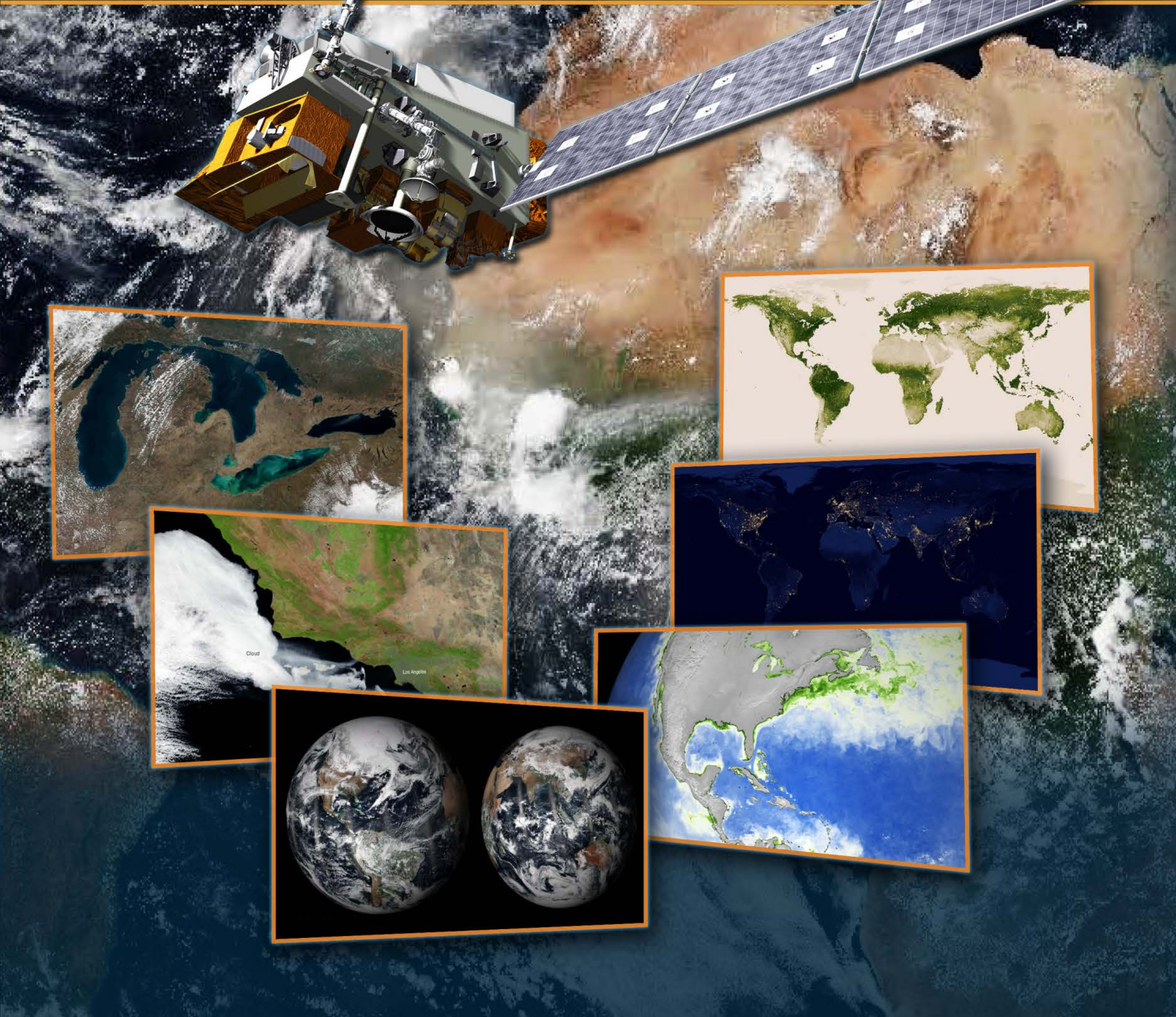
Joint Polar Satellite System Science Seminar Annual Digest 2015



Front and back cover: VIIRS true color imagery for October 3, 2015, generated using NOAAView, shows weather events across the globe. Note dust transport from the Sahara into Atlantic (front), and Hurricane Joaquin in Caribbean, and cloud system feeding moisture into South Carolina resulting in record rainfall and flooding (back). Credit*: NOAA*

Front Cover:

JPSS-1 satellite rendering. Credit*: Ball*

Maps from left to right

Harmful Algal Blooms - Credit: *NOAA Visualization Laboratory, Suomi NPP, VIIRS*
Smoke, Ash, and Dust - Credit: *NOAA Visualization Laboratory, Suomi NPP, VIIRS*
The Earth in True Color - Credit: *NOAA Visualization Laboratory, Suomi NPP, VIIRS*
Monitoring Ocean Health - Credit: *NOAA's Center for Satellite Applications and Research (STAR), Suomi NPP, VIIRS*
The Earth at Night. Credit: *Chris Elvidge, National Centers for Environmental Information (NCEI), Suomi NPP, VIIRS*
Mapping Vegetation Health - Credit: *NOAA Visualization Laboratory*

Joint Polar Satellite System Science Seminar Annual Digest

2015

From the Senior Program Scientist

It is my pleasure to present to you the 2015 edition of the Joint Polar Satellite System (JPSS) Science Seminar Annual Digest. This digest, like its predecessors, features a collection of articles generated from our monthly science seminars. It also charts the progress of JPSS Program Science through showcases of the operational capabilities of the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite. Suomi NPP is the first next-generation polar-orbiting satellite in the JPSS constellation, and NOAA's primary polar-orbiting satellite. An important distinction between this year's digest and the previous editions is the inclusion of web features. These are interesting news and highlights from our website that underscore the importance of JPSS for key applications. For more information on our web features please visit http://www.jpss.noaa.gov/.

Our data users are continuously engaged through support from the JPSS Proving Ground and Risk Reduction (PGRR) Program. It is through the PGRR that Program Science receives user feedback on the impact of Suomi NPP/JPSS data. This feedback helps us to identify improvements needed for products and applications. This digest is part of our continuing commitment to provide you with key information on these ever-evolving applications of Suomi NPP data. We hope that this information enables you to identify the trends showing the positive outcomes from JPSS. This digest also serves as your virtual window into the exclusive science innovations taking place in the JPSS PGRR Program. Through this program we have established a close relationship between developers and users to conceptualize and develop applications that help improve the use of JPSS data to enhance key services. From this we have grown in expertise, scope and sophistication, and this digest is intended to help demonstrate the importance of these collaborative ventures. Our goal is to keep you abreast on the leading edge technologies from our initiatives in the JPSS PGRR.

Notable accomplishments this year included an increase in the use of Suomi NPP data in operational missions. For example, the use of ATMS data in the Hurricane Weather Research Forecast (HWRF) model was first demonstrated in the JPSS PGRR and is now operational at NOAA's National Centers for Environmental Prediction (NCEP). In addition, VIIRS data for cloud imagery, fire /smoke monitoring, fog detection and ice detection is now used routinely.

And, last but not least, VIIRS ocean color and SST data are being used routinely by NOAA's National Marine Fisheries Service (NMFS) and National Ocean Service (NOS).

In March 2015, we conducted a very successful Airborne Validation Campaign in Greenland. This campaign sought to further establish the accuracy of measurements from the sensors onboard Suomi NPP. Measurements captured by the sensors on NASA's ER-2 aircraft were used to reconcile known differences between observations from various satellite sensors, including the Cross-track Infrared Sounder (CrIS) on Suomi NPP, the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua, and the Infrared Atmospheric Sounding Interferometer (IASI) on the European MetOp-A and MetOp-B for very cold atmospheric regimes. It also sought to provide data for validating and improving our products and methodologies in these extreme conditions. You can read more about these leading-edge approaches in this issue.

This past year there was a strong push to use national and international conferences and technical forums to highlight the operational value of Suomi NPP data to scientists and the public alike. JPSS personnel and their key partners helped organize the 20th Conference on Satellite Meteorology and Oceanography, the 11th Annual Symposium on New Generation Operational Environmental Satellite Systems, and the third Symposium on the Joint Center for Satellite Data Assimilation (JCSDA) at the American Meteorological Society's Annual meeting in January 4-8, 2015 in Phoenix AZ. JPSS also co-sponsored a town hall entitled, "Advances in OCONUS Satellite Applications Enabled by the Current and New Generation of Polar-Orbiting and Geostationary Satellites," and co-hosted the inaugural student reception. JPSS played just as an important of a role in the smaller forums such as the 2015 NOAA Satellite Science Week, which took place from February 23–27, 2015. Science Week is an internal NOAA Technical Interchange Meeting between research and application developers and the NOAA end user community. This joint meeting, between NOAA's major satellite programs, JPSS and GOES-R, sought to review and discuss the state of their science portfolios. The meeting had over 130 participants including NOAA's science and operational community, and national and international associates. This was an opportunity for developers of polar and geostationary products to showcase their products' capabilities to NOAA end users and also an opportunity to generate ideas on leveraging these capabilities to maximize their value to the NOAA operational mission.

In April 2015, another key meeting was hosted by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in Darmstadt, Germany. This was the second Community Satellite Processing Package (CSPP) and International MODIS/AIRS Processing Package (IMAPP) Users' Group Meeting. This meeting brought together the worldwide community of CSPP and IMAPP users to discuss issues relevant to reception, processing, and applications of data acquired by direct broadcast from operational polar-orbiting satellites including Suomi NPP, Terra, Aqua, and Metop.

Equally important was the JPSS planning and participation in the 2015 NOAA Satellite Conference, which took place between 27 April and 1 May, 2015. This biennial conference provided a perfect environment to draw together users and providers of polar-orbiting and geostationary satellite data, products, and applications. This year's conference had over 600 attendees from the government, public, private, and academic sectors, along with national and international associates. Personnel from the JPSS Program and team members from the PGRR projects provided oral presentations and posters throughout the Conference. The use of Suomi NPP data by the international end-user community and by our partners at the Department of Defense (DoD) was also highlighted.

Also of note, our VIIRS boat detection project led by Dr. Chris Elvidge, was highlighted in a press release[1] issued by The White House, on October 5, 2015. The product captures nighttime lights from fishing boats and will be available globally by 2017. This product can provide fishery agencies with up-to-date information of night-time fishing activity and can also provide indications of illegal fishing in restricted areas and incursions across Exclusive Economic Zone (EEZ) boundaries and Marine Protected Areas (MPAs).

One of our biggest challenges and also our greatest opportunity is to ensure that users are ready for Suomi NPP/JPSS data. We also have to ensure that this data improves their key operational and research product and services. In 2013 we established the River Ice and Flooding Initiative, as part of our efforts to increase the use and utility of Suomi NPP and JPSS data products in operations, particularly for NOAA users. The products generated under this Initiative were well-received and the demand for them increased significantly. VIIRS data for river ice and flood detection is now routinely used by National Weather Service (NWS) River Forecast Centers (RFCs), and will soon follow the path to operations. Following on this success, in 2014, we established two additional Initiatives, Fire and Smoke and Atmospheric Soundings. At present our Initiatives have expanded to include Numerical Weather Prediction, Advanced Weather Information Processing System (AWIPS) Operational Demonstrations in the OCONUS and at NCEP Centers, Cryosphere, Land Data Assimilation, Oceans and Coasts, Atmospheric Chemistry, Hydrology, Aerosol Data Assimilation, Innovation, and Training. Under these Initiatives the PGRR program not only expanded across a broad range of applications, but also aims to double the number of JPSS data products that are used operationally within 4 years.

At the end of a very busy and productive year, I would like to thank our federal staff, private sector support staff, and numerous partners whose contributions and dedicated efforts make these digests a big success. I want to acknowledge Julie Price for leading the development of the seminar articles, and many thanks to Stephanie Moore for the web articles included in this document. I would also like to give special thanks to my Program Science staff, JPSS Communications, and the NOAA JPSS Office, for their ongoing support in the development of this digest; and to the authors and editors. It is through our collective efforts that we can present this information to you. I hope you enjoy reading this digest and that you find it useful.

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[1] https://www.whitehouse.gov/the-press-office/2015/10/05/fact-sheet-preserving-and-protecting-oceans-and-americas-waterways

From the Director

As we reflect upon another successful year at JPSS, we also look forward to 2016 and beyond. 2015 marked many JPSS achievements. The JPSS-1 spacecraft has moved into its testing phase to ready it for launch early in 2017. After launch and commissioning it will be known as NOAA 20. Work on the JPSS-2 instruments continued to progress well and JPSS-2 spacecraft work has started and is making good progress. We also saw the fourth anniversary of the launch of the NOAA/NASA Suomi-NPP satellite. In its just over four years of operations, we continue to see excellent performance from the observatory, the ground, and the data product science. Finally, we are in the test and verification phase of delivering a major update and upgrade to the Ground system in 2016, which will provide a more robust, secure, higher capacity and flexible capability to fly the missions and deliver the data products to our users.

JPSS is the new generation of United States' Polar-orbiting Operational Environmental Satellites in the afternoon sun-synchronous orbit. JPSS is part of the infrastructure of NOAA, a bureau of the U.S. Department of Commerce, to support NOAA's missions to enable a weather ready nation; healthy oceans; climate adaptation and mitigation; and resilient coastal communities and economies. Polar orbiting environmental satellites provide timely and global space based observations of weather and environmental phenomena for forecasts, monitoring, and impact assessment.

In 2014 alone, eight severe weather and climate disaster events occurred across the United States with losses exceeding $1 billion each. Receiving accurate and timely warnings are of critical importance to protect lives and property, enable faster recovery from severe weather and weather related environmental phenomena, and support economic efficiency. Our advanced weather enterprise gives the critical advanced warnings to achieve these societal benefits. NOAA's National Weather Service (NWS) incorporates Suomi NPP data into its weather prediction models that help generate medium-to-long range forecasts to better predict medium- and long-term weather, including severe weather phenomena. Over 80% of the data these models depend on come from polar orbiting environmental satellites. These data are provided fully and openly to other Federal, State and local users; commercial weather sector; and international partners. In-turn, we receive data from our international and inter-agency partners that greatly increase the benefits received from our own satellites.

Suomi NPP continues to provide critical data derived from the next generation instruments that fly on the JPSS series satellites: Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), Ozone Mapping and Profiler Suite (OMPS). Suomi-NPP also hosts the fifth Cloud and Earth Radiant Energy System (CERES). These represent substantial advances over NOAA's legacy Polar-orbiting Operational Environmental Satellites, building on capabilities pioneered by the NASA's Earth Observing System Satellites, to provide substantial increases in data quality and some unique new capabilities such as the Day Night Band on VIIRS which provides unprecedented ability to monitor weather and other related environmental phenomena at night.

In addition to feeding the Numerical Weather Programs with Sensor Data Records such as the vertical atmospheric temperature and moisture profiles from the ATMS and CrIS sounders, which are most critical to the models, JPSS data are used to generate dozens of environmental data products, clouds, vegetation, ocean color, and land and sea surface temperatures. JPSS products are available via NOAA's Comprehensive Large Array-Data Stewardship (CLASS) website, which currently houses more than 4.8 petabytes (equivalent to 305,000 16 gigabyte smartphones) of data from the satellite, typically receiving 2.1 terabytes of data a day. Currently VIIRS data is the most frequently accessed environmental data from CLASS. In addition, NOAA's partner NASA is using JPSS data to create multi-decadal climate quality data records begun under the Earth Observing Program in the early 2000's. NOAA and other research scientists throughout the U.S. and the world use JPSS data as they study severe weather, atmospheric and oceanographic phenomena, and climate.

JPSS has also invested in extensive user readiness and risk reduction activities leading to substantial advances over legacy products based on legacy sensors, and have introduced several new capabilities based on JPSS instrument features such as the Day Night Band. Highlights include utilization of sounder products for operational forecasting, and imagery products for fog, sea ice, active fires, floods, volcanic ash, drought, vegetation stress, harmful algal blooms, and coral bleaching.

Suomi NPP serves as the primary tool for predicting weather in locations that are not visible to conventional observing systems. In the Pacific region, a vast data sparse area, Suomi NPP data provides information to accurately track and predict severe weather events. The region's distinctive geography has a high vulnerability to hazards and climate variables such as typhoons, heavy rains, droughts and tropical cyclones. The VIIRS day/night band is sensitive enough to provide storm information even under limited moonlight conditions, a major advancement for storm analysis.

JPSS is also the primary weather observation satellite system for Alaska and the Polar Regions. In Alaska, Suomi-NPP provides critical data for aviation weather forecasting as well as for the economically vital maritime, oil and gas industries. Aviation touches all aspects of life in Alaska, and is a basic mode of transportation because approximately 90% of Alaska is not served by roads. Data from Suomi NPP also contribute to the U.S National Ice Center, which provides snow and ice products to support the military as well as the transportation and energy sectors.

Every indication is that Suomi NPP will continue to provide the critical polar satellite observations while JPSS-1/NOAA-20 is thoroughly tested after launch in preparation for transition to operations. The orbital position of JPSS-1/NOAA-20 relative to Suomi NPP will allow data from both spacecraft to be used more advantageously in the national weather prediction models.

I am happy to report that the President's FY 2016 Budget request outlines a plan to re-build robustness in the NOAA early afternoon polar weather satellite system that was enjoyed in the

1980’s through the early 2000’s by adding two additional JPSS missions. The request was the culmination of 3 years of analysis and planning to establish the best means to ensure we can continue to deliver the critical polar weather and environmental data into the late 2030’s. The critical first step in 2016 is to begin development instruments which will fly on Polar Follow On (PFO) / JPSS-3 and PFO/JPSS-4.

I offer my thanks for the many contributors to this digest, and to our JPSS science team and community for their outstanding contributions to JPSS. I hope you enjoy the 2015 Digest highlighting the successes and progress of our many hard working team members who ensure the JPSS Program delivers on its commitments.

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Contents

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Enhancing Land Surface Modeling of Agricultural Drought With Land Products From The Suomi-National Polar-orbiting Partnership (Suomi-NPP)

*This article is based in part on the **October 20, 2014** JPSS science seminar presented by Xiwu Zhan and Chris Hain, NOAA-NESDIS Center for Satellite Applications and Research (STAR).*

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

Dry lake bed. (Credit: NOAA)

Drought is one of the costliest natural disasters in the United States. According to the National Climatic Data Center's (NCDC) "U.S. Billion-dollar Weather and Climate Disasters[2]," economic losses from drought account for almost 24 percent of all losses from major weather events, including severe storms, wildfires, floods, and tropical cyclones. Drought events exhibit periods of abnormally dry weather that may persist long enough to cause serious problems such as water supply shortages, reduced crop yields and/or livestock losses. However, unlike other weather disasters that are usually preceded by hours or days of advance notice and warning, the onset of drought often goes unnoticed. This is because drought is not an abrupt and dramatic event, but rather a slow evolving phenomenon whose impacts may not be immediately apparent.

Challenges in Measuring Drought

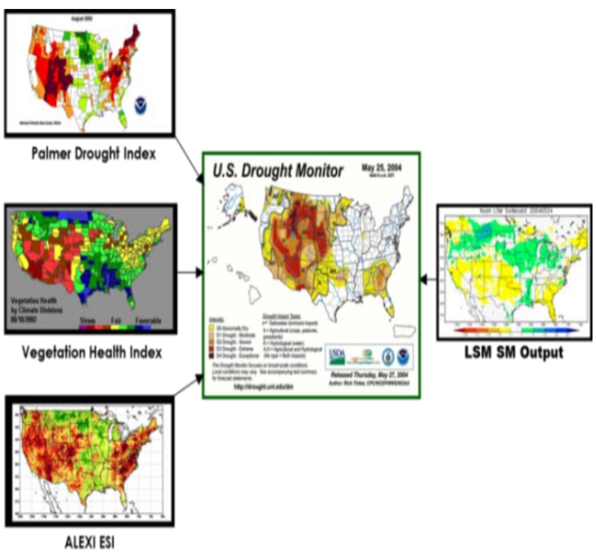
For more than a decade satellite-based remote sensing has been used to monitor various environmental phenomena, including drought. Drought conditions typically depend upon geographic location, weather patterns, soils, water use patterns, and overall water quantity; thus their impacts are often unique to a particular region and the people they affect. As drought conditions develop gradually, they are often not identifiable immediately. In addition the effect of a drought may not be fully felt for months or even years, making it difficult to accurately pinpoint its onset or end, and also determine how best to mitigate its impact. These characteristics include large geographic and temporal variability and the wide-ranging complexity of drought impacts, and they make it challenging to measure drought.

Satellites provide a rapid method of acquiring information over a large geographical area, which would be challenging using only ground-based observations. For drought monitoring and early

[2] Smith, A., and R. Katz, 2013: U.S. Billion-dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy and Biases. *Natural Hazards*. DOI: 10.1007/s11069-013-0566-5

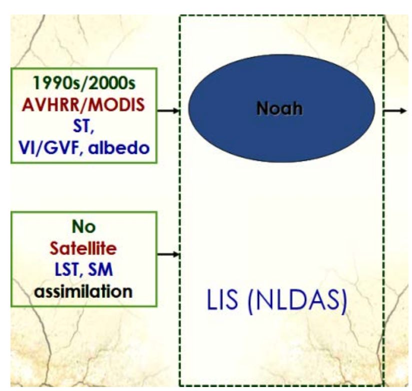
warning applications, satellite remote sensing has unique advantages over conventional observations of drought conditions. This is especially evident with ground-based observation methods, which are often tedious, time consuming, and difficult. Weather station networks, for example, are sparse and not uniformly distributed. Observations from environmental satellite sensors can lead to early detection of drought, and are becoming cornerstones of most drought preparation, risk management, and hazard mitigation activities. Satellites, such as the Nation's next generation polar-orbiting operational environmental satellite (POES), Suomi-NPP, provide an opportunity to measure and analyze key features of droughts routinely with relatively high repetition rates, synoptic coverage and increased spatial detail of vegetation conditions compared to information provided by conventional monitoring systems.

The United States Drought Monitor



Current Drought Monitoring Methods

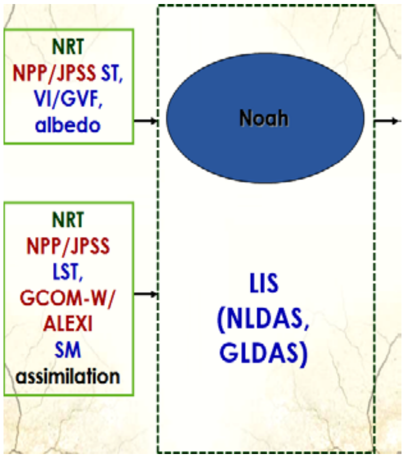
One of the most widely used drought status assessment products is the United States Drought Monitor (USDM). The USDM (example shown left) supports a wide range of users, including those responsible for making decisions regarding drought management, mitigation, and policy. Some of the resource inputs into the USDM include the Palmer Drought Index (PDI), the Vegetation Health Index (VHI) and the Atmosphere-Land Exchange Inverse (ALEXI) ESI. However, the main data source for the USDM is the soil moisture output Land Surface Model (LSM) within the North America Land Data Assimilation System (NLDAS). The SM Output data feeds come from static satellite surface type (ST), albedo, and Green Vegetation Fraction/ Vegetation Index (GVF/VI). The USDM is accessed through the U.S. Drought Portal, or www.drought.gov, a website that pulls together many resources, including drought monitoring LSMs. LSMs help increase our understanding on the interactions between land-surface conditions and different components in the Earth system. LSMs are used to represent characteristics of the land's surface (e.g., land cover parameters) or the state of the land surface such as soil moisture (SM) and temperature. LSMs also represent terrestrial processes such as evaporation, runoff, and photosynthesis.



Current Noah LSM runs

Soil moisture plays a key role in controlling the exchange of water and heat energy between the land surface and the atmosphere. It is one of the key factors in estimating drought severity. The National Centers for Environmental Prediction (NCEP), Oregon State University, Air Force Weather Agency, and NOAA Office of Hydrology (NOAH) is the operational LSM run at NCEP. The model (shown right) is driven by near-surface atmospheric forcing data obtained from satellite observations. The observations include: GVF derived from NDVI; seasonal land surface albedo; and the global land cover map generated by the University of Maryland which uses an archive of data – dating back to the 1990s – from the Advanced Very High Resolution Radiometer (AVHRR) aboard NOAA polar-orbiting satellites. These observations are used to generate static maps of multiyear climatological averages. However, unlike near real-time (NRT) satellite observations, multi-year average data are not always representative of observed conditions, especially at shorter time scales (daily and hourly).

While much progress has been made to improve and refine LSMs, some processes are not well captured. For example, some land surface temperature (LST) and SM retrievals are currently not assimilated into the operational LDAS. This can negatively impact our ability to understand land-atmosphere interactions and ultimately our ability to accurately predict severe phenomena such as drought. Various satellite sensors generate land data products such as ST, albedo, GVF/VI, LST and SM (shown right), for LSM in near real time. As a result, more NRT satellite retrievals are becoming available. NOAA scientists are assimilating retrievals from various satellites including Suomi NPP, the current Geostationary Operational Environmental Satellites (GOES), and the Japan Aerospace Exploration Agency's (JAXA) Global Change Observation Mission 1st-Water (GCOM-W1) into the operational LSM simulations. Inserting these retrievals into LSMs can produce more accurate representations of observed conditions, and lead to more accurate forecasts of drought. They also plan to include retrievals from the Joint Polar Satellite System (JPSS) and GOES-R satellites.



Enhanced Noah LSM runs

Impact of NRT ST, GVF and albedo on LSM SM Estimates

Among many sensitive parameters and forcing inputs to LSMs, surface albedo, GVF and solar insolation directly impact the energy balance of land surface, and thus, the accuracy in these important parameters is critical to SM and drought monitoring. To demonstrate the impact of NRT ST, GVF and albedo on soil moisture estimates from LSMs, scientists at STAR ran the LSM in two modes. As shown in the table below, one used conventional multiyear averages as inputs while the other used NRT data. Root-zone soil moisture is an important variable in drought monitoring applications. The RMSE of these two runs was compared against in situ observations to judge which one performed better.

ID	Parameters	Description of parameters (resolution and data source)			Simulation period
		Temporal	Spatial	Data source	
S01	GVF Climatology	5-year average	0.144°	AVHRR	2000 – 2012
	Albedo Climatology	5-year average	0.144°	AVHRR	2000 – 2012

	NARR Insolation	Hourly	0.125°	NLDAS-2 NARR	2000 – 2012
S02	NRT GVF	8-day composite	1 km	MODIS	2000 – 2012
S03	NRT Albedo	8-day composite	1 km	MODIS	2000 – 2012
S04	NRT ST	8-day	833 m	MODIS	2007– 2010
* S01: Noah simulation with climatological parameters of ST, GVF and albedo * S02 – 04: Noah simulations with single replacement of one of the three NRT parameters as model inputs					

The table below shows the improvements of soil moisture from Noah LSM using NRT albedo and GVF inputs. The validated results showed a positive impact on SM simulations for both surface and root zone SM from the Noah LSM after the insertion of NRT parameters.

Impact Assessment Statistics

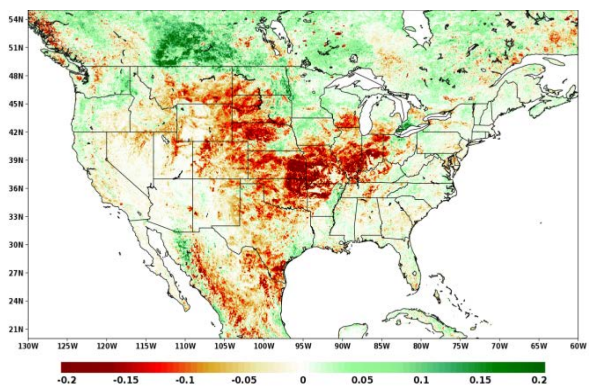
Variables	Average Normalized RMSE improvement (%)		Maximum impact period (MIP) DOY (beg. – end.)		Maximum Normalized RMSE improvement (%)		Number (%) of improved sites	
	Surface	Rootzone	Surface	Rootzone	Surface	Rootzone	Surface	Rootzone
GVF	0.63	1.50	230-280	230-280	11.8	12.38	51.01	57.03
Albedo	0.23	0.56	221-256	249-283	1.67	3.97	66.04	64.42
Insolation	1.67	0.93	94-111	128-184	3.98	10.00	69.79	52.61
Combined	0.62	10.7	222-281	222-277	2.49	12.65	62.10	55.13

Among the three parameters studied in this work, the NRT insolation was found to produce the greatest impact on surface SM estimates by improving the normalized RMSE by 1.67 percent on average. The magnitude of improvement with the insertion of NRT GVF is 0.63 percent to surface and 1.50 percent to rootzone SM. Even though the impact of NRT albedo on SM estimates is limited, validation results still show the slightly positive improvement by 0.23 percent to surface SM and 0.56% to rootzone. The insertion of NRT GVF has the maximum impact with 2.29 percent improvement on the normalized RMSE over the period from middle Aug. to early Oct., while NRT insolation with 2.5 percent over 8-week period starting from early May. Overall, improvements can be detected to around 62.3 percent (55 percent) on average of the total NASMD sites with single assimilation of NRT parameters and approximately 62.1 percent (55.1 percent) with all three parameters combined to the surface (rootzone) SM estimates.

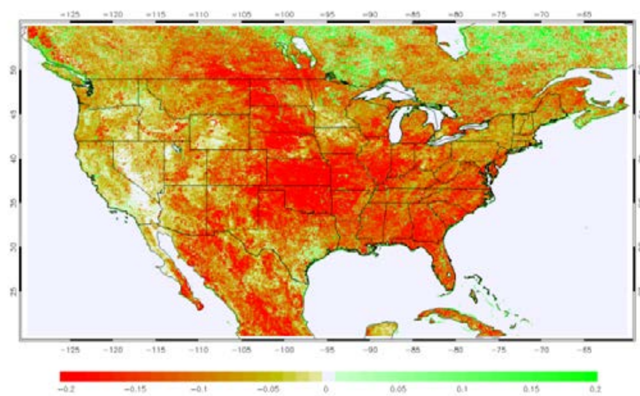
Impact of NRT GVF on CONUS Drought Mapping

Scientists at STAR also looked at the impact of NRT GVF on drought mapping over the Contiguous U.S. (CONUS). They ran the NLDAS Noah LSM using multi-year averages of weekly GVF from AVHRR, which was used as the control; while current year weekly GVF from AVHRR was used to simulate NRT. There were significant differences in the climatological and near real-time GVF values. These would inevitably impact the Noah LSM through the partitioning of available energy into surface fluxes of sensible and latent heat, and in turn LSM forecasts. The differences represented the impact of NRT GVF on drought monitoring.

During the Spring/Summer of 2012, there was a major anomaly in GVF over central and eastern North America, which was associated with the exceptionally warm early spring temperatures in March 2012. The maps below depict NRT MODIS (left) and VIIRS (right) GVF for 2012 compared against the 12-13 year average. They show negative GVF anomalies (up to 20 percent) during the significant drought of 2012 which occurred across much of the central CONUS. NOAA scientists began generating the GVF product experimentally on August 08, 2012. While the two maps cover time periods that are almost two weeks apart, they both display similar patterns. Research using VIIRS GVF is still in the early stages, but appears very promising. Currently available (~1 year) VIIRS GVF data indicated magnitude and seasonal patterns very similar to MODIS and AVHRR, so before we have a longer term (for example 5 years) VIIRS GVF data to assess NRT VIIRS GVF impact on drought monitoring, we used AVHRR/MODIS data to demonstrate the significance of NRT GVF utilization.



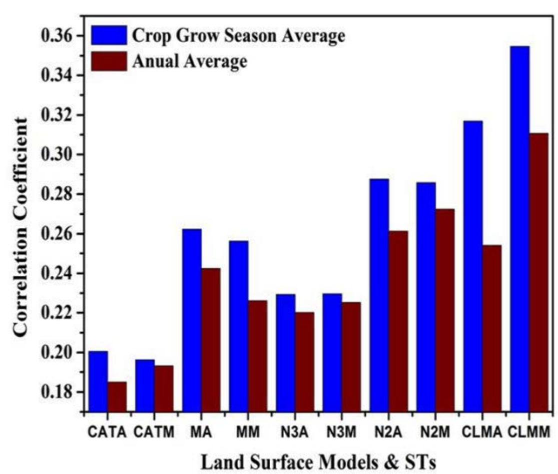
MODIS GVF anomaly (5 August 2012)



VIIRS GVF anomaly (15 August 2012)

Impact of NRT ST on LSM SM Estimates

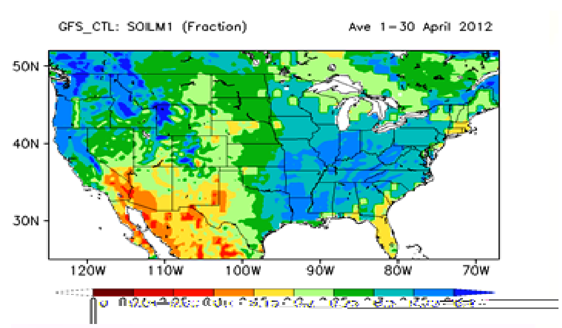
To study the impact of surface type (ST) on LSM SM estimates, STAR scientists tested the GLDAS using either archived ST data from AVHRR or Quarterly Surface Type IP (QST IP) from the Visible Infrared Imaging Radiometer Suite (VIIRS). Model integrations are conducted on a gridded domain covering China mainland (from 17°N, 73°E to 55°N, 136°E) at 25 km spatial resolution using either AVHRR or MODIS/S-NPP land cover maps. All simulations are forced by the Global Data Assimilation System (GDAS) of NOAA NCEP. All the model runs are spun up by cycling the period from January 2001 to December 2012 with one half hour time step inputs and daily



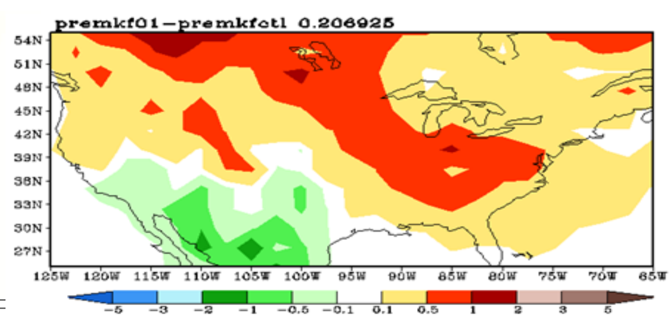
If correlation coefficients are more than 0.16, 0.22 and 0.29, they are significant with credibility level 0.05, 0.01 and 0.001 separately. Crop grow season is from April to September in 2011 and 2012. The symbols of CATA, CATM, MA, MM, N3A, N2A, N2M CLMA and CLMM indicate Catchment, Mosaic, Noah3.2, Noah2.7.1 and CLM2.0 land surface models (LSM) implemented in LIS respectively.

outputs. The simulations conducted during 2011-2012 period are employed to assess LSM performances using the in situ observations at depth of 10 cm to match 10 cm thickness of Mosaic, Noah2.7.1, Noah 3.2 and 12.36 cm thickness of CLM2.0. The scientists looked at the relationship between in-situ observational relative SM of 108 stations and SM simulated by LSMs with AVHRR and Moderate Resolution Imaging Spectroradiometer[3] (MODIS) land cover over mainland China from January 2011 to December 2012. Their sample size of 324 consisted of data for every ten-day observation time interval from 108 stations. Their results (as shown in the figure on the right) showed that the root-zone SM estimates based on MODIS ST were generally in better agreement with in-situ measurements than those based on the AVHRR ST data. VIIRS surface type map becomes available after this study was finished. Preliminary assessment of the VIIRS ST data indicated that the global distribution of surface types from the VIIRS data is very similar to the MODIS land cover map. Thus the above results should be valid for VIIRS surface type observations.

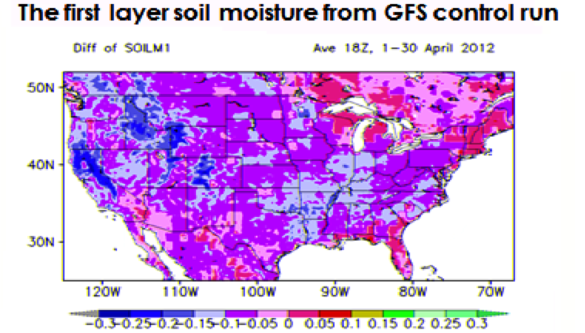
The Soil Moisture Operational Products System (SMOPS) combines soil moisture retrievals from multiple satellites sensors to create a blended global soil moisture map with more spatial and temporal coverage. To study the impact of SM DA on the NCEP GFS, STAR scientists assimilated SMOPS SM product in the NCEP GFS using an ensemble Kalman filter (EnKF). Their results showed a positive impact on the GFS performance, particularly for precipitation forecasts. The image on the left shows soil moisture maps with and without the SMOPS SM assimilation. The lower image shows that in April the observations were much drier than modeled. The impact of SMOPS soil moisture on GFS is also reflected on 2 meter humidity and air temperature too. The plot on right demonstrated the differences of 2 meter air temperature 5-day forecasts resulting from the soil moisture data assimilation.



The first layer soil moisture from GFS control run



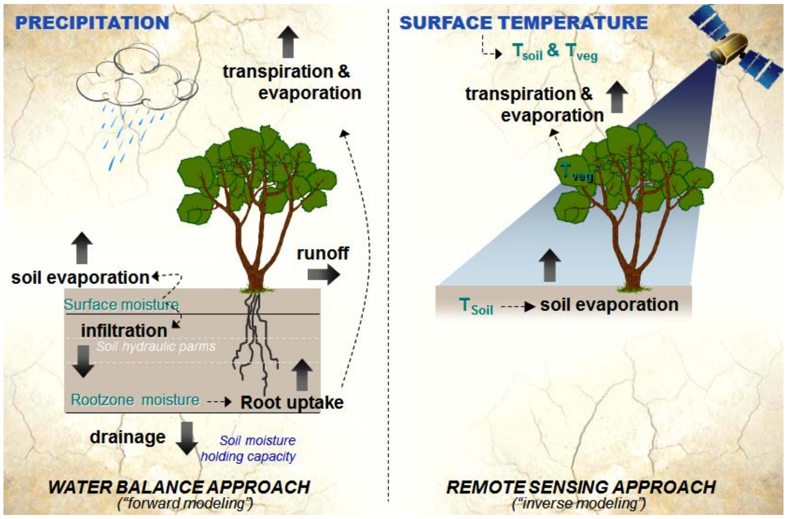
Difference map of 2m air temperature 5 day forecasts from GFS resulting from assimilating satellite soil moisture data



Difference between GFS sensitivity and control run

[3] Onboard NASA's Terra and Aqua satellites

Land Surface Temperature Sensing for Drought Monitoring

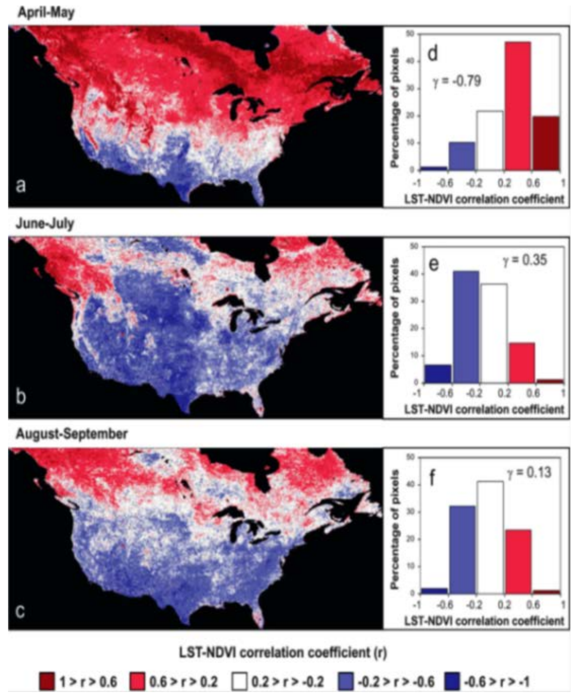


The traditional LSM approach used in drought monitoring (left) requires an intricate knowledge of various parameters including root uptake, vegetation exchange with the atmosphere, precipitation, how that precipitation turns into soil moisture, and so forth. These parameters are needed to model how the exchange of water and energy between the land surface and atmosphere occurs. STAR scientists have developed a broader more diagnostic remote sensing approach (right) in which LST is used to deduce how much water loss is required to keep the soil and vegetation at the temperatures observed by the satellite. STAR scientists have used this method to develop a remote sensing tool known as the Evaporative Stress Index (ESI). The ALEXI ESI represents temporal anomalies in the ratio of actual evapotranspiration (ET) to potential ET, which is the maximum ET that could be expected for a given region. ET demonstrates water loss due to evaporation and plant transpiration to the atmosphere, and is an indicator of what the plants are experiencing. Using remotely sensed LST measurements STAR scientists have simplified the estimation of ET, which is used to deduce the current state of soil moisture without precipitation data, soil characteristics or some of the harder to observe parametrized variables that are more prevalent in LSMs. Thus ESI may be more robust in regions with minimal in-situ precipitation monitoring. Another advantage of ALEXI ESI is it includes non-precipitation related moisture signals (such as irrigation; vegetation rooted to groundwater; lateral flows) that need to be modeled a priori in prognostic LSM schemes.

