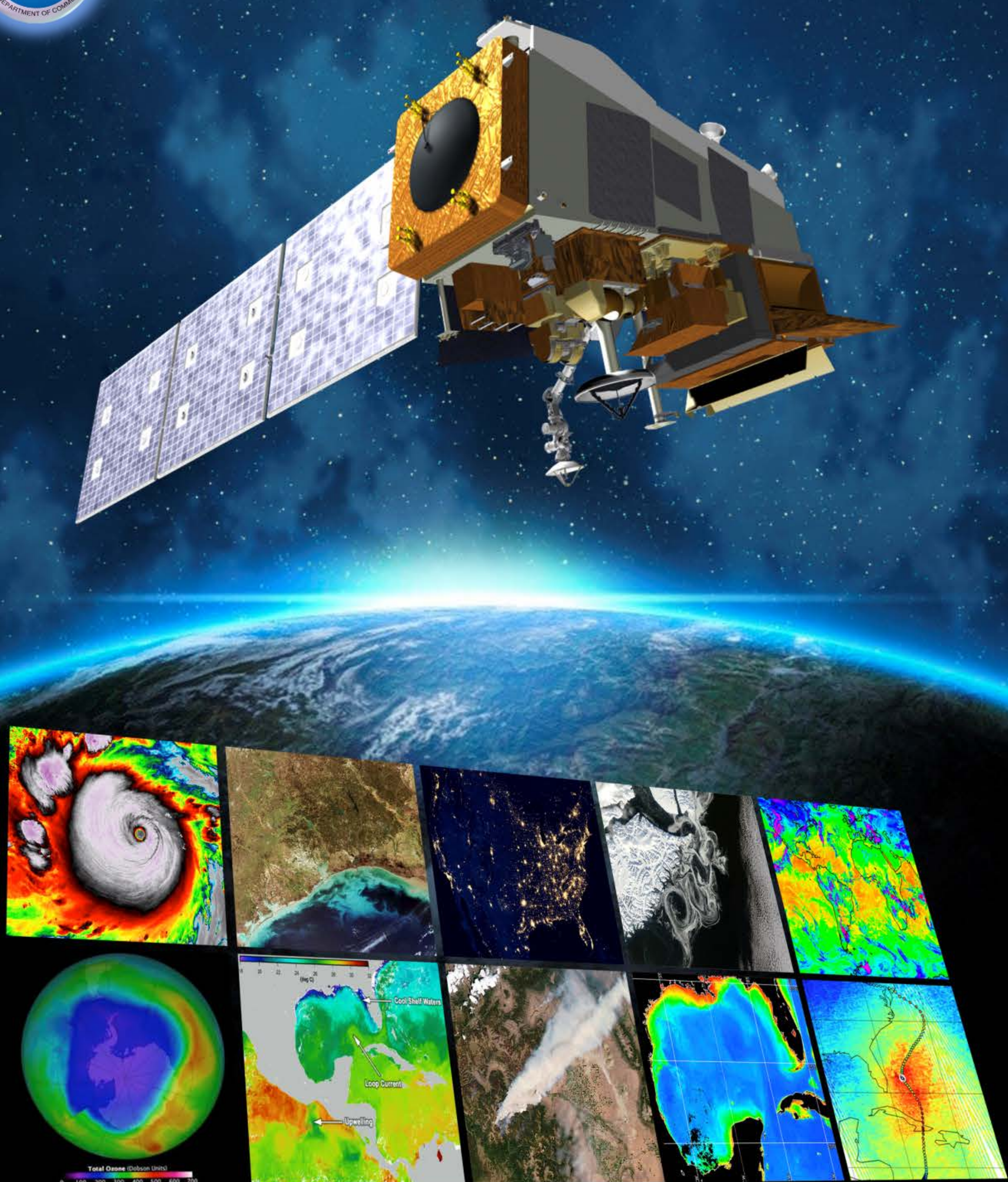
Joint Polar Satellite System

Science Seminar Annual Digest

2013



Joint Polar Satellite System Science Seminar Annual Digest

2013

From the Senior Program Scientist

On behalf of the Joint Polar Satellite System (JPSS) Program Science, it is my pleasure to present this digest, which is a collection of technical articles generated from a series of monthly science seminars during fiscal year 2013. The digest captures the importance of the close collaborative efforts between product developers and key users to conceptualize and develop new products that help improve the use of JPSS data to enhance key services, such as forecasting of severe weather events and environmental monitoring of land, ocean and the cryosphere. I would like to thank our federal staff, private sector support staff, and university partners whose contributions and dedicated efforts have made JPSS a big success.

The JPSS program is committed to ensuring that its user community is prepared to utilize the satellite imagery and data available from JPSS – the United States' next generation polar-orbiting operational environmental satellite system. JPSS provides environmental observations which are used in a wide range of application areas that include severe weather, hazards, aviation, ocean, coastal, land, imagery and data assimilation.

We have established a comprehensive Proving Ground and Risk Reduction Program (PGRR) to support projects that promote the most innovative use of new and improved JPSS capabilities. In addition to engaging the user community, the PGRR guides the transition of these capabilities from research to operations. The JPSS PGRR Program invests heavily in numerous science seminars, scientific conferences, training meetings, product evaluations, and solicitations of user feedback, which assist in maintaining communication between it and project teams. These forums, which are a key element of the PGRR Program, also enable the JPSS user community to identify ways to improve their services, products and support to their own end users.

I also want to emphasize the importance of the nation's premier environmental satellite in polar orbit, Suomi-National Polar-orbiting Partnership (S-NPP) – the bridge between NOAA Polar-orbiting Operational Environmental Satellites (POES) and the next generation Joint Polar Satellite System (JPSS) – to national and international communities. There are over 30 domestic and international sites currently accessing S-NPP data through direct readout for regional applications and faster access to the data. For example, the US Forest Service (USFS), Mexico, Australia, South Africa, and Brazil use S-NPP direct readout to support fire detection and monitoring. The National Weather Service (NWS) in Alaska, the Swedish Meteorological and Hydrological Institute (SMHI) and many other agencies use direct readout for regional weather forecasting and coastal ice monitoring and many other applications.

Below is a descriptive summary showing the dates when S-NPP data began operational use by some key weather agencies:

- May 1, 2012, VIIRS imagery used to support local warning and forecast operations throughout the NWS Alaska Region.
- May 22, 2012, the Advanced Technology Microwave Sounder (ATMS) radiances were operationally assimilated in the National Centers for Environmental Prediction's (NCEP)/ NWS Global Forecast System (GFS).
- September 25, 2012, ATMS data was assimilated operationally into the European Centre for Medium-Range Weather Forecasts (ECMWF) weather forecast models.
- April 2013, the United Kingdom Meteorology Office began assimilating operational data from the Cross-track Imaging Radiometer Suite (CrIS) and ATMS into its weather forecast models.
- August 20, 2013, NCEP began incorporating S-NPP CrIS satellite data operationally into the GFS.
- October 31, 2013, NCEP/Climate Prediction Center (CPC) started to use OMPS ozone operationally to monitor global ozone
- And, November 2013, the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) started to use ATMS operationally in their global forecast model.

I hope you enjoy reading this digest, which covers a wide range of topics on the most innovative uses of S-NPP data, and that you find it useful. I would like to thank Julie Price for leading the development of these articles, Bill Sjoberg for his coordination and support of PGRR projects, and the NOAA JPSS Office for their ongoing support in the development of this digest.

Mitch Goldberg
Senior Program Scientist, Joint Polar Satellite System (JPSS)
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From the Director

JPSS experienced a challenging and rewarding year in 2013. America's next generation polar-orbiting satellite system is seeing great success, and is providing operational continuity of satellite-based observations beyond the National Oceanic and Atmospheric Administration's (NOAA) Polar-orbiting Operational Environmental Satellites (POES) and the National Aeronautics and Space Administration (NASA) Earth Observing System (EOS).

The JPSS satellites represent significant technological and scientific advances for more accurate weather forecasting to improve prediction capabilities that save lives, facilitate the flow of commerce, and protect the economic interests of both the public and private sectors during severe weather events. A study done by the ECMWF showed the value of polar-orbiting satellites to develop life-saving forecasts with longer lead times. According to the study – which ran experiments that excluded polar-orbiting satellite data from their numerical weather models and re-ran their forecasts for Hurricane Sandy – NOAA forecasts of the hurricane's track could have been hundreds of miles off without information from polar-orbiting satellites. Rather than identifying the New Jersey landfall location within 30-miles five-days before landfall, the models would have shown Sandy remaining at sea. Combining the data from polar-orbiting satellites with other observational sources, computing, numerical models, and the experience and skill of NOAA's forecasters allowed Sandy to be tracked starting as a tropical wave, turning into a hurricane, and finally morphing into post-tropical cyclone. The results of this study were widely recognized in a December 2012 NOAA press release.

Having just celebrated its second launch anniversary, S-NPP is a great success. S-NPP is producing outstanding data on orbit. Instruments are meeting or exceeding user expectations and data availability is now regularly at 99.99 percent. Data records from both S-NPP's ATMS and CrIS are being incorporated into weather prediction models. Information from these sensors are improving the quality and accuracy of NWS global weather forecasts. ATMS was the first S-NPP instrument to become operational. And now, CrIS data is being incorporated operationally into the Global Data Assimilation System (GDAS). Both instruments work in tandem to provide detailed atmospheric temperature and moisture observations for short and long term weather applications with greater accuracy than legacy instruments.

The use of S-NPP's Visible Infrared Imaging Radiometer Suite (VIIRS) data was critical in tracking numerous key 2013 weather events. VIIRS captured images of a massive dust cloud with wind gusts upwards of 70 miles per hour and 6,000 feet high as it rolled over Texas. VIIRS' Day Night Band (DNB) located Tropical Storm Flossie when it reformed in the Hawaiian region and showed that it had drifted more north than expected; indicating that the Big Island would be spared a direct hit while placing Oahu, Molokai and Maui under a tropical storm warning. VIIRS detected a thermal anomaly that pointed to increased volcanic activity at Mount Sakurajima 14 hours before it erupted. And VIIRS provided valuable imagery of the West Fork Complex Fires in southern Colorado which not only provided locations but identified the intensities of each fire.

JPSS successfully completed no less than five key programmatic reviews and decision points in 2013; Program System Definition Review (P/SDR), JPSS-1 Mission Preliminary Design Review (M/PDR), Key Decision Point-C (KDP-C), Key Decision Point-I (KDP-I), and the National Environmental Satellite, Data, and Information Service (NESDIS) satellite enterprise Independent Review. Successfully completing the P/SDR and the M/PDR in June showed that the program was ready to move to the next phase. The KDP-C and KDP-I were completed in July where final approval was given to move forward into the final design and fabrication stage for JPSS-1 and the implementation phase for the program. Both the JPPS-1 mission and the program were formally baselined at these decision points. JPSS participated in the NESDIS independent review in August where the Independent Review Team (IRT) members recognized the great progress made over the last year. JPSS met 100 percent of its 11 external milestones on time or early, and in February 2013, the JPSS Program transitioned operations of S-NPP to NOAA /NESDIS Office of Satellite and Product Operations.

JPSS also faced several challenges this year with the roll-out of the significant programmatic changes in the FY 2014 President's Budget, coupled with sequestration and FY 2013 Budget reductions. As a result, Free Flyer-1 and A-DCS-2 were removed from the program, and the climate sensors were transferred to NASA. In addition, the program's life cycle was reduced by three years. The Program focused on implementing the direction outlined in Acting Secretary Blank's direction letter, which provided guidance to update critical baselined documents and finalize the Program Office Estimate. The Standing Review Board recognized the outstanding job the program did in responding to these challenges while maintaining launch schedules. JPSS still faces challenges and must carefully monitor development and risks, but is still ready to move ahead into the execution phase with the completion of these critical milestone reviews, including KDP-I.

JPSS-1 is executing on plan and proceeding well. Mission instruments and spacecraft are at Critical Design Review (CDR) level or beyond. Ground elements are at PDR level or beyond. All instruments are assembled and in testing. The Level One Requirements Document (L1RD) has been baselined to prioritize NOAA's weather mission. JPSS-1 is on track for launch no later than the second quarter of FY2017.

JPSS-2 procurement activities are well underway, with one instrument already under contract. The rest of the instrument Requests for Proposals (RFPs) are out. A Rapid Spacecraft Development Office (RSDO) Study Request for Offer (RFO) has been awarded.

In response to an IRT recommendation, JPSS has made great strides in educating the public and its users of the national importance of its mission. In 2013, JPSS launched a new website, and released the Green: Vegetation on Our Planet project in partnership with NOAA Visualization Laboratory, resulting in the most successful social media campaign in the history of NESDIS. JPSS successfully presented at multiple conferences, including the American Meteorological Society, quarterly customer forums, the virtual satellite science week, the National Space Symposium, the NOAA Satellite Conference, and the International Geoscience and Remote Sensing Symposium. Because of JPSS' efforts to inform its users and the public, polar-orbiting satellites are being increasingly recognized in the media for their value to the nation.

JPSS is poised to successfully complete our next milestone, the JPSS-1 mission CDR in early 2014, and remains on track to launch JPSS-1 on schedule. Overall, JPSS is two years into its approximately 14-year flight operations, halfway through its flight builds, and halfway through ground redevelopment. JPSS is on track, on budget and on schedule. And the best is yet to come.

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Contents

Updated: November 25, 2013

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Section 1

The JPSS Fire Weather Proving Ground: Improving Decision Support Tools for Detection, Monitoring, Predicting and Mitigating Fire Events

The information in this article is based in part on the JPSS science seminar given by Ivan Csiszar, Environmental Monitoring Branch Chief, Satellite Meteorology & Climatology Division (SMCD), Center for Satellite Applications and Research (STAR), and Active Fires team lead, on ***November 19, 2012****.*

Contributing editors: Ivan Csiszar, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

The JPSS Proving Ground Program is working with the fire user community, particularly the National Weather Service and the United States Forest Service to improve the use of JPSS fire products in decision support tools. Such tools are important for making critical and timely decisions in response to a fire event of any magnitude. To achieve this objective, the JPSS Proving Ground sponsor projects to engage product developers with end-users, so there is an improved understanding from both sides on the satellite product attributes and the tools used by users in providing assessments and warnings. The outcome is improved decision tools by better utilizing satellite data combined with other information acquired by the user.

Why Should We Care About Fire Detection?

Fires – whether natural or anthropogenic – occur across a wide range of ecosystems around the world, including remote and unpopulated areas. Anthropogenic fires are commonly used in a variety of land use, land management and agricultural applications, including deforestation, land clearing, and grassland management.

Incident meteorologist on the front line

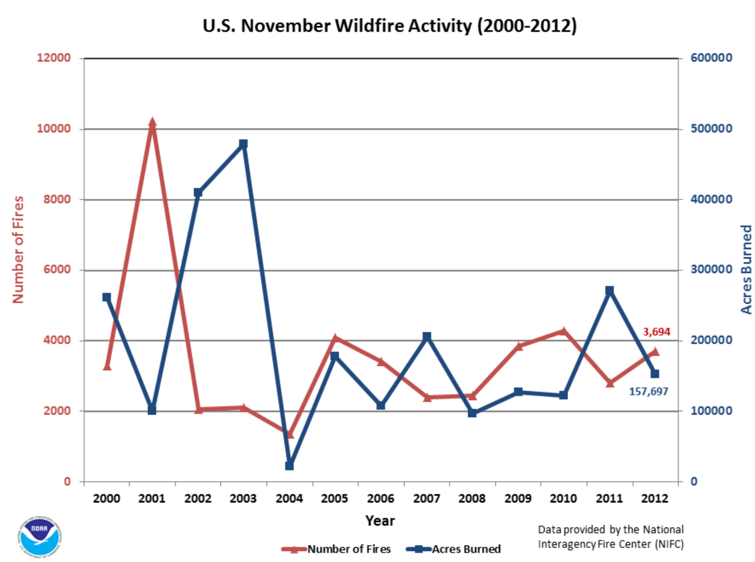
Credit: NOAA

A fire event can have far-reaching impact on the environment, including ecosystem change, and permanently altered landscapes. In addition, fires can have negative effects on weather, climate, and atmospheric composition. Smoke emissions affect air quality and represent a major health hazard. In the human/urban interface in particular, fire events pose the danger of life and property loss. In fact, one cannot overstate the destruction that can be caused by a fire, given the potential adverse impacts to the environment, and severe impacts on human life and property. It is very important to determine the current location of a fire and also to gather as much information as possible on its history. It is also important to map the burned areas after the actual burning to estimate how much vegetation burned and how much of that burning resulted in the emission of gases and particulate matter into the atmosphere. A comparison of burned areas with pre-burn conditions provides an indication of ecosystem change and the severity of the fire.

According to the National Climatic Data Center, for the period ending November 2012, the year-to-date average fire size was the most since 2000 for any January through November period, with the year-to-date total acreage burned being the 2nd highest since 2000. However, the year-to-date total of 55,505 fires was the least since records began in 2000 for any January through November period[1].

Year-to-Date Wildfire Statistics*					
	January–November	Rank (out of 13 years)	Record		10-Year Average (2001-2010)
			Value	Year	
Acres Burned	9,156,278	2nd Most / 12th Least	9,508,251	2006	6,346,769.6
Number of Fires	55,505	13th Most / Least on Record	91,094	2000	73,841
Acres Burned per Fire	165.0	Most on Record / 13th Least	165	2012	88.5

Data Source: The National Interagency Fire Center (NIFC)



Number of fires & acres burned in November 2000-2012

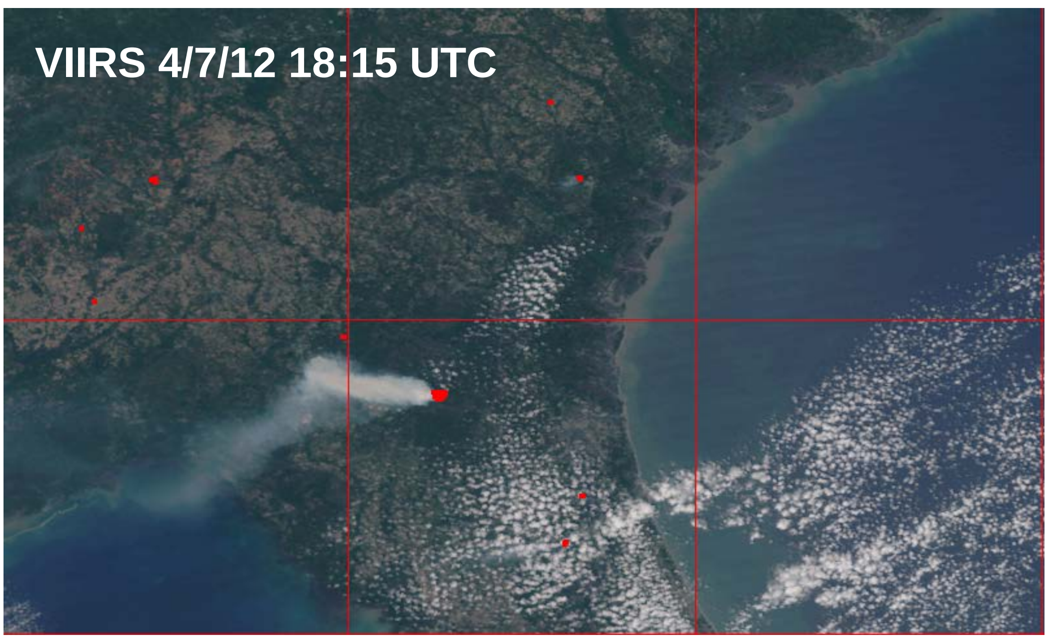
Timely detection of active fires and accurate assessment of fire danger can be quite challenging, but to be effective, these necessary tasks require continuous, early and quick responses. To accomplish such a demanding task, satellite-based systems are the most practical and feasible means for accurate and consistent large-scale fire monitoring. More importantly, in many parts of the world, polar orbiting satellites are the only observing system that provides this vital capability.

[1] NOAA National Climatic Data Center, State of the Climate: Wildfires for November 2012, published online December 2012, retrieved on November 12, 2013 from http://www.ncdc.noaa.gov/sotc/fire/2012/11.

Active Fire Detection Using Satellites

Satellites are able to detect fires from the radiation emitted by fires also known as "hot targets." Satellites carry sensors that are extremely sensitive to the radiative signal. These sensors help scientists to spot the areas where a fire is occurring and differentiate them from the non-burning background. The sensors are capable of detecting relatively small fires often before detecting a signature from the associated smoke.

Around the world, long-term and large-scale detection and monitoring of fire activity has been achieved using a variety of space-borne systems and sensors. In the United States, the first sensor used for fire detection was the Advanced Very High Resolution Radiometer (AVHRR) aboard the National Oceanic and Atmospheric Administration's (NOAA) polar orbiting satellites. The Moderate Resolution Imaging Spectroradiometer (MODIS) on the National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) Terra and Aqua satellites was the first sensor with dedicated bands for fire detection. The newest sensor on US polar orbiting satellites, the Visible Infrared Imager Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite provides continuing capabilities for fire detection.



Suomi NPP VIIRS observation of the County Line, FL fire on April 7, 2012. The data are from the official Interface Data Processing Segment (IDPS) product.

Satellite data, however, cannot be relied upon exclusively in every single fire event. For example, in densely populated areas with proper coverage using ground based observation, satellites can be used in complement to provide a synoptic view.

VIIRS Active Fires Team

The Suomi NPP VIIRS Active Fires product development and evaluation work is a collaborative effort between team lead Ivan Csiszar, NOAA/NESIDS/STAR employee, and scientists of the University of Maryland, College Park (UMCP). Wilfrid Schroeder is with the UMCP Earth System Science Interdisciplinary Center (ESSIC), focusing on product monitoring, validation and the development of alternative data products. The rest of the team is with UMCP Department of Geographical Sciences. Louis Giglio is the author of the heritage MODIS algorithm and is working on VIIRS-specific algorithm updates. Evan Ellicott is leading the user readiness and proving ground effort. Brad Wind provides programming and data analysis support, while Krishna Vadrevu leads to coordination with international data users. Christopher O. Justice works on coordination between the NOAA and NASA Suomi NPP product development efforts, user readiness and MODIS continuity.

The product team works closely with representatives of the end user community. Peter Roohr (National Weather Service, Office of Science and Technology) is the liaison with the NWS Incident Meteorologist (IMET) community. Brad Quayle (USDA Forest Service Remote Sensing Applications Center) is a key user of the VIIRS Active Fires product derived from Direct Readout data in daily operations to serve a number of end users.

VIIRS Active Fires Product

The VIIRS Active Fires (AF) Product is built on the heritage MODIS algorithm. However, the differences between the two sensors result in differences in the fires detected. For example, as VIIRS spatial resolution is higher than that of MODIS, it is expected to detect smaller fires. This effect is particularly present for areas viewed farther from the sub-satellite point, where the increase of VIIRS pixel sizes is far less significant than that of MODIS.

Front page of the Suomi NPP VIIRS Active Fire product website. (http://viirsfire.geog.umd.edu)

Active Fires is one of the operational environmental data products generated from the VIIRS sensor on the Suomi NPP satellite. The AF Product generated by the Suomi NPP Interface Data Processing Segment (IDPS) processes radiometric measurements from the VIIRS 750m moderate resolution bands. It achieved Beta maturity in October 2012, thereby making it available to the public through the NOAA CLASS (Comprehensive Large-array Data Stewardship System) data portal

(www.nsof.class.noaa.gov/saa/products/welcome).

During the 2012 active fire season, the VIIRS AF Team and selected NWS IMETs worked in coordination to implement product improvements and to prepare for retrospective analyses of select fires. IMETs are specially trained meteorologists that are sent to provide on-site weather support for incidents such as wildfires, oil spills, and HAZMAT (hazardous materials). They also provide warning and consultation services to firefighters, incident responders, etc.

Challenges: Some of the immediate challenges the AF team faced included:

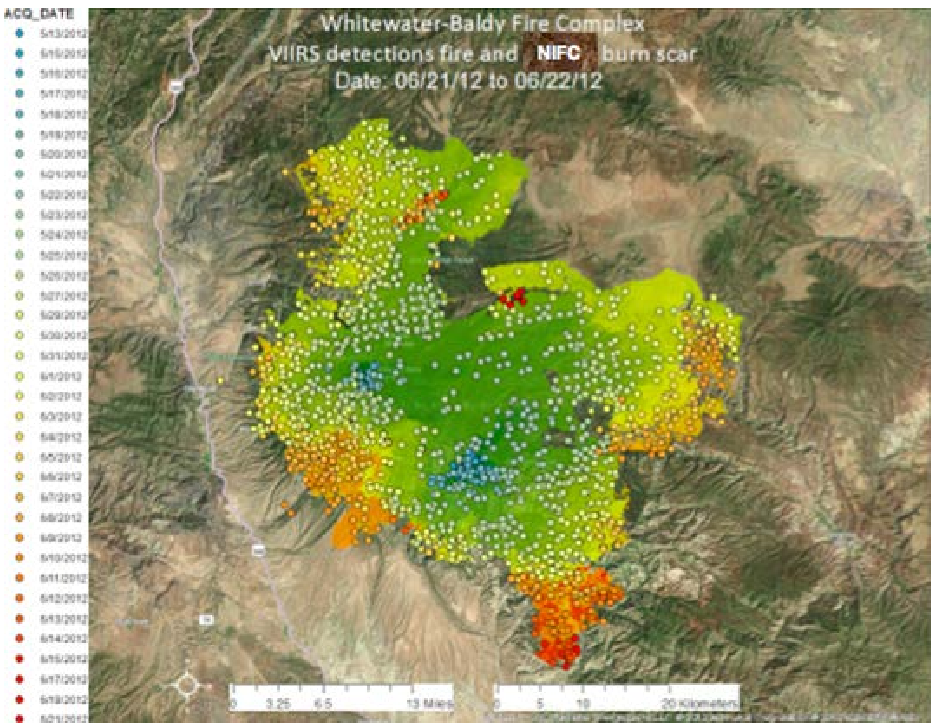
1. Product Calibration and Validation: Getting the product ready for use, getting a user friendly interface where people could access the data.
2. Communications: Some of the people that really need the data don't have the communications to be able to obtain it, thus getting the data as close to the fire line as possible is a challenge.
3. Operational Use: Blending the VIIRS data with other sources of data i.e., other satellite and airborne data, ground based observations etc.
4. Latency: Early fire detection is critical, but current CLASS latency is insufficient for Near Real Time (NRT) applications. Direct Broadcast is key to solving some of the latency issues. There is also a need for quick direct access to IDPS output to serve end users outside of the DB network and for development / demonstration purposes.

To meet the challenges above Dr. Csiszar and his team:

1. Built a web-based data visualization, analysis, and distribution system which would be used to provide near-real-time data and an archive of all VIIRS fire observations over North America. The VIIRS AF team also uses this interface as an evaluation and education platform, particularly with the IMETs as they get educated on how to use the capability. The system includes background information and VIIRS-MODIS comparisons, which are helpful in product evaluation. To reciprocate, the IMETS provide feedback on how the interface works and also offer possible improvements to the VIIRS active fire algorithm. The system is also a testbed for evaluating enhanced and experimental algorithms.
2. Worked closely with NWS iMETS and other users to ensure that the interface works for them, i.e., getting it into their system in a way that they can use it.
3. Established partnerships with end users for enhanced data services and user outreach, such as the ones with the USDA Forest Service, and NWS IMETS.
4. Participated in international outreach through GOFC-GOLD Regional Networks. GOFC-GOLD (Global Observation of Forest and Landcover Dynamics), is a panel of the Global Terrestrial Observing System.
5. Provided science support and coordination to the domestic and international direct readout user community, which is incorporating VIIRS fire data into near-real-time applications.
6. Built a strong partnership with the GOES-R Program to be on the forefront in the fusion between GOES-R and JPSS fire products.

The AF team uses various mechanisms to measure the effectiveness of their work. These include: customer / end-user feedback, the partnerships they have developed, such as the one with the Forest Service, and by conducting retrospective case studies, where they go back and assess previous fires based on incident reports and the satellite data that is available.

In addition, the VIIRS sensor is capable of doing more than detecting and mapping the location of a fire as it is capable of measuring Fire Radiative Power (FRP) - an indicator or fire intensity - which helps the people on the ground determine which fires require priority. FRP is planned to be included in future versions of the operational JPSS product.



Comparison of VIIRS detected fires and the extent of the burn scar for the Whitewater-Baldy Fire Complex. The different colors correspond to time. The blue circles are VIIRS fires detected in early May and the red circles are those detect at the maximum extent of the burn scar which occurred during the third week of June 2012. Clearly VIIRS detected fires and FRP will support efforts for early detection, monitoring, and mitigation of forest fires of different magnitudes.

Summary

Fire is a natural and vital process that affects ecological systems across the globe. Positive impacts from a fire event, such as forest regeneration, insect and disease control, habitat creation, and plant germination are very much part of the ecological cycle. On the adverse, a fire event can be hazardous to human and animal life. It can lead to the increased release of carbon dioxide into the air, decreased air quality from smoke emissions, water contamination, and soil erosion. Consequently the VIIRS Active Fires product, which is expected to be used by real-time resource and disaster management; air quality monitoring; ecosystem monitoring; climate studies, and so forth, will potentially be a valuable tool in disaster and resource management.

Section 2

Using the Community Satellite Processing Package to Transform Raw Satellite Observations into Data Products and Images within Minutes

The information in this article is based in part on the JPSS science seminar given by Kathy Strabala and Liam Gumley, Space Science & Engineering Center at the University of Wisconsin-Madison, on ***December 17, 2012***.

Contributing editors: Kathy Strabala, Liam Gumley, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

Severe weather events such as heavy rain, blizzards, hurricanes, tornadoes, and flash floods impact communities across the globe. These and other severe weather events can create life-threatening conditions that may result in injury and loss of life, and also cause damage to infrastructure and property. In the US, severe tropical cyclones which are often characterized by their strong winds and heavy rain, batter and flood coastlines as well as low lying inland areas. Winter storms such as blizzards, heavy snowfalls and freezing rain cause major disruptions as they wreak havoc across the nation. In the summer, heat waves, often accompanied by poor air quality in major cities, raise the potential for increased mortality and morbidity among the frail and the elderly. Providing an accurate forecast in advance of a severe weather event is therefore essential for effective disaster planning, mitigation, and response. Furthermore, it is crucial that there are tools in place to provide the data needed to make these weather predictions in a timely manner. Satellite data is one of these vital tools.

People shovel snow as flood waters go down Coral Street February 9, 2013 in Winthrop, Mass. The powerful storm knocked out power to 650,000 homes and businesses and dumped more than two feet of snow in parts of New England. (Darren McCollester/Getty Images)

NOAA weather forecasters utilize satellite data observations to monitor the environment and any potential hazards, citing weather warnings, watches, and advisories. Specifically, observations from polar satellites helped NOAA forecasters predict the blizzard that crippled the Atlantic Coast in February 2010, a striking 5 days ahead of time. Another prominent example would be that of Super storm Sandy in October 2012. During the early stages of Sandy, polar-orbiting satellite data helped NOAA's National Weather Service (NWS) accurately predict the hurricane's track and resultant 'left hook' landfall into New York and New Jersey—more than 5 days in advance. Finally, a study of super storm Sandy done by the European Centre for Medium-Range Forecasting (ECMWF) showed that without polar satellite data, forecast models would have shown Sandy headed out to sea.

Aerial shot shows the burned remains of homes at a beachfront neighborhood in Queens. More than 100 homes in the community were completely destroyed by fires during super storm Sandy.

The premier American satellite in the polar orbit is the Suomi-National Polar-orbiting Partnership (SNPP), the bridge between NOAA Polar-orbiting Operational Environmental Satellites (POES) and the next generation Joint Polar Satellite System (JPSS). The SNPP satellite is commanded from the NOAA Satellite Operations Facility (NSOF) in Suitland, Maryland, through a ground station in Svalbard, Norway. It sends data once per orbit to the ground station in Svalbard, and continuously to local direct broadcast users. SNPP has the unique capability to instantaneously transmit its observations to ground stations on Earth, provided there is an antenna to receive the data. Anyone with compatible ground receiving equipment can receive these data through its Direct Broadcast (DB) capabilities in real time. Users can process SNPP data and generate their own local products, allowing SNPP to provide high-quality data to the user community in near-real time.

What makes Direct Broadcast data useful to forecasters?

One of the key features of Direct Broadcast is that products are delivered much faster to forecasters. The direct downlink enables forecasters and other users to receive data in 30 minutes instead of more than two hours from centralized processing using the link between Svalbard, Norway, where SNPP sends its data, and the NSOF where the data is processed and distributed.

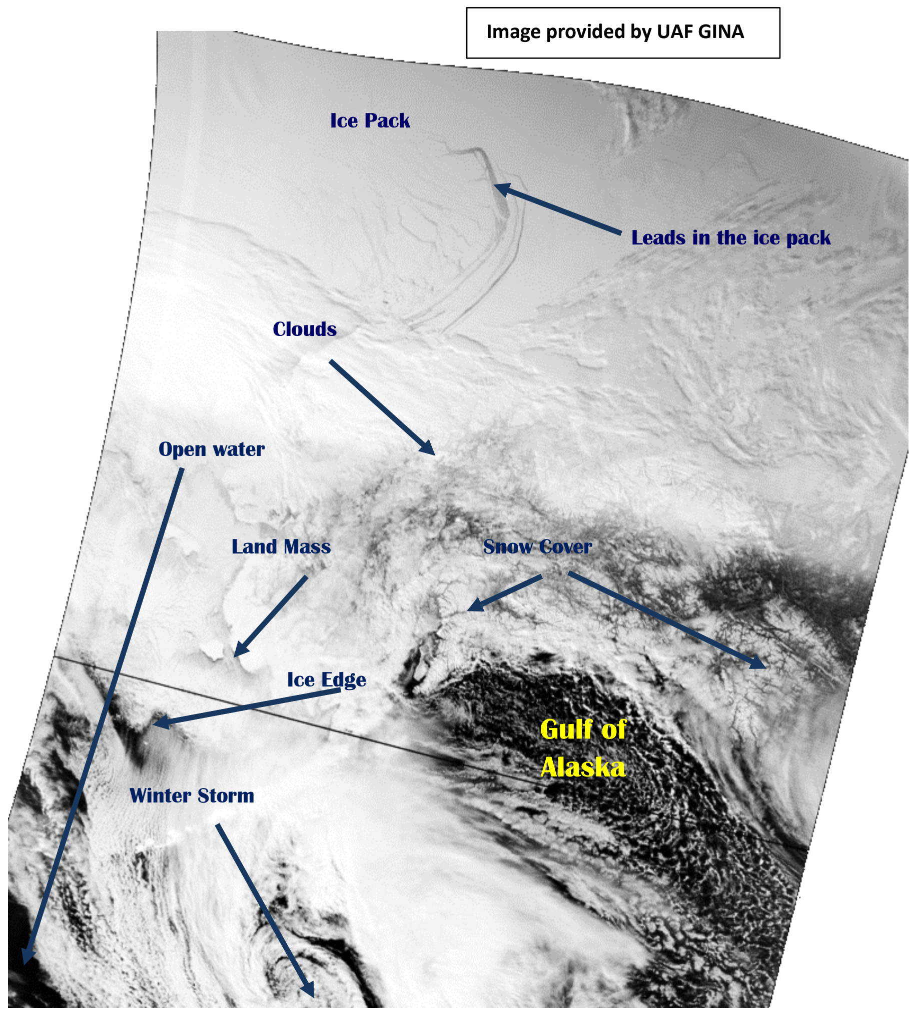
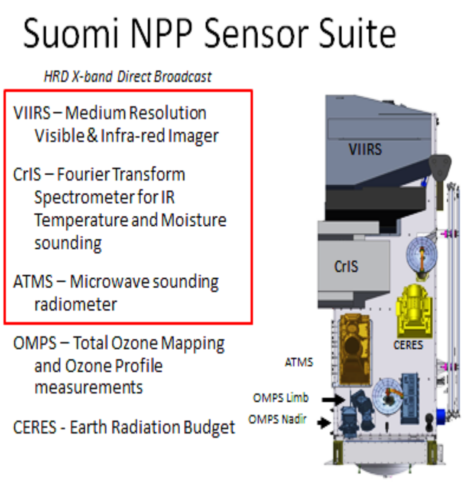


Image taken 25 February, 2013 at 3:13 AM local Alaskan time (12:13 UTC). Data captured and processed at the University of Alaska, Fairbanks. Visible imagery made possible by the Day-Night Band on VIIRS shows some features of interest such as a winter storm churning in the open waters of Alaska, snow cover, clouds and ice packs.

