS, Suomi-NPP,
Northwest US, 3-Day
BLOB
VIIRSN, Suomi-NPP,
Global, 4km,
Chlorophyll, OCI
Algorithm, 8-Day
Ocean
Color
SST
Upwelling
Wind Stress, METOP ASCAT, Global,
Near Real Time (14 Day Composite)
Scatterometry
Currents, Gyres
NRL HYCOM+NCODA,
Apr 2014 to Now,
Forecasts, at Surface
Modeled SSHA



Satellite & Subsurface Remote Sensing: potential influence of an upwelling event on HAB dynamics in San Pedro Bay, CA
Gregory J. Doucette, National Ocean Service
GHRSST
VIIRS chl-a
MODIS chl-a
GHRSST DATA (° C)
chlorophyll-a (mg m⁻³)
Total PN
Total PN (cells L⁻¹)
DA
Domoic Acid (ng L⁻¹)
15Mar-30Apr 2014 ESPmack
(Julian Days)
Purple line (1): peak of upwelling event revealed by GHRSST data, corresponding to the appearance of cells in HAB genus, Pseudo-nitzschia (PN), at ESPmack mooring
GHRSST: San Pedro Bay, CA; 1-day composite (2014-04-03)
ESPmack
VIIRS Chl: San Pedro Bay, CA; 8-day composite (2014-04-11)
Blue line (2): peak of domoic acid (DA) concentration following upwelling relaxation & corresponding to high VIIRS chl signature & continued presence of Pseudo-nitzschia cells at ESPmack mooring
Environmental Sample Processor (ESPmack): subsurface HAB & toxin detection at mooring (☆)
Observations
GHRSST data revealed strong upwelling event at ESP mooring preceding toxic HAB
VIIRS chlorophyll data consistent with PN HAB associated with upwelling event
HAB DA toxicity peaked during upwelling relaxation period
NOAA
NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
coastalscience.noaa.gov
August 2015

Conclusion

Earth observing satellites collect routine measurements which provide essential information on environmental features in the oceans, atmosphere, and on land. The value of ocean satellite data is substantial and they have become indispensable for many marine research applications. Sea-surface temperature and ocean color are two examples of important data provided by satellites. These measurements help the oceanographic community monitor and characterize marine ecosystems, and have increased our ability to observe the oceans.

Despite the growth of satellite data and associated satellite data products, there are still potential users within NMFS and NOS who are not aware of the data available, and lack the skills to easily obtain and analyze this data. The ERD at NOAA has taken up the task of facilitating the oceanographic community's access to satellite data through means like the ERDDAP. The ERDDAP, the data server that is now the backbone of all the tools and services, and other key tools like the EDC and Xtractomatic scripts, are now making it easier for those end-users who work with platforms that were previously incompatible with satellite data, e.g., GIS to utilize it within these platforms.

In addition to the actions taken to make ocean products more accessible, the annual Ocean Satellite Course has proven its value. This course has become a cornerstone in demonstrating how to access satellite data using the tools and services generated at the ERD. It has proven to be an effective method of bringing satellite data, such as that from VIIRS to this group of NMFS and NOS end-users. These courses have been instrumental in engaging end-users from NMFS and NOS, and helping them consider how to use satellite data to support their agency-specific missions and activities. The foundation of this course is the direct involvement of these users in identifying their unique mission challenges and determining how VIIRS data can be used to help them solve those challenges.

JPSS USER PERSPECTIVE

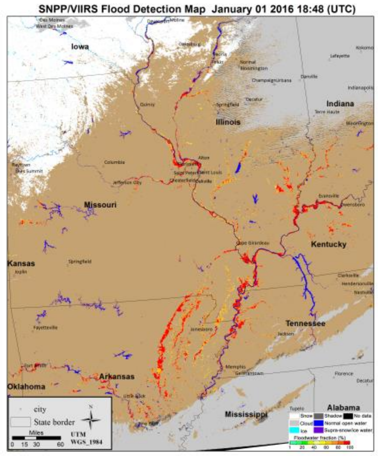
What the users are telling us about JPSS

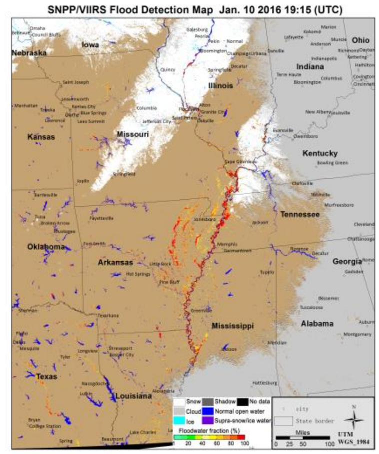
Automatic Near Real-Time Flood Detection Using Imagery from the Joint Polar Satellite System (JPSS)

*This article is based in part on the **March 7, 2016** JPSS science seminar presented by Donglian Sun, Sanmei Li, George Mason University, (GMU).*

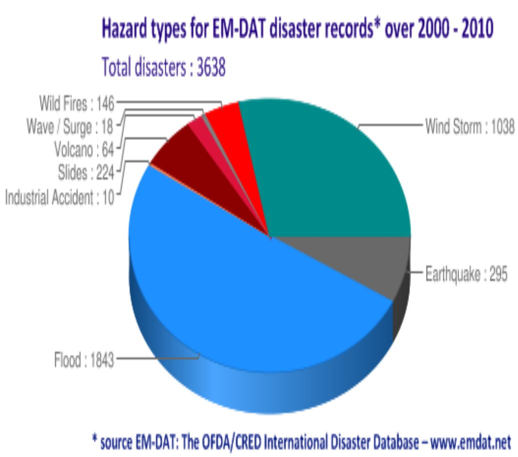
Additional project contributors: David Santek, Jay Hoffman, Space Science and Engineering Center (SSEC)

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg





In April and May of 2011, some of the largest and most damaging floods recorded along the U.S. waterways came across the Mississippi River and took with them an estimated 392 lives. Economic losses from these floods were close to 2.8 billion dollars. In 2012, flooding induced by the infamous Superstorm Sandy that battered the entire East Coast of the U.S., caused close to 300 deaths. In 2015 and leading into 2016, major flooding induced by several rain-swollen rivers including the Mississippi posed major threats to many areas across the U.S. Midwest. And recently in August of 2016, Louisiana experienced historical floods. While these may sound like rare events, they are not. Floods are the most frequent natural disasters around the globe, accounting for almost fifty percent of the disasters reported worldwide. In the United States alone, floods cause more loss of life and property than any other types of severe weather events. Flood events can occur over very large areas such as major river valleys or over small areas (e.g., urban flooding). The high incidence of flood related events, and the significant risk of damages they pose especially in densely populated urban areas, signifies a strong need for monitoring their evolution and dynamics in near real time.



Forecasting Floods with Near-Real Time Satellite Imagery

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) operates several River Forecast Centers (RFCs) across the country that forecast river flood events. River forecasters in these centers rely on an arsenal of tools including river gauge data, observations from river watch, aerial photography, and satellite imagery from multiple sources to determine flood extent. Satellite remote sensing, or the ability to observe the Earth from space enables us to see the big picture of floods. It also provides a useful data source that helps to detect, determine, and estimate the extent of flood, as well as the damage and impact over rivers and land bodies. Satellite products and imagery from the Joint-Polar Satellite System (JPSS) have proved to be extremely beneficial for situational awareness and decision support in NWS forecast operations, especially in the high latitudes which tend to be remote and hard to reach places with very few ground-based observing systems. Of note are river flood detection products derived from the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor aboard the Suomi National Polar-orbiting Partnership (Suomi NPP), the first next-generation polar-orbiting satellite in the JPSS constellation. JPSS is NOAA's primary weather satellite in polar orbit, and the primary weather observation satellite system for Alaska and the Polar Regions.

The VIIRS Advantage

The strength of VIIRS is that it has a constant 375-m spatial resolution across the scan in Imager bands with a large 3000km swath without gaps even at the equator—much better than that of legacy imagers. Also VIIRS has five Imager bands from the visible, near-infrared to thermal infrared channels. All these award it special advantages in flood detection. Initialized by a team from George Mason University (GMU) as part of the JPSS Proving Ground and Risk Reduction (PGRR) Program, a software package has been developed for automatic near real-time flood mapping using SNPP/VIIRS imagery. In the software, a series of algorithms have been implemented varying from water/non-water classification, cloud shadow removal, terrain shadow removal, minor flood detection, water fraction retrieval and flooding water determination. The software can generate flood maps from VIIRS imagery in any regions between 80°s and 80°N in latitudes. Of note though, is its value in remote areas with minimal or no aircraft surveillance. Currently, it is routinely running in the Space Science and Engineering Center (SSEC) of University of Wisconsin at Madison and the Geographic Information Network of Alaska (GINA) in University of Alaska using direct broadcast VIIRS data, to generate flood maps for five RFCs in the USA. Near real-time flood maps for the five RFCs are both available in SSEC's Real Earth and NOAA's AWIPS-II (Advanced Weather Interactive Processing System). These flood maps enable river forecasters and hydrologists to better identify and monitor both river based and non-river near real-time flooding. This "situational awareness" is a vital first step in making accurate flooding forecasts.

Flood Product Application Examples

Yukon River at Galena, Alaska

Flooding in the Yukon River Community, Galena, Alaska, May 2013. National Weather Service photo.

The GMU VIIRS River Flood Product is often combined with a River Ice Product that was developed by a team from the City College of New York (CCNY) in response to flooding induced by ice jams in the winter. These products were first used during a flooding event near Galena Alaska on the Yukon River in May 2013. Alaska is a high latitude region that presents many difficult challenges for NWS forecasters. Some of these challenges include areas of responsibility that are huge and topographically complex and scarce meteorological data from conventional observing systems.

Because of its high latitude, Alaska enjoys more frequent passes from polar-orbiting satellites than any other part of the nation. This includes multiple overlapping daily passes from Suomi NPP that are essential to the region as they help fill the data gaps over areas that are not well covered by other ground-based observing systems. In the 2013 spring breakup season, an ice jam formed in the Yukon River and caused major flooding, which backed up catastrophic amounts of water into the river community of Galena. Prior to the flooding in Galena, science teams from GMU and CCNY had been working on JPSS PGRR products to monitor and track ice and flooding conditions using data from the Suomi NPP satellite. These products helped the local management officials and emergency response teams to determine where help was needed the most. They also helped facilitate daily operations as crews worked to rebuild the impacted areas in the region. The initial success of this application advanced the use of these products not only in Alaska but in other northern state RFCs during the winters of 2014 and 2015. The VIIRS River Flood products have proven themselves in many different ways, and most prominently in generating extensive data for NWS forecasters that has helped guide their flood advisories and warnings. On top of everything, they can help forecasters make fairly accurate predictions of river ice breakup.

Image courtesy: Department of Transportation and Public Facilities in Alaska. Photo was taken on April 08, 2015 around the inundated Dalton Highway near Sag River.

The Dalton Highway, Alaska

In April 2015, parts of the James W. Dalton Highway near the Sagavanirktok (Sag) River in northern Alaska experienced unprecedented levels of flooding, which caused closures over large stretches of the road. The Dalton Highway is the only route from Alaska's interior to the Prudhoe Bay oil fields in the North Slope. It plays a critical role in the transportation of food, supplies and equipment to the oil fields. This event had an adverse impact on the delivery of critical supplies to personnel in the oil fields, which resulted in a state-level crisis. According to an article[12] published in the Alaska Climate Dispatch, the severe breakup flooding on the Sag River was not due to the typical ice jam and release process, instead it was due to Aufeis—a German term for "top ice" or "on ice". Aufeis is a hydrologic winter process that occurs in arctic and subarctic streams and rivers. In sub-freezing temperatures, water under pressure flows out on top of the ice where it subsequently freezes, adding to the thickness of the ice in the channel and floodplain. This process can repeat itself many times throughout the winter. Because an unusually large amount of river aufeis had accumulated in the bottom of the shallow and braided Sag River, it pushed the flowing water to the top, resulting in an overflow

[12] A TALE OF TWO FLOODS: SPRING 2015 ON THE DALTON HIGHWAY, Crane Johnson and Scott Lindsey, National Weather Service Alaska-Pacific River Forecast Center, ALASKA CLIMATE DISPATCH, June 2015, https://accap.uaf.edu/sites/default/files/Alaska_Climate_Dispatch_Jun_2015.pdf

also known as a supra-snow/ice flood. In addition to the aufeis, warmer than average spring season temperatures, resulted in rapid snowmelt which pushed the Sag River over the Dalton Highway washing out some stretches of the road. When the flood occurred, trucks moving along the highway were immobilized. Decision-makers from Alaska's Department of Transportation (D.O.T) utilized the VIIRS River Flood Product to track changes during this event. This helped them determine the appropriate actions to needed to reopen this critical pipeline.

New Year's Day Mississippi River Flooding

In late December 2015 and early into January 2016, communities living along Midwest River Basins and the Mississippi River Valley experienced record level flooding after a series of storms brought heavy rains to the region.

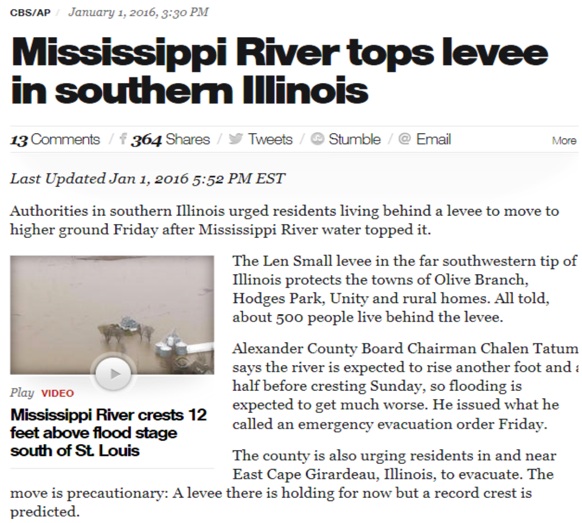
'It's going to get ugly': Midwest calls in national guard as flood disaster unfolds

Sixteen states issue flood warnings as waters blamed for 22 deaths in Illinois, while Missouri governor expects record-breaking disaster

Roads remained submerged in Missouri on Saturday after the Mississippi burst its banks. Photograph: David Carson/AP

Floods have submerged towns, roads, casinos and shopping malls around the south and midwest for more than three days, prompting governors in Illinois and Iowa to call in the national guard.

Sixteen states issued flood warnings covering some eight million people. By Saturday floodwaters had begun to subside in many areas, reopening several important highways, after topping levees in the region late on Friday.



CBS/AP / January 1, 2016, 3:30 PM

Mississippi River tops levee in southern Illinois

13 Comments / 364 Shares / Tweets / Stumble / Email More

Last Updated Jan 1, 2016 5:52 PM EST

Authorities in southern Illinois urged residents living behind a levee to move to higher ground Friday after Mississippi River water topped it.

Play VIDEO

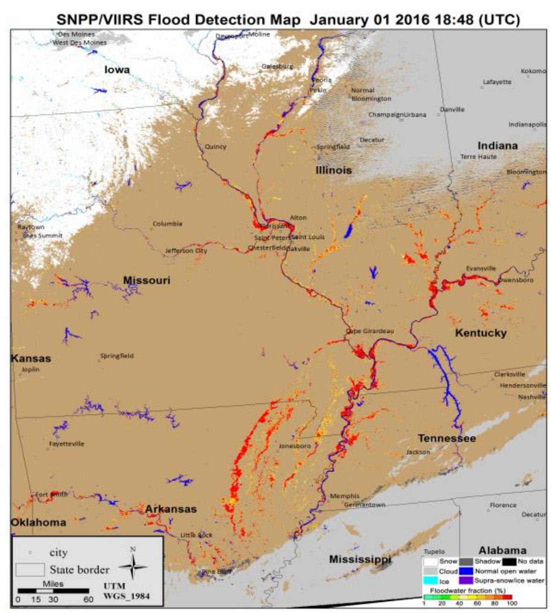
Mississippi River crests 12 feet above flood stage south of St. Louis

The Len Small levee in the far southwestern tip of Illinois protects the towns of Olive Branch, Hodges Park, Unity and rural homes. All told, about 500 people live behind the levee.

Alexander County Board Chairman Chalen Tatum says the river is expected to rise another foot and a half before cresting Sunday, so flooding is expected to get much worse. He issued what he called an emergency evacuation order Friday.

The county is also urging residents in and near East Cape Girardeau, Illinois, to evacuate. The move is precautionary: A levee there is holding for now but a record crest is predicted.

With the developed VIIRS flood detection software, a series of flood maps were generated to reflect the spatial distribution of flooding water and dynamic change of the inundation process along the Mississippi River and its branches. On the right is a VIIRS 375-m flood map, generated on January 01, 2016 at 18:48 (UTC), in which flooding water is represented in flooding water fractions (water percentage in a VIIRS 375-m pixel) and shown in colors from green to red. More red means larger flooding water extent. Compared with river gauge observations which only show flooding status at discrete locations, VIIRS-based flood maps provide continuous areal flood extent; compared with hydrologic model outputs from NWS's flood watch and outlook products which provide regional flood watch and warning at large scale, VIIRS flood

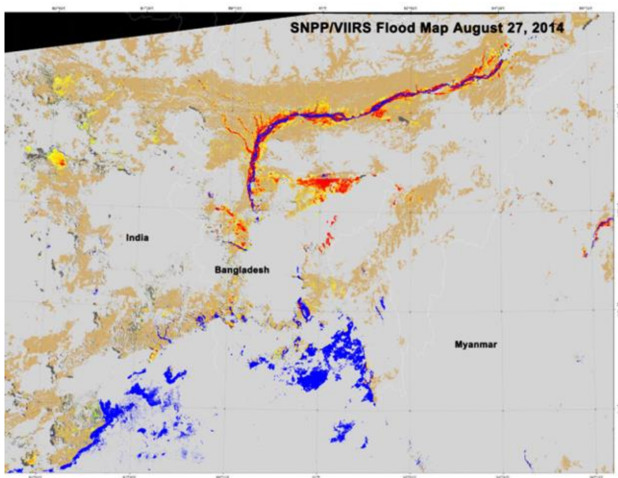


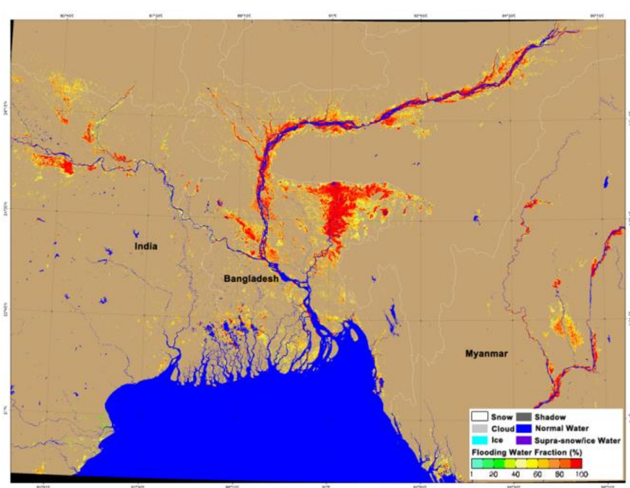
VIIRS-based Flood Map (18:48 UTC 1 January 2016). Image courtesy S. Li (GMU).

maps show much richer detail than these products. All these features make VIIRS near real-time flood maps a great supplemental resource for river observations and forecasting process.

Limitations of Current VIIRS Flood Product

The system is not without limitations. However, these limitations have provided the developers with opportunities to look at their product with fresh eyes, and iterate through it to find meaningful improvements that support the seamless blending of new additions with the existing product.



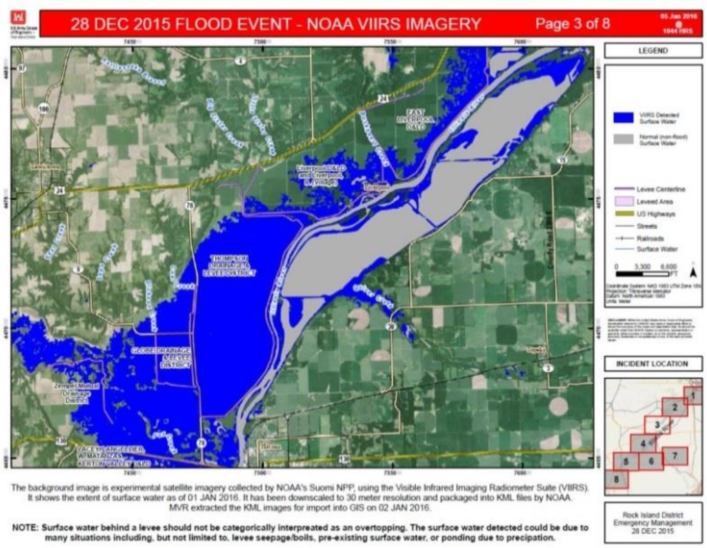


The biggest limitation for flood detection using VIIRS imagery is cloud cover. The VIIRS visible and near-infrared channels cannot see through most cloud cover, which makes it difficult to detect flooding under cloudy conditions. This limitation can thus cause a delay in detecting flood water from heavy rainfall as was the case in August 2014 in Bangladesh. The image on the left shows the rivers in Bangladesh were in flood stage but only part of the flooding water could be detected on August 27's flood map due to cloud cover. Because of cloud cover, it is anticipated that the river had been in flood stage for several days prior to it becoming completely available on VIIRS Flood Product. Additionally, some flash floods caused by heavy rainfall may not be tracked by VIIRS flood maps as well. To get a maximal flood extent during a flood event, multi-day composition from near-real-time flood maps with partially clear-sky coverage here and there may help produce a composited flood map to reduce cloud impact. Based on flood maps in Bangladesh from August 27 through Sep. 03 in 2014, such composition process was applied to derive a flood map shown on the right with the maximal flood extent during this flood event.

Other limitations can be caused by observing time and spatial resolution. Since flood detection mainly relies on visible, near-infrared, and short-wave infrared channels, VIIRS flood maps are only available during daytime. The moderate spatial resolution of VIIRS at 375 meters limits its capability to identify floods at small scales.

New Features Coming Soon

The current VIIRS flood product processed routinely is with 375-m spatial resolution, which only allows the product to address macro horizontal flood extent without any vertical inundation information. To obtain more flood information, the GMU team is now under developing a downscaling model to derive 3-D flood products with high spatial resolution. This model can push the spatial resolution of VIIRS flood maps from 375 meters down to 30 meters or even 10 meters. The model can also output flood water surface levels at 375-m resolution and flood water depth at 30-m or 10-m resolution, which enables the VIIRS flood products to contain 3-D inundation information and allow the product to address much more detailed spatial distribution of flooding water.



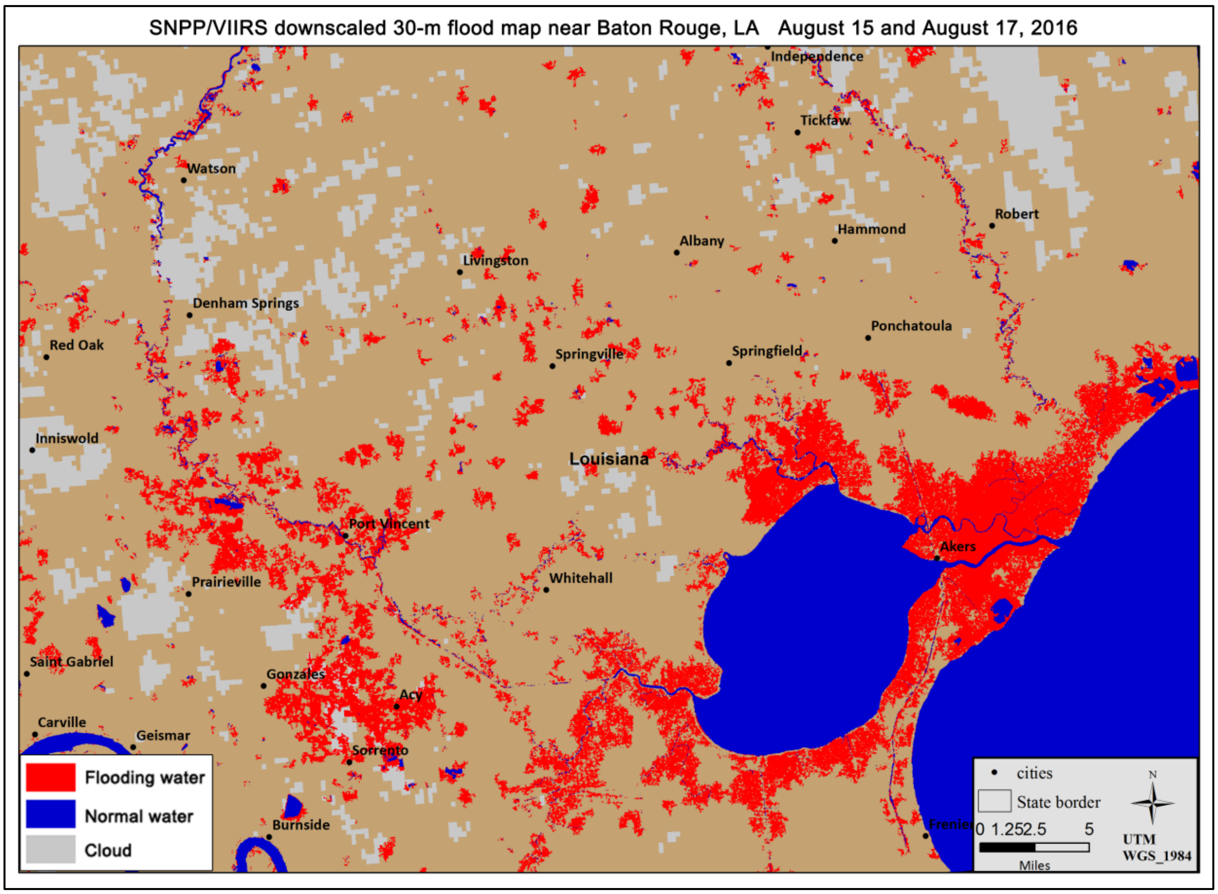
The downscaling model greatly enhances the capability of coarse-to-moderate-resolution satellite sensors. Comparing with the current flood product at 375-m spatial resolution, the downscaled flood maps are with 30-m or even 10-m spatial resolution with 3-D inundation information. Landsat imagery is the primary dataset that are with 30-m spatial resolution. However, the swath width of Landsat is only about 189km and it takes about 16 days to collect imagery with global coverage. Comparing with Landsat imagery, the downscaled flood maps are not only with spatial resolution similar to or even higher than Landsat imagery, but also inherit VIIRS 3000-km swath width and daily global coverage. Moreover, the downscaling model doesn't require any input from river gauge observations. This makes VIIRS flood products particularly helpful in regions where ground river observing systems or gauge observations are unavailable.