LST is important for drought, water stress and vegetation stress. This is because signatures of vegetation stress are manifested in the LST signal and can be detected before any deterioration of vegetation cover occurs. These signatures are seen in thermal infrared (TIR)-based drought indices such as the NDVI. Thus, TIR-based drought indices can provide an effective early warning of impending agricultural drought.

ALEXI takes important forcings on LST into account, whereas empirical TIR-based drought indices do not, and can therefore generate spurious drought detections under certain circumstances. ALEXI addresses these issues through a full coupling of current vegetation state, available energy, mid-morning rise in LST (which are more related to soil moisture stress) and the evolution of the mid-morning boundary layer.

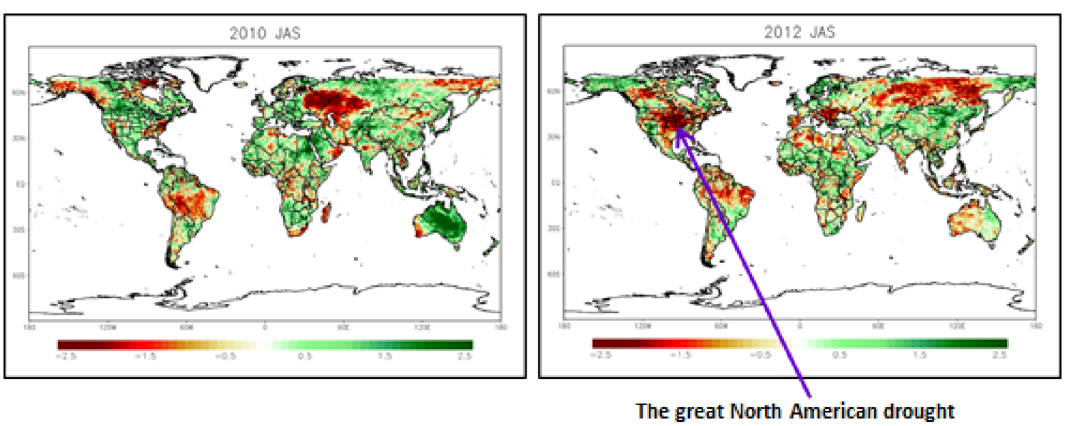
LST-based Drought Data Products



The example on the left, from a study by Karnieli et al. (2010), shows some LST-NDVI correlations covering the months of April-May, June-July and August-September. The red shaded pixels represent regions where LST-NDVI correlations are positive, i.e., constraints on ET are related to available energy and not soil moisture. Therefore, products such as the VHI have very limited skill over the northern tier in April-May and even in some parts of Canada during the warmest parts of the season. The index still performs well over parts of the Midwest in June-July and August-September. But in the regions shaded red, the use of empirical LST-based indices can lead to spurious drought signals, and anomalously high LST does not infer soil moisture stress when the correlations between LST and NDVI are positive.

MODIS/VIIRS LST for ALEXI ESI

Before ALEXI, NOAA scientists relied on geostationary data. However, recent research has led to the development of a new methodology which uses day-night LST differences from sensors such as MODIS and VIIRS to estimate the mid-morning rise in LST needed by ALEXI. The methodology relies on a regression model, trained with geostationary data from GOES and MSG to develop relationships between twice-daily observations of LST (day/night) and the mid-morning rise in LST. An initial validation from 2000 to 2013 indicates that the regression model can predict to within 6 to 10 percent the mid-morning LST from the LST that is observed twice-daily. The following ESI maps are an example from the first version of this tool. The maps, which cover a three month period from July to September for the years 2010 and 2012, match pretty well to the bigger droughts that were observed during those years.



Summary

Drought is a complex phenomenon that impacts many regions of the world including the U.S. Drought often results in agricultural losses, which can have local, regional, and national effects. Often, these effects ripple into other sectors of the economy, including transportation, power and water supplies, navigation, recreation and etc.

As there is no standard validation for drought, a convergence of evidence from different independent datasets provides the only means by which informed decisions relating to drought can be made. Data from NOAA POES are inputs to LDAS, such as GLDAS and NLDAS. These LDAS use advanced LSM and data assimilation techniques to provide high quality spatial and vertical resolution SM information and are potentially useful tools in monitoring droughts. However, to maximize the value of this data, NRT satellite data products of ST, LST and SM need to be assimilated in the LSM operational runs. Soil moisture is highly variable both spatially and temporally and rather difficult to measure on a large scale. To supplement the current Noah LSM assimilations in both GLDAS and NLDAS modes, NOAA scientists are assimilating satellite observations including VIIRS ST, albedo, GVF, and LST into LSMs. These observations are available on the Suomi NPP, and will be available on the JPSS satellites, and the next generation GOES-R satellites, as well as the GCOM-W1.

The past decade has witnessed the launch of many advanced remote sensing instruments that collect data which is used monitor different aspects of drought. Furthermore, enhancements in processing and analysis techniques and improved computing capabilities have resulted in new approaches that could be used for drought monitoring. Examples of enhancements include ALEXI ESI, which provides an independent assessment of current drought conditions, supplementing precipitation and modeling-based indices. ALEXI ESI has become an invaluable resource, especially for the decision-makers who have often had to rely on a convergence of information in the decision making process.

NRT GVF leads to better partition between surface heating and evaporation, and is more representative of actual surface conditions. The introduction of NRT satellite-based observations is of great value to drought detection at shorter time scales (hourly or daily). Advanced modeling methods such as the ones featured in this article, demonstrate how assimilations of satellite observations into LSMs can lead to the more skillful characterization of drought. These new modeling methods assimilate NRT data in place of the multi-year averages of monthly GVF that are more commonly used in community models. These improvements will have a positive impact on almost every area of the world-wide agricultural economy.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Utilization of JPSS and GOES-R for Quantifying the Horizontal Extent of Hazardous Low Clouds

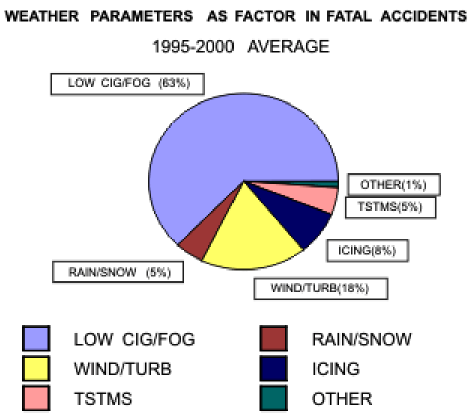
Joint JPSS/GOES-R Science Seminar

This article is based in part on the ***December 1, 2014*** *Joint JPSS and GOES-R science seminar presented by Mike Pavolonis, NOAA-NESDIS Center for Satellite Applications and Research (STAR). Additional contributors: Corey Calvert, Shane Hubbard, and Scott Lindstrom, (UW-CIMSS).*

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

Advection fog over the Golden Gate Bridge in San Francisco, CA.

Low clouds and fog are weather hazards and high-impact events for transportation in general, which nearly every forecaster, in nearly every National Weather Service (NWS) Weather Forecast Office (WFO), must regularly address. Visibility can sharply decrease in foggy conditions, creating dangerous travel conditions on roadways as well as in aviation, rail, and marine means of transport. Some adverse impacts of low clouds and fog include multi-vehicle collisions and the inability for many general aviation pilots to fly due to Instrument Flight Rules (IFR). The National Highway Traffic Safety Administration (NHTSA) analyzed vehicular accident records from 1995 to 2005. From these, the administration established that in the U.S. an annual average of 38,700 vehicular accidents were directly related to fog. These accidents caused 16,300 injuries and 600 deaths. In 2002, the NWS prepared a statistical summary[4] of all fatal aircraft accidents that occurred in the United States, including Alaska, Hawaii and coastal waters, which involved general aviation and small commuter aviation aircraft from 1995-2000. The summary was centered around data on fatal accidents in which the National Transportation Safety Board (NTSB) cited weather to be a cause or contributing factor. Aviation accidents in which fog and low clouds play a major role often prove fatal. The figure on the right provides a summary of the weather conditions most likely to cause these fatal accidents.



There are negative economic impacts from fog and low clouds as well. Commercial airlines lose millions of dollars each year from cancellations, delays, and rerouting forced by low visibilities at airports. Consequently, reliable methods for detecting and characterizing hazardous low clouds are needed.

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[4] Pearson, D. C., 2002: *VFR Flight Not Recommended: A Study of Weather-Related Fatal Aviation Accidents.* Technical Attachment SR/SSD 2002-18
Available from: http://www.srh.noaa.gov/topics/attach/html/ssd02-18.htm

VFR - Visual flight rules
ceiling > 3000 ft and vis > 5 mi

MVFR - Marginal visual flight rules
1000 ft < ceiling < 3000 ft or 3 mi < vis < 5 mi

IFR - Instrument flight rules
***500 ft < ceiling < 1000 ft* or 1 mi < vis < 3 mi**

LIFR - Low instrument flight rules
ceiling < 500 ft or vis < 1 mi

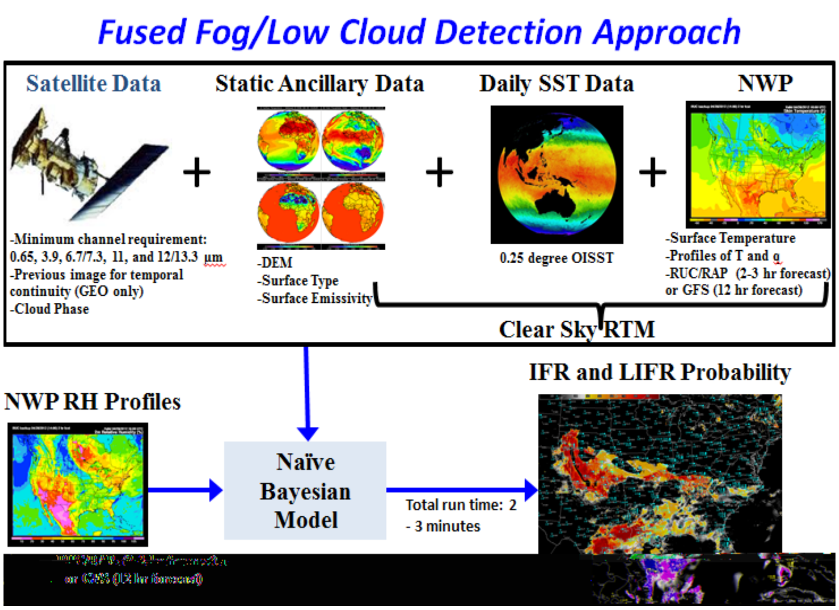
Pilots must be able to see the ground at all times

Pilots should be aware of conditions that may exceed their capabilities

Pilots have special training and equipment to fly in clouds

National forecast centers such as the Aviation Weather Center (AWC) Alaska Aviation Weather Unit (AAWU), and the Ocean Prediction Center (OPC) are responsible for issuing low ceiling and visibility related products. The figure above shows the categories of low cloud and visibility aviation forecasts. Aircrafts must be properly instrumented in order to operate in specific visual flight rule conditions. Pilots finding themselves in conditions without the proper instrumentation put themselves and their passengers at risk.

In response to these operational requirements, the satellite fog and low stratus (FLS) product was developed. This article focuses on the work being done on the FLS product to blend data from the Suomi National Polar Satellite Program (Suomi-NPP) with data from the Geostationary Operational Environmental Satellite R-Series (GOES-R) program, to create a very high-resolution depiction of ceilings and fog boundaries. In addition, the relevance of the FLS products to NWS operations is discussed.

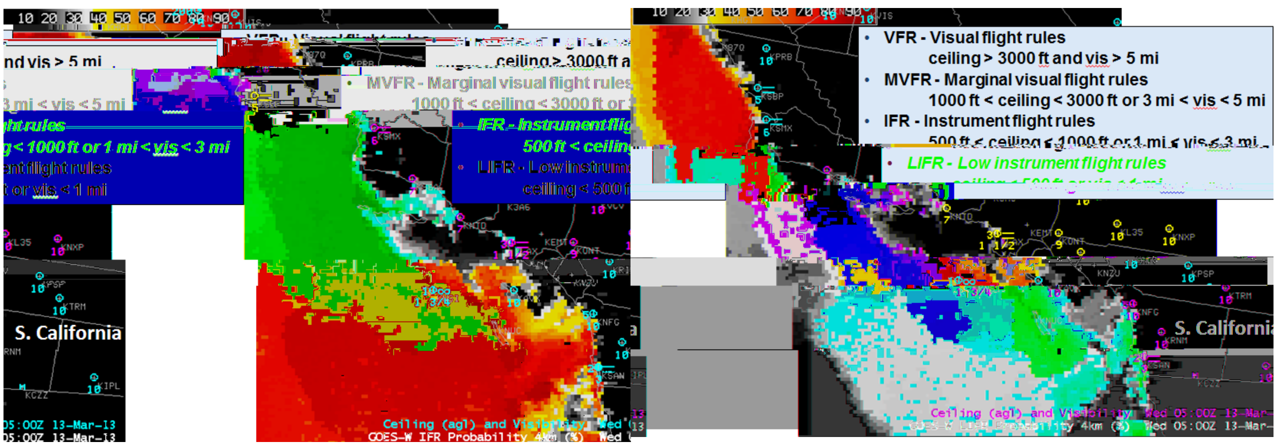


The FLS work was started eight years ago by the GOES-R Algorithm Working Group (AWG). The group first worked on the core definitions of "fog" and "low stratus" in the context of satellite imagery. The definitions had to be meaningful to the end users and also fully apply satellite data sensitivity. The algorithm initially only utilized data from a single geostationary satellite and was of similar quality as the traditional satellite product for FLS. In 2010, NWS forecasters evaluated the AWG product as part of the GOES-R Proving Ground. Their feedback indicated a desire for a product that greatly improved upon the traditional FLS product. In response, the AWG converted the algorithm into a fused (satellite and numerical weather prediction model data) probabilistic approach. The fused AWG FLS product was made available to forecasters participating in the GOES-R Proving Ground in late 2011. This time, the forecaster feedback was predominantly positive and forecasters began using the products with regularity that continues today. The Joint Polar Satellite System (JPSS) and GOES-R Risk Reduction Programs have become important partners in this effort.

Background on Blended FLS Product

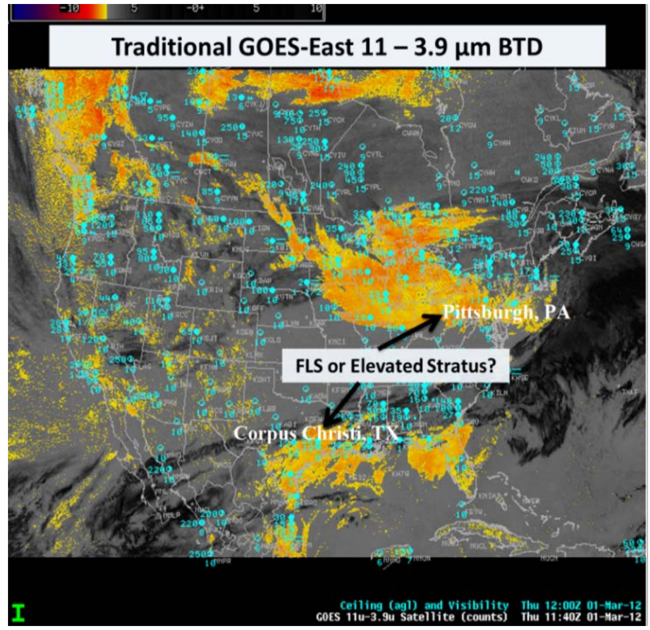
Traditionally, hazardous areas of Fog and Low Stratus (FLS) are identified using the Brightness Temperature Difference (BTD) between the near infrared (3.9 microns) and the window channel (near 11 microns), which exploits the emissivity differences in water clouds that exist at those two wavelengths. The 3.9-11 μm BTD has several major limitations.

While satellite imagery is useful, it does not provide quantitative information on cloud ceilings and/or surface visibility. Satellite measurements struggle to diagnose fog and low cloud when multiple cloud layers are present. The traditional BTD, for instance, does not differentiate between elevated stratus clouds (that are not hazardous) and low stratus clouds (that are hazardous). Also, the traditional BTD product is mostly a nighttime product, and as solar reflection during the day changes the BTD signal, it complicates the interpretation of the data fields.



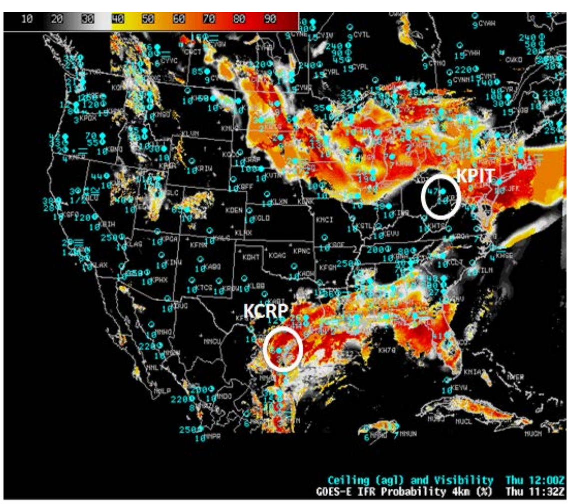
The GOES-R team adopted a probabilistic approach to the FLS Product. The GOES-R FLS provides the probability that a given location falls into a given flight rule category. That is, a given satellite pixel contains IFR, or lower, conditions defined as having cloud ceilings below 1000 feet above ground level or surface visibility less than 3 statute miles. Examples of IFR (left) and LIFR (right) are shown above. The LIFR category is best correlated with fog i.e., clouds in contact with the surface.

On the right is an example showing two regions where the difference in brightness temperatures between the 3.9 and 11 micron is similar. The traditional nighttime BTD product detects all liquid water clouds located in relatively stable atmospheric layers whether they are low to the ground or elevated. Thus, it is difficult to differentiate between hazardous low cloud layers from non-hazardous elevated stratus clouds using this product alone. Note how the clouds in western Pennsylvania and southeast Texas are depicted by very similar colors (yellow/orange in this case) in the traditional BTD product.



This image is a depiction of the BTD product that has been traditionally used in the past to detect nighttime FLS. Yellow/orange represents FLS.

The observation at Corpus Christi TX shows a surface visibility of 3 miles and a cloud ceiling of 600 feet. These observations are consistent with IFR rules. The radiosonde from Corpus Christi, TX showed near-surface saturation, which were consistent with the observations. This indicates that the cloud is located within the isothermal or inversion layer close to the surface. Western Pennsylvania has a BTD signal that is similar to that over Texas. However, the surface station at Pittsburgh, PA reported a visibility of 10 miles and a cloud ceiling height of 4700 feet. Thus, according to the BTDs there was a likelihood of low clouds in both regions, however, this turned out to be an accurate representation of the observed conditions in Corpus Christi only. The sounding from Pittsburgh, PA showed an elevated saturated layer, again consistent with the observation from the surface station of a cloud ceiling of ~4700 ft. This elevated cloud in Pittsburgh has roughly the same BTD signal as the low cloud from Corpus Christi, thus making it difficult to differentiate the hazardous FLS clouds from the non-hazardous stratus clouds using the 11-3.9 micron BTD alone.



IFR probabilities computed from GOES-E

The blended FLS product, shown on the left, is skilled at isolating IFR inducing clouds. In the image, the product gives a probability of nearly zero for IFR conditions in Pittsburgh, and nearly 100 percent for Corpus Christi. It also outperforms the traditional product at detecting shallow fog layers. The products are unique in that they provide a quantitative assessment of whether IFR conditions are present or not. The fused approach allows weaknesses in the individual predictors to be mitigated. The process allows for confident identification of IFR conditions even when one of the individual predictors fails at highlighting the potential for IFR conditions. Once some experience is gained with the IFR probability product, it is generally easy to determine which type of predictor (satellite or model) is influencing the results the most.

Forecaster Feedback and Operational Impacts

The FLS products are available in AWIPS and have been evaluated within NWS operations during the last three years as part of the JPSS and GOES-R Satellite Proving Grounds. Forecaster feedback has been predominantly positive and product improvements have been made as a result of the feedback. References to these products within Area Forecast Discussions (AFDs) indicate that the products are influencing operational forecasts. The FLS products have been cited in no less than 100 NWS area forecast discussions from at least 16 different WFOs. And, the CIMSS "Fog Blog", which can be accessed at: http://fusedfog.ssec.wisc.edu, has reported close to 200 hits daily.

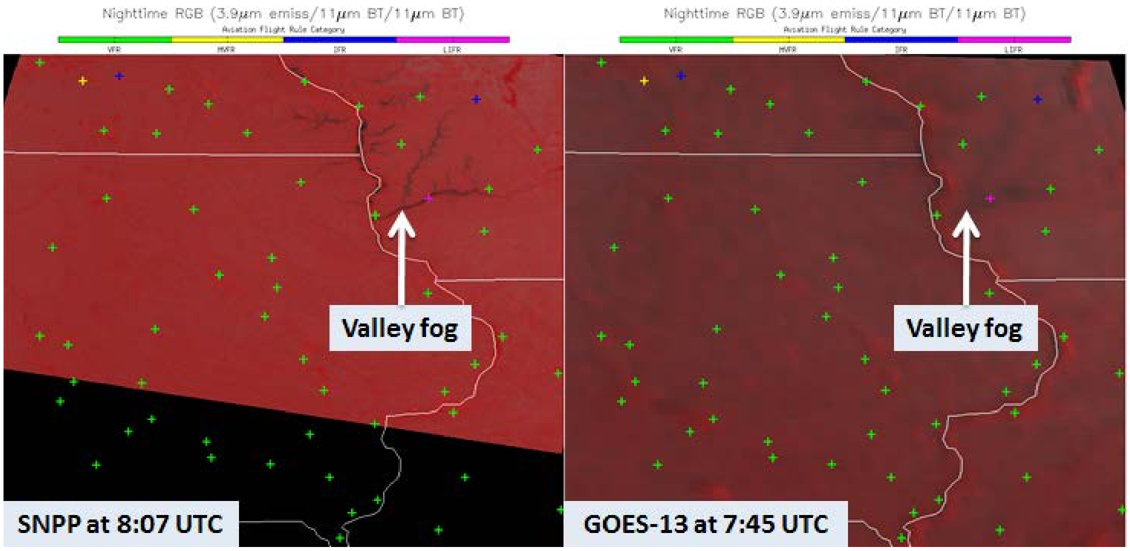
New Research – Blending GEO, LEO, and Landform Classifiers

Detecting and characterizing hazardous low clouds are of prime importance for aviation hazard mitigation. Surface observations play a key role in the WFOs in determining whether fog and low clouds are present. But, as they are point measurements, they can be of limited representativeness, thus satellite measurements can provide some of the best opportunities to detect low clouds. For small-scale fog events the location of surface reports is very important. For example, if a reporting station is not in or near a valley where fog is present then the report may be misleading.

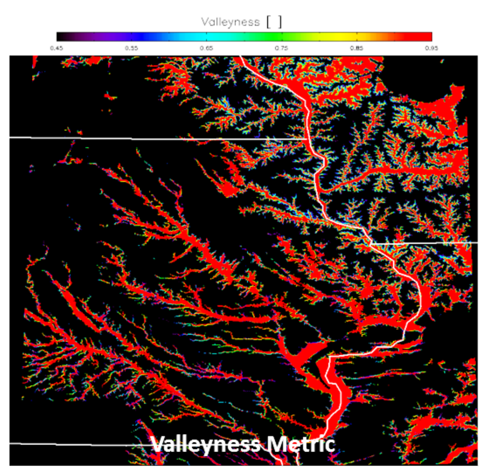
The horizontal resolution of current geostationary satellites is not sufficient to identify small-scale fog events like valley fogs. One of the dangers of valley fog is the rapid changes that can occur in visibility over short distances. Moreover, situations with patchy dense valley fog can be dangerous, especially when motorists encounter large drops in visibilities on interstates and highways. The infrequent revisit times of polar-orbiting satellites may result in their inability to observe short-term low cloud and fog events that occur between satellite passes. Therefore the FLS product became a prime candidate for blending the higher horizontal resolution of the polar satellites with the better temporal resolution of the geostationary satellites.

In an effort to mitigate the limitations of the BTD product, an enterprise system was developed. The system fuses satellite data from a variety of current polar-orbiting and geostationary spacecraft such as the Suomi-NPP and GOES. Data from future satellites such as JPSS-1 and GOES-R will be added. This data is fused with products from Numerical Weather Prediction (NWP) models such as the Global Forecast System (GFS), Rapid Update Cycle (RUC), and Rapid Refresh (RAP) along with daily Sea Surface Temperature (SST) analyses. The visualization of the final FLS product use digital surface elevation maps, surface emissivity maps, and surface type maps to show areas of IFR conditions.

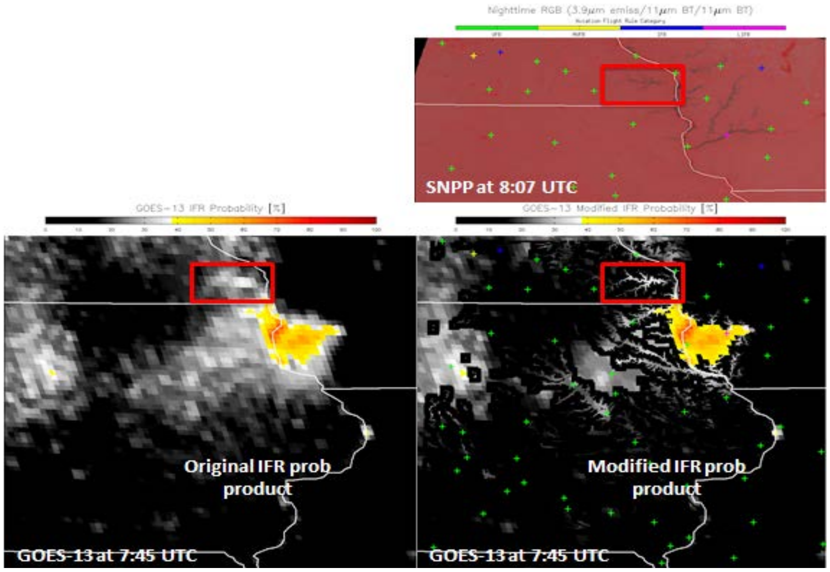
The example below shows a predominantly shallow fog event that took place on September 22, 2014 in parts of Wisconsin, Minnesota and Iowa. The fog was largely confined to valleys. Shallow fogs are inherently difficult to detect with satellites, especially from geostationary platforms such as GOES, which have much larger Field of Views (FOVs) than polar-orbiting platforms such as Suomi-NPP.



The RGB image above shows tendrils of darker areas that correspond well to where the valleys are (left) and are also the areas where S-NPP detected low clouds and fog. While the corresponding GOES-13 image (right) uses the same RGB as the Suomi-NPP image, it provides far less details. The spatial resolution of VIIRS (0.75 km) provides a much clearer picture of the spatial extent of the fog within the valleys. The river valleys are much smaller than the spatial resolution of GOES-13 (>4 km) making it much more difficult to distinguish the sub-pixel low cloud signal from other sources. To improve detection/depiction of valley fogs, NOAA scientists are incorporating morphometric characterization of landforms into satellite data. By modifying the GOES-R IFR probabilities using high-resolution topographic information, the low-resolution GOES IFR probabilities can be altered to capture more small-scale detail previously only available from higher-resolution instruments like VIIRS.



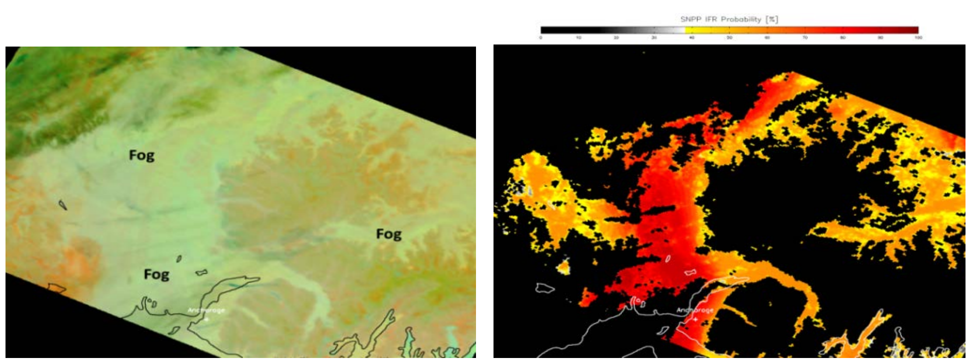
Limitations of GOES satellite measurements include poor spatial resolution and some radiometric issues. These make it impossible to differentiate the weak signals associated with sub-pixel valley fogs from background noise. NOAA scientists have developed a rather unique mechanism – the "valleyness metric" – that combines GOES measurements and up-scales them in a physically based manner with digital elevation model data. The metric assigns values of "zero" or "one" to quantify the extent to which a given location is in a valley. The metric takes the lower spatial resolution measurements from the GOES satellite and amplifies them based on information derived from a digital elevation model to identify regions that are in a valley versus outside of a valley. In the image shown right the red areas are values of one and the black areas are values of zero.



The boxed area shows how the valleyness data can be used to up-scale the GOES data to highlight sub-pixel valley fog events.

The images shown left are for a fog event in the valleys of the Mississippi river at the border between Wisconsin and Iowa. They provide a great example of how these fused probability forecasts can be harnessed. These images were captured by the Suomi-NPP and GOES-13 satellites on September 22, 2014. The Suomi-NPP image (top right) shows with nice scale where the fog is forming in the valley. On the bottom, the left shows a very coarse spatial resolution image from the original IFR product derived from GOES-13, which showed an enhanced probability of low clouds present in the region. The right shows the modified IFR product that uses the valleyness metric. Even though the modified product is derived using very coarse resolution measurements, it generates an image that is consistent with the one derived from VIIRS measurements.

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. The influence of low-level clouds and fog poses a strong threat to aviation throughout Alaska. Polar orbiting satellites provide more passes per day over Alaska than over the Lower 48. 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 in high latitude regions like Alaska. The image that follows shows a fog cloud layer around anchorage, Alaska on December 8, 2013.



On the right is a VIIRS false color depiction of the cloud layer and on the right is the IFR probability product derived from VIIRS. As the IFR probability product uses the enterprise approach, it can be applied to multiple sensors including VIIRS. In the high latitude regions, such as Alaska, NOAA scientists combine the valleyness metric to both GOES and Suomi-NPP data. This is achieved by adding an additional constraint on how the image is spatially enhanced. Similar to the algorithms developed for GOES-R, VIIRS algorithms, in addition to showing whether a region is in a valley or not, automatically determine the probability that hazardous low cloud conditions are present. Integrating the features from Suomi-NPP and GOES with the valleyness metric is less of a challenge where VIIRS and GOES align in time quite well. However, after the VIIRS overpass, temporal continuity is maintained with consecutive GOES images until the next VIIRS overpass. In effect, the results from the LEO overpass that influence the GOES are used by the next GOES scan until the next VIIRS overpass. The GOES temporal history is used as a means to transport the VIIRS features during periods when it is not available at a location.

As shown above, vast improvements (bottom) to the traditional FLS (top right) product occurred from combining GOES measurements with the valleyness metric (top middle). Further value was added by combining this metric to VIIRS. To maintain temporal continuity between VIIRS overpasses, enhanced measurements – obtained from a GOES scan influenced by VIIRS – are used to propagate the information forward until the next VIIRS overpass.

Summary

As Fog and Low Stratus has a great impact on aviation, the detection and characterization of hazardous low clouds are crucial for aviation hazard mitigation. The FLS products, especially, would be particularly beneficial for aviation guidance purposes in high latitude regions such as Alaska, due to the relatively sparse network of observations in these areas. The higher spatial resolution from the VIIRS sensor on Suomi-NPP is particularly useful in helping better detect/depict valley fogs, and define the areal coverage of these inland fog/stratus features.

Thus far the GOES-R FLS product is providing more than twice the skill of the BTD product in detecting IFR conditions. Unlike qualitative imagery based products, the FLS products can be used to quantitatively identify IFR producing cloud layers, even when multiple cloud layers are present, day and night. Another advantage the GOES-R proxy products have over the BTD products is their skill in locating IFR hazards that accompany low clouds at night. Thus the GOES-R products can replace the traditional products. In addition, innovations from the JPSS and GOES-R Proving Grounds aimed at blending GOES with VIIRS to create a very high-resolution depiction of fog boundaries within valleys are expected to further advance the capabilities of the next generation FLS product.

The 375-meter resolution 3.75 and 11 mm imaging band on VIIRS has led to better monitoring of difficult to detect small-scale valley fog events. The Nation's next generation polar-orbiting satellite, Suomi-NPP, offers higher resolutions with more capabilities over its predecessors. By combining the advanced capabilities from Suomi-NPP, with the capabilities of the current generation GOES, NOAA forecasters are better able to observe the rapid change in visibility due to low clouds and fog from one valley to the next. These new capabilities have also provided a great opportunity for impact based decision support services by enabling NOAA forecasters to more accurately identify hazards caused by reduced visibility and/or low ceilings, and relay the information to the public.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

The Cold and the Dark: JPSS and the Cryosphere

*This article is based in part on the **December 15, 2014** JPSS science seminar presented by Eric Stevens, GINA, University of Alaska-Fairbanks, Mary-Beth Schreck, NOAA/NWS Alaska, and Jeff Key, NOAA/NESDIS/STAR at University of Wisconsin-Madison..*

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

Defining the Frozen Stuff

The term cryosphere[5] refers collectively to the frozen parts of the Earth's surface. Elements of the cryosphere include ice and snow on land such as the continental ice sheets, as well as ice caps, glaciers, and areas of snow and permafrost. Another element of the cryosphere is the ice that is found in water. This includes frozen parts of the ocean, and lake and river ice. These elements of the cryosphere play an important role in the Earth's climate. But, as a vast majority of the global population does not inhabit areas covered by ice and snow, much about the cryosphere remains relatively unknown. This is despite its large size and contribution to global climate. Snow and ice reflect heat from the sun, helping to regulate our planet's temperature, while the high insulating capacity of snow and ice keeps heat in the ocean. So why are we concerned about frozen parts of the Earth in some of the most remote areas of the planet? Variability in the cryosphere has major impacts on sea transportation, water resources, ecosystems, weather, and sea level change. These changes can also lead to land and cryosphere-related hazards like floods, and droughts. As such, observations of the cryosphere can help improve weather forecasting and hazard warnings. The observations can also provide benefits such as helping reduce the risk of loss of life and property from natural and human-induced disasters.

[5] For more information on the cryosphere visit the Global Cryosphere Watch website at: http://www.globalcryospherewatch.org

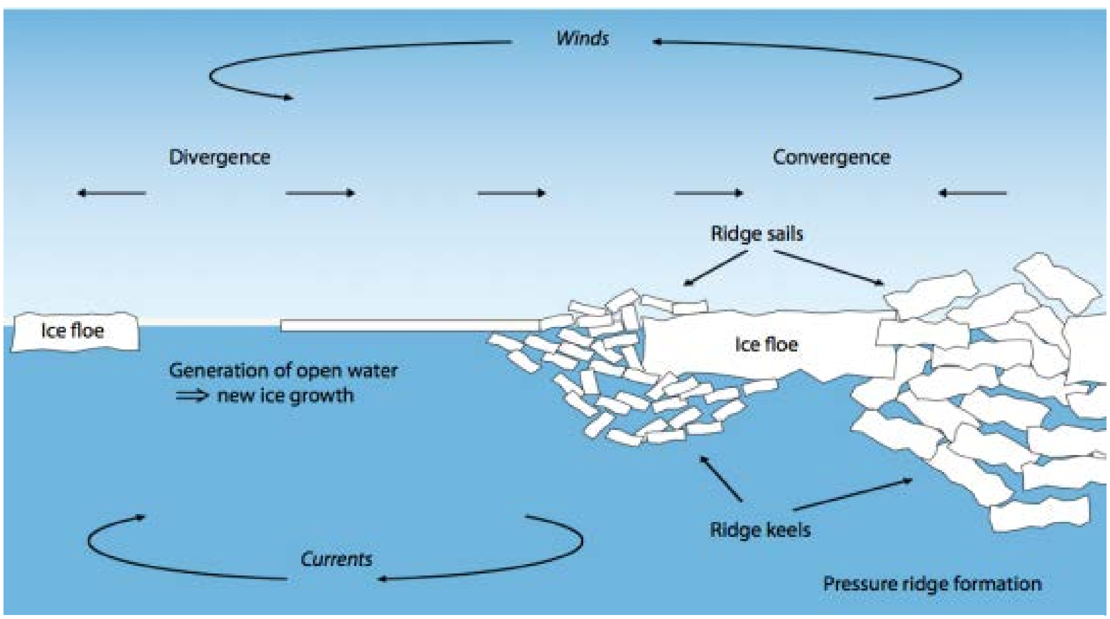
Why Do We Care About Ice Thickness?

The thickness of sea ice is a result of past growth, melt and deformation, and accordingly, an important indicator of climatic conditions. Thickness provides an integrated measure of changes in the energy balance. It is also closely connected to ice strength, and so changes in thickness are critical to: navigation by ships, the stability of the ice as a platform for use by humans and marine mammals, light transmission through the ice cover, and so forth.

This article focuses on a particular aspect of the cryosphere, sea ice thickness. Changes in sea ice thickness have a fundamental impact on the ocean-atmosphere energy exchange, and operational applications such as shipping, offshore drilling, and hazard mitigation. They play a significant role in the Polar Region's weather and climate. Also, they can be a key indicator of Arctic climate change. Conventional observations of sea ice properties are sparse, particularly sea ice thickness. Satellite data provide an opportunity to monitor the cryosphere routinely with relatively high spatial and temporal resolutions for both sea ice, and lake and river ice.

Satellite Observations Helping the Sea Ice Mission

Sea ice is not a uniform layer. Its thickness varies considerably. How thick the ice is depends on a wide range of factors including wind, ocean currents and sea and air surface temperatures.