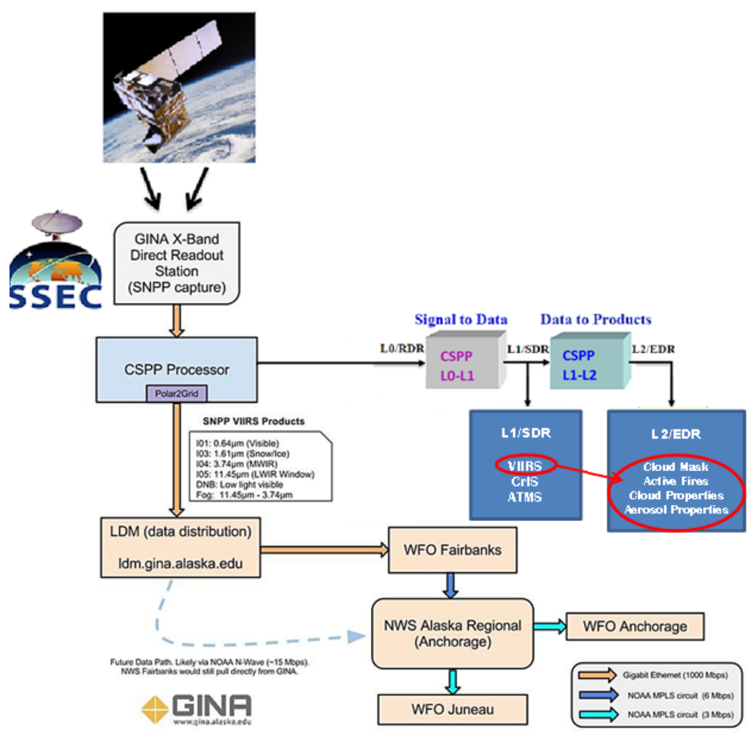
One of the instruments aboard the SNPP spacecraft is the Visible Infrared Imager Radiometer Suite (VIIRS), which has unique spectral bands such as the Day/Night Band (DNB) that provides observations of visible light at night. It has been particularly important for the Alaska region given the sparsity in conventional surface observations. High latitude regions like Alaska, which get frequent polar overpasses, benefit from VIIRS data as the data from geostationary (GEO) satellites is less effective in monitoring small scale events due to large view angles. In addition, VIIRS has better spatial resolution than GEO imagers. VIIRS complements the 15 minute GEO data and products with high spatial and spectral resolution and prepares forecasters for the spectral bands that will be on GEO in the future. Finally, previous experience with the Terra and Aqua satellite Moderate Resolution Imaging Spectroradiometer (MODIS) instrument proves that polar orbiter data can be used for forecast decision making. Thus, receiving this data in near-real time (< 30 minutes) enables forecasters to quickly evaluate regional weather events and rapidly disseminate information.

The Community Satellite Processing Package (CSPP) for Suomi-NPP



Direct broadcast users are able to receive real-time data from SNPP through an unencrypted direct X-band 15 Mbps High Rate Data direct broadcast of mission data downlink. Users can then process, or convert the data to calibrated and geolocated product files using the Community Satellite Processing Package (CSPP). The CSPP is a JPSS funded processing package that was developed by the Cooperative Institute for Meteorological Satellite Studies/ Space Science and Engineering Center (CIMSS/SSEC) at the University of Wisconsin-Madison. CSPP is based on the JPSS Algorithm Development Library (ADL) that was developed by Raytheon – identical to the software that runs in the Interface Data Processing Segment (IDPS), which is used to create data products for environmental monitoring and research at NSOF. CSPP has the inherent capability to support multiple satellites and will eventually be expanded to include other international polar orbiting meteorological and environmental satellites for the global Real Time Regional (RTR) user community.

CSPP transforms VIIRS, CrIS, and ATMS Raw Data Records (RDRs) (i.e. Level 0) to Sensor Data Records (SDRs) (i.e. Level 1), and SDRs to Environmental Data Records (EDRs) (i.e. Level 2). Real-time processing starts as soon as the server acquires demodulated telemetry, and all passes can be processed and distributed within 30 minutes of the end of the pass.

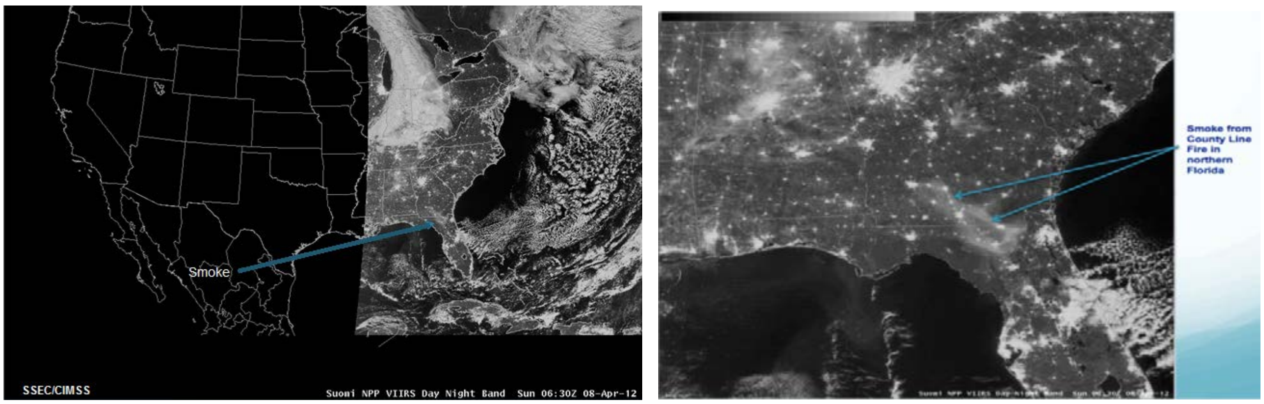


The SNPP real-time processing and data flow chart (modified with additional data flow layers) was taken from the "VIIRS Direct Broadcast Use in Alaska" PowerPoint presentation by Eric Stevens and Dayne Broderson, GINA and James Nelson, NWS Anchorage.

SNPP Real-Time Processing and Data Delivery

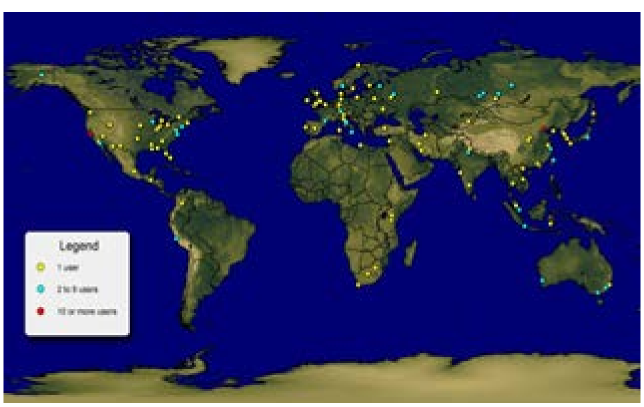
CSPP demonstrates how polar environmental satellites can be useful to operational users such as the US National Weather Service, as well as researchers, other domestic and international environmental agencies, and global direct broadcast users. The CSPP algorithms are often tailored to a user's local unique environments and applications such as air quality monitoring, fire and smoke detection (see image below), and sea surface temperatures.

Fire/Smoke Detection 8 April 2012



The VIIRS Day/Night Band measures emitted and reflected visible data at night. The example above shows how much can be observed when the moon is full, making it easy to identify clouds and even smoke.

An example of an international CSPP user is the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) whose Advanced Retransmission Service (EARS) uses existing DB sites to improve data transmission latency while increasing the number of people who have access to the data. EARS collects data from a selected set of Direct Readout stations and retransmits the data to end users via the EUMETCast satellite broadcast mechanism.

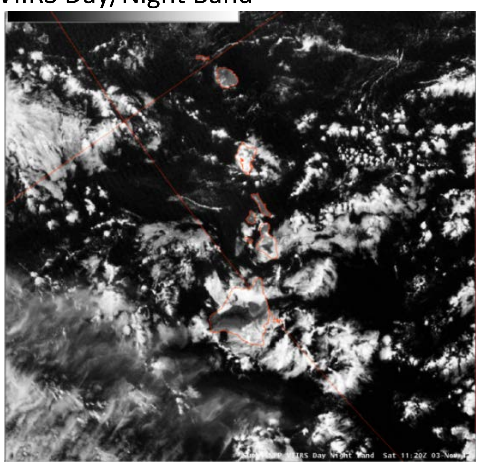


- EUMETSAT for EARS-NPP EUMETCast distribution
- UK Met Office
- Météo-France
- CSIR South Africa
- Swedish Met Service
- DWD – German Met Service
- Australia Bureau of Meteorology
- Taiwan Central Weather Bureau
- Belarus National Academy of Science
- Indonesia Government Space Agency (LAPAN)
- German Aerospace Center
- CONABIO Mexico
- EURAC Remote Sensing Institute Italy
- China National Satellite Meteorological Center
- Brazil INPE
- Danish Meteorological Institute
- Japanese Meteorological Agency
- Norwegian Meteorological Institute
- Swedish Met Institute
- Kazakhstan Space Investigation Institute
- UK Plymouth Marine Lab
- Naval Research Lab
- Vendors SeaSpace, ScanEx, Spacetec and others.
- In addition, CSPP DB products are being used in the US NWS in HI, Alaska and CONUS

Thus far, More than 250 people have registered or downloaded some part of the CSPP suite of products representing 33 different countries on 7 continents.

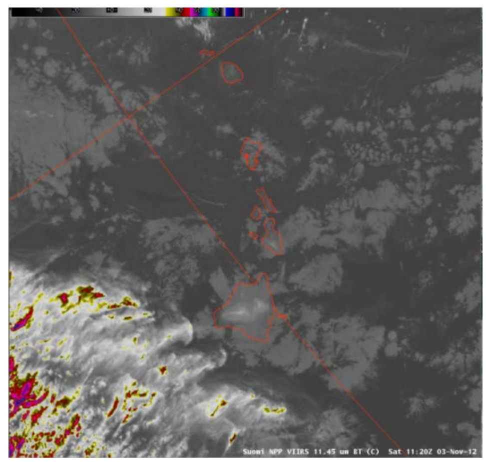
CSPP software also includes a package that will remap and reproject the native SNPP VIIRS SDR files into a format that can be displayed in the NWS visualization and analysis tool called the Advanced Weather Interactive Processing System (AWIPS). This software is currently being run at direct broadcast antenna stations in Alaska, Hawaii and Wisconsin (Contiguous United States), in support of operational NWS forecasters in all of those regions. In addition to installing CSPP at those locations, CIMSS researchers provide forecaster training which includes personal WFO visits, a VISITview training module and direct broadcast workshops. This training introduces new users to SNPP VIIRS direct broadcast data and also helps operations personnel understand the kind of situations where the high resolution data will be most useful. The use of specific satellite images from SNPP is invaluable in describing the capabilities of each sensor. For example, in the images below, the image on the right is a display of the VIIRS high spatial resolution Infrared Window band. The image on the left is a display of the VIIRS Day/Night band from the same time, supplying forecasters with visible data at night. Note how the Day/Night band provides much more detail in the clouds, including cloud type (thin cirrus versus cumulus) and relative cloud height.

VIIRS Day/Night Band



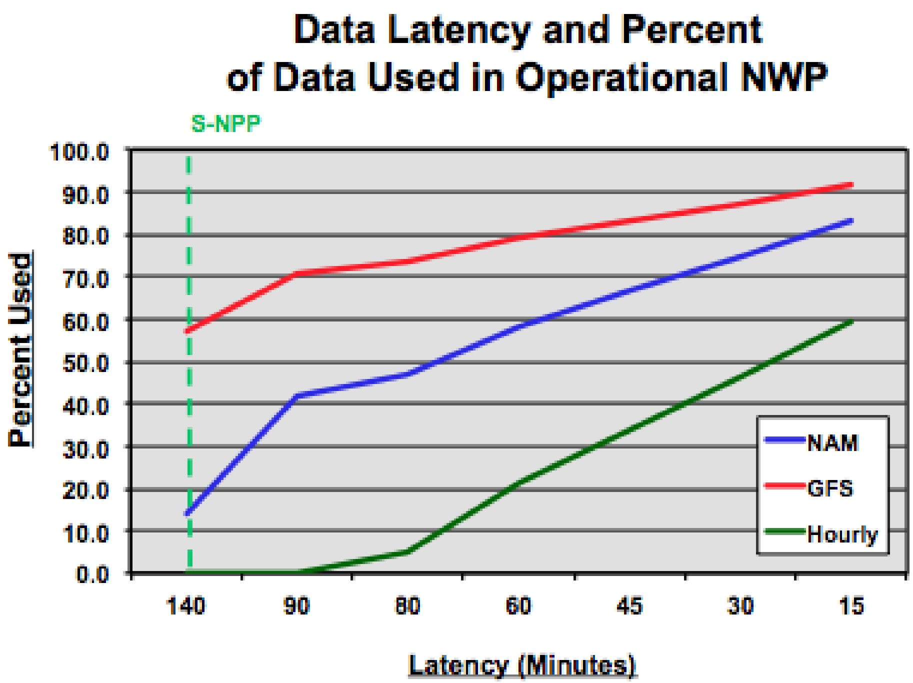
VIIRS Day/Night Band 3 Nov 2012 11:20 UTC

VIIRS 11 micron IR window data



VIIRS IR Window 3 Nov 2012 11:20 UTC

Improving the latency of CrIS and ATMS sounder data through CSPP is expected to benefit regional forecast models. These models run more frequently than the global model and as a result the cutoff times for data going into its data assimilation system is much shorter. Using just one ground station at Svalbard for SNPP stored mission data results in an over two hour data latency, which does not provide data soon enough to be used by regional models. The use of direct broadcast will allow the assimilation of significantly more data in both global and regional models.



The figure above shows the amount of data used by the Global Forecast System (GFS), which runs every 6 hours, the North American Mesoscale (NAM) model (every three hours), and the hourly model. Note the significant increase of data being used by each model as latency improves.

The Community Satellite Processing Package (CSPP) provides a robust, and an easy to install and use, software package for converting direct broadcast SNPP data into valuable science products in real time. This enables the customization of algorithms to suit the needs of local users for regional applications. These applications include facilitating the management of quickly changing regional events such as rapidly spreading wildfires, heat waves, snow pack melts, and erupting volcanoes that could severely impact the communities that live in these areas. CSPP has established a framework towards building a sustained global user base supporting NPP/JPSS real time regional applications. This diverse global user community that uses the CSPP to create products tailored towards their local environments (in the US and around the world) shows its accessibility, versatility and most importantly, its value to weather forecasting.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Section 3

Using SNPP Data to Support Alaska Missions

The information in this article is based in part on the JPSS science seminar given by Eric Stevens and Dayne Broderson (GINA), and Jim Nelson (NOAA/NWS Anchorage), on ***January 29, 2013.***

Contributing editors: Eric Stevens, Dayne Broderson, Jim Nelson, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

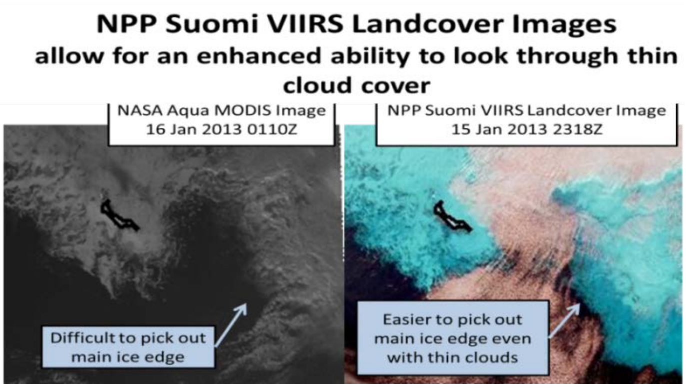
Alaska is a vast state covering 571,949[2] square miles. It contains 54% of the United States (US) Coastline and 66% of the US Continental Shelf. The National Weather Service (NWS) covers this great state with only three Weather Forecast Offices (WFOs), namely in Fairbanks, Juneau and Anchorage, each of which provide warning and forecast services for huge geographic areas. For example, the Fairbanks WFO forecasts for over 300,000 square miles of land and marine zones, much of which is considered remote wilderness. Furthermore, the NWS meteorologists across Alaska have to address diverse forecast areas where multiple weather patterns and events occur simultaneously. A short drive across the state can result in a 30-degree temperature change as the landscape quickly changes from coastal fjords to interior mountainous terrain, highlighting the prevalence of microclimates throughout the state. In essence, Alaska's size, geography, weather patterns, remoteness, and regional infrastructure present many unique challenges for weather forecasting and warning services.

The importance of satellite imagery in Alaska

With Alaska's complex topography and prominence of microclimates, surface observations can be of limited representativeness. For the Alaskan region, polar-orbiting satellites provide the data needed to fill-in the gaps of surface and atmospheric temperature profiles over the areas that are not adequately covered by conventional observing systems. Additionally, polar orbiting satellites provide more passes per day over Alaska than over the Lower 48. The effective use of satellite observations over polar regions is necessary for accurate forecasting and warning of events such as rapid sea ice formation, extra-tropical storms and polar lows, storm surge, volcanic ash, hurricane force winds, and other coastal hazards such as floods. Therefore, polar satellite imagery is spatially comprehensive in Alaska, which allows NWS forecasters to observe features and weather patterns that otherwise may have been missed by conventional observations.

JPSS data is key to NWS operational and research products and services as it provides valuable polar imagery and products in areas not well covered by NOAA geostationary satellites. Forecasts and warnings for public, aviation, and marine interests on severe weather events such as blizzards, coastal flooding, volcanic ash, and icing are fundamental for the Alaska WFOs, all of which rely on up-to-date satellite imagery of these events. The JPSS proving ground in Alaska is currently poised to provide Suomi National Polar-orbiting Partnership (SNPP) data products, including Visible Infrared Imager Radiometer

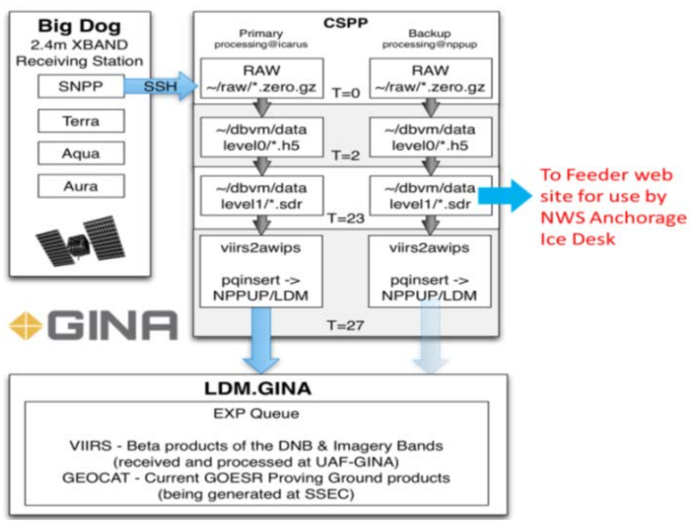
[2] Source: National Atlas of the United States at http://nationalatlas.gov/articles/mapping/a_general.html#one



Suite (VIIRS) imagery, via the direct satellite data broadcast over the Geographic Information Network of Alaska[3] (GINA).

VIIRS, the imager instrument aboard the SNPP has spectral bands such as the Day/Night Band (DNB) which provides observations of visible features at night. By using dim light sources such as city lights and reflected moonlight, the DNB can detect changes in clouds, snow cover, and sea ice over night, monitoring which is particularly important for Alaska given the region's relatively sparse conventional surface observations due to its complex terrain.

The flow of direct broadcast imagery to the NWS in Alaska



It takes a pass about 15 minutes to be completely received via Direct Broadcast at GINA, and then data processing begins.

The T=0 represents the number of minutes accumulated in processing the data since the reception of the complete pass.

Upshot is that it takes GINA at most 27 minutes to turn the DB data into imagery ready for delivery to the NWS.

For passes that don't fly straight overhead, the resulting image is smaller, and processing time is proportionally faster.

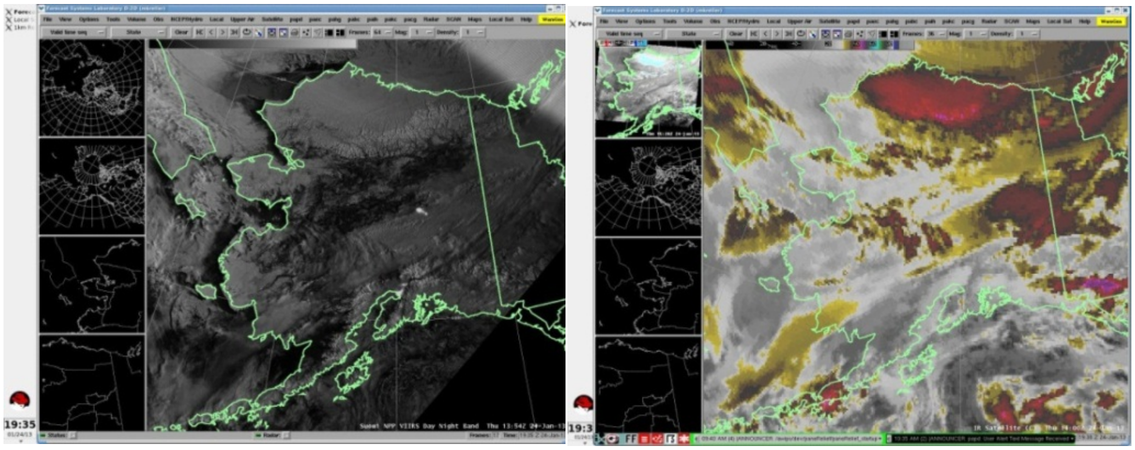
Direct Broadcast (DB) of the data from the satellite to the user community allows the Alaska operational users to obtain this crucial data at a low latency. NOAA's NWS considers this service very valuable as forecasters need access to the latest satellite imagery as quickly as possible. Direct Broadcast of SNPP imagery is obtained and disseminated through GINA, which offers more than an hour reduction in data latency when compared to standard internet delivery options.

With SNPP data available so rapidly, NOAA/NWS forecasters are better equipped to make accurate determinations on the severity of a weather-related threat and issue the coordinating warning. Continued support of the Direct Broadcast effort is then critical to forecasting operations in Alaska, support which will be given jointly by the Joint Polar Satellite System (JPSS) Proving Ground and the NWS.

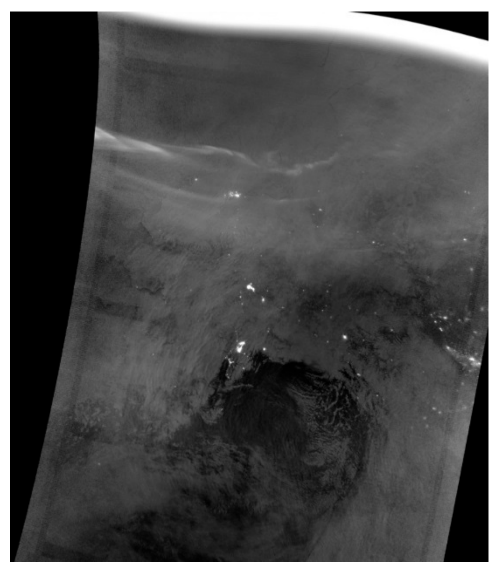
[3] http://www.gina.alaska.edu/

Alaska's Unique Challenges

VIIRS Day Night Band (left) and GOES Infrared (IR)



During the typical Alaskan winter, the months of November to January have little daylight, and a region like Fairbanks can see an average of less than four hours of daylight. For example, on December 26, 2012, Fairbanks experienced 3 hours, 46 minutes of sunshine and 19 hours 45 minutes of moonshine. Washington, DC in comparison experienced 9 hours, 27 minutes of sunshine and 14 hours, 51 minutes of moonshine. For Barrow - the northernmost town in the United States – the Sun remains below the horizon from about November 20-January 24.The DNB becomes particularly important as visible channels are rendered unusable during these long Alaskan winters. And even though passive microwave sensors can monitor sea ice through the winter, it's at a much lower resolution. Now, imagine if during these "polar nights", there were no polar orbiters at all! Satellite imagery would be restricted to geostationary satellite data where there is no low-light imagery. Then only the infrared data, like the GOES IR channel (top right), would be available for all terrestrial locations including the poles. GOES imagery, moreover, is centered on the equator, creating large viewing angle at high latitudes due to the curvature of the Earth. This results in degraded imagery for polar regions. Polar-orbiting satellites provide the needed imagery around the poles. The sharp details provided by the NOAA polar-orbiting suite, which includes SNPP VIIRS DNB and infrared imagery, allow forecasters to issue warnings throughout the year with higher confidence than if they only had geostationary satellite data.



VIIRS Day Night Band during new moon in December 2012: Even with no moonlight, meteorologically relevant signals are still discernible, such as cloud bands over the Gulf of Alaska.

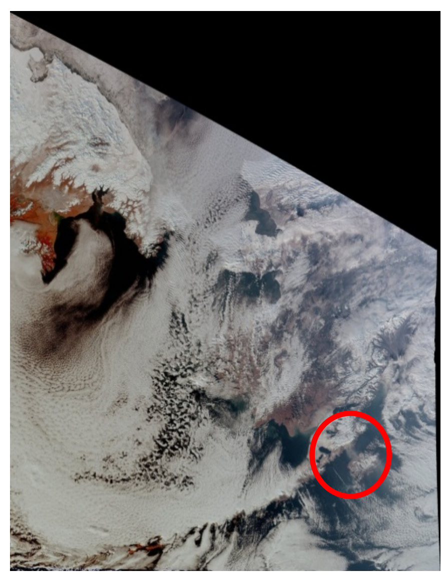
SNPP data has already proved a valuable tool in forecasting throughout Alaska. Unlike those in the lower 48 states, many Alaskan communities are not accessible by road, and therefore depend on aviation and marine systems for transportation and access to goods and services, presenting unique forecasting challenges outside of simply interior road conditions.

Icing buildup on the wing of a small aircraft
Image credit UCAR.

Alaska is more dependent on general aviation and small aircraft commercial aviation than any other state in the nation. The region's harsh and challenging weather and varied topographic conditions denote a complex environment with many hazards present in every season. Ice accumulation on airplanes, low-visibility conditions and volcanic events all constitute major risks to the Alaskan aviation industry.

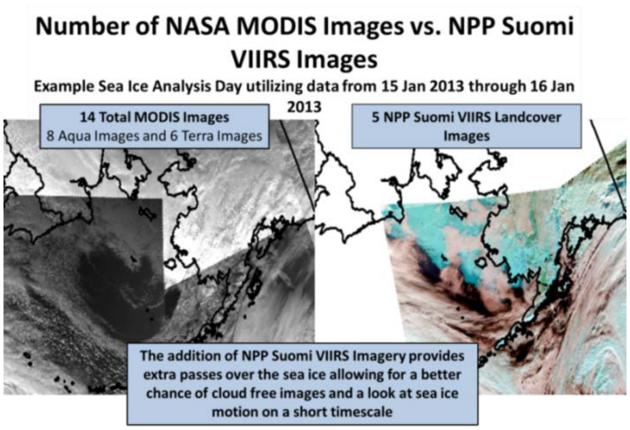
During colder months, Alaskan aviation, especially the small airplanes which fly lower in the atmosphere, are prone to ice buildup on aircraft surfaces, known as "icing." Structural icing on wings and control surfaces increases aircraft weight, generates false instrument readings, and compromises control of the aircraft. To aid in predicting these hazardous events, NOAA/NWS forecasters utilize imagery from satellites and data from other localized platforms to identify potential icing conditions and the coordinating degree of severity.

In addition, the influence of low-level clouds and fog poses a strong threat to aviation throughout Alaska. SNPP VIIRS imagery has already become a key tool for detection of low-visibility conditions throughout data-sparse Alaska. Markedly improving low cloud forecasts over the nighttime hours is the DNB, a powerful imagery tool over the long Alaskan winter nights. Forecasters employ and have begun to rely on SNPP data to issue digital and graphical weather statements and warnings on low-visibility conditions, helping to save lives and property in the key Alaskan aviation industry.

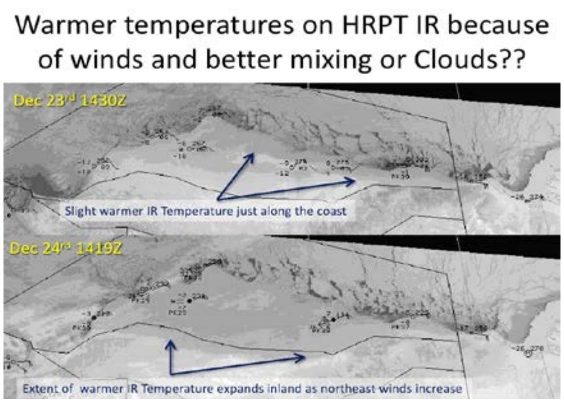


VIIRS True Color image, October 30, 2012
Area within red circle shows "re-suspension" of volcanic ash from Katmai being blown to Kodiak Island.

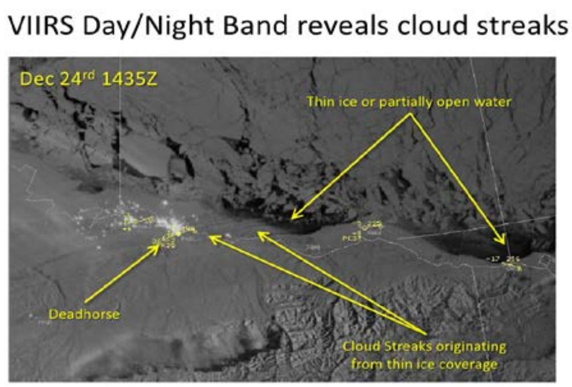
Flight routes over Alaska face the potential risk of encountering volcanic ash from any of the state's major active volcanoes, creating another hazard for the aviation community. Even volcanoes upstream in eastern Russia can produce major ash clouds which are able to drift great distances from their source, creating a serious hazard thousands of miles from an eruption. Volcanic ash clouds can damage critical aircraft systems when ingested, even causing engine failure, and present the hazard of diminished visibility. More than simply dangerous to aviation, airborne volcanic ash is a threat to local communities as it can significantly affect respiratory health and can damage infrastructure and property. Satellite imagery is the main data source for observing volcanic activity. Its use is vital to tracking volcanic ash and monitoring volcanoes for thermal hotspots, and its analysis involves real-time monitoring and data warnings. GINA captures real-time satellite imagery and data from NOAA's SNPP and provides it to the Alaska Volcano Observatory (AVO) to identify, track and assess volcanic eruptions and ash clouds. The GINA-provided satellite data are also key inputs in ash transport forecast models such as PUFF. The model was developed to simulate the movement of airborne ash in near real-time following an eruption for the purposes of hazard warning. The AVO provides key services in support of the NWS Alaska Aviation Weather Unit (AAWU), which issues warnings and advisories for air traffic over the US Arctic region which covers the Arctic Ocean, the Alaskan landmass, the Aleutian chain, the Bering Sea, and the North Pacific.



Over and above the aviation applications, VIIRS imagery in Alaska has demonstrated its capability to trace ice movement, growth and decay. Ice pack changes are particularly important to Alaska's marine industries of fishing, tourism, and passenger transportation and recreational boating. For ships, the ice imagery enables navigation decision makers to differentiate between the areas where there is ice melt and reformation, and clear water passages. The VIIRS DNB adds additional aid to tracking ice flow and changes, allowing for nighttime observations in low-light conditions. Since SNPP passes frequently over Alaska in its polar orbit, it augments and improves the sea ice observations currently done in Alaska by other NOAA polar-orbiting satellites. However, with the DNB and the near-real time delivery of data, SNPP VIIRS imagery has quickly become key to ensuring safe marine vessel.



Comparison of day-night band with IR from the previous generation of polar orbiter. Passes are about 90 minutes apart in time



The resolution of the DNB helps show that the cloud streaks are wind parallel bands that are being fed by bands of moisture. It also shows a thin layer of marine fog forming.

Another way VIIRS sea ice capabilities are of value is determining the extent of sea ice along the arctic coastline. In coastal regions sea ice acts as a protective barrier against the impact of waves. Diminishing sea ice has left Alaskan coastlines, many of which are low in elevation, more susceptible to battering waves, and intense storm surges. These storms can result in a sea level rise of 10 feet or more, and when combined with high tide, the storm surge becomes even greater and can be accompanied by waves that contain ice. For example, Kivalina, a coastal community that has lost much of its sea ice buffer, has experienced higher surges from ocean storms and severe erosion caused by waves. Without adequate real-time meteorological observations in the U.S. Arctic waters, it is difficult to provide accurate forecasts of ocean storms, which have the potential to threaten Alaska's coastal communities with storm surges and other inundation hazards. NOAA researchers learned from hurricane Irene (2011) that it took an average of seven hours to evacuate Connecticut's coastal residents. By contrast, coastal residents along Alaska's west coast – where hurricane-strength storms are becoming more frequent – need almost 24 daylight hours to evacuate, urging the need for more accurate and advanced notice regarding potential hazards.

Storm waves batter Kivalina.
Photo courtesy Alaska Department of Environmental Conservation.

Alaska presents many diverse environmental hazards which continually challenge weather forecasting and warning services. When severe weather events impact lives and cause widespread devastation, emergency response efforts are often hindered by the remote nature of Alaskan communities, the state's harsh climate and its rugged terrain. Therefore, it is essential that decision makers receive timely and accurate environmental data to assist in effective disaster planning, mitigation, and response. The use of polar-orbiting satellite data, specifically SNPP VIIRS imagery via Direct Broadcast by GINA, has proven invaluable to the Alaska Region's ability to make these timely forecasts and decisions.

The JPSS Proving Ground Program has been instrumental in demonstrating the uses of SNPP VIIRS through GINA and will continue to support Alaskan efforts by providing innovative opportunities to test new JPSS capabilities in operational environments. Transitioning JPSS capabilities from research to operations will build on the success of the uses of data from current satellite systems and prepare Alaskan users to better support their most critical NOAA missions.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Section 4

NASA/Short-term Prediction Research and Transition (SPoRT) Activities for the JPSS Proving Ground

The information in this article is based in part on the JPSS science seminar given by Gary Jedlovec (NASA) and Matt Smith (University of Alabama Huntsville), on ***February 19, 2013.***

Contributing editors: Gary Jedlovec, Matt Smith, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

The Short-term Prediction Research and Transition (SPoRT) project was established in 2002 to demonstrate the utility of real-time NASA Earth Observing System (EOS) observations. Since 2009 the NOAA/JPSS have funded SPoRT projects, to build on NASA's EOS data exploitations in preparation for the Suomi-National Polar-orbiting Partnership (SNPP) satellite. With the launch of SNPP the JPSS Proving Ground and Risk Reduction Program has teamed with SPoRT to evaluate and document the benefits of NOAA's SNPP data products to National Weather Service (NWS) operations.