The model has been successfully applied in several severe flood events such as the December 2015 flooding events that impacted the Midwest River Basins and the Mississippi River Valley. These new flood products are well received by river forecasters and other agencies. During the December 2015's flood event, the Army Corps of Engineers (USACE) used the products to visualize flooding along sections of the Illinois River. The USACE overlaid this model output onto their products, which displayed the detailed extent of the flooding along the Illinois River watershed. This allowed them to communicate timely information of any looming threats to the towns along the river.

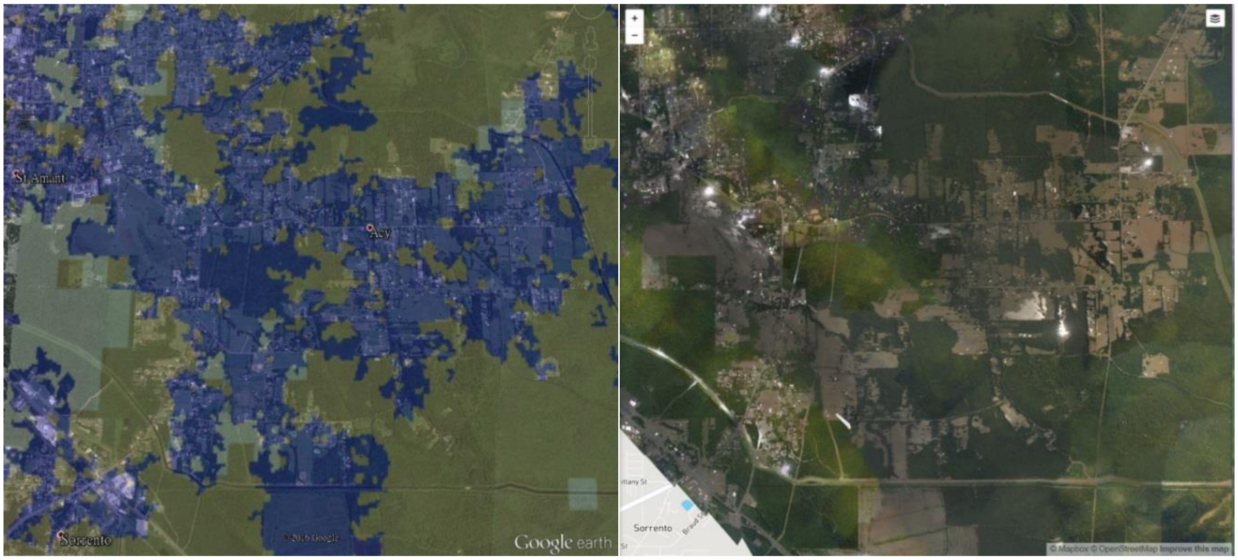
Summer 2016: Catastrophic Floods Devastate Baton Rouge, Louisiana

Even more recently, in August 2016, the downscaled VIIRS flood maps were deployed in Baton Rouge, Louisiana when heavy rains and massive flooding ravaged the state. Between August 12 and 14, heavy downpours dumped over four trillion gallons of rain over parts of Louisiana.

With some areas receiving accumulations estimated to be in excess of 20 inches (510 mm)—rivers were rapidly rising and gauges were setting all-time record highs. The flood now considered as the worst natural disaster in the United States since Superstorm Sandy, deluged many parishes in southeast Louisiana and forced thousands of evacuations. At the request of the Federal Emergency Management Agency, or FEMA, NASA and the Dartmouth Flood Observatory at the University of Colorado, Boulder, the PGRR science team composited the VIIRS downscaled 30-m flood maps on August 15 and August 17 to derive relatively maximal flood extent in the region. Aerial photographs at 50-cm resolution from NOAA's Remote Sensing Division taken on August 14, 15 and 18 were used for validation and proved of consistent and promising results from VIIRS 30-m flood maps in comparison to the ground truth.

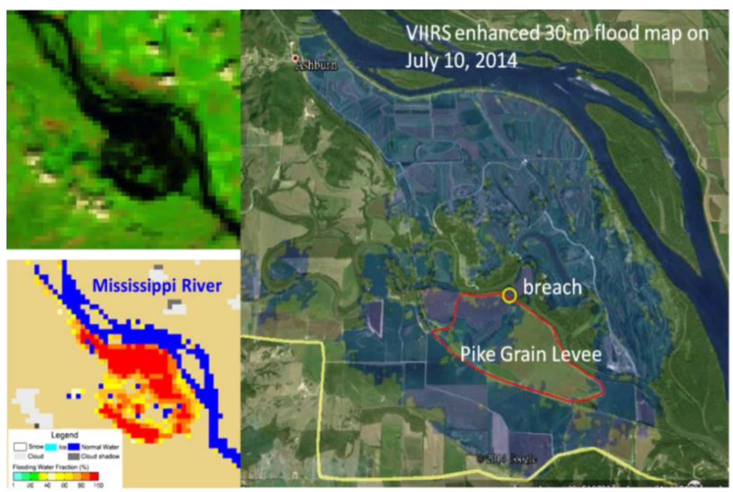


An overview of flooding water near Baton Rouge using VIIRS downscaled 30-m flood map composited from August 15 and August 17, 2016.



Comparison between VIIRS 30-m flood map (left) on 17 Aug. 2016 and aerial photo (right) on 18 Aug. 2016 near Acy, Louisiana

As no effective flood maps of Baton Rouge were obtained from other high-spatial-resolution satellites such as Radarsat and NASA's Earth Observing Mission 1 (EO-1), the VIIRS downscaled 30-m flood maps served as one of the primary data sources for FEMA officials and ultimately helped them investigate flood extent and inundation, determine areas of damage, and aid in flood response, recovery and mitigation.



One of the more important applications of the downscaled flood products is levee monitoring and management whereby the flood product has helped river forecasters and hydrologists to investigate flood status and risks of levees breaching. The downscaled flood maps which are based on flood extent products have turned out to be key sources of detailed information on levee breaches, potential leaks and flooding water volume estimations. The image on the right is of the Pike Grain Levee on the Mississippi River that breached on July 10, 2014. Of the two smaller images, VIIRS false-color image appears at the top, while a 375-m flood map appears at the bottom. NWS personnel were unaware of the breach until it became visible on the satellite imagery. Fortunately, the campgrounds in that area were unoccupied and no lives were at risk.

Conclusion and outlook

While prompted by a request from the NWS Alaska for a product to help better detect floods caused by ice-jams and snow-melt during the spring break-up season, the VIIRS flood detection software has become a key component of Decision Support Services in RFCs across the nation. In a three-year team effort led by the JPSS/PGRR Program, in conjunction with several affiliate science team members, the software has undergone several iterations and morphed from an experimental test product covering spring floods in Alaska to a mature tool that has been embraced by RFCs across the nation. The team consists of members from George Mason University, Space Science and Engineering Center in University of Wisconsin/Madison, Geographic Information Network of Alaska in University of Alaska/Fairbanks, the five River Forecast Centers (APRFC, NCRFC, MBRFC, NERFC and WGRFC) and Alaska/Fairbanks Weather Office. The active collaboration and interactions between developers and users have laid the solid base for this the Initiative and guided the future development of satellite-based flood detection.

The routine flood products have been well received by river forecasters and hydrologists in support of their operations. In some RFCs, river forecasters and hydrologists are beginning to heavily rely on these products to get situational awareness for river forecasting and management applications. In Alaska, these products are even being used to support state transportation managers from the Alaska Department of Transportation and Public Facilities in response to events such as spring breakup over essential economic corridors like the Dalton Highway.

After experimental application in several flood events, the new developed 3-D flood products, which greatly enhance the flood detection capability of the JPSS and provide much more inundation detail, have attracted great interest from RFCs and their customers including the USACE and FEMA. With these new products, the software package is expected to have larger user groups from different agencies and departments across the nation. All these efforts will help improve the applications of JPSS satellites and products in hydrological management as well as risk reduction from floods.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

JPSS and GOES-R Shed New Light on Analyzing and Forecasting Weather Events

Joint JPSS/GOES-R Science Seminar

This article is based in part on the ***May 18, 2016*** *Joint JPSS and GOES-R science seminar presented by Dr. Michael J. Folmer, Cooperative Institute for Climate and Satellites, ESSIC, University of Maryland, College Park,*

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg

The measurements from NOAA's polar orbiting and geostationary environmental satellites are a major component of the National Weather Service (NWS) forecast operations. These satellites observe the Earth's surface and collect measurements that allow forecasters to detect and track potentially dangerous weather phenomena including volcanic ash clouds, dense fog, changing hurricane intensity, and severe weather. This helps ensure that we are prepared for any and all weather events across the nation. Proper situation awareness can help mitigate adverse impacts of weather disasters; however, this logical end goal begins with the need for environmental data that is not only accurate and consistent, but understandable as well. To achieve this end goal, the Proving Ground and Risk Reduction (PGRR) Programs for NOAA's next generation polar-orbiting and geostationary satellites, the Joint Polar Satellite System (JPSS) and the Geostationary Operational Environmental Satellite-R Series (GOES-R), are ardently working to introduce and promote the use of satellite data within the NWS, focusing on the service centers at the National Centers for Environmental Prediction (NCEP).

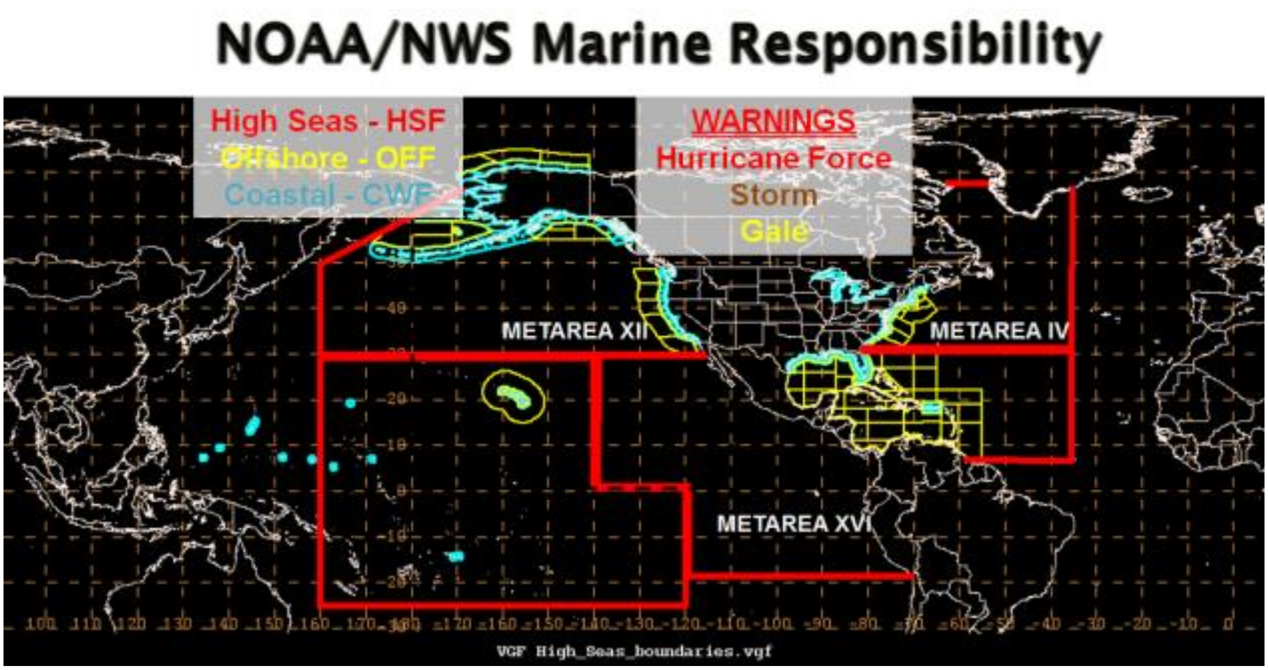
Decision Support Tools for a Weather Ready Nation (WRN)

One of the strategic goals outlined in the NWS's plan for the 21st century is to achieve a Weather Ready Nation (WRN). To support this goal NOAA has taken actions aimed at improving the precision of forecasts and warnings, disseminating information on the risks associated with extreme weather and water events, and communicating them more effectively.

NOAA's NCEP houses nine service centers under its umbrella, which form part of the NWS. These centers support the nation's growing need for environmental information through a plethora of products that enable them to deliver weather, water, climate and space weather guidance, forecasts, warnings and analyses to communities across the nation and the globe.

Among these centers, the Weather Prediction Center (WPC) is the nation's go-to center for high-impact precipitation events. With an approximate 500 environmental products coming from the center daily, it is able to offer a wide range of services. These include quantitative precipitation forecasting, medium range forecasting (three to eight days), and the interpretation of numerical weather prediction models. The WPC provides forecasts and advisories on storm systems that have the potential to cause significant rainfall and snowfall to parts of the nation. The center also generates precipitation forecast guidance for the continental United States for systems expected to impact the country over the next seven days.

Also under NCEP is the Ocean Prediction Center (OPC) http://www.opc.ncep.noaa.gov/, which monitors and forecasts weather and sea conditions year-round. The center provides forecast services for the Atlantic and Pacific high seas and the Atlantic and Pacific offshore zones. Services for the high seas focus on synoptic weather patterns, whereas services for the offshore zones focus on features such as convection. In addition, the center provides medium-range outlooks as well as special projects which include support to the National Marine Fisheries Service in Antarctica, Arctic collaboration with the Alaska region and Canada, as well as a freezing spray Initiative.



The National Hurricane Center (NHC), also a component of NCEP, is responsible for issuing watches, warnings, forecasts, and analyses of hazardous tropical weather. One branch within the NHC, the Tropical Analysis and Forecast Branch (TAFB) http://www.nhc.noaa.gov/abouttafb.shtml, is involved in the forecast process. Complementary to the OPC, the TAFB provides year-round products involving marine forecasting, aviation forecasts and warnings, and surface analyses. It also delivers satellite-derived rainfall estimates along with their interpretation for the international community. During the hurricane season, the TAFB supports the NHC in various ways including the provision of tropical cyclone intensity estimates using the Dvorak technique, radar tracking of tropical cyclones, and marine forecast support to hurricane specialists. In addition, the Branch offers multi-lingual media support, which makes it a truly international help center!

Another center that offers several products and services to the NWS is the Satellite Analysis Branch (SAB). But, unlike the NCEP service centers the SAB is housed under the National Environmental Satellite, Data, and Information Service (NESDIS). This Branch serves as the operational focal point for real-time imagery products within NESDIS. Beyond round-the-clock monitoring, it also distributes products related to volcanic eruptions, ash extent and movement—critical to aviation forecasting and also aviation safety hazards, global tropical cyclone analysis, wildfire detection and smoke emissions monitoring, and heavy precipitation nowcasting and analysis. These disaster mitigation and warning services are provided to the international community as well. In addition to distributing near real-time satellite derived imagery, the Branch works closely with its operational partners including NWS Weather Forecast Offices (WFOs) and NCEP Centers, to assess the utility of new satellite analyses. Combined, these National Centers comprise the Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis (MPS).

So Many Satellite-Derived Products, So Few Uptakes. What Gives?

Satellite data is an important input to weather prediction models, yet until recently, they were largely underutilized by the operational user community. These data and derived products can be difficult to access, manipulate and process, particularly for people who are unfamiliar with them. These data remain underutilized due to limited or minimal interaction with the high resolution imagery and microwave products due to latency issues and limited training on the datasets.

The JPSS and GOES-R PGRR Programs were created to demonstrate and familiarize forecasters with the products and capabilities that will be incorporated into the NWS and NESDIS operations. The Programs' help ensure user readiness in the area of satellite services, and are fundamental elements of the NOAA's satellite training program. They make satellite products available to forecasters through a variety of means. These include satellite liaisons or subject matter experts at NWS National Centers. The Satellite Liaisons play an important role in ensuring that NOAA's operational forecasters have access to and are able to utilize that satellite products in the forecaster's display systems such as the NCEP Advanced Weather Interactive Processing System (N-AWIPS), Man computer Interactive Data Access System (McIDAS), and AWIPS II.

Prior to the PGRR efforts, there were so many satellite-derived products being generated, yet many remained unused. Data from polar-orbiting satellites was primarily focused on Numerical Weather Prediction (NWP), used by the Environmental Modeling Center (EMC) as part of the robust data assimilation schemes used in the Global Forecast System (GFS) among other models. Data from geostationary satellites was used more predominantly than that from polar-orbiting satellites; but it was delivered at poor spatial resolutions ranging from 1–28 km, and at temporal cadences that averaged anywhere from 30 minutes to one hour.

Integrating Satellite Products and Techniques into Forecast Operations

Satellite Liaisons are key members of the JPSS and GOES-R PGRR Programs. They provide support to NCEP and NWS Forecast Offices. To serve the different needs and skills of satellite data users, liaisons employ various methods to familiarize forecasters with satellite products and how satellite data can be incorporated within tools already in use. These methods include establishing various satellite capability demonstrations, setting up seasonal focused applications, and providing training on an ongoing basis to the operational forecasters at their location. They are essentially research-to-operations liaisons, as they provide training for satellite product users. At the centers, they maintain a consistent presence on the operations floor, which helps promote the continuous use of satellite data amongst the operational user community, particularly in solving their specific forecast challenges.

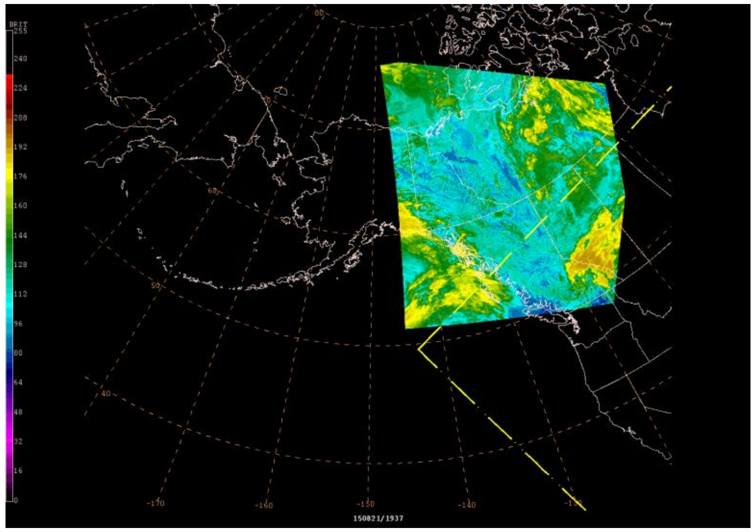
Satellite Liaisons also gather and synthesize user feedback on these products, which helps product developers during iterations to find meaningful improvements. More than a link between the developers and users, Satellite Liaisons are considered the local subject matter experts (SMEs) that provide valuable input into the development and execution of the training programs. Liaisons also provide training to operational forecasters in Weather Forecast Offices (WFOs) as the opportunity allows, which includes having a liaison at the Operations Proving Ground (OPG) in the National Weather Service Training Center (NWSTC) in Kansas City, MO where WFO forecasters are invited to evaluate new satellite capabilities or products in a controlled setting that replicates an NWS WFO.

Satellite liaisons will become even more critical in the future in response to the challenges of the operational integration of the large volume of data from NOAA next generation satellites. They will be critical in ensuring the more intelligent integration of information derived from blended satellite products (e.g., geostationary and polar satellite observations), multi-dimensional classification of severe storm potential by combining satellite, radar, in-situ data and models, and new ways of visualizing satellite data within the next generation operational decision support platform known as the Advanced Weather Interactive Processing System (AWIPS-II).

Below are some examples of how Satellite Liaisons have helped national centers integrate satellite data into their operations.

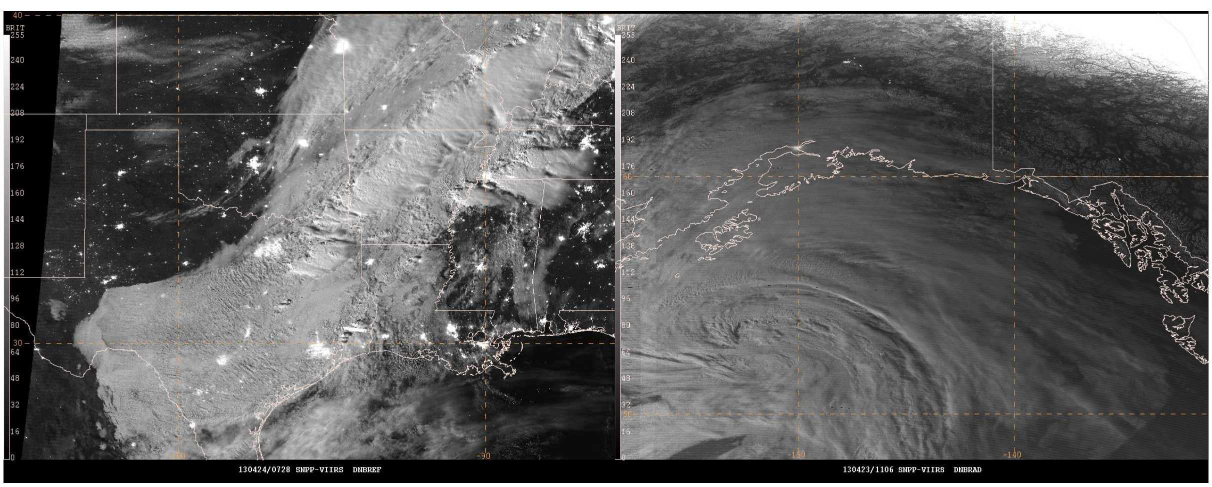
Combining VIIRS and MODIS in One Display

With help from NASA's Short-term Prediction Research and Transition Center (SPoRT), forecasters at the OPC/WPC/SAB now have the capability of looping multiple polar-orbiter images in one display. This was not previously available and would lead to forecasters having multiple windows open to assess on meteorological feature. SPoRT (http://weather.msfc.nasa.gov/sport/) is a NASA project to transition unique observations and research capabilities to the operational weather community to improve short-term forecasts on a regional scale.



MODIS/VIIRS Longwave IR. Courtesy of CIMSS and NASA SPoRT

CONUS ALASKA

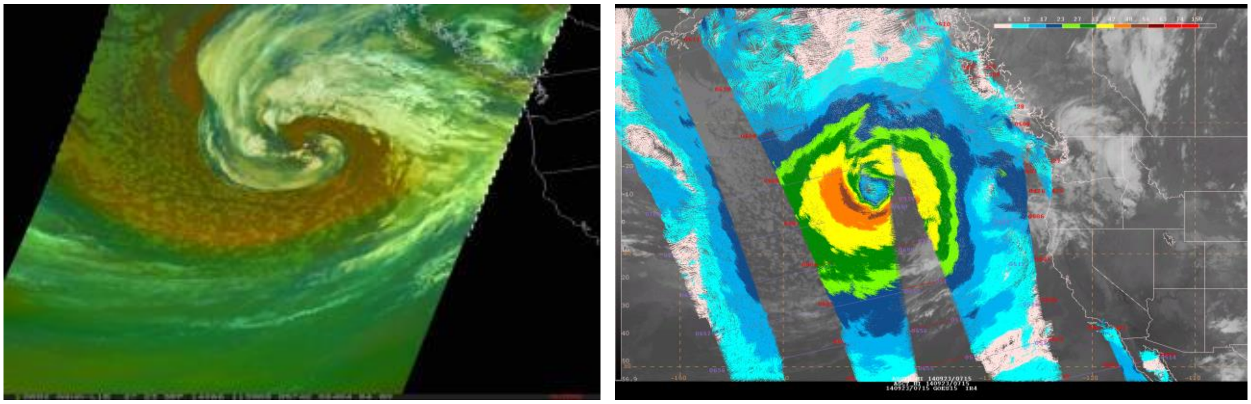


Day-Night Band used by WPC and OPC to monitor cold front and storms at night with moonlight! Courtesy of CIMSS and NASA SPoRT

The Visible Infrared Imaging Radiometer Suite (VIIRS) Day-Night Band (DNB) aboard the first JPSS spacecraft, the Suomi-National Polar-orbiting Partnership (Suomi NPP), has provided forecasters with the opportunity to observe weather systems by moonlight! The DNB helps forecasters analyze the cloud textures and frontal positions with higher quality, night-time visible-like imagery.