Processes that affect Ice thickness (from SWIPA, 2011)

Monitoring ice thickness has been and remains a challenge, however, the amount of satellite data available in the last few years from both polar regions has increased markedly, providing a large and growing resource. An important source of information used to derive sea ice thickness on an Arctic wide scale is radar altimetry from polar orbiting satellites. Visible/IR satellite sensors and submarine data have provided multi-decadal ice thickness estimates. Passive microwave sensors such as the Scanning Multichannel Microwave Radiometer (SMMR), Special Sensor Microwave Imager (SSM/I), and Advanced Microwave Scanning Radiometer 2 (AMSR2) have provided the longest record of sea ice concentration and type, but do not provide data on sea ice thickness. There are a few numerical ocean sea ice atmosphere models that simulate ice thickness distribution, but the result is generally at a much lower resolution. Recent advances in remote sensing technology have made it possible to estimate ice thickness from space using a variety of techniques. These techniques include:

- The One-dimensional Thermodynamic Ice Model (OTIM), which is an energy budget approach for estimating sea and lake ice thickness with visible, near-infrared, and infrared satellite data from sensors such as the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard NOAA's primary satellite, Suomi National Polar-orbiting Partnership (Suomi NPP), the Advanced Very High Resolution Radiometer (AVHRR), and the Moderate Resolution Imaging Spectroradiometer (MODIS). VIIRS was designed to improve upon the capabilities of the heritage AVHRR and provide observation continuity with NASA's Earth Observing System, MODIS.

OTIM retrieved ice thickness based on VIIRS data on March 21, 2013

- Laser and radar altimeter data from the Jet Propulsion Lab's ICESat and Alfred Wegener Institute's CryoSat-2 satellites, which estimate ice thickness from ice elevation.
- Low-frequency passive microwave data from the University of Hamburg's, Soil Moisture and Ocean Salinity (SMOS) mission, and
- The Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS).

Preliminary results show that sea ice thickness from various sensors including MODIS, PIOMAS, and CryoSat-2 agree reasonably well overall, albeit with differences that arise from limitations of the different sensors and methods. However, these techniques provide much higher resolution data and have enabled more accurate, consistent, and detailed ice thickness and age data, which are critical for a wide range of applications from climate change detection and climate modeling to operational uses such as shipping and hazard mitigation.

Sea Ice and the Alaska Fishing Industry

According to the National Marine Fisheries Service (NMFS) most recent economic report[6] on the Nation's commercial and recreational fishing activities, and fishing-related industries, Alaska continues to play a major role in the nation's commercial fisheries.

NOAA Fisheries reports that in 2012 Alaska remained a national leader for its commercial fishery landings with 56 percent of the U.S. total. The reports further states that in the same year, Alaska's seafood industry generated $4.2 billion in sales impacts, $1.8 billion in income impacts, and over 56,000 jobs. Additionally, seafood processing and dealer operations contributed 25 percent to in-state sales for Alaskan businesses, and generated well over $1.1 billion. In addition, the commercial harvester sector generated more impacts than any other sector with approximately 69 percent of total impacts.

Fishing, and especially, the crab fishery in the Bering Sea, is one of the most dangerous industries/occupations in the United States. Prior to 1995 the average yearly death/vessel loss rate for the preceding ten years was five men dead/ two vessels lost per crabbing season. During the crabbing seasons of 1998 through 2003, the industry experienced the loss of life or vessels during only one year. This makes the imagery that is used daily to improve ice analysis and forecasts critical to the mission of the National Weather Service (NWS) in Alaska.

JPSS Capabilities in NWS Alaska: Keeping an Eye on Sea Ice Movement and Development

In the Arctic, polar orbiting satellite products are vital to operations within the NWS, especially in Alaska. Of those operations, the NWS Sea Ice Program (http://pafc.arh.noaa.gov/ice.php) uses satellite products to monitor ice movement and development. These products are used by a variety of customers including state and federal government agencies, local communities, and varied industries. The oil industry for example, relies on ice location and movement information to ensure safe oil operations in the region. This industry utilizes the Sea Ice program's satellite products and services from the development stage through production and product delivery. Products from the Sea Ice program are also been used to aid ships navigating in and near the ice-covered waters surrounding Alaska, and coastal communities existing with the annual presence of sea ice. These products are of prime importance to this region, where maritime and coastal hazards often require 24 hour access to changing sea ice conditions.

Suomi NPP products are delivered by the Geographic Information Network of Alaska (GINA) to the NWS Ice Desk – a key interface with the Alaska user community. The section that follows briefly describes how imagery flows from GINA to the NWS in Alaska. It also describes two types of products that are of particular use by the NWS Ice Desk; the VIIRS Day Night Band (DNB) and False Color imagery.

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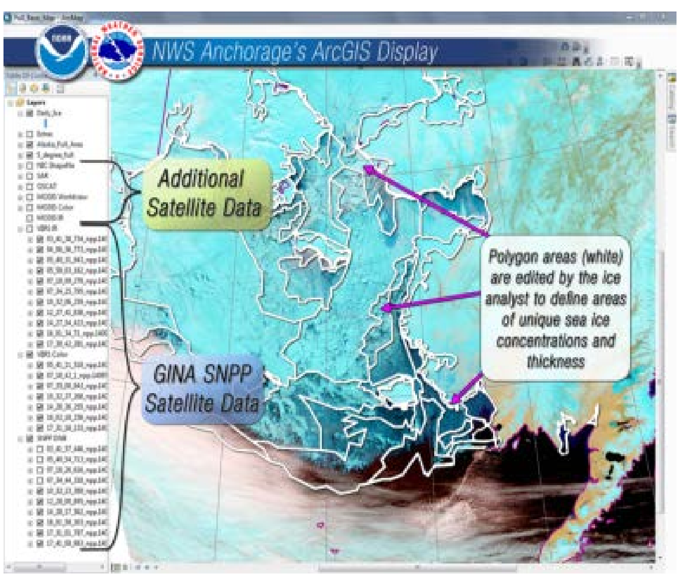
[6] National Marine Fisheries Service. 2014. Fisheries Economics of the United States, 2012. U.S. Dept. Commerce, NOAA. Tech. Memo. NMFS-F/SPO-137, 175p. Available at: https://www.st.nmfs.noaa.gov/st5/publication/index.html.

Delivering Suomi NPP VIIRS Imagery to NWS, Alaska

The Sea Ice program relies on near-real time (NRT) satellite imagery for its ice analysis and decision support services, which have a huge impact on the major shipping routes and some of the largest fisheries in the world. Imagery, such as that produced by the VIIRS sensor is used to support local warning and forecast operations throughout the region. The imagery is provided by the High Latitude Proving Ground[7] (HLPG) via the Geographic Information Network of Alaska (GINA) in formats that explicitly suit the Ice program's operational needs. GINA (http://www.gina.alaska.edu) is located on the University of Alaska Fairbanks campus. It is a mechanism for sharing data and technical capacity among Alaskan, Arctic, and global communities.

GINA captures Suomi NPP data via Direct Broadcast (DB). Direct Broadcast (DB) of the data from the satellite minimizing the latency in the delivery of this crucial data to the NWS forecasters in Alaska and thereby increasing the utility of these products in the forecast process. The data are processed into imagery at GINA via the University of Wisconsin's Community Satellite Processing Package (CSPP), and the resulting products are then delivered to NWS Alaska via the Local Data Manager (LDM) feed into the Advanced Weather Interactive Processing System (AWIPS). GINA created a web application specifically to serve the Sea Ice Program, called Puffin Feeder (feeder.gina.alaska.edu) that serves data in GIS ready formats to sea ice analysts. Imagery is also delivered in Geo-TIFF format for use in a GIS environment outside of AWIPS. On the right is an example of imagery from the HLPG to the Sea Ice Program. The circled satellite image, obtained by the Suomi NPP satellite, shows a mostly snow-free land surface. A strip of sea ice attached to land persists along the north coast until break-up in July.



NWS sea ice charts and forecast created in ArcGIS using Suomi-NPP imagery from GINA Puffin Feeder and additional satellite data from other sources.

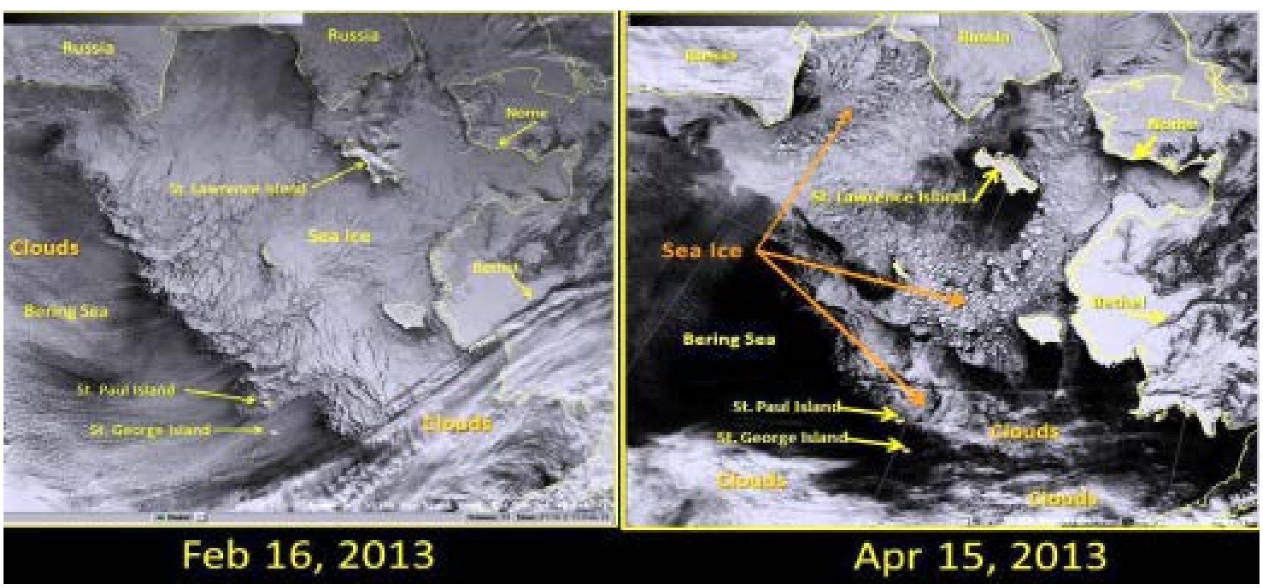
The NWS Sea Ice Program utilizes ArcGIS to bring in data from numerous sources. These include, imagery obtained from Suomi NPP and MODIS visible imagery. http://pafc.arh.noaa.gov/ice.php. Satellite data is ingested into the ArcGIS software program where sea ice analysts discern areas of unique sea ice thickness and concentration. In addition, ice analysts also consult weather and ice models on the web and through AWIPS.

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

Day-Night Band

The VIIRS DNB collects highly detailed imagery of the Arctic even under low light levels. The DNB becomes particularly important as visible channels are rendered unusable when polar darkness prevails. And even though passive microwave sensors can "see" through clouds and deliver data that allows scientists to monitor sea ice through the winter, the information content is vastly inferior due to their much lower resolutions. Some other satellite sensors cannot penetrate clouds to take data, so the results are sporadic and dependent upon weather conditions. Still other sensors can see through clouds, but they do not cover the entire region of the globe where sea ice exists every day, making near-real-time monitoring difficult. Polar-orbiting satellites observe most locations twice daily, except at higher latitudes where coverage is more frequent due to the overlap by consecutive orbits. In the far northern latitudes the superior spatial resolution of imagery from these satellites provides much clearer views of many surface features. DNB imagery is especially useful along the north coast of Alaska, particularly in helping to determine polynyas forming as well as ice movement and stability. Polynyas are areas of open water within an ice-covered region. They are important feeding areas for marine mammals and birds.

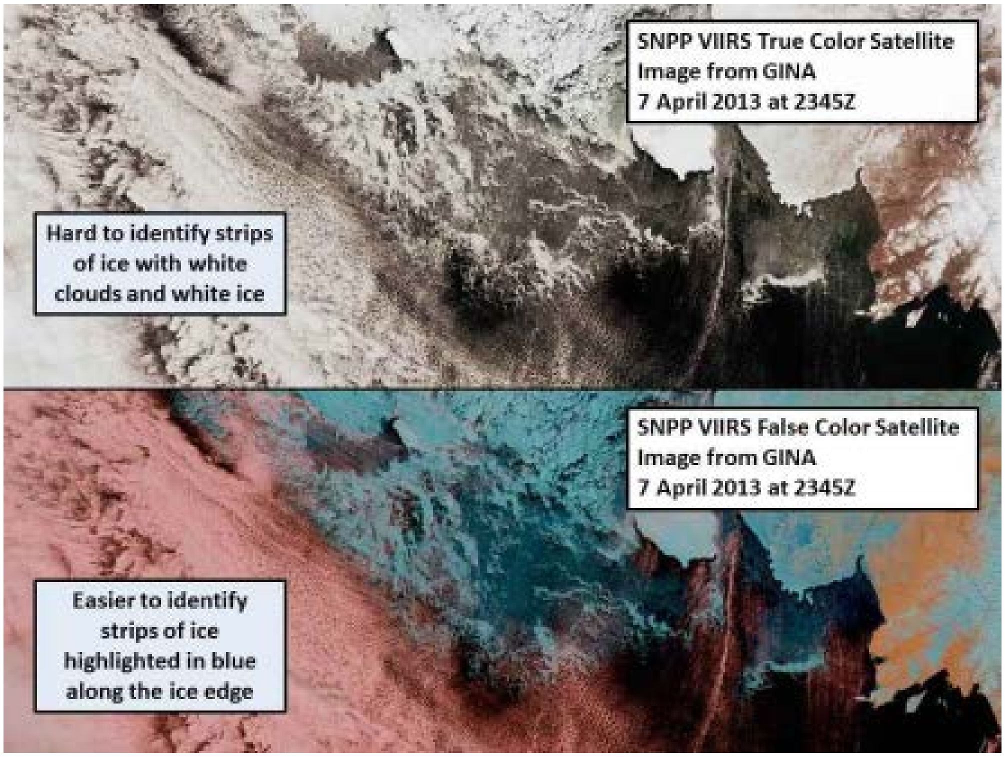
VIIRS imagery in Alaska has demonstrated its capability to trace ice movement, growth and decay. Ice pack changes are particularly important to Alaska's marine industries of fishing, tourism, and passenger transportation and recreational boating. For ships, the ice imagery enables navigation decision makers to differentiate between the areas where there is ice melt (as shown in the image that follow) 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 Suomi NPP 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.



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

False Color Imagery

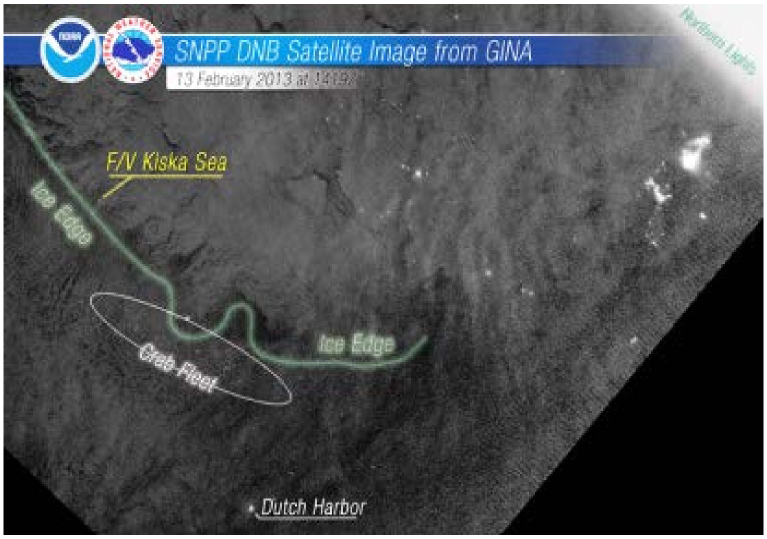
False color imagery is generated when satellite data is converted into visual color. This color enhanced imagery acts as an aid to satellite interpretation as the colors make it much easier to see the features which are of special interest. False color images make data stand out. The Suomi NPP False Color imagery that GINA generates and delivers to the NWS Ice Desk is a variety of "RGB" imagery. It is the result of combining three stand-alone satellite products into one content-packed image, such that the three ingredient products are each assigned to the Red, Green, or Blue portions (hence the term "RGB") of the resulting full-color image. The power of this combination of VIIRS bands is an end product that allows the NWS Ice Desk to quickly discriminate clouds from sea ice. However, because the False color imagery product includes imager bands that are in the visible portion of the spectrum (I01 at 0.64 micron), it relies on reflected sunlight and thus won't work in the dark.



The images above were captured by the Suomi NPP satellite on 7 April 2013. They show strips of ice in true color (top) and false color (bottom). In the true color image it is hard to differentiate between the strips of ice, white clouds and white ice. However, in the false color image, it is much easier to identify the strips of ice as they are highlighted in blue along the ice edge.

The Use of Suomi NPP Data in Arctic Crises

The following section presents some examples of the NWS Ice Desk applying DNB and False Color imagery during specific real-world scenarios, including the delivery of guidance from the NWS Ice Desk to a crabbing vessel that was in danger of being overrun by sea ice, and the support provided to the US Coast Guard during rescue operations in the Arctic Ocean.



Data from Suomi NPP was ingested into GINA to create the image above, which was used by NWS Sea Ice personnel to help a crab vessel navigate out of sea ice.

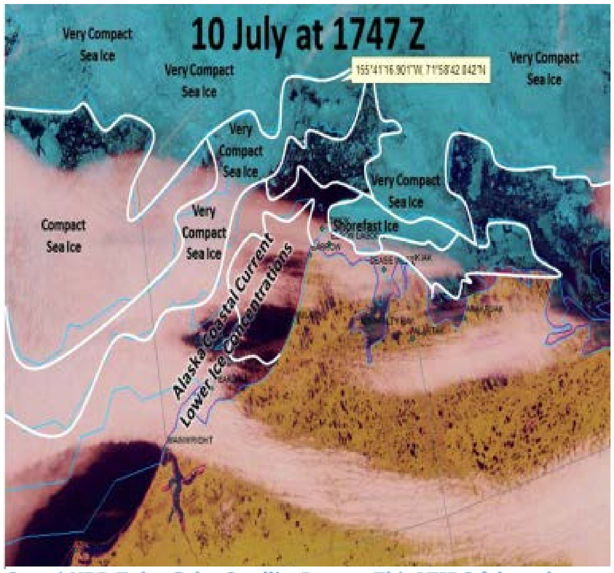
The Kiska Sea Crabbing Vessel Calls on the NWS Sea Ice Program for Navigation Help

On 7 February, 2013, strong Northerly winds caused an ice pack to advance rapidly. Crab pots belonging to the Kiska Sea – the northern most vessel in the Bering Sea Crab fleet – were considered in danger of being overrun by sea ice. Over the next three days, the exchange of ice information between the Kiska Sea and the NWS Sea Ice Program assisted the captain in finding his goods through the increasing ice field. On February 13 the vessel was surrounded by sea ice, some in excess of three feet thick. VIIRS DNB images from the previous night clearly showed the lights from the vessel and the surrounding ice pack. NWS Sea Ice personnel were able to assist the captain to plot a track out of the ice pack, avoiding areas of thicker and higher concentrations sea ice. The timeliness of the DNB images provided an essential tool for this vessel assist.

NWS Alaska Ice Desk helps the US Coast Guard respond to May Day Call

NOAA's satellite observations proved critical in July 2014 when a 35-foot aluminum hull sailing vessel traveling the Northwest Passage on its way to eastern Canada became trapped in ice 25 nautical miles northeast of Barrow, Alaska. The vessel was surrounded by sea ice in an area of 70-90 percent ice cover with strong winds that were shifting the ice. The U.S. Coast Guard (USCG) contacted the NWS Ice Desk requesting assistance.

USCG Rescues Mariner in Sailboat Trapped in Ice North of Barrow. CREDIT: United States Coast Guard



Suomi NPP False Color Satellite Image. This VIIRS false color image was generated using the VIIRS I01 band (0.64micron), I02 band (0.86micron) and I03 band (1.62micron) comprise the red, green, and blue portions of the color spectrum, respectively.

Becki Legatt and Mary-Beth Schreck, members of the Anchorage Weather Forecast Office (WFO) Sea Ice Program, reviewed the latest sea ice conditions, coordinated with the WFO in Fairbanks, Alaska, and were able to share and assist the Coast Guard with sea ice analyses, forecasts and imagery, including the Suomi NPP false color imagery shown below.

The false-color image shown left was generated by GINA and delivered to the NWS Alaska. The image helped personnel discriminate between “compact” and “very compact” sea ice, and also between areas of high and low ice concentration. With this information Legatt and Schreck were able to help guide the vessel away from the high concentrations of sea ice and determine that best path toward Barrow.

After the incident, Rear Adm. Dan Abel, commander, 17th Coast Guard District said that the sea ice forecasters from the Anchorage WFO provided “phenomenal weather products” that proved key to USCG decision makers.

Summary

The cryosphere has profound socio-economic value due to its role in water resources and its impact on transportation, fisheries, and agriculture. The cryosphere also plays a significant role in climate, and its characterization and distribution are critical for accurate weather forecasts.

The effective use of satellite observations over polar regions is necessary for accurate forecasting and warning of hazardous events such as rapid sea ice formation, volcanic ash, and coastal hazards like floods. These observations provide a host of benefits which include, helping improve weather forecasting and hazard warnings; improving the management of energy and water resources including flood forecasting; helping us understand, assess, predict, mitigate, and adapt to climate variability and change; and improving the management and protection of terrestrial, coastal, and marine ecosystems.

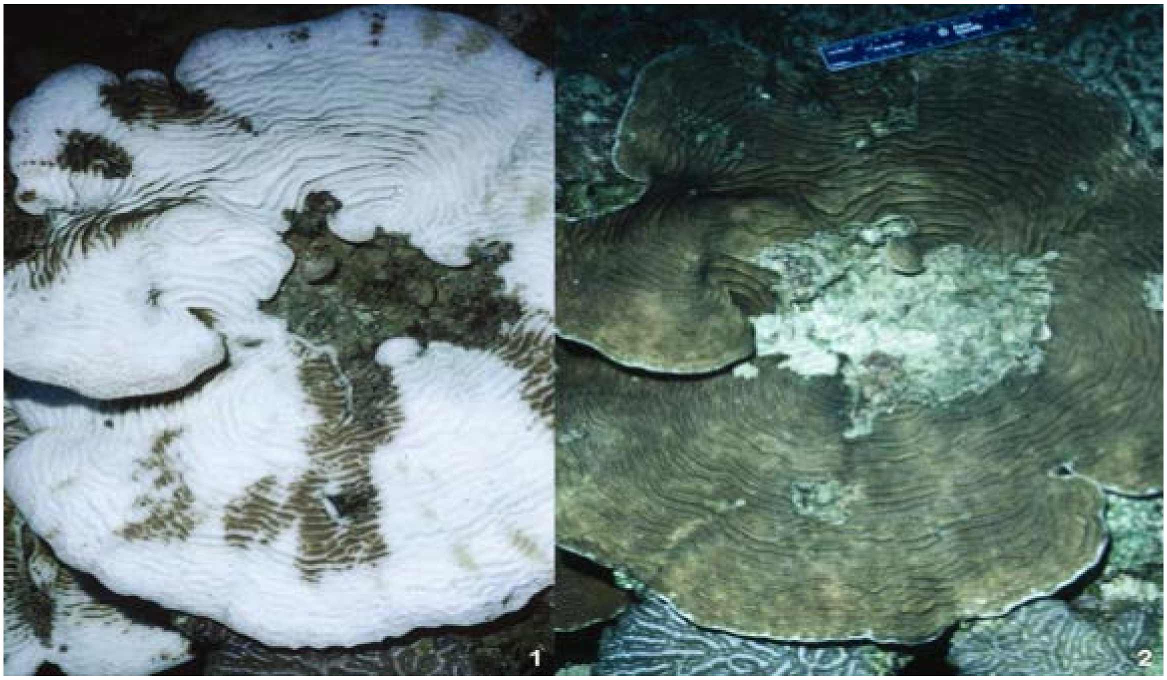
JPSS data is key to the NWS Alaska operational and research products and services as it provides valuable polar imagery and products. The VIIRS DNB imagery is enabling significant improvements in forecasting weather and monitoring sea ice changes in Alaska. With the DNB and near-real time delivery of data, Suomi NPP VIIRS imagery has quickly become key to ensuring safe marine transport.

The JPSS data and products utilized by the NWS Alaska, have allowed the NWS Ice Desk to provide various key services including aid ships navigating in and near the ice-covered waters surrounding Alaska and coastal communities existing with the annual presence of sea ice.

Pushing the Limits: Increasing Resolution of Satellite-Derived Coral Bleaching Products using VIIRS and Geo-Polar Blended SSTs

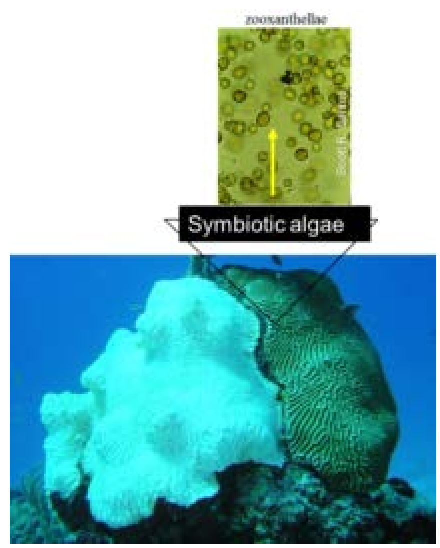
This article is based in part on the ***January 26, 2015*** *JPSS Science Seminar presented by C. Mark Eakin, Coordinator, NOAA's Coral Reef Watch at NOAA/NESDIS/STAR.*

Contributing editors: Jacqueline De La Cour and Erick Geiger (NOAA Coral Reef Watch), Mitch Goldberg, Julie Price, and William Sjoberg



An Agaricia coral colony shows 1) bleached and 2) almost recovered from a bleaching event. Image courtesy of Andy Bruckner, NOAA National Marine Fisheries Service.

Hidden beneath the ocean waters of the world are some of oldest and most diverse ecosystems on the planet. Better known as coral reefs, these hotspots of diversity exist in all variations of rainbow colors, which come from *zooxanthellae,* tiny symbiotic algae living in corals' tissues. The algae provide the coral with oxygen and other nutrients needed for survival. The corals in return provide carbon dioxide and other needed substances to the algae.



Coral Bleaching

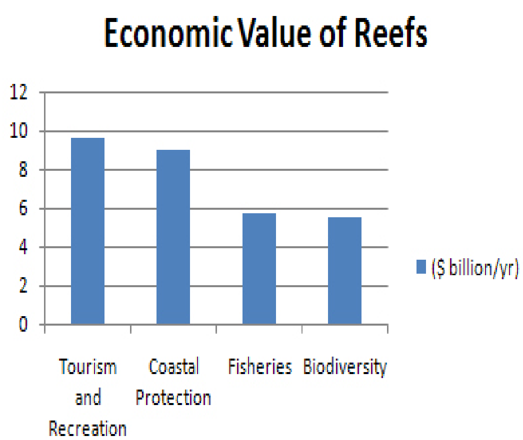
Coral reefs are stressed by natural phenomena such as hurricanes and disease. However, a number of human activities, including destructive fishing practices and uncontrolled coastal development have degraded reefs as well. Additions to the list of suspects contributing to the demise of this natural resource include water pollution, ship groundings, and the global effects of climate change and ocean acidification. Increasing in prominence as a serious threat to coral reef ecosystems worldwide, is a condition known as bleaching.

Coral bleaching occurs when the relationship between a coral host and *zooxanthellae*, breaks down. The breakdown is often attributed to stress, induced by changes in conditions such as light, nutrients, and especially due to high temperature. Due to the stress, corals expel the algae causing them to lose their pigmentation. This can cause the corals to stop growing and reproducing.

Save the Reefs! It's a Big Deal!

Even though they cover less than 1/10th of one percent of the Earth's surface, the importance of coral reefs should not be underestimated. They provide habitat and are spawning and nursery grounds for an array of marine life. Reefs are home to nearly 25 percent of all documented marine species, with more than 4,000 species of fish alone. Sharks, manta rays, bottlenose dolphins, lobsters, seahorses, sea urchins, sponges, and sea turtles are just some of the animals that depend on reefs for their survival.

The coral reef structure also buffers coastlines from erosion, waves, storms, and floods, helping to prevent loss of life, property damage, and erosion. Several million people live in U.S. coastal areas adjacent to or near coral reefs, and the well-being of their communities and economies is directly dependent on the health of these reefs.



The chart above depicts the breakdown of components that contribute to the global annual value of coral ecosystems. Accessed from the NOAA Coral Reef Conservation Program. http://coralreef.noaa.gov/aboutcorals/values/

More than Tourist Destinations

Coral reefs provide valuable and vital services. More than tourist destinations and biodiversity hotspots, healthy coral reefs are a significant food source for over a billion people worldwide. Of that number, almost 85 percent rely on fish as their major source of protein[8]. Coral reef ecosystems also provide jobs and income from fishing, recreation, tourism, and other reef-ecosystem based businesses. In the United States, coral reef ecosystems support hundreds of commercial and recreational fisheries worth millions of dollars to state and local economies. The NOAA National Marine Fisheries Service (NMFS) estimates the commercial value of U.S. fisheries from coral reefs is over $100 million. Each year, over four million tourists visit the Florida Keys, contributing $1.2 billion annually to tourism-related services. In fact, the Florida Keys are the number one dive destination in the world. In Hawai'i, a state with many coral reefs, one popular reef alone receives over three million tourists annually. In the U.S. territories of Guam and the Northern Mariana Islands, over 90 percent of new economic development is dependent on coastal tourism, including reef tourism.

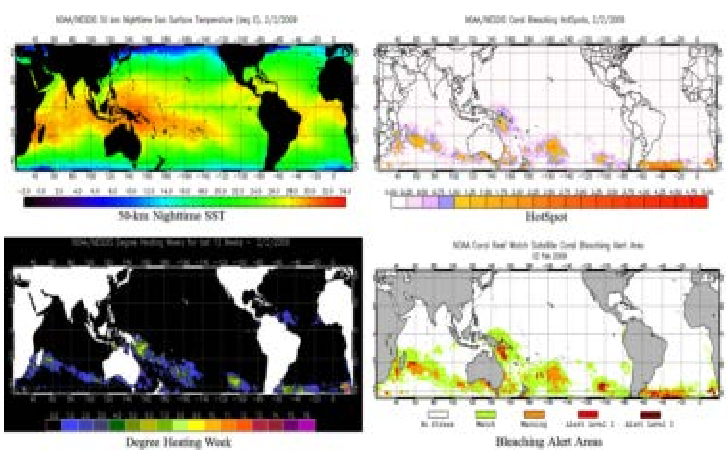
Coral Reef Watch (CRW)

The NOAA Coral Reef Watch (CRW) program is housed in the Center for Satellite Applications and Research (STAR) within the National Environmental Satellite, Data, and Information Service (NESDIS). It is funded predominantly by the Coral Reef Conservation Program (CRCP), headquartered in the National Ocean Service and managed by four NOAA Line Offices, but also receives funding from other NOAA programs. CRW continues to provide the only near-real-time (NRT) global Decision Support System (DSS) for coral bleaching management in the world. Since January 2000, polar-orbiting environmental satellites (POES) have provided near-real-

[8] http://coralreef.noaa.gov/aboutcorals/values/fisheries/

time observations of sea surface temperature (SST) and thermal stress to corals at 50-km spatial resolution. While the input data are at 4-km resolution, these products are globally gap-filled and gridded at 50-km resolution. These POES measurements have enabled CRW to deliver satellite-based products, maps, and coral bleaching alerts to coral reef managers, scientists, and the public. With these measurements CRW has been able to provide current reef environmental conditions that help to quickly identify areas where reefs are at risk for coral bleaching (http://coralreefwatch.noaa.gov). In early 2015, CRW released a new suite of products that provide a substantial increase in data per pixel by utilizing new algorithms and leveraging the capabilities from a blend of nighttime-only observations from sensors on low-Earth orbit (LEO) and geostationary Earth orbit (GEO) satellites. These sensors include the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard NOAA's primary satellite, the Suomi-National Polar-orbiting Partnership (Suomi-NPP). These new products have the capability to focus on reef areas using 5x5 km spatial resolution, with an increase of as much as 50 times more data than before.

Recent funding from the Joint Polar-orbiting Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) program has allowed CRW to experiment on the potential for even higher-resolution, sub-km scale coral bleaching products using SST data from VIIRS. This would bring CRW's products almost to the same spatial scale as most coral reefs. Part of this has involved the development of a system to allow testing of VIIRS SSTs against coastal *in situ* data and augmenting the coastal database of calibration/validation stations with more nearshore data. The new observations are coming from key coral reef zones including Hawai'i, the Great Barrier Reef, and many Pacific islands. More details of the value of this initiative are presented in a subsequent section.



A snapshot of some products from the heritage suite of CRW 50-km Satellite SST-Based Coral Bleaching Thermal Stress Products

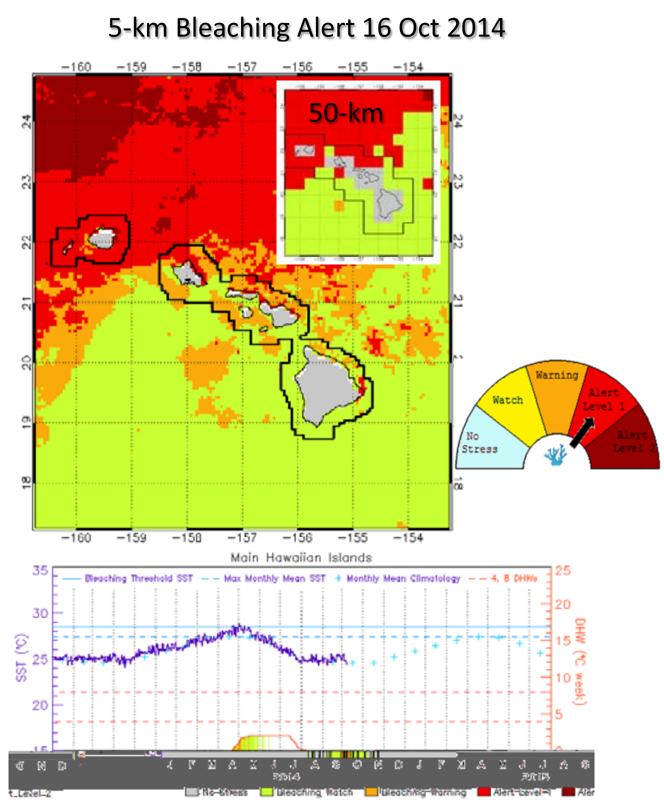
CRW's heritage operational products are based on relatively coarse (50-km) nighttime-only SST data from the Advanced Very High Resolution Radiometer (AVHRR) onboard NOAA's heritage POES. Nighttime-only satellite observations are used to eliminate daily warming caused by solar heating at the sea surface (primarily at the "skin" interface, 10-20 µm) during the day and to avoid contamination from solar glare. In addition, nighttime SST provides more conservative and stable estimates of thermal stress felt by corals living from a meter to tens of meters deep. The operational 50-km satellite-based product suite includes SST and SST Anomaly, which is the difference between today's temperature and the long-term average and is useful for looking at oceanographic events but not particularly predictive of the thermal stress experienced by corals. The products that are specific to corals include: HotSpot, which measures occurrence and magnitude of the instantaneous thermal stress capable of causing coral bleaching; Degree Heating Week (DHW), which show the accumulated thermal stress that is a good predictor of coral bleaching; and Bleaching Alert Area, which is the product used most by coral reef managers. The Bleaching Alert Area outlines areas where bleaching thermal stress currently reaches critical thresholds, based on satellite SST monitoring. These products have been very successful in detecting and monitoring thermal stress typically associated with mass coral bleaching.

Why Blended Products?

No satellite is an island, and history is key to understanding the present

Even with multiple polar-orbiters available, the 50-km polar-only heritage products use data from only one polar-orbiter at a time, giving a maximum of one observation per day. Cloud cover limits the amount of data available, so single-satellite data coverage is largely insufficient to compute reliable coral thermal stress products at single-pixel (4-km), daily resolution. For example, only 12.6 percent of data in the AVHRR pathfinder reprocessed dataset from 35°S – 35°N are of useable quality. In polar regions, data quality drops so that in the area from 90°S – 90°N only 7.8 percent of data are considered usable.

Areas of frequent cloud are problematic for the acquisition of satellite imagery, resulting in persistent gaps in the imagery produced. This is an issue of particular importance in coral reef regions that are under constant cloud cover. As an example, in 2010, Thailand's Tao Island and part of the Coral Triangle experienced 6-months of persistent cloud cover. Around the same time, there was a severe bleaching event taking place, but due to cloud cover new satellite data could not be retrieved and the opportunity to capture this significant event was lost. The Coral Triangle – an area which covers much of Southeast Asia and the western Pacific – is one the most biodiverse marine regions on the planet, with numerous reefs that support high coral cover.



Improved spatial resolution is evident in the 5-km Bleaching Alert during the first-ever mass coral bleaching event in Hawai'i, derived from NOAA's Operational Geo-Polar SST, 10/16/14

By moving towards blended products, CRW mitigates these weaknesses. The blending of multiple satellite observations allows for greatly enhanced temporal resolution and eliminates almost all data gaps due to cloud cover.

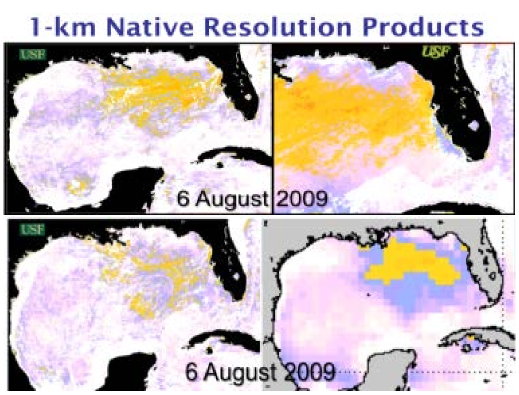
Given the limitations above, and in response to user requests for higher spatial resolution products, CRW is switching to a new suite of 5-km products. The global product suite was developed jointly by NOAA and NASA, and under a collaborative effort that includes the University of South Florida, NASA Ames, the University of Colorado, and others. The product suite, which is updated daily, has 100 times finer resolution and uses up to 50 times more satellite observations per pixel than the current 50-km operational product suite (see example on the right). Even more observations are expected – 60 times more – when data from Japan's new Himawari-8 and NOAA's GOES-R satellites go online.

VIIRS SST: Bringing You Even Closer to the Coastline

Due to the complexity of the atmospheric and oceanographic conditions in nearshore zones, it is challenging to obtain highly accurate SST measurements using high-spatial-resolution satellite sensors. While satellite observations provide a broad picture of the spatial patterns of environmental parameters like SST, they have to be verified with *in situ* data. One of the challenges in nearshore zones is sun glint contamination. Shallow water creates a surf zone, where white caps can be observed during high winds. The increased roughness of the water in this zone appears to make the water more susceptible to sun glint contamination. The presence of even small amounts of sun glint increases uncertainty in this zone. Additionally, aerosols, tiny particles of dust, water droplets, and other compounds in the atmosphere that can reflect, refract, or absorb light, are different over land than they are over water. Both land and ocean aerosols mix along the coasts.

Along with these problems of contamination of coastal satellite records, circulation and mixing of coastal waters is quite complex. Waves circulate surface and deeper waters. Tides pump water into and away from the shore. Estuaries and bays have their own complex mixing and interactions with offshore waters. This makes changes in environmental parameters, such as SST, highly variable in the coastal zone.

These factors can introduce errors that can overwhelm the true signal of water leaving radiance and lead to extremely inaccurate satellite retrievals. Consequently, data from within 10 km of the coastline previously have been excluded from the *in situ* SST Quality Monitor (iQuam; www.star.nesdis.noaa.gov/sod/sst/iquam/) analysis. However, most coral reefs exist near the coast. Without any matchups in the coastal zone, and with limited capabilities to perform an analysis, it has been very difficult to determine how well the products work in coral reef areas. It also affects the ability to monitor coral reefs directly. As a result, the iQUAM cal/val system is being reprogrammed to analyze all nearshore data.