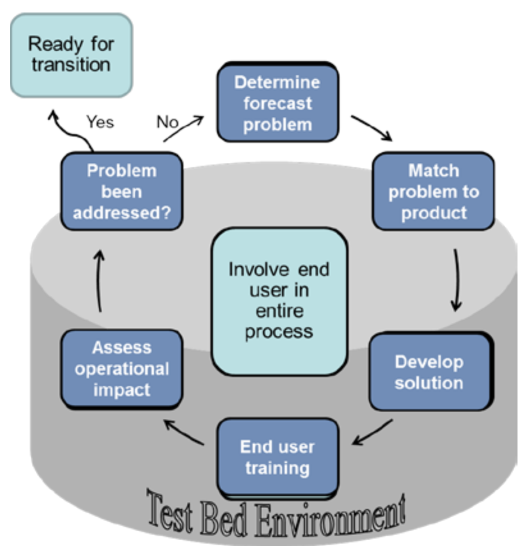
SPoRT has focused on transitioning unique NOAA and NASA observations and research capabilities to the operational weather community. The goal of this activity is to help forecasters better understand the environment, improve short-term weather forecasts, and enhance situational awareness on a regional and local scale. The core mission of SPoRT is well aligned with NOAA's Weather Ready Nation goal to improve the precision of weather forecasts and decision support services by delivering integrated satellite and support solutions to the national and local emergency management communities. By working with numerous NWS Weather Forecast Offices (WFOs) across the country, the SPoRT program has successfully implemented enhanced satellite-derived forecasting products to directly affect public safety and economic output.

Why are SPoRT's efforts to transition satellite capabilities from research to operations so successful?

SPoRT's research to operations cycle is a series of procedures in the transition of research and experimental data to operations (R2O) cycle, as seen schematically.

SPoRT teams work with end users to match forecast problems to observations/capabilities.

The first step in SPoRT's R2O cycle is to establish and maintain collaborative partnerships. Once established these relationships maintained through site visits, coordination phone calls, informative web blogs, and collaborative workshops. Via these interactions, the SPoRT team determines the unique and challenging weather forecast problems in the region for which their collaborators are responsible.



Next, SPoRT works to develop solutions to the forecasting issues by creating and adapting satellite-derived products which provide insight into the forecast problem. SPoRT evaluates these products in a testbed environment, and determines how best to transition them to the collaborator's operational decision support system.

Training is key to the transition of products to operations

The next step in the R2O cycle is to work to familiarize the collaborative community with the product through training. SPoRT utilizes a variety of training modules to accommodate a wide range of forecaster and end-user learning styles. These include "quick guides" for easy forecaster reference, voice-to-voice or face-to-face explanations of some of the products called science sharing sessions, and short (15-20 minute) self-directed training modules. This training draws upon the end-user's experience. The modules also incorporate case studies to demonstrate what the data look like in their decision support system addressing their particular forecast challenge.

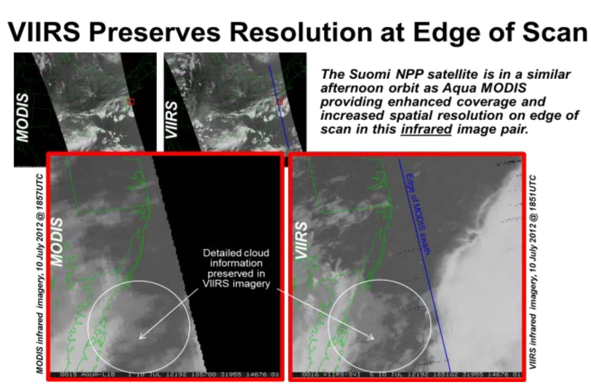
Finally, SPoRT deploys the product, such that it can be validated for its utility in the last phase of R2O. A wide range of assessments are done to determine whether a particular solution or procedure has made an impact on the established forecast challenge by improving either the end user's situational awareness or forecast environment itself. These assessments are captured through forums, direct feedback, blogs, and emails. Additionally, the end users provide feedback on how the new products and capabilities impact their operational forecasting. In some cases, a solution may require a number of iterations of the R2O cycle. For example, a solution may have a positive effect on forecasting, but cannot reach the end user in real-time and therefore has limited impact. If a solution or product has a positive impact on helping to resolve a forecast challenge, the SPoRT development team works to determine how to make it more widely available throughout the operational weather community.

Partnerships and End Users

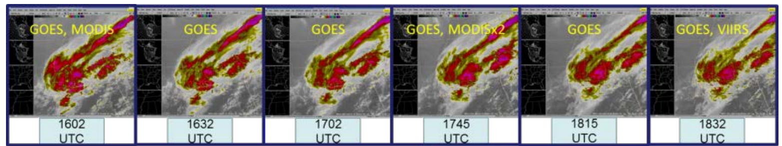
Access to real-time data and products is key to operational usage.

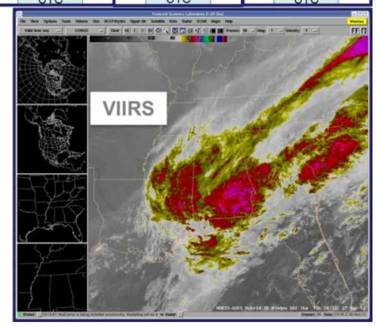
SPoRT's partnerships with NOAA, university partners and the Department of Defense (DoD) allow for access to real-time data from direct broadcast systems to support the operational weather community. The availability of EOS, and now SNPP, data in real-time enables quick use of SPoRT data products for local and regional weather events by the end user.

Operational forecaster feedback to the SPoRT program on the utility of SNPP data products from the VIIRS sensor has shown it is widely used throughout the country, and there is a preference for the broader swath coverage from VIIRS as opposed to NASA's MODIS sensor. The image to the right shows that the VIIRS products have fewer gaps from one swath to the next. Forecasters



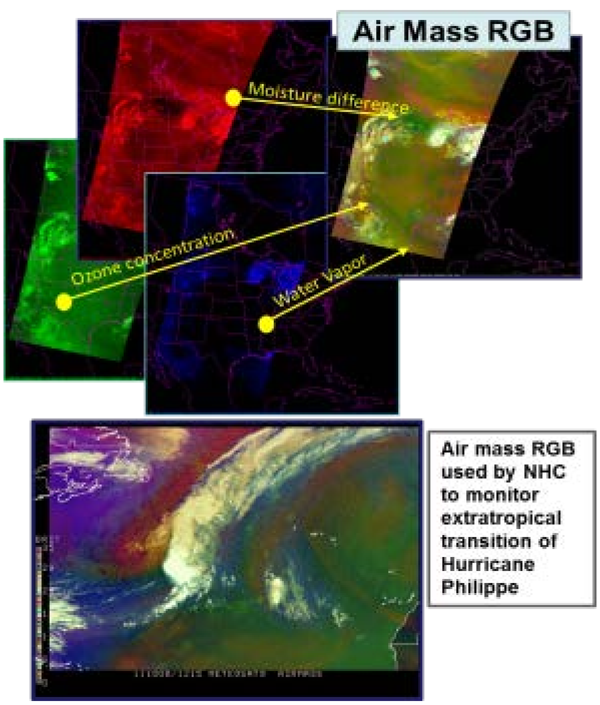
additionally preferred the improved spatial resolution from VIIRS along the edge of the limb as shown in the image to the right.





As a result of the SPoRT R2O feedback loop, forecasters noted that there was limited value in animating polar orbiting data over the United States. Therefore, to make use of the polar imagery in an animation, SPoRT developed a Polar-Geostationary Operational Environmental Satellite (GOES) imagery hybrid product that inserts polar imagery from MODIS and VIIRS into a base GOES image (bottom right). MODIS and VIIRS are supplemented by GOES data when polar data are unavailable, creating an integrated product. Presentation of data in this form allows polar images to be animated within the context of the dependable GOES imagery. SPoRT uses this hybrid concept to increase the utility of VIIRS data and have exploited this concept for visible and infrared channels, as well as for selected Red-Green-Blue (RGB) imagery products.

Red-Green-Blue (RGB) Composite Imagery

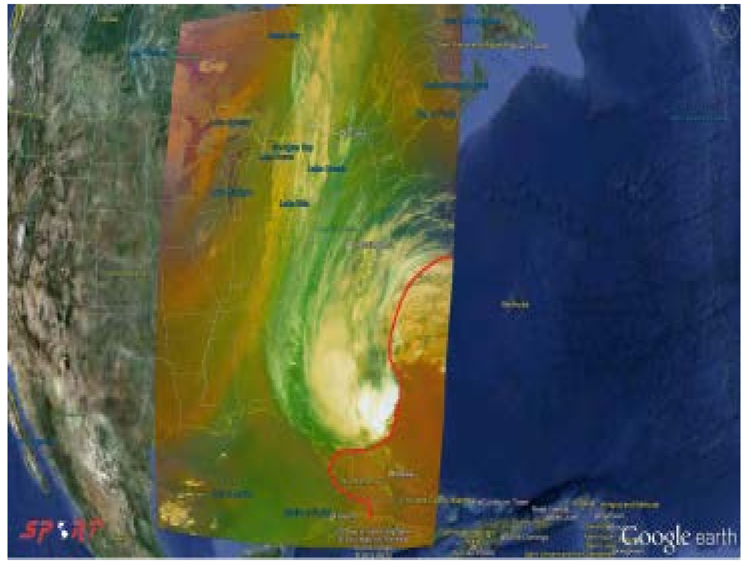


The air mass product tells forecasters a lot about the structure of water vapor, as well some information about warmer and colder airmasses in association with water vapor at the various layers.

Another important SPoRT initiative was evaluating the operational use of RGB composite imagery. This imagery is the use of multiple channels to show air mass characteristics, atmospheric moisture, temperature, and microphysical properties in a single image, thereby reducing data volume. Partners have emphasized the utility of such a product to SPoRT who have developed RGB enhancements for SNPP VIIRS.

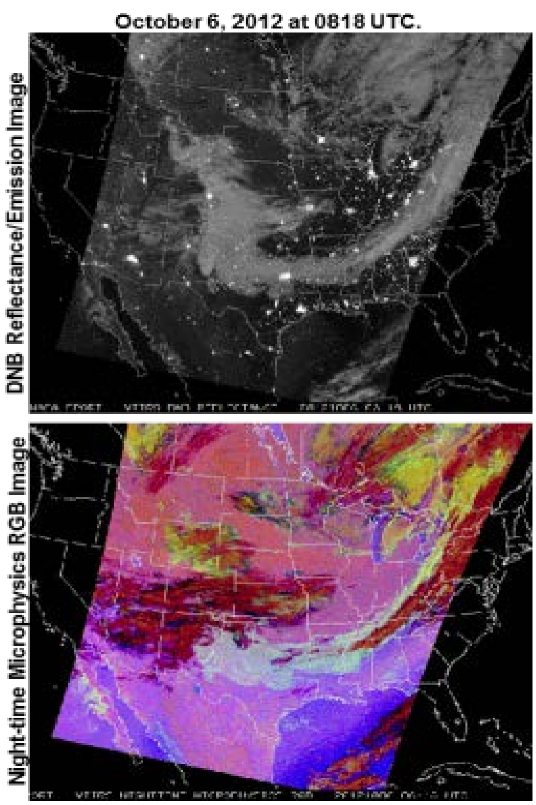
Composite RGB imagery helps forecasters identify key structures within a developing weather pattern. Forecasters use the polar Air Mass products from MODIS and the European geostationary sensor SEVIRI to monitor tropical systems in the Pacific and Atlantic oceans and to better understand the intensity and structure of these storms.

SPoRT has leveraged data from other polar sensors to create SNPP RGB products. While VIIRS has many spectral similarities to MODIS, it cannot be used in the exact same fashion as it is missing water vapor and ozone channels used to monitor storm dynamics. To make up for these channels being unavailable, SPoRT has fused water vapor and ozone channels (left image) from CrIS and VIIRS sensors to produce an air mass composite product. Incorporating CrIS water vapor and ozone channels allows for a qualitative view of the structure of the storm environment. As a result of SPoRT's efforts, NWS forecasters utilized this RGB product to monitor Hurricane Sandy as seen to the right.



The SNPP VIIRS RGB Air Mass image using Google Earth 10/27/12 Everything to the right of the red line is very dry air at high altitude that is cutting into Sandy's tropical environment

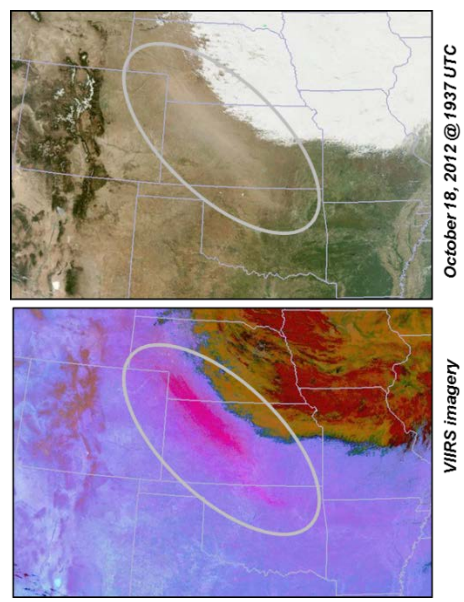
In partnership with the use of the Day-Night Band (DNB) for cloud detection, an RGB image can clarify cloud levels. Demonstrated to the left, the RGB image product complements the DNB imagery and helps identify the variations in cloud height and type present in the scene. The VIIRS RGB composite product gives the forecaster a better understanding of the clouds over their region of interest, providing more information about the structure of the clouds and their height. This can be directly used to improve situational awareness and SPoRT is providing this product to a variety of users in their decision support systems.



Low clouds tend to be a bright aqua color (TX and LA)

Further north, low clouds exhibit a more yellow tone due to lower temperatures (WY and Great Lakes areas)

Higher clouds are red and purple shades, depending on their thickness.



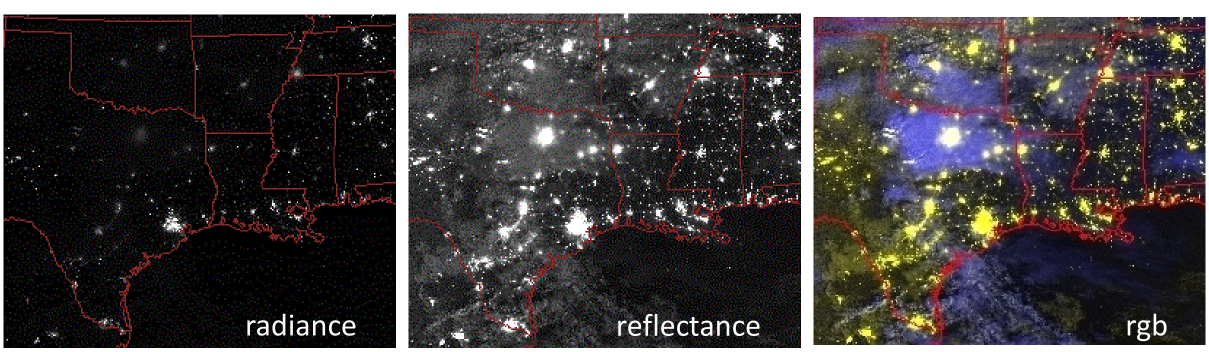
VIIRS spatial coverage and spectral characteristics allow for the better detection of atmospheric features than other operational sensors.

Dust-scattered sunrise over Huntsville

RGB products can be used for more than cloud detection. In October 2012, dust storms with winds approaching 70 mph occurred on the back side of a low pressure system as a cold front moved south. Dust was picked up from the drought-stricken areas of Nebraska and transported thousands of miles. The dust plume is clearly seen in the VIIRS true color and dust RGB imagery to the left; this plume caused interstate highway accidents and created spectacular sunrise events in Wyoming, Nebraska and Oklahoma. SNPP VIIRS data provided critical support to weather forecasters and decision makers in the region, thanks to direct broadcast data products provided by SPoRT.

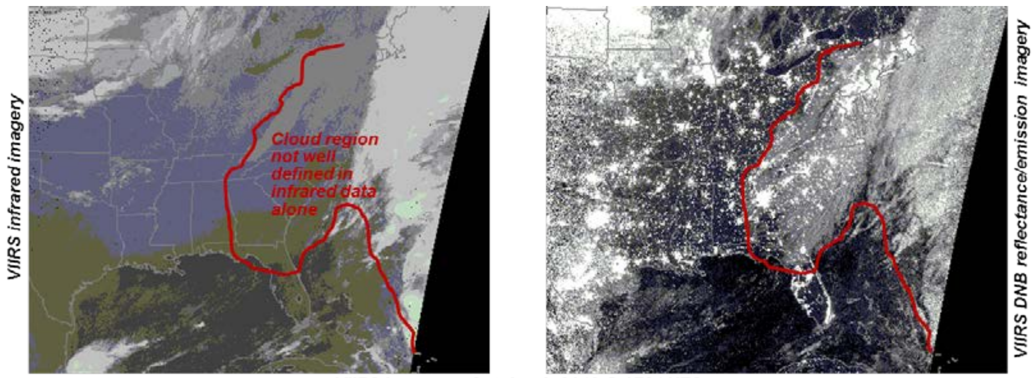
Use of VIIRS data at night to better understand cloud variability, fog and low-level features

The SNPP VIIRS Day-Night Band (DNB) product leverages the VIIRS ability to sense moonlight reflected from clouds, fog, and surface features such as snow, in addition to emitted light from cities, fires and other sources. This capability has quickly proven to be an invaluable tool in identifying clouds, fog, and other low-level features at night. Work on the operational application of the DNB has shown that these important environmental features can be detected even in times of very low moonlight. An example of this application is shown below. The basic DNB image below on the left shows a small portion of the southern U.S. Lights from the major cities are apparent in this image. With post processing to correct for available moonlight and the creation of an RGB composite using an infrared window channel, help identify the location of smaller cities and associated road networks. These features can then be used in concert with the reflectance product (center) which is created by normalizing the radiance seen by the available moonlight, to bring out the less intense features and clouds over Texas, Oklahoma and Arkansas. Combining the reflectance product with an infrared image produces the VIIRS DNB reflectance RGB product (right). Here the colder (higher) clouds including thin cirrus are now apparent as blue colors in the composite image.



VIIRS DNB imagery over the southern part of the U.S. for 0740UTC on April 2, 2013.

The VIIRS DNB can also be used to verify cloud levels demonstrated in the infrared (IR) imagery product. The VIIRS IR image (seen below on the left) indicates that high, cold clouds, denoted by dark gray, are apparent over the Great Lakes region and that low level, warm clouds exist off the East Coast, extending down into the SE US. The corresponding DNB and derived reflectance / emission product (seen on the right) confirms the extension of low clouds and fog into the Carolinas, eastern Tennessee, Georgia, and northern Florida. The IR image alone provides a decent approximation of cloud cover but, when combined with the VIIRS DNB, provides a better indication of low clouds and fog. Forecasters therefore have an enhanced low-cloud detection tool which allows them to better assess and forecast the cloud cover that they would otherwise not have noted.



VIIRS imagery – October 9, 2012 @ 0721 UTC

SPoRT helping the operational weather community evolve SNPP capabilities

SPoRT continues to work with its NOAA and NASA PG partners to enhance real-time data access of SNPP data to augment forecasting expertise throughout the nation. SPoRT successful participation in the JPSS Proving Ground to develop SNPP products and services has shown an improvement in forecaster situational awareness and short-term weather forecasts. SPoRT, provides the operational weather community an opportunity to test and evaluate current and future applications of SNPP data. With NWS weather offices in the Continental US region, SPoRT focuses on products which address challenging forecast issues related to convective storm diagnostics, reduction in visibility and ceilings, and unpredicted variations in regional weather. In work with the NWS weather offices in Alaska and the Pacific, SPoRT is evaluating atmospheric and cloud products to address nowcasting issues. A key to SPoRT's success has been the direct infusion of data into the user decision support system. These diverse applications help the operational weather community to better understand underlying feature dynamics and explain surface phenomena, especially in data-sparse regions such as over the ocean. These activities demonstrate future JPSS observing capabilities through exploitation of SNPP data and help to evolve existent forecasting capabilities throughout the nation.

Section 5

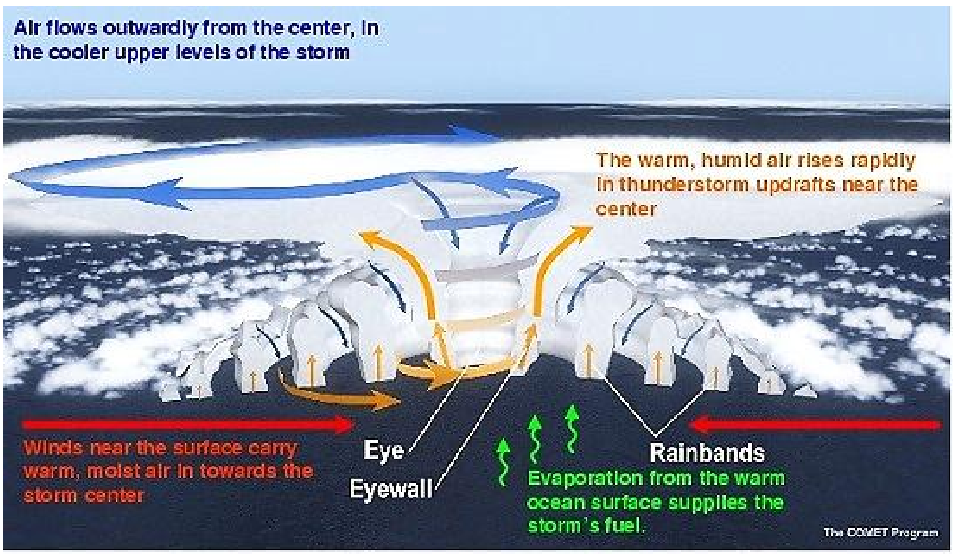
Using Suomi NPP Sounder Observations to Improve Hurricane Structure Monitoring and Intensity Forecasts

The information in this article is based in part on the JPSS science seminar given by Fuzhong Weng (NESDIS/STAR), on ***March 27, 2013.***

Contributing editors: Fuzhong Weng, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

Tropical cyclones (TCs) are warm-core, non-frontal synoptic-scale systems, originating over tropical or subtropical waters with organized deep convection and a closed surface wind circulation about a well-defined center. In warm-core storm systems moist air is concentrated near the center of the storm compared to the surrounding colder atmosphere. Once a cluster of thunderstorms forms, it begins to develop a circulation center, giving the storms their characteristic spiral rain bands as convective cells are pulled toward the center of the storm.

Depending on their location and strength, TCs are referred to by names such as hurricane, typhoon, tropical storm, cyclonic storm, tropical depression, and simply cyclone. Hurricanes are tropical cyclones in which the maximum 1-minute sustained surface wind is 64 knots (74 mph) or greater. Forecasting



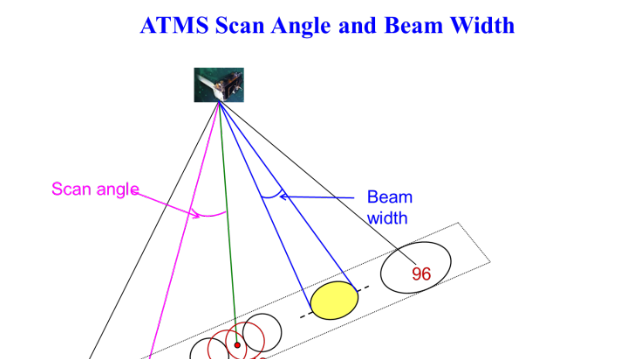
The above illustration shows tropical cyclone structure. It depicts a well formed eye that is surrounded by an eyewall – an area with the strongest winds. Outside the eyewall are the rainbands that spiral around the cyclone. (Image courtesy of UCAR/COMET.)

hurricane or TC development, intensification rate and movement are a challenge to any weather forecaster responsible for characterizing the storm's threat to islands and coastal land areas. Both hurricane track and intensity are of serious concern to people in its path.

Satellite imagery and satellite data assimilation into tailored TC models have played a critical role in the improvement of track forecasts in the past 20 years. However, accurate prediction of the storm life cycle remains a very challenging area of research, particularly understanding better a hurricane's initial formation, intensity changes, and the final dissipation. The challenge comes partially from the lack of knowledge on hurricane structures. Determining the hurricane structure and how it changes is especially important when tropical cyclone circulations are weak and diffuse over open oceans. There is an additional challenge in these areas, because they have few upper-air and surface observations, ship reports, or buoy data. Also these regions are too remote, and the TCs are often too weak, to warrant the use of hurricane penetration reconnaissance flights.

Imagine if we could look into the heart of a hurricane and gather information on all its different working parts—we could learn how fast a storm is moving, how strong it is, and most importantly, where it is going. Luckily current satellite programs have a myriad of remotely observing instruments that enable just this type of structural analysis. Foremost among them are microwave sounding instruments such as the Advanced Microwave Sounding Unit-A (AMSU-A), Microwave Humidity Sounder (MHS), and the Advanced Technology Microwave Sounder (ATMS) which capture data from within TCs and their surrounding environment. These microwave instruments have proven invaluable in providing detailed inner wall structure, accurate eye placement, and changing vertical movement in rainbands, in the often heaviest cloud shields of the most intense hurricanes.

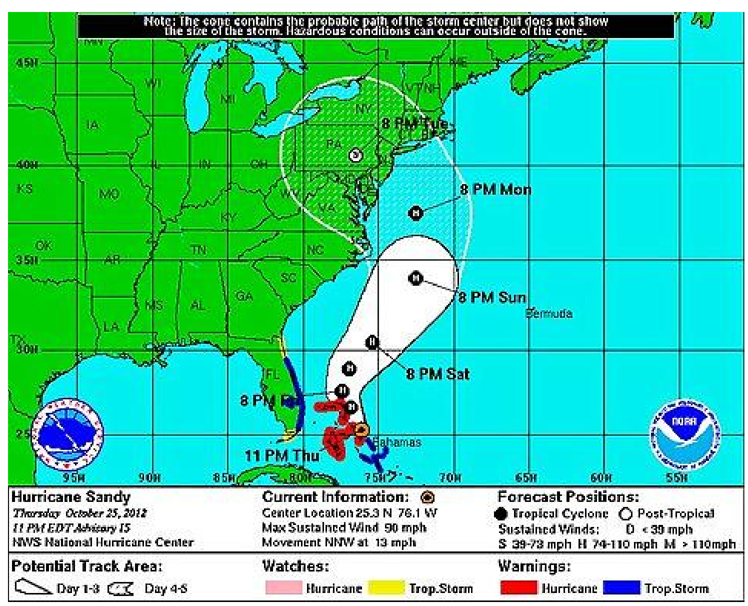
The Suomi National Polar-orbiting Partnership (SNPP) ATMS instrument captures atmospheric temperature and water vapor information in the lower troposphere and provides details of vertical temperature and moisture structures throughout the atmospheric column. ATMS is a cross-track scanning instrument which combines the capabilities of its predecessors, AMSU-A and MHS from NOAA and MetOp satellites, and includes several additional sensing channels. Like its predecessors, ATMS has the ability to penetrate through deep, non-precipitating clouds and therefore can provide vertical soundings under all weather conditions.



Channel		Nadir Resolution (km)		Outmost FOV size (km)			
ATMS	AMSU	ATMS	AMSU	Cross-track		Along-track	
				ATMS	AMSU	ATMS	AMSU
1-2	1-2	74.8	48.6	323.1	155.2	141.8	85.6
3-16	3-15	31.6	48.6	136.7	155.2	60.0	85.6
17-22	16-20	15.8	16.2	68.4	58.9	30.0	6666

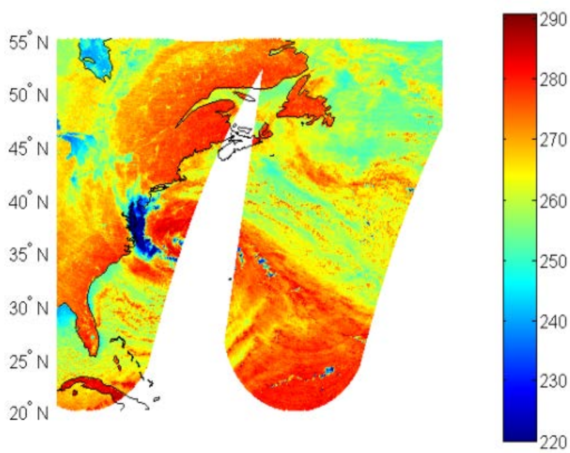
ATMS provides 96 fields of view (FOV), which means that during each scan cycle the earth is viewed at 96 different angles. In addition, a wide scan swath provides consistent data between passes, allowing for no gaps between two consecutive orbits, therefore offering an improved spatial coverage over its predecessors. ATMS' continuous scanning along- and cross-track allows for oversampling in the atmosphere that is used to enhance the spatial resolution and reduce the instrument noise.

Microwave sounding data are critical to both observations, but more importantly to numerical weather prediction. Numerical models of hurricanes utilize the sounding data to improve TC track, intensity and structure forecasts. To further this research, the JPSS Proving Ground (PG) is sponsoring a project at the NOAA Center For Satellite Applications and Research (STAR) to improve TC forecasts by assimilating new data provided by SNPP



ATMS. The products developed as part of this project are demonstrated and evaluated within the National Hurricane Center (NHC) testbed facility. The NHC uses, critiques, and makes suggestions on improvements to the products from STAR, allowing STAR scientists to communicate the benefits and challenges of their work to JPSS. Ultimately, all parties obtain a better understanding of improved satellite product attributes and the tools which can benefit the end users by providing enhanced assessments and warnings. The outcome is improved decision support tools by better utilizing satellite data combined with other information acquired by the user, in this case the NHC.

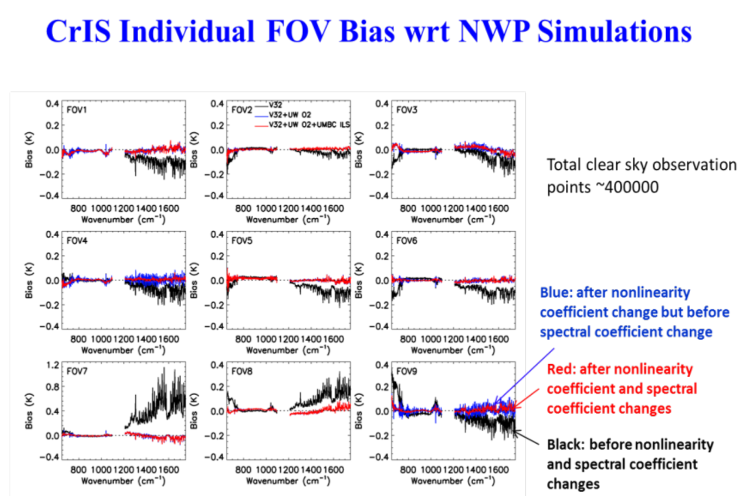
With ATMS' oversampling hurricane forecasters can obtain the whole structure of the hurricane and in particular the thermal structure of the sounding (also known as a retrieval), temperature retrieval, and temperature anomaly with respect to the surrounding environment. Oversampling data also allows for much better depiction of a TC warm core anomaly which is directly correlated to hurricane intensity. As the magnitude or height of the warm anomaly of the TC changes, so does the TC intensity. ATMS data over the Atlantic and Pacific oceans are therefore extremely valuable oceanic regions where in situ observations from aircraft or land-based systems are rarely available.



AMSR-2 image of Hurricane Sandy showing heavy rain in the blue area. 10-28-2012 06 UTC

Another sensor that is being evaluated for tropical cyclone forecasting is the Japanese Aerospace Exploration Agency (JAXA) Advanced Microwave Scanning Radiometer-2 (AMSR-2) sensor, onboard its Global Change Observation Mission 1st - Water (GCOM-W1) satellite. AMSR-2 builds on the proven success of its predecessor AMSR-E. Like AMSR-E it relies on a combination of its large swath and a superb spatial resolution. These capabilities will allow AMSR-2 to capture small storm features, changes in tropical cyclone interior structures related to clouds and precipitation, and sea surface temperature and wind. These features are often missed by coarser resolution sensors. The AMSR-2 capabilities, like its predecessor, will prove critical to forecasters' abilities to identify tropical cyclone center position, intensity, and changes in tropical cyclone phase. All are key to accurate tropical cyclone forecasting.

In addition to microwave sounders, SNPP provides infrared (IR) products from the Cross-Track Infrared Sounder (CrIS) instrument. CrIS also gives environmental



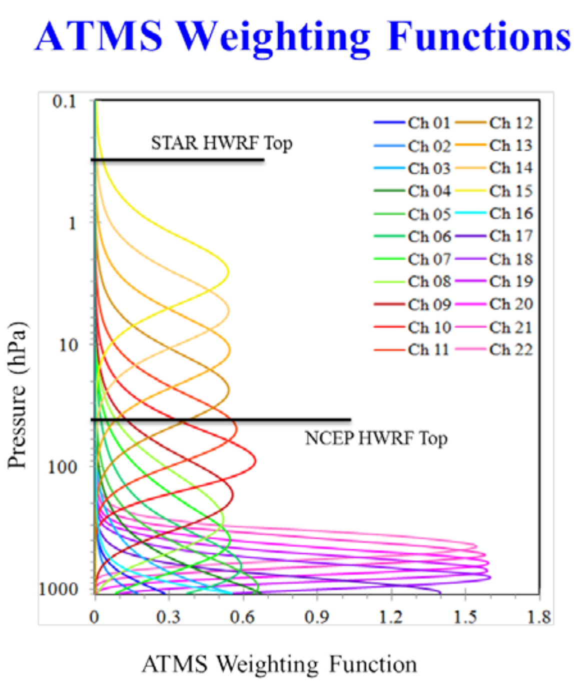
information on thermal and moisture structure for track and precipitation forecasts, this time in the spectrum, which serves to corroborate and enhance the atmospheric vertical structure retrieved by ATMS.

CrIS has nine FOV, and all have similar bias across the spectrum, allowing for key Numerical Weather Prediction (NWP) applications. Scientists at STAR are characterizing the bias for each individual FOV such that the spectral and radiometric uncertainties are uniform across all 9 fields. This helps the NWP community establish whether all FOVs can be assimilated, thereby maximizing the use of the radiance data. JPSS continues to work with the Joint Center for Satellite Data Assimilation (JCSDA) to incorporate CrIS into NWP models, thereby maximizing the use of both SNPP sounding instruments.

Together, CrIS, ATMS and AMSR-2 provide high vertical resolution temperature and water vapor information and surface observational needed to maintain and improve NWP forecast skill. Inclusion of both SNPP sounders should aid in forecasts 5 to 7 days out in advance for extreme weather events, including hurricane intensity and track prediction.

Revisiting the Gridpoint Statistical Interpolation (GSI) Interface with Hurricane Weather Research Forecast (HWRF)

Satellite data is included in NWP models using data assimilation techniques which use the data to bring NWP forecasts closer to observed values derived by satellites. Currently, the NCEP Gridpoint Statistical Interpolation (GSI) – a three-dimensional variational (3D-Var) data assimilation system is being used by the hurricane research community for both global and regional model analysis. Scientsists at STAR tested the resultant GSI-derived forecasts against what really happened for a particular meteorological event. They discovered that some interfaces were not optimized for regional model applications, particularly where the model top was very low, causing forecast errors. In practice the 2011 and 2012 Hurricane Weather Research Forecast (HWRF) model forecasts created by NCEP did not use most of satellite data since its model top was very low.