OPC Decision Process

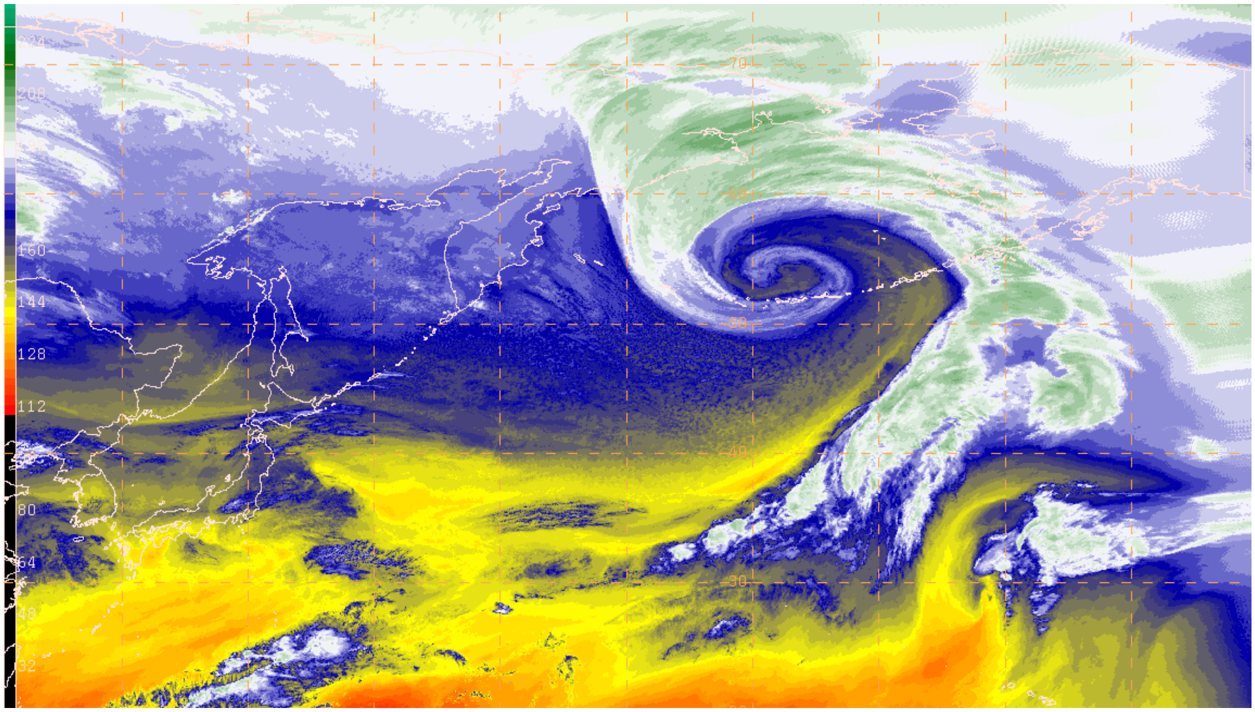
MODIS AIR MASS RGB | ASCAT WINDS ON



Hurricane-Force Low 1130 UTC on 09/23/14. Courtesy of NASA SPoRT

On the left, the MODIS Air Mass RGB product reveals a hurricane-force extratropical cyclone near the Pacific Northwest with a significant amount of drying (red/orange coloring) due to a stratospheric intrusion. Forecasters at OPC used this imagery along with the scatterometer data (right) to assess the situation and upgrade the storm to a hurricane-force low in the absence of additional data.

The incorporation of these products into the operational forecast process has led to greater satellite guidance lead times, increased situational awareness, and higher confidence in analysis and forecasts of meteorological events.



Hurricane-Force Low 0600 UTC on 12/13/15 using the 7.3 μm Low-Level Water Vapor channel on Himawari-8. Courtesy of JMA, NESDIS STAR, and CIRA.

The Himawari-8 image above showcases an explosive cyclone that affected Adak Island and other parts of the Aleutian Islands in mid-December 2015 with winds gusting to ~122 mph. Himawari-8 is giving the forecasters at WPC, OPC, and SAB the opportunity to analyze these systems at GOES-R resolutions, therefore opening the path to better satellite integration into forecast operations. Research has started in the MPS Proving Ground on combining Himawari-8 imagery and JPSS products such as the NOAA Unique Combined Atmospheric Profiles (NUCAPS) to help assess and forecast these high impact storms.

Summary

The measurements from NOAA's polar orbiting and geostationary environmental satellites are a major component of the NWS forecasting system. But due to a myriad of reasons, these data were not available to forecasters at the NWS NCEP centers until the advent of the Satellite Proving Ground. Given that these centers provide key services including weather, water, climate and space weather guidance, forecasts, warnings and analyses to communities across the nation and the globe, it is important that the operational forecasters in these centers are able to take advantage of the plethora of satellite derived products to address their forecast challenges. It is also important that they are acquainted with the satellite products available to them, and that they are knowledgeable of how these data can be incorporated within tools already in use.

The JPSS and GOES-R PGRR Programs were conceived to demonstrate and familiarize forecasters with the next generation geostationary and polar-orbiting satellite products and capabilities that will be incorporated into NWS and NESDIS operations. By providing Satellite Liaisons to these centers, these PGs are helping forecasters by integrating new satellite products and techniques into forecast operations and assisting with training to ensure readiness for JPSS-1 and GOES-R from day one. Not only are the satellite products enabling these centers to better analyze meteorological events, but to better serve the public as well.

The use of satellite derived products at the MPS Proving Ground has bought with it increased opportunities for forecasters at these centers to discover operational applications of data from NOAA's next generation satellites JPSS and GOES-R.

JPSS USER PERSPECTIVE

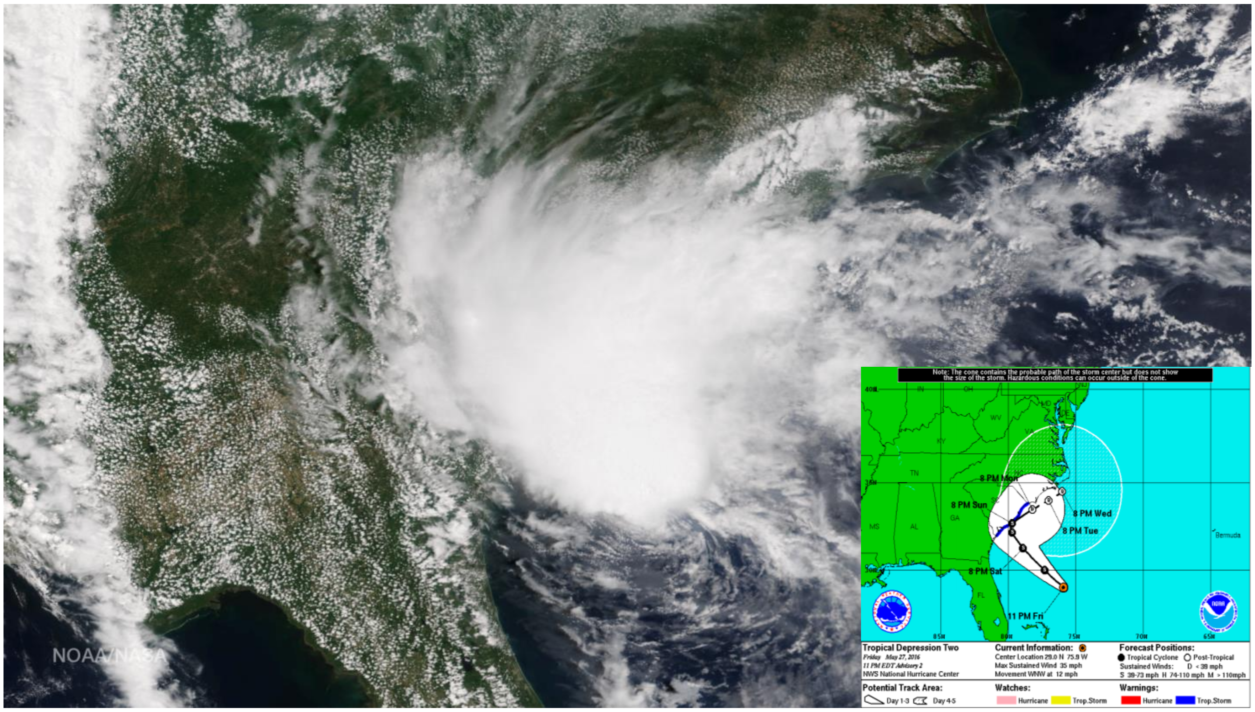
What the users are telling us about JPSS

Improving JPSS and GOES-R Applications with CIMSS Near Real-Time Satellite Data Assimilation for Tropical Cyclone Forecasts

Joint JPSS/GOES-R Science Seminar

*This article is based in part on the **June 20, 2016** joint JPSS and GOES-R science seminar presented by Dr. Jun Li, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison.*

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg

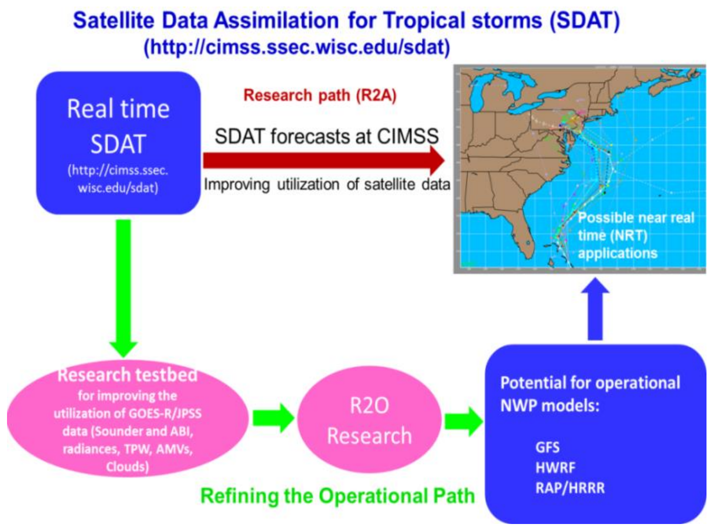


Tropical Storm Bonnie over the South Carolina Coast May 28, 2016. This image was taken by the Suomi NPP satellite's VIIRS instrument around 1910 UTC on May 28, 2016. Image courtesy NOAA Environmental Visualization Laboratory (NNVL) ***http://www.nnvl.noaa.gov/MediaDetail2.php?MediaID=1883&MediaTypeID=1****. Inset: National Hurricane Center 5-Day track forecast, uncertainty cone, and watch/warning,* ***http://www.nhc.noaa.gov/archive/2016/graphics/al02/loop_5W.shtml***

Observations from the next generation of environmental sensors onboard the Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite R-Series (GOES-R), provide high resolution and high temporal information needed for numerical weather prediction (NWP). In particular, observations of atmospheric temperature and moisture in the environment provide information that contributes significantly towards the prediction of tropical cyclones (TCs). This includes the prediction of aspects such as their genesis, intensification, motion, rainfall potential, and track changes. The Cross-Track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) on the first satellite in the JPSS Series, the Suomi National Polar-orbiting Partnership (Suomi NPP), provide the high vertical resolution temperature and water vapor information needed to improve NWP forecast skill. Currently only the IR sounder data that is available when there is little or no cloud cover is utilized in assimilation. This means that satellite observations which could contain valuable information are discarded because they are obtained from environments where multiple cloud layers are present, which tends to limit their application in TC and local storm forecasts with regional NWP. Research scientists from the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at University of Wisconsin-Madison are making the most of the high resolution atmospheric temperature and moisture information provided by JPSS and attempting to expand radiance assimilation into cloudy skies. In addition, they are exploring the use of high temporal resolution water vapor measurements from GOES-R in NWP for TC and local storm forecasts.

The Satellite Data Assimilation for Tropical storms (SDAT)

The Satellite Data Assimilation for Tropical storm forecasts (SDAT) (http://cimss.ssec.wisc.edu/sdat) is a near realtime regional system developed by research scientists from CIMSS. The system is built with the community Gridpoint Statistical Interpolation (GSI) assimilation and advanced Weather Research Forecast (WRF) model. With GSI, SDAT can assimilate all operational available satellite data including radiances from sensors such as ATMS, AMSUA/AMSUB, GOES, HIRS, MHS, AIRS and IASI and some satellite derived products. SDAT also assimilates satellite-derived total precipitable water (TPW), the layered precipitable water (LPW) and atmospheric motion vector (AMV) products into the system.



SDAT functions as a research to applications (R2A) toolkit whereby the forecast products can be used by a local user community or the broader research community. In addition, the assimilation of JPSS and GOES-R data in regional NWP (e.g., handling clouds, using high temporal and spatial resolution water vapor and AMV information, etc.) enables SDAT to serve as a research testbed for improving high impact weather (HIW) forecasts. As a testbed; SDAT provides a pathway for experimental products to be assimilated in operational TC forecast models such as the Hurricane Weather Research Forecast (HWRF) and Global Forecast System (GFS).

The SDAT system has three components. One is the Gridpoint Statistical Interpolation (GSI), which was developed by NOAA NCEP. GSI is a unified variational data assimilation system for both global and regional applications. It is the core of the NDAS for NAM, GDAS for GFS at NOAA, and various operational systems.

The second is the Weather Research and Forecasting Model (WRF), the next-generation mesoscale numerical weather prediction system developed by NCAR, NOAA, AFWA, NRL, OU, and FAA. It is applicable for both meteorological research and numerical weather prediction. It is available in both online and offline versions. The online version is currently offered at a resolution of 18 km for real time applications whereas the off-line version, which is mainly used as a research testbed is available at resolutions ranging from 4–12 km.

The third is the Community Radiative Transfer Model (CRTM) for data assimilation (DA). This is a fast radiative transfer model which is used to calculate radiances and Jacobians for satellite IR or MW radiometers. It was developed by JCSDA as an important component in the NOAA/NCEP data analysis system. In addition, tools are also developed to convert the research products (soundings, tpw, amv and so forth) into GSI accepted bufr format and a vortex relocation algorithm is recently added into SDAT system.

SDAT in Testbed Environments

Using SDAT as a research testbed, studies are conducted to show how to improve HIW forecasts through better usage of cloud information for satellite data assimilation. SDAT has been used as a testbed to study how to improve the Infrared (IR) and Microwave (MW) sounder radiance assimilation, especially in cloudy regions. The goal is to figure out how to better detect the clear areas and how to assimilate IR sounder thermodynamic information in partially cloudy skies. By collocating data from high spatial resolution sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS) or the Visible Infrared Imaging Radiometer Suite (VIIRS) with the corresponding data from hyperspectral resolution sounders such as Atmospheric InfraRed Sounder (AIRS) or Cross-track Infrared Sounder (CrIS), precise clear pixels of AIRS/CrIS can be identified and some partially or thin cloud contamination from pixels can be removed by taking advantage of high spatial resolution and high accurate MODIS/VIIRS cloud information. The results have demonstrated that both of these strategies have greatly improved the hurricane track and intensity forecast. Similar studies have also been tested in the microwave sounders by the collocation of AMSU/MODIS and ATMS/VIIRS data. Most of these research results have been published (Wang et al, 2014, 2015; Han et al, 2016, Li et al. 2016).

Impact studies

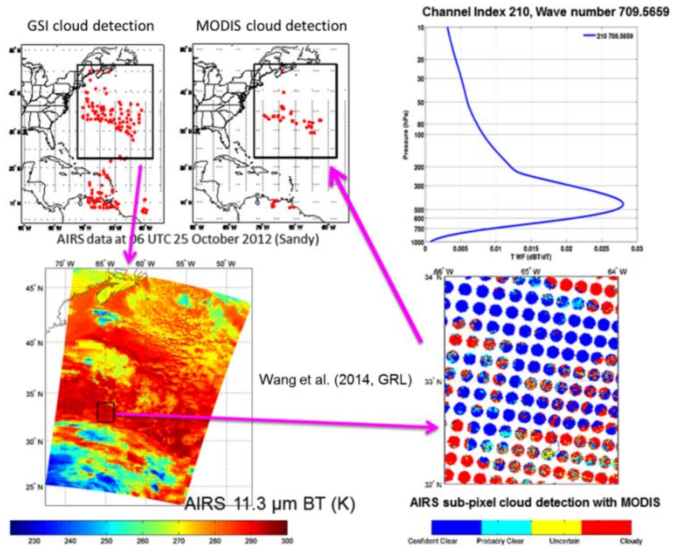
Handling Clouds in Radiance Assimilation

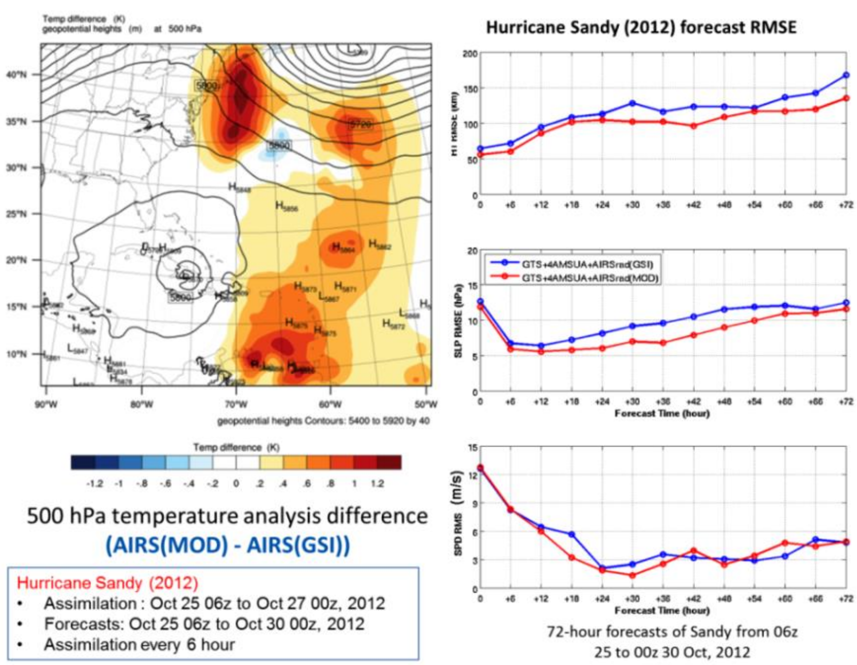
The assimilation of IR radiances is very challenging, particular for cloudy regions because (1) both NWP and radiative transfer models have large uncertainties in cloud situations, (2) there is a significant change in the temperature Jacobians at cloud level, (3) satellite observations and NWP may be inconsistent on clouds (e.g., the satellite sees clouds but NWP does not, vice versa), and (4) radiances are much more nonlinear to the atmospheric parameters in cloudy situations than in the clear skies. Due to these difficulties, most operational centers focus solely on clear sky and clear channel IR sounder radiance assimilation.

Better Cloud Detection

To improve the clear sky IR sounder radiance assimilation, a good clear radiance detection algorithm is needed. Currently most operational NWP centers are using IR sounder data alone for clear pixel detection or clear channel detection (e.g., by comparing the observed and the simulated brightness temperature calculated through the forward model from the background), which could result in treating some cloudy footprints as “clear” during assimilation and therefore cause residual bias in the analysis. A new cloud detection method uses collocated high spatial resolution imager data i.e., MODIS onboard the same platform as the satellite sounders to help IR sounders (i.e., AIRS) sub-pixel cloud detection (Li et al., 2004). The MODIS cloud mask provides a level of confidence for the observed skies as confident clear, probably clear, probably cloudy, and confident cloudy. The AIRS sub-pixels with confident clear from the MODIS cloud mask are kept as clear observations; otherwise, the AIRS subpixels are rejected as cloudy. AIRS cloud detection using the collocated MODIS cloud mask removes the cloud FOVs, which reduces loud contamination and improves the assimilation.

The images on the right show Superstorm Sandy (2012) in cloudy conditions. They were generated using GSI cloud detection and MODIS cloud detection (upper left two panels). They indicate that the data coverage using AIRS/MODIS collocation method is much less than that of GSI/AIRS alone. However the more accurate clear sky detection removes the possible cloud contaminated pixels for assimilation and further improves the storm's track and intensity forecast as shown below. A similar collocation algorithm was also applied to AMSU/MODIS and VIIRS/ATMS data with the combination of MODIS/VIIRS cloud property data. The results also show the improvement of microwave sounder (AMSU/ATMS) data assimilation (Han et al 2016).



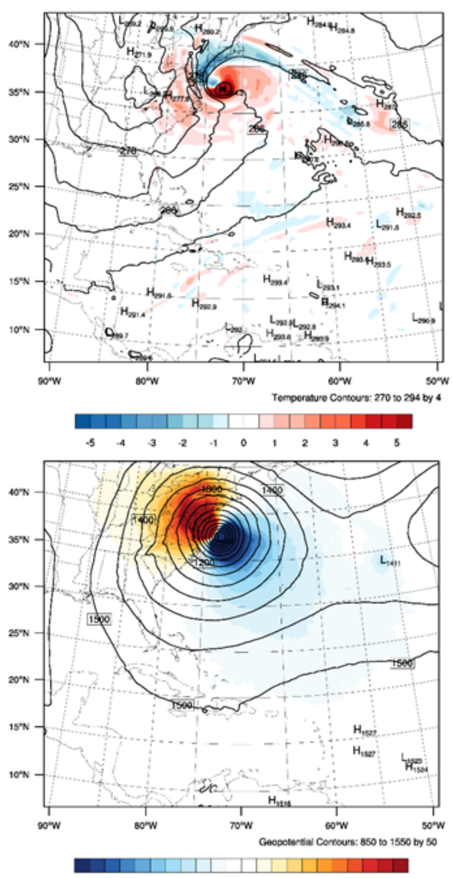


Impact of Assimilating Cloud-Cleared Radiances on Forecasts

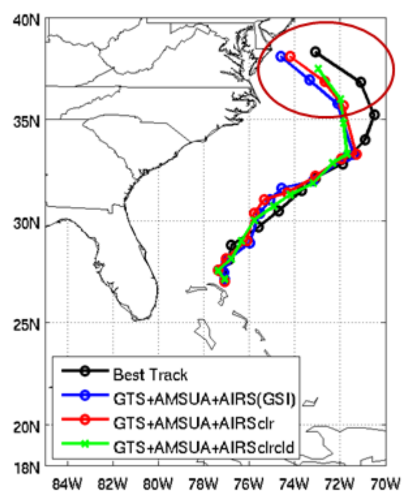
The availability of IR sounder clear radiance is fairly limited, which impacts the application of advanced IR sounder observations.Therefore, adding more information from cloudy region would help improve the satellite data application and NWP forecast. Given that assimilating cloudy IR radiances directly is riddled with challenges, an alternative way using the cloudy observations is to assimilate the cloud-cleared radiances, which removes the cloud effect in IR field of view (FOV) by using additional information in cloudy skies and obtains the clear equivalent IR radiances.

An imager based cloud-clearing method developed by Goldberg et al. (2005) and Li et al. (2005) removes the cloud effect from an IR sounder FOV with partial cloud cover by using collocated clear sky imager IR radiance. Using the collocated clear portion of MODIS IR radiances within the two adjacent AIRS FOVs' cloudy radiances, a cloud-clearing parameter call N* can be derived by spatially averaging MODIS clear radiances to AIRS footprints and spectrally convolving AIRS radiances to MODIS bands by applying MODIS Spectral Response Functions (SRFs) to the AIRS radiance spectrum. Once N* is derived, it can be applied to the cloudy radiances from the measurements of these two FOV's and derive the clear equivalent radiance spectrum representing the common clear portion of radiances within the two adjacent AIRS FOVs. Additional quality controls are further applied to ensure the quality of the cloud-cleared radiance.

The number and quality of observations highly affected the data assimilation, whereby better quality observations usually led to better analysis/forecast. After applying the cloud-clearing algorithm, the cloud effect on the partial cloud pixels is removed. As a result, the generation of clear equivalence radiance leads to an increase in the number of observations in the partially cloudy regions. As shown in the figure below, the forecast error of the temperature fields and the RMSE of the hurricane track become smaller consequent to the assimilation of high quality cloud-cleared radiances.



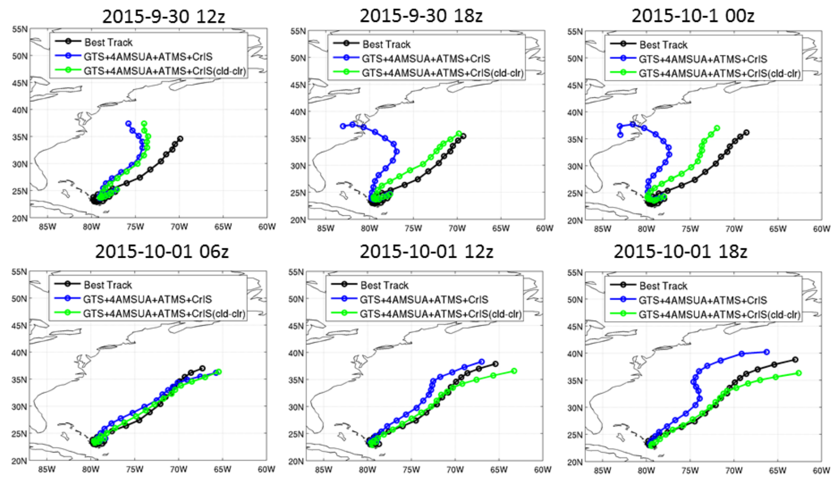
72-hour forecast
AIRS (MOD clr-cld) – AIRS (MOD clr)



72–hour forecast hurricane tracks From 18 UTC 26 to 18 UTC 29 Oct, 2012.

- The difference in temperature indicates AIRS (MOD cld-clr) is warmer at southeast, and colder at northwest of hurricane center. (upper left panel)
- Geopotential height of AIRS (MOD cld-clr) is lower at the southeast, and higher at the northwest of hurricane center. (lower left panel)
- The warmer temperature and lower geopotential height region of AIRS (MOD cld-clr) is further southeast compared to AIRS (MOD clr). (left two panels)
- The difference indicates the hurricane center of AIRS (MOD cld-clr) is southeast of the hurricane center of AIRS (MOD clr). (right panel)

The imager-based cloud-clearing approach has been successfully applied to process VIIRS/CrIS. Below is a figure showing hurricane Joaquin (2015) track and intensity 120-hour forecasts with two approaches for CrIS radiance assimilation: GSI (operational) approach (blue), and CrIS cloud-cleared radiances with help of VIIRS (green). Using SDAT as research testbed, it is found that the CrIS cloud-cleared radiances with help of VIIRS provide value-added impact on TC forecasts over clear sky radiances, which indicates that the cloud-clearing method can be an alternative approach for assimilating CrIS radiances in cloudy skies. Global CrIS cloud-cleared radiances have also been generated for testing at EMC (Environmental Modeling Center) GFS application.