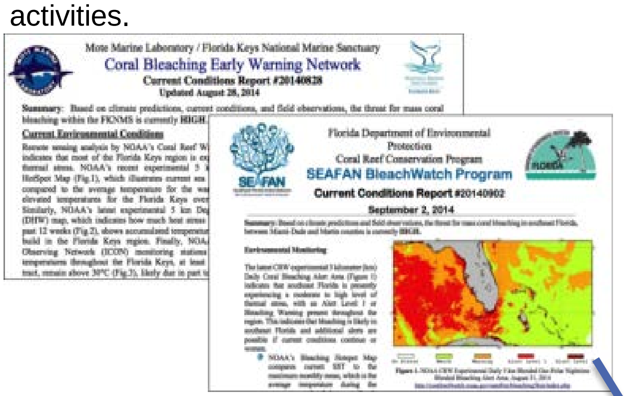
Shown on the left is a comparison of regional 1-km HotSpots for the Gulf of Mexico and Florida derived from MODIS Aqua 11 µm (left) and the LAC AVHRR (right), and between the MODIS Aqua 4 µm (lower left) and CRW's Enhanced 50-km (E50) product (lower right). MODIS SST data were used to test the CRW's coral bleaching products at a single satellite's native resolution. This has helped provide insights into the practicality of sub-km products from VIIRS, which was designed to improve upon the capabilities of AVHRR.

Once issues of calibration and validation are resolved, CRW expects the higher spatial resolution products using VIIRS will enable monitoring of bleaching thermal stress at relatively small scales specific to coral reefs and subject to localized effects (e.g., shallow water, tidal mixing, and coastal runoff). They will also allow CRW to more accurately predict local variations in mass coral bleaching events, as well as more accurately account for episodes of minor or no coral bleaching.

Additional efforts in the pipeline include the use of Sub-km VIIRS SSTs to develop a sub-km version of the CRW coral bleaching thermal stress products and a future plan to blend these with 2-km data from Himawari-8 and GOES-R. These products will be shared with users for testing and evaluation.

Corals in Crisis: Performance of the New 5-km Products During Bleaching Events In 2014 and the 2015 Bleaching Outlook

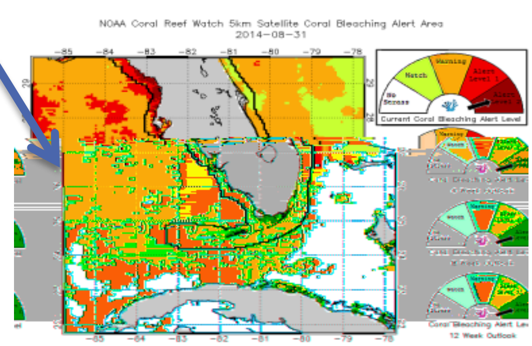
NOAA CRW's 5-km products – derived using SST measurements from various sensors including VIIRS – were launched just in time to predict and track record-breaking coral bleaching and mortality events in 2014. Satellite observations indicated that coral bleaching was widespread across the vast waters of the northern Pacific, including the Marshall Islands, Guam, the Mariana Islands, and the Northwestern Hawaiian Islands (NWHI), as well as in the Atlantic in Florida. In the Main Hawaiian Islands mass coral bleaching was seen for the first time. CRW's near reef-scale products were immediately picked up and used by regional resource management agencies. The products, which significantly advance the ability of coral reef researchers and managers to monitor coral thermal stress in NRT, have already been adopted by Hawai'i and Florida resource managers to direct coral bleaching monitoring activities.



Examples of the 5-km products in use at the Florida Keys and southeast Florida BleachWatch programs, http://www.dep.state.fl.us/coastal/programs/coral/bleachwatch.htm

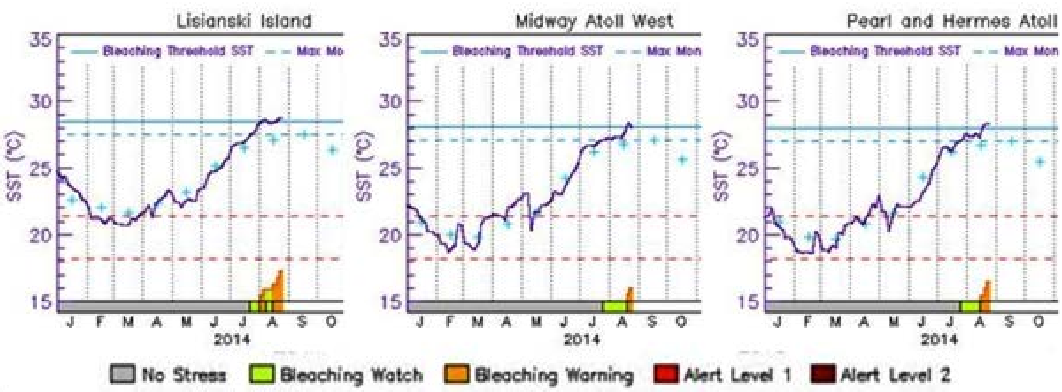
Florida Keys and Southeast Florida

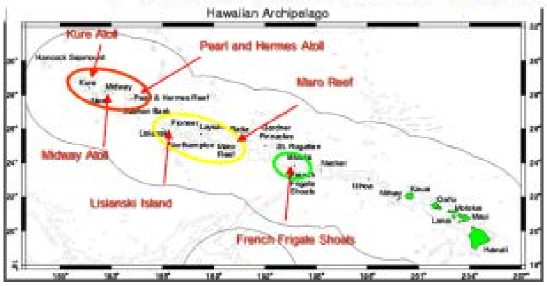
In the Florida Keys, for example, the products have helped officials from the state guide rapid response efforts to assess reef conditions (BleachWatch) and inform the public about what may be happening on the reef when corals are visibly stressed. While managers in Florida have yet to restrict access to reefs during bleaching events and disease outbreaks, as managers in some parts of the world have, such actions may become a necessity in the future. Local partners reported that bleaching observed in-water in the Florida Keys in 2014 was the worst they had seen since 1998. Additionally, CRW's 50-km products indicated that



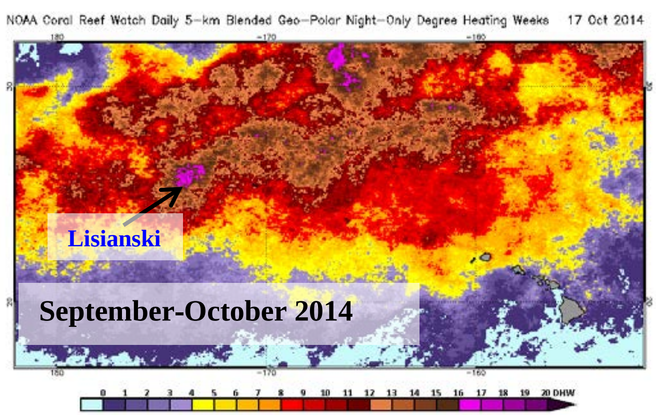
2014, especially the month of August, was one of the most severe years for thermal stress in the region since 2000. This was of particular concern to the nurseries being used to recover threatened species of corals.

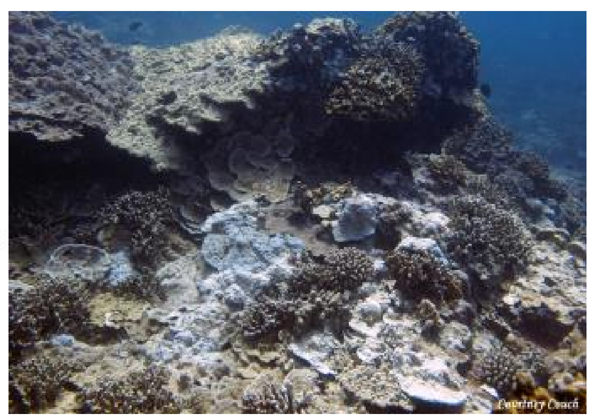
The Hawaiian Islands





Starting in late August 2014, CRW monitored and issued alerts to its users about substantial coral bleaching thermal stress across the Hawaiian archipelago.



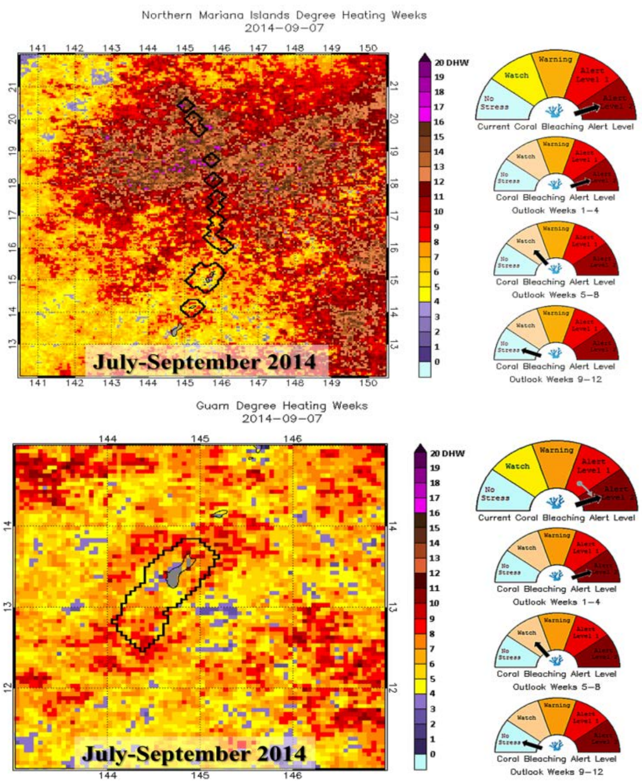


Bleached coral in the NWHI very early in the event, late August 2014. The pale coral is bleached due to thermal stress. Image courtesy Courtney Couch, NOAA.

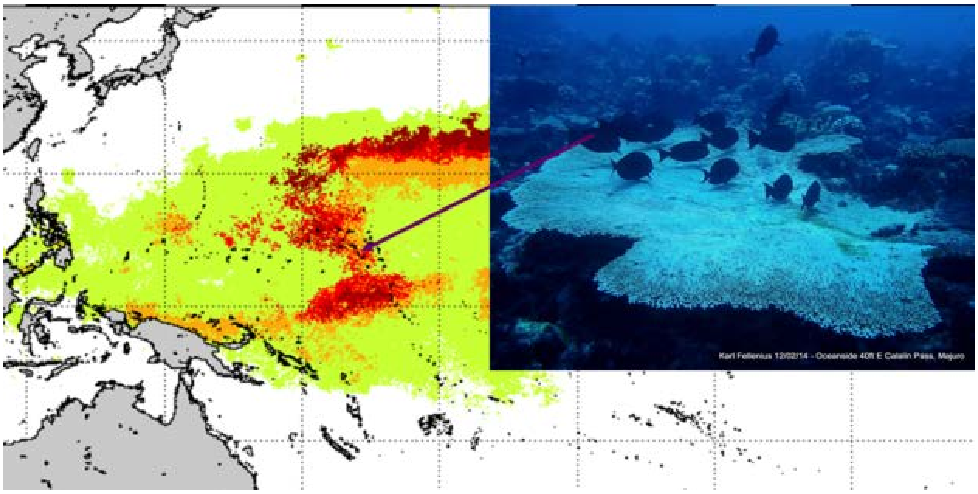
By early October, CRW's daily global 5-km satellite coral bleaching thermal stress monitoring product suite showed thermal stress reaching Alert Level 2 (figure above), associated with significant, widespread coral bleaching and mortality, in many locations within the Northwestern Hawaiian Islands (NWHI – the area encompassed by the Papahānaumokuākea Marine National Monument). Of note, the 2014 thermal stress records for the region (DHW>12) eclipsed the record set in the 2002 bleaching event. In the main Hawaiian Islands (MHI), where island-wide mass coral bleaching had never been reported, thermal stress reached Alert Level 1 (significant bleaching) in Kauai and O‘ahu. CRW’s satellite- and climate model-based outlook products were used extensively throughout the three-month event by Hawai‘i’s Division of Aquatic Resources (DAR) Eyes of the Reef program and local marine resource managers to support planning and prioritization of resources and to assist in-situ surveys and bleaching response efforts by Hawai‘i’s coral reef monitoring networks.

Commonwealth of the Northern Mariana Islands and Guam

Bleaching in Guam and the Commonwealth of the Northern Mariana Islands (CNMI) was especially alarming because it followed on the heels of an unprecedented coral bleaching event in the preceding year. As in 2013, CRW’s 5-km DHW product (right) indicated that in 2014 there was more severe and widespread bleaching thermal stress in the northern parts (top right) of the CNMI in 2014 than in the southern parts (bottom right) of the CNMI and Guam. CRW’s products were used by the local coral reef management community to activate its bleaching response plan and enhance monitoring efforts on its reefs from July through September 2014. Bleaching severity was confirmed by in-situ bleaching observations from monitoring cruises to the northern CNMI in 2014. Along with signs of high coral mortality from the 2013 event, including over 90% mortality of *Pocillopora* and *Acropora* spp, the survey team saw extensive bleaching and high mortality of most species of corals in the northern CNMI, while bleaching around Guam and Saipan was documented to be serious, but much less severe.



Marshall Islands



Marshall Islands Bleaching, October-November 2014

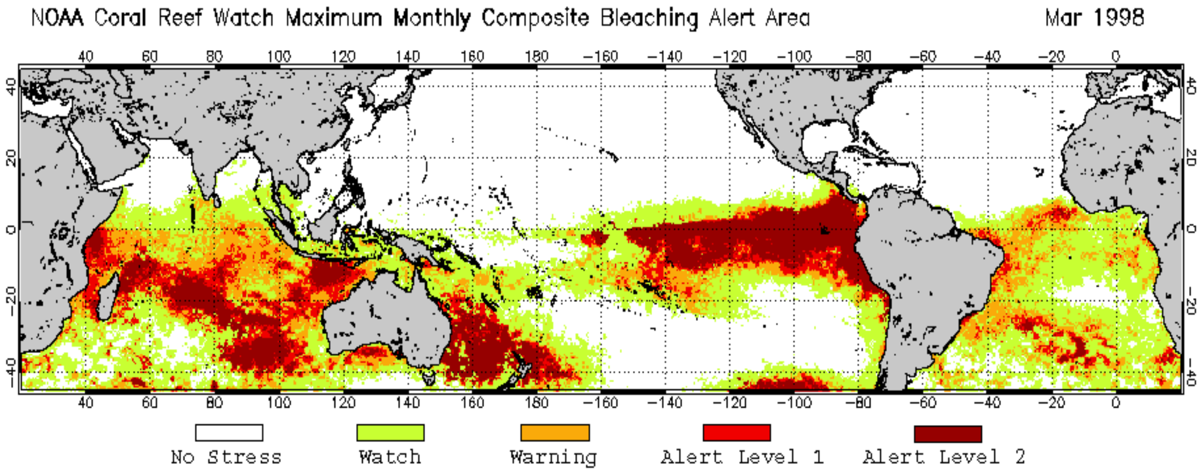
Oceanside Excavation Pits Long Island W of Bridge, Majuro. Credit Karl Fellenius, University of Hawai'i Sea Grant College Program (UH Sea Grant).

While no stranger to bleaching events, in 2014, the Marshall Islands were hit with bleaching at a scale not experienced previously. Observations around Majuro, Arno and Kwajalein atolls showed unprecedented bleaching. In shallow reefs, as shown on the left, bleaching could be seen from the surface looking down in the water.

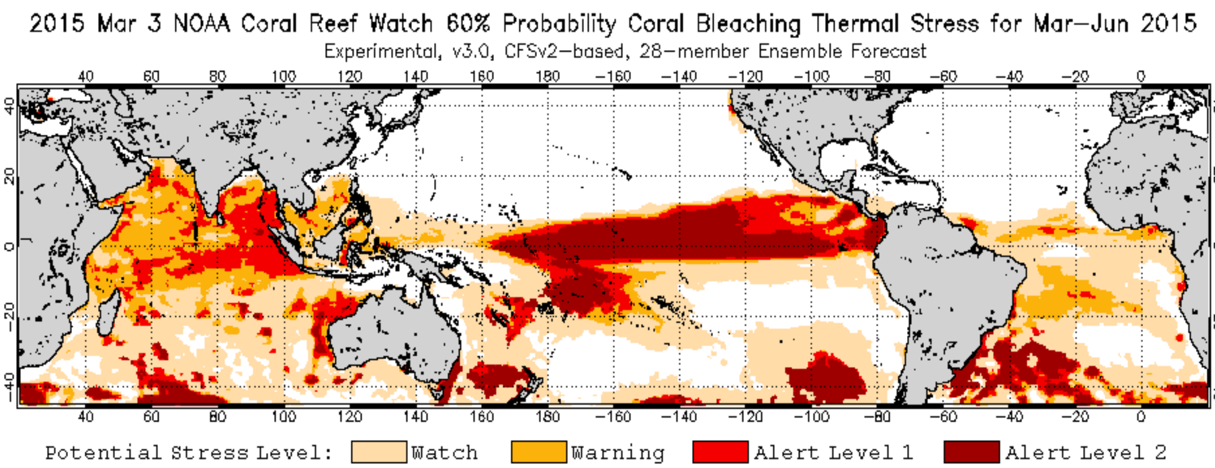
What About 2015?

Corals that are exposed to bleaching events over long periods often die. In 1998, coral reefs around the world experienced the worst bleaching event on record (see image below). A massive El Niño event combined with climate change to raise global sea and air temperatures to unprecedented levels and destroy an estimated 15 percent of the world's coral reefs. A second global wave of severe coral bleaching and mortality came in 2010.

CRW's Four-Month Bleaching Outlook uses the daily SST forecast from NOAA's Climate Forecast System Version 2 climate model to provide an outlook of regions that may be most susceptible to coral bleaching due to high temperatures. The current Outlook (from March 3, 2015) shows a pattern similar to that observed during the 1998 and 2010 global coral bleaching events. The weak El Niño along with very warm North Pacific Ocean temperatures suggest that similar significant bleaching events may unfold in 2015.



Global Bleaching Alert Area from March 1998 showing patterns of accumulated thermal stress sufficient to cause coral bleaching. By early 1998, the classic El Niño pattern was fully developed, with broader areas of high temperature in the eastern Tropical Pacific and extending up the Central American coast past Costa Rica, including all of the eastern Tropical Pacific islands; high temperatures in these regions did not begin to dissipate until June. Bleaching levels of warming were seen along the Great Barrier Reef in February-March. Warming also began in the eastern to central Indian Ocean south of the equator, spreading to the eastern Indian Ocean by March, and dissipating after May.



CRW's Four-Month Bleaching Thermal Stress Outlook of March 3, 2015 indicating significant threats for coral bleaching through June 2015 for the western Pacific and Indian Oceans in areas such American Samoa, Samoa, Western Australia, and Indonesia. (Credit: NOAA). Image available at: ***http://coralreefwatch.noaa.gov/satellite/bleachingoutlook_cfs/current_images/cur_img_v3_ss_outlook_cfs_rank12_45ns.gif***

In the March 3, 2015 Outlook, the swath of red across the Pacific Ocean places the many island nations of the South Pacific in the immediate line of fire. In these locations, heat stress has already started to cause coral bleaching. In American Samoa, scientists have seen the worst bleaching of their shallow reefs ever-recorded. Over the next few months, these conditions could spread to the Line Islands, Cook Islands, and to the eastern Pacific Ocean.

In the Indian Ocean, heat stress has already reached bleaching levels around Madagascar and nearby islands. Bleaching also may impact the central/eastern Indian Ocean and across to Western Australia and parts of Indonesia.

Summary

When corals are exposed to changes in conditions such as temperature, light, or nutrients they become stressed. They can recover from mild bleaching, especially if the reef ecosystem is generally healthy. Continuous monitoring of SST at global scales provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. CRW's global decision support system (DSS) of satellite and modeled products for coral bleaching management provides a first-hand look at coral reef environmental conditions when SSTs exceed bleaching thresholds. When bleaching conditions occur, tools such as CRW's bleaching alerts can be used to trigger monitoring networks' bleaching response plans and support appropriate management decisions.

NOAA's CRW program continues to provide bleaching alerts that help support management responses to one of the greatest threats facing coral reef ecosystems. With advance warning of potential temperature stress, decision makers, including reef managers, around the world can take appropriate actions such as limiting diving and fishing on reefs, treating coral disease, or reducing coastal runoff. By reducing other stressors, especially local threats, corals have a better chance at surviving the impacts of climate change.

Enhancements to CRW's DSS for coral bleaching management have enabled the delivery of near-real-time information on coral reef environmental conditions at higher spatial (5-km) and temporal (daily) resolutions. In 2014, the 5-km satellite coral bleaching products (derived from SST measurements taken by a combination of geostationary and polar-orbiting environmental satellites, including Suomi-NPP) and modeled Four-Month Bleaching Thermal Stress Outlook helped predict and track record-breaking bleaching and mortality events; CRW will continue to alert managers to bleaching thermal stress conditions throughout 2015 and beyond. These new products, which include observations from VIIRS, significantly increase near-shore coverage and advance CRW's monitoring capabilities to directly cover over 98 percent of coral reefs and significantly reduce data gaps caused by cloud cover. This will help resource managers keep better track of conditions that are likely to cause bleaching in coral reef environments.

NASA/Short-term Prediction Research and Transition (SPoRT) support to JPSS: Demonstrating the Utility of Suomi-NPP / JPSS Data to Weather Forecast Operations

This article is based in part on the ***February 18, 2015*** *JPSS science seminar given by presented by Kevin Fuell, Matt Smith, Emily Berndt, University of Alabama in Huntsville / NASA-SPoRT, Brad Zavodsky, NASA-SPoRT.*

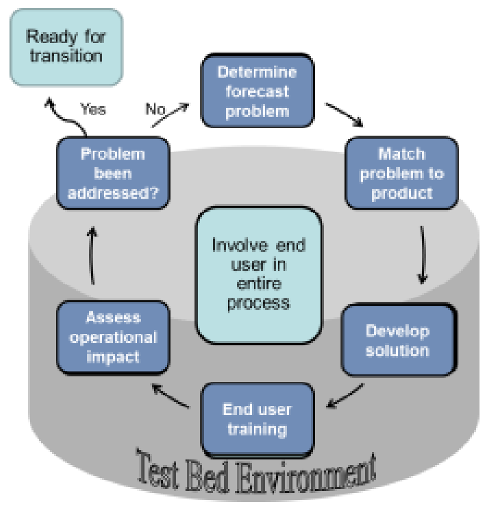
Collaborators on the NUCAPS work include Nadia Smith (CIMSS), Jack Dostalek (CIRA), and Eric Stevens (GINA).
*The SFR product was developed at NOAA/NESDIS by Huan Meng (NOAA/NESDIS)***.**

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

The Short-term Prediction Research and Transition (SPoRT) project focuses on the transition of unique NOAA and NASA satellite observations and modeling capabilities to support short-term, regional weather forecasting. 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. SPoRT is located at NASA's Marshall Space Flight Center (MSFC) Earth Science Office (ESO) at the National Space Science and Technology Center (NSSTC), in Huntsville, Alabama. The ESO is physically collocated with the University of Alabama in Huntsville (UAH) Atmospheric Science Department, the UAH Earth System Science and Global Hydrology Resource Centers, and the Huntsville National Weather Service (NWS) Weather Forecast Office (WFO). The Huntsville WFO is the only NOAA WFO collocated with a NASA facility. Unique to the Huntsville WFO is a shared Collaborative Research Area (CRA) located adjacent to the operations floor in the WFO where scientists from NOAA, NASA, and UAH work collaboratively in a testbed environment to develop new forecasting tools and capabilities.

SPoRT teams work with end users to match forecast problems to

SPoRT maintains a close collaboration with numerous NOAA/NWS WFOs across the U.S. Its core mission is also very closely-aligned with NOAA's Weather Ready Nation (WRN) 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.



The SPoRT Program works within the NOAA/Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) Program to disseminate satellite data and products, which are specifically created to address region-specific forecast challenges at selected WFOs. An important part of the SPoRT paradigm is the assessment of research products. SPoRT engages its collaborative partners, including the University of Alaska Fairbanks (UAF) Geographic Information Network of Alaska (GINA), to help assess and document the utility of these satellite data and products in the WFOs operational environment as well as within data assimilation and numerical model capabilities. The WFOs provide comprehensive feedback on the utility of the products being evaluated. SPoRT utilizes this feedback to determine the effectiveness of the products transitioned and to guide improvements for future product development.

SPoRT operates within the JPSS PGRR framework to evaluate the benefits of data products from the Suomi-National Polar-orbiting Partnership[9] (Suomi-NPP) satellite on NWS forecast

[9] The nation's primary polar-orbiting weather satellite

operations. These evaluations, conducted through forums, direct feedback, blogs, and emails, help SPoRT determine whether a particular solution or procedure has made an impact on the established forecast challenge by improving either the short-term weather forecasts or the end user's situational awareness.

SPoRT Support to Aviation Weather and Cloud Analysis in Alaska

SPoRT recently performed assessments on three products from support initiatives in high-latitude regions. The products, which include the Nighttime Microphysics and the Day-Night Band (DNB) RGB imagery; the NOAA Unique Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) Processing Systems (NUCAPS) Cold-Air Aloft; and the land snowfall rate (SFR) were derived using measurements from NOAA's primary satellite, Suomi-NPP. They were created to address challenging forecast issues related to fog and low clouds, cold air aloft and snowfall rates in high latitude regions. More details of these assessments are presented in a subsequent section.

Alaska, unlike any other state, is uniquely dependent upon air transportation. The combination of cold air, wind and other conditions, including snow can pose serious threats to aircraft operations, and also impact the normal functioning of local communities.

Air temperatures along jet aircraft routes can get so cold (minus 65°C and below) that they pose a risk of jet fuel freezing. This is known as Cold Air Aloft, and it is potentially hazardous to aviation. Outbreaks of "cold air aloft" can occur over the Arctic Ocean and Alaska. National forecast centers, such as the Aviation Weather Center (AWC) and Alaska Aviation Weather Unit (AAWU), provide near-global forecast products related to aviation hazards of convection, icing, and turbulence as well as winds and temperature at various flight levels. The NWS local WFOs are responsible for issuing short-term Terminal Aerodrome Forecasts (TAFs) at specific airports within their warning area. The national centers rely upon accurate information from satellites and other remote sensing platforms concerning both the spatial extent and timing of hazards that may affect aviation operations in regions with little to no in-situ observations. These help to identify a variety of conditions including low ceiling/visibility, cold air aloft and snowfall rates, and their coordinating degree of severity. Sensors aboard Suomi-NPP such as the Advanced Technology Microwave Sounder (ATMS), and imagery from the Visible Infrared Imaging Radiometer Suite (VIIRS) have quickly gained prominence in helping detect these conditions throughout Alaska.

Low Clouds and Fog

Low clouds and fog are weather hazards and high-impact events for transportation in general. But more than that, they are events that forecasters in almost all NWS WFOs must regularly address. In Alaska low-level clouds and fog present significant ceiling and visibility hazards to aircraft operations. Forecasters have traditionally relied upon imagery from NOAA geostationary satellites to analyze and track low clouds and fog. However, due to their viewing angle at high latitudes, geostationary satellites produce lower-resolution imagery for the polar regions compared to the tropics or mid-latitudes. Forecasters employ and have begun to rely on Suomi-NPP 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.

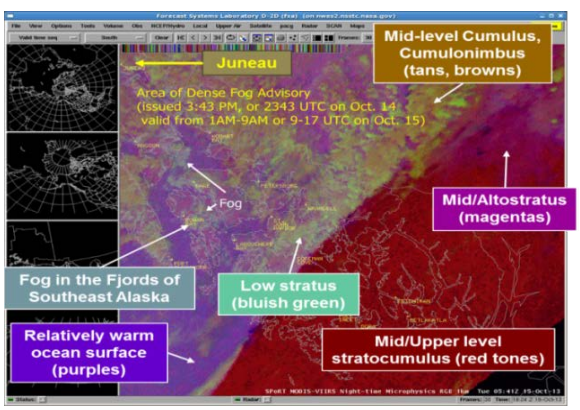
Assessing the Value of RGB Imagery in Alaska

In the winter of 2013/14, NWS operational users in Alaska assessed the Nighttime Microphysics and the Day-Night Band (DNB) RGB imagery to determine the value added to the short-term forecast of ceiling and visibility, particularly as they apply to TAFs issued by high-latitude WFOs. In addition, the assessment exposed forecasters to the application of complex multi-spectral imagery (i.e. RGB composite), and hence, the future paradigm of satellite imagery that will become available in the JPSS and GOES-R/-S eras. This first assessment of the Nighttime Microphysics RGB imagery for aviation and cloud analysis specifically sought to differentiate fog from low stratus clouds. After considering user feedback, a second assessment in the winter of 2014/15, sought to determine the value of a 24-Hour Microphysics RGB, (24hr Micro) compared to the Nighttime Microphysics RGB (NT Micro) in order to potentially have a single product for both day and night. Due to the long hours of daylight in the northern hemisphere summer at high latitude the NT Micro product is less frequently available.

NASA/SPoRT, in collaboration with university partners from the GINA, leverages data from VIIRS as well as the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Aqua and Terra satellites to generate a suite of RGB imagery products for use by the NWS in Alaska. The data used to generate these products is received via direct broadcast at GINA and processed into imagery by SPoRT software hosted on virtual machines at GINA in order to reduce product latency. The resulting imagery is then delivered to the NWS for display in the operational decision support platform – the Advanced Weather Interactive Processing System (AWIPS).

These RGB products are created by combining a number of satellite channels at different wavelengths. The NT Micro red component uses the 12.0-10.8 micron difference which is related to cloud optical depth and is a proxy to cloud thickness. The green component uses the 10.8-3.9 micron difference to identify clouds with small water droplets. And, finally, the blue component uses the 10.8 micron signal to provide the thermal characteristics of the cloud or surface.

Various combinations of these colors point out cloud features such as fog in the Fjords of southeast Alaska and a variety of other cloud types as illustrated in the following image.



VIIRS Night-time Microphysics RGB from 0541 UTC on October 15, 2013

The 12.0µm-10.8µm Thicker = more red

The 10.8µm-3.9µm Small water droplets = more green

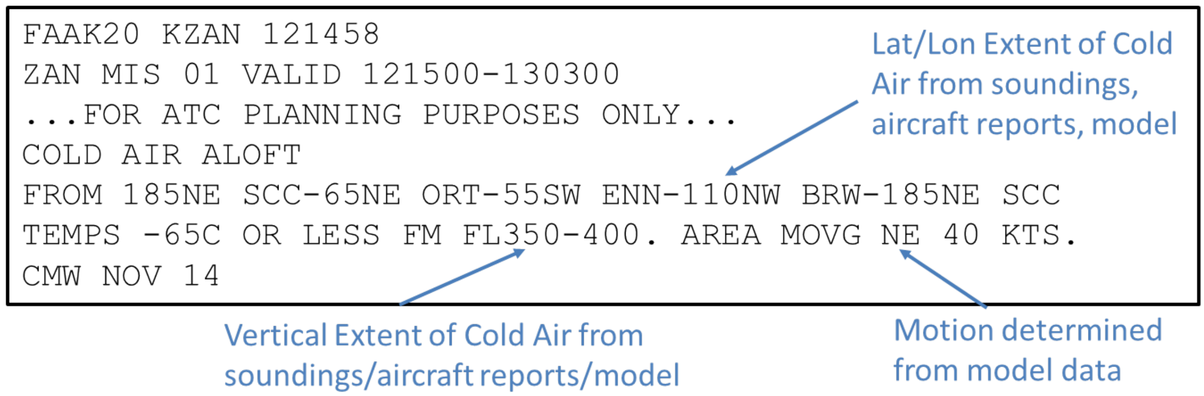
The 10.8µm Warmer = more blue

The 24hr Micro, however, differs in its use of the green channel. While the NT Micro uses the 10.8-3.9 micron difference, which is the legacy “fog product” that has been employed by meteorologists for years, the 24hr Micro uses a 10.8-8.7 micron difference (see image below). The 8.7 micron channel is not affected by solar reflectance, while the 3.9 micron channel is influenced by both radiance and solar reflectance during the day. Consequently, the 10.8-3.9 difference changes its relationship to clouds as night gives way to day and is not usable for fog and low cloud analysis once the sun comes up. Therefore, the 3.9 micron channel is replaced by the 8.7 micron channel so there isn’t any change in the appearance of clouds from darkness to daylight in the 24hr Micro in terms of reflected sunlight.

At night the NT Micro shows more details and is conceivably superior to the coarser looking 24hr Micro. However, the NT Micro is rendered unusable during the transition from darkness to daylight, while the 24hr Micro provides consistent imagery. Feedback to the SPoRT program on the utility of the 24hr Micro product has shown that it may prove increasingly useful in Alaska as the long dark Alaskan winter gives way to a summer of almost continual daylight.

Furthermore, the 3.9um channel can become noisy at temperatures less than -20 Celsius. That is, the 3.9µm brightness temperature used in the green component of the NtMicro RGB has a short-term noise (i.e. error) that increases exponentially as the temperature of the objects become less than -20 Celsius. The resulting image enhancement will have a speckled or “noisy” appearance as some pixels will have much colder temperatures than a neighboring pixel. Similarly, at high latitudes in winter, a cold air mass and associated cloud features at less than -20 Celsius can limit the effectiveness of the green component of the NtMicro RGB to differentiate cloud objects. Thus, the 24hr Micro RGB may be required for high latitude winters, particularly in extremely cold temperatures.

Cold-Air Aloft



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FAAK20 KZAN 121458
ZAN MIS 01 VALID 121500-130300
...FOR ATC PLANNING PURPOSES ONLY...
COLD AIR ALOFT
FROM 185NE SCC-65NE ORT-55SW ENN-110NW BRW-185NE SCC
TEMPS -65C OR LESS FM FL350-400. AREA MOVG NE 40 KTS.
CMW NOV 14
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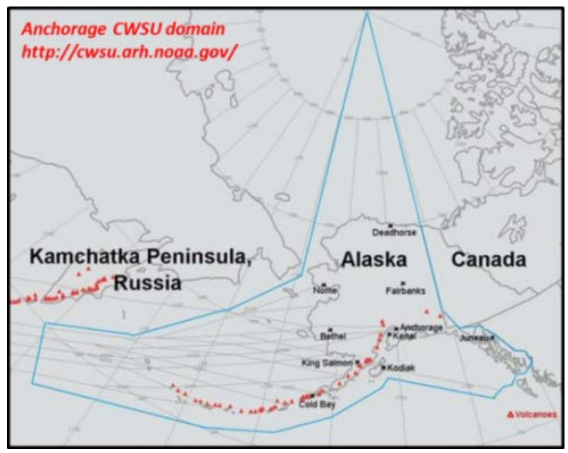
Alaska is more dependent on general aviation and small aircraft commercial aviation than any other state in the nation. As a result, forecasting cold air aloft is critical for the region's aviation industry and helps promote the safe and efficient flow of air traffic.

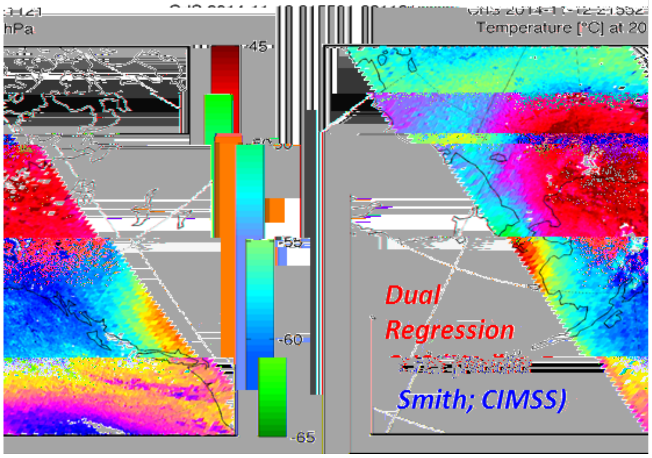


The NWS's Center Weather Service Unit (CWSU) in Anchorage, Alaska provides weather support to air traffic controllers directing traffic over the Arctic Ocean and Alaska. CWSU provides Meteorological Impact Statements (MIS) to air traffic controllers to direct flights around cold air aloft. The MIS help guide traffic management personnel when making critical weather decisions.

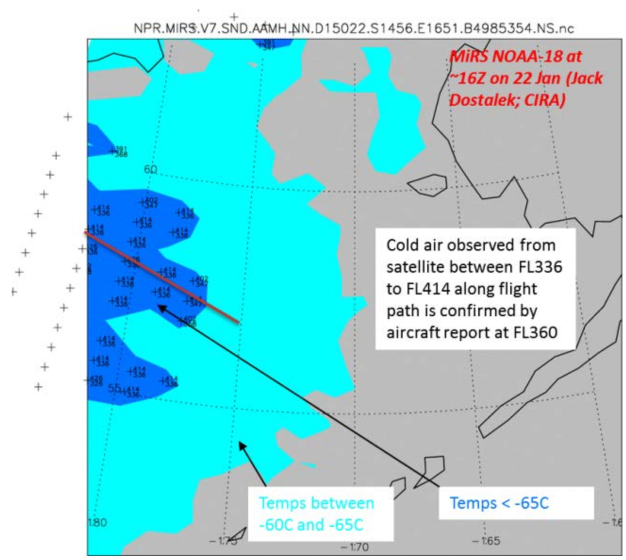
Even though numerical weather prediction models help meteorologists forecast the occurrence and movement of cold air aloft, NWS meteorologists have had to rely on analysis and model fields and very limited radiosonde observations to guess the 3D extent of the cold air aloft. Accordingly, forecasters at the CWSU have expressed the need for an observational product from satellites that can help locate these cold areas and also give confidence in the model output.

The use of satellite observations, and in particular from polar-orbiting satellites, provides an opportunity for forecasters to observe the 3D extent of the cold areas in real-time where conventional observations are lacking. Hyperspectral sounders, such as the Cross-track Infrared Sounder (CrIS) aboard the Suomi-NPP satellite, are well-suited for observing cold air aloft over Alaska and the Arctic Ocean due to the sensitivity of these instruments and the comparatively high number of passes satellites in polar orbits make per day over the high latitudes. Satellite-borne hyperspectral sounders perform well at elevations above cloud tops, which happen to be where cold air exists and also the altitude range used by passenger and cargo jet aircraft, typically below 45,000 ft.

Assessing the Value of the NOAA Unique CrIS and ATMS Processing Systems (NUCAPS) Cold-Air Aloft product



The NOAA Unique CrIS and ATMS processing System (NUCAPS) is the operational retrieval system for sounding products from the Suomi-NPP. NUCAPS produces cloud-cleared radiances from the Cross-track Infrared Sounder (CrIS) field-of-regard that is co-located with ATMS. The AK CWSU is evaluating single-layer slices of CrIS profiles from the University of Wisconsin (UW) Cooperative Institute for Meteorological Satellite Studies (CIMSS) dual-regression algorithm. CIRA developed a product using MIRS soundings, which shows minimum temperature in the vertical profile and defines the flight levels of the bottom and top of the Cold Air Aloft layer based on retrieval pressure level. The product tracks regions of cold air, and in particular, cold air which exists at altitudes used by passenger and cargo jet aircraft, typically below 45,000 ft. The product displays are available in NRT on CIRA webpage http://rammb.cira.colostate.edu/ramsdis/online/cold_air_aloft.asp.



On the right is an example of this CIRA visualization of Suomi-NPP using observations from a legacy NOAA polar-orbiting sounder that show flight levels where temperatures of -65C are observed. Super-imposed on this image is a flight route of an aircraft (the red line). This aircraft confirmed temperatures below -65C at its flight level of 36, 000 feet from lat/lon 54N/175W to 56N/177E at 1642z on 22 January. Most aircraft fly at FL330 or lower in that area. Where the coldest air is less than -65°C and exists below 45,000 ft, the satellite footprint is marked by a '+'. The web page allows for a quick implementation of ideas, as well as serves those agencies which would be interested in the information but don't have access to the next generation operational decision support platform AWIPS II.