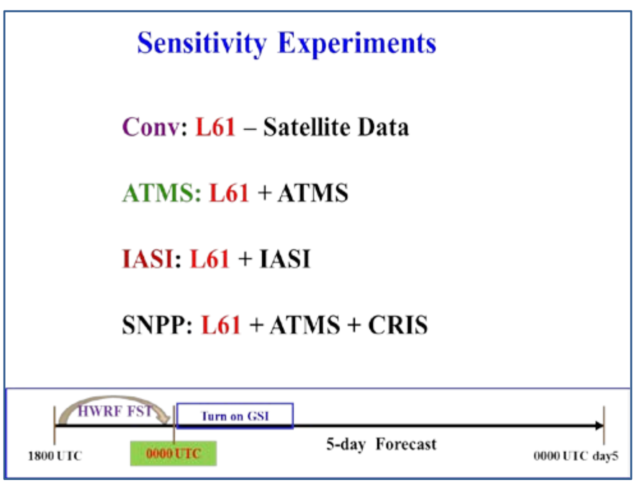
By limiting the model top much of the satellite radiance information is missed, particularly in the Polar Regions as shown in the image on the left. A shallow model top tends to exclude temperature data in the region, which in turn disallows more satellite data to be assimilated into the regional HWRF model, thereby creating a negative effect on downstream operational forecasts.

Improvements to HWRF Data Assimilation

To account for the missing data and to fully utilize the ATMS sounding in the HWRF, the scientists at STAR raised the model top which allows for more satellite data to be assimilated into the forecast model. Other improvements to the HWRF data assimilation include: working out an optimal configuration of HWRF modeling domains and how that effects the GSI data assimilation system; examining the quality control procedures for all ingested data and implementing additional criteria for removing all clouds-affected radiances from microwave sounder; improving the radiative transfer modeling processes for effectively assimilating cloud-affected radiances in HWRF and characterize the error covariances within each of HWRF domains; and refining the bias correction algorithms at various domains and according to cloud and precipitation type.[4]

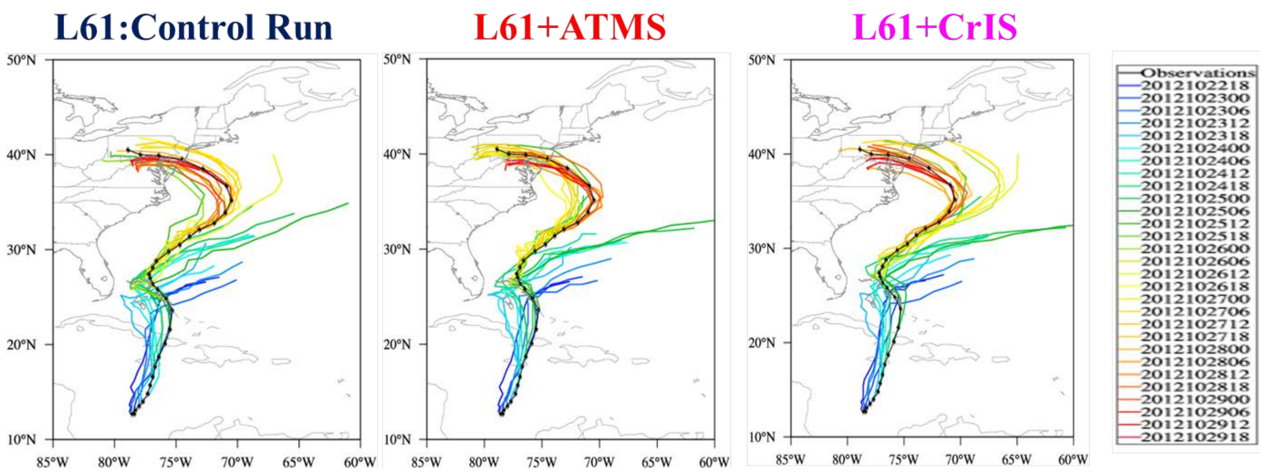
Impacts of Direct Assimilation of SNPP ATMS and CrIS Radiances on Hurricane Sandy's Track

To evaluate the impacts of SNPP ATMS and ATMS+CrIS data assimilation on their modified HWRF model hurricane forecasts, STAR scientists performed sensitivity experiments using 6-hr HWRF forecasts as the background. Testing against different assimilation scenarios, the scientists focused on differences with the SNPP models versus the MetOp Infrared Atmospheric Sounding Interferometer (IASI) instrument. Simulations of this 61-vertical level experiment (L61) were noted as Control (Conv), ATMS, IASI, CrIS (missing from list) and SNPP (ATMS + CrIS) were used to set up initial fields and boundary conditions for the HWRF model run as seen in the figure below.



[4] Bias correction schemes for satellite data developed for the global model applications have not been fully vetted for regional model applications.

STAR scientists focused their work on the 2012 hurricane season, directly assimilating ATMS and CrIS radiance data to produce experimental products for hurricane monitoring. Results are shown below for Hurricane Sandy.

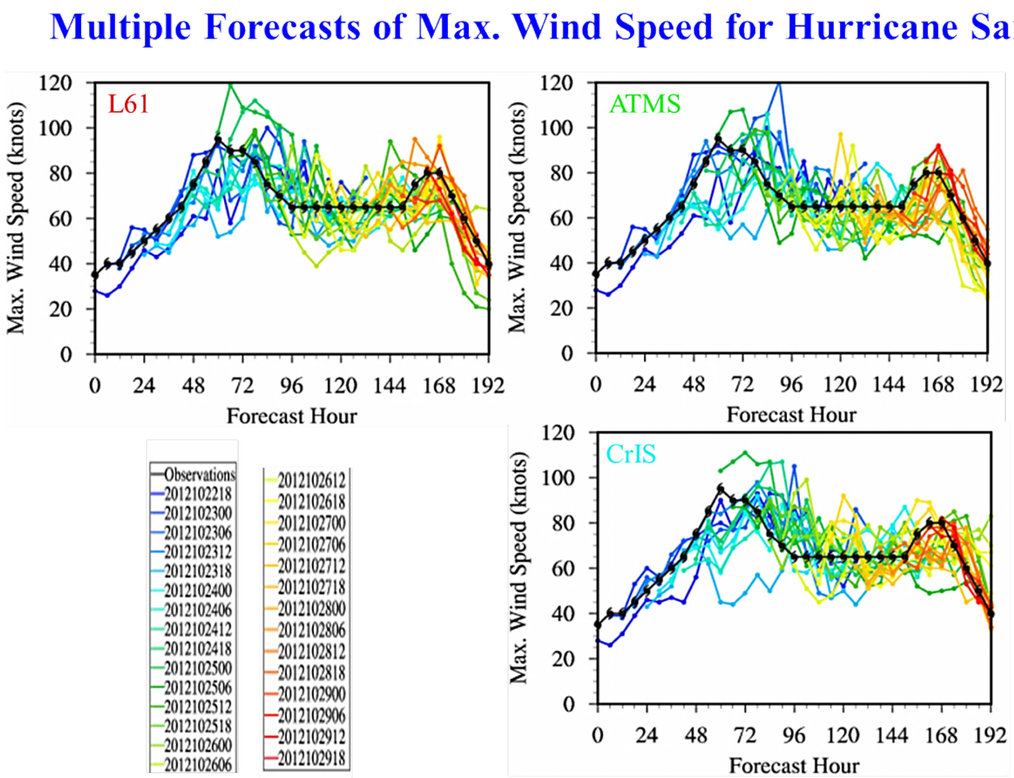


Predicted vs. observed track for Hurricane Sandy during October 22 to 29.NCEP 2012HWRF is revised with a high model and 6 hr. forecast as background for direct satellite radiance assimilation in GSI. Control Run: All conventional data and NOAA/METOP/EOS/COSMIC. It is clearly demonstrated that assimilation of SNPP ATMS and CrIS radiance data reduce the forecast errors of Hurricane Sandy's track.

The experiments also showed that satellite data had the largest impact on a hurricane's track and intensity as it neared landfall, and particularly with ATMS assimilation. Impacts from CrIS were also positive although it is not as significant as ATMS. Satellite data impacts on a hurricane's track were highest during the first three-day forecasts over open water. For conventional-only experiments, the forecast errors of hurricane tracks increased rapidly when a hurricane was near landfall whereas the inclusion of satellite data served to reduce such landfall-induced errors. However, quality control and bias correction schemes in the current GSI for CrIS and other satellite data types are shown to be major issues and need to be updated, thus caution must be applied to these findings.

The preliminary results from the control and sensitivity experiments showed that uses of ATMS and CrIS data in HWRF improved the hurricane forecasts in both intensity and track compared to the control. As seen above, ATMS had the largest impact on Sandy's track, picking up on the recurvature toward land much faster than the control run.

HWF simulations also derive predicted hurricane strength, or intensity. Evaluating how low the central pressure within a TC gets indicates storm intensity and allows forecasters to predict the magnitude of the storm as it makes landfall. As seen in the Hurricane Sandy graphics below, this variable is difficult to simulate well. Satellite data can have a significant impact here too. As seen in the CrIS direct radiance assimilation, the reintensification Sandy experienced is better captured with the help of IR data.



Improving hurricane intensity forecasts remains an active area of research within the tropical cyclone prediction and satellite data assimilation communities. The JPSS Proving Ground (PG) continues to support such efforts in order to continually improve and enhance operational hurricane forecasting.

Conclusion

NOAA polar-orbiting satellites, including SNPP, provide critical information on atmospheric vertical temperature structure for hurricane monitoring and forecasts. The capabilities of the CrIS and ATMS sensors on SNPP, and AMSR-2 on GCOM-W1, provide more detailed atmospheric thermal structures, and have a direct impact on the improvement of tropical cyclone forecasting. Early results show the value of ATMS in resolving hurricane warm core features through spatial oversampling and additional channels. The CrIS and ATMS sensors offer new advancements in channel frequency, resolutions, and swath width allow better initialization and satellite data assimilation for tropical cyclones. The NHC is working collaboratively with NESDIS/STAR through the JPSS PG to demonstrate the benefits and uses of SNPP data. Direct SNPP satellite radiance data assimilation in the HWRF model has shown marked improvements in the track and intensity forecasts for most of study cases including Hurricane Sandy. Future studies will provide the critical insight needed to leverage these SNPP capabilities to their maximum extent.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Section 6

Introducing New Polar-orbiting Data into Operations at NOAA's National Centers for Environmental Prediction (NCEP)

The information in this article is based in part on the JPSS science seminar given by Michael J. Folmer (UMCP/ESSIC/CICS, Satellite Liaison at WPC/OPC/TAFB/SAB, on ***April 30, 2013.***

Contributing editors: Michael J. Folmer, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

There is no substitute for polar-orbiting satellite data in monitoring the environment and predicting the weather. The use of polar-orbiting satellite data at the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) is 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. Weather forecasters within National Weather Service (NWS) National Centers, however, rarely utilize polar-orbiting satellite data observations to monitor potential hazards, aid in generating weather warnings, watches, and advisories due to lack of familiarity. Forecasters have had very minimal interaction with the high resolution imagery and microwave products due to latency issues and limited training on the datasets. Consequently the Joint Polar Satellite System (JPSS) Satellite Proving Ground is avidly working to introduce and promote the use of polar-orbiting satellite data within the NWS, focusing on National Center use.

Introducing Polar Data and Products to the NOAA National Centers

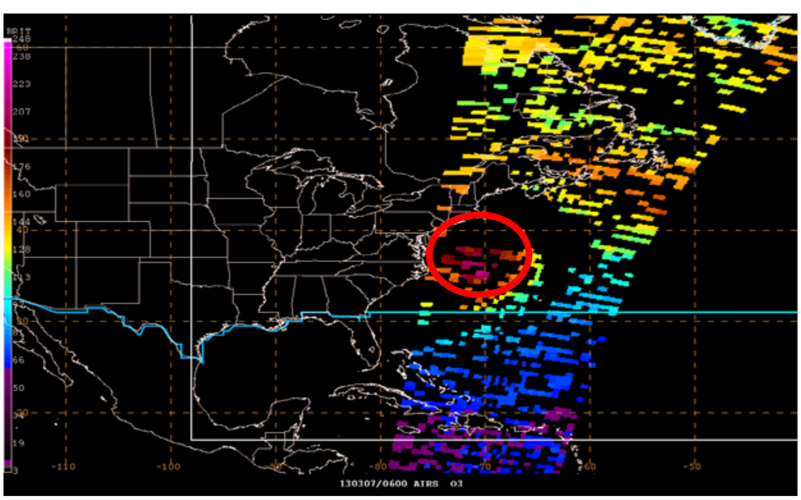
So how does the JPSS Proving Ground familiarize forecasters and operational centers with polar-orbiting data when they have historically relied on geostationary data? A viable technique used by the JPSS is to demonstrate the usability of the data during a major meteorological event. Superstorm Sandy was the impetus for bringing Suomi National Polar-orbiting Partnership (SNPP) data into operations at several NCEP centers, highlighting SNPP-unique capabilities as the storm developed and moved towards the East Coast. Of great value were the nighttime images produced from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day-Night Band (DNB) which allowed for continuity of visible imagery as the storm strengthened during the night time hours of October 30, 2012. SNPP data has continued to be valuable in the months since Sandy as it is now more widely accessible in additional NCEP Centers and forecasters learn the utility of the products. Moreover, introduction of new JPSS satellite products at the Weather Prediction Center (WPC), Ocean Prediction Center (OPC), the National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Analysis Branch (SAB), and National Hurricane Center (NHC) afford forecasters at these centers the ability to discover operational applications of the SNPP satellite data. With help from the Satellite Proving Ground these centers have progressed from using basic satellite imagery channels to implementing new satellite techniques and products in everyday use.

The NCEP WPC and OPC provide short-term and medium-range forecast guidance of heavy precipitation, strong winds, and other features often associated with mid-latitude cyclones over land and the ocean, respectively. Therefore, detection of phenomena that lead to rapid cyclogenesis (storm development) and high wind events is key to improving forecast skill. One such phenomenon is the intrusion of stratospheric air (dry, ozone-rich) that mixes deeply into the lower atmosphere through tropopause folds (occurs on the troposphere/stratosphere boundary); as a result, potential vorticity (PV), or the potential for rotation within cyclogenesis, descends (sometimes rapidly) deep into the mid-troposphere. Satellite observations aid in detection of stratospheric air intrusion (SAI) regions with multispectral composite imagery. Differing imagery spectral bands are assigned red, green, and blue (RGB) colors such that dry air (red) can be detected, as shown to the right with RGB imagery from Superstorm Sandy. Thus, dry stratospheric air associated with PV advection is discernible and alerts forecasters to the possibility of a rapidly strengthening storm system.

RGB images are not new to the forecasters at the NHC, WPC, NHC, and OPC. As part of the GOES-R Proving Ground, they have been using center-unique multiple channels satellite composite products. These products are generated from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and the EUMETSAT's Spinning Enhanced Visible and Infrared Imager (SEVIRI) instruments, and are used to monitor large scale weather systems that pose significant weather threats to the United States. RGB imagery products can be crafted to show air mass characteristics, atmospheric moisture, temperature, and microphysical properties in a single image. Single channel or RGB satellite imagery lacks quantitative information about atmospheric moisture and therefore complementary satellite observations are needed to capture a complete picture of a developing storm system in a composite image. The RGB Air Mass product from MODIS and SEVIRI is used by NHC to monitor tropical cyclones in the Pacific and Atlantic oceans and to better understand the intensity and structure of these storms. New to the NCEP centers, the SNPP composite RGB imagery uses imagery channels from VIIRS, and water vapor contributions from the Cross-track Infrared Sounder (CrIS). This imagery complements similar products forecasters have been evaluating from other satellites.

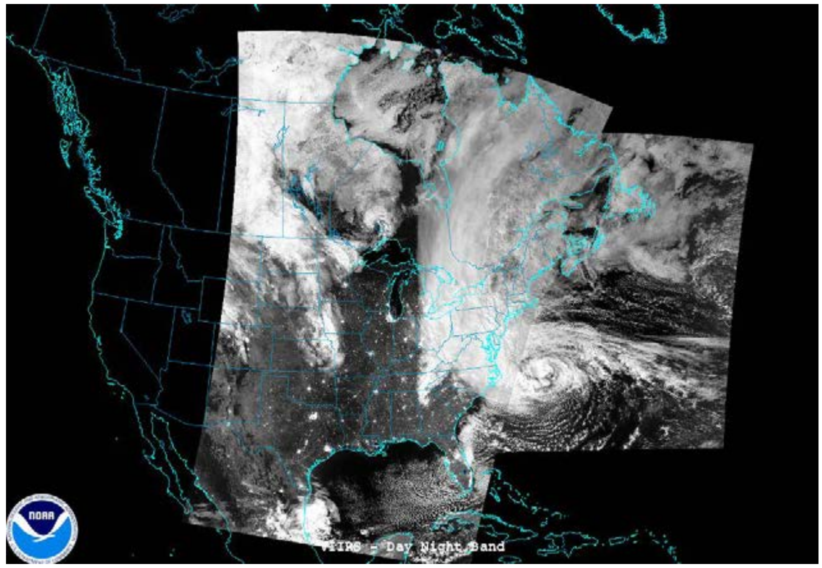
Advances in Space-based Nighttime Visible Observation

Nighttime monitoring of cyclogenesis and other hazardous events is an area of great focus for polar-orbiting satellite data use. For example, total column ozone (TCO) retrieval products give an indication of tropopause folds and storm development. The NASA Atmospheric Infrared Sounder (AIRS) TCO product, produced by NASA SPoRT, retrieves ozone during both day and night as the sensor measures in the infrared spectrum. Retrievals derived from the AIRS hyperspectral sounder are used to confirm the extent and magnitude of SAIs, as TOC is a good proxy for defining locations and intensity of cyclogenesis, as seen below in the March 2013 case. The Satellite Proving Ground is working with NCEP centers to further use this product for nighttime storm intensification monitoring.



Snapshot from March, 2013 snow storm which was billed as "Snowquester". The very dark reds in the center are about 500 Dobson units of ozone or higher, which is fairly significant and indicates a highly anomalous stratospheric intrusion.

With the very high resolution infrared and visible bands at very high spatial resolution, the SNPP VIIRS DNB imagery can provide crucial imagery at night. Currently deployed in the NCEP Advanced Weather Interactive Processing System (NAWIPS) workstations and used in WPC, OPC, and SAB, the DNB uses dim light sources such as city lights and reflected moonlight to detect cloud and snow cover. Operational forecasters can then monitor cold fronts and storms at night. In higher latitudes where SNPP views the poles multiple times per night, changes in cloud cover and even rapid ice movement can be detected. Forecasters across the United States have implemented the DNB imagery to identify crucial weather events, from fog to continuous monitoring of storms like Superstorm Sandy seen above.

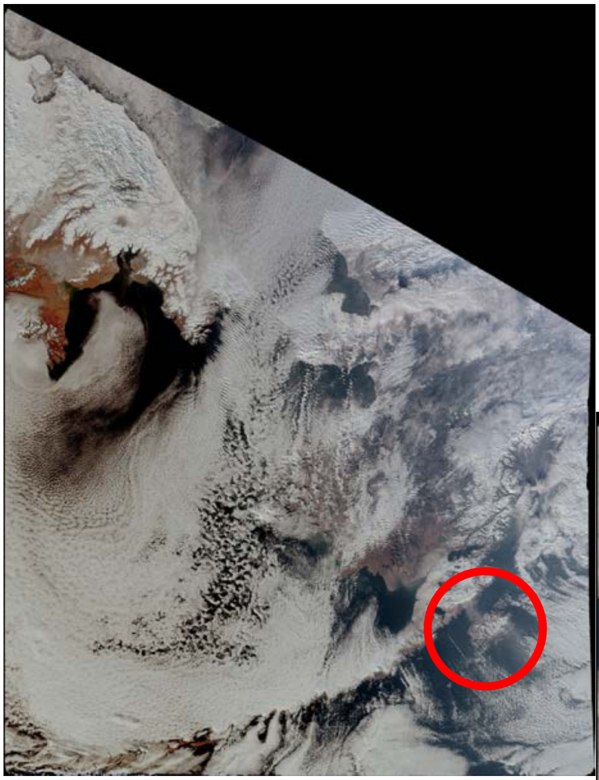


Suomi-NPP VIIRS Day-Night Band composite of Hurricane Sandy overnight on 10/28/12

Supporting a Weather Ready Nation with Enhanced Decision Support Tools Using SNPP Data

The NESDIS SAB generates and distributes a wide variety of satellite-derived imagery products. SAB provides smoke and fire detection as well as volcanic ash tracking, both of which are critical to aviation forecasting and have a direct impact on aviation safety.

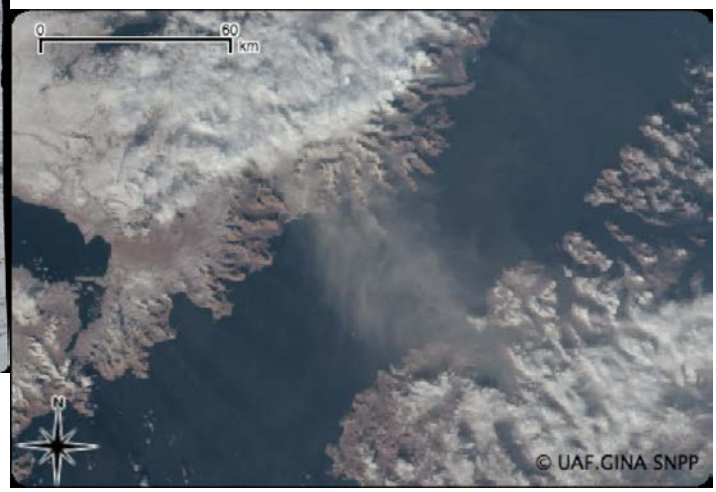
Around the world, long-term and large-scale detection and monitoring of fire activity has been achieved by blending multiple satellite sensors from both geostationary and polar platforms. The United States first used the Advanced Very High Resolution Radiometer (AVHRR) instrument on NOAA polar-orbiting satellites for fire detection. Later, MODIS data from NASA's Terra and Aqua satellites was added for enhanced fire detection, using satellite data bands dedicated solely for this effort. VIIRS on the SNPP satellite provides its own outstanding fire detection capability to SAB's mission. The SAB Smoke, Fire and Air Quality Program performs fire and smoke analysis on the Hazard Mapping System (HMS) for the continental US, Alaska, Hawaii, Canada and Mexico/Central America. Besides detecting and mapping the location of a fire, the VIIRS sensor can measure Fire Radiative Power (FRP), an indicator of fire intensity, which helps forecasters and emergency managers pinpoint the developing and most intense fires which require immediate attention.



VIIRS True Color image, October 30, 2012

“Re---suspension” of volcanic ash from Katmai

Volcanic activity poses a great environmental hazard. Levels of volcanic ash and sulfuric acid impact every area of public health and safety. Determining the movement of volcanic ash and the chemical contents of these clouds, are critical to determining the amount of ash accumulated on land, air quality forecasts, and what changes are needed in airport operations and commercial and private aviation airspace use. To meet these challenges, in 1997, the International Civil Aviation Organization (ICAO) divided the world’s airspace into nine Volcanic Ash Advisory Centers (VAACs); NOAA/NWS assumed responsibility for VAACs, Anchorage, Alaska and Washington D.C., the latter is in joint responsibility with SAB. Together these two VAACs cover the Alaskan region to the North Pole and the United States, Caribbean through the top half of South America and most of the northern Pacific Ocean. SNPP data has already proved a valuable tool in monitoring volcanic activity throughout Alaska, as facilitated by the JPSS Satellite Proving Ground. Flight routes over Alaska face the potential risk of encountering volcanic ash from any of the state’s major active volcanoes and polar-orbiting satellite data is the main data source for tracking volcanic ash and monitoring thermal hotspots. The Proving Ground allows for SNPP data to be transferred directly to the Alaska Volcano Observatory (AVO) using the Geographic Information Network of Alaska (GINA). The GINA real-time direct broadcast network provides polar images used extensively by the NWS in Alaska, as seen above for the Katmai eruption. Real-time imagery data are key inputs in ash transport forecast models that simulate the movement of airborne ash following an eruption for the purposes of hazardous warning. The Satellite Proving Ground is also working with the Washington D.C. VAAC on the uses of enhanced imagery from VIIRS.



Bringing Crucial NOAA Polar-orbiting data to the NWS National Centers

The JPSS Satellite Proving Ground provides ever more critical data in support of operational forecasting throughout the NWS. As of the first week of April 2013, VIIRS data was officially available on all NAWIPS workstations at WPC, OPC, and SAB. These inputs will significantly improve weather forecasting and hazard monitoring capabilities, creating better forecasts as the user community becomes more familiar with the SNPP product suite.

In coordination with the GOES-R Proving Ground, SNPP products will continue to enhance current programs. Consistent user engagement is critical. The Proving Ground blog, established by Michael Folmer, the GOES-R/JPSS Satellite Liaison at WPC/OPC/TAFB/SAB, provides operational users the opportunity to learn new and enhanced products which can have a positive effect on their forecasting. Michael works directly with on-shift forecasters to allow for an in-situ evaluation on the efficiency and relevance of the SNPP data in operations.

The JPSS Satellite Proving Ground will continue to engage and work with the NOAA and international operational user community to explore new satellite techniques that will enhance operations and lessen forecast errors. The blended CrIS/VIIRS RGB Air Mass product is a great example of the type of exciting product that we can expect from the Joint Polar Satellite System (JPSS) in support of operational weather forecasting.

Section 7

Applications of Suomi NPP data in the Joint Center for Satellite Data Assimilation (JCSDA) Operations to Research/Research to Operations (O2R/R2O) capabilities

The information in this article is based in part on the JPSS science seminar given by James A. Jung (Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin - Madison), on ***May 29, 2013.***

Contributing editors: James A. Jung, Mitch Goldberg, Julie Price, William Sjoberg, and Kathryn Shontz

Everything you read, see or hear about weather, climate and ocean forecasts begins with numerical prediction models

Satellite Data Assimilation (DA) is the process of incorporating atmospheric observations into Numerical Weather Prediction (NWP) models to accurately describe the state of the atmosphere. Gridded datasets of satellite observations are key for weather analysis and forecasting. In fact, satellite data provide approximately 90% of all assimilated data for NWP as they give global atmospheric information, reporting in both remote areas and over the ocean.

Operational NWP models, such as the Global Forecast System (GFS) run at the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) rely heavily on the latest data assimilation techniques to ensure accurate results. In coordination with the Joint Center for Satellite Data Assimilation (JCSDA), the Joint Polar Satellite System (JPSS) Proving Ground (PG) science teams are working to improve and augment the data assimilation schemes and systems used today. Specifically, the PG teams are working to incorporate new data from the Suomi National Polar-orbiting Partnership (SNPP) satellite, focusing on the Advanced Technology Microwave Sounder (ATMS) and the Cross-track Infrared Sounder (CrIS) to develop advanced techniques of microwave and infrared sensor channel DA.

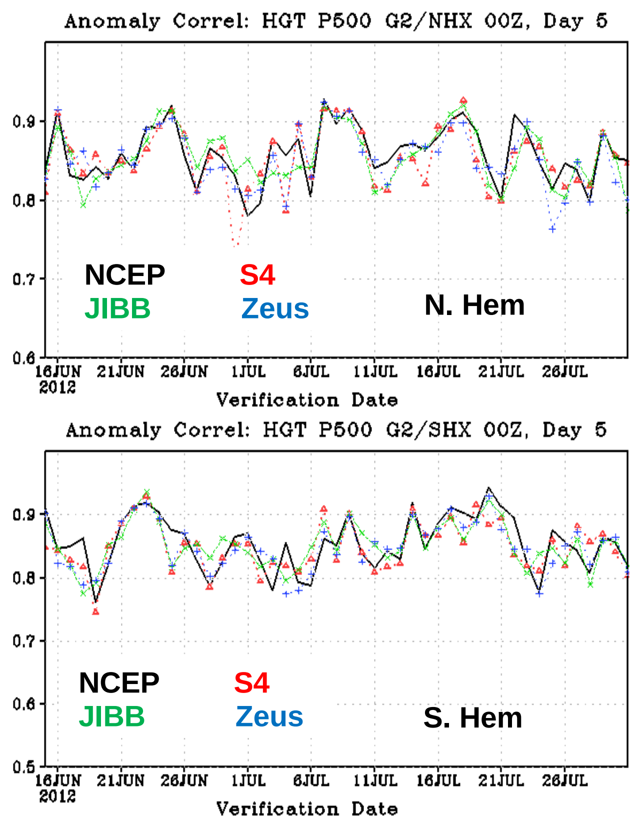
Building the Infrastructure for an Effective Operations to Research (O2R) and a Streamlined and Research to Operations (R2O)

The process of transitioning operational data assimilation systems for use by the research community, then transitioning new techniques and processes back to operations, is an integral part of improving the NOAA weather forecast system, and maintaining this O2R/R2O capability is essential to success. Moreover, software management, observation availability, and benchmarking procedures are a key part of this success. R2O and O2R synergy is essential to ultimately make NOAA's forecast weather systems of benefit to the National Weather Service (NWS) and for the algorithm developers to take advantage of the meteorological expertise of the NWS to help validate their work. By creating a streamlined research-to-operations (R2O) and operations-to-research (O2R) process, an iterative, two-way interaction between science and technology (S&T) development and NWS operations is optimized.

The R2O transition to NCEP/EMC is a path to operations for those scientific activities/outcomes that show a positive impact on the forecast skill. R2O transitions do not rely solely on physics-based numerical models. Some transitions are based on new models (both conceptual and numerical), new observation platforms, and new tools. Furthermore, R2O requires O2R as the research community needs access to operational codes and adequate computer resources. The JCSDA facilitates this by making sure that "operational" data assimilation systems are available to the research community. This is achieved through a multi-step process which includes: collaboration with NCEP/EMC on experiment design and logistics; subversion software management used to control/document changes; software coding standards and run-time performance review; and science reviews. In addition, NCEP/EMC combines various changes and assesses forecast impact, then transitions them to NCEP Central

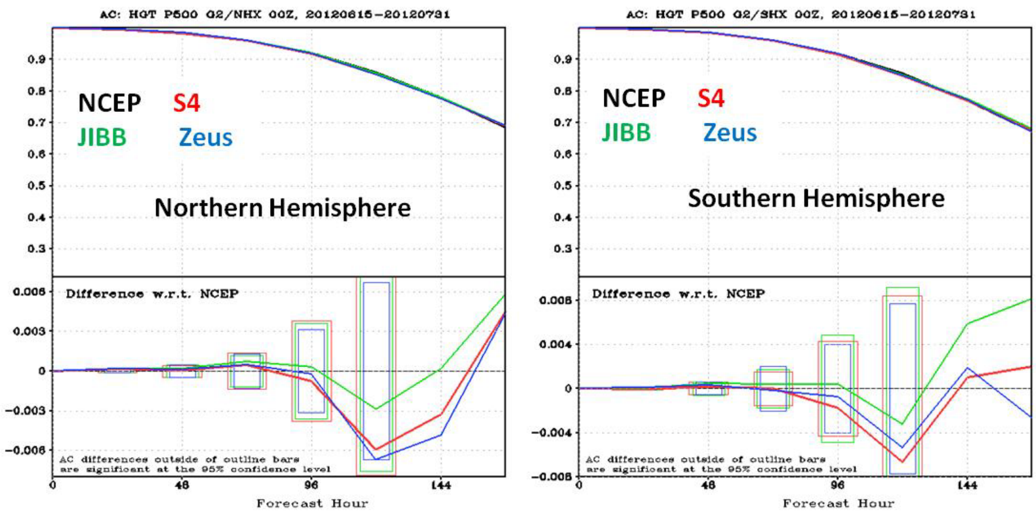
Operations (NCO). The JCSDA supercomputer Joint Center in a Big Box (JIBB) and the NESDIS Supercomputer for Satellite Simulations and data assimilation Studies (S4) have been used in implementing this R2O/O2R concept.

Within the JCSDA, a lot of time and effort is devoted to ensuring GDAS/GFS results from the S4 and JIBB are similar to those obtained from NCEP and the NOAA R&D machine(s). These experiments are designed to mimic NCEP operations as much as possible. In the example below, the initial validation was done approximately 45 days during the extreme (summer and winter) seasons. For these experiments, differences in forecast skill with NCEP operations were expected. These forecast skill differences are the result of differences in computer hardware, operating systems, bug fixes, restricted data access, and so forth. Nonetheless, satellite DA scientists at the JCSDA made every attempt to get as close to operations as possible, while realizing that forecast results cannot be identical given the inherent differences.



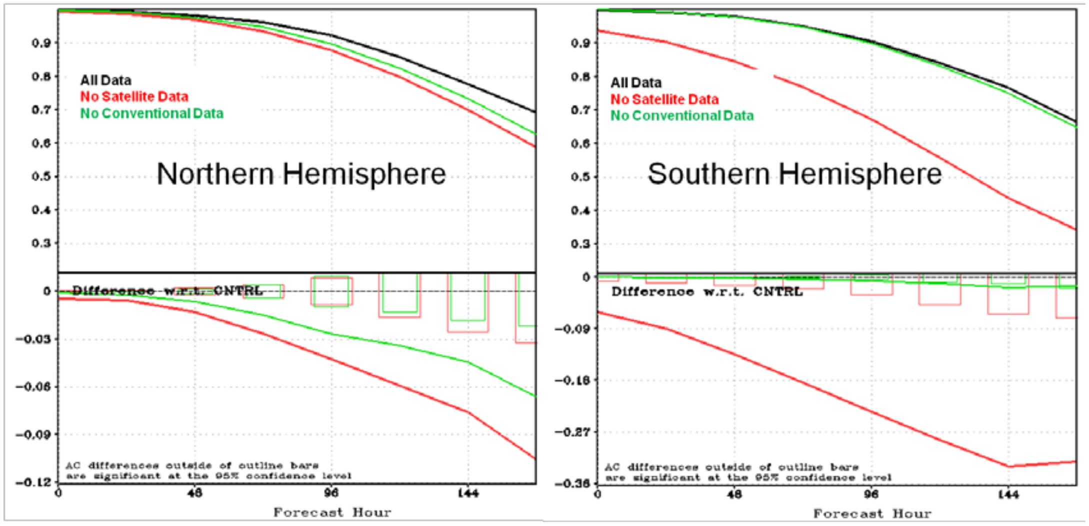
Benchmarks were performed comparing the NCEP operational GDAS /GFS to the versions installed on the JCSDA (JIBB and S4) and NOAA R&D (Zeus) computers. This benchmark was conducted at the NCEP operational resolution of T574 and included the latest addition to the GDAS of the hybrid ensembles. The latest version of the Global Data Assimilation System/Global Forecast System (GDAS/GFS) ported to the JIBB and S4 is the May 2012 NCEP operational upgrade. As the build on JIBB and S4 took longer than expected, some of the GDAS pieces were updated to newer versions than are currently being used by NCEP operations, specifically the Gridpoint Statistical Interpolation (GSI) and the global spectral forecast model. The PREP step and updated versions of the GSI and forecast model introduced more variability in a specific forecast but the overall statistics still show (right) the JIBB and S4 versions of the GDAS/GFS are statistically similar to NCEP operations.