Due to their high temporal resolutions, geostationary satellites are an excellent source of data. Therefore, data from GOES as well as from the Advanced Himawari Imager (AHI) onboard Japan's geostationary weather satellite, Himawari 8 have been tested. Assimilating high temporal precipitable water (PW) data has been shown to improve both analysis and forecast fields in several local cases as well as for one of the strongest TCs to strike during the Pacific typhoon season in 2015, typhoon Soudelor. Furthermore a vortex relocation algorithm has been added to the SDAT system. The seasonal run for 2015 Atlantic Ocean domain tropical storms shows that SDAT has large track skill, including track errors that are comparable with the NHC's best operational models. However, it has a large intensity error compared to other operational models. With vortex initialization implemented, the intensity error is expected to be reduced in the coming 2016 hurricane season.

Future plans

Currently, clear location and cloud-cleared radiances are only used in data assimilation. Thus future plans include the addition of clear channel radiances in assimilation by including clear channel detection into the algorithm. In this way, more observational data will be used, which will help further improve the analysis field. The VIIRS-based CrIS cloud-cleared radiances will be further tested through collaboration with EMC. Other plans include collaborative research with Andrew Collard (EMC) and Chris Barnet to compare the different cloud-cleared products and their impacts on TC forecasts. The potential impacts of high temporal resolution GOES-R layered precipitable water (LPW) on the intensity of tropical storms and the precipitation of local storms will be further studied.

Along with this research, planned improvements for SDAT include relocation and vortex initialization for 2016 hurricane season, and further study on whether SDAT adds to consensus track model skill. CIMSS has partnered with the NWS Weather Forecast Office (WFO) in

Milwaukee/Sullivan to better understand its forecasters' needs for SDAT products as well as the tools needed to help meet those needs. In addition, CIMSS has a goal to highlight to forecasters how products from weather satellites can prove useful. As a result future plans under this project include the use of SDAT in potential applications to operations in the Milwaukee/Sullivan WFO. These include the application of SDAT precipitation forecasts, and simulated GOES-R images.

Summary

The application of SDAT as a research testbed has enabled studies on improving the use of satellite data from JPSS and GOES-R in NWP models. These include studies on better methods of assimilating hyperspectral IR sounder radiances in cloud detection and better ways to assimilate CrIS radiances in cloudy skies. Additional test areas will focus on how to better use the high temporal resolution moisture in NWP for local storm forecasts. Since the fall of 2013, the SDAT system has been running in near real time. Hurricane forecasts covering the Northern Atlantic Ocean domain in 2015 were analyzed and compared with other operational models. Results from these runs showed SDAT to have large track skill, including track errors that are comparable with the NHC's best operational models. Future research work will be focused on improving the assimilation of CrIS radiances for HWRF which has been benchmarked at NOAA's Operations-To-Research (O2R) environment on the Supercomputer for Satellite Simulations and data assimilation Studies (S4) which is physically located at SSEC. The research progress made by assimilating CrIS radiances in SDAT will also be tested for potential operational transition into the HWRF.

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JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Motivation for a JPSS Sulfur Dioxide (SO2) Initiative for Volcanic Cloud Detection, Characterization, Modeling, and Alerting Applications

*This article is based in part on the **July 18, 2016** JPSS science seminar presented by Mike Pavolonis, NOAA/ National Environmental Satellite, Data, and Information Service/ Center for Satellite Applications and Research.*

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg

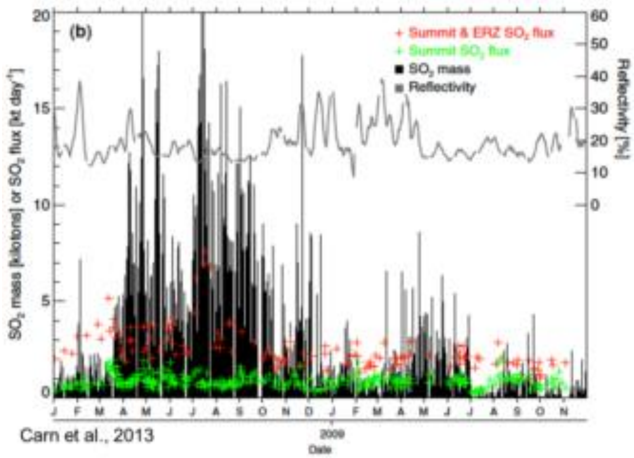
Ash plume erupting from the Sarychev Volcano on June 12, 2009. The volcano is located in the Kuril Island chain stretching north of Japan and east of Russia. Image credit: NASA

https://www.nasa.gov/sites/default/files/images/363385main_iss020e009048_levels_full.jpg

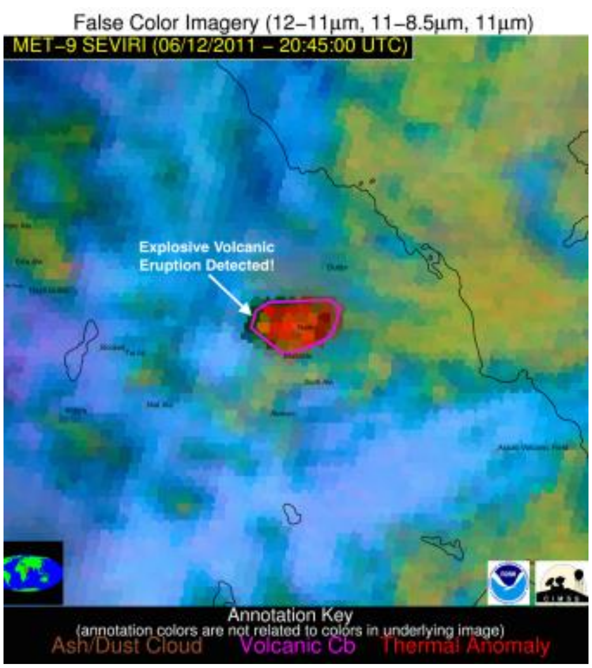
Volcanic ash clouds are formed during explosive eruptions that occur when gases dissolved in molten rock expand and escape violently into the air. They are also formed when water, heated by the molten rock, abruptly flashes into steam. The hot ash and gas can be ejected to great heights in the atmosphere, sometimes towering above 30,000 feet in the air. This ash can pose major threats to transportation, health and infrastructure. Encounters between flying aircraft and volcanic clouds can lead to engine failure and put the lives of flight crews and passengers at risk. But more than that, the clouds produced from these volcanoes are able to transported great distances from their source, which can create a serious hazard thousands of miles from an eruption. Knowing the characteristics of volcanic clouds and being prepared for volcanic unrest can significantly reduce the impacts.

Importance of Monitoring Volcanic Activity from Space

Only about 10 percent of the world's volcanoes are routinely monitored from the ground (Ph. Bally Ed. 2012). Earth observations including those from NOAA's polar and geostationary orbiting satellites can reliably identify volcanic eruptions anywhere in the world. Significant improvements are coming from the next generation Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite-R Series (GOES-R). These satellites offer the advantage of obtaining measurements over broad spatial and temporal coverage that enables the detection and characterization of high impact environmental events such as volcanic eruptions. However, the properties of volcanic clouds are complicated and highly variable. While no single instrument or sensor has all the attributes needed to effectively detect and characterize all types of volcanic clouds, individual sensors are capable of capturing certain markers or tracers, which scientists can use to monitor basic volcanic activity and possibly detect changes in volcano behavior. Chief among these tracers is sulfur dioxide (SO_2), an abundant volcanic gas that is hazardous to human health, infrastructure and the environment. SO_2 information is critical for volcano monitoring, volcanic ash tracking, and for understanding the impacts of volcanic aerosols on weather and climate in the wake of a large eruption. Large concentrations of SO_2 are especially harmful to human health, and more so for those with preexisting respiratory conditions such as asthma, and chronic bronchitis. SO_2 is also a very reactive gas that can readily combine with water to form sulfuric acid. Chronic exposure to sulfuric acid can damage the airframe of jet aircraft and is costly to repair.



SO_2 emission time series are critical for monitoring changes in volcanic activity and can help with eruption prediction (Credit: Carn et al., 2013)



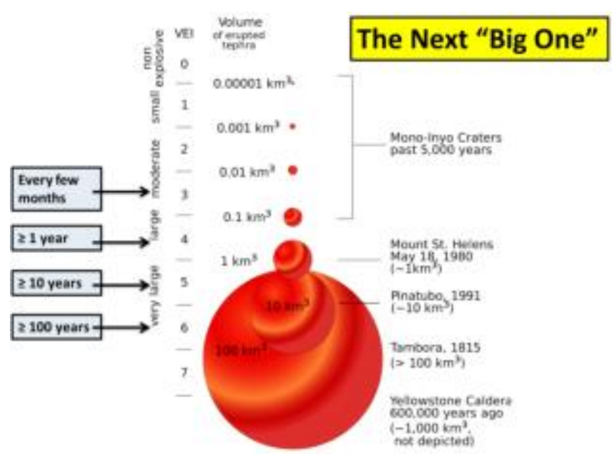
Short-term exposures to high levels of SO_2 can be life-threatening. SO_2 emissions can cause acid rain and air pollution downwind of a volcano causing persistent health problems for downwind populations. That is why it is important to detect and characterize large concentrations of sulfur dioxide as quickly as possible for operational and safety reasons, particularly in the remotest regions. In 2011, an eruption in Eritrea's remote Nabro volcano remained undetected for seven and a half hours. Subsequent analysis using NOAA's alerting tool, which utilizes all relevant (NOAA and non-NOAA) satellite sensors in geostationary and low earth orbit, automatically detected the eruption within 15 minutes of the start time as opposed to 7.5 hours. In addition, post event studies revealed that the Nabro cloud contained very large amounts of SO_2 (e.g. Theys et al., 2013), thus any environmental exposure could have led to adverse and potentially dangerous results.

Satellite measurements, including those from three key sensors onboard the JPSS, the Visible Infrared Imaging Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CrIS), and the Ozone Mapping Profiler Suite (OMPS) are sensitive to the presence of SO_2 and provide scientists with the much needed information to help characterize volcanic unrest, enhance volcanic ash tracking, and assess the climate impacts of very large eruptions. These include Ultraviolet (UV) measurements from OMPS, which allow scientists to monitor the evolution of volcanic activity over time. The UV-based OMPS SO_2 loading product is very useful, even in the presence of dense underlying cloud cover, but requires sufficient sunlight to deliver any useful information. Another sensor that provides SO_2 measurements is the IR-based CrIS that can be used to retrieve SO_2 mass loading and height, independent of solar zenith angle. At present CrIS is only being used to generate a yes/no flag when SO_2 is suspected. VIIRS, which is presently not being utilized for this application, is capable of quantitatively mapping SO_2 with revolutionary spatial detail for a meteorological satellite sensor. The downside though is VIIRS lacks the spectral resolution and coverage needed to accurately retrieve SO_2 mass loading and cloud height, and its detection capabilities are particularly limited in the presence of background cloud cover. More details on each sensor's limitations are presented further in this article.

These limitations are driving a significant effort within the JPSS Proving Ground and Risk Reduction (PGRR) Program to create a fused JPSS based SO_2 product suite for SO_2 detection and characterization and utilization in tandem with weather, dispersion, and climate models. This information will help ensure that NOAA can provide high quality, objectively derived, environmental intelligence on SO_2. Earth observation satellites like JPSS provide some of the most critical inputs needed to model the impacts of SO_2. This information is especially vital to the decision support systems at Volcanic Ash Advisory Centers (VAACs), meteorological watch offices, weather forecast offices (WFOs), volcano observatories (including the USGS), and the military. They also serve as key inputs for operational dispersion, weather, and climate models, and for research applications as well.

Early Detection of the Next Big One

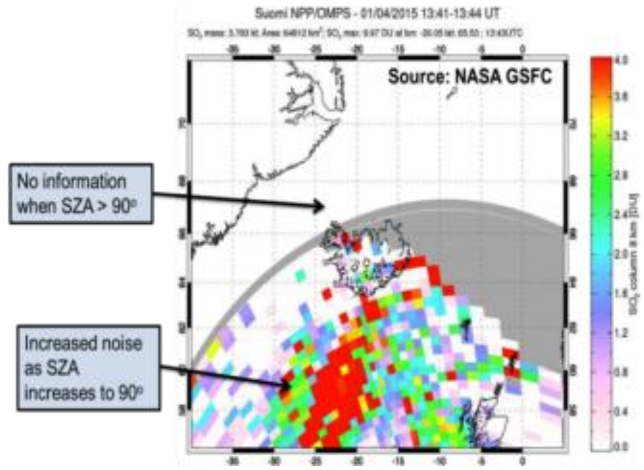
SO_2 is an effective tracer for volcanic ash because unlike ash clouds, liquid water and ice clouds, which continuously absorb radiation across the electromagnetic spectrum, it absorbs radiation within select parts of the spectrum. This means that there are some regions of the electromagnetic spectrum where there is moderate to strong SO_2 absorption and a lot of regions where there is essentially none. This attribute makes SO_2 much easier to detect than volcanic ash.



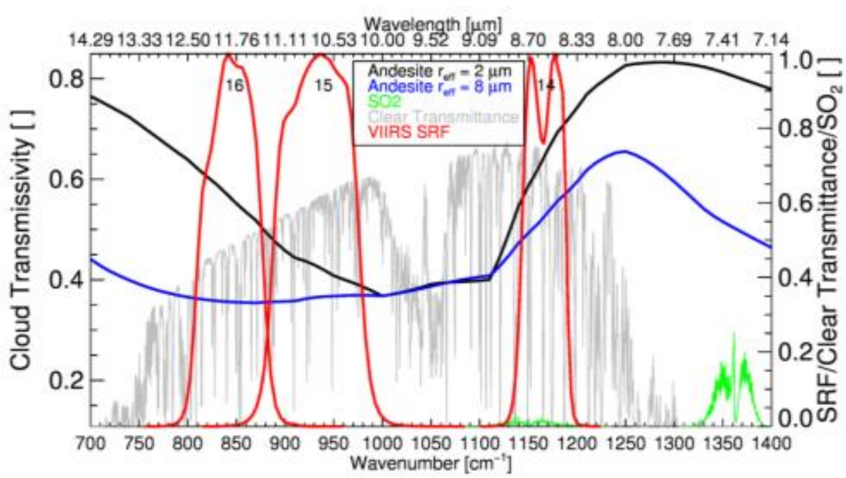
In fact, NOAA's ash detection algorithm utilizes a spectral metric that is marginally sensitive to volcanic ash but very sensitive to SO_2. This is used in tandem with spectral metrics that are sensitive to volcanic ash. The SO_2 metric enables scientists to better detect volcanic ash as it disperses in time and becomes more optically thin and difficult to detect. Historically, eruptions with the potential to influence climate in the short term have occurred approximately every 10–30 years. Not knowing when the next big one will occur is a big motivator to continuously monitor SO_2 in a robust manner.

Sensing SO_2 with the Joint Polar Satellite System

Observations from the VIIRS, CrIS, and OMPS measurement suite from JPSS are helping scientists capture the SO_2 signature and provide much needed information to help in many applications including characterizing volcanic unrest. These include Ultraviolet (UV) measurements from OMPS, which allow scientists to monitor the evolution of volcanic activity over time.

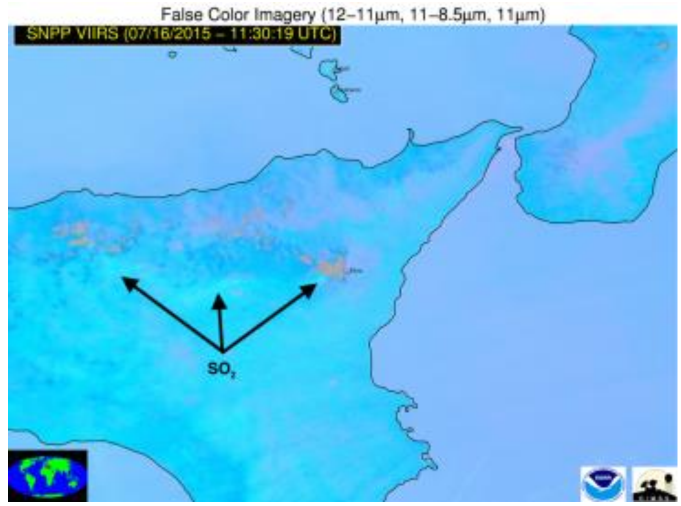


The advantage of OMPS is that it is very sensitive to the presence of SO_2 under many conditions including in the presence of clouds (liquid, ice, and aerosol) and over bright surfaces, sensitive to SO_2 loading, and also has some sensitivity to SO_2 height. However, without sufficient sunlight, OMPS will fail to detect the SO_2 signal. This data gaps occur when the sun is near or below the horizon. Due to this limitation, it is important to consider other measurements that do not require sunlight. UV also has a relatively large spatial footprint and noise, which can impact one's ability to quantify SO_2 from degassing volcanoes.

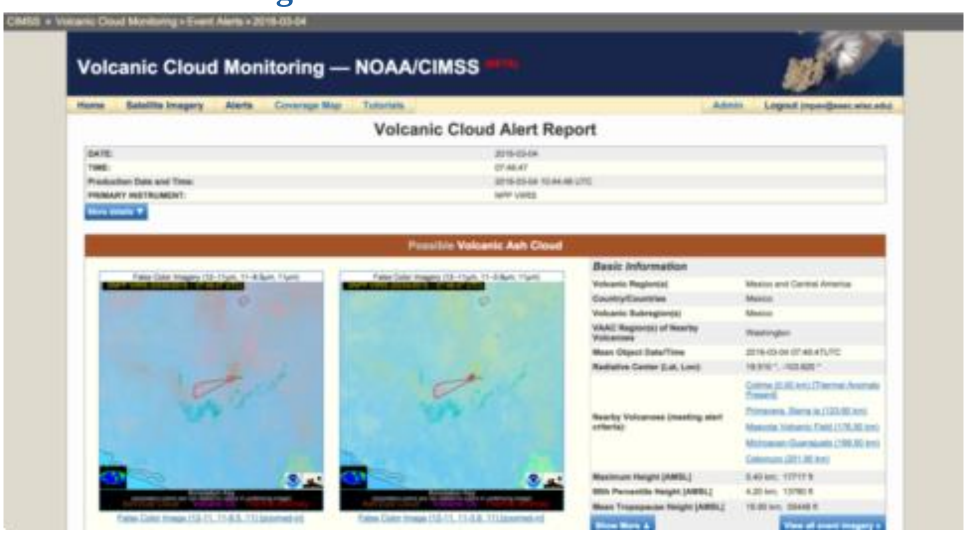


In the IR, there are two regions of the spectrum that are particularly sensitive to SO_2. The green lines in the figure above show the strength of the SO_2 absorption as a function of wavelength. There are two primary SO_2 absorption features in the infrared near 7.3 and 8.6 μm. CrIS provides coverage of the 7.3 μm absorption feature and VIIRS samples the 8.6 μm feature. The combination of VIIRS and CrIS allows for detection of low, mid, and high level SO_2 during the day and at night.

As a supplement to UV measurements, hyperspectral Infrared (IR) measurements offered by sensors such as the CrIS are not limited by the sun angle, and therefore can provide mid to upper level SO_2 information day and night. Similar to UV sensors, hyperspectral IR instruments are also sensitive to SO_2 loading and height. However, their sensitivity to lower tropospheric SO_2 is very limited. Also similar to UV, hyperspectral IR also has a large footprint size relative to the spatial scale of many SO_2 plumes. Another key contributor of SO_2 measurements is the VIIRS instrument which provides high spatial resolution imagery of SO_2 clouds and plumes under many conditions day and night. VIIRS however has a much larger lower limit of detection compared to UV and hyperspectral IR, especially in the presence of clouds. With only one SO_2 absorption band, it is more challenging to extract quantitative information with VIIRS; therefore it needs to be combined with other measurements to help constrain the problem.



Measurement Integration Plan



Leveraging from previous efforts, NOAA scientists plan to integrate the SO_2 information from the JPSS measurement suite into the VOLcanic Cloud Analysis Toolkit (VOLCAT) http://volcano.ssec.wisc.edu. VOLCAT is a multi-faceted system that has been in development over the past ten years. The system's developers seek to integrate the full capabilities of the environmental satellite constellation to create a globally applicable automated system that can detect and characterize nearly all types of volcanic clouds.

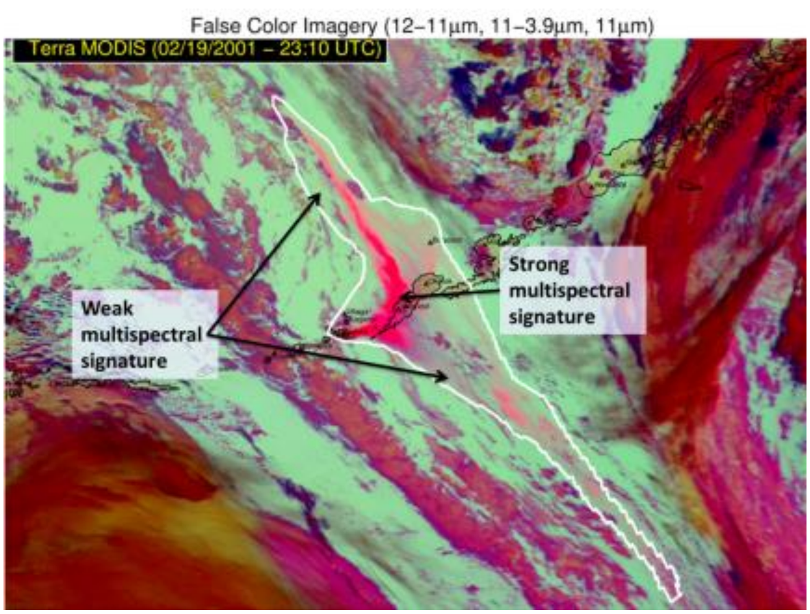
Components of VOLCAT

VOLCAT comprises multiple dataset application systems. It has several components, functions and ways to be deployed. Among them are unrest alerts which are prompted upon the detection of thermal anomalies. These alerts provide situational awareness to VAAC's and volcano observatories. Another component is an eruption alert designed to detect a large variety of eruption types. Once an eruption is detected, an alert in the form of a text message or email is sent automatically to users. The same methodology can be applied to SO_2 detection. Another component involves volcanic cloud tracking, whereby ash clouds as well as SO_2 are tracked through time. Volcanic cloud characterization provides value added pieces of information on features such as height and loading. This information is needed by models to help generate forecasts of volcanic cloud dispersion and transport. In addition, accurate volcanic cloud characterization is needed to construct time series from which import attributes such as mass eruption rate, SO_2 fluxes, and SO_2 conversion rates can be computed. Another key component of VOLCAT, that is under development, is dispersion forecasting in which the quantitative information derived from measurements is integrated into models such as weather, dispersion, or climate.

Volcanic Cloud Detection

Within the VOLCAT system are sophisticated detection techniques that have been implemented specifically for volcanic ash, which is a continuous absorber of radiation (unlike SO_2) and therefore much more difficult to detect. The VOLCAT detection approach is multi-faceted and employs five conceptual models to identify volcanic clouds across the spectrum of eruption cloud types. However, only three of these physical models are directly applicable to SO_2, i.e., pure spectral based detection of SO_2 on a cloud object basis, plume detection from volcanoes, and tracking in time. These three are discussed below.

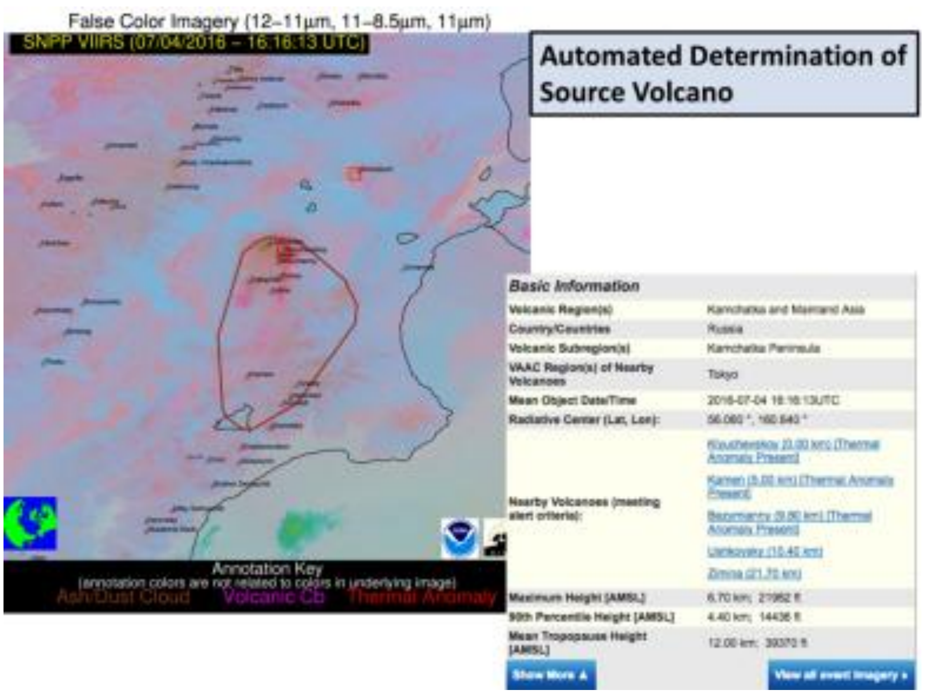
Spectrally Enhanced Cloud Objects (SECO)



The Spectrally Enhanced Cloud Objects (SECO) algorithm is designed to identify volcanic ash and dust in manner that is more consistent with human expert interpretation of multispectral satellite imagery than traditional techniques. In an image with varying degrees of the spectral signature relative to the ash, the human eye can pick out even the faintest spectral areas and can recognize complex spatial patterns and associate that with the correct feature. The SECO method uses several advanced multi spectral metrics to compute the probability that a given pixel contains volcanic ash. The SECO method takes all the given probabilities, and using a complicated threshold function, determines that any pixel with a probability that exceeds some dynamic threshold can be part of a cloud object. A cloud object is a group of spatially connected pixels that meets a certain set of criteria. The algorithm then analyzes each cloud object to determine whether it contains at least some pixels that have a really robust spectral signature related to the feature of interest, be it volcanic ash or SO_2. The algorithm then decides which cloud objects represent the feature of interest. The final product resembles detection that is comparable to how a human would extract the feature manually from imagery.