A collaborative effort led by SPoRT and involving CIMSS, CIRA, GINA, and the Alaska CWSU aims to make this information available in an AWIPS II. Tests to find out whether these visualization capabilities and types of data can help with the forecast challenge have already begun. These tests were performed using the dual-regression products that are already available in CSPP for direct broadcast. The dual-regression products were well received by forecasters in Alaska, and are currently under their evaluation.

Snowfall

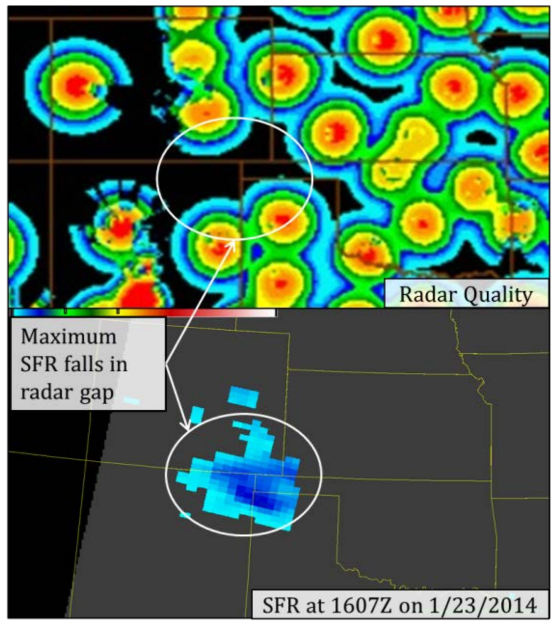
Snowfall is a predominant form of precipitation in the high-latitude and mountainous regions of North America. Snow storms, even moderate ones can cause a variety of problems ranging from serious economic disruptions to significant injuries and deaths. Snowfall is an important weather element, yet it is extremely challenging to measure accurately and consistently. Since 1890, the NWS has relied on volunteers and the general public to provide snowfall measurements over a region. The volunteers are part of the NWS network of observers, and are the nation’s primary source for snowfall data.

Weather forecasters mainly rely on radar and station observations for their snowfall forecasts. However, high-latitude regions such as Alaska have sparse surface weather observations, and receive limited ground radar coverage, which make snowfall measurements very hard to achieve. An experimental, real-time land snowfall rate (SFR) product developed by NOAA/NESDIS and transitioned to NWS forecasters by SPoRT has the capability to detect and estimate snowfall areas associated with large mid-latitude storm systems in “temperate” climate zones. The product is based on algorithms that use multiple channels that are sensitive to different atmospheric levels in order to sample the intensity of snowfall through the entire precipitation layer. This provides an advantage over ground-based radar, which scans single vertical levels and may miss higher concentrations of precipitation above or below the scan of the beam. The SFR product uses data from polar-orbiting microwave sensors including the Suomi-NPP ATMS instrument. The ATMS sensor greatly improves upon the previous operational microwave sounders, like the Advanced Microwave Sounding Unit (AMSU) and Microwave Humidity Sounder (MHS) because it offers more channels, better resolution, and a wider swath that allow for improved vertical sampling of the precipitation layer and minimize surface affects. The SFR products can fill in gaps where no conventional snowfall data are available to forecasters. The products can also be used to confirm radar and gauge snowfall data and increase forecasters' confidence in their prediction.

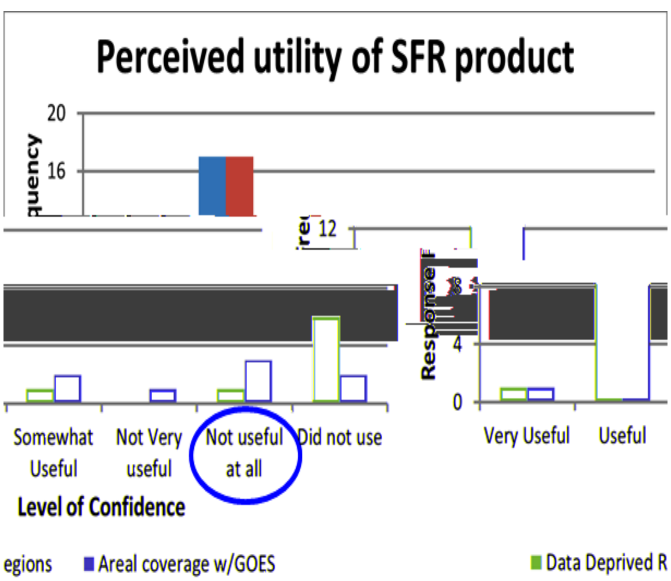
The utility of the SFR was also demonstrated on January 27, 2015, when a massive snow storm pounded through some areas of the Northeast. The epic blizzard heaped snow over New England where accumulations in some areas reached, or exceeded, two feet. On the left above is an example of the output from the ATMS SFR product displayed in AWIPS II. The image depicts heavy snow over most of the New England states. In the image, the increased spatial resolution of ATMS is apparent. From the image NOAA forecasters were also able to infer that the heaviest snowfall at the time was centered over southeastern Connecticut with rates from 1-1.5 inches of solid snow per hour, which was consistent with observed values.

Assessing the Value of the NESDIS SFR Product

In winter of 2014, SPoRT and NESDIS collaborated to evaluate the SFR at NWS WFOs in Albuquerque, NM (ABQ); Burlington, VT (BTV); Charleston, WV (RLX); and Sterling, VA (LWX) NWS WFOs; and the NOAA/NESDIS Satellite Analysis Branch (SAB). This assessment sought to determine the utility in the SFR product for tracking snow features in data void regions and in determining the edge and maxima of the snowfall in a large precipitation system.



For example, on January 23, 2014 the SFR product was used by the Albuquerque (ABQ) WFO – an area with very limited radar coverage. The images on the right compare the areal extent and quality of data received from radar (top) and the SFR product (bottom) during a snow event in Albuquerque, NM. The areal coverage provided by the SFR product, which filled in the gap from northeastern NM to southeastern CO, was very good compared with the observations. Although nowcasts had already been issued for the snowfall, the product helped increase confidence in the area where the snowfall was reported.



A tremendous amount of feedback was generated from 26 surveys, 10 blog posts, and over 50 emails. This particular assessment established that the impact of the SFR product on the operational process was very large. Most forecasters rated the product 'Useful' or 'Very Useful'. Their feedback revealed product issues impacting its applications in operations. These included latency; a limitation of cold air at the surface, which meant that snow could not be detected in colder air masses, and also the reason for all three 'Not useful at all' ratings; and inadequate detection of light snow.

Based on product feedback, a new version of the SFR product has been developed that increases the amount of light snow that can be detected and allows for use of the product in colder regions. Coupled with other microwave sensors on board other NOAA and European satellites, up to 10 swaths of observations are generated. When used in conjunction with GOES imagery and radar, these observations allow forecasters to track of various snowfall features during these weather events. These observations are being provided in near-real-time (less than 30 minutes latency) through access to data from direct broadcast provided by CIMSS for the continental U.S., and from GINA for Alaska. An evaluation of this updated product was performed during winter 2015 with expanded participants, including Alaskan WFOs, Boulder (DEN), and Cheyenne (CYS).

More planned efforts include finalizing its cases from the first two years of testbed activities, to enable wider distribution of the SFR product to other interested WFOs. In addition, NESDIS plans to develop a merged radar SFR product that will more specifically fill in the gaps of the radar coverage but still rely on traditional radar where strong.

Summary

SPoRT operations, including those taking place within the JPSS PGRR framework, enable NOAA's WFOs to evaluate the benefits of data products from key satellites including Suomi-NPP. The assessment of product impact in the operational environment is important to their sustained and successful use in NWS operations. These assessments provide a valuable feedback loop between the operational user and the product developer or researcher (i.e. O2R aspect of transition). The feedback loop allows for incremental product improvements and enhancements to its application within the user's decision support systems. 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 capability or product has consistent positive impact to a forecast challenge, the SPoRT development team works to determine how to make it more widely available throughout the operational weather community.

Key to the successful use of satellite data, and especially from polar-orbiters such the Suomi-NPP, by WFOs is the integration of these data and products into decision support systems such as AWIPS/AWIPS II. Accordingly, SPoRT continues to work with university partners including GINA, and several of the NOAA Cooperative Institutes, to bring unique data and products directly into AWIPS II for use by operational forecasters to address region-specific forecast issues throughout the nation.

While particularly useful in the higher latitudes, data from NOAA's polar orbiting satellites have proven to be integral to all regions for specific forecast challenges. These data play a vital role in providing timely, high resolution observations for improved situational awareness, short-term forecasts, and warnings. Thus, the sustained use of polar orbiting data by WFOs in these regions, with the help of SPoRT, has proven absolutely essential for accurate forecasting and warnings.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Applications of Satellite Retrievals of Suomi-NPP ATMS Snowfall Rates in Weather Forecasting

This article is based in part on the ***March 23, 2015*** *JPSS science seminar presented by Huan Meng, NOAA/NESDIS/Center for Satellite Applications and Research (STAR).*

Collaborators: Cezar Kongoli, SSIC/University of Maryland Cooperative Institute for Climate and Satellites, Jun Dong, SSIC/University of Maryland Cooperative Institute for Climate and Satellites, Nai-Yu Wang, I.M. Systems Group, Inc., Ralph Ferraro, NOAA/NESDIS/Center for Satellite Applications and Research, and Banghua Yan, NOAA/NESDIS/Office of Satellite and Product Operations, and Bradley Zavodsky, NASA/Short-term Prediction Research and Transition (SPoRT) Center. Development of the ATMS SFR algorithm and its transition to forecasters was funded through the NOAA JPSS Proving Ground and NASA Science Mission Directorate.

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

Photo accessed from ***http://www.noaa.gov/features/02_monitoring/snowstorms.html****.* *Credit: NOAA*

Snowfall

The need for measuring snowfall is driven by the roles snow plays in the Earth's climate system, and in providing freshwater resources. Snow accumulations are an important resource for ecological and human needs. Snowmelt is a major source of water supply for human and animal sustenance. Freshwater from snowmelt provides needed moisture to many plants. It also helps replenish rivers and reservoirs in many regions of the world, especially the western United States. Part of the water supplies in the Arctic and high-latitude North Atlantic oceans are derived from over-ocean snowfall, along with seasonal runoff from snowmelt. Sometimes, snow storms, even moderate ones can cause a variety of problems ranging from serious economic disruptions to significant injuries and deaths. Moreover, if too much snow falls and then melts too quickly during the spring season, it can lead to flooding. This is an issue of particular concern in the Northern Plains and parts of the Intermountain West.

Snowfall is an important weather element, yet it is challenging to measure accurately and consistently. Much of the Earth's surface, for which snowfall can play a significant role, is not well-monitored by conventional observations due to a variety of challenges. Observations from polar-orbiting satellites provide an effective way to monitor snowfall with global coverage. Snowfall Rate is a measure of the intensity of snowfall. It is measured by calculating the amount of snow that falls to the earth surface per unit area per unit of time. Since 1890, the National Weather Service (NWS) has relied on volunteers and the general public to provide snowfall measurements over a region. The snowfall rate (SFR) product from NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) has the capability to detect and estimate snowfall in areas associated with large mid-latitude storm systems in "temperate" climate zones. It is based on algorithms that use multiple satellite channels that are sensitive to different atmospheric levels in order to sample the intensity of snowfall through the entire vertical layer where precipitation is falling. Use of radar in higher elevations is limited by range degradation and beam blockage from mountains. As a result, radars may fail to detect snow from low level clouds. Consequently, the SFR provides an advantage over ground-based radar, which scans single vertical levels and may miss higher concentrations of precipitation above or below the scan level of the beam.

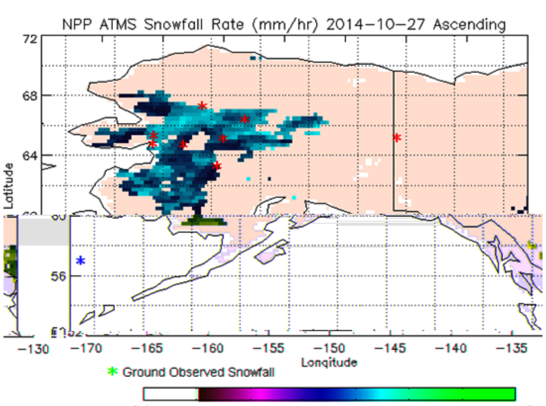
Passive microwave measurements at certain high frequencies are sensitive to the scattering effect of snow particles, and can be utilized to retrieve snowfall properties. Some of the microwave sensors with snowfall sensitive channels include the Advanced Microwave Sounding Unit (AMSU) and Microwave Humidity Sounder (MHS) aboard POES and Metop satellites; and the Advanced Technology Microwave Sounder (ATMS) aboard NOAA's primary weather satellite, Suomi-NPP.

NESDIS Snowfall Rate Product

An AMSU and MHS based land SFR product is running operationally at NESDIS. Since conventional radar or in situ observations are required for the development and validation of the current SFR algorithm, the scarcity of such observations over the ocean limits the NESDIS SFR to a land only product. Based on the AMSU/MHS SFR, an ATMS SFR algorithm was developed in a project supported by the JPSS PGRR Program. The ATMS sensor greatly improves upon AMSU and MHS because it offers better resolution, a wider swath, and more channels, especially two water vapor channels that allow for improved vertical sampling of the precipitation layer and minimizing surface effects. Much improvement has been made since the original ATMS SFR algorithm was developed as a result of user assessment (see Product Assessment section).

Application in Alaska

In the Contiguous US, weather forecasters can rely on radar and station observations for snowfall forecast in most areas. But, high latitude regions such as Alaska have sparse surface weather observations, and receive limited ground radar coverage, which make snowfall measurements very difficult. Polar-orbiting satellites provide the data needed to fill-in the gaps over the areas that are not adequately covered by conventional observing systems. Polar-orbiting satellites pass a location twice per day (12 hours apart) at mid-latitudes; however, they provide more passes per day over Alaska than over the contiguous United States (CONUS). Currently, SFR is generated from five satellites: Suomi-NPP, NOAA-18, NOAA-19, Metop-A, and Metop-B. The suite of satellites provides up to ten SFR estimates, 5 morning; 5 afternoon overpasses at any land location in mid-latitude, and up to 50 estimates near the poles.

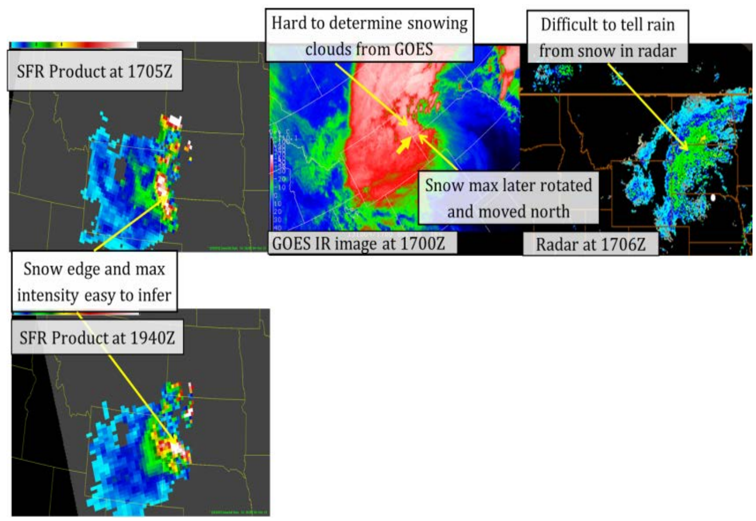


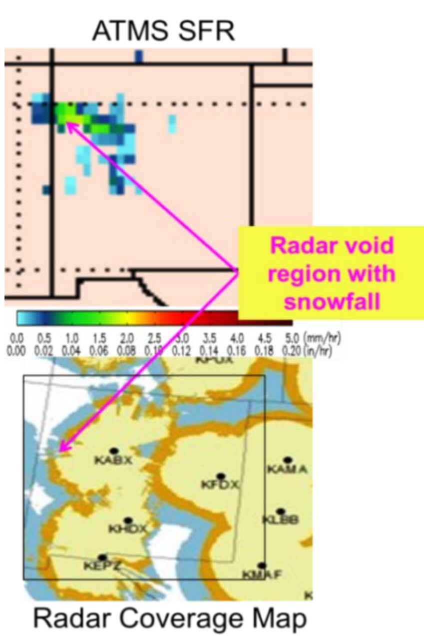
On the left is an example which demonstrates the significance of this application. The interior of Alaska mostly experiences light snowfall during winter. It is a challenge for satellite based algorithms to detect this type of snowfall, in part because of the weak snowfall signals. However, the ATMS SFR algorithm was able to capture the very light snowfall in the case shown. Snowfall in the majority of the detected area was confirmed by ground observations (red stars).

Application in Weather Forecasting

The SFR product provides a unique, space-based perspective on the locations of frozen precipitation that can be used to easily identify the extent of a snowstorm and the location of the most intense snowfall. These two features might not be readily apparent from traditional IR or VIS satellite imagery or radar.

The SFR product provides quantitative snowfall information to complement snowfall observations or estimations from other sources such as stations, radar, and GOES imagery. Radar, for example, is of limited use due to beam blockage in higher elevations, and the inherent difficulty to distinguish between rain and snow in some regions. In the image on the right, the movement and strength of a feature identified in SFR can be inferred or tracked using radar or GOES imagery between SFR overpasses. The SFR adds additional information to radar and GOES data.



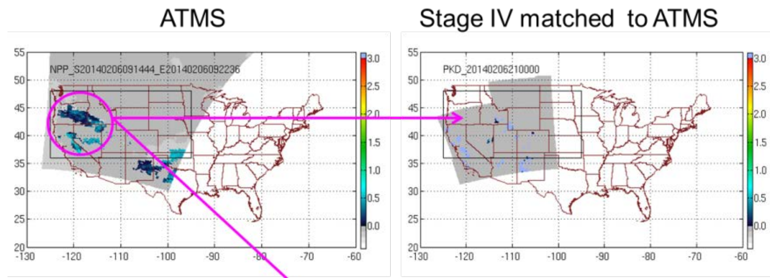


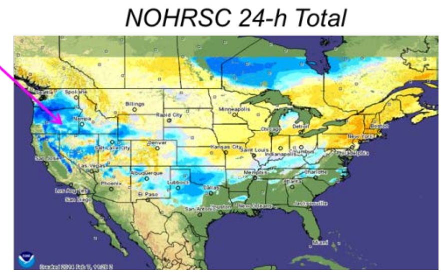
On January 14, 2015, the SFR product was used by the Albuquerque (ABQ) WFO in an area with very limited radar coverage. Feedback from a forecaster at the WFO indicated that the 919UTC image (left) matched the NAM12 QPF forecast very well within this data sparse region.

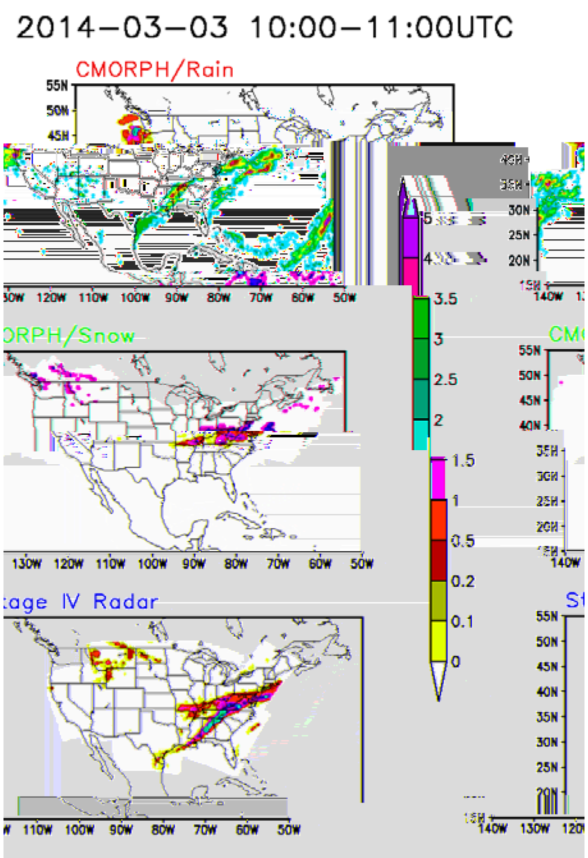
In an additional statement, the forecaster stated *"from this information I was able to determine the NAM forecast was too slow with the evolution of the precipitation. The radar values dropped off away from the KABX radar which is expected, whereas the SFR product increased in the area of heaviest snowfall. Rates were close to the observed value at KGUP."*

In addition, the New Mexico Department of Transportation (DOT) web page indicated difficult driving conditions within this region.

The example on the right compares ATMS snowfall rate with Stage IV (radar and gauge combined precipitation analysis) on Feb 6, 2014. Stage IV missed most snowfall occurrences over the Pacific Northwest due to poor radar coverage, while the snowfall captured by ATMS SFR fell within the snow areas indicated by the National Operational Hydrologic Remote Sensing Center (NOHRSC) 24-hour snow accumulation data. The latter is a product generated from a snow data assimilation model.







Other Hydrology Applications

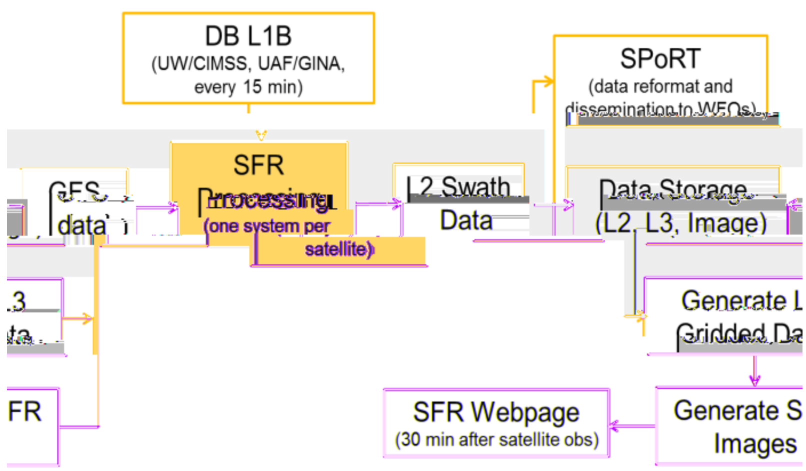
The SFR has enabled scientists from NOAA's Climate Prediction Center (CPC) to develop an integrated snowfall rate analysis under the CMORPH framework. The figure on the left is an application example of an improved snowfall representation from the new CMORPH.

On March 3, 2014, a powerful snow storm hit the U.S. East Coast with freezing rain, snow and frigid temperatures. Most computer models foresaw a widespread heavy-snow event, and this storm did not disappoint them. While the old CMORPH captured the event, the results it generated, which are illustrated in the figure on the right, pointed out some deficiencies within the system. The top image shows the traditional CMORPH, which picked up the rainfall in the warm part of the system but missed the snowfall. The middle image shows the improved product, CMORPH/Snow, which captured the snow in the cold part of the system. The bottom radar image illustrates two bands of precipitation (rain/snow) associated with the warm and cold part of the frontal system. By combining the traditional CMORPH, with the improved product, they produce an excellent match with radar.

The utility of the SFR was also demonstrated on January 27, 2015, when a massive snow storm pounded through some areas of the Northeast. The epic blizzard heaped snow over New England where accumulations in some areas reached, or exceeded, two feet. On the lower left is a screenshot from the NASA SPoRT website, which captures the visualization of the imagery from the ATMS SFR product in the format seen in the NWS next generation operational decision support platform, Advanced Weather Interactive Processing System (AWIPS II). The image depicts heavy snow over most of the New England states. From the image NOAA forecasters were also able to infer that the heaviest snowfall at the time was centered over southeastern Connecticut with rates from 1-1.5 inches of solid snow per hour, which was consistent with observed values.

Product Assessment

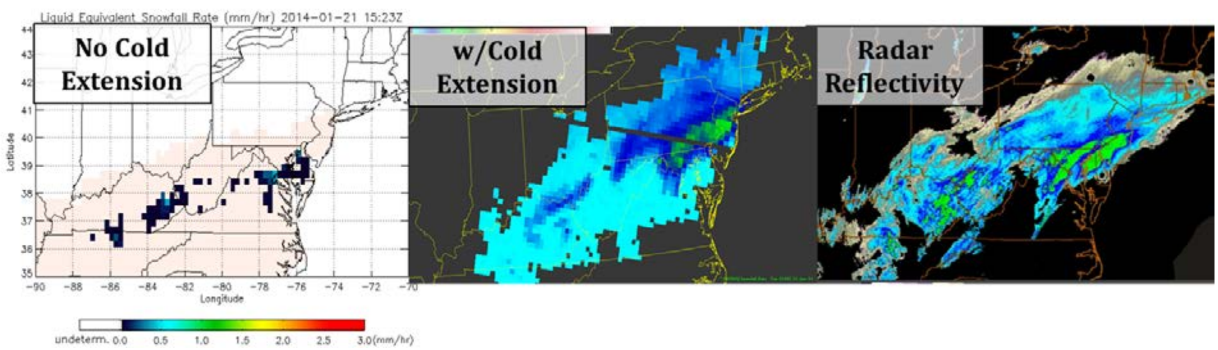
Assessments of the ATMS SFR, along with the AMSU/MHS SFR, are being performed in operational environments at several NWS Weather Forecast Offices (WFOs). These assessments are led by NASA's Short-term Prediction Research and Transition (SPoRT) project, and performed in collaboration with NOAA and the Cooperative Institute of Climate and Satellites (CICS) at the University of Maryland. SPoRT focuses on the transition of unique NOAA and NASA satellite observations and modeling capabilities to support short-term, regional weather forecasting. The NESDIS SFR project team also collaborated with SPoRT to develop SFR training materials and conduct teletraining (an approach that combines the use of the Internet and audio conferencing) sessions prior to the product evaluation period.



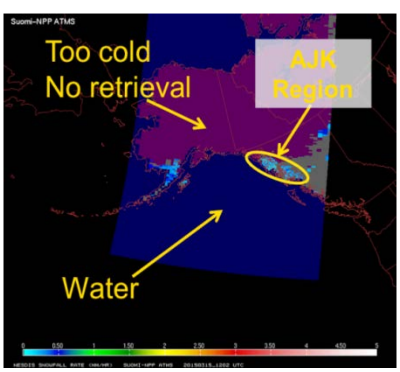
Feedback from a previous assessment of the AMSU/MHS SFR indicated that latency was a major factor limiting its application in operations. Consequently, the project team developed the capability to utilize Direct Broadcast (DB) data for the SFR assessment that took place this past winter. With DB, a satellite can 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 DB capabilities in real time. When compared to standard operational delivery options, DB of the data from the satellite to the user community provides a substantial reduction in latency. DB data is processed at the University of Wisconsin (UW) Cooperative Institute for Meteorological Satellite Studies (CIMSS) and University of Alaska Fairbanks (UAF) Geographic Information Network of Alaska (GINA). The SFR project team retrieves the DB data from CIMSS and GINA, generates the SFR product, and sends the SFR data to SPoRT for reformatting within 30 minutes of satellite observations. SPoRT then delivers the resulting imagery to the WFOs formatted for display in AWIPS / AWIPS II in their operations. The SFR developers also maintain a project webpage where SFR images are posted at near real-time.

Extension to Cold Regime

The Year 1 product assessment also revealed another factor that limited the product's application. It was the relatively high minimum temperature (22° F) that the algorithm can be applied. Forecasters from the Burlington, VT (BTV); Charleston, WV (RLX); and Sterling, VA (LWX) NWS WFOs identified the case below where radar (right) showed a large swath of snow, but SFR (left) showed very little snow due to colder temperatures. As a result of the feedback, the project team developed a cold extension algorithm that lowered the minimum 2-meter temperature for SFR from about 22°F to about 7°F, and thereby drastically increases the probability of detection of snowfall in colder weather (usually light-moderate snowfall). The new snowfall detection algorithm also reduces false alarm rate through the use of a comprehensive training database. The advanced algorithm was implemented prior to the Year 2 assessment. The use of cold extension (middle) better matches both coverage and intensity compared to radar in the case below.



Inclusion of Ocean SFR



Due to limitations of available observations over water, the current SFR product is only retrieved over land. When utilizing the current SFR, The WFO in Juneau, AK (AJK) found that only a small path of data was available during snow events. This lack of data was attributed to 1) no SFR retrieval due to extremely cold temperatures along the mountains bordering the interior, and 2) no retrieval over ocean. Based upon this product feedback, a new version of the SFR product will include an ocean algorithm. This will be of particular benefit to coastal communities, especially communities in Alaska for snowfall systems coming from ocean, and the U.S. East Coast for the spiraling snow bands reaching land.

Addition of Liquid Water Emission into the RTM

Another limitation with the current SFR is the lack of super cooled liquid water in the radiative transfer model (RTM). Emission from super cooled liquid water masks the scattering effect of snow particles and might cause the product to miss snowfall or cause underestimation. The algorithm developers will improve the RTM by adding the effect from super cooled liquid water in the future.

Summary and Path Forward

Snowfall is an important weather element, yet it is challenging to measure accurately and consistently. Moreover, high-latitude regions, where snowfall plays such significant roles, are not adequately monitored by surface observations. It is also difficult to measure snowfall at high-latitudes with geostationary imagery due to the larger viewing angle of the instrument. Thus, data from NOAA's polar orbiting satellites play a vital role in providing timely observations for improved situational awareness, short-term forecasts, and warnings in these regions.

The SFR product, in particular, has helped NOAA forecasters track snow features in data sparse regions. It has also helped determine the edge and maxima of snowfall in large precipitation systems. Some improvement has been made to the initial ATMS SFR algorithm including a cold temperature extension and snowfall rate bias adjustment, which has significantly improved the quality of the product. Moreover, DB has enabled SPoRT to process data from polar-orbiting satellites including Suomi-NPP, and generate and deliver products such as the NESDIS SFR to the user community in near-real time.

Feedback obtained from a series of SPoRT-led assessments with operational forecasters at NWS WFOs, have provided valuable information on the product's strengths and limitations. Throughout these assessments the product has evolved iteratively. Based on recent feedback, several important efforts have been proposed to further improve the current SFR. These include the development of a new snowfall detection algorithm based on cloud top height as the current SFR misses snowfall due to low cloud top. The addition of an ocean SFR algorithm as the current SFR is a land only product, and the addition of emission from liquid water in the RTM to prevent SFR underestimations.

The SFR product has also evolved based on technological changes, including the transition from heritage sensors such as the AMSU on NOAA POES to ATMS on the next generation Suomi-NPP. With these changes forecasters can look forward to new sources of atmospheric observations, and further advances in weather forecast applications as well as the transition to next generation satellite systems including Suomi-NPP. For example, the ATMS sensor's wider swath width and additional channels in the water vapor band more than double the observations from the heritage AMSU-A and MHS sensors. Recent feedback from SPoRT assessments has already demonstrated that ATMS is performing better than AMSU. This will make the ATMS sensor, and ultimately the SFR product, an asset in weather forecasting and hydrological applications that will be relied upon to provide snowfall rate measurements to operational forecasters nationwide.

JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Environmental Satellites: Providing Critical Severe Weather Imagery on Your Nightly Weather Broadcasts

Joint JPSS/GOES-R Science Seminar

*This article is based in part on the **April 20, 2015** Joint JPSS and GOES-R science seminar presented by Dan Satterfield, Chief Meteorologist WBOC TV, Salisbury Md**.***

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

Dan Satterfield, Chief Meteorologist WBOC TV in Salisbury Maryland displays satellite imagery of smoke from Canadian wildfires. The smoke drifted into the central parts of the United States and as far south as southern Missouri, and spread all the way to the Atlantic Coast.

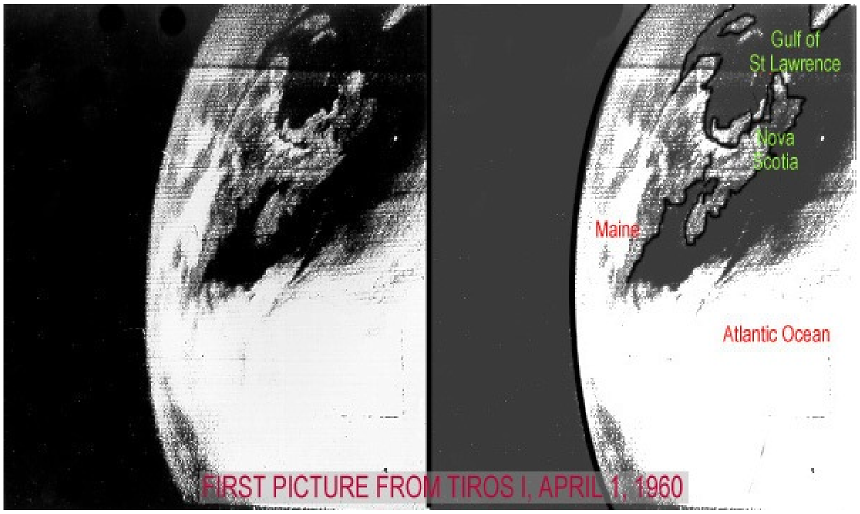
The United States experiences some of the most severe weather events across the globe. Extreme weather or climate events—such as hurricanes, flooding, heavy rain, blizzards, tornadoes, drought, and heat waves— can create life threatening conditions that may result in injury and loss of life, and also cause damage to infrastructure and property. According to NOAA's National Centers for Environmental Information[10] (NCEI) – the Nation's Scorekeeper in terms of addressing severe weather and climate events in their historical perspective – since 1980 the U.S. has endured 178 weather and climate disasters with billions of dollars in losses.

When it comes to reducing the risks associated with 'high-impact' weather events, an informed and educated public is essential. TV weathercasters are the front-line communicators of this information to the public. They provide supplementary observations, in-depth analysis and interpretation, which helps the general public understand not only the weather, but weather related impacts as well. Providing an accurate forecast in advance of a severe weather event is 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 and disseminate the information in a timely manner.

TV weathercasters use several different tools to help them predict future weather conditions and phenomena. One of the most common tools is the weather radar. The Doppler radar has become a staple of the nightly broadcast and many local stations provide radar imagery on their websites and cell phone apps. The public have become comfortable interpreting radar returns with its frequent updates and intuitive display of severe weather. On the converse, the use of weather satellite imagery – a key tool used to convey information on current and future weather

[10] Formerly the National Climatic Data Center (NCDC)

conditions and phenomena – in nightly broadcasts is much less frequent. Earth observation satellites provide a large-scale view of precipitation, but, unlike radar, which can show severe weather signatures and precipitation intensity, satellite imagery requires interpretation skills beyond those of the average viewer. However, this is offset by the ability of satellites to continuously take measurements of the planet's dynamic environment over large areas such as oceans and remote desolate places like Antarctica, where very few conventional observations exist. This allows the viewer to peer into these remote and exotic places. Global satellite observations account for more than 90 percent of the input to the nation's three-to-seven-day weather forecasting models making them critical to the forecasters that provide the nightly weather broadcasts, yet this value is often not readily apparent to the viewers.



First picture from Space - TIROS I satellite, April 1, 1960
Image credit: NOAASIS home page http://noaasis.noaa.gov/NOAASIS/gif/photo1.jpg

The Early Use of Satellite Imagery

April 1, 1960, marked a new dawn in the meteorological world. With its launch, on this day, the first polar-orbiting weather satellite, Television and Infrared Observation Satellite (TIROS 1), introduced a way to view weather systems and clouds from outer space, as shown on the left. TIROS 1 could only operate in daylight, hence coverage was not continuous. Nonetheless, it produced pictures, albeit grainy, of clouds and storms around the globe that might have otherwise gone undetected for days using conventional observation methods.

Despite this early success, satellite imagery still appears sporadically in weathercasts. With the introduction of computer graphics in the 1980's, it was possible to remap the black and white satellite imagery over the color backgrounds. However, this was done at a lower resolution. Moreover, this remapping was poorly done with both visible and infrared (IR). Often the IR remap on cold mornings showed clouds when it was clear and the ground just cold! This could be one explanation behind the slow adoption of satellite data by broadcast television.

It wasn't until the past couple of years that broadcasters could automatically get satellite imagery at the full resolution available (at least from geostationary satellite data). Still, satellite imagery is not updated at the same frequency as radar data, and in general can be more complex to explain than the radar data that viewers have become accustomed. Even though some weathercasters are getting raw data directly from polar-orbiting satellites, and showing it on air, the process requires considerable time and effort to facilitate. Despite this, some broadcast stations are jumping at the opportunity to task and interpret the arsenal of data from Earth-observing satellites, and incorporating it into their weathercasts. The satellite data has enabled the stations to deliver to their viewers' particularly powerful information, which reveals both comprehensive visualizations and surprising details of weather phenomenon occurring across various spatial scales. One station that utilizes a broad range of satellite imagery in its weathercasts is WBOC TV in Salisbury Maryland. The station's Chief Meteorologist, Dan Satterfield, incorporates imagery from various satellite sensors into his forecasts to provide his local viewers with glimpses of weather phenomenon occurring in their immediate location and across the globe.

Data from polar-orbiting satellites, including the Suomi National Polar-orbiting Partnership (Suomi-NPP) and NASA's Terra and Aqua satellites is not automatically downloaded into the graphic systems of television broadcast stations. Most weathercasters retrieve this data manually. In addition, they have to convert this data into graphics for their weathercast. During severe weather situations (when this is most useful), and especially during live telecasts, they cannot pause to manually download data. To get weathercasts to the public expeditiously, TV weathercasters need to upload, access and review content fast. Processing the high resolution satellite imagery is a very time consuming effort, which makes it a less attractive option to radar. As time constraints play a huge role in on-air presentations, using satellite imagery happens only when time allows.

Finally, even though satellite imagery is widely available, the TV broadcast community is not as motivated to use it because of several factors; among them is a lack of training. Interpreting satellite imagery is a highly specialized skill that requires training, and even though weathercasters experience high levels of audience credibility, they are not necessarily well-trained and well-informed experts. Also, weathercasts now tend to be hyperlocal, thus TV stations are more focused on providing weather content that is tied to a specific geographical location. Earth-observing satellites such as Suomi-NPP have shrunk the Earth into a global village, and are providing data that enables TV stations to expand their audiences to new continents. But, as most imagery from older generation satellites such as GOES[11] have coarse spatial resolutions, this gives them limited utility. However, with vastly improved spatial resolutions from Suomi-NPP/JPSS[12] and future GOES-R, weathercasters will be able to employ this data more effectively. Moreover, as JPSS has the advantage of global coverage, opportunity exists for weathercasters to showcase environmental and weather events across the world.