Standard forecast skill measurements are compared between the various machines to quantify differences and similarities. The anomaly correlation time series for forecast day 5 (right) shows daily differences in the forecast skill but are statistically equivalent. The 500 hPa anomaly correlation curves (below) show very little average difference between computers, and therefore the differences are not statistically significant.



Impact of Satellite Data on Operational Forecasts

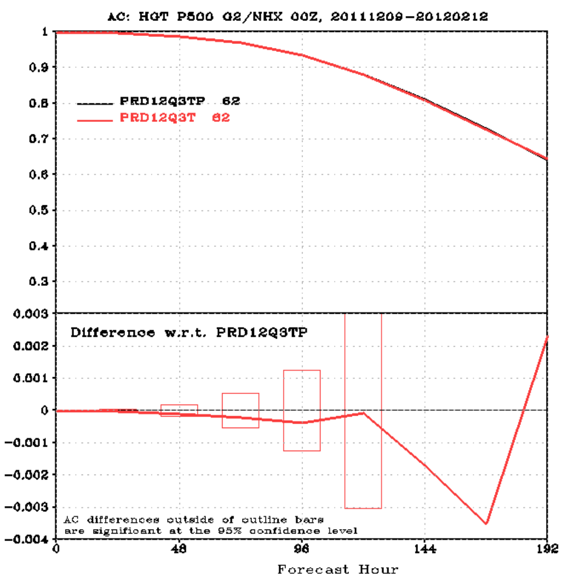
With the goal to improve NWP forecasts, much focus has been dedicated to quantifying the impact and therefore importance of satellite DA. As such, the JPSS PG team and the JCSDA looked into the impact of satellite data on NWP forecasts. The figure below shows the anomaly correlation (AC) for 500mb height calculated for the NCEP GDAS/GFS during August-September. The experiment design used the JCSDA-JIBB version of the NCEP GDAS/GFS with all operational satellite and conventional data as the benchmark. Then, one test removed all the satellite data and the other test removed all the conventional data. Differences are defined as the reduction of forecast skill observed from removing the specific data (satellite or conventional). In the Northern Hemisphere (left panel), removing the satellite and conventional data produces similar degradations in the forecast skill with the satellite data having a slightly greater impact. In the Southern Hemisphere (right panel), the removal of the satellite data causes a significant reduction in forecast skill whereas the conventional data produces only a minimal impact. This implies that satellite data plays a significant role in the quality of NOAA's global weather forecasts.



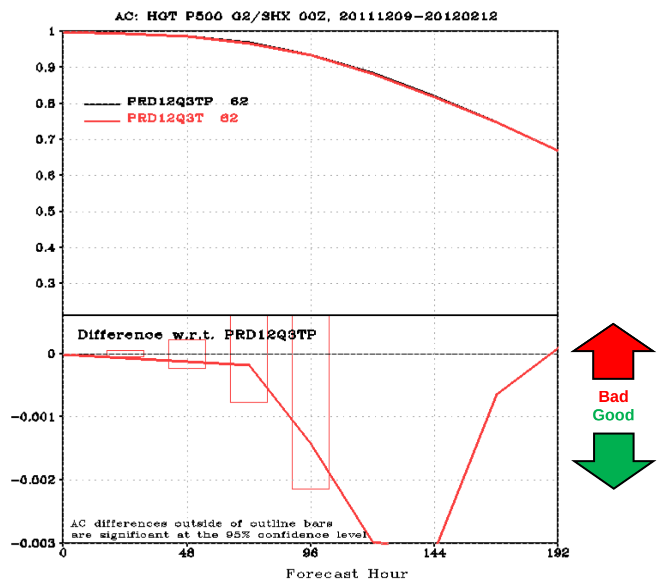
Even with the advances made in forecast skills, a lot remains to be done to help decrease the frequency of larger than normal forecast errors. The assimilation of satellite observations will be a key contribution to that improvement, given the developments made in the area of space-borne observing systems.

Preparing for ATMS and CrIS assimilation in the NCEP Global Model

The Advanced Technology Microwave Sounder (ATMS) is a 22-channel passive microwave radiometer. It observes atmospheric temperature and water vapor information throughout the stratosphere and troposphere. It provides details of vertical temperature and moisture structures throughout the atmospheric column at spatial and spectral resolutions far greater than those of its predecessors. ATMS is a cross-track scanning instrument which builds on the strengths of AMSU-A and MHS from NOAA and MetOp satellites, and includes several additional sensing channels. It has the ability to penetrate through deep, non-precipitating clouds. Therefore, with channels similar to AMSU-A/MHS, most of the AMSU-A/MHS processing can be directly applied to it. However, ATMS has different field of view (FOV) sizes and separations. The figures below (courtesy of Andrew Collard (NCEP)) show the improvements the ATMS sensor has already made on the GDAS/GFS Geopotential Height anomaly correlation, a standard measure of forecast skill and ATMS is already used by NCEP Operations



N. Hemisphere 500hPa Geopotential Height Anomaly Correlation

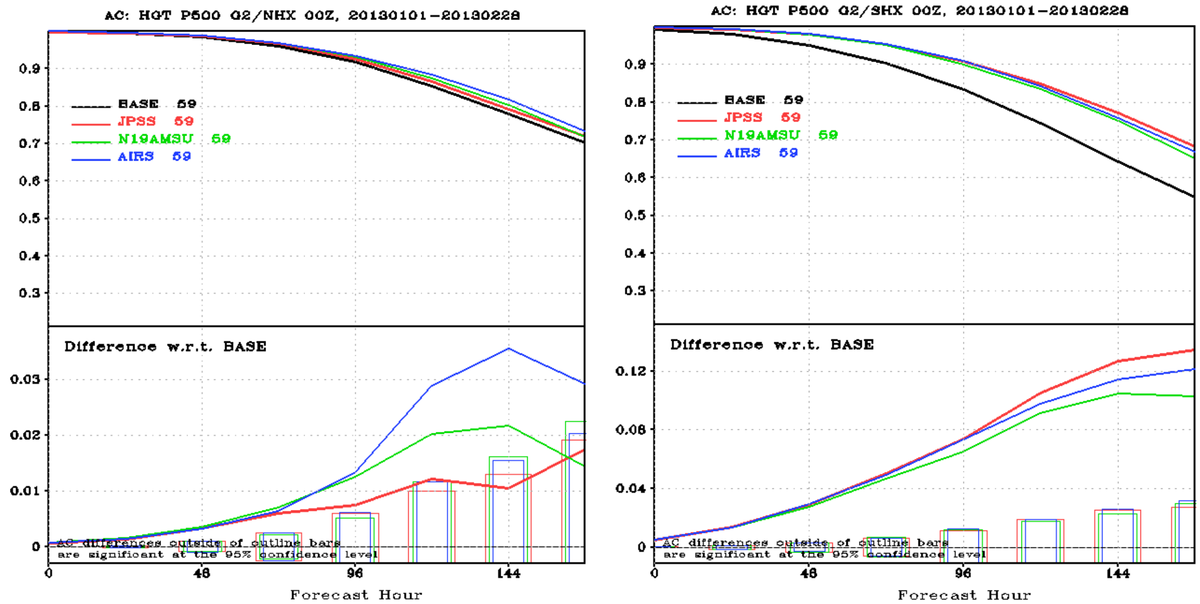


S. Hemisphere 500hPa Geopotential Height Anomaly Correlation

In addition to microwave sounders, SNPP provides infrared (IR) products from the Cross-Track Infrared Sounder (CrIS) instrument.

The Cross-track Infrared Sounder (CrIS), a Fourier transform spectrometer with 1305 spectral channels, will produce high-resolution, three-dimensional temperature, pressure, and moisture profiles. It builds on the strength of the HIRS instrument but with an improved horizontal spatial resolution and an ability to measure temperature profiles with keen vertical resolution to an accuracy approaching 1 Kelvin. This ensures its capabilities are similar to those of the AIRS and IASI instruments. The CrIS instrument is still in the testing phase and is potentially scheduled for operational implementation with the next GDAS/GFS upgrade.

The improvements shown in the figure above are relatively small because in addition to ATMS, data from five operating AMSU-A sensors on current POES and MeTOP satellites as well as data from IASI and AIRS are also assimilated. Impact studies of a single instrument are now being performed to answer some fundamental questions, including how does the impact of a single ATMS compare with a single AMSU-A/MHS? How does a single CrIS compare with a single ATMS?, and so on. The figure below shows some early results, where the baseline configuration of the GFS has no satellite data, and then experiments with single instruments are conducted. Here we can see that the impact of a single ATMS, AMSU and AIRS are all comparable.



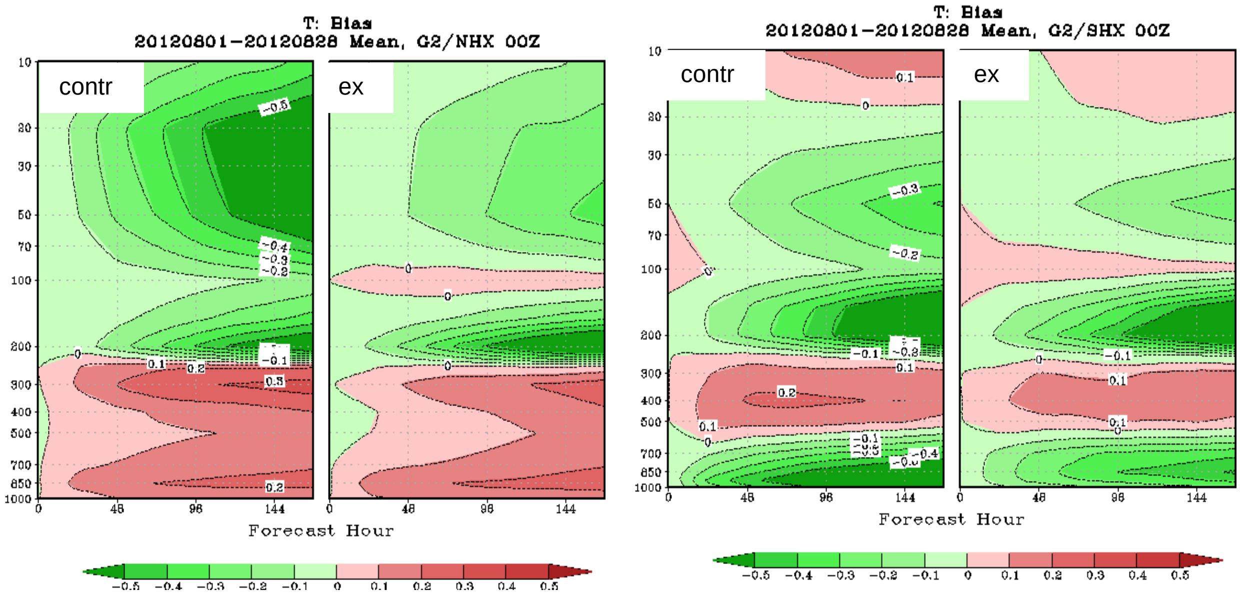
N. Hemisphere and S. Hemisphere 500hPa Geopotential Height Anomaly Correlation, Base = no satellite data, JPSS = ATMS, NOAA19 = AMSU and MHS, and AIRS is a proxy for CrIS.

Water Vapor Assimilation Experiment

This project has begun to look at the value of some of the preliminary work by the JCSDA and JPSS proving ground scientists to look at how water vapor assimilation could result in improvements in non-traditional forecast skill measurements. Water vapor is a unique greenhouse gas due to its variability throughout the atmosphere. The amount of water vapor in the air has impacts on humidity, cloud formation, precipitation as well as plant and animal life. Yet, water vapor information from satellites is one of the most under-utilized sources in NWP. Its non-linearity and multivariate nature makes it difficult (but not impossible) to use.

The example below illustrates the affect water vapor has on the radiational heating and cooling rates in the GDAS/GFS. When the water vapor concentrations are improved (more realistic) in the experiment, the daily model forecast temperature improves at almost all levels. This is shown by the decreased temperature bias and is true for both the Northern (left) and Southern (right) hemispheres.

Temperature time series



Lighter colors (near zero) are better
At almost all levels, the experiment is better in the Northern Hemisphere (left panel) and Southern

Obtaining more information from the existing water vapor channels from the CrIS through improved data assimilation techniques and channel selection will not only lead to improvements in NOAA's weather prediction models for both short and long-term forecasts, but will also improve the amount of information obtained from other sensors such as IASI, and AIRS as well. JPSS continues to work with the JCSDA, NCEP and other data assimilation groups to incorporate CrIS into NWP models, thereby maximizing the use of both SNPP sounding instruments.

Conclusion

Satellite data has a significant contribution to NWP forecast skill. The JCSDA provides a bridge from assessment to operational utilization of satellite data. The JPSS/PG science teams are working with the JCSDA to improve NWP forecasts with SNPP. Even though some issues for existing and future satellite systems remain to be addressed, a lot of progress is being made with CrIS and ATMS. These sensors offer new advancements in channel frequency, resolutions, and swath width which allow for better satellite data assimilation in NWP forecast models.

Having an operational environment and established procedures to transition research to operations is critical to improving the use of satellite data in NWP. To facilitate effective R2O activities, researchers need computing resources as well as the tools (software and computer hardware) consistent with those in operational environments. The synchronization (and regular update) of these codes to match operational software versions, as well as a solid system maintenance is critical to the success of R2O. In the R2O environment, greater collaboration between researchers and the operational science partners would ensure that researchers better understand the required procedures and protocols to follow the R2O path, such as coding standards and rigorous testing.

The O2R/R2O environment within the JCSDA has, and will continue, to aid in the transition of new sensors and improved assimilation techniques into NWS operations. ATMS has already demonstrated improvements in weather forecasting and is now part of the operational NCEP GDAS/GFS. CrIS and various improved assimilation techniques will be following this same path to NOAA operations.

Scientists continue to gain a better understanding of the atmosphere from the SNPP sensors through data assimilation. With an effective O2R/R2O environment, this knowledge will continue to lead to better weather predictions for commerce and the safety of our nation.

Section 8

NOAA CoastWatch User Engagement, Quality Assessment, Product Development, Data Distribution Portal, and Chesapeake Bay Ecosystem Modeling

The information in this article is based in part on the JPSS science seminar given by Kent Hughes and Sathya Ramachandran (NOAA/NESDIS/CoastWatch) and Tom Ihde (NOAA/NMFS Chesapeake Bay Office), on ***June 26, 2013.***

Contributing editors: Kent Hughes, Sathya Ramachandran, Tom Ihde, Mitch Goldberg, Julie Price, and William Sjoberg

NOAA CoastWatch began in 1987 by providing near real-time SST for the Mid-Atlantic following several outbreaks of Harmful Algal Bloom (HAB)—red tide — along the coast of North Carolina. It started collecting satellite data to monitor the conditions of such blooms and give coastal managers advance warning of similar circumstances. The program became operational in 1991. In the late 1990s CoastWatch began distribution of ocean color data for U.S. coastal areas and in 2005 initiated support for the National Ocean Service's (NOS) HAB Forecasts and Warning System. In 2007 CoastWatch developed NOAA's first operational biogeochemical environmental remote sensing system.

Photo obtained from NOAA Ocean Service
Credit: Kai Schumann, California Department of Public Health volunteer

CoastWatch has evolved from providing high resolution data from the NOAA's Polar Orbiter satellites to providing a variety of environmental data (i.e. SST, ocean color, winds, etc.) from multiple satellite platforms covering all U.S. coastal waters, including Hawaii and Alaska. Biologists, for example, utilize ocean color radiometry (OCR) data, derived chlorophyll-a, and total suspended matter/turbidity products to identify runoff plumes and blooms and also predict HABs.

This article presents a summary of the recent efforts undertaken by NOAA CoastWatch, between 2012 and extending into 2014, to establish and affirm the quality of the Visible Infrared Imager Radiometer Suite (VIIRS) ocean color. It also highlights the efforts made by CoastWatch to expand the role of VIIRS ocean color as the Nation's premier ocean color sensor.

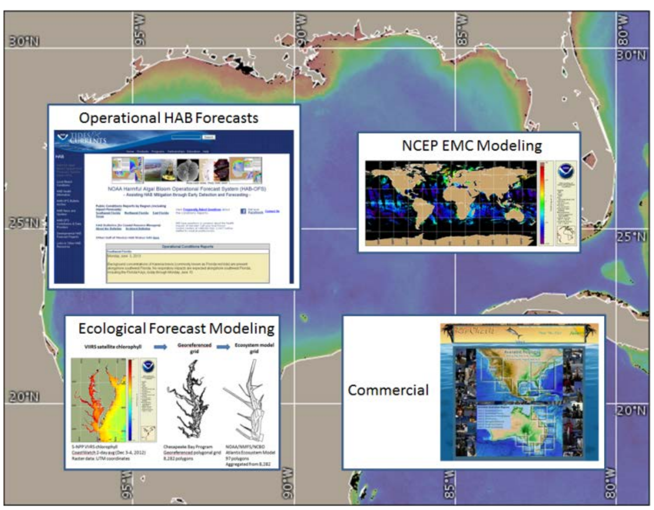
What can we learn from Ocean Color?

Phytoplankton – microscopic organisms or algae that live in the ocean's surface waters – contribute almost half of the world's total primary production, which is the process by which carbon dioxide is taken up by plants and converted to new organic matter by photosynthesis. These organisms form the base of the marine food web. Phytoplankton, however, can sometimes grow explosively, creating what is referred to as a "bloom". An intense bloom can produce harmful impacts on marine ecosystems. For example, when masses of algae die and decompose, they can deplete oxygen in the water, leading to a condition known as hypoxia, which occurs when oxygen concentrations fall below the level necessary to sustain most animal life. Furthermore, even a small percentage of algae produces powerful toxins that can kill fish, shellfish, marine mammals and birds, and may directly or indirectly cause illness in people. Satellite ocean color observations, such as chlorophyll concentration, provide measurements of phytoplankton abundance in the ocean's surface waters. In addition, related parameters derived from the satellite ocean color observations can be used to monitor harmful algal blooms (HABs), and the health of important fisheries' habitat. Advanced warning of HABs increases the options for managing similar events. Moreover, it can help scientists, resource managers and decision makers minimize harm to people and marine life. Thus, understanding HABs promotes the development of tools to help mitigate their impacts and ultimately to control or prevent them.

JPSS Ocean Color Proving Ground

The JPSS Proving Ground (PG) engages NOAA users such as the NOS, the National Weather Service (NWS), and the National Marine Fisheries Service (NMFS) for operational NOAA uses of VIIRS data. Through discussions with users, the JPSS PG is able to establish requirements for their access to ocean color data through the Thematic Realtime Environmental Distributed Data Services (THREDDS), web pages, and X-Band direct broadcast antennas. The THREDDS capability established in 2010 has quickly established itself as a premier web server to provide metadata and data access for scientific datasets. It is a package designed to make it easier for creators of scientific datasets to make them available to users. These datasets are available in a variety of formats and are spread out over many geographic locations. However, only the data essential to the datasets themselves are presented to the user. Features such as data format and location information remain transparent to the users. For data, the requirements include global products at a full-resolution of 750m, reduced-resolution products at 4km, and CONUS products at a full-resolution of 750m. Quality assurance requirements include monitoring (data flow, production, distribution), and running comparisons to MODIS, and to VIIRS algorithms.

VIIRS Ocean Color Independent Quality Assessment



Starting in 2012, NOAA CoastWatch began work on establishing and affirming the quality of VIIRS ocean color and expanding its role as the Nation's premier ocean color sensor. Among the tasks initiated and completed by the CoastWatch team was an independent user based assessment of NOAA based ocean color production. The assessment was conducted using criteria established in collaboration with the NOS. Additional quality requirements were obtained from the NMFS/Honolulu Laboratory, and the NWS/Environmental Modeling Center (EMC). The NOS, a longstanding NOAA CoastWatch data user, specifically indicated that it requires VIIRS measurement comparability to heritage measurements in operationally supported regions, and seamless line office utilization with present analysis systems. Consequently, the CoastWatch team plans to compare NOAA’s ocean color to NASA’s (Ocean Biology Processing Group – OBPG) community consensus decade-long ocean color climatology. The final selection of the algorithm to be used for operations will be decided using the NOS designated comparisons in areas of comparable bathymetry and chlorophyll concentrations.

The CoastWatch team also performed an exhaustive analysis of NOAA's requirements for ocean color data and products. As part of the process, operational, science and routine user requests were categorized and analyzed. In addition, the Coastwatch team carried out interviews with data users in NOS, NMFS and NWS to better understand and refine their user requests, and in some cases expand their requirement. Additional new user requests were obtained from the National Centers for Environmental Prediction (NCEP)/EMC.

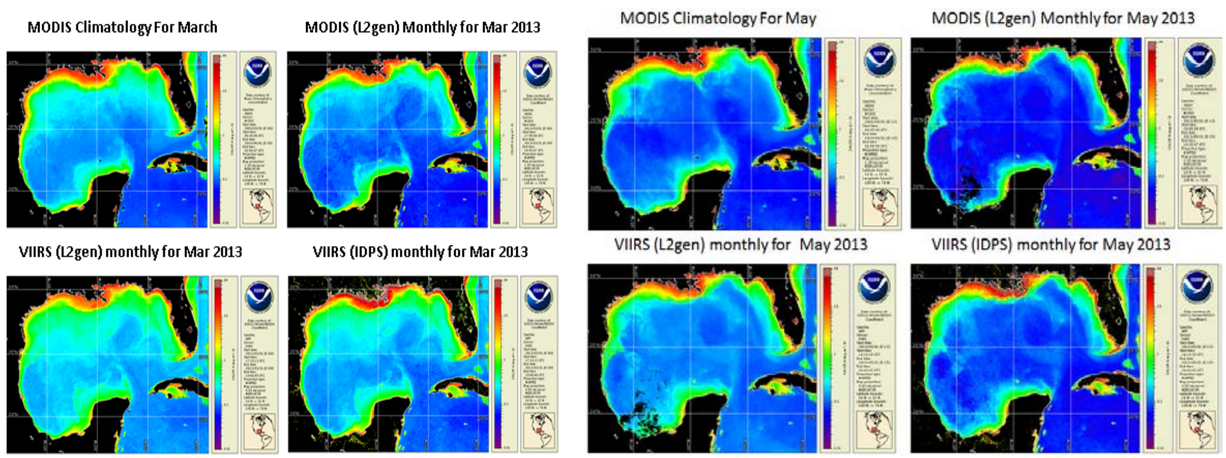
Through discussions between Ron Vogel (CoastWatch) and the NOAA Chesapeake Bay Office (NCBO) modeling team (NMFS) regarding mutually beneficial products, it was established that the fisheries management (NMFS) needed a VIIRS ocean color and temperature data application to dramatically improve the spatial and temporal resolution of the ecosystem model's input parameters and reduce the input data variability. CoastWatch, therefore has planned model runs that will focus on investigating the implications of applying the fine spatial and temporal resolution satellite data on model accuracy and precision. The NOAA Chesapeake Bay Office has developed a model, the Chesapeake Atlantis Model – CAM, based on the Atlantis software, which was developed by the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO). More details about the CAM, its predecessor the Atlantis Model, and how VIIRS will be utilized in CAMS will be discussed later in this article. NOAA researcher Ron Vogel (CoastWatch), working with NMFS/ NCBO researchers, Tom Ihde, Howard Townsend and Mejs Hasan will seek to determine whether VIIRS data improves the accuracy and variability of estimates over time as compared to those of the relatively coarse input data currently in use. The effect of these data on estimates of higher trophic level dynamics (fished and forage species) are of particular interest. The highly resolved satellite data will improve understanding of the relationships between nutrient enrichment to production to harvested species in our complex ecosystem model.

For almost two decades NASA has supported the distribution of ocean color data and products to the user community. With the advent of ownership of JPSS (beginning with JPSS-1) the responsibility for distribution of those data and products (not only ocean color but SST as well) will fall to NOAA. The CoastWatch team conducted web surveys of the community of systems that distribute data and products to operational and science communities. Results of the survey indicated the need for expansion and refinement of the NOAA distribution system to better meet users' needs. The team has completed work on the following items: the VIIRS Granule Selector, the THREDDS server for global data, and various portal enhancements. NASA has achieved remarkable utilization of ocean color data and products, and in succession, NOAA must establish and sustain comparable user requested ocean color products and services.

The CoastWatch team has thus far demonstrated the capability to sustain and distribute global products, at 750m and 4km, including chlorophyll-a and selected NOAA unique anomaly products needed for NOAA operational applications such as the transition of Okeanos – a flexible, expandable software system for generating CoastWatch operational ocean color products – from experimental status to operational. A primary example from Okeanos is the HAB Anomaly (chlorophyll-a) for the Gulf of Mexico in support of the NOS HAB Forecast and Warning Bulletin. For the Marine Optical Buoy Operations (MOBY), ocean color calibration necessary for satellite calibration and product validation have been performed. And, as of June 2013 NOAA's suite of experimental ocean color data and products has been freely and openly distributed via the Center for Satellite Applications and Research (STAR) Thredds server. These are essential to establishing and maintaining data and product quality, intercomparability, and user acceptance.

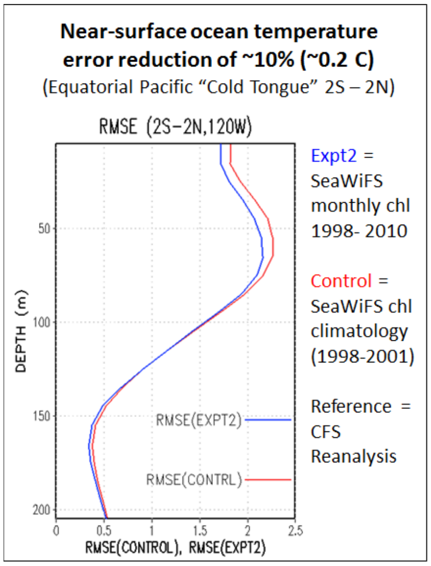
Applications

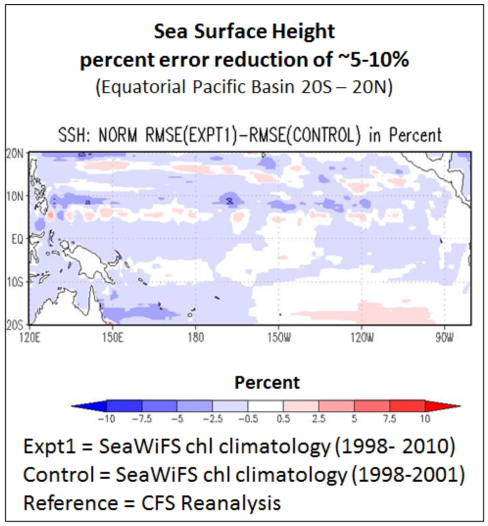
As mentioned above, satellite ocean color helps to track the location and movement of HABs. Daily anomalies of chlorophyll concentration reveal areas of high phytoplankton presence. Combining this information with other environmental and in-situ data, NOS issues weekly bulletins and HAB conditions reports for the Gulf of Mexico so that coastal resource managers can assess the impact of the toxic HABs on public health and living resources.



Chlorophyll images from various algorithms (MODIS – top, VIIRS – bottom)
Red and yellow areas indicate high, green intermediate, and blue low chlorophyll concentrations.

Phytoplankton alter the penetration of solar radiation in the upper layers of the ocean, which affects the vertical distribution of heat, near surface heat content, and the surface heat flux. The current NCEP ocean models use a very limited climatology of SeaWiFS chlorophyll, but the EMC plans to improve the ocean models used in weather forecasting (WF) by incorporating near real- time satellite chlorophyll. The operational near real-time use of VIIRS chlorophyll will properly represent temporal change of upper ocean heat distribution, and vastly improve the upper-ocean heat content and buoyancy flux of the Hycom ocean circulation model used in the NWS Real-Time Ocean Forecast System (RTOFS).





Source: E. Bayler, S. Nadiga, A. Mehra, D. Behringer

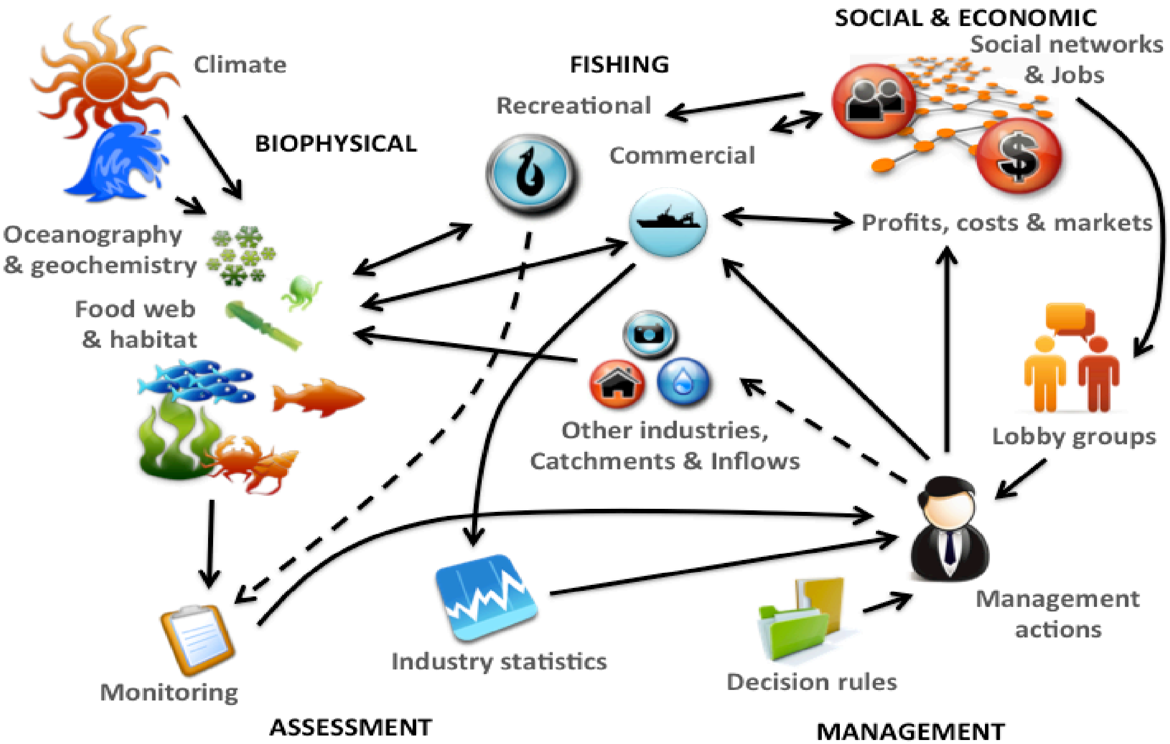
GODAS/CFS improvement (MOM4 Ocean Model, currently with SeaWiFS climatology

Initial results of two experiments (see figures above) using SeaWiFS climatological data have indicated quantitative improvements in reduction in near-surface ocean temperature errors on the order of 10% and sea surface height error reduction on the order of 5-10%.

The Atlantis Ecosystem Model

Atlantis is a whole-system modeling approach which has primarily been used to address fisheries management questions (e.g. appropriate strategic management options for regional fisheries). This approach is now increasingly being used to consider other facets of how marine systems function. Developed by the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) – Atlantis integrates data from a variety of aspects of the environment including climate, tides, currents, nutrients, geology, chemistry, food web interactions, fisheries harvests, human uses, and economics, which helps decision makers to evaluate trade-offs of societal decisions.

The model attempts to include as much of the environment as possible. Recent efforts by NOAA include applications on both the West and East Coasts. On the West Coast, Atlantis has been applied to model the California Current ecosystem. This work has proven useful for testing ecological indicators, setting federal (both sanctuary and fishery council) management for marine protected areas in an ecosystem context, and evaluating effects of individual transferable quotas.

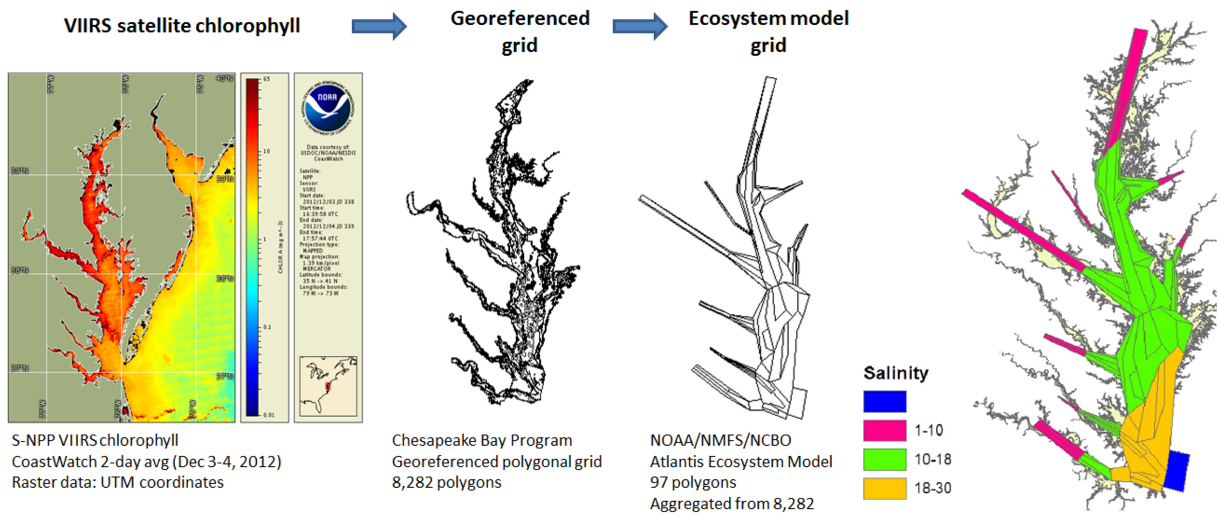


Atlantis is the most detailed full-system model available for fisheries production. It is a multi-dimensional simulation model that incorporates nutrient inputs, physical dynamic forcing, biological, habitat and trophic interactions. It also incorporates feedbacks and estimation of system change over time and space, and integrates diverse data collected at a variety of spatial and temporal scales.

CoastWatch and NMFS are conducting experiments for utilizing satellite chlorophyll in the Atlantis ecosystem model. If satellite chlorophyll can improve the model accuracy, better forecasts of fisheries stocks will be available for fish stock assessments and living marine resource management.

There are a variety of important benefits to developing the Atlantis model for the Chesapeake Bay. This initiative has resulted in the creation of the Chesapeake Atlantis Model (CAM). This work allows for the exploration of the ecosystem effects of environmental changes, policy options and management strategies. Furthermore, it lends itself to the exploration of a wide variety of different scenarios of interest to management. Once the CAM model is fully developed, a wide variety of topical questions can potentially be explored. For instance, what will be the likely ecosystem effects of loss/gain of marsh habitat, or of blue crab? Or the ecosystem effects of increasing/decreasing nutrient input, or of increasing population size along the coasts of the Chesapeake? These types of questions can be explored with the Atlantis approach, and importantly, such questions can be explored by area, because Atlantis is a spatially explicit modeling approach. Through CAM, researchers will be able to test the effects of the vastly improved spatial and temporal resolution of chlorophyll a and total suspended solids (TSS) data on model predictions. In addition, it will enable them to capture/ model system effects of episodic events, and to minimize lower trophic-level errors & consequently, limit error propagation.

Underlying the usefulness of model forecasts is the availability of pertinent data; consequently, another important use of CAM will be to help identify and prioritize the most critical needs for research within the Chesapeake Bay ecosystem.



Schematic diagram showing the steps in the conversion of VIIRS satellite data in CoastWatch-HDF format to the Atlantis ecosystem model grid. The conversion process enables satellite data to be used as input to the Atlantis ecosystem model for Chesapeake Bay fisheries modeling.