Plume Detection from Volcanoes

The shape of cloud objects also helps the SECO algorithm detect more subtle features, that is, features that a human can extract from an image albeit with increased difficulty due to a lack of spectrally robust pixels. For example, in the image below, a human expert can pick out a weak volcanic ash plume. The algorithm, on the other hand, analyzes the geometric properties presented and through the SECO method is able to detect the ash plume because it takes on a plume like shape. Moreover, factors such as the plume like shape and location can also help scientists pinpoint the source volcano. The same concept can be used to detect SO_2 plumes that are associated with passive degassing which are traditionally more difficult to detect automatically even using UV measurements.

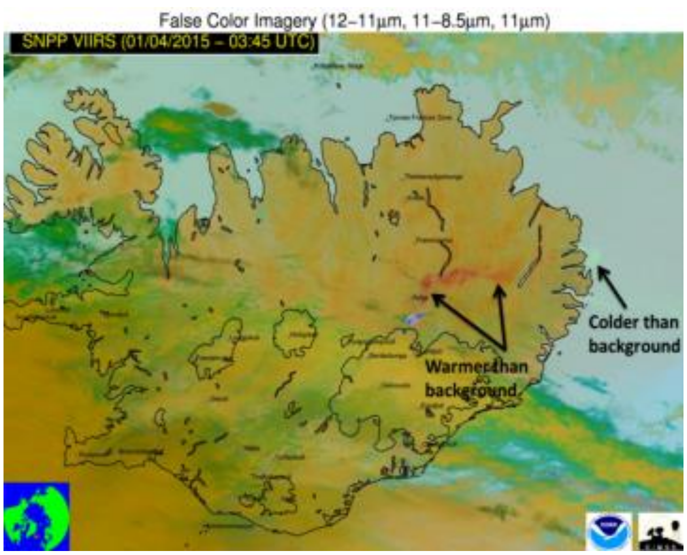


Tracking in Time

As clouds evolve and disperse in time, their spectral signature becomes less robust and therefore it becomes more difficult to detect ash clouds based solely on spectral information. Keeping a historical record of an object (or set of objects) under observation in time can help ensure robust detection of volcanic ash or SO_2 as volcanic clouds disperse. The VOLCAT system utilizes a feature-tracking algorithm to ensure more consistent feature detection and characterization through the lifetime of a volcanic cloud.

Nuances and Exceptions with SO_2 Remote Sensing

Typically in the IR what makes an SO_2 cloud detectable is that the cloud is much colder compared to the atmospheric background. However, this is not always the case as there are instances—especially in the winter when temperature inversions are most likely to occur—where the SO_2 cloud is much warmer than the background. Limited sunlight can make UV measurements particularly difficult to use, which increases dependence on IR measurements. But when temperature inversions occur, it can distort the IR multispectral signature giving the opposite effect.



In the example (left) from January in Iceland, the red feature in the multi spectral imagery is a concentrated SO_2 cloud that is warmer than the background because it is located in a strong temperature inversion region. Even though the feature is shown in VIIRS it has the opposite multi spectral signature than one would expect. These nuances further illustrate the need to develop a rigorous SO_2 algorithm for the VIIRS, CrIS, and OMPS measurement suite.

Applying the SECO Method to SO_2 Detection

Hyperspectral IR instruments like CrIS are far more sensitive to SO_2 than imagers like VIIRS, especially in the mid and upper levels of the atmosphere. VIIRS, however, can provide valuable spatial detail not possible with the hyperspectral instruments. Thus, a multi-sensor JPSS SO_2 detection product will be created by utilizing OMPS and CrIS to construct an *a priori* probability for the VIIRS implementation of the SECO method. As such, the final SO_2 detection results will be at the spatial resolution of VIIRS.

Polygons will then be automatically fit to the fused SO_2 detection product, which is especially helpful for users at VAAC's due to their reliance on imagery in forecast operations and for their decision support systems (DSS). These auto-generated polygons can be overlaid onto multispectral imagery allowing users at these centers to see exactly how the detected SO_2 corresponds to what they can see in the imagery relative to both the SO_2 features or volcanic ash features and other background information. The fused JPSS SO_2 detection results can be further tracked using the high temporal resolution offered by geostationary satellites. NOAA's current GOES Imager scans the Earth approximately every 30 minutes—an interval that will be reduced to 15 minutes or less with the next generation GOES-R. Scientists plan to take advantage of the high temporal resolution offered by GOES and the high spatial resolution offered by JPSS by integrating the JPSS SO_2 measurements into with features from the GEO satellite infrared data.

In addition to SO_2 detection, a multi-sensor approach will be developed to estimate the loading and height of SO_2 clouds. As with the detection algorithm, OMPS and CrIS will be used to mathematically constrain the estimate of these properties from VIIRS so that high spatial resolution products are created.

Collaborations

Fusing information from many sensors is challenging but nonetheless necessary. Thus, collaborations with hyperspectral UV and IR SO_2 remote sensing groups at NASA and in academia are important and would be beneficial. In addition, a collaborative effort with the USGS, academia, and international partners (e.g. the Iceland Met office, IMO which does many studies in collaboration with their university partners) is needed to validate the fused JPSS SO_2 analysis. The USGS for example has a group dedicated to taking ground-based measurements of SO_2 at certain volcanoes. These measurements would provide an excellent and important validation source. International collaboration is needed to work towards best practices for combining measurements from multiple satellite sensors. The recent WMO sponsored international intercomparison of satellite-derived volcanic ash retrievals (http://www.wmo.int/pages/prog/sat/documents/SCOPE-NWC-PP2_VAIntercompWSReport2015.pdf) can serve as the starting point for international collaboration and coordination. Moreover, collaboration with the dispersion, weather, and climate modeling communities are critical to ensure that the impact of the information is maximized.

Summary

Our ability to monitor and identify volcanic unrest on a global scale cannot be accomplished without Earth observation satellites. In part, this is because robust ground-based methods of monitoring volcanoes are limited to a small subset of volcanoes. Earth observation satellites like JPSS provide some of the most critical inputs needed to model the impacts of SO_2. This information is especially vital to the decision support systems at Volcanic Ash Advisory Centers (VAACs), meteorological watch offices, weather forecast offices (WFOs), volcano observatories (including the USGS), and the military. They also serve as key inputs for operational dispersion, weather, and climate models, and for research applications as well.

Driven by the lack of a single sensor with all the attributes needed to accurately detect and characterize SO_2 constantly, a significant effort within the JPSS PGRR has commenced to create a multi-sensor SO_2 analysis. Based on an already established and highly successful VOLCAT system and previous SO_2 remote sensing research, the SO_2 product suite will combine measurements from three key sensors onboard the JPSS, the VIIRS, CrIS, and OMPS. In addition, the JPSS SO_2 product suite can be used to improve the accuracy of SO_2 products derived from high temporal resolution GOES-R measurements, thereby maximizing the value of NOAA's Earth Observation satellites for volcanic cloud monitoring. The SO_2 technique developed for JPSS will be general enough that it can be applied to low earth orbit satellites operated by NOAA's international partners.

Fusing information from VIIRS, CrIS, and OMPS will help ensure that NOAA can provide high quality, objectively derived, environmental intelligence on SO_2. The SO_2 information is critical for volcano monitoring, volcanic ash tracking, and understanding the impacts of volcanic aerosols on weather and climate in the wake of a large eruption. A significant collaborative effort is needed to ensure that an “optimal” JPSS based SO_2 product suite can be created, validated, and utilized in weather, dispersion, and climate models.

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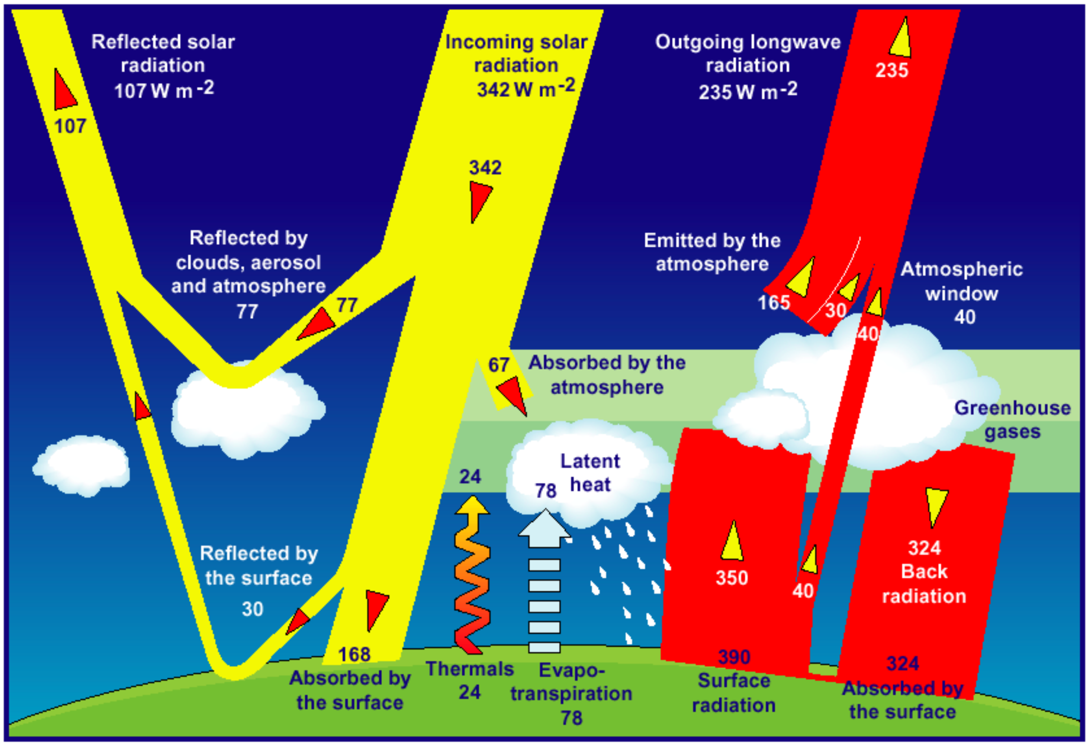
Extending Four Decades of the High resolution Infrared Radiation Sounder (HIRS) Data Stream into the Future with Current Sounders in Polar Orbit

*This article is based in part on the **August 29, 2016** JPSS science seminar presented by Dr. W. Paul Menzel, Cooperative Institute for Meteorological Satellite Studies Space Science and Engineering Center (SSEC).*

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg



Climate System Energy Balance. Radiation Balance of the Earth (Jeffrey T. Kiehl and Kevin Trenberth) Image accessed from [https://ceres.larc.nasa.gov/ceres_brochure.php?page](https://ceres.larc.nasa.gov/ceres_brochure.php?page=2)=2

Among the atmospheric properties being monitored and examined from space, clouds are particularly important due to their influence on the Earth's atmosphere, weather and climate. Clouds play an importance role in how the Earth maintains a balance between the energy that comes from the sun and the energy that is reflected back out to space. Approximately 75% of the Earth is covered by clouds at any one time, yet their constantly evolving nature and interactions with the surrounding atmosphere (especially atmospheric water vapor) make them a major source of uncertainty in weather forecast and climate models.

Tracking Global Cloud and Moisture Properties

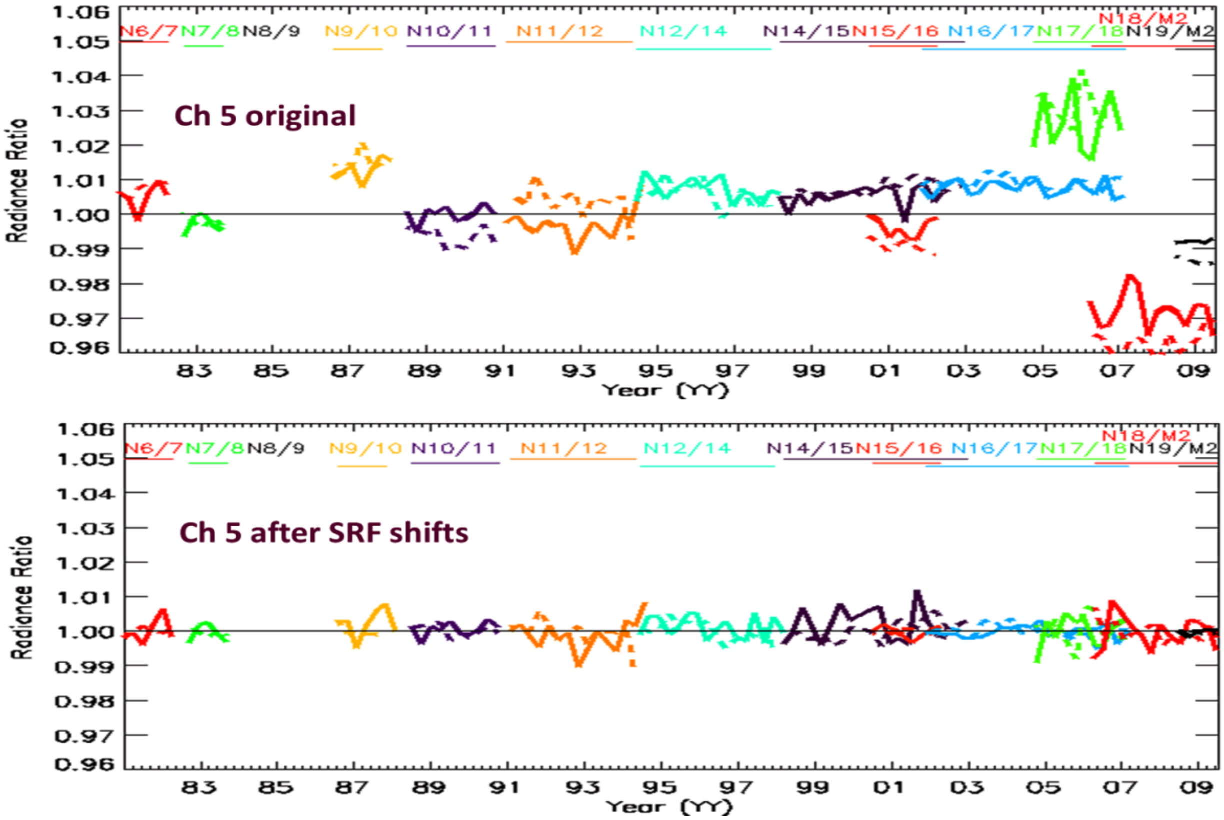
Observations from NOAA's legacy infrared sounder—the High resolution Infrared Radiation Sounder (HIRS) provide one of the longest records of the satellite measurements that stretches back to more than 40 years ago aboard NASA's NIMBUS-6 satellite in 1975. The HIRS is used to determine clear sky atmospheric temperature and humidity profiles and cloudy sky radiative cooling. The HIRS has flown on eighteen satellites starting with NIMBUS-6 and then followed by the NOAA polar-orbiting satellite, Television Infrared Observation Satellite (TIROS-N), through to NOAA-19—the last of the TIROS satellites (now known as POES, or Polar-orbiting Operational Environmental Satellites), and the European satellites METOP-A and -B which carry both the HIRS and Infrared Atmospheric Sounding Interferometer (IASI). The measurements from past and current environmental satellites carrying the HIRS provide an opportunity to form a long term data record. Moreover this record can be extended into the future with the next generation instruments introduced in 2006 with the IASI on MetOp and the Cross-track Infrared Sounder (CrIS) which came online in 2011 with the launch of Suomi NPP, the first spacecraft in the Joint Polar Satellite System (JPSS). Given their significant enhancements over HIRS, IASI and CrIS are expected to provide more accurate, detailed atmospheric temperature, moisture, and cloud observations for weather and climate applications. The opportunity for continuation of the HIRS record is extremely important for understanding environmental changes and mitigating related risks.

Challenges in Obtaining a Consistent Dataset

While gathering the HIRS data record it is important to understand that over the years the HIRS instrument has undergone several changes.Differences in the spectral response functions (SRF) between HIRS instruments have led to inconsistent radiance measurements between the different HIRS sensors. The field of view reduction that took place during the shift from HIRS version 3 to HIRS version 4 improved the FOV to 10 km sampled from the previous 20 km, altered the cloud detection frequency. Orbital drifts led to later local times of observation that influenced long term trend analyses by mixing in diurnal changes. These changes in HIRS observations have made it more challenging to combine the measurements from different satellites; they have made it necessary to homogenize them as much as possible to correspond to a common standard. To ensure consistency and reduce the uncertainties associated with data from all the different HIRS instruments, scientists from the JPSS Proving Ground and Risk Reduction Program are researching four ways to mitigate differences. (1) Accommodate the effects of orbital drift by splitting the daily processing into four parts (night, morning, afternoon, and evening); (2) improve calibration consistency by adjusting the HIRS spectral response function to achieve better agreement with one reference; (3) account for calculation and observed clear radiance differences by introducing a radiance bias adjustment in clear sky radiative transfer model simulations; and (4) compare overlapping sensor measurements at nearly simultaneous temporal and spatial locations using the Simultaneous Nadir Overpass (SNO) technique.

Recalibrating by Adjusting the HIRS Spectral Response Function

Spectral response functions indicate the part of the spectrum that is being measured with the HIRS instrument. SRF determination is difficult and not known well enough; it has been shown that a simple spectral shift can produce better agreement between sensors (Tobin et al., 2006).

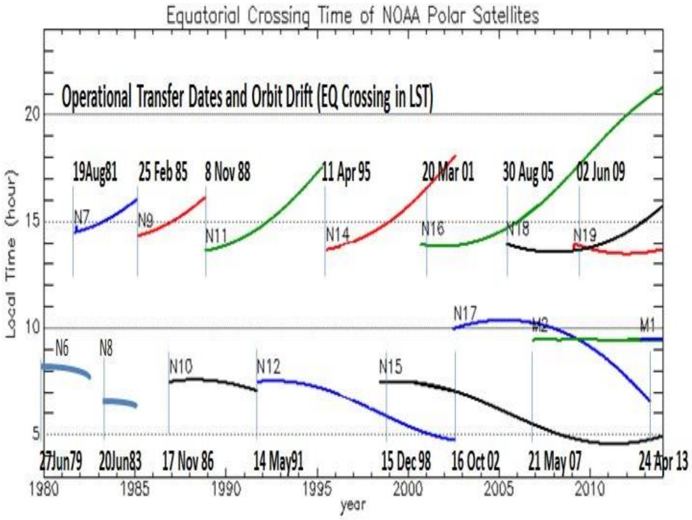


The figures above show the radiance ratios for the HIRS channel 5 for NOAA-6 through NOAA-19 and MetOp-A (M2) over a period ranging from 1982 to 2009. Prior to the correction (top panel) the ratios varied widely. After the shifts were applied (bottom panel) there was a significant reduction in the ratio differences. Ratios within .01 imply brightness temperature agreement within 0.5 K.

The high spectral resolution infrared sensors like IASI and the Atmospheric Infrared Sounder (AIRS) are providing reliable calibration references for HIRS, and helping to reduce sensor to sensor calibration differences via SRF adjustment. The HIRS and IASI on MetOp-A provide global simultaneous collocated measurements every day. Based on the approach of Tobin et al. (2006), IASI measurements have been used to estimate the HIRS SRF shifts that produce the best HIRS and IASI inter-calibration.

SNO: Simultaneous Nadir Overpass

The remaining HIRS are then recalibrated in serial fashion (NOAA-19 with MetOp-A, NOAA-18 with NOAA-19, and so on) at SNO locations. In this way recalibration is accomplished using IASI as a reference. When two polar-orbiting satellites fly with different equator crossing times, there is a possibility that they will intersect over an area. The observations from this location are referred as simultaneous measurements because both satellites obtain readings at the same time and place, and, if all things are equal, both satellites should give identical readings.



Local Time of descending node equator crossing is shown below along with operational transfer dates.

Mitigating effects of Orbit Drift

Over time satellites start to drift and can end up with a changed local time for satellite observations. This can introduce a diurnal signal on top of an annual trend. To compensate for the orbit drift, the day is divided into four time periods—daytime before and after local noon and nighttime before and after midnight.

Morning SZA <= 85° and Local Time Before Noon
Afternoon SZA <= 85° and Local Time After Noon
Evening SZA > 85° and Local Time Before Midnight
Night SZA > 85° and Local Time After Midnight

Identifying clouds in the HIRS data and Establishing Calculated and Observed Clear sky Radiance Biases

Separation of clear from cloudy HIRS fields of view (FOV) is accomplished using the Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Atmospheres-Extended (PATMOS-x) cloud mask taking advantage of its higher spatial resolution of 4 km (Heidinger et al. 2012). The clear sky measurements in the HIRS CO2 absorption bands from the current month are composited and compared to forward model calculations of clear-sky channel radiances using the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) temperature, moisture, and ozone soundings. These comparisons are made to establish the biases in the modeled clear-sky radiance calculations with respect to the observed clear sky radiance measurements. In a second iteration, a screening for thin cirrus is applied to the remaining clear-sky HIRS pixels using the CO2 channels. Biases are recalculated and saved as daily and monthly Clear-Sky-Radiance-Biases (CSRBs). The biases are applied in the radiative transfer equation solution of cloud height.

Using the MODIS Algorithms on HIRS Data to Establish a Long Term Record of Clouds and Atmospheric Moisture

An important application of the HIRS carbon dioxide and water vapor sensitive spectral channels is the retrieval cloud and moisture records. It is possible to study and long term trends in the distribution and interplay of moisture and clouds in the earth energy budget. Moisture column TPW and UTH are determined for clear sky radiances measured by HIRS over land and ocean both day and night using a statistical regression developed from the SeeBor data base (Borbas et al. 2005). The retrieval approach is borrowed from MODIS (Seemann et al. 2003, Seemann et al. 2008). Cloud top pressure (CTP) and cloud effective emissivity (εf) (cloud fraction multiplied by cloud emissivity) are derived using the 15 µm spectral bands in a CO2 slicing approach (Wylie et al. 2005, Menzel et al. 2008) that has proven to be effective for characterizing high altitude, transmissive ice clouds. The CO2 slicing technique is based on the atmosphere becoming more opaque due to CO2 absorption as the wavelength increases from

13.3 to 15 μm, thereby causing radiances obtained from these spectral bands to be sensitive to a different layer in the atmosphere. Semi-transparent clouds are correctly assigned heights as the cloud fraction and cloud emissivity is accounted for in the algorithm.

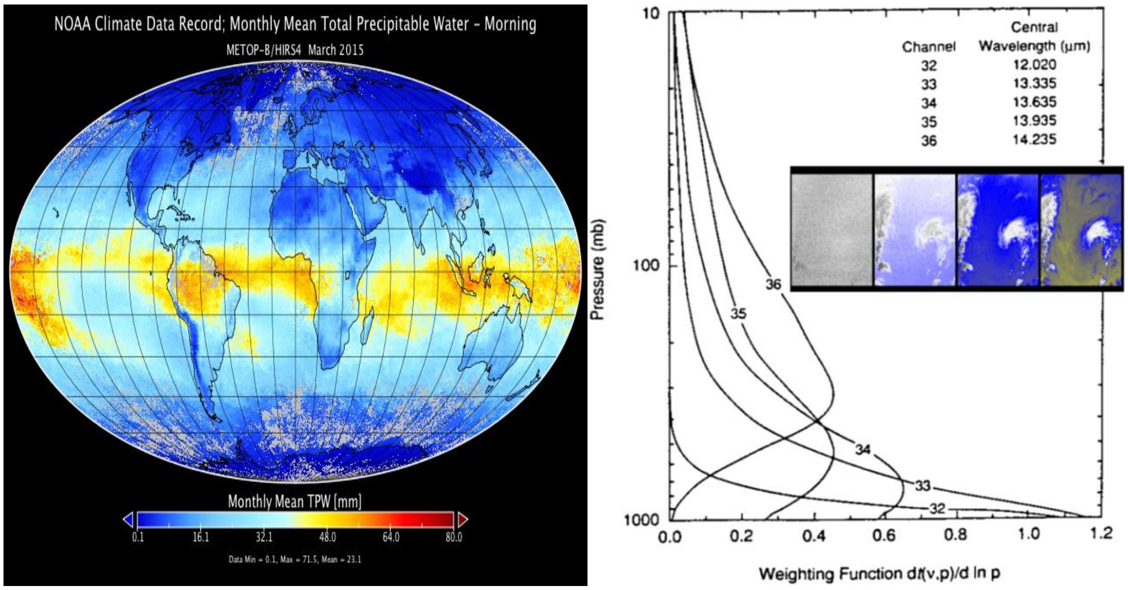


Figure: (left) Total Column Precipitable Water Vapor determined by HIRS on MetOp-A for March 2015. (right) CO2 channel weighting or contribution functions demonstrating that less opaque channels see deeper into the atmosphere, and finally to the earth surface.

Reprocessing of the HIRS data record for 1980 to 2015 has clouds being found in ~75% of all HIRS observations over 60N-60S; hi clouds (HiCld) are found in ~35%. Study of the hemispheric balance of clouds and moisture has revealed the following. The frequency of hemispheric (NH and SH) seasonal HiCld detections are exactly out of phase (minimum in the NH when maximum in the SH and vice versa); NH HiCld is more prevalent than SH on average (Menzel et al., 2016). The HIRS moisture determinations reveal that hemispheric seasonal HiCld and TPW are in phase (see the Figure below for the SH example) and that the NH seasonal TPW fluctuation is greater than SH.