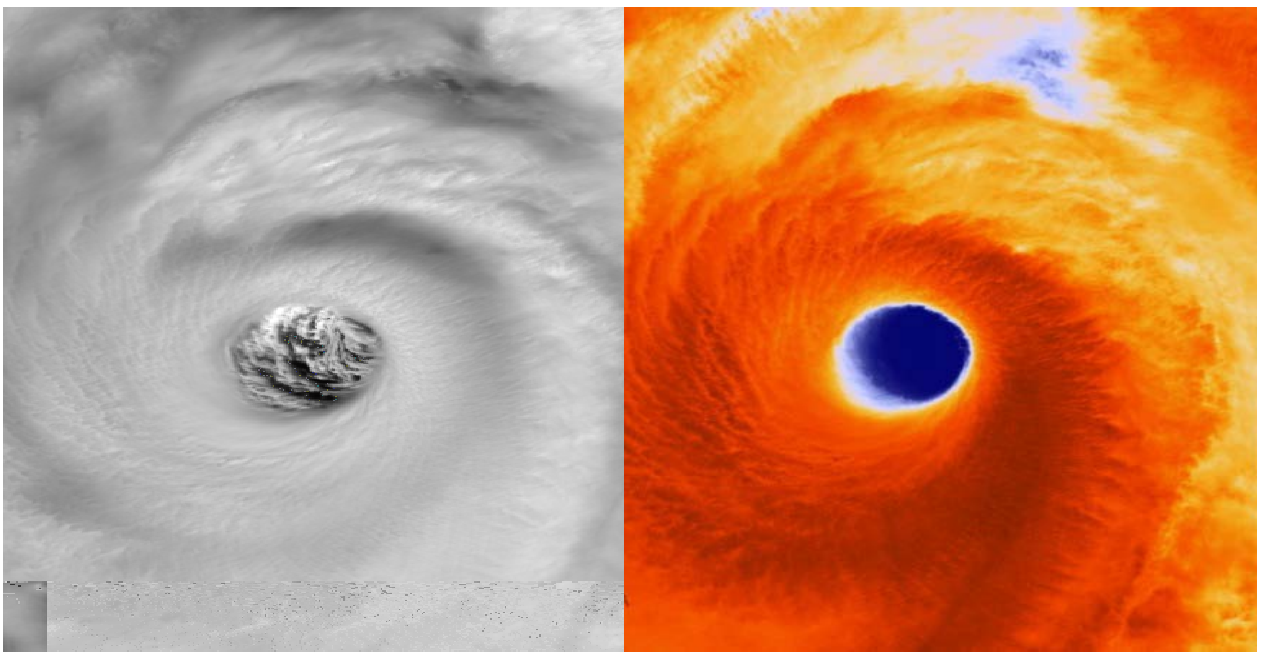
Environmental Satellites' New Capabilities Turn the Tide

Today's Earth observing satellites are larger and far more advanced. With far finer spectral and spatial resolutions and more frequent measurements, they provide forecasters with extremely detailed images and other useful information about the Earth and its surrounding environment. Broadcasters now have access to imagery from both Geostationary and Polar-orbiting Satellites. At approximately 36, 000 km over the earth, geostationary satellites orbit over the same equatorial surface location at the same rate that the Earth rotates. This allows them to always view the same portion of the globe. Most of the satellite images appearing on TV

[11] Geostationary Operational Environmental Satellite
[12] Joint Polar Satellite System

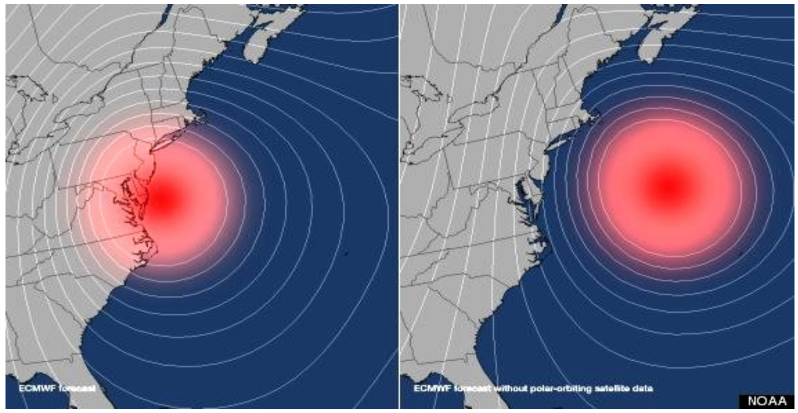
weathercasts are obtained from geostationary satellites. Their “stationary” orbit allows them to provide a constant watch for atmospheric "triggers" for severe weather conditions such as tornadoes, flash floods, and hurricanes. Polar-orbiting satellites, on the other hand, circle the Earth from the North to the South Pole and back. They are located much nearer to the surface (some as low as 800 km) and provide highly detailed, close-up images of weather systems all over the world.

When it launched on October 28, 2011, Suomi-NPP was heralded as the link between NOAA’s legacy polar satellite fleet, NASA’s Earth observing missions and the next-generation JPSS. The sensors on Suomi-NPP deliver critical environmental data to key users including NOAA's National Weather Service (NWS) and others around the world. For example, in October 2014, NOAA satellites charted the movement of the powerful Super Typhoon Vongfong across the western Pacific Ocean. The Visible and Infrared Imaging and Radiometer Suite (VIIRS) sensor on the Suomi-NPP satellite captured the eye of Super Typhoon as it moved north towards Japan. Below on the left is a high resolution visible image and the right is a colorized infrared image. Using VIIRS, forecasters were able to estimate that the eye was approximately 50 miles wide.



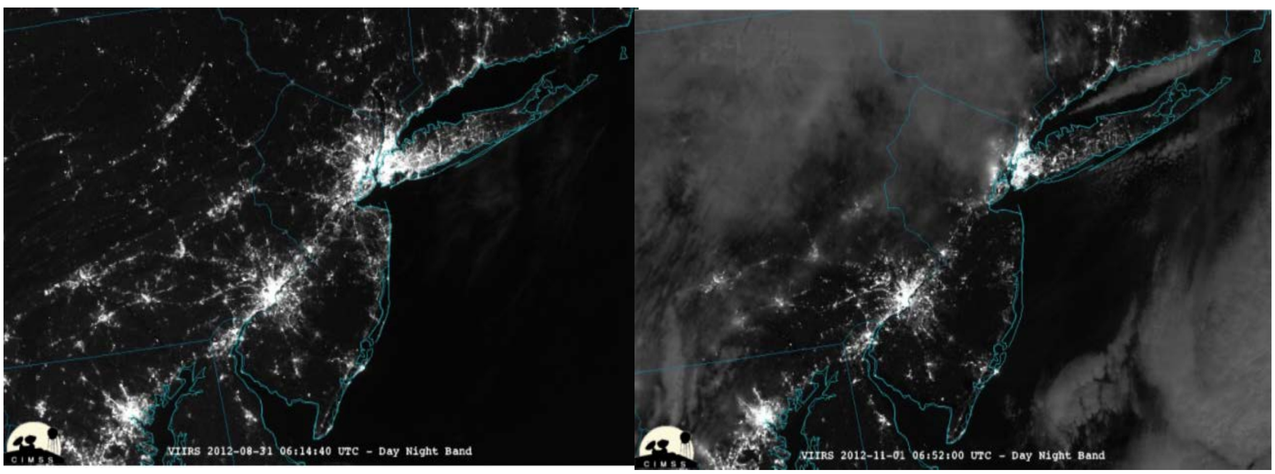
Since launch, data from Suomi-NPP have helped improve the NOAA National Weather Service’s (NWS) ability to accurately forecast severe weather events in the three-to-seven day window. Sandy, one of the worst storms to ever hit the East Coast, came through the mid-Atlantic, Northeast, and Ohio Valley regions in late October 2012. Sandy was an extreme event that had major societal impacts. It affected a wide swath of the Atlantic, including more than a dozen states in the US. Some neighborhoods in its path were completely decimated. Satellite loops of superstorm Sandy clearly illustrated the calamitous storm’s movement, and as a result were of extreme value to TV weathercasters in communicating this information to the public. The accurateness of its forecasted path was, from a technological perspective, notable.

Measurements from polar satellites enabled forecasters to predict Sandy's infamous "left hook." Without this data, weather models would not have identified this left-hand turn and forecasts would have placed the storm out to sea.



Hurricane Sandy's path with and without polar satellite data

Like TIROS 1, many of today's satellites look at the Earth during the day, when they can observe relatively bright objects – especially those illuminated by the sun. But the VIIRS day-night band (DNB) is equipped with advanced technology that extends the view of Earth's atmosphere and surface into the nighttime hours. The DNB is sensitive enough to detect lights as small as a single street lamp and even the nocturnal glow produced by the Earth's own atmosphere.



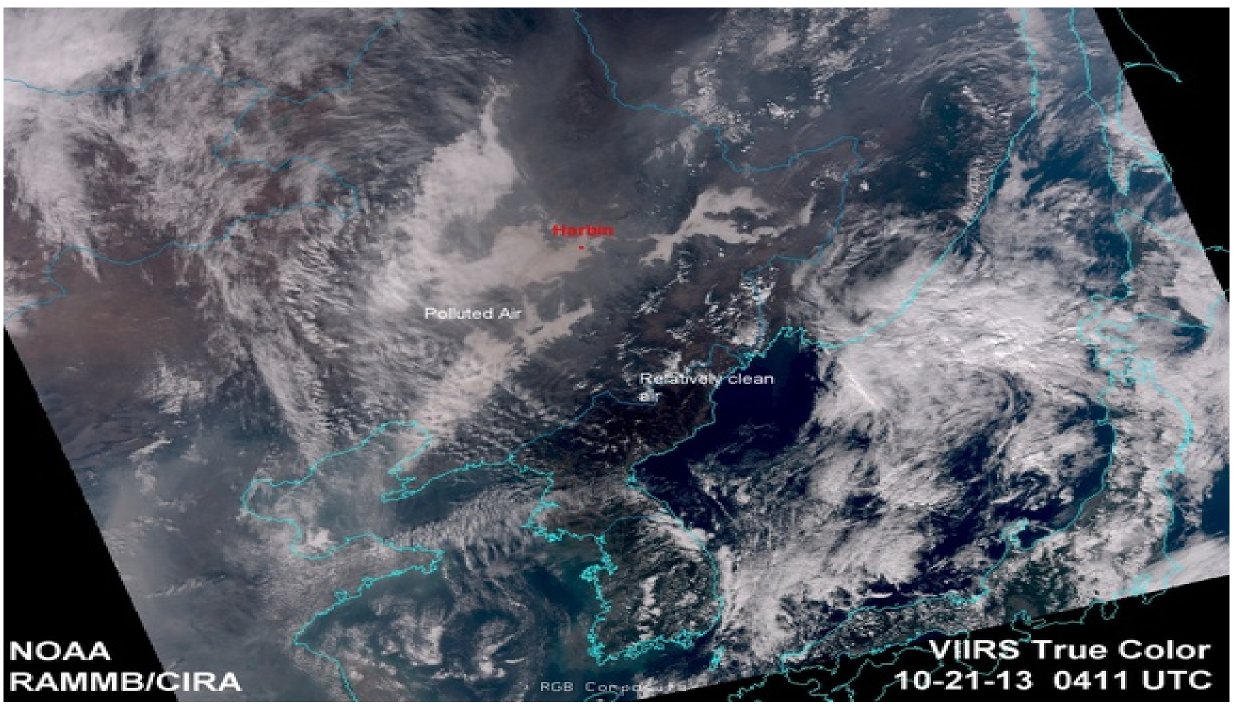
Suomi-NPP VIIRS 0.7 Âµm Day/Night Band images (pre-Sandy, and post-Sandy).
Image credits: Cooperative Institute for Meteorological Satellite Studies (CIMSS), Space Science and Engineering Center (SSEC), University of Wisconsin-Madison

The VIIRS DNB watched Sandy, illuminated by moonlight, as it made landfall over New Jersey on the evening of Oct. 29. Night time images (above right) showed the widespread power outages that left millions in darkness in the wake of the tremendous storm. Previously, storms like Sandy were observed primarily with infrared bands.

Every satellite image tells a story: Some Stories of the Earth from Suomi-NPP

Since launch, Suomi-NPP, has delivered spectacular views of the Earth, and provided critical weather data to forecasters. Suomi-NPP exemplifies the high resolution weather and climate monitoring that keeps us prepared for extreme weather events and other changes in the environment. Visionary weathercasters are realizing the ability to present high resolution satellite imagery to viewers. Hence, the trajectory of satellite imagery into more and more on-air presentations is heading upwards.

It is a challenge trying to understand the extent of extreme environmental events happening across the globe until you see it from space. In mid-October 2013, air-chocking smog blanketed one of northeastern China's largest cities. The sources of the smog were traced back to a spurt in the usage of coal-powered heating systems in Harbin - a city of more than 10 million people – due to chilly temperatures in northern China. The smog reduced visibility drastically – to less than 30 feet – which caused extremely unsafe travel conditions. In addition, as this was the end of the harvest season, farmers were burning their harvest debris in preparation for the next planting season. This brought the region's air pollution to toxic levels. Fine, airborne particulate matter (PM) that are smaller than 2.5 microns – small enough to penetrate deep into the lungs and enter the bloodstream – can be hazardous to human health. Most PM2.5 aerosol particles come from the burning of fossil fuels and of biomass (wood fires and agricultural burning). Critical measurements from Earth-observing environmental satellites helped draw worldwide attention to the air pollution events in China and the level of environmental degradation they caused.



Brown cloud of pollution over China
Image credit: NOAA/NASA

The image above showing polluted air over northeastern China was captured on Oct. 21 by Suomi-NPP VIIRS.

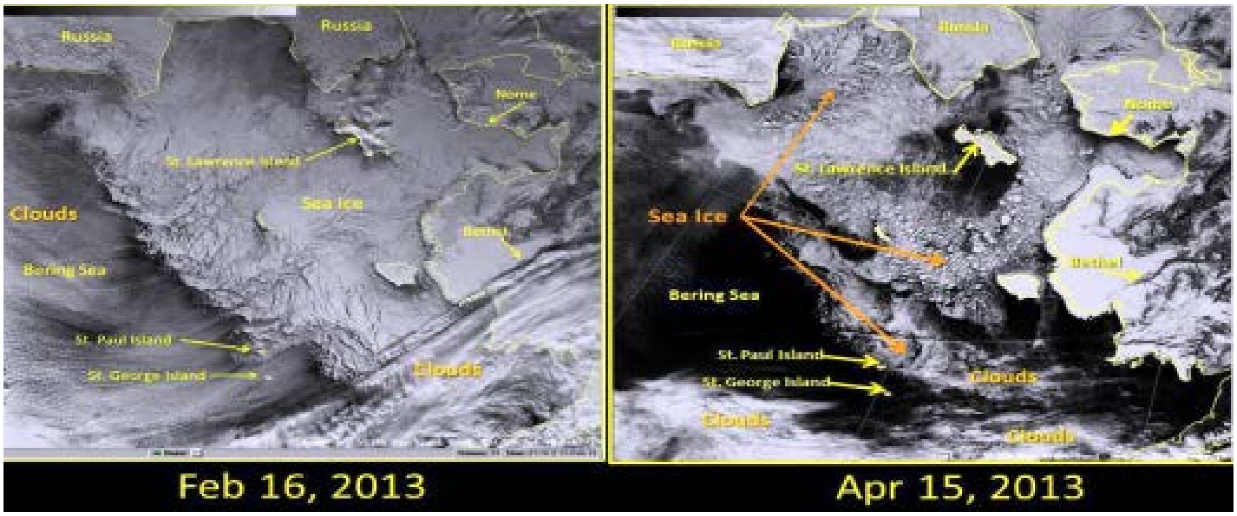
Other Polar-orbiting Capabilities that Could be Used on Weather Broadcasts

The darkest green areas are the lushest in vegetation, while the pale colors are sparse in vegetation cover due to snow, drought, rock or urban areas. Image credit: NOAA Visualization Lab

NOAA's environmental satellites carry instruments that consistently take measurements of the Earth's atmosphere, lands, and oceans. These instruments can detect changes in the Earth's vegetation, sea state, ocean color, and ice fields. Their observations, among other things, help to analyze coastal waters, monitor coral reefs, harmful algal blooms, fires, volcanic ash, the mountain snowpack that provides water to cities, help farmers assess soil conditions, and track tropical storms and hurricanes.

A year's worth of data from the VIIRS sensor was used to generate a series of vegetation maps depicting changes in vegetation over time. For decades, satellites have been generating data from which scientists have generated maps. However, these maps revealed that even though 75 percent of the Earth's surface is covered in water, twenty-five percent is covered in varying degrees of vegetation. In addition to showing detailed patterns of nature, the maps also revealed the visible fingerprints that humans have left on the surface. This information from these maps can be used to forecast events like wildfires and drought, and to make decisions on land use practices.

In maritime regions like Alaska, VIIRS imagery 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 (as shown in the images that follow) and reformation, and clear water passages. The DNB, in particular, adds additional aid to tracking ice flow and changes, allowing for nighttime observations in low-light conditions – particularly important as visible channels are virtually rendered unusable. The DNB uses dim light sources such as city lights and reflected moonlight. It can detect changes in clouds, snow cover, and sea ice overnight. Since Suomi-NPP 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.



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

Already in motion are several efforts aimed at enhancing the relevance of satellite data for on-air presentations and quality decision making. These efforts aim to ensure that NOAA's satellite data is made available as quickly and efficiently as possible. Particularly when decisions are being made or where the opportunity for influencing the outcomes is present. They include making high resolution satellite imagery more available to those who want it and those who need to use it. Huge losses are garnered when data cannot be translated due to lack of operational tools or the technical proficiency to leverage it. Thus vendors of satellite imagery must ensure that it is available to TV stations in on-air ready formats. Also, the data from these satellites cannot be relayed correctly in the absence of the necessary scientific knowledge, experience and technical skills. Hence, this necessitates adequate training and education. Therefore, TV stations must ensure that their weathercasters are adequately trained and educated as they are frontline communicators of weather phenomenon, and especially "high-impact" weather events.

The Future

Imagery from Earth-observing satellites have created a wealth of new information about our planet and its dynamic environment, and driven forward our understanding of Earth-system processes. The world's first weather satellite, TIROS 1, produced thousands of pictures of cloud patterns forming and moving across the Earth. This satellite made it possible to foresee and prepare for potential disasters before they arrived. Today's Earth-observing satellites are far more advanced. With far much finer spectral and spatial resolutions and more frequent measurements, the satellites, including NOAA's Suomi-NPP, carry an array of exquisitely sophisticated sensors and continue to reveal what would otherwise be hidden from our view. For example, Earth-observing satellites including Suomi-NPP gave insight to a complex set of atmospheric interactions that would be absolutely invisible to us – like warm water streaming past the coast of Africa and triggering the catastrophic Superstorm Sandy half a world away, on the Atlantic coast of the United States. Data from Suomi-NPP played a key role in protecting homes, businesses, and saving lives. Data from NOAA satellites helped forecast Sandy days in advance, which also allowed TV weathercasters to alert the public in advance. With the future GOES-R there will be significant improvements including faster imaging (with more geographical areas scanned), and higher spatial resolution. The Imager will have sixteen spectral bands, compared to five on the current GOES Imager, and will provide full disk images up to every 5 minutes, and as often as 1 minute to regional areas. In addition, the resolution will improve from 4 to 2 km for the infrared bands and 1 to 0.5 km for the 0.64 micrometer visible band, and there will the first ever geostationary lightning mapper. These new capabilities will open the door for more satellite data being shown by weathercasters.

With today's technology there is a growing spectrum of options for accessing relevant weather content, including the internet, commercial TV and radio, and the NOAA Weather Radio. However, TV remains the primary source of delivering warning information for a majority of the population. TV weathercasters add value to weather warnings by explaining impending threats with visualizations from radar and satellite imagery. TV stations need to take the next evolutionary step and take full advantage of the images from space. Moreover, there's no better vehicle than satellite imagery for showing the Earth and its environment about what's' happening on a day to day basis. As vendors of satellite imagery make them more compatible with the formats used in broadcast media, and accelerate the delivery of this imagery, more TV stations are bound to integrate them into their weathercasts. Expectedly, public awareness on this valuable source of weather content and the demand for these satellite capabilities is bound to increase. And, as more viewers become familiar with satellite imagery of cities, highways or fishing boats lit by the moon, one could expect that the demand for satellite data on the nightly news will increase as well.

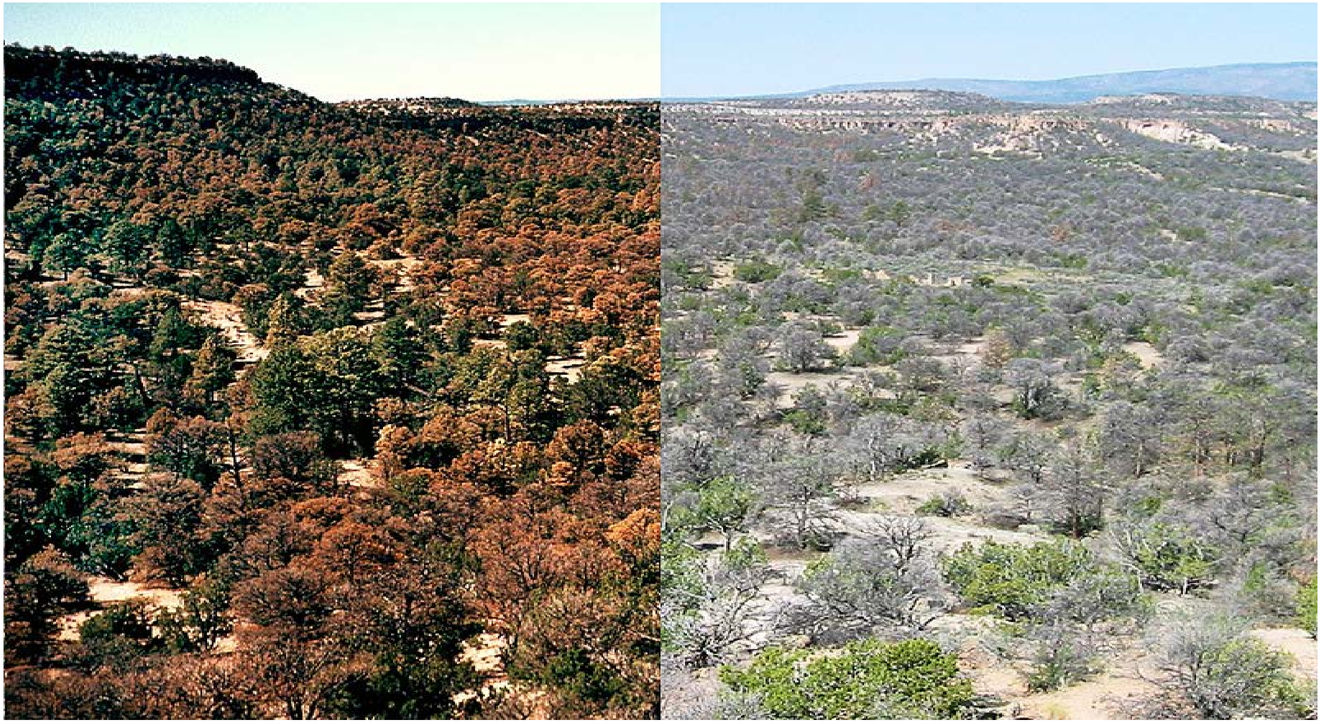
JPSS USER PERSPECTIVE

What the users are telling us about JPSS

Satellite-Derived Vegetation Health Indices: Powerful Tools for Monitoring and Predicting the Ebb and Flow of Drought and Vector-borne Diseases

This article is based in part on the ***May 18, 2015*** *JPSS science seminar presented by Felix Kogan, Physical Scientist, NOAA/NESDIS/Center for Satellite Applications and Research..*

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



Pinyon pine forests near Los Alamos, N.M., had already begun to turn brown from drought stress in the image at left, in 2002, and another photo taken in 2004 from the same vantage point, at right, show them largely grey and dead. (Photo by Craig Allen, U.S. Geological Survey)

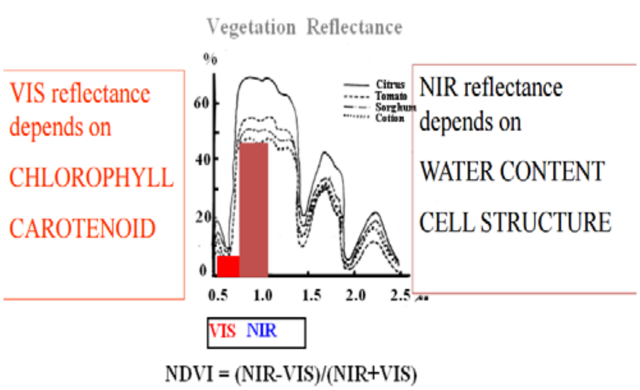
Vegetation covers a considerable portion of the planet, and is one of the most important components of the global ecosystem. It plays a vital role in global energy balances and climate modulations. Changes in vegetation can reflect the impact of the earth's most critical biogeochemical cycles, e.g., water, carbon, and nitrogen. Satellite observations and studies of these variations in vegetation have led to a better understanding of their importance and impact on our health, the economy, and on many aspects of the environment. Several factors can affect the condition of vegetation in a specific area. These range from land degradation through processes like desertification and deforestation, extreme weather, accelerated population growth, decelerated food production, imbalances between food supply and demand, and the declining stock of natural resources like water and land.

Satellite remote sensing provides excellent capabilities to map vegetation at different spatial scales that span from local to global. Vegetation Health Index (VHI) maps derived from Earth-observation satellites, such as the Suomi-National Polar-orbiting Partnership (Suomi-NPP), provide valuable insight into the dynamics of vegetation across different spatial scales. They are prominently used in drought monitoring and agricultural activities, and more recently, to monitor environmental conditions that may correspond to the spread of disease vectors and subsequently diseases caused by host-pathogen systems. Because vegetation greatly affects the runoff, surface temperature, and relative humidity of an area, NOAA scientists are beginning to integrate vegetation dynamics into numerical models for part of their weather forecasting applications.

Measuring Vegetation Health

Measuring the health of global vegetation prior to satellites was a challenge. Even countries with thriving farming and forestry industries were limited to ground based reporting from adhoc groups of farmers, ranchers, and foresters belonging to regional organizations. Periodic ground and airborne studies sponsored by governments, universities and research institutes would provide finer vegetative details, but these studies could not be counted on as a permanent source of data to track changing patterns. In remote and poorer areas of the world, large regions were defined by simple vegetation classifications with only infrequent updates coming from government or research surveys. The advent of the satellite era changed all that. Scientists began using satellite remote sensors to measure and map the Earth's vegetation to help document changes in vegetation and understand how they affect the environment. Since 1981, NOAA has charted the world's vegetation using data from the Advanced Very High Resolution Radiometer (AVHRR), onboard its legacy polar-orbiting satellites. Using satellite observations of vegetation greenness and temperature, NOAA scientists have developed vegetation health (VH) method and products, including weekly global Vegetation Health Index (VHI) maps at resolutions ranging from 500 meters to 4 kilometers (km). These maps have been used to characterize vegetation, which is useful for monitoring changes in its cover, composition, and structure due to natural or anthropogenic event. The maps have also been used to keep inventory of the current stock of vegetation, and set conservation and management goals.

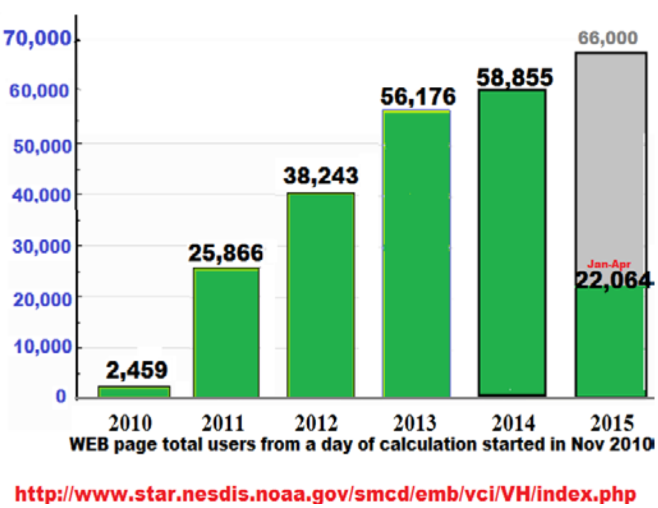
Remote sensing of VH is based on the properties of green vegetation to reflect and emit solar radiation. It characterizes plant health based on measurements of the sunlight (VIS) and near infrared radiation (NIR) reflected, and the infrared radiation (IR) emitted, by the vegetation canopy. In drought-free years, green and vigorous vegetation reflects little radiation in the visible (VIS) part of solar spectrum (due to high solar light absorption by chlorophyll) and much in the near infrared (NIR) part (due to specificity of scattering the light by leaf internal tissues and water content impact). Following these properties, the difference between NIR and VIS becomes large, indicating that vegetation is very green and vigorous. In dry years, the vegetation canopy overheats and loses vigor (due to a reduction in chlorophyll and water content). This intensifies the negative effects of the low moisture levels and slows vegetation development, reducing productivity. Satellite data of temperature and the NDVI are often used together to estimate vegetation health. NDVI shows vegetation distribution and weather impact while Brightness Temperature (BT) from the thermal infrared shows how hot the surface is. The VHI is based on a combination of Vegetation Condition Index (VCI) and Temperature Condition Index (TCI). VCI is based on the Normalized Difference Vegetation Index (NDVI = (NIR-VIS)/(NIR+VIS)), and is a proxy for moisture condition. TCI is based on the difference between the 10 and 11 micron thermal infrared window channels and is a proxy for thermal condition.



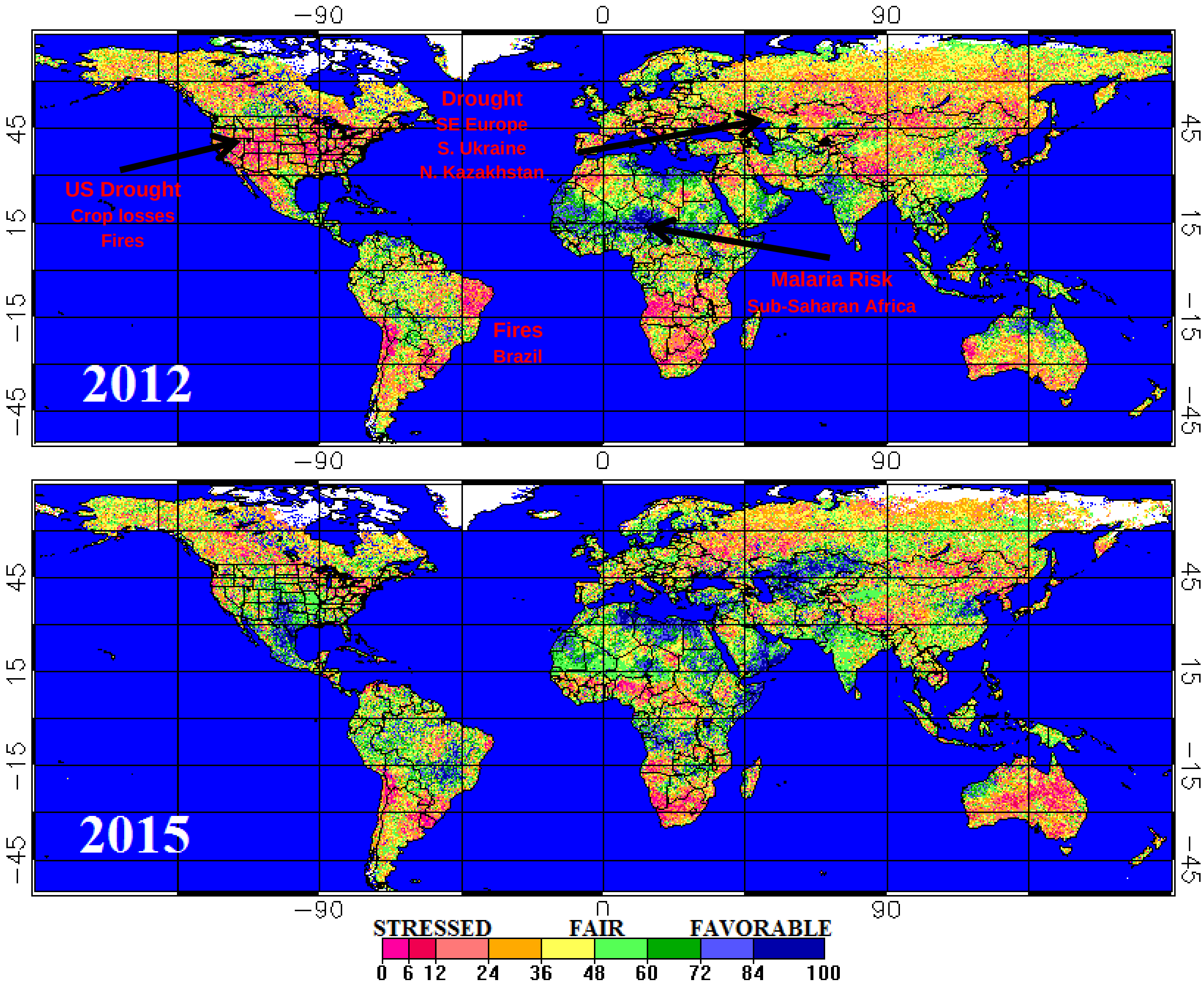
Data Continuity with NOAA's New Eye in the Sky: VIIRS

Noise reduced NDVI derived from AVHRR (left, 4km resolution) and VIIRS (right, 500m resolution).

The year 2011 ushered in Suomi-NPP, the first next generation polar-orbiter in the series of Joint Polar Satellite System (JPSS) satellites. Since its launch the role of satellite observations for climate and land services have increased considerably, and are expected to continue for the next two decades with future launches of the JPSS satellites. The Visible-Infrared Imaging Radiometer Suite (VIIRS) sensor on Suomi-NPP is used to monitor the Earth's surface and its surrounding environment. VIIRS accommodates the best technical and scientific features of its predecessors, NOAA/AVHRR and the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites. AVHRR has provided observations for over three and a half decades, while MODIS has provided observations for nearly 15 years. VIIRS has new capabilities which include a swath that is 1.3 times wider than that of its operational predecessors, sharper view of the swath edge, excellent radiometric features, faster data processing and availability, higher resolution of 375m at nadir, more satellite channels across the spectrum, and new products and services. With these new capabilities VIIRS is able to provide vegetation health data, with eight times more detail, and at a much higher and more consistent quality. In addition, VIIRS will provide multi-year services vital for land cover and climate change detection.



NOAA's VH products can be used in a wide range of applications including the advanced prediction of crop losses, monitoring vegetation health, drought, soil saturation, moisture and thermal conditions, fire risk, greenness of vegetation cover, vegetation fraction, leave area index, desertification, mosquito-borne diseases, invasive species, ecological resources, land degradation, and so forth. Since 2010, the Center of Satellite Applications and Research (STAR) has seen a continual increase in the number of visitors to the website.



During droughts, satellites can detect decreases in vegetation greenness and hotter temperature. These changes are depicted by the dark red color, in the image above, which signifies extreme stress due to dry and hot conditions.

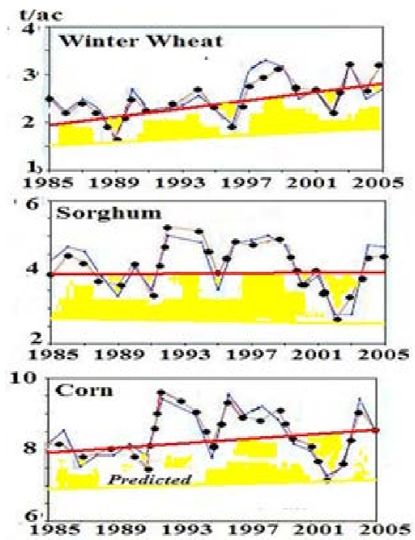
The maps above, derived from VIIRS data, show Global Vegetation Health (sampled from 375 m to 16 km pixel size for global display) for June 4, 2012 and 2015. The maps display color-coded vegetation health data (ranging from 0 to 100 with values above 50 indicating fair conditions and below 40 indicating vegetation stress or drought). They show that vegetation conditions in 2015, in the U.S. and especially in the Great Plains, are much better than they were over the same period in 2012. Similarly, vegetation health conditions in Europe, Russia, Ukraine, Kazakhstan, China and India are better in 2015 than in 2012. For Sub-Saharan Africa, the 2015 map shows vegetation stress, which indicates potential drought in the region. Drought conditions could lead to widespread crop losses, and water and food shortages in the region.

In addition to providing information on drought, these maps can also be used to predict where some mosquito-borne diseases are most likely to occur. For example VHI maps have shown great promise in estimating malaria well in advance thus allowing for preventive measures to be taken. More details are presented in a subsequent section.

Vegetation Health Applications

The availability of detailed seasonal Vegetation Health products has opened the door for their use in a wide variety of applications. These include VHI maps that cover all the continents except Arctic and Antarctica, and are used for weather and ecological forecasting, identifying areas of drought, determining fire risk regions, estimating production and losses in agriculture, evaluating policies on best practices for land use, and studying human health epidemics. For example NOAA's VHI maps, characterize changes in vegetation, and have been used successfully to provide early warnings for outbreaks of drought, hazardous fire conditions, and even malaria break-outs in Sub-Saharan Africa.

Using satellite data to assess crop yields in Kansas

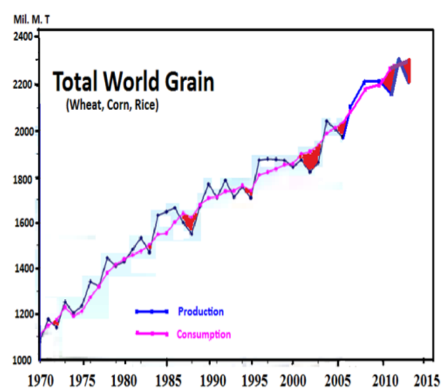


Observed & Predicted Yield, USA, Kansas

Kansas is an important agricultural state, with a leading role in the nation's agricultural economy. Kansas is the nation's top wheat grower, and also a leading producer of sorghum and corn. The state's wheat harvests account for 24 percent of the nation's total value of crop production. This is followed closely by sorghum at 39 percent. Scientists used VH data to look at the state's crop yield losses that were associated with weather events. The scientists computed data from the AVHRR sensor, obtained over a 21-year period (1985–2005). Over this period, a strong correlation was found between crop yield and VH indices. In addition, modeling and independent testing showed that the yield of all three crops can be effectively predicted from the indices 2–4 months before harvest, giving farmers and others in the industry the opportunity to use this information to make more efficient crop management and market decisions.

The Value of Vegetation Health to Drought Monitoring

Unlike other weather disasters, the start of a drought normally goes unnoticed. This is because drought is not an abrupt and dramatic event, but rather a slow evolving phenomenon whose impacts may not be immediately apparent.



World grain production and consumption (1970 to 2014)

According to the United Nations (UN) Food and Agriculture Organization (FAO), exclusive of meat, 15 crop plants provide 90 percent of the world's food energy intake, with rice, corn and wheat comprising two-thirds of human food consumption. The three are the staples of over 4 billion people[13]. If staple crops are threatened by drought, pests or nutrient-poor soils, hunger and poverty can rise dramatically. The chart on the right shows

[13] United Nations Food and Agriculture Organization: Agriculture and Consumer Protection. "Dimensions of Need - Staples: What do people eat?" Accessed 05-22-15 from http://www.fao.org/docrep/U8480E/U8480E07.htm#Staple foods What do people eat.

that, since 1970, grain production generally kept pace with consumption.

Droughts

2013: Argentina, Brazil, Australia, USA
2012: USA
2011: USA
2010: Russia, Ukraine, Kazakhstan, Argentina
2007: Australia, China, Argentina, Brazil
2003: USA, Europe, Australia, India, China
1996: USA, Russia, Argentina, Kazakhstan Australia
1988: USA

However, the periods in which grain production fell below consumption levels also coincided with periods of drought (shown left). Drought can lead to a reduction in agricultural production levels. When these levels fall below consumption levels, this can lead into food shortages.