The real power of the Atlantis approach is for informing decision-makers with most current science for system effects likely to result from their policies. For example, a wide variety of estimates for populations and habitats are made simultaneously; predictions are on the same scale, and thus allow decision-makers to consider trade-offs on a "level playing field." Since system feedbacks between components are also modeled within the Atlantis framework, CAM also captures cumulative, non-linear & non-intuitive system effects that might not be anticipated by decision-makers. In addition, results can be aggregated to whatever level is of interest -- geographically, or by ecological group of interest -- resource managers can make better, science-informed, ecosystem-based decisions. The socioeconomic module for example, provides managers with integrated information on fisheries populations, the effects on economies, different fishing groups, and the effects of management strategies like MPA's or catch shares.

Conclusion

In the first year alone, the CoastWatch Proving Ground has interviewed the existing NOAA Program Users (NOS and NMFS) and engaged new NOAA Users (NWS/NCEP, and Commercial). It has also expanded and strengthened user requests. CoastWatch performed an independent user driven quality assessment and provided the user community with some recommendations such as the IDPS product for global ocean operations.

The JPSS Proving Ground projects ensure continuity of heritage and other NOAA unique products using VIIRS OCR data; independently assess data/product quality and ensure end user utilization. Through the JPSS Proving Ground, requirements for data access, quality assurance, and global products have been established. While the development process is not yet defined, new users and new uses continue to be explored and developed, and the need for new product continue to emerge. Data distribution portal enhancements are rolling out, with more to come. Significant development is expected in the coming years for utilization in NWS/NCEP and NMFS application areas. Through support from the JPSS PG, CoastWatch is exploring the use of SNPP data in models such as the Atlantis Model. Through this work, CoastWatch will be able to determine whether VIIRS data improves the accuracy and variability of estimates over time, as compared to those of the relatively coarse input data currently in use. SNPP data is also expected to be used in the Chesapeake Atlantis Model. Through CAM, researchers will be able to test the effects of the vastly improved spatial and temporal resolution of chlorophyll a and total suspended solids (TSS) data on model predictions.

Section 9

JPSS Proving Ground Hyperspectral Sounder Applications: Enhancing Real-Time Applications and Decision Making

The information in this article is based in part on the JPSS science seminar given by Elisabeth Weisz, William L. Smith Sr., and Nadia Smith, Space Science and Engineering Center, University of Wisconsin-Madison, on ***July 22, 2013.***

Contributing editors: Elisabeth Weisz, William L. Smith Sr., Nadia Smith, Mitch Goldberg, Julie Price, and William Sjoberg

Accurate retrievals from hyperspectral sounder radiance measurements under both clear and cloudy sky conditions are becoming indispensable sources of mesoscale information in a wide range of applications. Important for a variety of applications (e.g. forecasting and climate research), the new generation of hyperspectral sounding instruments measure top of atmosphere radiance along the full infrared spectrum with several thousand channels, which are sensitive to temperature, water vapor and trace gases at different heights in the atmosphere. Researchers use the radiance measurements to retrieve vertical profiles of atmospheric conditions (e.g. temperature and humidity), as well as cloud parameters (e.g. cloud height, temperature and optical thickness), wind speed and surface conditions (e.g. temperature and emissivity).

This article provides an overview of current research at the University of Wisconsin supported by the JPSS proving ground (PG) program regarding possible real-time applications of retrievals from polar-orbiting sounders. It presents an overview of the research on the value and applicability of retrievals from multiple sounders in high latitude regions (such as Alaska). A multi-instrument approach allows an increased frequency of atmospheric profile, cloud and surface retrievals and this holds great potential for the analysis of severe weather events such as the Enhanced Fujita (EF)-5 tornado that struck Moore, Oklahoma. The EF scale rates the strength of tornadoes in the United States and Canada based on the damage they cause. EF-5 is the highest category, which is given when wind speeds are estimated to be over 200 mph.

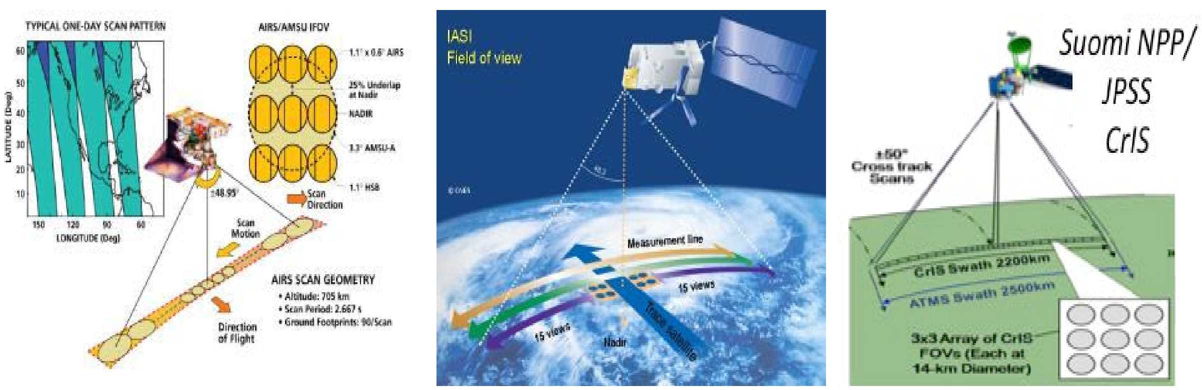


Figure 1: Polar-Orbiting Hyper-Spectral Sounders

NOAA's ability to issue timely and accurate forecasts for all kinds of high-impact weather is facilitated by the sounder data that is assimilated from the current fleet of operational satellites. The University of Wisconsin through the JPSS PG program is utilizing the four satellites in Polar orbit carrying hyperspectral sounding instruments, to develop a variety of polar satellite sounder applications for high latitude regions such as Alaska and also for high-impact weather events. The sensors are: AIRS (Atmospheric Infrared Sounder) on Aqua, CrIS (Cross-Track Infrared Sounder) on the Suomi National Polar-orbiting Partnership (SNPP) and IASI (Infrared Atmospheric Sounding Interferometer) one on each of Metop-A and Metop-B. These applications are made possible through application of the dual-regression retrieval algorithm to hyperspectral radiance measurements from any of the four sounders. The dual-regression retrieval algorithm, developed at CIMSS/University of Wisconsin, is accessible to a broad community of users through the Community Satellite Processing Package (CSPP), which can be downloaded from http://cimss.ssec.wisc.edu/cspp/. CSPP is a software system for processing Direct Broadcast (DB) data from polar orbiting meteorological satellites. It supports the DB satellite community through the packaging and distribution of open source science software.

The dual-regression retrieval algorithm retrieves quantitative information about the atmosphere from high spectral resolution radiance measurements and when used in conjunction with high spatial resolution visible imagery and products from broadband imagers such as the Visible Infrared Imaging Radiometer Suite (VIIRS) interpretation of events is greatly enhanced. This regression based retrieval algorithm permits a real-time and efficient acquisition of the current atmospheric conditions for the analysis of localized atmospheric temperature and moisture variation, cloud properties, atmospheric stability, as well as time tendencies from consecutive overpasses. These sounding retrievals provide 3-d structures of storm systems, which can enhance real-time applications and decision making. The data from these numerous satellite provides outstanding opportunities to evaluate rapidly changing weather events/outbreaks. These opportunities will diminish as satellite sounders cease operations without being replaced.

To encourage the operational use of hyperspectral retrieval data in NOAA's National Weather Service (NWS) forecasting offices the retrieval products are currently prepared for near real-time viewing and analysis through the Advanced Weather Interactive Processing System (AWIPS).

The frequency of overpasses by polar-orbiting satellites is larger in high latitudes, creates almost geostationary-like sounding information. However, hyperspectral retrievals obtained at lower latitudes (e.g. over CONUS) also provide valuable information about the atmospheric state and therefore indicate great potential value to many remote sensing applications. Examples of how weather forecasters have leveraged the multiple satellite instruments available are presented in this article.

Moore Oklahoma Tornado

On May 20, 2013, a supercell thunderstorm spawned a large destructive tornado that struck Moore, Oklahoma, and caused extensive EF5 damage, substantial loss of life, and hundreds of injuries. An EF5 tornado is an extremely rare event. According to the NWS records there have been 14 EF5 tornadoes recorded in Oklahoma in 108 years. Moreover, only one in 1,000 tornadoes achieve deadly EF5 status with wind gusts greater than 200 miles per hour. Thus, Moore was a unique situation, and the multiple satellite passes provided valuable data of opportunity, insightful information, and images of this rare severe weather event. Six days before the tornado struck, data from sounder instruments onboard polar-orbiting satellites

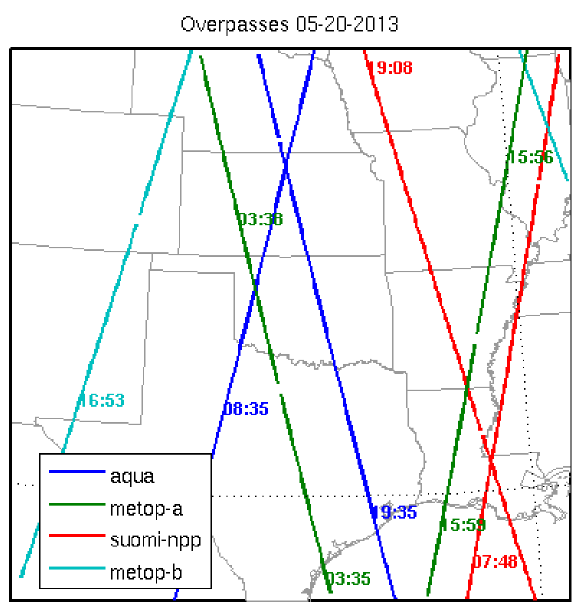
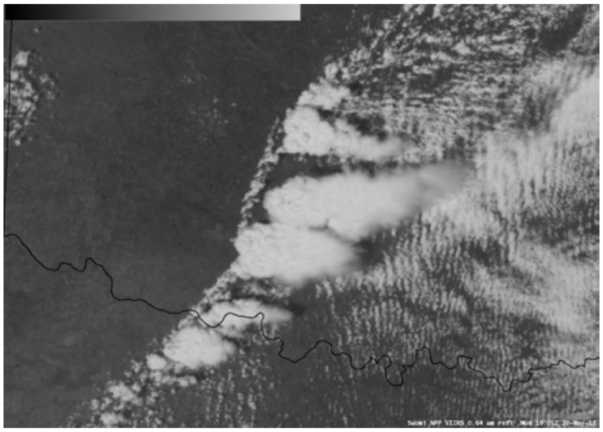


Figure 2: Satellite passes over Moore, Oklahoma

helped NOAA forecasters accurately pinpoint areas where the atmospheric conditions were prime for severe weather. As 20 May approached, the value of polar-imagers became obvious. Fig 2 shows the number of satellite passes over the Oklahoma area right as the severe weather began to develop.



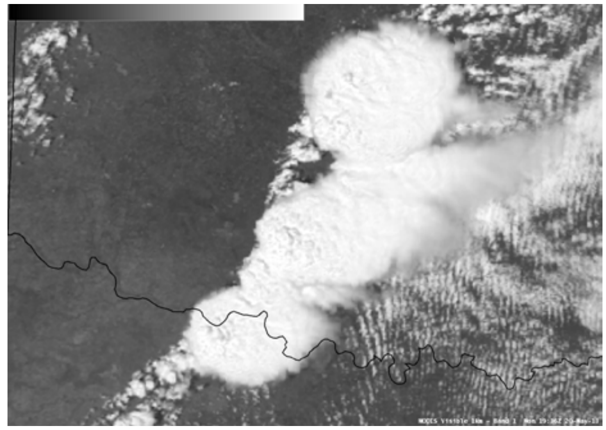


Figure 3: Suomi NPP VIIRS 0.64 µm visible and 11.45 µm IR channel

Aqua MODIS 0.65 µm visible and 11.0 µm IR channel

Above is an AWIPS comparison of 1-km resolution SNPP VIIRS 0.64 µm visible channel and 11.45 µm IR channel images about an hour before the tornado arrived in Moore (Fig 3 on the left) revealed the presence of shadowing from overshooting tops and cloud-top IR brightness temperatures as cold as -68º C. About 30 minutes prior to the Moore tornado, a comparison of 1-km resolution Aqua MODIS 0.65 µm visible channel and 11.0 µm IR channel images (Fig 3 on the right) again indicated signatures of vigorous overshooting tops, with cloud-top IR temperatures as cold as -76º C.

On the fateful day, meteorologists issued warnings 16 minutes before the EF-5 tornado touched down, allowing some residents to seek out safety. Four days prior to the weather event, NWS forecasters began issuing the alarm for a potential severe weather breakout for central Oklahoma. Years ago, the residents of Moore would have likely had no idea that a tornado was coming until it was sighted, giving people barely a moment's notice. Following his tour of the areas damaged by the tornado, President Obama met with NWS staff from the Norman, Oklahoma Forecast Office and the Storm Prediction Center (SPC). He praised NWS forecasters for their efforts in issuing timely and accurate forecasts, watches and warnings ahead of the tornado.

Super storm Sandy

In figure 4, Cloud Top Pressure (CTOP) and Brightness Temperature (BT) retrievals of Super storm Sandy were created using data from the CrIS and AIRS sounder instruments. These retrievals provide a quantitative interpretation of the VIIRS (Top right), and MODIS Vis and IR images (Bottom right).

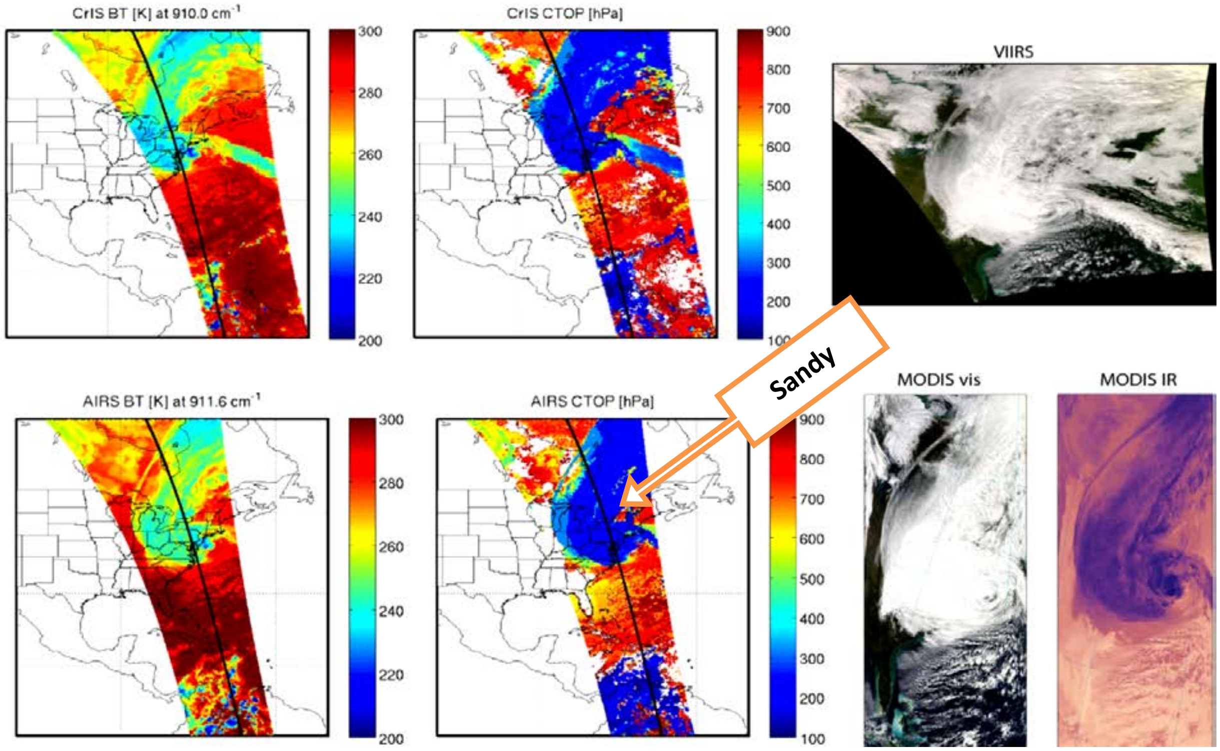


Figure 4: Hurricane Sandy (29 Oct 2012). The CrIS BT and CTOP products (Top left and middle), and the AIRS BT and CTOP products (bottom left and middle), provide a quantitative interpretation of the VIIRS (Top right), and MODIS Vis and IR images (bottom right)

Alaskan Region (AR) Applications

The hyperspectral sensors are even more important in providing high temporal resolution sounding and imagery for the Alaskan region. The JPSS PG Program has been working with Alaska to use this data to improve their situational awareness of current weather conditions. Alaska's lack of radar, surface stations, and upper air sounding coverage makes satellite data critical to its environmental support missions. The sounder data provides quantitative interpretation of weather imagery (e.g., the altitude of cloud and moisture features). High temporal frequency of polar satellite soundings at these latitudes can be critical to the observation of atmospheric tendencies (e.g., stability change) and moisture flux and wind profiles. The figure on the right shows the frequent satellite overpasses that often provide the key input for tracking dangerous winter storms as they quickly transverse the area. Through the JPSS PG projects work is being done to determine the best application of sea surface and land temperature, atmospheric stability tendencies, and moisture flux observations. The goal is to ensure that this type of data becomes a cornerstone of the NWS's "Warn on Forecast" system designed to provide earlier warnings of severe weather.

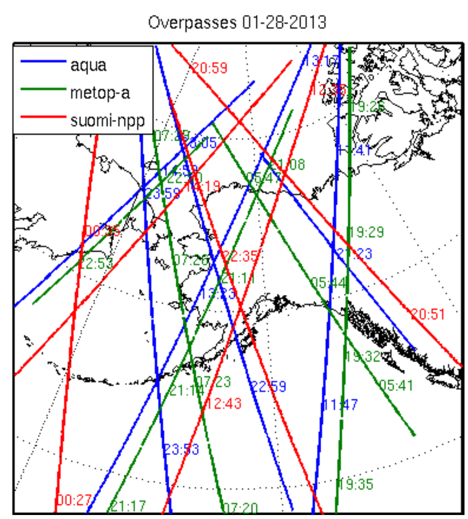
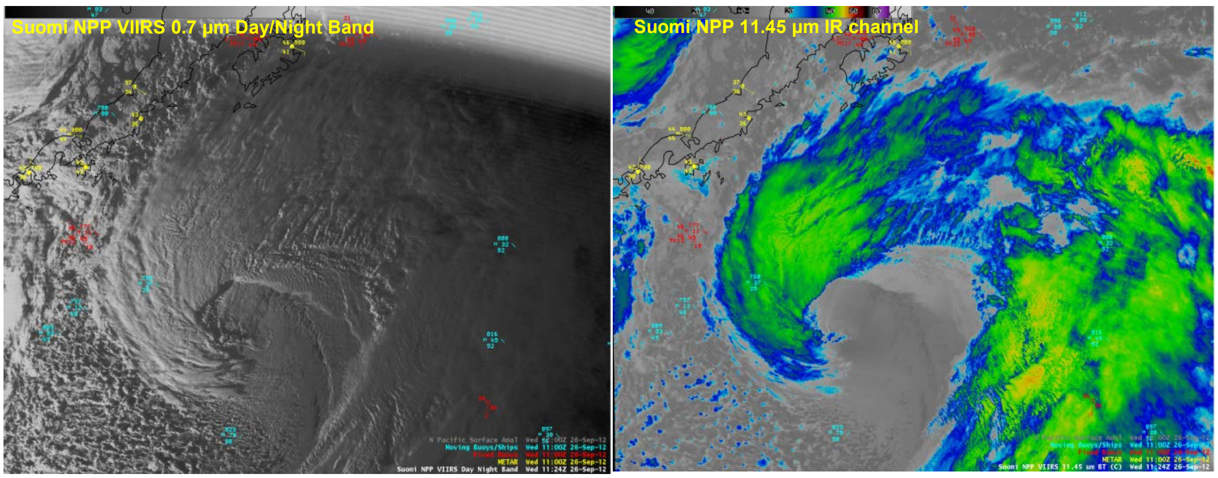


Figure 5: 28 Jan 2013 – AQUA, Metop-A, and SNPP passing over Alaska

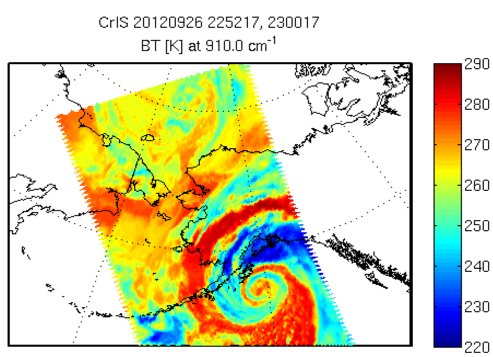
An example of this type of application is shown below. A cyclone rapidly intensified (deepening from 1002 millibars (mb) to less than 960 mb in 24 hours) in the Gulf of Alaska on 26 September 2012, and was expected to produce hurricane-force winds and high seas. That magnitude of rapid intensification is rare even for strong hurricanes, and far exceeds established criteria for so called “Bomb Cyclogenesis” which is 23 mb of deepening in 24 hours at 55 degrees latitude. The storm, which at its strongest was at 952 mb (28.11 inches), built up high seas throughout the Gulf of Alaska.



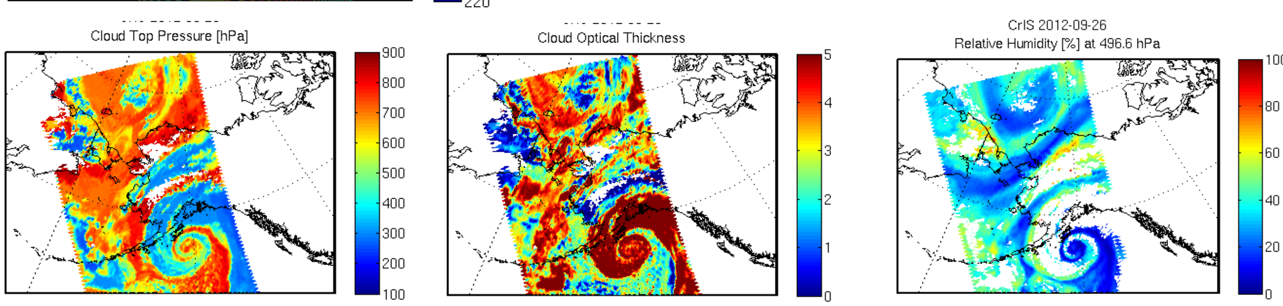
http://cimss.ssec.wisc.edu/goes/blog/archives/date/2012/09/26

Figure 6: Powerful Gulf of Alaska Storm

The images above are an AWIPS comparison of Suomi NPP VIIRS 0.7 µm Day/Night Band (top left) and 11.45 µm IR channel (top right) at 11:24 UTC which show great detail to the cloud features as the storm began to exhibit a classic “cusp” signature as rapid intensification was underway (IR image with surface analysis overlay).



The bottom three panels in this image show cloud and water vapor profile products derived from the CrIS hyperspectral sounder data which provide a quantitative interpretation of the VIIRS high spatial resolution cloud images (Fig 6).



Conclusion

The accuracy and reliability of weather forecasts has come to depend on the availability of, and rapid access to, satellite observations. To bolster the amount and quality of data available to operational forecasters, NOAA has teamed with several domestic and foreign research and operational satellite programs. For example, the University of Wisconsin through the JPSS PG program uses hyperspectral measurements from polar orbiting infrared sounders such as AIRS (Atmospheric Infrared Sounder) on the Aqua NASA program, and IASI (Infrared Atmospheric Sounding Interferometer) on EUMETSAT's Metop-A and Metop-B. By working together these partners have been able to develop a variety of polar satellite sounder applications for high latitude regions such as Alaska and for assimilation into the forecast models providing essential long-term forecasts for high-impact weather events.

The DR retrieval algorithm can be applied to AIRS, IASI or CrIS radiances. It provides accurate sounding profiles, surface and cloud parameters under any sky condition (anywhere on the globe twice daily per instrument); it can provide data rapidly through direct broadcast; and it is easily accessible to a broad community of users through the CSPP. The examples documented in this article have shown that this data is proving to be a vital tool to forecasters as they grapple with the rapidly-changing weather conditions in remote areas of the globe.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Section 10

Suomi NPP VIIRS Day/Night Band: A New Dawn to Nocturnal Remote Sensing

The information in this article is based in part on the JPSS science seminar given by Steven D. Miller (Cooperative Institute for Research in the Atmosphere (CIRA)), Colorado State University, on ***August 19, 2013.***

Contributing editors: Steven D. Miller, Mitch Goldberg, Julie Price, and William Sjoberg

The Not-So-Dark Night...

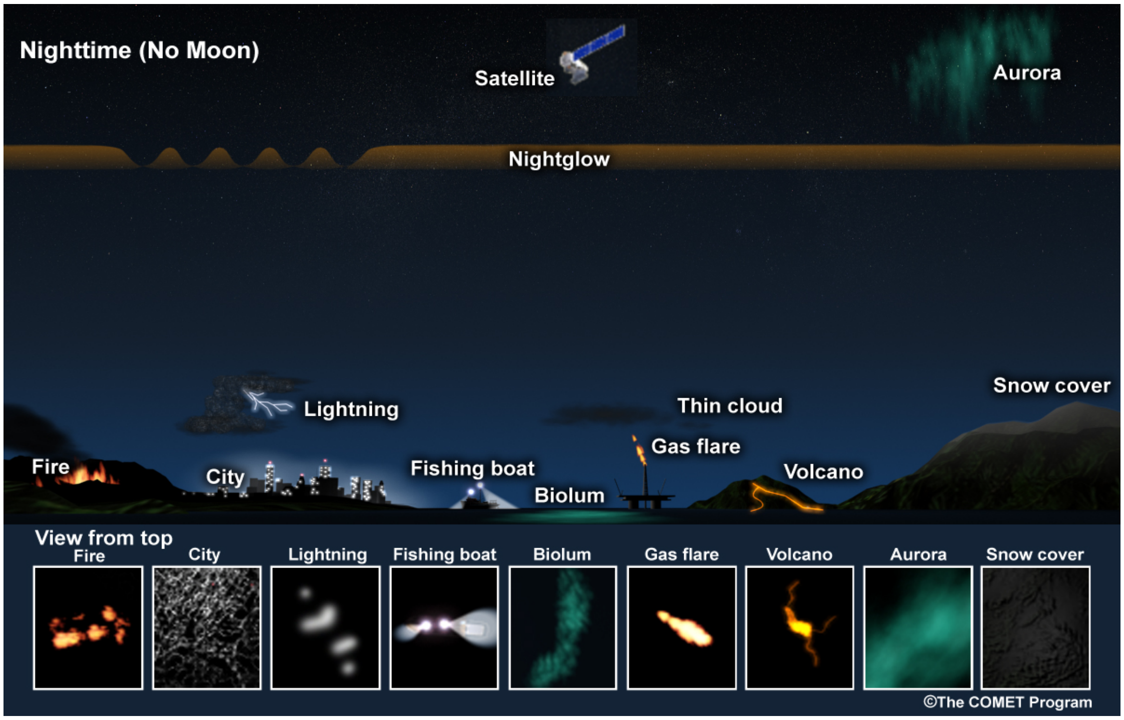


Figure 1: Revision to the nighttime low-light visible source inventory, based on interactions between S. Miller (CIRA) and S. Deyo (COMET). Notably, the presence of nightglow is now illustrated, including its occasional modulation by tropospheric effects such as strong convection.

Many environmental satellites are equipped to look at the Earth under day time conditions, using the Sun's illumination. When the Sun goes down, observations at visible light wavelengths typically are rendered useless. The Visible Infrared Imager Radiometer Suite (VIIRS), onboard the Suomi National Polar-orbiting Partnership (SNPP) satellite, features the first fully calibrated low-light visible-band sensor known as the Day/Night Band (DNB) that redefines the meaning of 'darkness' and transcends many of the traditionally understood limitations of nighttime environmental sensing. The DNB revolutionizes nighttime remote sensing capabilities by leveraging reflected moonlight to sense clouds, fog, and surface features such as snow cover, in addition to emitted light from cities, fires, gas flares, and other sources never before considered.

This article presents a brief survey of the VIIRS DNB sensor and some of the fundamental capabilities enabled by sensitivity to very low levels of visible light at night, including examples of clouds/fog, dust/aerosols, fires, lightning flashes, snow cover, sea ice, human settlements, and the unprecedented ability to produce a form of visible imagery on moonless nights via the atmospheric nightglow. A model for the calculation of lunar irradiance (necessary for quantitative nighttime applications) and its preliminary application to the retrieval of cloud optical depth at night is also presented. Of particular relevance are the operational impacts at high latitudes (i.e., the Arctic and Antarctic Regions) especially during the winter months where the challenges related to nighttime environmental characterization are mostly felt. This is also when visible channels are rendered unusable. Even though passive thermal-band sensors can detect some environmental parameters at night they face inherent physical limitations on sensitivity. For example, satellite measurements in the near-infrared 3.9 µm band (coupled traditionally with the 11.0 µm band as a means to detecting low clouds and fog) lose sensitivity over very cold surface temperatures. Here, nighttime moonlight reflectance measurements, enabled by coupling DNB radiances with lunar irradiance predictions, would in certain cases provide the necessary contrast for feature detection (particularly over snow/ice-free backgrounds). In terms of snow/ice detection, limited IR sensitivity and the relatively coarse spatial resolution of passive microwave bands translate to the loss of important structural details at night. In addition, biomass smoke plumes, which are readily observed during the day, are mostly transparent at IR bands and so go undetected at night; there are numerous examples of DNB detection of biomass smoke plumes.

The Lunar Irradiance Model

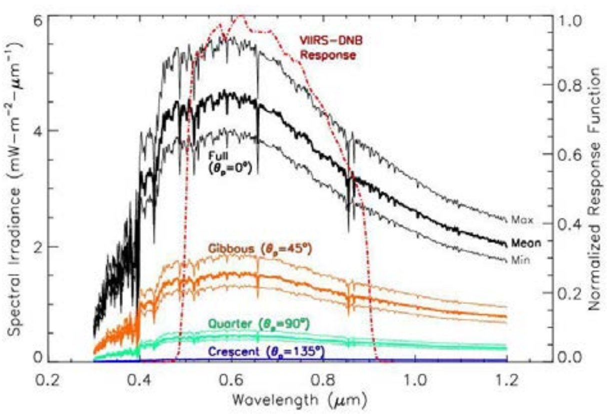


Figure 2: Lunar irradiance model output, showing highly variable magnitude as function of lunar phase

The lunar irradiance model, which is applicable to night (astronomically dark conditions) only, is useful for both qualitative and quantitative applications. Qualitatively, it can be used to compute an equivalent reflectance which, when presented as imagery, brightens and improves the quality of images as if the moon were full and directly overhead. It is a form of near constant contrast (NCC) imagery, meaning that the image looks the same regardless of the lunar phase or elevation. The model takes into account the sun, lunar, and earth geometry to correct images for elevation angle and phase, turning a difficult to interpret image – for example one taken during the crescent moon phase and at a low elevation angle – into a vivid bright useful image, thereby dramatically increasing the level of detail. This greatly extends the usefulness of the data and makes it a much more viable forecasting tool. In addition, the availability of reflectance data enables calculation of cloud and aerosol optical depth, among other environmental parameters that require visible reflectance. The unprecedented capability to track the diurnal properties of marine stratocumulus clouds—limited by infrared bands due to lack of sensitivity—is now in development.

The VIIRS Day-Night Band; Improvements over Legacy Capabilities

The DNB sensor builds upon the low-light visible technology from the Defense Meteorological Satellite Program's (DMSP) Operational Linescan System (OLS), which was developed in the late 1960s. Some prominent advances in the SNPP DNB technology over the OLS include significantly higher spatial and radiometric resolution. The DNB's 742 m resolution results in dramatically higher city light detail compared to the OLS as shown in figure 3. This new technology has effectively 45 times better spatial resolution than the OLS, 14 bit depth (16,348 levels of information) compared to 6 bit depth (64 levels), and is accompanied by numerous other near- and thermal-infrared bands on VIIRS that allow for novel multi-spectral applications (in contrast to the OLS which only offered one accompanying thermal infrared window band).

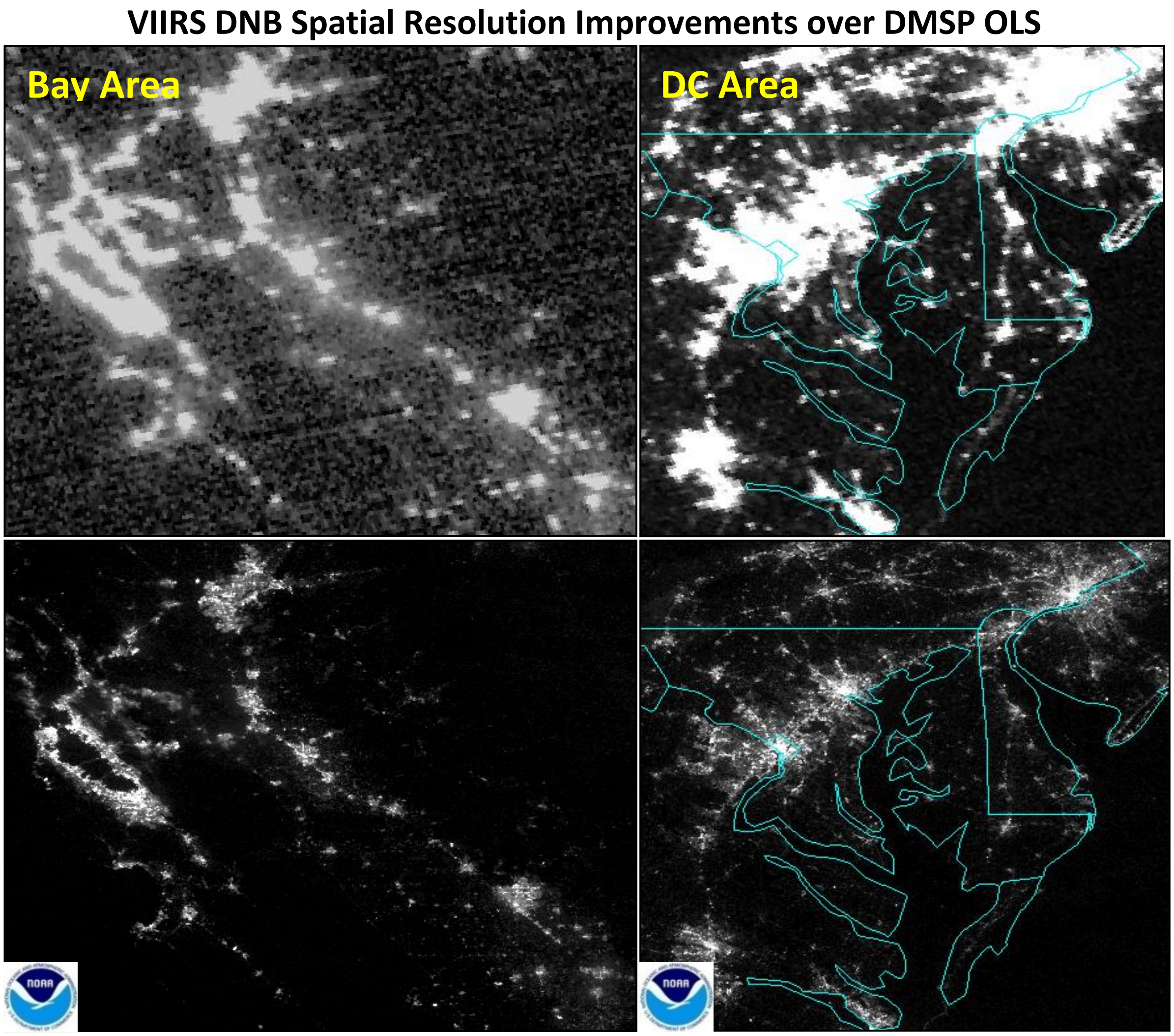


Figure 3 highlights the improvements in the VIIRS DNB 742 m resolution over the DMSP OLS, and in particular how the DNB shows much higher city light detail compared to the OLS. The lights in the San Francisco Bay Area (lower left panel) and Washington D.C. area (right panel) appear blurred in the OLS images (top left and right panels).