Other features evident in the HIRS data records include (1) full disk seasonal HiCld and TPW are out of phase (since NH TPW shows greater seasonal swings than the SH TPW, and vice versa for HiCld), (2) there is an increase in tropical TPW during La Nina events, and (3) the eastern Pacific Basin upper tropospheric low stratospheric clouds show correlation with El Nino 3.4 SSTs.

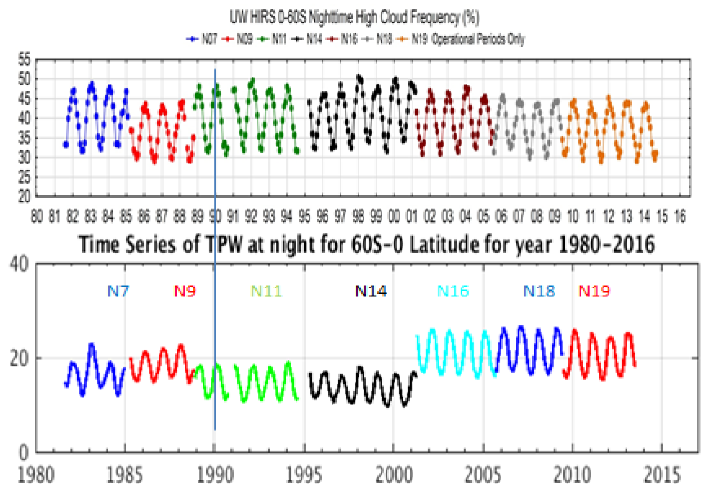


Figure: (top) Percentage of HIRS observations that found high clouds in the southern hemisphere 0˚ to 60˚S from 1980 to 2015. (bottom) The corresponding average total column precipitable water vapor found in the southern hemisphere 0˚ to 60˚S from 1980 to 2015. Note how the seasonal maxima are aligned.

Continuing the HIRS record with CrIS and IASI

Global cloud and moisture record continuation with IASI-AVHRR and CrIS-VIIRS offers the possibility of a 50+ year data record. Hyperspectral sounders provide high vertical resolution measurements of coincident soundings and cloud parameters which enable trends in atmospheric features to be measured globally at consistent temporal and spatial intervals. Using the adjacent imagers to indicate the presence of clouds provides the opportunity to continue the HIRS AVHRR data records.

Summary and Path Forward

With more than forty years of measurements the HIRS provides one of the longest and most extensive global cloud and moisture data records. HIRS recalibration using IASI as a reference has mitigated (but not eliminated) sensor to sensor calibration differences and now offers a dataset worthy of exploring for climate studies. Continuing the HIRS Moisture and Cloud Records with CrIS and IASI offers the opportunity to extend the record beyond fifty years and to better understand the energy balances influenced by clouds and moisture in the atmosphere.

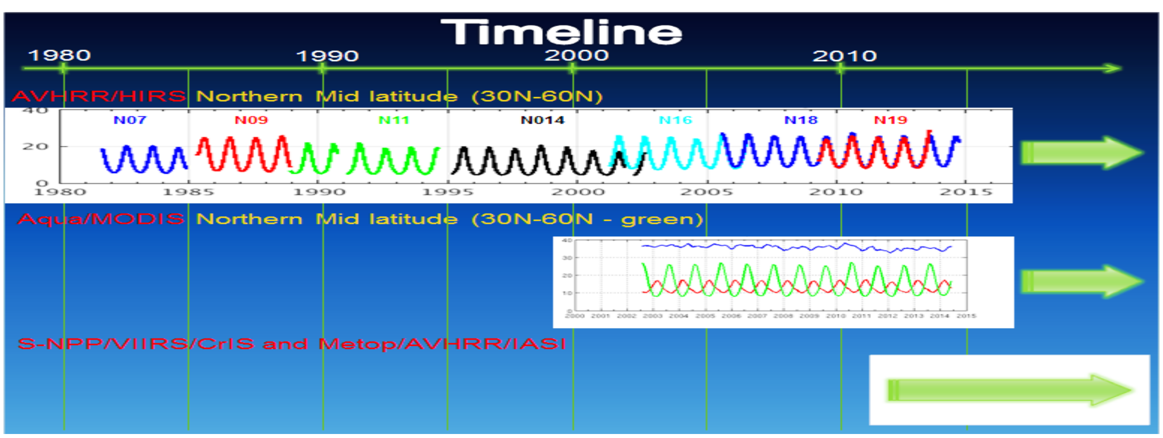


Figure. Building on the HIRS/AVHRR and MODIS moisture records with IASI/AVHRR and CrIS/VIIRS.

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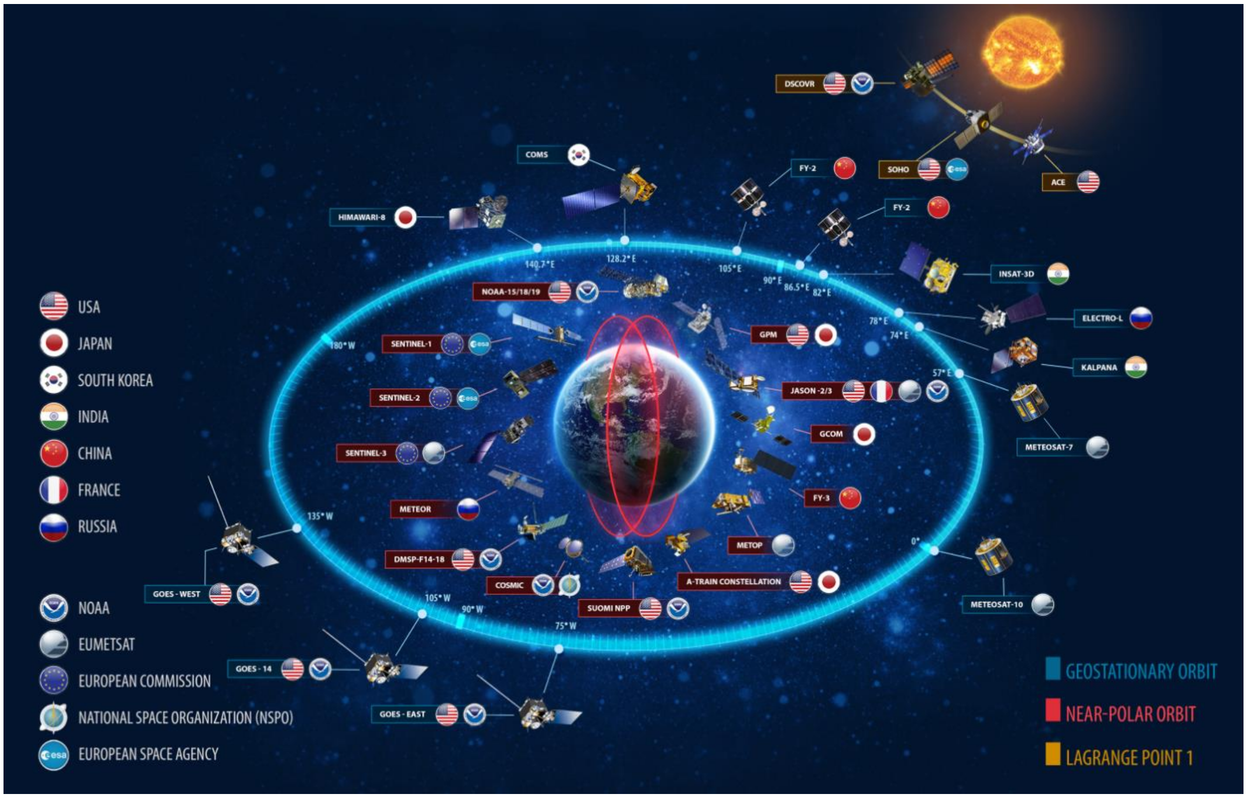
JPSS USER PERSPECTIVE

What the users are telling us about JPSS

The Contribution of the Global Space-based Inter-Calibration System (GSICS) to US-International Partnerships

*This article is based in part on the **September 19, 2016** JPSS science seminar presented by Dr. Mitch Goldberg, NOAA/NESDIS/JPSS*

Contributing editors: Mitch Goldberg, Julie Price, and William Sjoberg

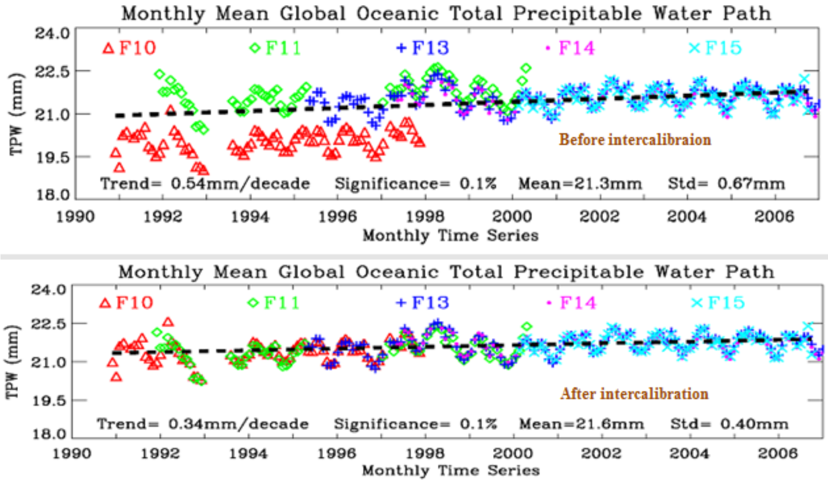


This image shows the current space-based portion of the World Meteorological Organization's Global Observing System, plus additional space weather and environmental satellites. Credit: NOAA.

Image accessed from [**http://www.nesdis.noaa.gov/news_archives/images/global_satellites.jpg**](http://www.nesdis.noaa.gov/news_archives/images/global_satellites.jpg)

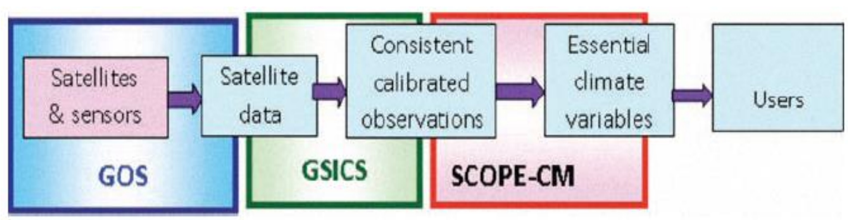
Many nations, including the United States operate environmental satellites that help to monitor and keep track of environmental events occurring in the Earth's atmosphere, and across vast areas of the oceans and land surfaces. These observations represent a large majority of the inputs used in the Numerical Weather Prediction (NWP) models of agencies such as NOAA's National Weather Service (NWS). These space-based observations have become valuable and indispensable sources of environmental information used to monitor and understand the weather and climate phenomena that impact society. These include high impact events such as hurricanes, tornadoes, volcanic eruptions, droughts, forest fires, blizzards. As indicated in the figure above there are many nations and satellite programs involved in maintaining the extensive database necessary for the global environmental requirements. Each satellite program builds its sensors to meet its own unique requirements. As this data is made available to the international environmental community it is critical that standards be adopted and applied to create a cohesive, functioning, and sustainable global database. To be reliable and interoperable, these different data sources must be precisely calibrated with similar methods and common references.

Inter-Calibration is Critical



The figure above (top panel) illustrates the challenges associated with data that is not intercalibrated. The figures show global oceanic total precipitable water (TPW) from the Special Sensor Microwave Imager/Sounder (SSMIS) aboard the Defense Meteorological Satellite Program (DMSP) satellites. In the top panel there is a wide variation in the sensor readings of the TPW measurements from multiple satellite instruments. This demonstrates that calibration uncertainties can translate to uncertainties in climate change detection, but even worse, they can result in little or no confidence in the datasets. The bottom panel shows a decrease in the range of uncertainty from 0.54 mm/decade to 0.34 mm/decade after these differences are corrected or intercalibrated. As illustrated above, without intercalibration the full benefits from these sensors cannot be realized.

Ensuring Consistent Measurements from Space-based Observing Systems Through the Global Space-based Inter-Calibration System (GSICS)



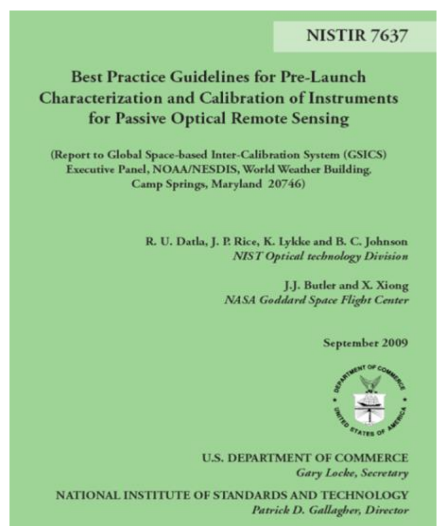
How do satellite data providers assure confidence in the quality of observations from the international constellation of satellite instruments? This is the role of the Global Space-based Inter-Calibration System (GSICS), which has been established to foster collaboration and cooperation amongst the satellite data providers contributing to the Global Observing System (GOS). GSICS is able to intercalibrate sensors on multiple space-based platforms in the GOS including operational low Earth-orbit (LEO) and geostationary Earth orbit (GEO) environmental satellites, as well as operational and science-based satellites. GSICS is an essential resource in communicating a particular sensor's error characteristics and the corrections needed to bring the data from this sensor back to common reference standards.

Background

The establishment of GSICS can be traced back to several long-standing recommendations from the World Meteorological Organization (WMO) and the Committee on Earth Observation Satellites (CEOS) related to intercomparing different sensors from different satellites. In response to these recommendations the Space Programme of the WMO was tasked to help build an international consensus and consortium for a Global Space-based Inter-Calibration System (GSICS) for the World Weather Watch (WWW) GOS. In 2005, the WMO Space Programme initiated a discussion and held several meetings with the incentive to conceptualize a GSICS. These meetings, chaired by NOAA/NESDIS, brought together local and international experts, as well as stakeholders including the Coordination Group for Meteorological Satellites (CGMS), who drew up the plan providing for the establishment of GSICS. Key direction and input from Johannes Schmetz (EUMETSAT), Tillman Mohr (former EUMETSAT Director General and WMO consultant), Jerome Lafueille (WMO), Don Hinsman (WMO Space Director), Toshi Kurino (JMA), Raju Datla (NIST), and Mitch Goldberg (NOAA/NESDIS) helped conceptualize the fundamental building blocks needed to accomplish the intercalibration of satellite sensors. The ideas became part of a comprehensive strategy that would satisfy the recommendations set forth by the WMO and CEOS. The building blocks (listed below) include such things as:

- Collocating the data between the different sensors, i.e., satellite to satellite and also satellite to in-situ observations; and with benchmark measurements.
- Collecting the collocated data and making it easily accessible through archives, or metadata provision.
- Coordinating operational data analyses by establishing processing centers for assembling collocated data, as well as expert teams.
- Making assessments: communication including recommendations, and vicarious coefficient updates for “drifting” sensors.

The comprehensive strategy is crafted to include prelaunch characterization, instrument performance monitoring, anomaly resolution, comparison of sensors, and correction if necessary. Through these activities, GSICS promotes greater understanding of instrument absolute calibration and root causes of biases, supports instrument global inter-operability and measurement quality, and enables better accuracy and global consistency of Level 2 environmental, climate and weather forecasting products. These specified best practices, standards, procedures and tools help develop the capacities of satellite agencies’. Moreover, they enable users to monitor, improve and harmonize the calibration of instruments aboard their operational meteorological, climate and other environmental satellites, which increases confidence in the data.


NISTIR 7637

Best Practice Guidelines for Pre-Launch Characterization and Calibration of Instruments for Passive Optical Remote Sensing

(Report to Global Space-based Inter-Calibration System (GSICS) Executive Panel, NOAA/NESDIS, World Weather Building, Camp Springs, Maryland 20746)

R. U. Datla, J. P. Rice, K. Lykke and B. C. Johnson
NIST Optical technology Division

J.J. Butler and X. Xiong
NASA Goddard Space Flight Center

September 2009

U.S. DEPARTMENT OF COMMERCE
Gary Locke, Secretary

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Patrick D. Gallagher, Director

Best Practice Guidelines for Pre-Launch Characterization and Calibration of Instruments for Passive Optical Remote Sensing. Report to GSICS Executive Panel

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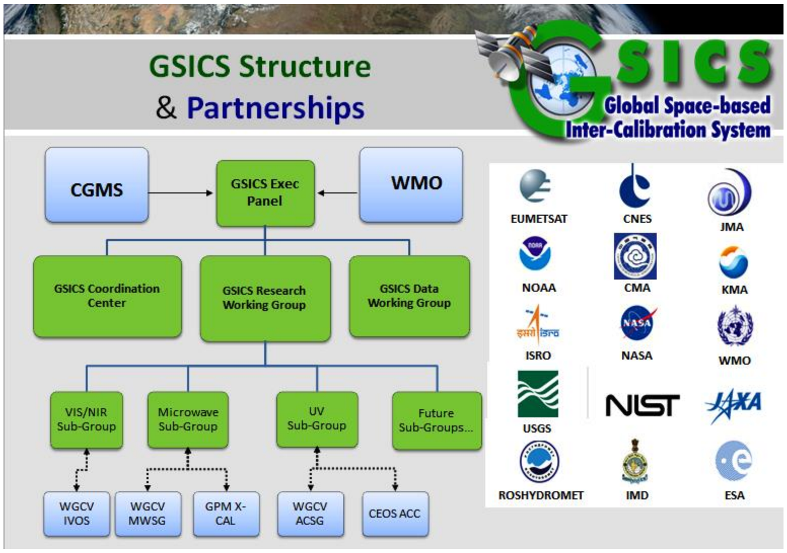


GSICS Structure

GSICS operates under the guidance of an Executive Panel. The panel, composed of designated representatives from participating organizations, works under the advisement of the Data Management Working Group (GDWG) and a Research Working Group (GRWG). It provides guidance to the GSICS Coordination Centre (GCC), located at the NOAA National Environmental Satellite Data and Information Service (NESDIS)/Center for Satellite Applications and Research (STAR). The GCC coordinates the definition of all its products and services, and maintains a repository of all practices, procedures and tools. As the GSICS axis of communications and outreach, the GCC supports the development of various GSICS publications including a quarterly newsletter that covers updates, events and news on GSICS activities. It also designs and maintains the GCC website, organizes Users Workshop to encourage participation of and receive feedback from users, and coordinates with the GRWG to promote scientific partnerships. (http://www.star.nesdis.noaa.gov/smcd/GCC/). GSICS also leverages upon on-going or collaborative activities with external partners such as the Global Precipitation Measurement Intercalibration (GPM X-CAL) Working Group, and the Committee on Earth Observation Satellites (CEOS) Atmospheric Composition Constellation (ACC) to enhance its program.

GSICS Intercalibration Approaches

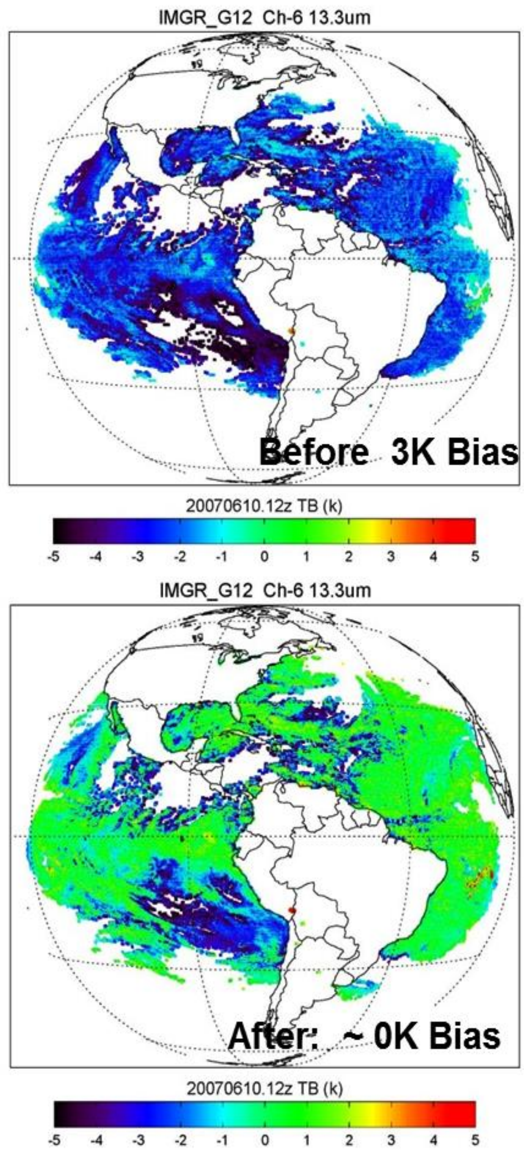
The GSICS portfolio has expanded to include inter-calibration of geo imagers channels in the reflected solar band, corrections for operational and heritage instruments, in near real-time and re-analysis modes, routine comparisons of satellite radiances against space-based reference standards, and functions to correct issued radiances. Some examples from these initiatives are shown below.

Simultaneous Nadir Overpass (SNO) Method: a core component in the Integrated Cal/Val System

The Simultaneous Nadir Overpass (SNO) technique developed at NOAA/NESDIS enabled two in-orbit satellite instruments to observe the same target under similar viewing conditions. The technique helped facilitate the integration and consistency of data between similar instruments in LEO platforms, and subsequently led to improvements in weather prediction and analysis as well, ensuring confidence in the observations from these instruments.

Demonstration of the GSICS GEO/LEO Inter-Calibration System

Unlike the instrument intercalibrations on LEO platforms, those on GEO platforms are far more complex. The primary instruments on geostationary satellites sense radiances whose values drift as the instruments degrade over time. This drawback motivated the first international coordinated project from GSICS to focus on the infrared imagers on geostationary satellites. To ensure the robustness of measurements generated by these instruments data was collected from IR channels on GEO imagers operated by several satellite data providers, including NOAA, EUMETSAT, and the JMA. The channels were intercalibrated with the EUMETSAT Infrared Atmospheric Sounding Interferometer (IASI), and the NASA Atmospheric InfraRed Sounder (AIRS) polar-orbiting sensor. Both of these sensors were already well characterized, stable in-orbit and provided consistent data over a number of years. When GSICS evaluated IASI and AIRS as reference instruments, they found that direct intercomparisons between the two instruments showed differences within 0.1 K with no appreciable trend over nearly four years of collocations.



Using these sensors, the GSICS was able to provide its first major deliverable to the user community—the GSICS correction algorithm for geostationary satellites. GSICS provided software and coefficients to enable a user to apply the correction to the original observations of a satellite instrument, adjust the data, and make them comparable to the best available space-based reference standards. This correction algorithm adjusts the geostationary IR sensor data to make them consistent with the high accuracy AIRS and IASI observations. Improvements in climate, weather forecasting and nowcasting applications were captured in consequence of these corrections. The figures to the right show the difference between observed and calculated brightness temperatures (from NCEP analysis) before and after correction. The bias is reduced from 3 K to nearly zero.

March 2015 Greenland Suomi NPP Campaign

For satellite derived measurements to be meaningful, their accuracy must be verified. This means that they and their sources must be thoroughly tested to ensure performance as described. Every satellite/instrument operator in the GOS is responsible for characterizing their own satellites. However, for their data to be used interchangeably, satellite operators should adhere to the GSICS community consensus algorithms. In 2011, NOAA's next-generation Cross-track Infrared Sounder (CrIS) on the Suomi National Polar-Orbiting Partnership (Suomi NPP) satellite became its newest addition to the GOS. As part of the existing satellite calibration validation approaches under the GSICS framework, the radiometric calibration and environmental product retrieval of CrIS in polar conditions were assessed using the aircraft based Scanning High-resolution Interferometer Sounder (S-HIS) during a calibration validation field campaign in 2015. Post-launch validation activities such as airborne field campaigns are able to provide simultaneous independent high spectral resolution radiance measurements that can be traced to the International System of Units (SI). Thus, they play a critical role in verifying the quality of satellite measurement systems (sensor, algorithms, and data products). The 2015 airborne field campaign over Greenland sought to better understand the differences between the cold scene observations from CrIS, AIRS, and IASI. Preliminary results from this campaign indicate that the radiometric accuracy of CrIS was consistently at the 0.1K level for all scene temperatures ranging from 250-225K.An earlier campaign in 2013 showed the same performance level of 0.1K but for warmer scenes ranging from 250K to 300K. Both campaigns provide the traceability needed to establish CrIS as a GSIC reference instrument for the infrared. Not only for intercalibration of non-reference instruments, but also for improved use of CrIS in NWP models since we now know that bias adjustments in models used to correct satellite observations are not needed for CrIS.

GSICS Now

Given the pressing requirements for weather and climate applications, including excellent accuracy and long-term stability, inter-calibrated instruments, high precision (low noise), and well characterized measurements, GSICS justifiably has an important role to play. The calibration and validation efforts from GSCIS members are producing observations that are well characterized and ready for immediate use in a variety of applications. The SNO technique, the GSICS GEO/LEO intercalibration, and the airborne campaign in Greenland are just a few examples of these efforts. The examples also demonstrate how these efforts generate benefits to satellite users and operators. Now, every satellite/instrument operator is responsible for characterizing their own satellites with community consensus algorithms, making them easily interoperable. As part of its forward looking vision, GSICS will continue promote capacity building through various activities, including the interaction of satellite testbeds/proving grounds, and the joint development of new satellite products.