According to the National Centers for Environmental Information's (NCEI) – formerly the National Climatic Data Center (NCDC) "U.S. Billion-dollar Weather and Climate Disasters[14]," economic losses from drought account for almost 24 percent of all losses from major weather events, including severe storms, wildfires, floods, and tropical cyclones. Across the globe, droughts have been known to result in food shortages, famine, population displacement and even mortality. Unlike other weather disasters that are usually preceded by hours or days of advance notice and warning, the onset of drought often goes unnoticed. This is because drought is a slow evolving phenomenon whose impacts may not be immediately apparent. Conventional observations of drought conditions are sparse and not uniformly distributed. Moreover, they tend to be tedious, time consuming, and difficult. Satellites have unique advantages over conventional observations of drought, due to their ability to acquire information over large geographical areas, measure and analyze key features of droughts routinely with relatively high repetition rates, and increased spatial detail of vegetation conditions. Early detection and monitoring from environmental satellite sensors has presented the next great frontier in developing mitigation measures and assessing the impacts from drought. NOAA's VH method has been applied to Suomi-NPP/VIIRS data, and is now regularly used for drought watches and impact assessments.

In the summer of 2011, record breaking hot and dry conditions plagued the southern states of the U.S. That same year, the National Weather Service (NWS) declared "exceptional drought"

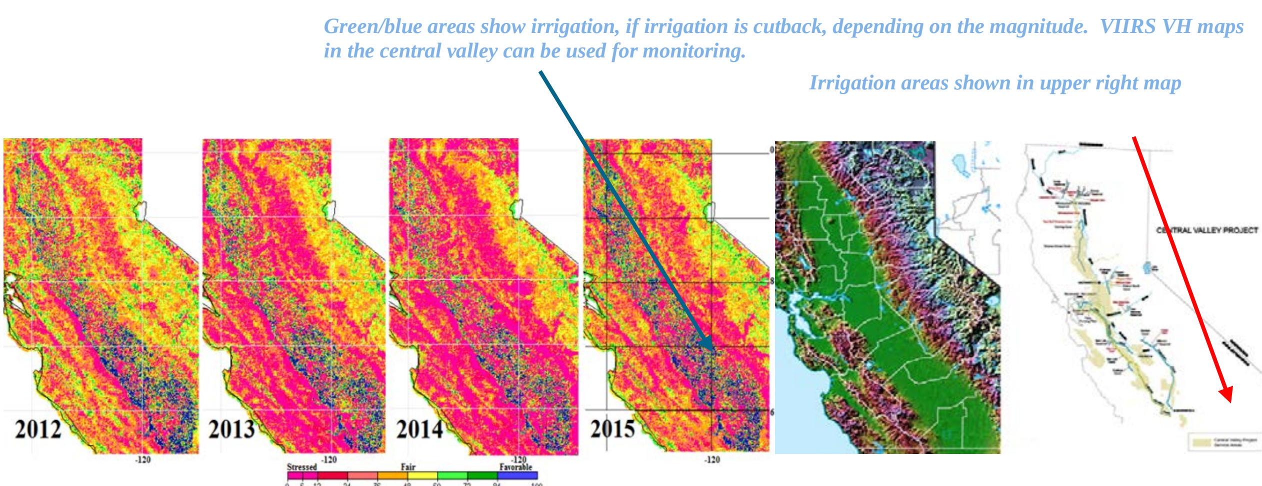
[14] Smith, A., and R. Katz, 2013: U.S. Billion-dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy and Biases. *Natural Hazards*. DOI: 10.1007/s11069-013-0566-5

from Arizona all the way to Georgia. The states of Texas, Oklahoma and New Mexico were particularly hit hard with crop and livestock losses estimated to be in excess of $7.62 billion. Additional losses came from wild fires, depletion of water in lakes and reservoirs, tourism, and deterioration of human health and the ways of living.

Prior to the 2011 and 2012 drought that impacted the U.S., in 2010 Russia experienced a very long and intensive drought, which occupied a huge area (the entire European Russia and western part of Russian Asia) and caused serious damages to the environment, economy and human health. Based on VH, this drought started in May and continued through November. A unique feature from this drought was intensive thermal stress, which started in April. This heat stress quickly dried up soil moisture resulting in deteriorating vegetation health. The drought was considered the worst since 1972, when a drought of similar intensity, duration and impact, covered the same spring and winter grain areas.

As the result of the 2010 drought, Russian grain production dropped to 75 million metric tons (compared to 97 in 2009). And, since it triggered very dry soil conditions over a huge area of winter wheat (occupying 65% of annual grain crops), the drought, which continued until November, also affected the 2011 harvest. Following this drought the Russian Government imposed an embargo on grain, which triggered a sharp increase in global wheat prices (the biggest since 1973). In addition to affecting grain harvest, drought triggered hundreds of fires accompanied by a very heavy and long-lasting smoke and heat waves, which affected human health and considerably enhanced the death rate in Russia.

Global VH maps are conveniently displayed with 4 and 16 km resolution pixels. For smaller regions the finest 500 m resolution pixels VH data are used. Below are VIIRS-based VHI maps indicating drought in California's Central Valley in early June 2012-2015. This drought was part of a 10-year mega drought that started in 2006 in the western USA, and intensified considerably during 2012-2014. This drought affected a significant part of Central Valley, which is the prime agricultural area of California. Vegetation in the Central Valley was under severe stress (magenta color). However, in some parts of the region, where irrigation is predominantly used, vegetation experienced more favorable conditions (green/blue color). If the drought continues



S-NPP/VIIRS-500m Vegetation health, June 12, USA, California, Central Valley

and water restrictions are enforced, NOAA's VH maps can be used to monitor any ensuing changes in the region's vegetation. The VHI data will also provide key information on vegetation conditions in the region and some estimation of potential losses in agricultural production.

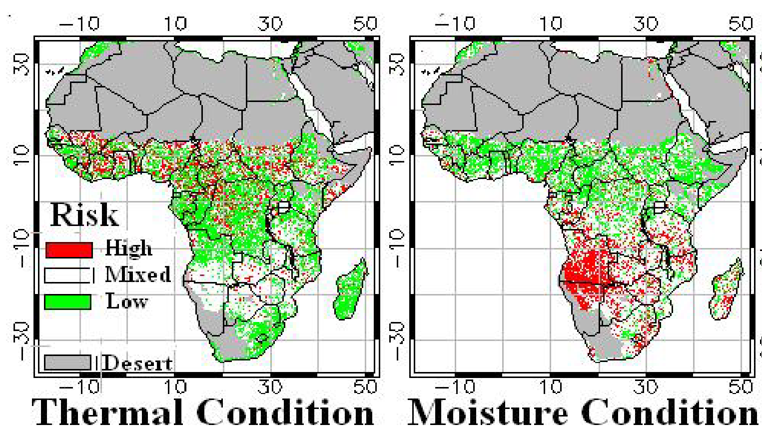
Predicting Where The Pathogens Are… From Space!

Satellite data can be used to identify good breeding conditions for disease-carrying mosquitoes
Photo Credit: James Gathany/ Centers for Disease Control (CDC) and Prevention's Public Health Image Library (PHIL). ID # 18761

NOAA's vegetation health data isn't limited to weather phenomenon. Its functionality allows for a wide array of applications. For example, NOAA scientists are using data from the VIIRS sensor to identify the conditions that signify the development of vector-borne diseases like malaria. The satellite data is computed weekly and converted to indices which are then used to map climatic conditions conducive to various vector-borne diseases at different spatial scales.

Malaria, a common infection in tropical and subtropical areas of the world, affects millions of people in sub-Saharan Africa – one of the most at-risk regions in the world, for these epidemics. According to a World Health Organization (WHO) malaria factsheet[15], in Africa, most deaths from malaria occur among children. According to the organization's estimates "a child dies from malaria every minute." Malaria is transmitted by an infective female Anopheles mosquito. Anopheles mosquitoes thrive in regions with warm temperatures, humid conditions, and high rainfall. Very hot temperatures and dry conditions are not conducive environments for these mosquitoes.

How does the VIIRS sensor see vectors, like mosquitoes from space? VIIRS doesn't see the pesky bugs, but, it detects certain conditions within their environment. As the maps reveal land surface conditions like temperature, moisture and greenness, which can signify the presence of these vectors, and help scientists establish the intensity and duration of malaria, and the areas affected. The data, which has helped scientists identify malaria approximately one-to-two months ahead of time, has shown promising results in assessing the risk of these vector-borne diseases. This increased lead time will allow for improved government response to deploy assets such as medicines and supplies. Malaria risk maps, such as the ones shown above right, identify priority areas and additional resource needed to fight epidemics effectively.



These maps are derived using VH data from NOAA satellites. They show weather conditions on August 26, 2008 for sub-Saharan Africa. The areas with prime conditions for intensive malaria are shown in red.

[15] Malaria: Fact sheet N°94. Available at: http://www.who.int/mediacentre/factsheets/fs094/en/

Summary

Since 1981 NOAA has used vegetation health indices from the satellite instruments in its polar orbit to measure and map the Earth's vegetation. These indexes have helped document variations in the Earth's vegetation to provide a better understanding of their effect on different aspects of the environment. The indexes have been used to monitor drought, the health of ecosystems, crops, detect forest fires, as well as for weather forecasting and climate research. The indexes which were generated using measurements from the AVHRR are now provided by the VIIRS from Suomi-NPP. They have helped map, monitor, and estimate a wide range of environmental parameters in fields that span the spectrum from meteorology to epidemiology. Successful applications include early drought detection and estimation of losses in crop and pasture production for winter wheat in the U.S., and the diagnoses of malaria risk in several regions of the world including Sub-Saharan Africa.

NOAA's AVHRR has the advantage of data that spans over three decades, which makes it ideal for comparisons over time. However, some advantages from NOAA's next generation satellite, Suomi-NPP, include more relevant and timely data, and a whole array of new measurements that may present the next great frontier for VH applications. The sphere of VIs is expected to widen as advancements in satellite technologies continue. This includes their use in non-weather applications such as public health and epidemiology, which have explored their pertinence and are currently demonstrating their utility in various field studies. The future JPSS VIIRS sensors will provide important continuity to the improved Suomi-NPP vegetative health products. We can anticipate that the applications of these products might open the door to even more innovative use of these satellite data to aid the global community's use of its scarce land resources.

Resources

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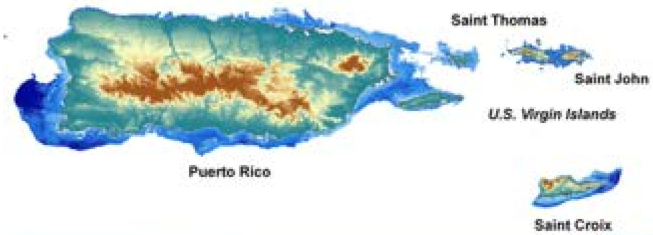
The OCONUS User Community Preparing for the New Generation of Polar-orbiting and Geostationary Environmental Satellites

Joint JPSS/GOES-R Science Seminar

*This article is based in part on the **June 29, 2015** Joint JPSS and GOES-R science seminar presented by Jordan J. Gerth, Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin, Madison.*

Contributors: Bill Ward, National Weather Service, Pacific Region Headquarters.

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



Lower left: Ash and Steam Plume, Soufrière Hills volcano, Montserrat. Image acquired October 11, 2009 by the NASA International Space Station, Expedition 21 crew. ***http://earthobservatory.nasa.gov/IOTD/view.php?id=40803&src=eoa-iotd***
Lower right: 8 January 2010 eruption. Image credit: Montserrat Volcano Observatory. Obtained from ***https://www.flickr.com/photos/mvo/4262197553/***

The regions Outside the Contiguous United States (OCONUS) geographically include Alaska; Hawaii; the territories of Puerto Rico, United States Virgin Islands (USVI), Guam, the Commonwealth of the Northern Mariana Islands (CNMI), American Samoa, and Micronesia; and Coastal Areas and Open Waters. The National Weather Service (NWS) field Weather Forecast Offices (WFOs) located in these regions grapple with a unique set of challenges that limit their ability to effectively conduct their forecasting operations, and greatly impact the local user communities. These include a wide range of meteorological phenomena on a variety of temporal and spatial scales. And, while most weather phenomena are not unique to OCONUS regions, adverse weather impacts are intensified due to the remote and isolated locations affected. This article focuses on the current activities taking place in, and those planned for, the Pacific Region. The area of responsibility for the WFOs in the Pacific Region is more than twice the size of the continental United States. Of the many challenges to overcome, perhaps the most important is that the Pacific Region covers a vast area void of observations, and especially in-situ data. Given the relatively few ground observing locations, these regions require a stronger reliance on remotely sensed data.

Advancements in the current and new generation of operational polar-orbiting and geostationary environmental satellite systems (JPSS[16], GOES-R[17], GCOM-W[18], Metop[19], DMSP[20], and Himawari[21]) are being accompanied by new and improved user applications. Many of these improved applications are being made available to the Pacific Region through direct broadcast (DB) technology and by other means. Due to a scarcity of other sources of data, NOAA forecasters and environmental managers in the region who rely on user applications such as tropical cyclone monitoring, low cloud and fog forecasting, and volcanic ash tracking, require weather satellite imagery as a central source of environmental information. In addition, a network of reliably positioned DB antennas ensures the delivery of critical data to the field WFOs. The use of these antennas offers the user many advantages such as reduced data latency, the ability to network with other DB sites to create wider regional coverage, and the ability to assimilate these data into forecast models to help generate locally-unique products.

NOAA's major satellite programs – JPSS and GOES-R, and the NWS have made great strides to enable NOAA's forecasters in the Pacific Region to effectively conduct their forecasting operations and ensure NOAA mission operations. These include significant investments in their technical resources and in their satellite receiving capabilities via the installation of new antennas in Honolulu, Hawaii, and training and satellite proving ground activities.

Putting the Tools of the Trade and Resources to Use in the OCONUS

The tools of a trade are invaluable objects. However, they are meaningless without the use of a skilled and trained operational meteorologist. To ensure that the NWS Pacific Region (NWS PR) is poised to exploit the wealth of NOAA's satellite data, products and services, several initiatives are underway as part of satellite proving ground activities in the region. In addition, new and experimental products are being integrated into operations. Some of these are discussed briefly in the following section.

Dishing it Out in the Pacific

DB sites are capable of receiving data from various satellites including the Suomi NPP, all other operational NOAA polar-orbiting and geostationary satellites, the Japan Aerospace Exploration Agency's (JAXA) GCOM-W, the MetOp from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), NASA Earth Observing Satellites (EOS), and future JPSS and GOES-R satellites. One of the key features of DB is that real-time imagery and selected derived products are delivered much faster to forecasters, thereby assisting them in leveraging these products in their response to rapidly changing weather events.

[16] Joint Polar Satellite System
[17] Geostationary Operational Environmental Satellite R-Series
[18] Global Change Observation Mission-Water
[19] Meteorological Operational Satellite Program of Europe
[20] Defense Meteorological Satellite Program
[21] Geostationary weather satellite operated by the Japan Meteorological Agency (JMA)

Image credit: Eric Lau, NWS Pacific Region

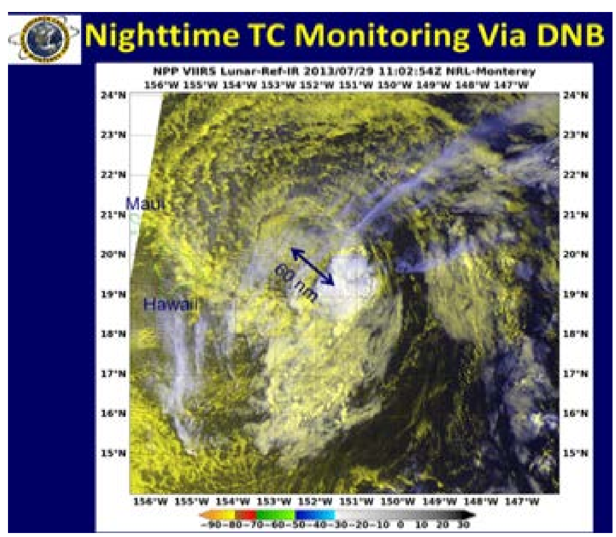
The image on the left shows the location for the new antennas planned for installation on NOAA's Inouye Regional Center building on Ford Island in Pearl Harbor, Hawaii. Beyond the recently built antenna in Miami, Florida, which supports the Caribbean region, there are plans for a new antenna in Mayaguez, Puerto Rico. Planning for the installation of a polar-orbiting and geostationary antenna at the NWS WFO in Guam is also underway. This capability is essential to the NWS WFOs in the OCONUS as they are dependent on the delivery and high availability of this data for their weather data and information services. In Alaska, polar-orbiting weather satellite data plays an even greater role in providing timely, high resolution observations for improved situational awareness, short-term forecasts, and warnings. NOAA's Suomi NPP provides moderate 375-meter spatial resolution imagery in multiple bands, large swath coverage and steady resolution at the swath edges. For certain situations this imagery can provide more detail about the current atmosphere than GOES. Ultimately, this enhanced detail enables operational forecasters to monitor rapid storm system changes, and more accurately predict future weather patterns and phenomena.

Because of the isolated and remote nature of many NWS WFOs and facilities in the Pacific Region, there needs to be more than one path to deliver satellite data, particularly to Honolulu which has to maintain a large forecasting operation. To that end, DB stations have required increased bandwidth between forecast offices in the Pacific Region.

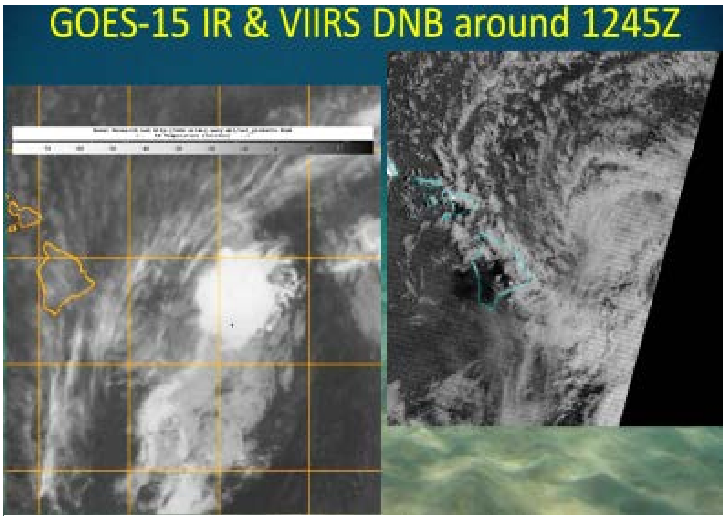
Keys to Success in the OCONUS

The JPSS Antenna at the Honolulu Community College

The JPSS and GOES-R programs invested in a new L/X-band antenna that was installed at the Honolulu Community College (HCC) in 2012 to support forecast offices in Pacific Region. This antenna is used to track Suomi NPP, EOS, FY, MetOp, and POES satellites to increase the capabilities of forecast operations in the Pacific. These satellites provided additional spectral information —imagery showing the atmosphere in more than just the visible and infrared



Monitoring Tropical Storm Flossie with the DNB. Image Courtesy: NRL window bands—and new products that were not readily available in the past. By exposing forecasters to bands from VIIRS and MODIS that do not have heritage on GOES, they get insight on how certain atmospheric features look in comparison with the products from the satellites currently available. A prominent example is the VIIRS Day/Night Band (DNB), which has been available in the primary display package of the NWS, the Advanced Weather Information Processing System (AWIPS), at the Honolulu Forecast Office (HFO) and Central Pacific Hurricane Center (CPHC) since August 2012. The DNB provides unique view of clouds at night.



Credit: Robert Ballard, WFO Honolulu, CPHC

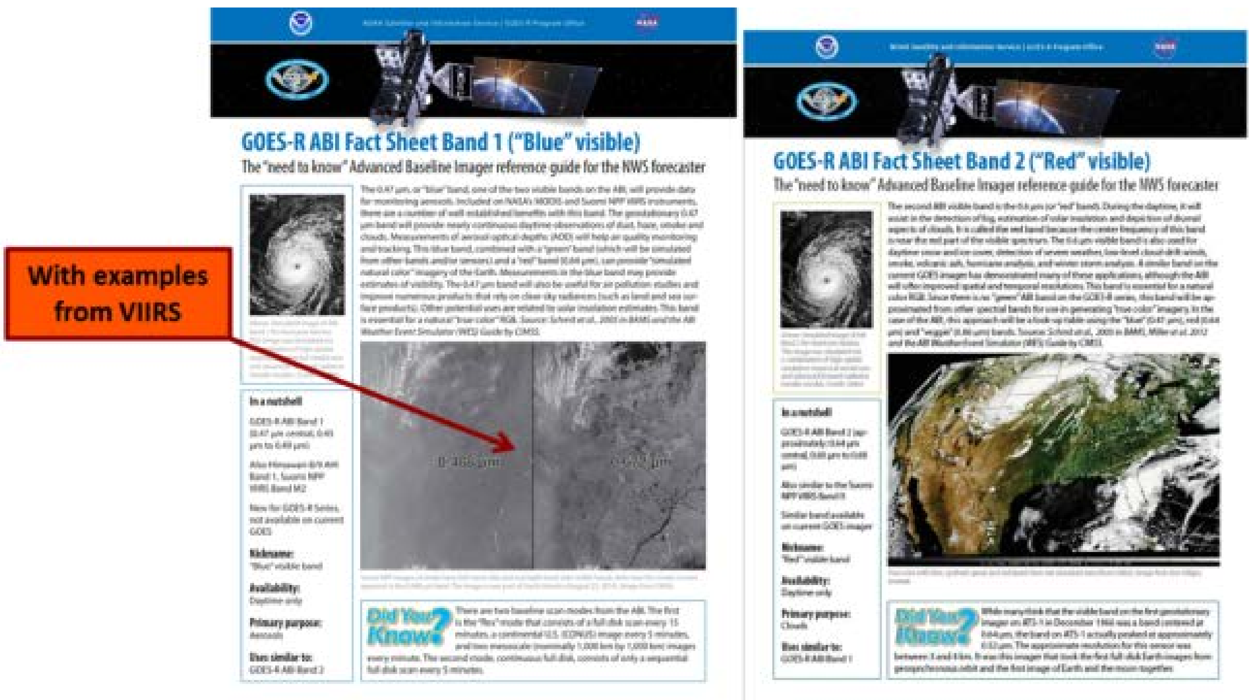
The VIIRS DNB proved its worth at the CPHC when it provided forecasters with images that were used to reposition Tropical Storm Flossie's center and adjust its track as it approached Hawaii (left). High clouds obscured Flossie's center of circulation before the DNB imagery revealed an exposed low level circulation center farther north than expected. When tropical cyclones encounter vertical wind shear, it can be nearly impossible for a meteorologist to identify the center of circulation using infrared window imagery. For this reason, the DNB is impactful to operations at the CPHC, and also remains very popular with HFO forecasters for assisting with routine weather analysis and forecasting responsibilities.

Training

Key elements of satellite training. Image Credit: Jordan Gerth

Satellite training ensures the successful operational application and exploitation of the capabilities on the current and new generation environmental satellites. It ensures the effective use of data from these satellite systems.

Training is one of the key methods used to help forecasters increase their operational usage of NOAA's satellite constellation in the Pacific Basin. To establish a critical core competency, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) has been funded to provide satellite training to staff in the Pacific WFOs. For the region, the training program being considered will offer a core course which will focus on "need-to-know" foundational information. There will also be a general course on meteorological uses of satellite imagery and products, and some transitional specialized cases. The first of these courses will be instructor-led Himawari training that will take place in Guam. This training will include an introduction to the Advanced Himawari Imager (AHI) and remote sensing concepts; band composites and RGBs; satellite applications for aviation forecasting; identifying weather systems and meteorological features; and tropical cyclones. The training, which will be in person will be a 20-hour workshop taught twice in one week by a three-person team. The course is slated for completion prior to the end of December 2015. A subsequent session is scheduled for the Honolulu WFO. Feedback from forecasters will be particularly useful in the development of training towards GOES-R.



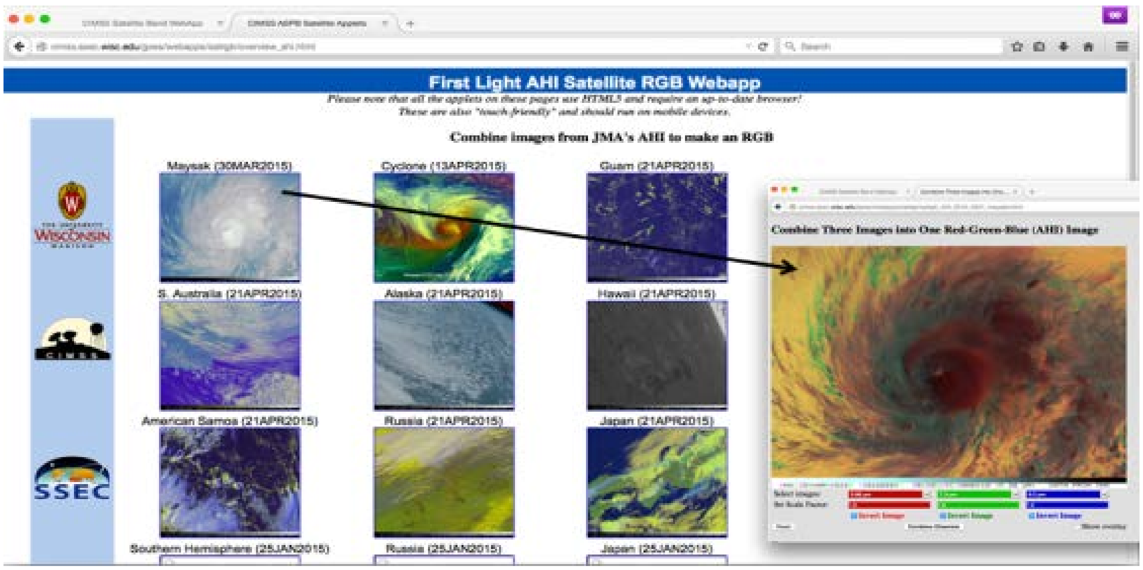
GOES-R ABI factsheets. Image Credit: Jordan Gerth

GOES-R ABI Fact sheets

Fact sheets serve as quick guides on the satellite's instruments, ground system and products. They are also used to reach out to forecasters not only in the OCONUS but also in the CONUS. The fact sheets provide summarized information on bands that are available with the GOES-R ABI, and the legacy of that band on past satellites. This includes information on what atmospheric features the band readily observes, the widespread meteorological applications associated with it, and its predominant usage. GOES-R fact sheets provide detailed summaries on each of the bands on the ABI using examples from similar bands on existing instruments such as VIIRS on Suomi NPP and the AHI on Himawari-8. A special Fact Sheet was made for the Green Channel on AHI. This channel is not on the GOES-R ABI.

Web Applications: Connecting Forecasters in the OCONUS in a Virtual Classroom

NOAA scientist Tim Schmit, from the Advanced Satellite Products Branch (ASPB), teamed up with CIMSS scientist Tom Whittaker to develop weather related web applications “WebApps” that demonstrate several basic remote-sensing concepts as well as specific attributes of the GOES-R series. These highly interactive WebApps allow users to explore temporal, spatial and spectral resolutions on satellite image interpretation. Examples include simulated GOES-R ABI, the current GOES imager, and the AHI as well as several case studies.

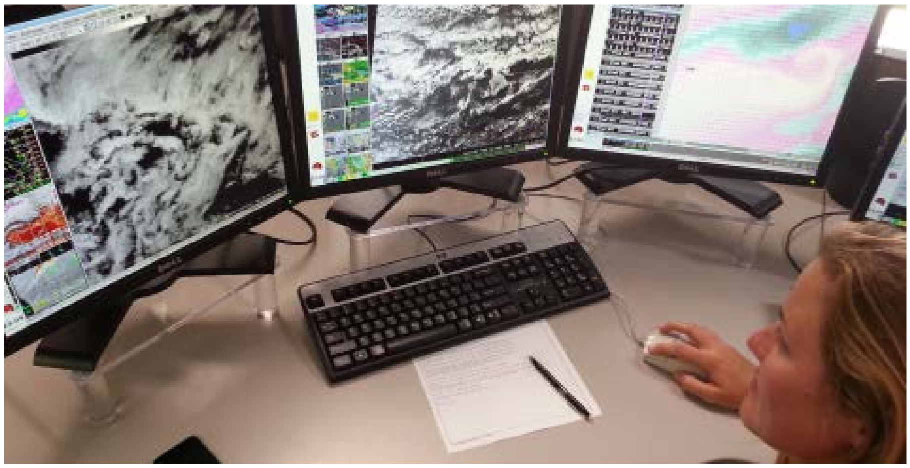


SatRGB Web Application. ***http://cimss.ssec.wisc.edu/goes/webapps/satrgb/overview_ahi.html***

Visiting Scientist Program (VSP)

In the Pacific Basin, forecasters are more likely to place higher value on satellite imagery and products, particularly due to the sparsity of in-situ observations. Given the opportunity for improvement therefore more emphasis is placed on baseline and under-demonstrated products. The NWS PR operates a Visiting Scientist Program (VSP) which helps ensure that forecasters in the region are easily and immediately able to incorporate the improved and increased information from new generation satellites into the forecast process. The VSP targets scientists with a legitimate interest in working with NWS operations in the Central Pacific, and in establishing a long-term relationship. It also gives high priority to scientists seeking to demonstrate baseline products, or new risk reduction products that solve tropical or subtropical forecast challenges or reduce workload. It is designed to bring satellite science product developers to interface directly with the field once the science product is suitable for field evaluation. The VSP provides funding for a scientist to sit down with forecasters to ensure they understand the potential utilities of new imagery and products. The VSP leads to two outcomes as a result of this. First, the product developer is able to make improvements to the science product based on forecaster feedback. Second, the forecasters gain increased knowledge about the capabilities of the satellite and science product. Past participants in the VSP have come from the NASA Short-term Prediction Research and Transition Center (SPoRT), who demonstrated the GOES-based Quantitative Precipitation Estimate (QPE) product developed at NESDIS. Forecasters provided feedback on the product's performance and recommended improvements as it was not capturing precipitation maxima. SPoRT and Robert Kuligowski (the product developer) are already working to improve the QPE product based on this feedback. In the interim, forecasters will continue to use infrared window imagery. Kathy Strabala and Liam Gumley from CIMSS conducted a workshop that provided training on how to use polar-orbiting satellite imagery for weather research and forecast tasks.

Imagery and Products Available to the NWS field WFOs



Aviation desk forecaster Leigh Anne Eaton uses satellite imagery from polar and geostationary platforms. Credit: Jordan Gerth

CIMSS has a program in which new satellite imagery and products are developed for, collaborated in conjunction with, and delivered to NWS field WFOs. The imagery is available online through the Space Science and Engineering Center's (SSEC) RealEarth Web Map Service in near real-time: http://realearth.ssec.wisc.edu/. This imagery is particularly helpful to forecasters in the field when access to AWIPS is not available. AWIPS, the primary NWS forecast tool, retrieves nearly all relevant weather data (including satellite), from a satellite-based delivery system known as NOAAPORT, decodes it, and stores it in network Common Data Form (netCDF) format. The AWIPS software package allows NWS forecasters to perform various meteorological workload tasks, including the display of satellite imagery with Display Two Dimensions (D2D), a graphical user interface. With AWIPS, meteorologists can load various meteorological, hydrological, satellite, and radar data. The satellite data comes from various platforms, including Suomi NPP and is available on multiple scales that range from global, regional, to specific to the location of the WFO.

Responding to the OCONUS Needs: The Future

NOAA's JPSS and GOES-R satellite programs and the NWS have made significant contributions to the forecasting operations of the NWS PR in response to the need for satellite data. These contributions include better access to current and new weather satellite observational datasets and increased support of collaborative research and training activities that are enabling operational forecasters in the region to effectively conduct their operations and fulfill NOAA's mission.

With scarce conventional observations to rely upon, satellite data are now the primary source of weather information in the OCONUS. NWS WFOs in regions such as the Pacific are now able to leverage upon advanced technological instrumentation such as the VIIRS DNB on Suomi NPP, which allows for nighttime observations in low-light conditions. The DNB is providing forecasters in the region the enhanced capability to track and monitor TCs at night. For mature TCs, center fixing is not difficult at night if the eye is pronounced. Still, with the DNB these forecasters are now able to do something that can sometimes be nearly impossible with GOES IR imagery – find the low-level center of TC at night and adjust its track. This unique aspect of the DNB is absolutely critical when time is a factor in saving lives.

NWS WFOs in the Pacific are also taking full advantage of the improved spatial, spectral, and temporal resolution of the AHI sensor in preparation for the ABI on the GOES-R. In addition to supporting the Pacific Region's forecast operations, imagery from the AHI is also serving as a spring board for training forecasters to explore its utility in the geostationary orbit. With the future GOES-R there will be significant improvements including faster imaging (with more geographical areas scanned in a shorter period of time), and higher spatial resolution. The Imager will have sixteen spectral bands, compared to five on the current GOES Imager, and will provide full disk images up to every 5 minutes, and as often as 30 seconds over small regions. In addition, the resolution will improve from 4 to 2 km for the infrared bands and 1 to 0.5 km for the 0.64 micrometer visible band. The first ever geostationary lightning mapper will complement the imagery to improve detection of storms. The finer spatial resolution will allow for better tropical cyclone monitoring, more accurate observations of low cloud and fog, and volcanic ash tracking by forecasters in the Pacific Region.

The growing network of reliably positioned DB antennas will ensure that the Pacific Region NWS has access to the critical high-resolution environmental observations from United States and international partner satellites. As most of the WFOs in the region are relatively isolated, the antennas are delivering the one thing they need the most, weather information! In addition to better access to existing and new satellite data, there are a number of training courses currently taking place and planned for the WFOs in the Pacific Region. The goal of these training sessions is to prepare operational forecasters in the Pacific Basin for the capabilities of the new generation weather satellites.

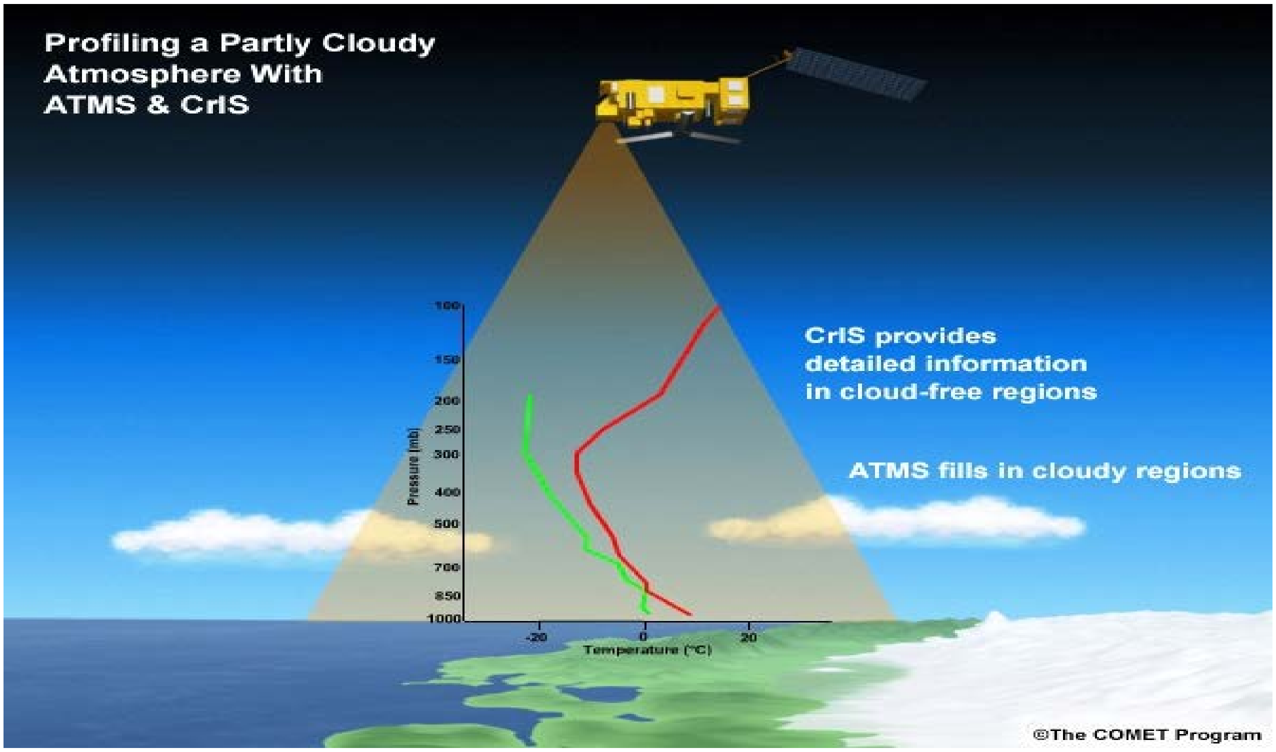
Data from Suomi NPP have presented the Pacific Region with opportunities to see early demonstrations of derived products and their applications in forecast operations, especially with the installation of the L/X-band antenna that was installed at the HCC in 2012. Additional antennas will soon acquire imagery from Himawari-8. The value of the products derived from these two satellite platforms has been appreciated throughout the Pacific Region and it is anticipated that future efforts will continue to produce even more high resolution imagery and products for the Pacific Basin. The future JPSS and GOES-R will present even more opportunities for the region to harness new and experimental products into their forecast operations. This will increase the use of data from satellite platforms for assessing routine weather conditions as well as threatening storms in the Pacific Basin.

The Innovative Use of JPSS Satellite-Based Soundings for Weather Applications

Joint JPSS/GOES-R Science Seminar

*This article is based in part on the **July 20, 2015** Joint JPSS-GOES-R science seminar presented by Chris Barnet, Science and Technology Corporation (STC).*

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



Sounding in partly cloudy environments using a combination of microwave and hyperspectral instruments.
Courtesy University Corporation for Atmospheric Research (UCAR) MetEd Lesson Plan "Suomi NPP: A New Generation of Environmental Monitoring Satellites" Produced by the COMET Program.
https://www.meted.ucar.edu/satmet/npp/navmenu.php?tab=1&page=3.5.0&type=text

Accurate forecasts thrive on timely and detailed observations. The fundamental observations used in weather forecasting are obtained from three-dimensional (3D) descriptions of temperature, moisture, and other atmospheric constituents. Satellite sounding measurements – called radiances - are used directly in NWP models along with other sources, including weather stations, radar, weather buoys, observations from ships and aircraft, weather balloons with rawinsondes. Converting the satellite radiances to temperature, moisture, and other constituents – a process called a retrieval – is essential to local forecast offices for issuing extreme weather warnings. Radiance is the energy in portions of the spectrum where it is absorbed and re-emitted by atmospheric constituents such as carbon dioxide, water vapor, and ozone. Hyperspectral sounders, in particular, sense energy at very high spectral resolution, and produce vertically resolved profiles of the atmosphere. Nearly all Numerical Weather Prediction (NWP) impact studies have shown that observations from hyperspectral sounders such as the Cross-track Infrared Sounder (CrIS) and microwave sounders such as the Advanced Technology Microwave Sounder (ATMS) have the largest impact for reducing forecast errors.

The Suomi National Polar-orbiting Partnership (Suomi NPP) is part of NOAA's next generation Joint Polar Satellite System (JPSS) constellation of polar-orbiting environmental satellites. With the launch of Suomi NPP in October 2011, NOAA brought next-generation sounders – the hyperspectral Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) – to its existing constellation. Together, CrIS and ATMS primarily provide data on the hydrologic cycle, which includes water vapor, clouds and precipitation. Because clouds are opaque in the infrared part of the spectrum (measured by the CrIS) and largely transparent at microwave frequencies (measured by ATMS), operating them together makes it possible to cover a broader range of weather conditions.