The DNB also provides the first calibrated nighttime visible measurements – the process of converting the DNB sensor output signal (in digital numbers) to physical units of radiance, using traceable calibration sources. Unlike OLS instruments, VIIRS has onboard calibration devices for all bands to ensure the accuracy and stability of the measurements. Onboard calibration ensures instrument performance while in orbit. It is achieved using reference targets onboard the satellite such as solar diffuser or blackbody for calibration. In the case of the DNB, the solar diffuser is used to calibrate the low gain stage of the sensor, and this calibration is transferred to the middle-gain and high-gain stages at the terminator to yield calibrated radiances on the terminator and nighttime sides of the SNPP orbit.

Nighttime Cloud Detection and Properties

An immediate benefit of low-light visible measurements is the improved ability to detect low clouds, particularly when they occur over regions where conventional nighttime infrared-based techniques experience challenges. For example, low clouds may blend in with surrounding clear sky backgrounds which are of similar temperatures, and mid-level clouds may likewise go undetected when surface skin temperatures are very cold (e.g., nocturnal temperature inversions). The multi-spectral infrared techniques often used for cloud detection do not always work in situations where emissivity differences are low (e.g., for large particle sizes near cloud top) or when optically thin cirrus is present. Here, lunar reflectance can play an essential role in detecting these clouds.

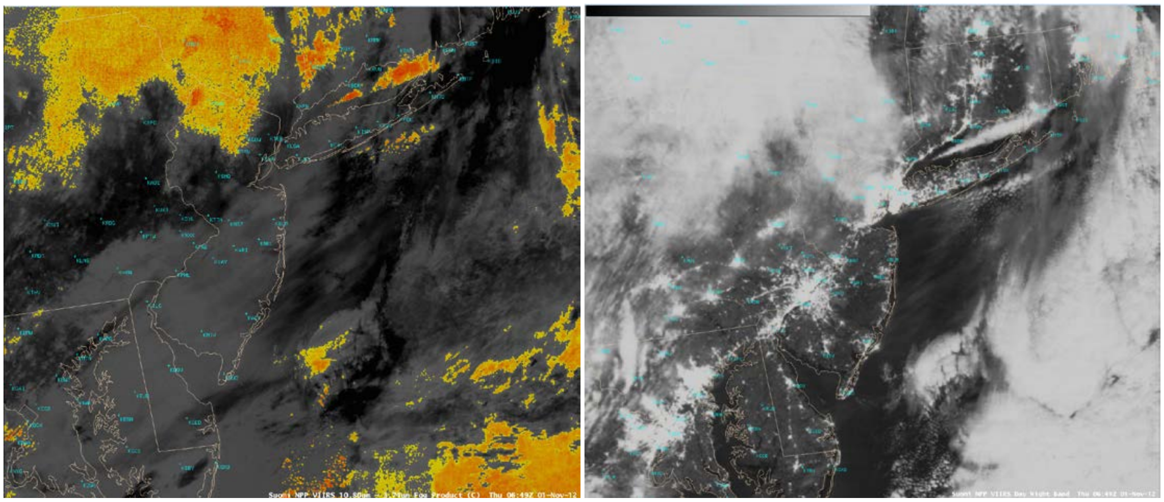


Figure 4: Cloud mask: The images above show an example how DNB can improve cloud detection. The left image shows difference M12 (3.75um) – M15 (11um) brightness temperature, one cloud test in the current cloud mask. Water clouds appear yellow and red. The right image shows VIIRS DNB, where water clouds are very bright. The DNB can detect low-level clouds which are often missed in IR.

Courtesy: Andi Walther, Andrew Heidinger, Steven D. Miller

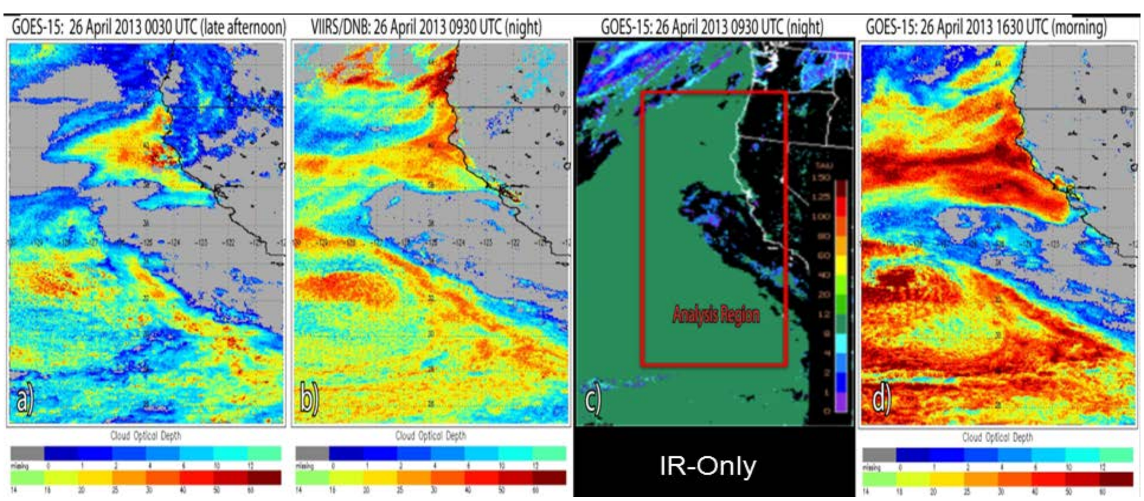


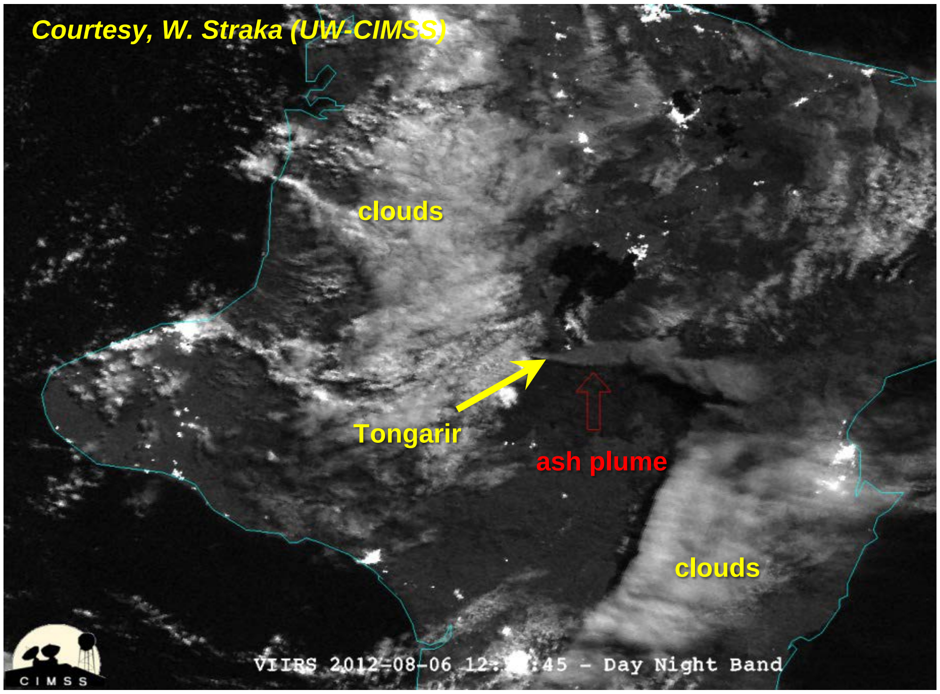
Figure 5: Time series of cloud optical depth retrievals for marine stratocumulus clouds off the California coast from a) GOES afternoon, b) VIIRS lunar reflectance at night, c) GOES nighttime infrared-based method, and d) GOES morning.

The comparison between panels b and c in figure 5 illustrate how the moonlight reflectance allows for capture of the evolving optical depth, whereas the GOES nighttime infrared-based methods necessarily truncate these retrievals at values of near 10.

Satellite-based nighttime observation of optical properties of clouds, e.g., cloud optical thickness, particle size and water path, were not possible prior to the launch of SNPP. Through use of the lunar irradiance model (described above), the DNB radiances can be converted to equivalent reflectance quantities which then can be related to the physical properties of the clouds. These measurements are sensitive enough to conduct cloud property retrievals, overcoming traditional sensitivity limitations of thermal infrared methods (where brightness temperature measurements saturate around an optical thickness of 10 or less, the visible reflectance measurements retain sensitivity to values much higher). Thus, the new retrieval will close the nighttime gap of cloud properties observations, enabling the first diurnal cloud property studies at the spatial resolution required to resolve most cloud features.

Volcanic Ash

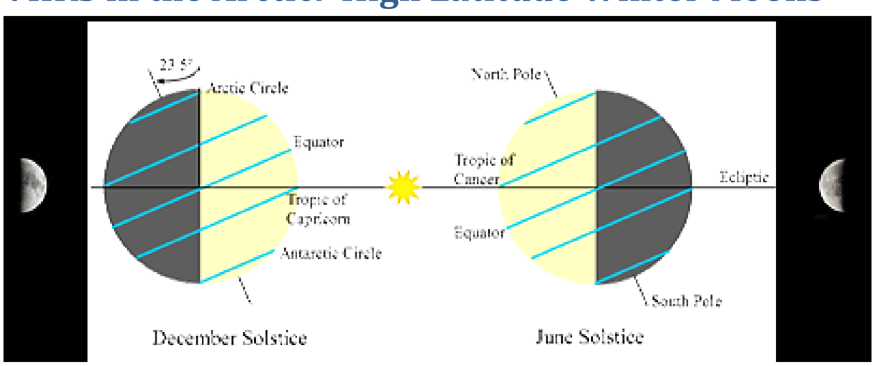
Ash clouds pose a significant hazard to aviation, owing to their ability to cause significant damage turbine engines, induce engine stalls, clog sensors, and frost the cockpit windshield. Alaska's volcanoes make up about 31% of all active volcanoes in the United States. More than any other region of the United States, flight routes over Alaska face the potential risk of encountering volcanic ash from any of the state's major active volcanoes. Moreover, the effects from volcanoes in remote and sparsely populated places in Alaska, and even upstream in eastern Russia can be felt in areas hundreds or thousands of miles away. These volcanoes can produce major ash clouds, which are able to transport great distances from their source, creating a serious hazard thousands of miles from an eruption.



The image above was captured by VIIRS on SNPP. It shows Mount Tongariro as it appeared at 12:55 a.m. New Zealand time on August 7, 2012 (12:55 p.m. Universal Time on August 6).

The DNB offers useful detection of volcanic plumes at night via lunar reflectance. On August 6, 2012, New Zealand's Mt Tongariro erupted for the first time since 1897. The VIIRS DNB captured an image (see above) of the volcano at 12.55 a.m. local New Zealand time. According to news reports from New Zealand, Tongariro sent ash at least 20,000 feet into the air. The New Zealand Civil Aviation Authority issued advisories to re-route air traffic around the ash plume so as to avoid damage to aircraft engines. In this case, the DNB measurements revealed a portion of the plume close to the eruption that provided poor thermal contrast (and hence was not detected) by thermal infrared imagery.

VIIRS in the Arctic: High Latitude Winter Moons

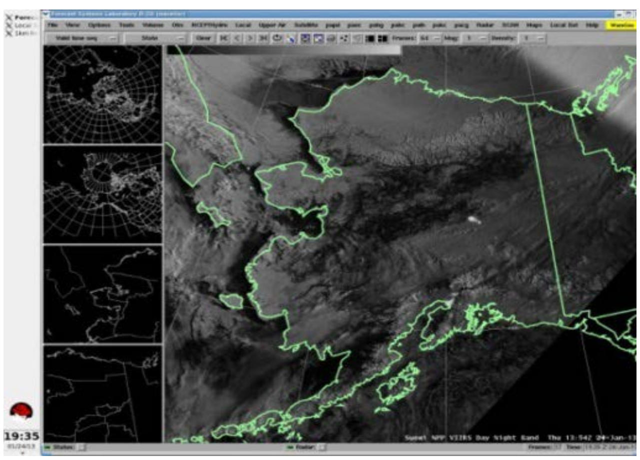


The graphic above shows how the Full Moon, being in opposition to the Sun, is inherently higher in the sky in the Winter hemisphere at night; a result of the lunar orbit being oriented close to the Ecliptic plane and the declination of Earth with respect to this plane. This circumstance benefits the high latitudes during the long winter nights by providing additional moonlight—a benefit that is further augmented by the enhanced revisit rate of the SNPP polar orbit at these latitudes.

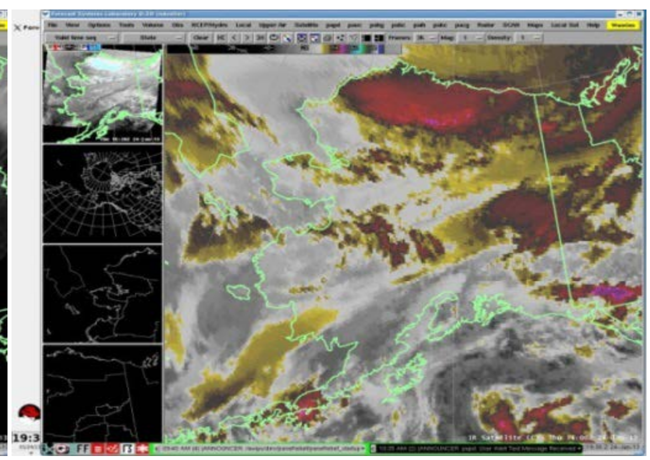
The lunar illumination varies throughout the ~29.3 day lunar cycle – from none during a new moon to more as the moon is closer to the full moon phase. Ultimately, a full moon provides the most illumination and brilliant DNB imagery. The DNB is capable of imaging meteorological features such as sea ice, volcanic ash, clouds and surface features such as snow cover and rivers, by way of city lights and reflected moonlight.

The DNB capabilities are particularly useful at high latitudes, considering the scarcity of visible light during the polar winter months. – Steve Miller

During the typical Alaskan winter, the months of November to January have little daylight. In these regions, low clouds and fog pose significant hazards to transportation by air, land, and sea. Detecting clouds over cold land surfaces and identifying snow and sea ice boundaries are particularly challenging tasks, especially during the winter season. The DNB becomes particularly important during these months as visible channels on most satellites are virtually unusable. Furthermore, infrared images are very difficult to discern. And, while passive microwave sensors can monitor environmental features such as sea ice through the winter, they do so at a much lower spatial resolution—missing key details such as sea ice edge, where crab fisherman tend to operate in order to minimize the effects of freezing ocean spray.



VIIRS Day Night Band

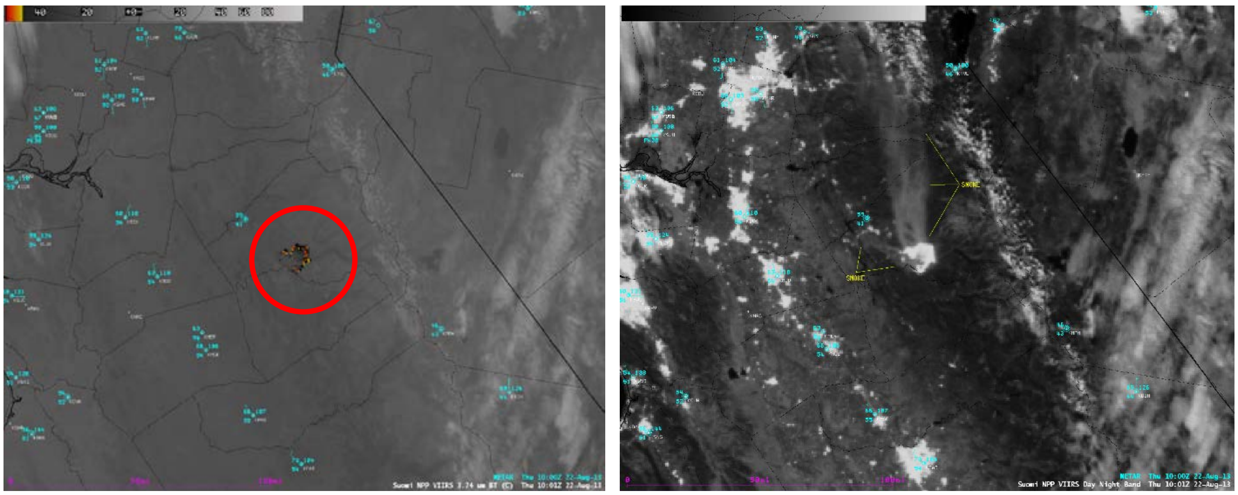


GOES Infrared (IR)

Previously, forecasters relied on infrared data such as geostationary satellite data, which lacks low-light imagery (above right). Moreover, a geostationary satellite such as GOES is centered on the equator, creating large viewing angle at high latitudes due to the curvature of the Earth. This results in degraded imagery for the Polar Regions. Forecasters also relied on microwave images, but these are obtained at a relatively coarse resolution, which greatly limits their utility. As a consequence, the DNB becomes especially critical for the Polar regions as it enables visible monitoring of the poles during winter. In addition, polar orbiting satellites provide more passes per day over Alaska than over the Lower 48 which results in much more complete spatial and temporal coverage than at any other region.

Forest Fires & Smoke

Satellites are able to detect fires from the radiation emitted by fires also known as "hot targets." Satellites carry sensors that are extremely sensitive to the radiative signal. These sensors help scientists to spot the areas where a fire is occurring and differentiate them from the non-burning background. The sensors are capable of detecting relatively small fires often before detecting a signature from the associated smoke.



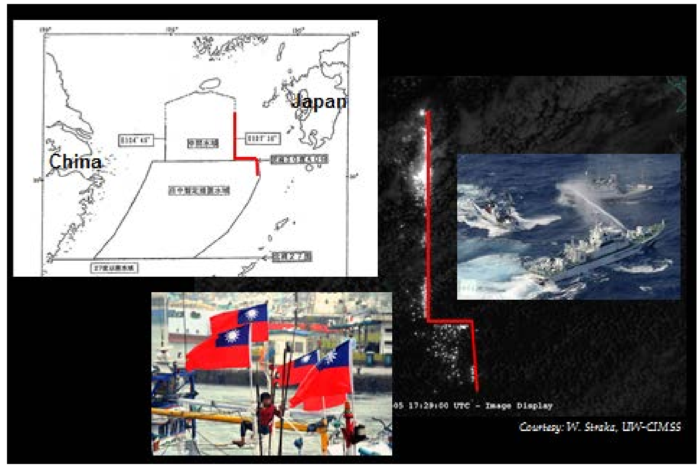
A night-time (10:01 UTC or 3:01 AM local time) comparison of AWIPS images of SNPP VIIRS 3.74 µm shortwave IR (left) and 0.7 µm Day/Night Band data (right) showed signatures of the Rim Fire which had been burning since 17 August near Yosemite National Park in California.

The images above, of the rim fire that scorched Yosemite National Park in California, were captured by the VIIRS instrument on August 22nd, 2013. Numerous "hot spots" (black to yellow to red enhancement) were observed in the shortwave IR image (left). These revealed the location of larger, hotter fires that were burning along the periphery of the large burn scar. In the DNB image (right) a bright white glow revealed the area of active fires. In this image, the light gray signatures revealed the primary middle to upper altitude smoke plume that was moving northward, in addition to an area of lower altitude smoke that was moving westward toward lower elevations. Due to ample illumination from a 98% full waning gibbous Moon phase, the "visible image at night" capability of the DNB proved to be useful for identifying the location of the smoke plumes. In the IR image the smoke plumes are no longer visible. The DNB uses moonlight to bring out the smoke. Knowing where the smoke plumes are at night is critical for understanding what is really happening.

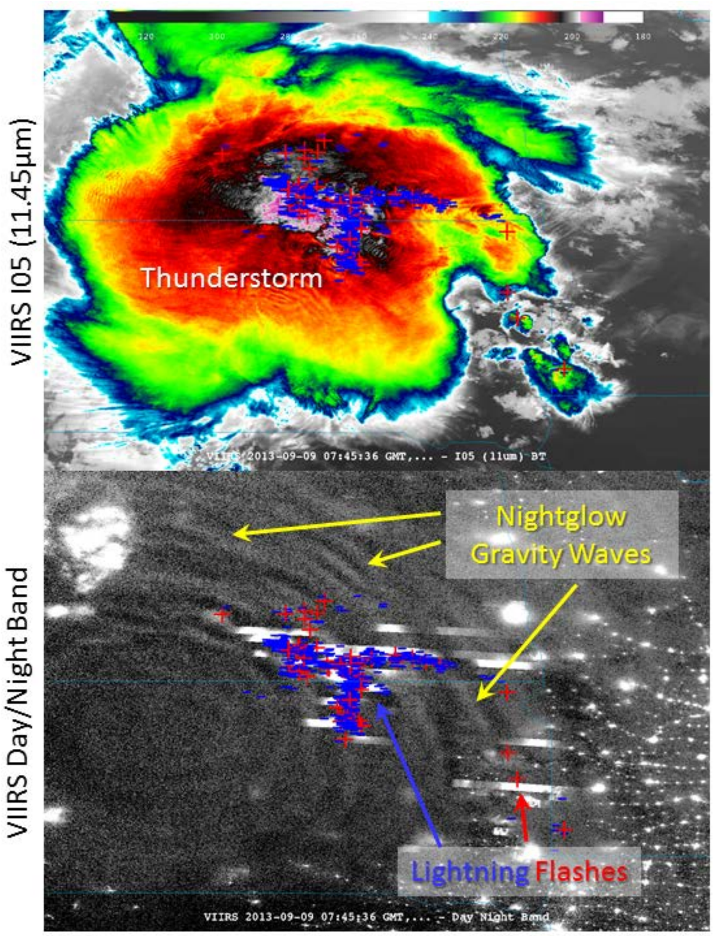
The Politics of Fishing

A unique capability of the DNB is inherently ability to detect and monitor the nocturnal activity of humans. While the most familiar examples are related to city lights (and associated power outages), there are other activities that reveal themselves only at night, and in some cases reveal curious behaviors.

The image on the right shows lights from a fleet of squid fishing boats in the shared waters between China and Japan. These boats operate massive arrays of flood lights to attract their catch to the surface. In this case, in addition to revealing the fishing activity itself, the imagery shows how VIIRS can visually depict the region's political realities. Here, the fishing boats following the L-shaped line are constrained by politically-defined zones in the region. Disputes over certain territories in these waters have led to occasional displays of force-in-numbers congregating along these boundaries.



Basking in the Nightglow…



An unexpected capability of the DNB was discovered during routine calibration/validation check-out of the instrument shortly after launch. Emerging from imagery that was supposed to be completely dark (collected over the open Pacific Ocean at ~1:30 AM local time during New Moon conditions) were distinct cloud structures—illuminated by some undetermined light source. After consulting with the astronomy community, it was soon realized that the source of light was coming from the atmosphere itself. Airglow (with the specific subset of processes occurring at night referred to as nightglow) is a form of chemical luminescence involving multiple gas species that occurs in the upper atmosphere (near the mesopause at 90 km and higher). At these altitudes, release of energy during various chemical reactions can occur in the form of photon emission. While this faint light source, nearly 100 times fainter than moonlight, serves as a source of noise to astronomers who seek to observe the stars, in this case it represents a ‘new’ source of illumination for low-light visible imagery thanks to the DNB’s extreme sensitivity. The upshot of this discovery is that it is never truly dark—a form of visible imagery is possible on even the darkest, moonless nights.

Perhaps even more surprising than observing the nightglow-illuminated clouds themselves, the direct emission of the nightglow layer (which resides principally between 85-95 km) can at times be detected. As shown in the case of a strong thunderstorm over North and South Dakota, gravity waves forced by the strong latent heat release of the storm can propagate through the stratosphere and beyond. When these waves perturb the nightglow layer, which is a strong function of ambient chemistry and temperature, the response is a manifestation of the waves as glowing ripples. Classical dynamics underscores the importance of these waves to determining the circulation of the upper atmosphere via the effects of gravity wave drag. Now, with the new DNB measurements which reveal these waves for the first time, scientists are in a better position to learn about their characteristics and distribution. This knowledge may lead to improvements to the current state of crude parameterization in general circulation models, thereby advancing our ability to predict climate as well as feedbacks to weather patterns in the troposphere.

DNB Assessment:

In myriad ways, the VIIRS/DNB offers significant advances to its heritage OLS technology. Its low-light sensing capabilities, which provide an array of applications both with and without moonlight, has redefined the meaning of ‘darkness’ and the understood limitations of nocturnal environmental sensing. The fundamental advance relates to the moonlight-based detection and characterization of low clouds, fog, and atmospheric terrestrial features that are not easily seen in infrared channels. This significantly enhances our capability to monitor and detect severe weather events and hazards. In the high latitude regions, there are numerous benefits of using the VIIRS DNB, especially during the winter months when sunlight is unavailable for extended periods. The DNB has proven itself in its ability to provide invaluable polar imagery and products in geographic areas, and under environmental conditions, that no other current satellite sensor is able to match. Additional applications related to light emissions stand to improve our ability to monitor forest fires and human activities. The discovery of nightglow sensitivity opens a new pathway for basic research and insight to coupling between the lower and upper atmosphere. It is possible that still more fascinating aspects of the nocturnal environment await discovery—if so, the SNPP and its novel VIIRS/DNB measurements will put us in prime position to shed light on them.

Section 11

The JPSS Proving Grounds: Advancing the Visible Infrared Imaging Radiometer Suite (VIIRS) Nightfire and Nighttime Lights

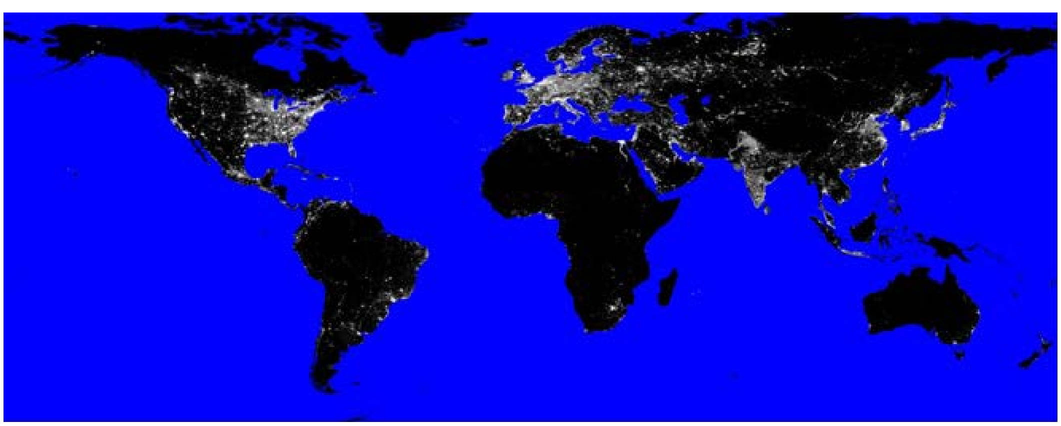
The information in this article is based in part on the JPSS science seminar given by Christopher D. Elvidge (Earth Observation Group, NOAA National Geophysical Data Center (NGDC)), on ***September 16, 2013.***

Contributing editors: Christopher D. Elvidge, Mitch Goldberg, Julie Price, and William Sjoberg

For twenty years the NGDC team has been the authoritative center for DMSP nighttime lights products. They pioneered many of the now recognized applications for satellite observed nighttime lights, including mapping economic activity, density of constructed surfaces, poverty levels, and estimation of natural gas flaring volumes. The NGDC team has now shifted its focus to work with nighttime data collected by the SNPP VIIRS. This article presents two product lines that NOAA's National Geophysical Data Center (NGDC) has developed using nighttime data collected by the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument onboard the Suomi National Polar Partnership (SNPP) satellite. The article also presents some illustrative examples from these product lines.

The first product, Nightfire, detects and characterizes combustion sources using six of the nine VIIRS spectral bands that collect data at night. This includes the low-light imaging day/night band (DNB), near-infrared, short-wave infrared, and mid-wave infrared spectral bands. Through Planck curve fitting, the algorithm calculates the temperature, source size and radiant heat. Standard satellite fire products use a mid-wave infrared spectral band for detection and a long-wave infrared spectral band as a reference. With detection in a single spectral band it is not possible to fit the Planck curve, so the temperature, size, and heat release cannot be calculated. The disadvantage of Nightfire is that the data can only be produced from nighttime VIIRS collections. Nightfire was developed for remote sensing of gas flares, which typically burn at about 1800 degrees K. However, the system also detects large numbers of vegetation fires, volcanic hot spots and industrial sites such as steel mills. Nightfire typically detects 15,000 to 20,000 hot pixels worldwide every 24 hours. Data are available at: http://www.ngdc.noaa.gov/eog/viirs/download_viirs_fire.html.

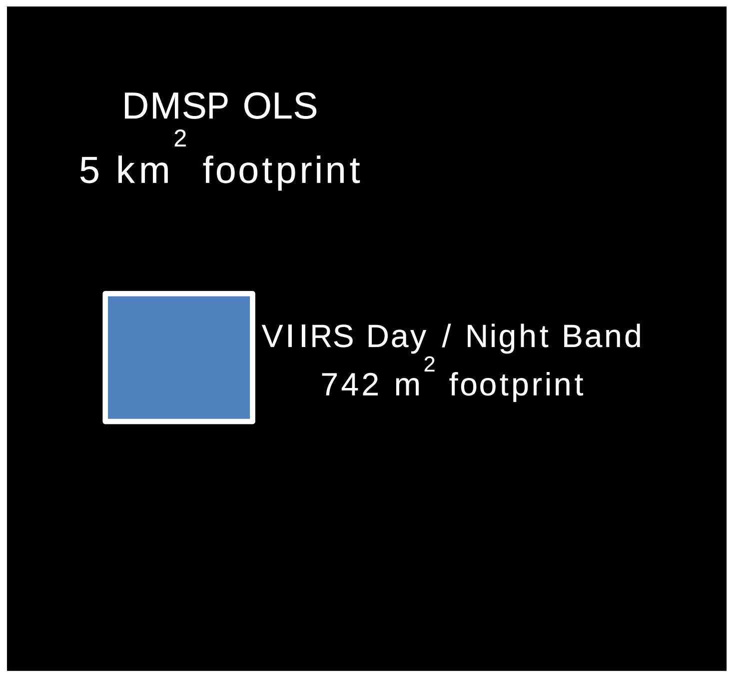
The second VIIRS product under development at NGDC is nighttime lights. NGDC produces a nightly global mosaic of DNB data (http://www.ngdc.noaa.gov/eog/viirs/download_ut_mos.html). They plan to map both monthly and annual nighttime lights products from VIIRS DNB data. Algorithm development is ongoing for the removal background noise and cloud-impacted lights. The VIIRS nighttime lights will be used for a wide range of applications, including power outage detection, socio-economic spatial modeling, studies on development impacts on ecosystems, modeling fossil fuel CO2 emissions, and detection of lit fishing boats.



Twenty year heritage with DMSP nighttime lights

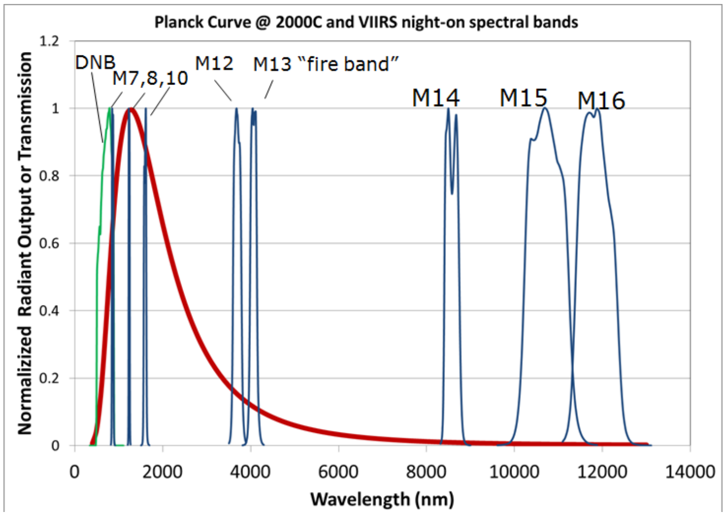
NGDC has been working with the second product, nighttime lights, for over twenty years. It now has a twenty-year time series of global maps of cloud-free annual nighttime lights from DMSP, which are available at: http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html. Nighttime lights are a class of satellite observations and derived products based on the detection of anthropogenic lighting present at the earth's surface. This style of product can only be produced using data from sensors that collect low light imaging data in spectral bands covering emissions generated by electric lights. The DMSP-OLS nighttime lights represent one of the most widely recognized global satellite data products and have proven valuable in a wide range of scientific applications. NGDC makes nightly mosaics of DNB data and has constructed three monthly "cloud-free" DNB composites. Current research includes the development of methods to produce cloud-free nighttime lights composites through filtering to remove background noise, aurora, biomass burning, terrain and cloud features.

How is VIIRS low-light imaging an Improvement Over DMSP?

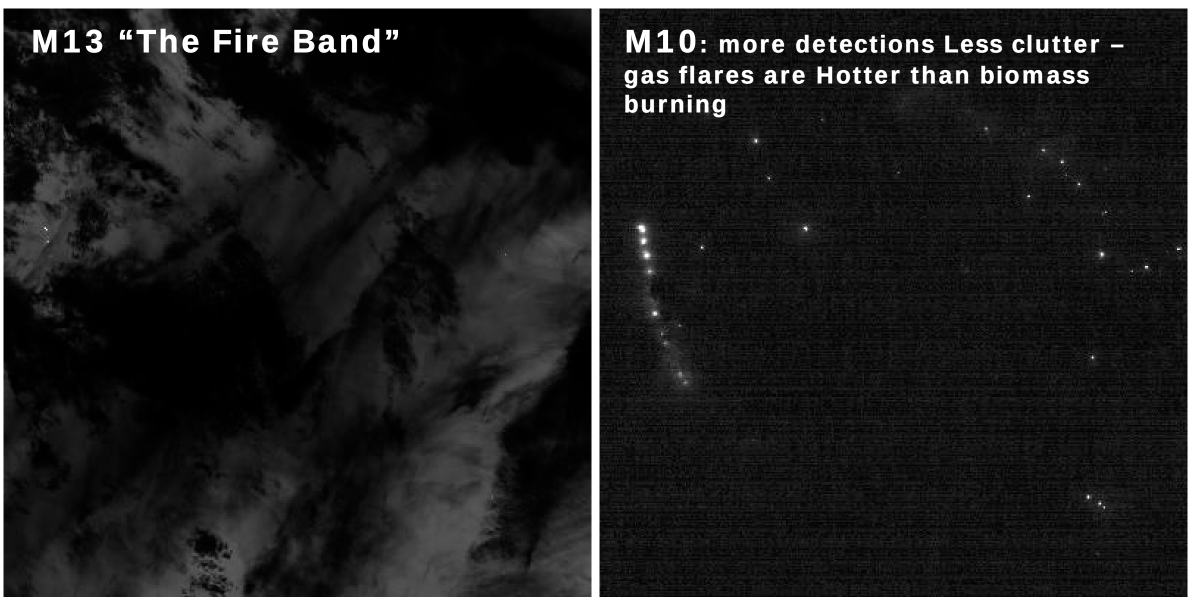


The VIIRS data collections offer substantial advantages over DMSP which include, improved spatial resolution, i.e., the VIIRS DNB footprint is 45 times smaller than the DMSP pixel footprint. In addition, VIIRS offers a much wider dynamic range. Due to limited dynamic range, DMSP data saturate on bright lights in operational data collections. VIIRS also has a much higher quantization at 14 bit compared to the 6 bit DMSP. VIIRS also has the on board calibration lacking on DMSP. Onboard calibration ensures the accuracy of measurements, and instrument performance while in orbit. It is achieved using reference targets onboard the satellite such as solar diffuser or blackbody for calibration. In the case of the DNB, the solar diffuser is used to calibrate the low gain stage of the sensor, and this calibration is transferred to the middle-gain and high-gain stages at the terminator to yield calibrated radiances on the terminator and nighttime sides of the SNPP orbit. The improved VIIRS technology allows for gas flaring detection in multiple spectral bands. These additional spectral bands discriminate combustion sources from lights and characterize the optical thickness of clouds. Additional detection features from VIIRS include gas flares, biomass burning, volcanoes and industrial sites.