Summary

Environmental satellite observations have become a fundamental part of the GOS and represent a large majority of the inputs used in the NWP models of agencies across the globe. It is important to ensure that these observations and their sources are deemed to be, among other things, well characterized, stable and accurate as these key qualities help determine their quality or value. The GSICS has embraced this challenge and emerged as an essential resource for satellite operators as they are better able to assess a particular sensor's error characteristics and the corrections needed to bring the data from this sensor back to common reference standards.

With a goal to improve and harmonize the quality of observations from operational weather and environmental satellites of the GOS, GSICS (through its members) is providing the best characterized data tied to reference instruments and enabling immediate use in a variety of applications. The important role of the GSICS has grown such that it is now the cornerstone for accurate observations from the GOS. Furthermore, the GSICS intercalibration of instruments has ensured comparability of measurements among the observing systems contributing to the GOS, and as the number of systems expands and becomes more diversified, so does the future role of GSICS in accurately integrating their data.

The GCC—the focal point for interagency cooperation—continues to play a pivotal role in facilitating data sharing and the exchange of information in science, products and algorithms, and applications.

Key publications such as the premier "GSICS best guidelines for prelaunch characterization of optical instruments" mapped procedures that if adhered to by each member agency will lead to much better-characterized instruments ready for launch into orbit.

The use of benchmark instruments to intercalibrate less well-calibrated satellite sensors will increase its impact on a variety of applications.

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JPSS USER PERSPECTIVE

Web Features

Suomi NPP Keeps an Eye on Hazardous River Ice and Floods

Ice jams along rivers are common occurrences during the winter and spring and can cause hazardous conditions for local residents.

When a frozen river begins to thaw and water levels rise, large ice chunks can break off and obstruct the natural flow of the river. When this occurs, the water that is held back can cause upstream flooding. If one of these ice jams breaks, the rushing waters can create flash flooding downstream.

That is why NOAA scientists with the Joint Polar Satellite System are working with experts in academia through the JPSS Proving Ground and Risk Reduction (PGGR) Program to help communities identify the risk of ice jams and prepare for these hazards. This effort is known as the River Ice and Flooding Initiative. The PGRR Program responds to this type of real-world environmental events using JPSS satellite data.

An Alaskan community at risk

Data and imagery from the Suomi NPP satellite VIIRS instrument aided in observing a major ice jam on the Yukon River that caused massive flooding in Galena, Alaska. Credit: NOAA

In May 2013, an ice jam formed on the Yukon River downstream from the village of Galena, Alaska. Waters rose 6.5 feet above flood stage- the established point at which a body of water poses a hazard to lives, property, or commerce- for a three day period. The record-level flooding caused half of Galena's occupied dwellings to be deemed uninhabitable.

Thankfully, two teams of scientists from City College of New York and George Mason University had been working on PGGR products to monitor and track ice and flooding conditions using data from the NOAA/NASA Suomi NPP satellite, the flagship satellite in NOAA's fleet of polar-orbiting satellites.

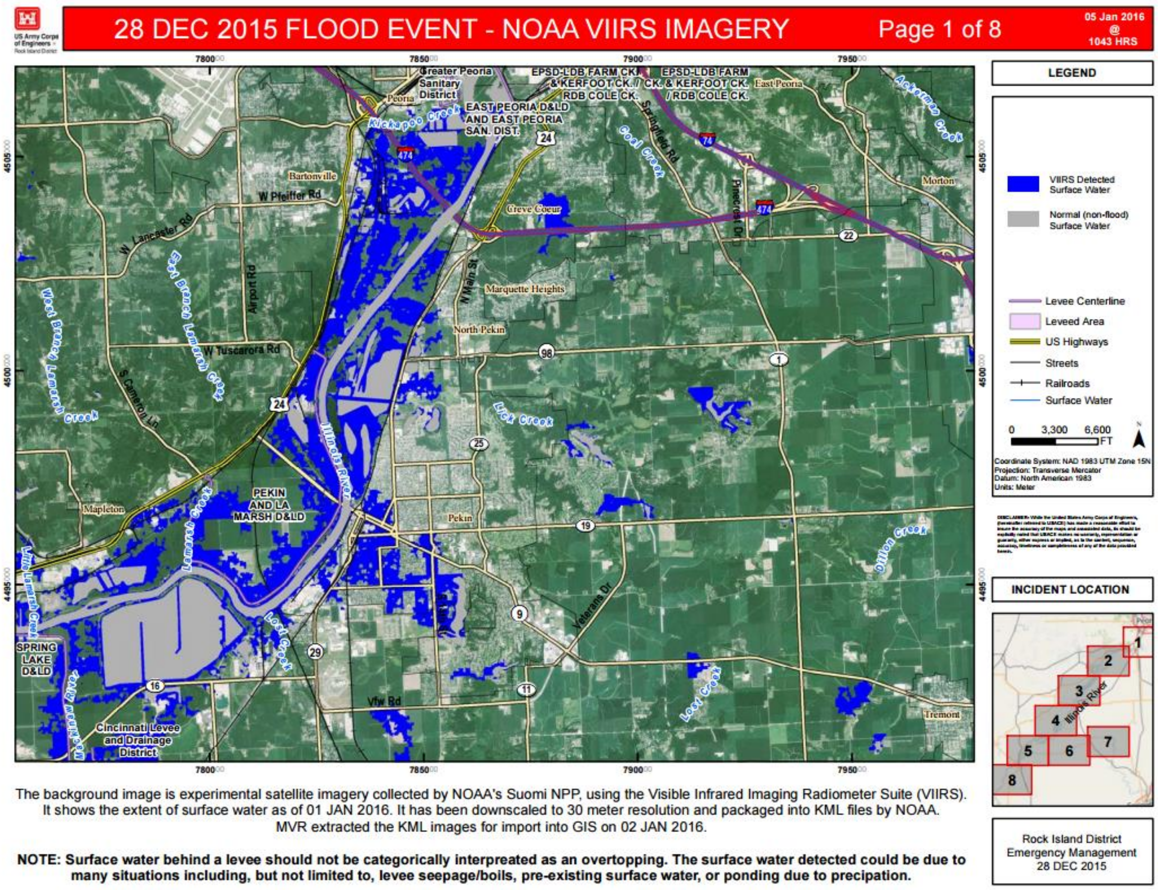
Working together, the teams were able to combine satellite imagery from multiple sources with river gauge data which was made available to Alaskan decision-makers to assist them in their response to the disaster.

Satellite data are especially crucial in the Alaska region where NOAA's Joint Polar Satellite System provides critical data for nearly all weather forecasting, filling gaps over areas that are not well covered by other ground-based observing systems.

2016 brings expanding use of river ice and flooding products

The George Mason University River Flooding Product recently used in December 2015 to monitor and track severe flooding that impacted the Midwest River Basins and the Mississippi River Valley. This flooding was tied to an extensive period of heavy rain in Missouri, Illinois and areas south.

NOAA's National Weather Service gave the product to the Army Corps of Engineers (USACE), which then used it to visualize flooding along sections of the Illinois River. Thanks to the University of Wisconsin-Madison's Space Science and Engineering Center (SSEC), the River Flooding Product is available on its RealEarth website.

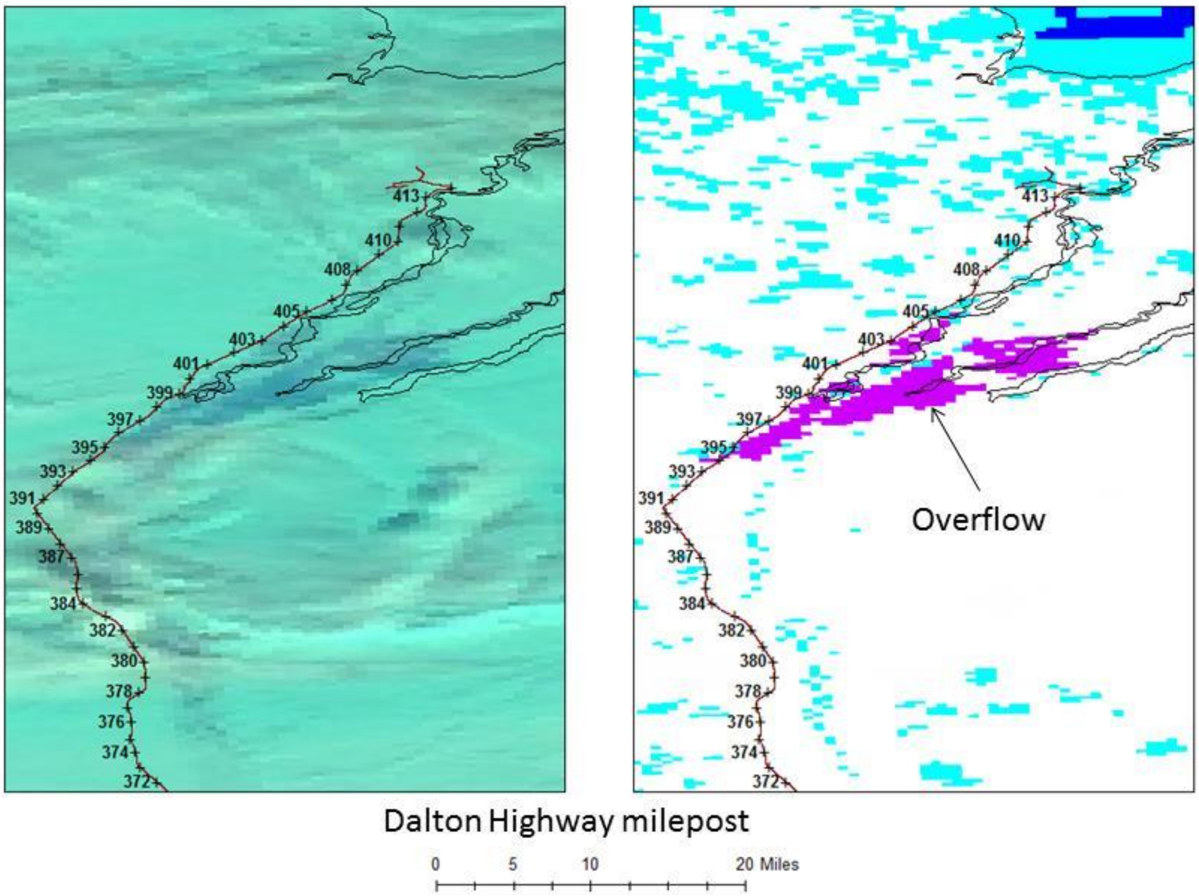


Imagery from Suomi NPP satellite VIIRS instrument is layered on Google Earth to visualize the flooding along the Illinois River. Credit: Army Corps of Engineers

These visualizations were so compelling that the Corp requested updates when JPSS's satellite passed over the area.

The River Ice and Flooding Product is a key component to this year's innovative Decision Support Services. They are provided by the Alaska-Pacific River Forecast Center and Alaska Region Climate Services. The Alaska Region Climate Services is providing week ahead to seasonal guidance and Alaska-Pacific River Forecast Center forecasters and hydrologists are providing briefing packets to assist the state transportation managers with planning and resource allocation to help the Alaska Department of Transportation (D.O.T.) and Public Facilities personnel as they work to minimize flooding impacts over the Dalton Highway which is a major transportation route between north of Fairbanks and a few miles from the Arctic Ocean and the Prudhoe Bay oil fields.

Within the guidance, the River Ice and Flooding product's very high-resolution post-processed imagery allow NWS hydrologists and forecasters to map the overflow and correlate on-ground observations with remote sensing products. Originally intended to detect flood inundation and river ice conditions, these products, are now being utilized to support emergency response to an essential economic corridor. Collaboration between NWS and D.O.T. staff is expected to continue through spring breakup into mid-May.



Direct Broadcast Reception Site at the University of Puerto Rico in Mayaguez, Puerto Rico. Credit: CIMSS

The River Ice and Flooding Initiative is just one example of how imagery from JPSS satellites will remain a critical resource to increase the timeliness and accuracy of public warnings and forecasts of severe flooding, thus reducing the potential loss of human life, enabling better preparedness, and building more resilient communities.

Satellite Monitors Pavlof Volcano Eruption

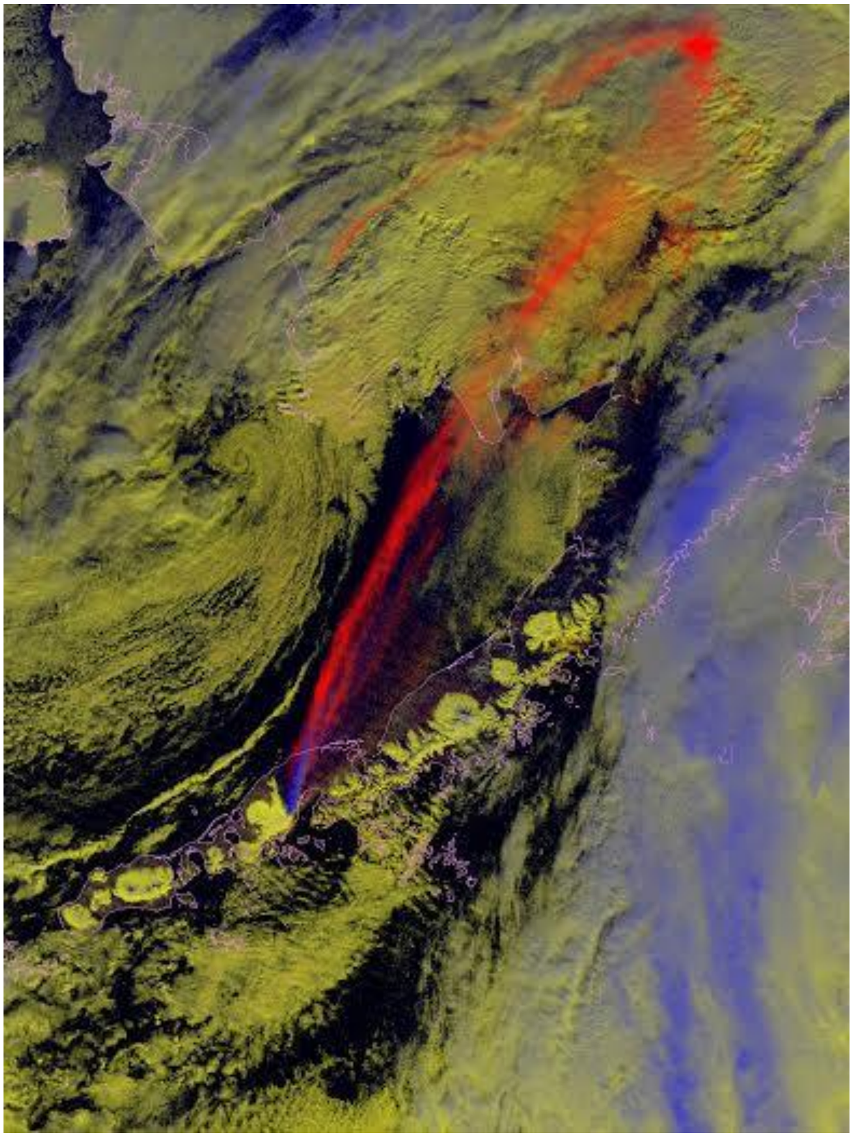
On any given day, the Alaska Region presents a wide assortment of challenges to forecasters, with an ever-changing mix of sea ice, snow cover, and multi-layered cloud patterns. When one of the Aleutian Chain volcanos erupts, spewing ash into all levels of the atmosphere, the stakes are raised for forecasters in the region.

Volcanic ash is a notorious hazard to the jet aircraft which frequent these skies on domestic and international routes. The fine, glass-like particles of some ash plumes can sand-blast cockpit windows, melt-upon and damage engine turbine blades, and even lead to engine flame-outs.

Such a catastrophe could not have been far from the minds of forecasters on the afternoon of March 27, 2016 when the Pavlof Volcano, one of the Aleutian Range's most active, erupted with a 20,000 foot high ash plume tracking rapidly to the northeast and into the heart of the Alaskan mainland.

View of Pavlof Volcano from 20,000 feet. Credit: Lieutenant Commander Nahshon Almandmoss, United States Coast Guard

To gain a better perspective on the Alaska Region, forecasters appeal to their ‘eyes in the sky.’ Some weather satellites carry instruments that provide critical information on a volcanic ash plume’s height and content.

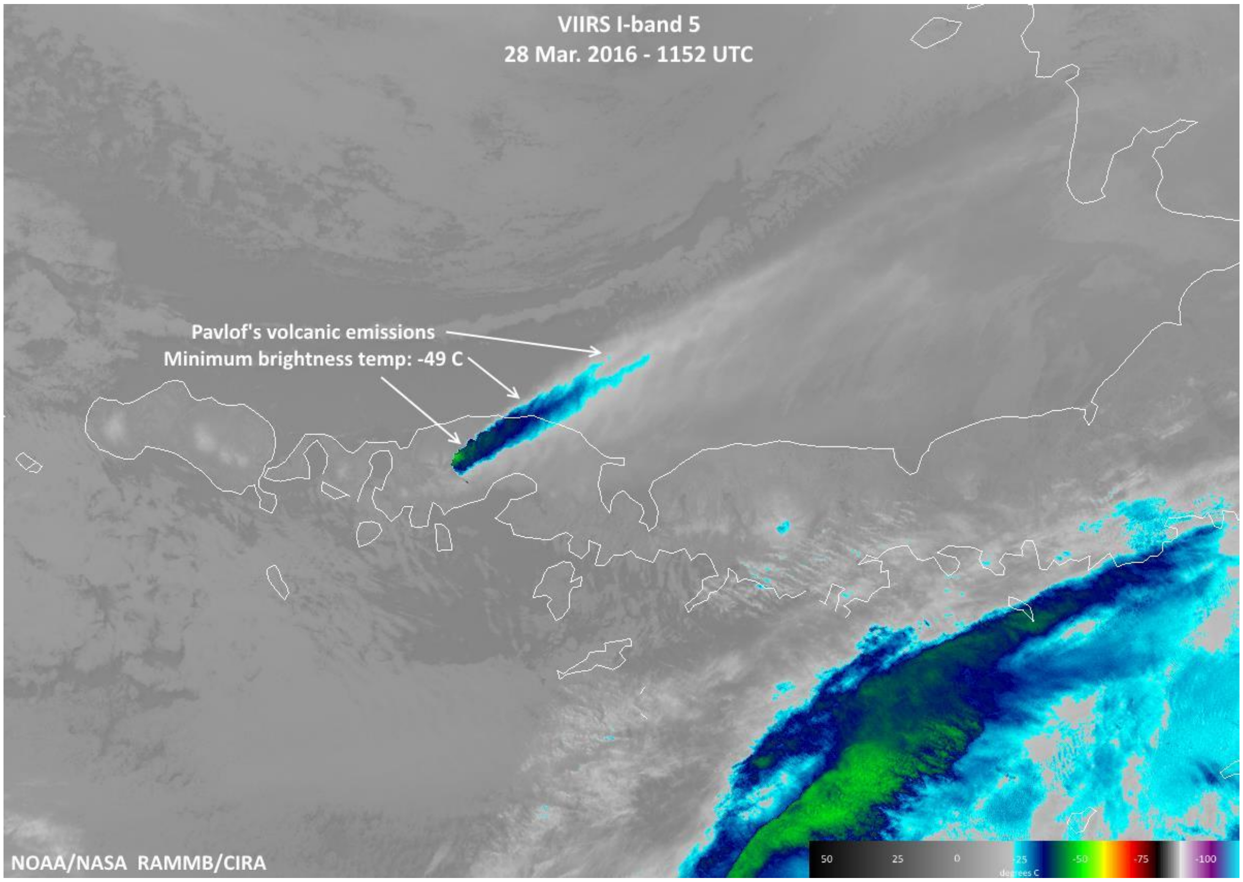


The image to the left, for example, was collected by the Suomi NPP satellite at about 1:30 a.m. local time, roughly 9 hours after the initial eruption. Information from Suomi NPP’s Day/Night Band sensor (measuring reflected moonlight off snow, clouds, and ash) has been blended with other measurements that are sensitive to the temperature and composition of water/ice clouds and volcanic ash.

With each unique observation playing its part, the low water clouds and snow cover are shown in yellow, higher/thicker ice clouds in shades of blue, and the heart of Pavlof’s ash plume streaming to the northeast is depicted in red/orange. For reference, the coastal boundaries are drawn in purple.

Credit: Steven D. Miller, Cooperative Institute for Research in the Atmosphere

Pavlof's eruption was ongoing as Suomi NPP passed overhead, with a sharp blue point defining the exact location of the volcano. The brightening of the yellow near the point of eruption is light being emitted from Pavlof’s lava.

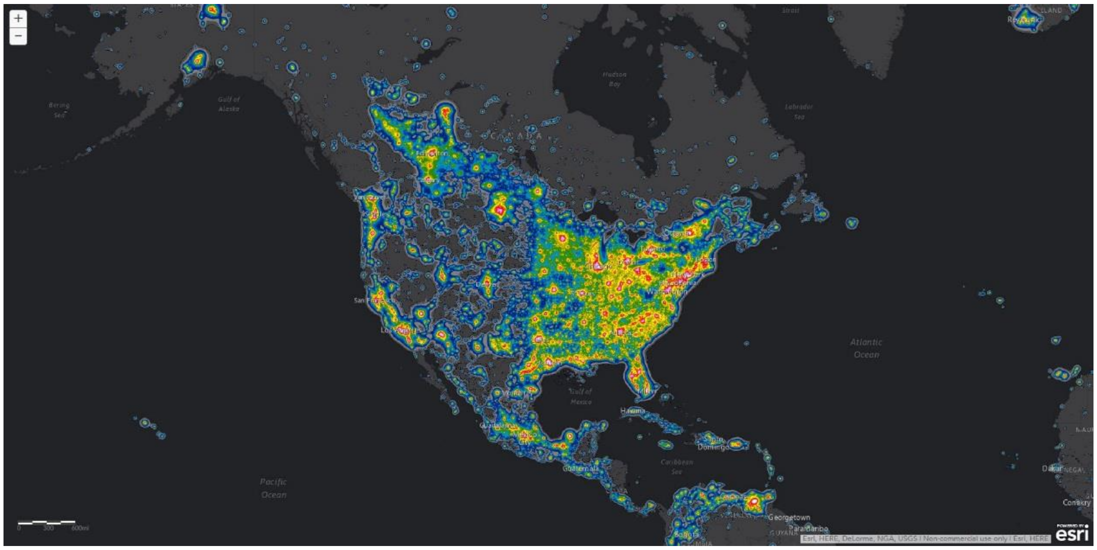


Credit: Steven D. Miller, Cooperative Institute for Research in the Atmosphere

Using a variety of satellite data, forecasters issued timely and accurate guidance for this rapidly changing hazard. Airlines used information provided by the Anchorage Volcanic Ash Advisory Center (VAAC) to re-route, and in some cases, cancel flights. NOAA operates the Washington D.C. and Anchorage, Alaska, VAAC, two of nine worldwide.

Data from polar-orbiting satellites like Suomi NPP (and the upcoming JPSS-1, which will launch in 2017) remain the most crucial sources of data for the Alaskan Region, providing a broad and accurate view of weather, climate, environmental and oceanographic conditions unavailable from other sources.

Data Used to Create World Atlas of Artificial Sky Brightness



The Milky Way, the brilliant river of stars that has dominated the night sky and human imaginations since time immemorial, **is but a faded memory to one third of humanity and 80 percent of Americans**, according to a new global atlas of light pollution produced by Italian and American scientists, including Chris Elvidge of NOAA's National Centers for Environmental Information and Kimberly Baugh of NOAA's Cooperative Institute for Research in Environmental Sciences.

"We've got whole generations of people in the United States who have never seen the Milky Way," said Elvidge. "It's a big part of our connection to the cosmos and it's been lost."

Light pollution is most extensive in countries like Singapore, Italy and South Korea, while Canada and Australia retain the darkest skies. In Western Europe, **only small areas of night sky remain relatively undiminished**, mainly in Scotland, Sweden and Norway. Despite the vast open spaces of the American west, **almost half of the U.S. experiences light—polluted nights**. Light pollution does more than rob humans of the opportunity to ponder the night sky. Unnatural light can confuse or expose wildlife like insects, birds and sea turtles, with often fatal consequences.

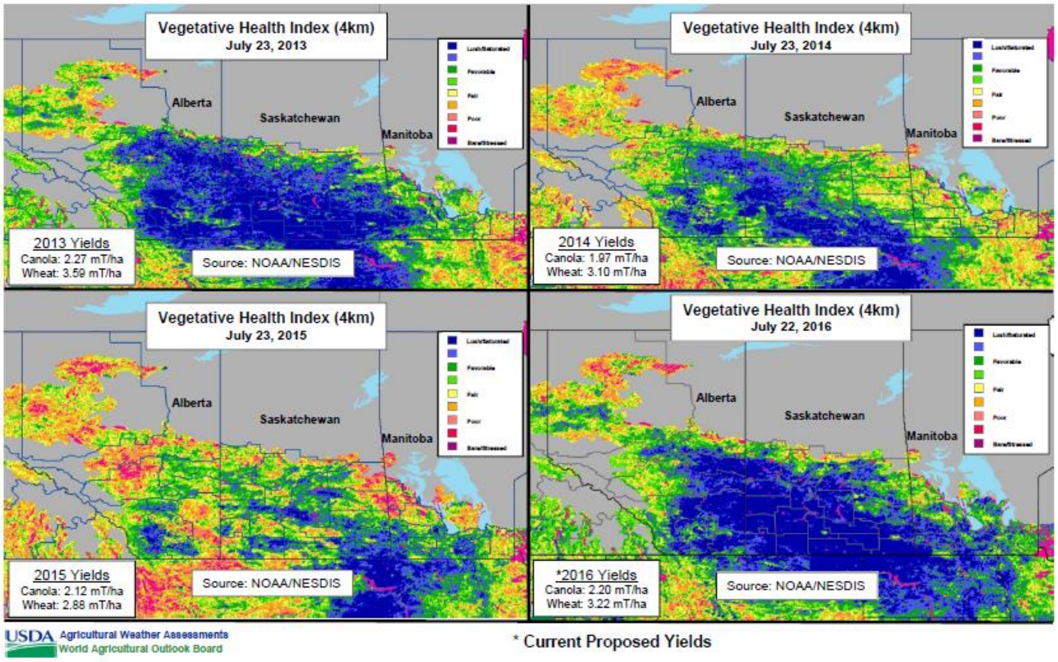
The atlas takes advantage of lowlight imaging now available from the NOAA/NASA Suomi National Polar-orbiting Partnership satellite, calibrated by thousands of ground observations. The brighter the area in this interactive map (at right), the harder it is to see stars and constellations in the night sky.

Satellite Data Helps Monitor the Trickle-Down Effects of Droughts

Perhaps you have noticed the price of avocados rising the last time you were at the store. Around 90 percent of the nation's avocado crop is produced in California, where drought conditions are expected to impact California's avocado yield. In order to assess weather conditions and help farmer's decision making, the California Avocado Commission relies on United States Drought Monitor for monthly weather outlooks that will allow farmers to maximize production of the fruit (that's right, avocados are fruits!).

It's not just about making your guacamole; droughts affect all agricultural areas and are among the nation's most costly weather related events. In 2016, drought has already cost an estimated 4.5 billion, hitting the western states the hardest. That's why farmers and livestock producers across the nation look to the U.S. Department of Agriculture (USDA), and in turn NOAA, to assist them in preparing for and responding to changing weather and climate conditions.

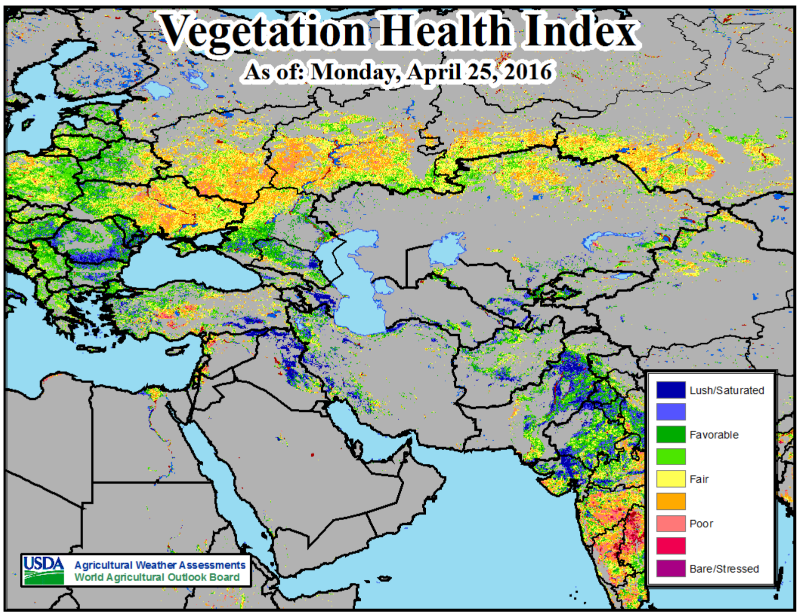
Key to the success of this effort are products derived from satellites like those in the Joint Polar Satellite System (JPSS) constellation, which can be of particular use to the agricultural community. Among these are blended or derived products that appear in the form of maps illustrating climactic conditions such as drought, precipitation totals, soil moisture, snow depth, and temperature.



The charts above show that this year's yield of Canada wheat and canola are similar in appearance to the record 2013 season. Credit: USDA

While not fully replacing in-situ data, the information is critical in providing information in data-sparse areas.

Satellites like JPSS have unique advantages over conventional observations of drought, due to their ability to acquire information over large geographical areas, measure and analyze key features of droughts routinely with increased spatial detail of vegetation conditions improving early drought detection. The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on JPSS is able to provide vegetation health data, with eight times more detail, and at a much higher and more consistent quality than earlier satellite radiometer instruments. Using this data, NOAA's Center for Satellite Applications and Research (STAR) has created the Vegetation Health Indices (VHI) product.



USDA uses the satellite weather data to look for potential problem areas.

"The VHI has quickly become an important component in USDA's effort to monitor world agricultural production, particularly in areas where in-situ data is sparse or non-existent," said Mark Brusberg, Deputy Chief Meteorologist at USDA.

VHI is used often to estimate crop condition and anticipated yield. A low index indicates different levels of vegetation stress such that losses of crop and pasture production might be expected; whereas high indices indicate a favorable condition where plentiful production might be expected. VHI is very useful for an advanced prediction of crop losses.

Since the creation of the Joint Agricultural Weather Facility in 1978, NOAA and USDA have partnered to collect and disseminate weather information from station- and satellite-derived meteorological data to the public. One avenue is the Weekly Weather and Crop Bulletin, a joint publication dating back to 1872. Another is the World Agricultural Supply and Demand Estimates (WASDE) report, a major economic publication detailing global production of major commodities. Meteorologists from USDA have increasingly become reliant on products like the VHI to aid in their assessments of crop yield in key international farming areas. The Foreign Agriculture Service (FAS) is another USDA component that incorporates satellite data (along with reporting from FAS's worldwide offices, official statistics of foreign governments, and analysis of economic data) in their contributions to the monthly release of the WASDE report.

The success of these programs underscore the importance of satellite monitoring to farmers, as well as policy makers, who need to quickly respond to a variety of challenges posed by weather and climate phenomena that cannot be monitored by station data alone.

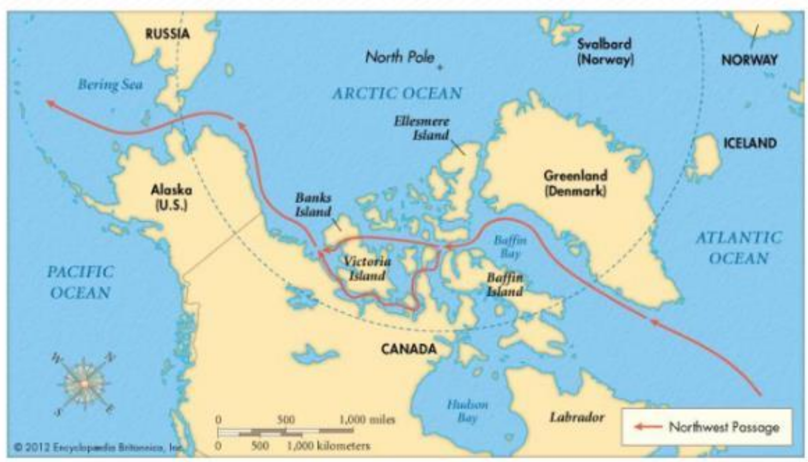
JPSS Satellites Help Ships Navigate the Northwest Passage

For centuries, global commercial interests have been eyeing the Northwest Passage as a shorter trade route between Europe and Asia. Unfortunately, this pathway through the Canadian Arctic is often choked with ice, making navigation too risky for most ocean vessels—or at least it used to be.

In 2015, NOAA's Climate.gov reported that, for the first time in recorded human history, the Northwest Passage may become a useful shipping route during the Arctic summer. If that assessment is correct, and current climate trends suggest it is, safe travel will require up to date monitoring of ice-flows and weather conditions. Thankfully, NOAA's Joint Polar Satellite System spacecraft are already on the job, providing this information to transporters around the globe.

A Shorter Route Means an Economic Advantage

The Northwest Passage connects the northern Atlantic and Pacific Oceans through the Arctic Ocean (marked in red in the map below). The route is about 9,000 kilometers shorter than the way through the Panama Canal and 17,000 km shorter than the trip around South America's Cape Horn. Therefore, ships that can travel via the Northwest Passage stand to benefit economically from the shorter, more efficient route. The risk to navigators remains high, however, as thousands of icebergs—some rising to 300 feet—can make the Northwest Passage a treacherous place to do business.



The Northwest Passage.
Encyclopædia Britannica, Inc.

In 2011, a route through the straits of the Canadian Arctic Archipelago opened for the fifth year in a row. Other routes across the Arctic may also open, providing ships with viable alternatives to traveling through the Panama Canal or around the southern tip of South America.

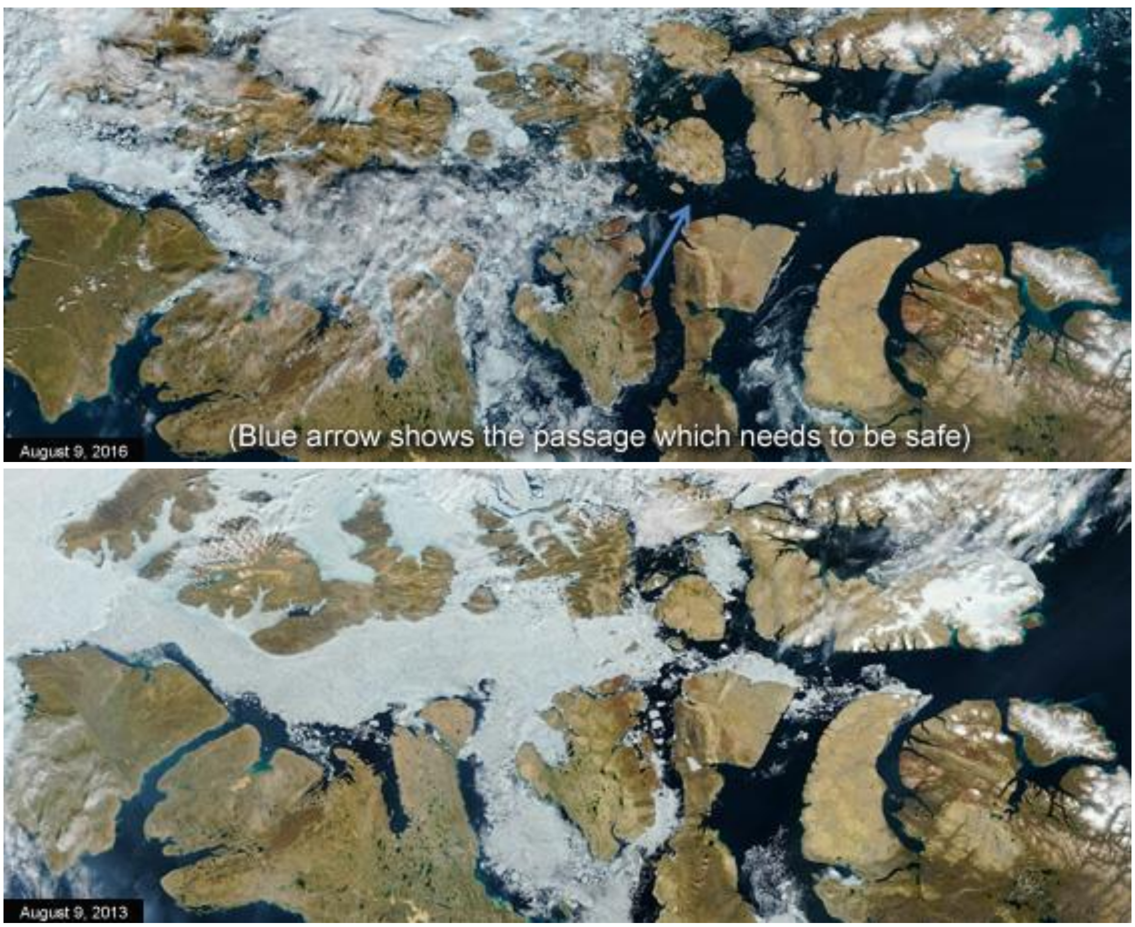
A melting Arctic will have impacts not only on the environment, but also on the global economy and national security, as nations compete to gain rights to shipping lanes and newly accessible resources in the region.

For the Serenity, a 1,000-passenger cruise ship, the risk finally seems worth it. This August, the Serenity began its first voyage along the Northwest Passage. To navigate the ice along the route, the ship receives on-demand satellite imagery updates and an escort by a British Antarctic Survey icebreaker. (You can see a webcam of their trip here.) As more ships traverse the Northwest Passage, satellite data will continue to be a critical component in safe navigation.

Satellites Show Sea Ice When Other Instruments Can't

NOAA's Joint Polar Satellite System (JPSS) spacecraft are already doing just that. The Suomi NPP satellite provides critical data for nearly all weather forecasting in Alaska, filling gaps over areas that are not well covered by observing systems on the ground. In addition, the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument aboard the satellite can observe the entire Arctic within 12 hours and at sub-kilometer spatial resolution.

This imagery is helping reveal which paths through the Northwest Passage are free of ice and therefore safe to travel.



Above are composites from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Aqua satellite imagery from August 2013 and Suomi NPP /VIIRS instrument in August of 2016. Image credit, NOAA/NASA

NOAA Celebrates Five-Year Anniversary of Suomi NPP Launch

After five years in space, the NOAA/NASA Suomi National Polar-orbiting Partnership (Suomi NPP) the mission continues to contribute significant advances in severe weather prediction and environmental monitoring leading to better forecasts and situational awareness for the nation and users worldwide.

Launched on Oct. 28, 2011, Suomi NPP is a bridge to National Oceanic and Atmospheric Administration's (NOAA) next generation Joint Polar Satellite System (JPSS) weather satellites. The JPSS-1 satellite is scheduled to launch in 2017 to complement the data from Suomi NPP.

Currently NOAA's primary polar-orbiting weather satellite, Suomi NPP data provide critical input into weather forecasts beyond 48 hours and is increasing the consistency and accuracy of forecasts three to seven days in advance of a severe weather event for NOAA's National Weather Service. These data are also provided to other federal, state and local users; commercial weather sector; and international partners.

Research scientists throughout the United States and the world use Suomi NPP data as they study severe weather, atmospheric and oceanographic phenomena and climate. Data produced by Suomi NPP are derived from a new generation of instruments that will also fly on future JPSS satellites: Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), and Ozone Mapping and Profiler Suite-Nadir (OMPS). Suomi NPP provides the first mission using these instruments, and also flies the fifth flight model of the Cloud and Earth Radiant Energy System (CERES).

Suomi NPP data are used to generate dozens of environmental data products, including measurements of atmosphere, oceans and land conditions. These include:

- Atmospheric temperature/moisture profiles
- Clouds
- Hurricane intensity and position
- Thunderstorms, tornado potential
- Ice detection
- Precipitation and floods
- Dense fog

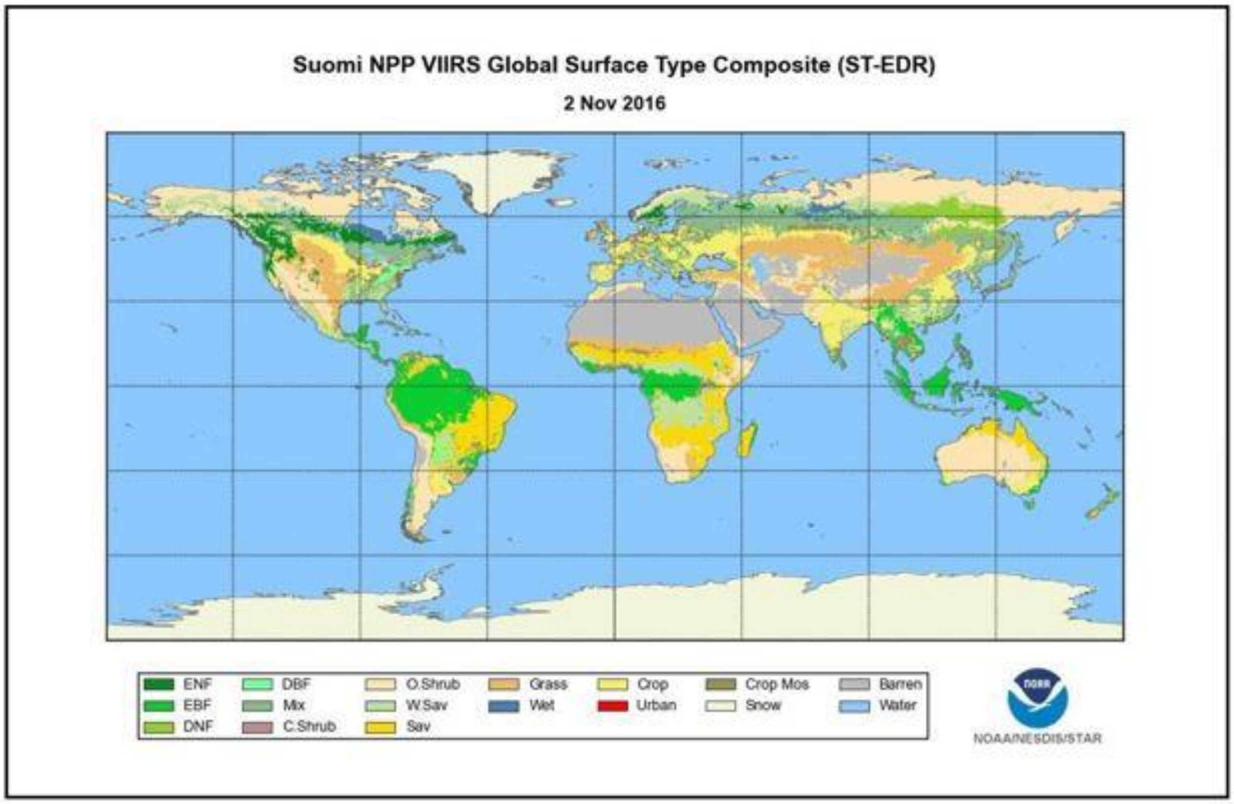
- Volcanic ash
- Fire and smoke
- Sea surface temperature, ocean color
- Sea ice extent and snow cover /depth
- Polar satellite derived winds (speed/direction/height
- Vegetation greenness indices and health
- Ozone
- Oil spills

It takes Suomi NPP 14 orbits to observe the entire Earth in one day. The weather and environmental mission data from its five instruments for each orbit are stored and transmitted to Earth every orbit.

Suomi NPP stored mission data is collected by a ground station in Svalbard, Norway, and is then routed to the NOAA Satellite Operations Facility in Suitland, Maryland, where it is processed and distributed. With JPSS-1, there will also be a transmission to antennas at McMurdo Station, Antarctica near the South Pole to enable data to be received and routed every half orbit, cutting the time processed data is sent to users by half.

In addition, Suomi NPP data are accessed by users through the use of direct broadcast antennas to quickly access Suomi NPP observations made while in view of each direct broadcast antenna to support critical missions.

Annual Update to Global Surface Type



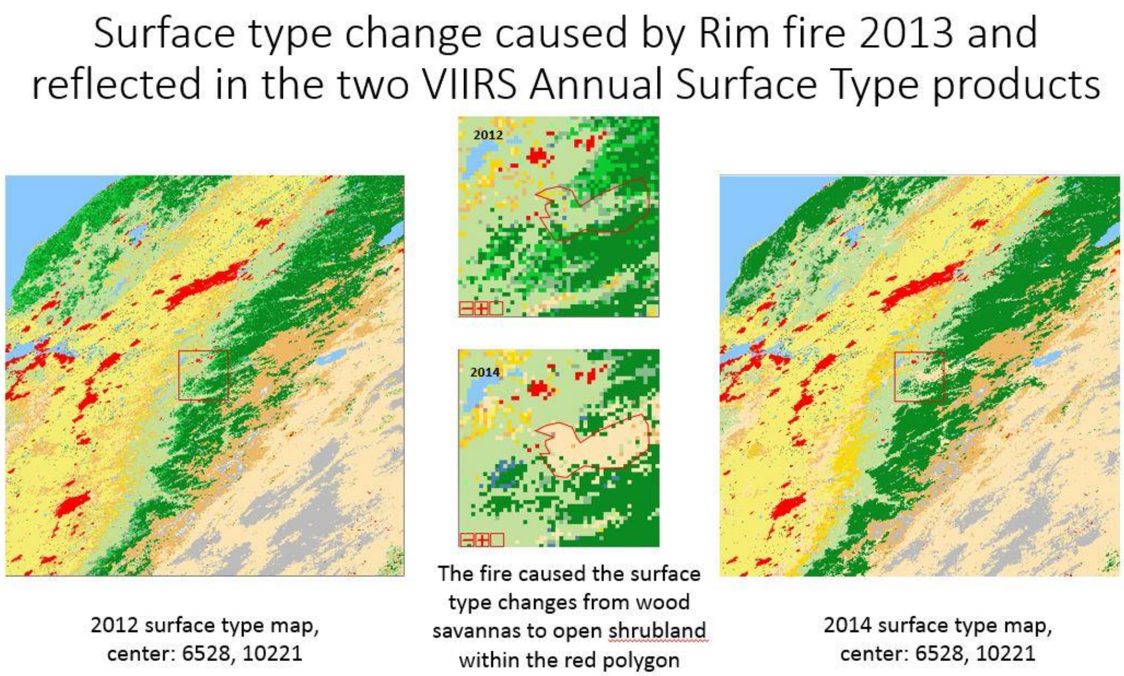
NOAA's Center for Satellite Applications and Research has announced the release of the 2016 update to the Global Surface Type (GST) data, provided by the NOAA/NASA Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS).

Updated annually, the GST data product provides users with the most recent information of global land surface type, which may change from year to year as a result of significant natural events (e.g., large scale wildfires) or human activities (e.g., deforestation, urbanization, reforestation, and so on). As such, it is a required input for many land surface models, including numerical weather prediction, climate and hydrological forecasts, studies on natural resources and disaster management.

The VIIRS GST product is generated with the 17-type classification scheme of the International Geosphere-Biosphere Program and is produced at a 1-kilometer spatial resolution based on the previous one or more years of data from VIIRS. The instrument's surface reflectance, brightness temperature and vegetation index data are vital to creating accurate GST products.

Although land surface type changes occur frequently around the world, some of the changes may take place over a multi-year timescale, whereas others may take place in just a few days. While the VIIRS annual global surface type product may not always capture significant, but short-term surface type changes, it does illustrate their consequences through the detection of such landscape features as burn scars or flooded areas.

For example, the more than 250,000-acre Rim Fire of 2013 resulted in large scale surface type changes in the State of California. As denoted by the red polygon in the graphic below, the GST products generated with 2012 and 2014 VIIRS data show how the surface type of the affected region has surface type changed from woody savanna to shrubland.



The VIIRS Global Surface Type Map—the latest in a series of land cover products of different spatial resolutions and legend definitions that date back to the early 1990s—represents a continuation of NASA and NOAA products created with MODIS-based surface reflectance data and 1 kilometer resolution Advanced Very High Resolution Radiometer data.

The Center for Satellite Applications and Research (STAR) is leading the NOAA-NASA Joint Polar Satellite Systems (JPSS) program efforts to develop, test, validate, and refine the algorithms used to process data from instruments aboard JPSS satellites. STAR-JPSS Surface Type team is tasked with generating the Global Surface Type product annually to provide the most recent land surface type information for users.

GOES-R and JPSS Working Together

The successful launch of the GOES-R (Geostationary Operational Environmental Satellite R-series), now GOES-16 satellite was a major achievement for NOAA on the path to implementing the nation's next generation of weather satellites. These will include completing and placing the upcoming GOES- S, T and U series satellites in geostationary orbit, as well as launching several polar satellites within the Joint Polar Satellite System (JPSS) in the next decade. The first satellite in the JPSS system is the existing NOAA/NASA Suomi-NPP, soon to be accompanied by JPSS-1, launching in 2017.

Polar and geostationary satellites are important and complementary components for weather forecasting, monitoring environmental conditions and mitigating the risks of severe weather, such as hurricanes, floods, fires and tornadoes. By orbiting above a fixed point on the Earth, GOES satellites provide imagery of the Western Hemisphere with high temporal resolution, producing an image every few minutes. By orbiting from pole to pole 14 times a day, JPSS's satellites provide images of higher spatial resolution covering the entire globe twice daily. Together the sets of data are used to improve forecasting and the accuracy of weather prediction models across the US.

In addition to the high spatial resolution, there are other important benefits of the JPSS mission. While geostationary satellites produce imagery of the Western Hemisphere with high frequency, polar satellites provide timely pictures of Alaska and the Arctic, as their relative coverage of the poles is much larger due to the wide swath crossing the poles every orbit. These images are vital for monitoring river ice, air quality, travel routes, wildfires and navigation in polar regions.

Satellites in the JPSS constellation carry the Visible Infrared Imaging Radiometer Suite (VIIRS), whose unique "day-night band" can capture the Earth even in the lowest moonlit conditions. This capability has proven useful for many applications including tracking storms at all hours of the day and monitoring ship traffic, a useful tool to address illegal fishing worldwide.

The most important aspect of JPSS data is as additional input for weather modeling and forecasting. The Advanced Technology Microwave Sounder and the Crosstrack Infrared Sounder, two instruments aboard Suomi NPP and upcoming JPSS satellites, provide three dimensional measurements of air temperature and moisture. These data are critical to the accuracy and timeliness of medium-to-long term (3- to 7-day) weather forecasts.

The JPSS constellation provides additional products to those mentioned above including precipitation type and rates, surface and sea surface temperature measurements, vegetation health assessments, ocean color and aerosol tracking from volcanic eruptions. Together, NOAA's polar and geostationary satellites provide the national with accurate and up-to-date environmental and weather monitoring.

ANNUAL DIGEST CONTRIBUTIONS

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Program Science: Julie Price – lead article writer, Bill Sjoberg, and Arron Layns

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Allen Larar

Ann-Marie Saucier-Gnall

Antonia Gambacorta

Arron L. Layns

Brad Pierce

Cara Wilson

Chris Barnet

Chris Elvidge

Dale Robinson

Dave Tobin

David Santek

Donglian Sun

Elliot Hazen

Eric Stevens

Gregory Frost

Jay Hoffman

Joe Taylor

Jun Li

Michael J. Folmer

Mike Pavolonis

Nadia Smith

Paul W. Menzel

Ravan Ahmadov

Roy Mendelssohn

Sanmei Li

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