What makes nighttime VIIRS data so useful for observing gas flares?

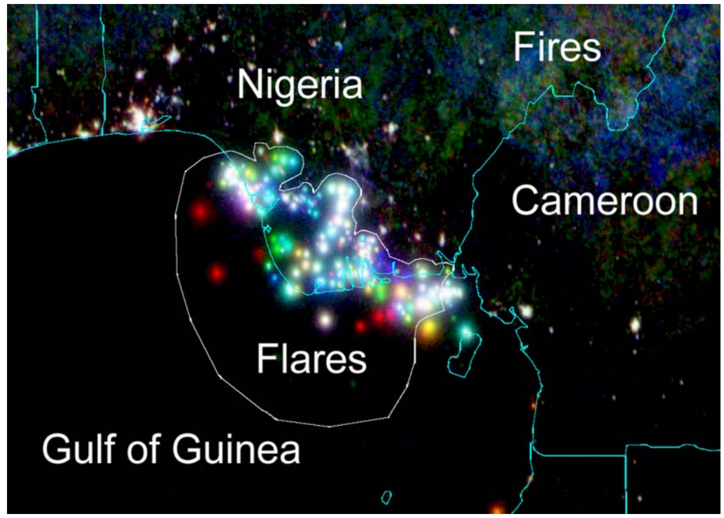


VIIRS collects nighttime data in visible, near infrared (NIR) and short-wave infrared (SWIR). The M7, 8, 10 (see Planck Curve) spectral bands are well placed to record the peak radiant emissions from flares. At night VIIRS collects data from these three daytime imaging bands. During daylight hours the signal is overwhelmed by sunlight. At night, however, combustion sources stand out clearly against the noise background. The nighttime M10 data in particular have a remarkable ability to detect combustion sources (see figure on page 3 showing combustion sources at night in Basra, Iraq). The M10 band has a very high radiant emission and very low atmospheric effects, which helps in getting temperature and radiant heat estimates that are relatively immune to major atmospheric effects.



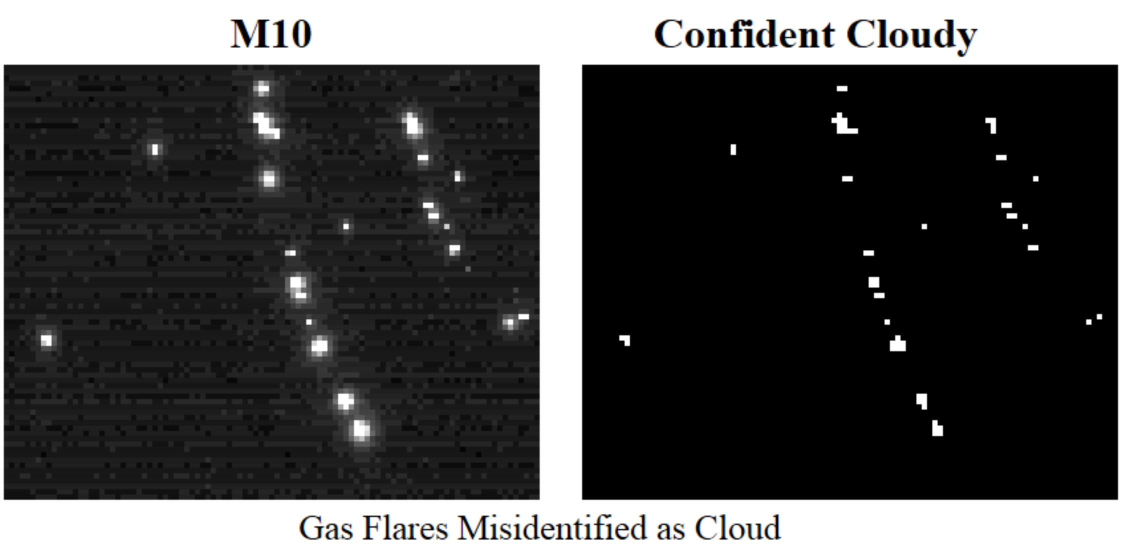
Detection of Combustion Sources Basra, Iraq Region at Night

Since 2004 NGDC has been monitoring annual gas flaring activity in sixty countries using the DMSP low light imaging data. The DMSP gas flaring record, spanning 1994 through 2011 was developed using a limited set of gas flaring volume reports provided by oil companies and individual countries. NGDC developed a method for estimating flared gas volumes using DMSP, which has the advantage of global coverage, a strong signal from flares, and a long archive. However, there are some disadvantages with it. For example the technique cannot be used when there is sunlight or heavy moonlight present. Also, there is an inability to distinguish between lights from gas flares, from lights from urban areas. Even outside of urban areas, there is some ambiguity about how much light is from gas flares and how much is from the facility itself. Finally, the spectral band on DMSP misses peak radiant emissions of flares.



Cloud-free annual composites
Vector drawn on gas flares for Nigeria.
Flares appears as large colored circles of light in red, green, blue composites.
F162004 = Red
F141998 = Green
F101992 = Blue

NGDC has also used their technique with MODIS. The advantage to this is that with MODIS on NASA's AQUA and TERRA spacecraft, four observations per day are available. Moreover, MODIS observations do not have lunar or solar constraints, which reduce the number of usable observations in DMSP data. The MODIS archive extends from 2000 to present. But like DMSP, MODIS has its disadvantages. A key disadvantage to using the MODIS fire radiative power product in monitoring gas flares is that it frequently skips over flares that can be clearly seen in the thermal band data. This is because MODIS is calibrated for biomass burning. In addition, MODIS has a weak signal from flares in mid wave infrared (MWIR), and its operational cloud-product often identifies gas flares as clouds. As the VIIRS operational cloud algorithm is based on the MODIS algorithm, it detects gas flares as clouds (see image below). Thus the spectral confusion issues encountered with the MODIS cloud algorithm will also occur in the VIIRS products.

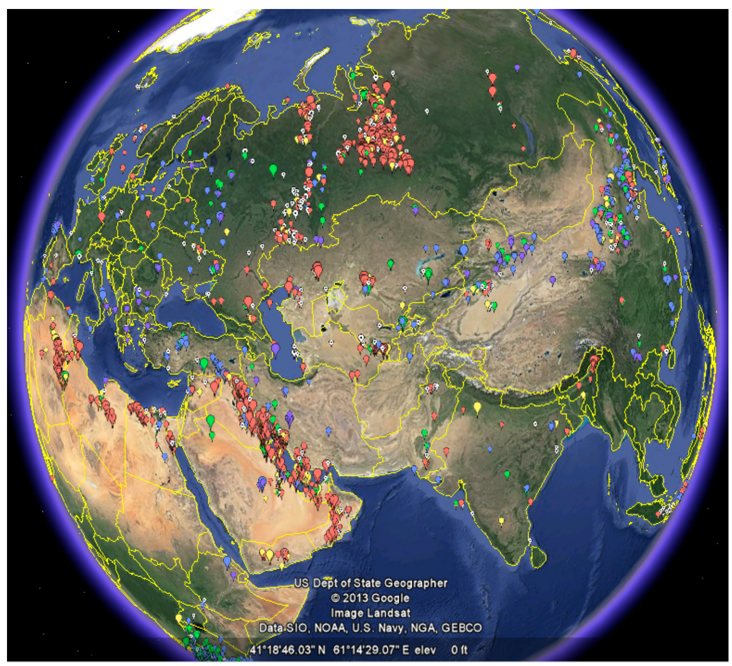


Cloud clearing done for isolated patches of cloud coincident with M10 hot pixels

Using Satellite Observations to Detect Gas Flares

Gas flaring is a widely used practice for the disposal of excess natural gas, primarily where oil is the major product. However, it is a waste of fuel and an added carbon burden on the atmosphere. This method of disposing natural gas is widely used in production and processing facilities where there is no infrastructure to make use of this gas. As a large number of countries do not have any self-reported gas flaring volumes, a considerable amount of uncertainty exists pertaining to the magnitude of gas flaring. Therefore, without independent data sources and methods for estimating gas flaring – how can progress towards its elimination be assessed? NGDC has made significant improvements in detecting global gas flares using the DMSP data. Using calibrated results from this data, NGDC has been able to produce estimates of trends in global gas flaring volumes. In addition, NGDC uses high resolution imagery in Google Earth to confirm the identity of flares and to remove false detections.

Satellite observations provide the capability for detecting flares and estimating both flared gas volumes and CO2 emissions. Satellite sensors have the advantage of observing the entire earth surface in a consistent and repeated manner. Polar orbiting meteorological satellite sensors in particular, have the added advantage of observing gas fields several times a day in various environmental conditions. If a meteorological sensor has the ability to measure the radiant emissions from gas flares, it may be possible to calibrate the observations to estimate both flared gas volume and CO2 emissions.



Google Earth used to confirm the identity of flares. Detections from September 11, 2003

NGDC provides nightfire and nighttime VIIRS data to a number of user groups. These include the Global Gas Flaring Reduction Initiative (GGFR) and the California Air Resources Board (CARB) which use this data to investigate where gas is being flared, how much is being flared, and how that changes over time. The World Bank's GGFR Initiative uses the data to track the effectiveness of gas flaring reduction efforts.

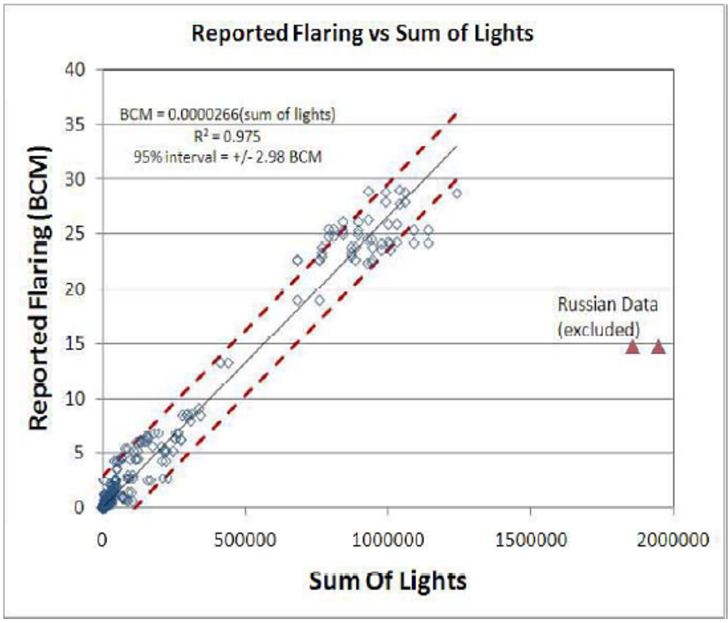


Figure above shows the DMSP 'sum-of-lights' calibration for estimation of gas flaring volumes. Note the error bars, setting the uncertainty in the estimation of gas flaring volumes at +/- 2.98 billion cubic meters.

The CARB uses the data to calculate the total carbon emissions associated with fuel imported into the state from various oil fields around the world. This is a critical capability for achieving the objective of the State of California Low Carbon Fuel Standard (LCFS). Both of these programs require routine updates of flaring activity to document the success of their efforts. This data is also useful to NOAA's Carbon Tracker (CT) program which attempts to identify CO2 emissions sources worldwide. The CT program then uses this data as input into its carbon models to help determine the spatial distribution and magnitude of these CO2 emissions.

Conclusion

Both the DMSP-OLS and SNPP VIIRS instruments have low light imaging capabilities suitable for collecting nighttime lights data. But VIIRS offers a substantial number of improvements over the OLS and MODIS. Improvements over OLS include spatial resolution, dynamic range, quantization, calibrations and the availability of spectral bands suitable for discrimination of thermal sources of light emissions. Side-by-side comparison of VIIRS and OLS cloud-free composites show the superiority of VIIRS product. DMSP nighttime lights have been successfully used for a wide variety of scientific applications, and have produced some of the most widely used and recognized images of the earth. VIIRS nighttime lights have enabled advances in the science applications that have shown promise using the DMSP products. VIIRS provides substantial improvements over both DMSP and MODIS for global observation of gas flaring, which include higher quality images and better estimates of gas burning. The VIIRS nighttime lights data can be used to model urban GHG emissions, and its nightfire data can be used to model GHG emissions from gas flares and biomass burning. VIIRS data from NGDC has helped the World Bank – through its Global Gas Flaring Reduction (GGFR) initiative -- heighten recognition on the benefits to reducing flaring by investing heavily in awareness campaigns and raising international attention on the reduction of gas flaring.

JPSS continues to engage the NOAA user community, ensuring that both the best products and new, enhanced products supporting these key missions, are made available in time for decision makers to take the appropriate actions.

Section 12

Active Fire Detection

An Eye in the Sky for the Boots on the Ground

The information in this article is based in part on a member of the NOAA/NASA Suomi-NPP VIIRS Active Fire team's fact finding mission, which begun on ***June 24, 2013****, into how VIIRS imagery is working today to detect fire and what other capabilities the instrument provides that are not yet being used in the field.*

Contributing editors: Evan Ellicott, Ivan Csiszar, William Straka, Mitch Goldberg, Julie Price, and William Sjoberg

Smoke rising from the West Fork Complex fire on June 24, 2013. The satellite image inset shows fire detections from the Suomi NPP VIIRS sensor of the same fire. Photo by Evan Ellicott.

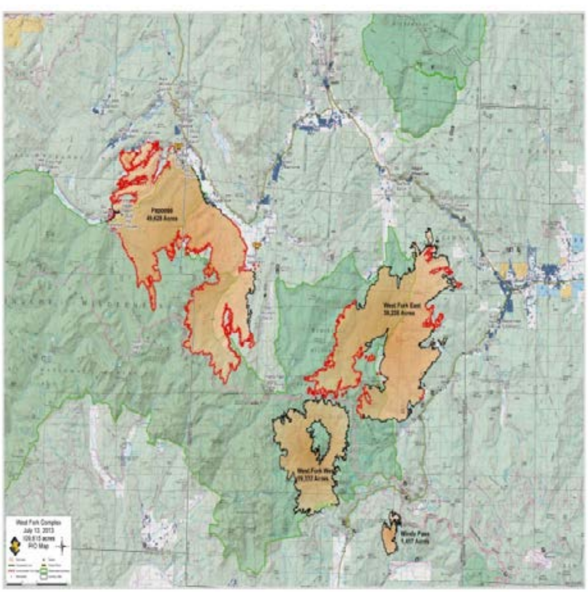
On Monday, June 24, 2013, Evan Ellicott landed in Denver Colorado for the long drive south. His plan was to visit the West Fork Complex in southern Colorado. The national news was already full of stories of yet another group of Colorado fires. The West Fork Complex fire was soon to become one of the largest wildfires in Colorado history. Evan's goal was to get as close to the front line as possible and meet with the key people fighting the fire. He wanted to evaluate their use of remotely sensed data and determine how the new Joint Polar Satellite System (JPSS) Visible Infrared Imaging Radiometer Suite (VIIRS) capabilities could make a difference. Five days later as he drove away from the command post, the smoke still stinging his eyes, he realized how incredibly valuable it was to have his boots on the grounds of this fire.

Evan is a member of the Suomi National Polar-orbiting Partnership (SNPP) VIIRS Active Fire (AF) product development and evaluation team, which is organized under the JPSS Algorithm Development, Calibration/Validation, and Proving Ground and Risk Reduction Programs. He is responsible for organizing and evaluating user readiness and the proving ground effort. The team works closely with representatives of the end user community such as Peter Roohr of the National Weather Service (NWS), Office of Science and Technology, who is the liaison with the NWS Incident Meteorologist (IMET) community; and Brad Quayle of the USDA Forest Service Remote Sensing Applications Center, who is a key user of the VIIRS Active Fires product derived from direct readout data in daily operations to serve a number of end users.

Evan and Peter developed an interactive information briefing on VIIRS and the AF product, which they presented to IMETs during their annual spring training as another source of data for fire locations.

IMETs are embedded in NWS offices around the country, and are deployed at a moment's notice to the front lines of volatile occurrences such as chemical and oil spills, wildfires or other incidents. They are the NWS equivalent of Special Forces, and they are sent to remote locations throughout the U.S. to provide on-site forecasting support. They provide tactical support to the fire management team, especially the fire behavior analysts from the U.S. Department of Agriculture's Forest Service (US Forest Service), the Department of Interior's Bureau of Land Management (BLM), and other federal, state and local fire control agencies who carry out the fire suppression operations. An IMET is generally requested when a Type 1 or 2 Incident Command Team (ICT) is asked to manage a fire. A Type 1 team is a national level team, while a Type 2 team is a regional team. Robyn Heffernan, the NWS liaison at the National Interagency Fire Center (NIFC) in Boise, ID, Peter, and Evan held follow-up discussions in which they wanted to find out how the VIIRS product was working for the end user. They also laid the groundwork for evaluating fire outbreaks to determine which fire presented the best conditions for Evan to visit. The CO fire outbreak in June provided the perfect opportunity. It was the goal of this team to see if one of their members could spend time at the command post of a forest fire to interact directly with people who were using satellite data to help fight the fire.

Evan arranged his trip with the NWS fire weather staff at the National Interagency Coordination Center (NICC) in Boise Idaho, including Robyn and Larry Van Bussum, Operations Section Chief. The NICC is the focal point for coordinating the mobilization of resources for wildland fire and other incidents throughout the United States. Working together they identified the West Fork Complex Fire as the candidate for his visit. On Monday, June 24, 2013, Evan was on the ground in CO. He visited the West Fork Complex to meet with incident team members such as the IMETs from the National Weather Service, Fire Behavior Analysts (FBANs) from the US Forest Service, GIS analysts, and other fire incident decision support cadre.



The final map of the West Fork Complex issued July 13, 2013. The fire was 50% contained at this point.

At the time of Evan's visit, the West Fork Complex fire was burning at 16% containment and was expected to burn for at least a month. Wildfires in Colorado were spreading fast and furious and the command post was well established and approved Evan's travel.

West Fork Complex Fire

The West Fork Complex consisted of three lightning-caused wildfires, West Fork, Windy Pass, and Papoose, which burned on the San Juan and Rio Grande National Forests and private lands in southern Colorado.

The biggest fire, known as the West Fork Fire, started after lightning struck in the San Juan National Forest backcountry on June 5. The Windy Pass Fire, which ignited on June 13, was the second and the smallest fire, growing at a much slower rate than the others. The third fire, known as the Papoose Fire, started Friday June 21, and was the most active at the time of Evan's visit.

Due to its size and complexity, the ICT tactically decided to switch the operations of the West Fork Complex into two zones, the West Zone in Pagosa Springs and the East Zone in Del Norte. The West Zone (Windy Pass and Western Part of West Fork Fires) Incident Command Post (ICP) was located at the local airport in Pagosa Springs, and was manned by a Type 2 fire management team. The East Zone (Papoose and Eastern Part of West Fork Fires) ICP was located at Del Norte High School and was manned by a Type 1 fire management team. The Type 1 team worked in conjunction with the U.S. Forest Service National Incident Management Organization (NIMO), to manage the three fires that made up the West Fork Complex, which was occurring in a vast complex area and difficult terrain. The NIMO team is usually called in when a fire has reached a size and level of complexity that requires further oversight. The personnel on the ground at the command post included all the team members that were needed to manage the fires from above and on the ground, i.e., incident commanders, safety operations, GIS specialists, fire behavior analysts and long term analysts from the U.S. Forest Service, logistics personnel (National Guard), smoke analysts from the U.S. Fish and Wildlife Service (USFWS), firefighting crews (BLM) and IMETs (NOAA). For the National Guard unit, this was the first time it had been deployed in such a capacity.

Boots on the Ground during Daily Operations

Evan arrived at the ICP in Pagosa Springs where IMET Mark Loeffelbein was dispatched. Another IMET, Kelly Hooper arrived the same day. He was dispatched to the West Fork Complex to provide an IMET for each zone, and thus added weather forecasting support. Both IMETs provided critical input to daily operations briefings as decision makers moved their resources to meet the changing fire scene.

Two standard briefings were held every morning and evening in both fire zones. The morning meetings occurred at the West Fork spike camp, where a team of fire fighters were camped. Once the operations commander came out, the information officer would provide a detailed recap of the previous day's events. Next the IMET and fire behavior analysts would provide a briefing on the weather, which would be followed by briefings from logistics, operations, safety, and communications.

The morning meetings were really critical to the team members on the ground. It was these meetings where they received their Incident Action Plans (IAPs), which included assignments, night infrared maps, logistics information, and weather forecast information. Nighttime data were collected using infrared (IR) flights, or National Infrared Operations (NIROPS). These aircraft collect thermal infrared data at the incidents, which provide information on heat perimeters and sources of intense heat. As this information was not available during the day when the fire was really taking off, Evan noted that this was an opportunity in which VIIRS data could be used when the NIROPS were unavailable.

Evaluating the Operational Use of Satellite Data

Evan's first meeting with Mark Loeffelbein was vital to Evan's goal to learn more about the role of an IMET at the incident. As he watched Mark go through the process of developing his forecasts he was able to see what data was used and to understand what strengths and limitations VIIRS data poses for an IMET. Discussions surrounding topics of data latency, access, and format, spatial resolution, and spectral channel availability followed. These informal talks allowed for a dialogue for Evan to better understand what the IMETs needed, and the hurdles they face in providing environmental support to the command post decision makers. It also allowed him to educate Mark about the VIIRS sensor and its products, particularly the active fires product.

Evan also met with several FBANs from the US Forest Service. The FBANs provide critical information about what they expect the fire to do over the coming hours to days based on fuels, terrain, and weather. Eric and Chris were both eager to learn more about how remotely sensed data could aid their job and Evan was happy to talk with them and demonstrate the data from VIIRS. On Thursday, June 27th, Evan accompanied the FBANs as they moved closer to the fire line. Evan was able to get a first-hand view of the FBANs in action and evaluate the variables they considered when making their daily fire behavior forecasts. In turn, Evan was able to provide imagery and fire detections in various formats such as Geographic Information Systems (GIS), as wells KMLs for Google Maps and Google Earth, which illustrated the potential of the VIIRS AF product. He also demonstrated direct broadcast capabilities to address the concerns of latency.

Finally, Evan met with other members of the Planning Section, including Mike Broughton, Air Resource Advisor, Cody Wienk, Long Term Analyst (LTAN), as well as the West Zone Incident Commander (IC), Curtis Heaton. These interactions provided invaluable intelligence on what the IC team faces in the short and long term and what value remotely sensed data provides to them.

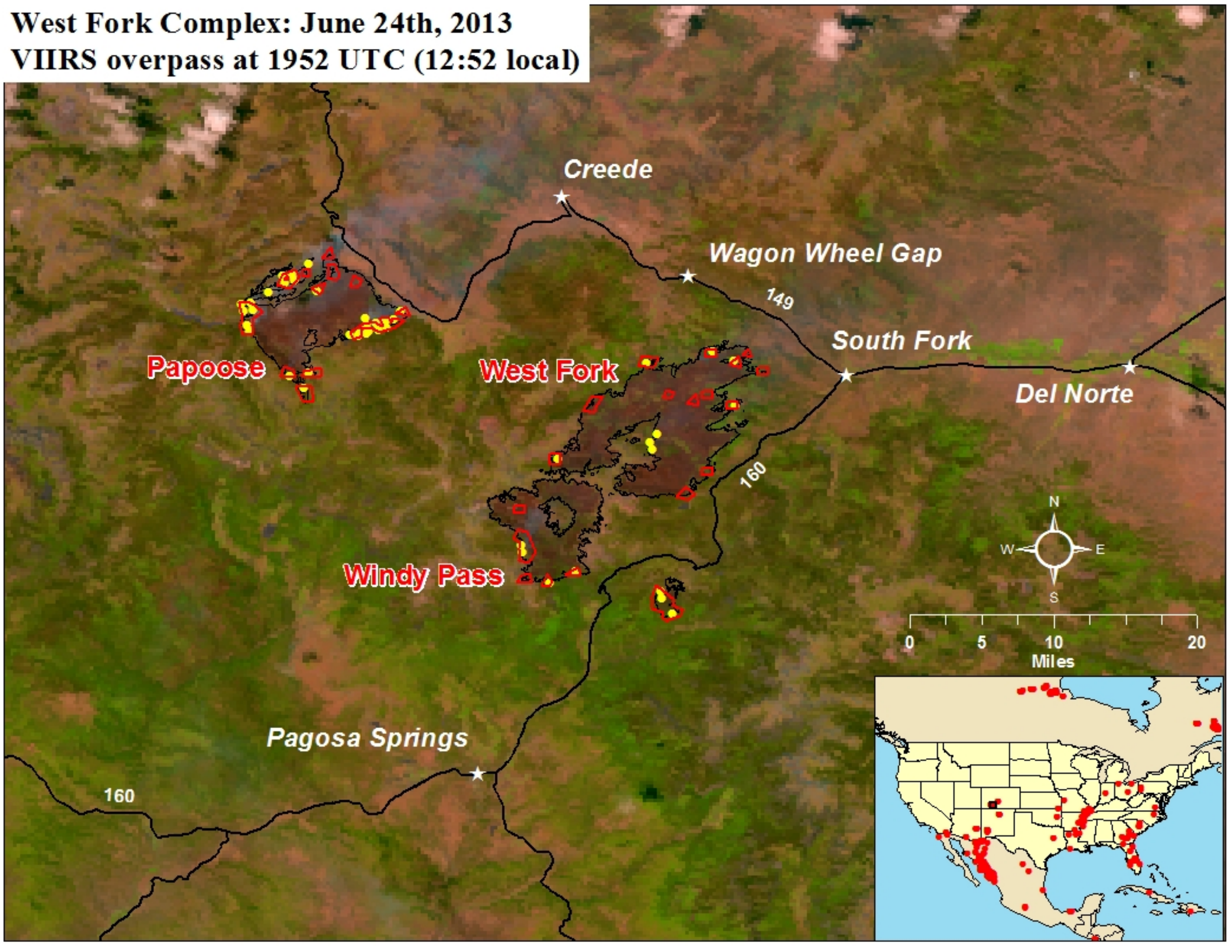
Path Forward

The AF team has spent a lot of time developing the VIIRS AF product and making it available in a way that is operationally useful. Evan set out on a fact finding mission to see how things were going and used this trip as an opportunity to demonstrate the use of polar orbiting satellite data to get a handle on fire detections. The NICC compiles annual wildland fire statistics for federal and state agencies. The center reported that in 2012 there were 67,774 wildfires with 9,326,238 acres burned. While fire suppression costs in 2012 were not the most expensive at $1,902,446,000, four fires namely, the Waldo Canyon fire, the Whitewater-Baldy (NM), White Draw (SD), and Long Draw (OR) made it onto the list of historically significant wildland fires. This trip revealed which end users were using VIIRS data. And, for those who were not, Evan used this opportunity to educate them on the potential of the VIIRS AF product. It was also educational for Evan as he obtained knowledge from the end user on what kind of data they needed, and how they needed it. This fact finding mission also helped Evan envision the kind of pressures and hurdles the end user faced when out in the field responding to an environmental event.

The issues of data latency and connectivity were evident during this trip. ***This fire revealed that VIIRS detection data needs to be available in time for the two daily meetings and integrated into the suite of information used for the planning and decision making process.*** In addition, timely updates during the day can provide valuable information to support decisions on specific firefighting actions. ***This can be achieved by ensuring access to direct broadcast data from various receivers across the country, typically 30 minutes or less after the satellite overpass.*** Timely access to NOAA's centralized data processing system, providing a stable data source with 2-hour latency, as a backup data source should also be established. ***The information regarding the fire needs to be available in a compressed format that can be easily downloaded through low-bandwidth cell phone and wireless networks, which then can be combined with other geospatial information on-site*.** Until a robust data access system is set up, the SNPP VIIRS Active Fire team is planning to provide ad-hoc remote support to end users for select fire events through partnerships established in part through Evan's visit to the West Fork Complex.

Further work is also needed to ensure the full capabilities of the VIIRS sensor to provide fire information at various spatial details during daytime as well as nighttime. ***VIIRS also has a capability to provide not only the location of fires, but also an indication of their intensity through the parameter called Fire Radiative Power (FRP). This information can help identify the most intense burning along extensive fire fronts, which might not be evident from other ground-based on airborne observations***. Continuous interaction with the end users also helps identify shortcomings of the fire detection scheme and thus supports further product improvements by the active fire product development team. Options for various data products, data formats, and background material are provided through the Active Fires Product Data and Evaluation Portal at http://viirsfire.geog.umd.edu.

This fact finding mission also highlighted that the JPSS program office is interacting with its key users in trying to find a way to ensure that its products are of most value to the missions of those users.



Remote sensing observations of the West Fork Complex fire. The image is a false color composite using VIIRS' 375m resolution Imagery bands (I-bands) from June 24th, 12:52 local time. The three fires are evident by the distinct burn scars in the center of the image, as is smoke emitted primarily from the Papoose fire. The yellow dots and red polygons denote fire detections from the VIIRS 750m resolution Moderate Bands (M-bands) and the I-bands, respectively. The black polyline is the latest fire area perimeter from the previous night's Night Infrared Operations (NIROPS) flight.

Section 13

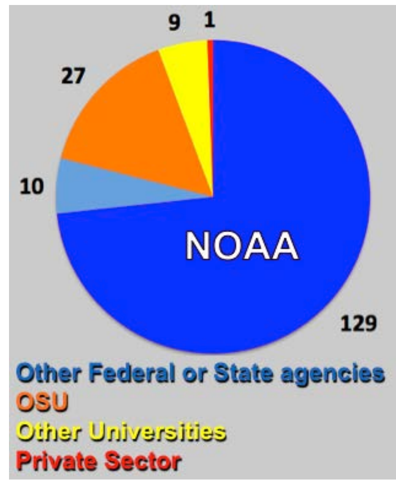
VIIRS -- Making the Difference for the NOAA Ocean Mission

*The information in this article is based in part on the 2013 NOAA Ocean Satellite Data Course was held **August 20-22, 2013** at Oregon State University (OSU).*

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

Since 2006 the Environmental Research Division (ERD) of NOAA's National Marine Fisheries Service (NMFS)/ Southwest Fisheries Science Center (SWFSC) has been conducting 3-day short courses in oceanographic satellite data[5]. These courses are aimed at NOAA participants and in particular, NMFS and National Ocean Service (NOS) scientists. They are also open to non-NOAA participants. The courses were developed by Cara Wilson and Dave Foley, both at NMFS/SWFSC/ERD, in conjunction with Ted Strub at the Cooperative Institute for Oceanographic Satellite Studies (CIOSS) at Oregon State University in Corvallis, OR.

According to the introductory briefing from the course provider, which can also be obtained at http://www.pfel.noaa.gov/events/workshops/NOAASatCourse2013/CourseInfo.html, over 170 people have taken the course since its inception, with participants from each of the six fisheries science centers, 11 of the 14 marine sanctuaries, as well as other government agencies such as the US Coast Guard (USCG), United States Geological Survey (USGS) and the United States Fish and Wildlife Service (USFWS).



The course consists of both lectures and labs. The lectures cover basic information about the various environmental satellite datasets available – ocean color, sea surface temperature, sea surface height, ocean surface vector winds and salinity.

The 2013 NOAA Ocean Satellite Data Course was held August 20-22, 2013 at Oregon State University (OSU). It was organized by ERD, and funded by the Joint Polar Satellite System (JPSS) of the NOAA National Environmental Satellite, Data, and Information Service (NESDIS). A total of 35 participants took the course including NMFS and NOS employees, and affiliates from OSU and the private sector. Satellite data can be difficult to access, manipulate and process, particularly for people who have never used it before. Therefore, one of the main goals of the course was to provide an overview of the types of environmental satellite data available, where and how to access the data, and methods of working with the data, including importing into Geographic Information Systems (GIS) applications, and accessing data through Matlab and R. The courses relies primarily upon data served off of the ERDDAP (Environmental research Division's Data Access Program) server at ERD. ERDDAP is both a web application and a web service, and was developed at ERD to provide an easier access to datasets. In the course particular emphasis was placed on accessing and utilizing ocean color data from the Visible Infrared Imager Radiometer Suite (VIIRS) sensor on Suomi National Polar-Orbiting Program (SNPP), which launched Oct 2011, through a variety of protocols.

Ocean color data is a critical for oceanographers and marine resource managers. These users have come to depend on data from the Sea-viewing Wide Field-of-view Sensor (SeaWIFS), the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, and the MEdium Resolution Imaging Spectrometer (MERIS) sensor. Given the demise of the SeaWiFS satellite, and the beyond-design life age

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

of both the MODIS and MERIS sensors, there has been concern about the future availability of ocean color data. VIIRS provides ocean color and SST data to the oceanographic community. VIIRS data will fill this critical gap and enable the continuation of this important time-series of ocean color data. 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. The JPSS Proving Ground (PG) projects ensure continuity of heritage and other NOAA products using VIIRS ocean color and SST data. To this end, the JPSS PG engages NOAA users such as the NOS and the NMFS for operational NOAA uses of VIIRS data.

On Course for Success

Based on the Ocean Satellite Data Course surveys, nearly 90% of the course participants had never used VIIRS, and were completely unaware of its capabilities and its value. Thus, oceanographic satellite data courses such as the ERD's are particularly helpful when both data providers and data users are involved. More specifically, providers educate participants about the availability, access, and use of satellite data. But even more importantly, from these courses, providers obtain a better understanding of user needs and requirements, and are better able to address those needs. The two responses below highlight the feedback received from the course surveys. NOS and NMFS participants consistently emphasized the value of the VIIRS information and their excitement as they consider how to use these data in their operational support.

"This course was a wealth of information! I have wanted to try using satellite data myself but I wasn't sure how to even access it. From the outside it seems like a daunting task, but it is very accessible once you know where to look. The tools presented at this course are very user friendly.*"*
Rebecca Miller, NMFS/SWFSC

"This course has been very useful to understand VIIRS data, and to have the opportunity to discuss one-to-one how VIIRS data can improve our current NOAA work"
Roberto Venegas. NMFS/PIFSC/CRED