For decades forecasters have launched rawinsondes twice-a-day across the United States. A rawinsonde is a helium balloon that has hanging from it a series of instruments that collect environmental parameters such as temperature, humidity, and pressure. It takes time for sounding data from rawinsondes to be obtained, processed, and run through models. Data from rawinsonde soundings are often collected within a matter of hours, roughly twelve hours apart, and they usually have a small area of coverage. A rawinsonde has hundreds to thousands of independent vertical measurements, whereas a satellite hyperspectral sounding has only tens of independent vertical measurements in the troposphere. However, a single hyper-spectral satellite instrument can provide hundreds of thousands of high quality soundings per day with both day and night global coverage while rawinsonde coverage is labor intensive and much sparser coverage. With rapidly changing weather conditions where every second counts, and especially when weather conditions can rapidly deteriorate and become life threatening, gaps in coverage can have an adverse effect on forecast skill. As satellite sensors can provide vertical soundings over large areas, they are the perfect source of supplementary data between rawinsonde launches. Suomi-NPP was launched such that it provided coverage in early-afternoon (roughly 1:30 am/pm local time, globally) – a time frame that is valuable to both weather models and local forecast offices.

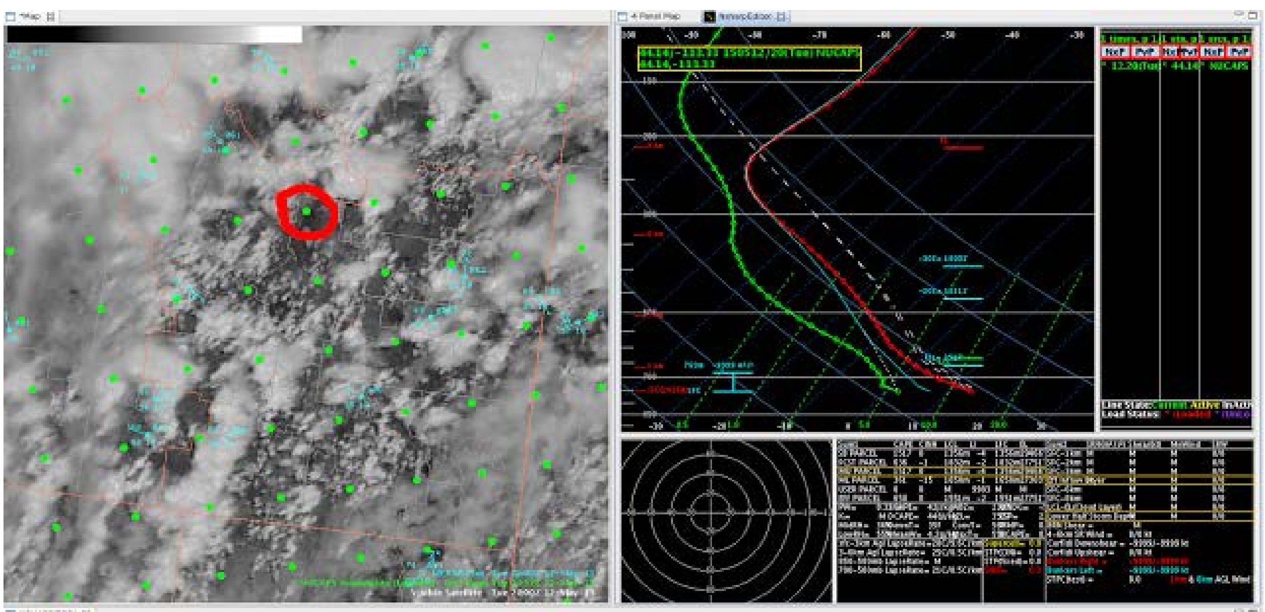


Image of NUCAPS sounding over Idaho, May 14 at 19 UTC. Accessed from the 2015 HWT-EWP webinar "Tales from the Testbed Week 2" given by Michael Stroz, Eureka, CA WFO. ***https://hwt.nssl.noaa.gov/spring_experiment/tales/2015-wk2/***

The image above depicts a NUCAPS sounding in a pre-convective environment that was studied at the Spring Experiment 2015. The sounding on the left (circled green dot) is located over Idaho, and is in a nearly cloud-free location. After the sounding was adjusted to include surface observations (right), it revealed plenty of instability and moisture at the surface. Later that day an intense thunderstorm, which had hail with it rolled over the area. The storm's occurrence validated the NUCAPS data. Data from the Suomi-NPP midafternoon overpass can provide valuable information on the possibility of convective development. This data is particularly valuable in areas with sparse conventional observations.

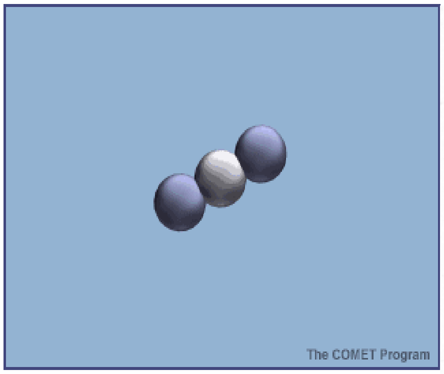
Atmospheric Sounding

An atmospheric sounding is a vertical profile of the atmosphere, meant to be representative of the atmospheric conditions at a particular point and time. It shows how temperature and moisture change with respect to height in the atmosphere. Sounding uses theoretical knowledge of the vibration and rotation of atmospheric molecules to "invert" the observed spectrum and retrieve the state (i.e., temperature and composition) of the atmosphere. Scientists can infer a surprising amount of information from soundings including the location of weather fronts, where clouds will or will not develop, and if there will be precipitation. The temperature and moisture profiles can be used to compute derived products, such as dew point and stability parameters such as convective available potential energy (CAPE).

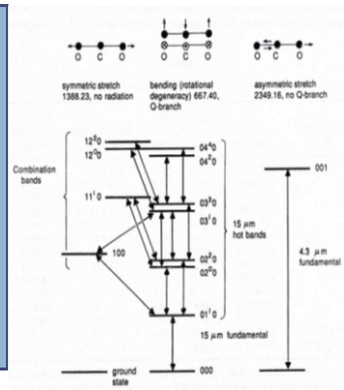
Infrared and Microwave Frequency Scales

Satellite sounders (infrared or microwave) measure the radiation emitted by the atmosphere at different wavelength bands (channels) usually given in milli-meters (mm) or micro-meters (μm). The Infrared (IR) channels are usually specified in wavenumbers (inverse centimeters or cm^{-1}) and are related to wavelength as: $\nu(cm^{-1}) = 10000/\lambda$ (μm). The microwave channels are usually specified in frequency units (GHz = 10^9 Hertz) and are related to wavelength as: f(GHz) = $300/\lambda$(mm).

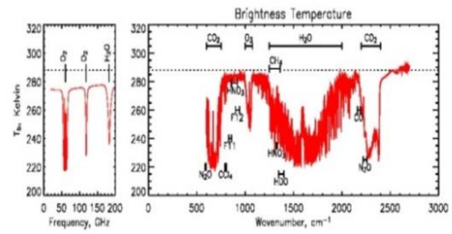
Molecules in the atmosphere absorb infrared and microwave radiation emitted by the Earth's atmosphere at specific wavelengths. When a molecule absorbs this energy it changes its rotational and vibrational modes. Laboratory knowledge of these modes enables scientists to compute a radiance spectrum at the channels measured by these sensors. This computation is called the forward model and is illustrated in the figure that follows. Molecules in the atmosphere (oxygen, carbon dioxide, ozone, methane, etc.) absorb energy (left panel). Knowledge of laboratory spectroscopy enables one to predict allowed vibration and rotation modes (middle panel) and with knowledge of radiation transfer we can compute the microwave and infrared radiances and brightness temperatures (right hand panel) measured by these sensors. This forward model can then be used to derive the atmospheric state.



Vibration/rotation of each molecule in the atmosphere is a function of pressure and temperature



Knowledge of quantum mechanics (lab spectroscopy) identifies what the spectrum should look like



Microwave (left) and infrared (right) spectrum can be computed from state of the atmosphere

Data assimilation (DA) and retrieval systems both take the observed sensor radiances and use the forward model to "invert" or infer the atmospheric temperatures and composition; however, they use the observational data differently, as described below.

Modern data assimilation systems ingest the radiances from IR and microwave sensors directly, from multiple satellites. For modern IR sounders, the limits on computing and storage power place significant restrictions on the use of IR channels. The volume of data from the IR channels is often too large for the computational load of the NWS data assimilation systems; hence most forecasters opt for an intelligent subset of these channels. These subsets are trimmed down even further due to the problems with the forward modeling of clouds and certain trace gases in the IR spectrum. Therefore, only those channels not impacted by clouds and trace gases, such as methane, CFCs, and sulfur dioxide, are considered for assimilation. As a result IR sensor measurements tend to be sparse and have a relatively low weight in DA compared to what is done in a retrieval.

With retrievals, data manipulations are based on a single satellite field of regard and only sensors on that satellite are considered. The retrieval forward model can take into account many more trace gases and the details of sensor error characteristics, including spectrally correlated noise within the sensor, can be accounted for in significantly more detail. More importantly, detailed calculations can be obtained in almost near-real time using a single CPU.

NOAA Unique Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) Processing System (NUCAPS)

The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is the operational retrieval system for sounding products from the Suomi National Polar-orbiting Partnership (Suomi NPP). By combining both the microwave and infrared sounding measurements on Suomi-NPP, NUCAPS exploits the full information content of these space-borne assets.

The NUCAPS science code was designed to be instrument independent. It is derived from the algorithm originally developed by the AIRS Science Team (AST). NOAA's National Environmental Satellite, Data and Information Service (NESDIS) center for Satellite Application and Research (STAR) ported this algorithm for operational use with the EUMETSAT Metop-A/B and, more recently, the Suomi-NPP. The same science code was also used operationally for the Aqua AIRS/AMSU and Metop IASI/AMSU/MHS and AVHRR instruments. In addition, the code is flexible and can be easily configured to process data from any instrument including AIRS, IASI, or CrIS. This property of NUCAPS meets NOAA's enterprise goals, that is, algorithms that can support multiple missions, but more importantly, it guarantees homogeneity across the multi-platform integrated dataset of retrieved Environmental Data Records (EDRs). The code can be used for simulation of hypothetical instruments; and can mix and match sensors (*e.g.*, Aqua AIRS and Suomi NPP ATMS).

Since April 2014, NUCAPS has been produced operationally at the NOAA/NESDIS Office of Satellite and Product Operations (OSPO). NUCAPS products were also made available to the National Weather Service through their Advanced Weather Interactive Processing System (AWIPS). As of February 2015 the first release of NUCAPS was placed on the Community Satellite Processing Package (CCSP) direct broadcast stations, making it available immediately to anyone with direct readout capabilities.

What Makes NUCAPS Unique?

The atmospheric sounding channels are located in parts of the infrared (IR) and microwave spectrum for which the atmosphere is the main contributor to the measured radiance. NUCAPS relies on a technique called 'cloud clearing' to remove the effect of clouds so that information can be obtained all the way to the surface, the region that is most relevant for most weather applications. Cloud clearing uses multiple scenes to remove the effect of the clouds. Therefore, cloud clearing sacrifices spatial resolution so that CrIS and ATMS can provide soundings in nearly 70 percent of scenes; however, this significantly increases the number of channels and scenes in which IR products have value to forecasters. ATMS can see through non-precipitating clouds, therefore in the Suomi NPP application, it virtually offers an all-weather capability, although at reduced vertical resolution compared to the IR. Cloudy scenes are also more likely to include interesting weather and these scenes are more likely to be useful to forecasters.

The physics behind atmospheric sounding limits soundings to a broad vertical region of the atmosphere, what is known as the error co-variance matrix, which is related to the vertical averaging kernel. NUCAPS soundings are smoother in the vertical than rawinsonde or model-derived soundings and have vertically correlated errors. Proper use of soundings requires knowledge of the error covariance matrix or, equivalently, the averaging kernel to properly describe the retrieval.

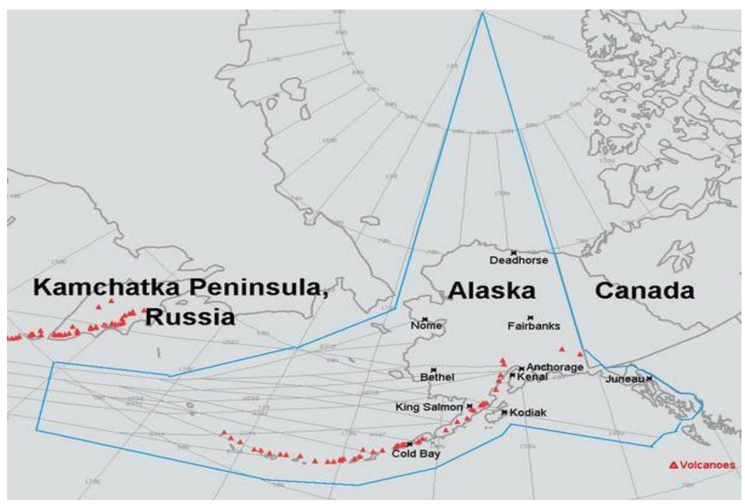
The NUCAPS code also reads in a pair of GFS forecasts and interpolates them to the time and location of the CrIS and ATMS observations. The only information used from the GFS forecast is surface pressure; however, GFS temperature, moisture, and ozone information is available for comparison to the NUCAPS products. This unique trait allows NUCAPS to compare every step and iteration to a "truth" data set and provide extensive diagnostic information for specific scenes. In operations, the GFS is used as the "truth" dataset; however, for off-line use, NUCAPS "truth" datasets can include other forecast models, rawinsondes, or other in-situ datasets. Developers can use this diagnostic information to understand situations where NUCAPS fails and ultimately improve NUCAPS soundings.

The Joint Polar Satellite Systems (JPSS) Initiatives for Sounding

The JPSS Program established the sounding initiative in July 2014. The objective of this initiative is to improve the operational use of SNPP NUCAPS soundings for NWS offices. This will be done through the evaluation and improvements of NUCAPS algorithms, the operational application and validation of NUCAPS products and initial and on-going NUCAPS training. Many of the concepts discussed above, from the use of cloud clearing to the limitations in the vertical information of satellite soundings, need to be conveyed to the users so they can properly interpret the value of the NUCAPS soundings. Forecasters have many observation types at their disposal and must make decisions using these data very quickly. This initiative explores ways to tailor the NUCAPS products to maximize their utility in the NOAA forecast offices. Several sub-initiatives were established in order to serve NWS forecasters better. These are discussed in the section that follows.

Aviation Weather Testbed: The Use of NUCAPS to Assist in Evaluating Cold Air Aloft in Alaska

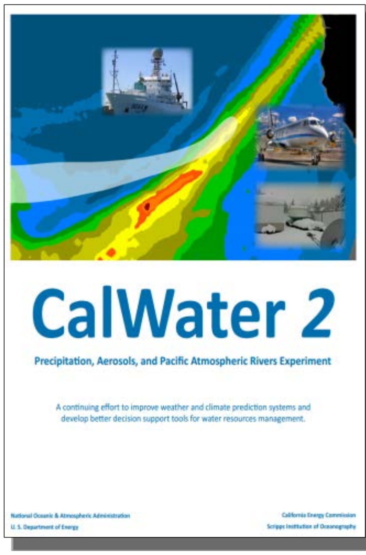
At high latitudes in the winter, temperatures at the altitudes taken by commercial jet air routes can get as cold as -65°C and below. At these temperatures there is a risk of the jet fuel losing some of its viscosity. This "thicker" fuel can have a real impact on engine performance increasing flight times and fuel costs. Alaskan aviation forecasters have routinely put out advisories to the airline industry concerning the time and altitudes of these super cooled air masses to allow pilots to direct their flights around this cold air aloft.

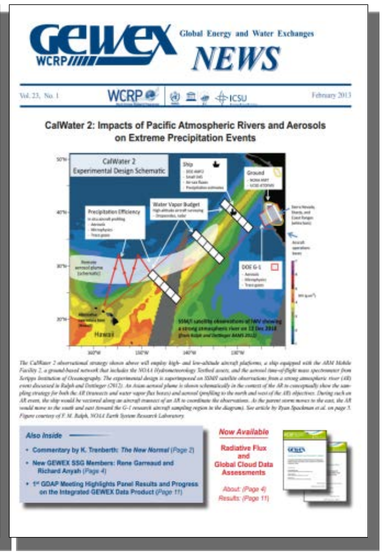


Anchorage Flight Information Area (FIR) encompasses 2.4 square million miles. Anchorage Airport was ranked 3rd worldwide for throughput cargo (90% of China to USA) and 1st in the USA for cargo poundage (5.9 Billion lbs.)

Alaskan forecasters have had difficulty determining the temporal, spatial and vertical location of these layers of cold air aloft. They usually rely on analysis and model fields to determine the 3D extent of cold air aloft events because radiosonde observations are sparse (approximately four per day). To that end, NUCAPS soundings are being evaluated in the Alaska region under the Aviation Weather Testbed.

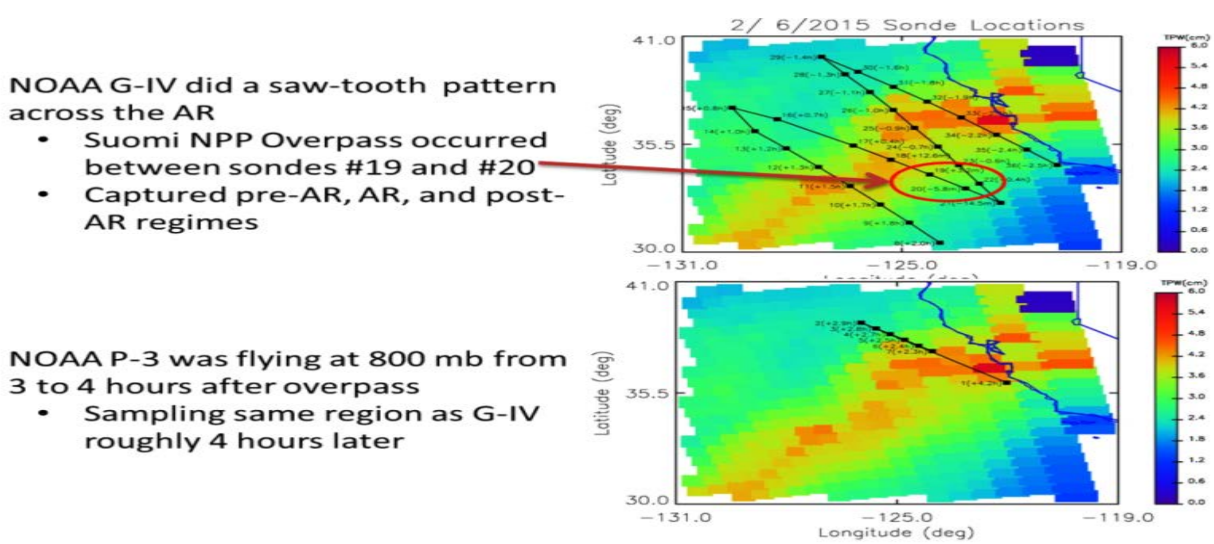
Satellite-borne hyperspectral sounders such as CrIS perform well at elevations above cloud tops, which happen to be where cold air exists and also the altitude range used by passenger and cargo jet aircraft, typically below 45,000 ft. Therefore, the use of NUCAPS provides an opportunity for forecasters to observe the 3D extent of the cold areas in real-time where conventional observations are lacking.





Hydrometeorology Testbed: The Value of NUCAPS to the CalWater-2015 Field Campaign

CalWater 2 is a 5-year broad interagency vision to address key water cycle science gaps along the US West Coast. These gaps were identified in a CalWater2 White Paper (left). The gaps were associated with atmospheric rivers (ARs) and aerosols – two phenomena that play key roles in the variability of the water supply and the incidence of extreme precipitation events along the West Coast of the United States. The paper is available at [http://esrl.noaa.gov/psd/calwater.](http://esrl.noaa.gov/psd/calwater) The objective of CalWater 2 is to examine the development and structure of ARs before they make landfall to improve forecasts of extreme precipitation events along the US West Coast. This study has presented opportunities to evaluate NUCAPS moisture products in extreme environments; develop new user applications; and train forecasters in their use.



Near Real time NUCAPS TPW snapshot taken 2/6/15 using Suomi NPP overpass, overlapped with the G-IV flight track. Dots indicate drop sonde locations. Points 19 and 20: closest NUCAPS-drop sonde match

ARs are relatively long (hundreds to thousands of miles) narrow moisture rich areas in the atmosphere. They are responsible for most of the horizontal transport of water vapor outside of the tropics, associated with major storms. Large ARs can transport as much as 13-26 km^3/day, almost 7.5-15 times the average discharge of the Mississippi River (Ralph 2011 Eos[22]). An approximate thirty to fifty percent of the annual precipitation on the U.S. West Coast is associated with ARs. ARs are the leading cause of severe storms, floods and extreme snowfall events over the US West Coast. However, not all ARs result in unfavorable environmental events – most are weak, and simply provide beneficial rain or snow that is crucial to water supply. A 2013[23] study analyzing drought events along the West Coast over the last 60 years found that in northern California alone, 40 percent of droughts were ended by AR events.

Within the CalWater 2 effort, in January 2015, NOAA, the U.S. Department of Energy (DOE), Scripps Institution of Oceanography, NASA, the U.S. Naval Research Laboratory, and the U.S. National Science Foundation kicked off a two-month long field campaign known as CalWater 2015. The focus of this campaign was the variability of the water supply and the incidence of extreme precipitation events along the West Coast of the United States. These studies of AR and aerosol phenomena were conducted using an array of observing platforms including the Suomi NPP satellite, research airplanes, state-of-the art monitoring equipment on-board NOAA Research Vessel Ronald H. Brown, and in situ observations from ground stations across California through NOAA's Hydrometeorology Testbeds (HMT). CalWater-2015 was an opportunity to test NUCAPS in extreme weather. Over 435 dropsondes were acquired during this campaign alone, and especially in regimes that are traditionally difficult to validate. The temperature and moisture data from the CrIS and ATMS instruments was acquired by direct broadcast antennas in Corvallis, Oregon and Honolulu, Hawaii, which, due to their proximity, enabled the NUCAPS products to show the entire CalWater field campaign region while the aircraft were in flight in near real-time. This low latency access to data proved valuable for field campaign logistical support. CalWater-2015 demonstrated the value of NUCAPS soundings in capturing high impact mesoscale events over otherwise poorly sampled regions.

The full direct broadcast antenna network covers all of North America and provides reliable data to NOAA's National Center for Environmental Prediction to assist in meeting the nation's environmental challenges while also allowing local markets to collect data directly from Suomi NPP.

[22] Ralph, F.M. and M.D. Dettinger 2011. Storms, floods, and the science of atmospheric rivers. Eos Transactions (AGU) v.92 p.265-266

[23] Dettinger, Michael D. (2013): Atmospheric Rivers as Drought Busters on the U.S. West Coast. J. Hydrometeor, 14, 1721–1732
http://journals.ametsoc.org/doi/pdf/10.1175/JHM-D-13-02.1

Hazardous Weather Testbed: The Operational Evaluation of NUCAPS in the 2015 Spring Experiment

NOAA's Hazardous Weather Testbed (HWT) develops, tests and evaluates severe weather forecast and warning techniques for the National Weather Service. The HWT is located at the National Weather Center in Norman, Oklahoma. It is jointly managed by the National Severe Storms Laboratory (NSSL), the Storm Prediction Center (SPC), and the National Weather Service Oklahoma City/Norman Weather Forecast Office (OUN).

Session at the HWT Spring Experiment

In spring – typically when the severe weather season ramps up – the NOAA HWT hosts multiple experiments to test the operational utility of cutting edge science, technology and products. These experiments offer an exceptional opportunity for NWS forecasters, broadcast meteorologists, and scientists to participate in experimental forecast and warning generation exercises, and work side-by-side to operational applicability as well as critique and suggest improvements for algorithms in different stages of their development cycle.

The HWT 2015 Spring Experiment was conducted over a five-week period from early May through early June. The HWT provided the JPSS and GOES-R Proving Ground Programs with an opportunity to demonstrate baseline, future capabilities, and decision aid products associated with the next generation JPSS and GOES-R satellite systems. The focus is on those capabilities that have the potential to improve short-range hazardous weather forecasting, nowcasting and warnings. The operational evaluation of NUCAPS in convective environments was a key part of the HWT 2015 Spring Experiment. There was a total of 30 forecasters and broadcast meteorologists that participated in this experiment with six (five NWS forecasters and one broadcaster) participants in attendance each week.

Forecasters were able to access NUCAPS soundings and evaluated their value to identify areas of instability that were often precursors to severe weather outbreaks. The forecasters also looked at soundings in what they considered to be stable environments to determine if satellite soundings were consistent with rawinsonde and model soundings. They were encouraged to document their short-term experimental mesoscale discussions in real-time. Also, when possible, participants recorded the reasoning behind experimental warnings, once again focusing on how the satellite products influenced their decisions. Participants provided additional feedback through daily and weekly debriefs, daily surveys, blog posts, and the once a week Tales from the Testbed Webinars. The feedback they provided documented the value of these satellite soundings in filling the gaps between the twice-daily rawinsonde launches. They only wished they could get these soundings more frequently. More detailed summaries of this evaluation will be captured in the Spring Experiment's final report which will be submitted to the JPSS/GOES-R Proving Ground and eventually provided to product developers so that recommended changes and improvements to products can be addressed.

NUCAPS Trace Gas Product Evaluation

This sub-initiative is based on two recent JPSS funded projects. One seeks to test and improve the accuracy of JPSS-retrieved data and demonstrate their usefulness in air quality and climate modeling studies. The other aims to address the need for low latency, web-based, high resolution forecasts of smoke dispersion for use by NWS Incident Meteorologists (IMETs) to support on-site decision support services for fire incident management teams.

This initiative uses models to interpolate the sparse field observations to the satellite temporal, spatial, and vertical sampling characteristics. This maximizes the utility of extremely sparse trace gas in-situ measurements in the middle troposphere where the CrIS derived products are most sensitive. These studies will focus on the Southeast Nexus (SENEX) field campaign that took place in the summer of 2013 and the Shale Oil and Natural Gas Nexus (SONEX) field campaign that took place in the spring of 2014. Both of these campaigns occurred before NUCAPS became operational, so these studies will utilize the re-processed NUCAPS datasets.

Future Plans for NUCAPS and the Path Forward

Feedback from all of these sub-initiatives has proven invaluable to the continued development of NUCAPS. Included in the evolutionary path of NUCAPS are a variety of improvements and upgrades on its potential utility in operations. Among these are improvements in AWIPS implementation, better visualizations, and automated profile modification.

The field campaign and spring experiment also generated a copious amount of training content, and as a result future plans for training were also included.

Additionally, retrievals from other satellites such as Metop-A and B, which were not originally part of the AWIPS plans, are now planned for inclusion into AWIPS-II and CSPP direct broadcast. This means even more soundings will be available to NWS forecasters. Also, Metop overpasses occur at 9:30 am/pm local time and will complement the NPP observations at 1:30 am/pm.

The improvements and identification of conditions where the performance of retrievals is degraded represent a very active part in the development of the NUCAPS system. As much of the NUCAPS retrieval skill comes from the use of cloud cleared radiances, several areas of further research are being considered. One involves a study using NUCAPS cloud cleared radiances within a NWP regional model such as the NCEP Weather Research and Forecast (WRF) model, and observations during super-storm Sandy (2012) and Typhoon Haiyan (2013).

Another will investigate the use of NUCAPS profiles (temperature, moisture, and ozone) to create an enhanced stratospheric depth product that will be assessed in the context of extratropical hurricane transition by NCEP forecasters at NHC, WPC, and OPC.

Summary and Conclusions

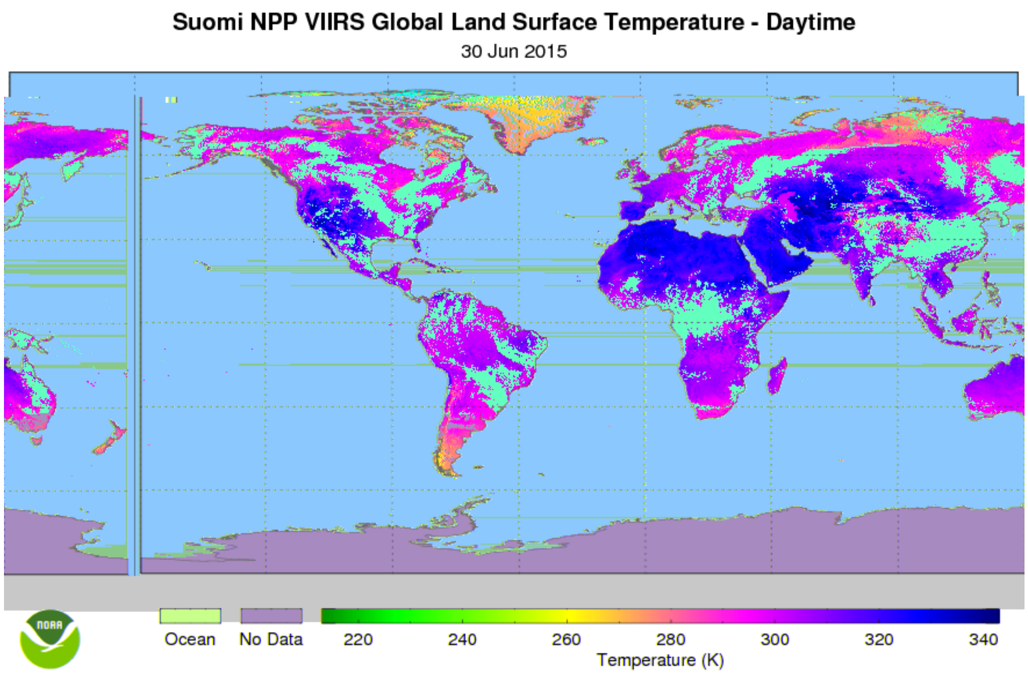
NOAA forecasters have found the use of soundings to be critical to the development of their forecasts. However the conventional rawinsondes are not launched frequently enough and do not cover a large enough geographic area to fulfill the forecaster's need for information about vertical temperature and moisture changes in fast moving severe weather environments. Moreover processing this data and running it through models can be time consuming. The launch of Suomi NPP enhanced NOAA's existing earth-observing satellite constellation with cutting edge new satellite sounders. Suomi NPP's CrIS and ATMS sensors contain a wealth of information about atmospheric temperature, humidity, and composition of trace gases. NUCAPS provides high spectral (and high spatial) resolution soundings derived from the CrIS and ATMS and is able to offer higher quality and reach higher altitudes than conventional radiosondes. In addition, NUCAPS data helps fill the spatial and temporal gaps between rawinsondes.

The JPSS Sounding Initiative has been critical to the effort to provide NUCAPS soundings to the NWS to help with all types of applications. Together CrIS and ATMS provide very detailed profiles of the atmosphere which allow for phenomenon such as atmospheric rivers to be mapped and tracked around the globe. Hence with NUCAPS the NWS is better able to monitor and predict these heavy, long duration precipitation events. The near real-time retrievals of NUCAPS temperature and moisture profiles help depict various atmospheric conditions that can provide signals for events such as tropical storms, and thereby assist in warnings of severe weather. NUCAPS successfully demonstrated support to a flight campaign with real time NUCAPS retrievals from CSPP stations. The value of NUCAPS, particularly its ability to see the entire domain of a field campaign in one snapshot, was made evident during the CalWater-2015 campaign which sampled ARs that develop over the Pacific Ocean and bring rain to the U.S. West Coast. With the success of its current efforts, the JPSS Initiative will help the operational weather community consider new ways to assist in the application of NUCAPS to other mission needs.

Issues in Developing and Validating Satellite-Derived Land Surface Temperature Products

This article is based in part on the ***August 17, 2015*** *JPSS science seminar presented by Yunyue (Bob) Yu, NOAA/NESDIS, Center for Satellite Applications and Research (STAR).*
Additional contributors: Yuling Yu,, Cooperative Institute for Climate Studies (CICS), University of Maryland (UMD)

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



Land Surface Temperature

Land Surface Temperature (LST) is the mean radiative temperature of all objects comprising the surface, as measured by ground-based, airborne, and spaceborne remote sensing instruments. It is integral to a radiative energy balance of the surface, as it provides the best approximation to the thermodynamic temperature which drives the outgoing longwave flux from surface to atmosphere and space. LST is determined by the difference between the absorbed energy from the sun and the outgoing longwave (thermal) and reflected shortwave energy from the Earth. It is also an important indicator of land/atmosphere feedbacks such as the greenhouse effect.

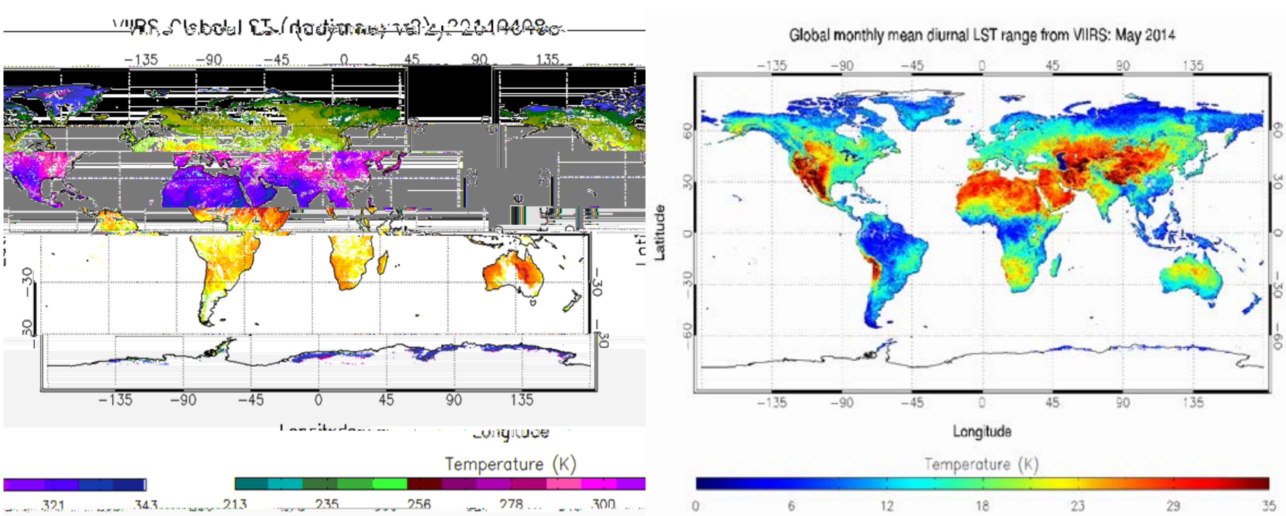
Satellite derived LST measurements have been successfully used in various applications including water management, monitoring the state of crops and vegetation, land cover changes, and fire monitoring. One of the benefits of LST is the role it plays in describing the physics of land-surface processes on regional and global scales. However, the LST databases are very inconsistent. Not many countries have the resources to build and maintain extensive networks of land-based temperatures. Even NWS' automated ground stations are widely dispersed and cannot be considered representative of conditions where the geography of the surrounding areas can change quickly. Thus, satellite derived LSTs in many regions are a particularly important source, and in some cases, the only source of surface air temperature.

NOAA's Center for Satellite Applications and Research (STAR) has generated a LST product derived from the VIIRS. The VIIRS LST product taps into the LST heritage of the Advanced Very High Resolution Radiometer (AVHRR) sensor on NOAA's Polar-orbiting Operational Environmental Satellites (POES) and MODIS. LST products from AVHRR and MODIS have been applied in operations ranging from drought monitoring, vegetation growth and crop yield estimation, to active fire applications such as mapping burned areas. In the U.S., the demand for satellite LST data including that from the Visible Infrared Imaging Radiometer Suite (VIIRS) comes from a variety of government agencies including the NOAA, the Department of Agriculture (USDA), the Environmental Protection Agency (EPA), the Department of the Interior (DOI), the Department of Defense (DOD), as well as from universities and research institutes worldwide. VIIRS is one of five sensors onboard NOAA's primary satellite in the afternoon polar orbit, Suomi National Polar-orbiting Partnership (Suomi NPP). In February 2015, LST products from NOAA's Geostationary Operational Environmental Satellites (GOES) became primary inputs into the operational NCEP/EMC weather forecast and data assimilation models. But even so, due to challenges in simulating land surface emissivity and temperature, LST products are not widely used by operational weather and climate centers via direct analysis or data assimilation in land surface and climate models. Moreover when compared against sea surface temperatures (SSTs) derived from the same sensor data, the LST uncertainty has been found to be significantly higher because the land surface is considerably more complex than the sea surface. This status has significantly restricted the satellite LST product, particularly in promoting its usage in the NWP model, which is a critical application domain of the satellite products at NOAA.

Nonetheless, the importance of LST cannot be understated and therefore calls for an understanding of the issues encountered in its development and validation. This understanding is vital to any and all approaches to improve the production of satellite-derived LST, and its assimilation into weather analysis and prediction models. Some of the issues encountered during algorithm development and validation of LST are discussed in the sections that follow.

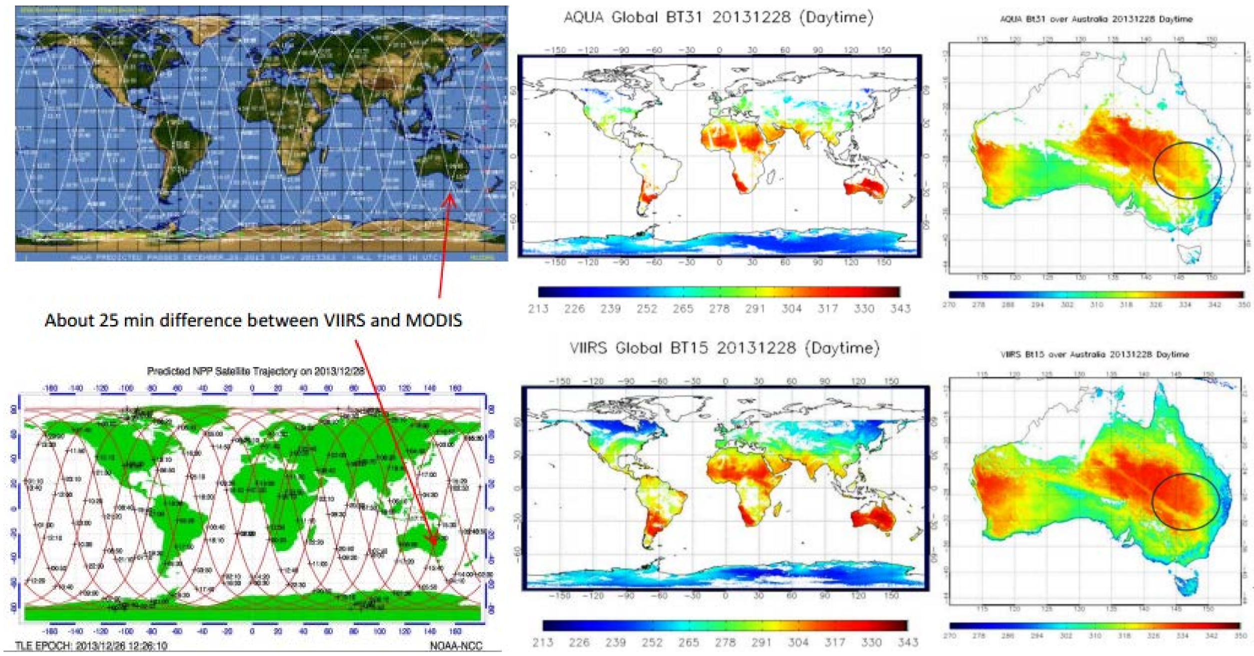
Challenges in Algorithm Development

Spatial and Temporal Variations



Variations in global LST observed over spatial (left) and temporal (right) scales

LST can vary significantly on a short scale of space and/or time. On the spatial scale, varied land surface types can be within a footprint of the view of the satellite sensor. Land heats very differently if it bare soil, crops, meadows, or mixed trees. These land surface types may differ significantly in thermal capacity and in emissive features. On the temporal scale, the thermal inertia of land surface may differ significantly due to the relative diurnal heating and cooling of these land surface types. Geography can play a role affecting LST both spatially and temporally. Hills and valleys heat and cool very differently throughout the day.

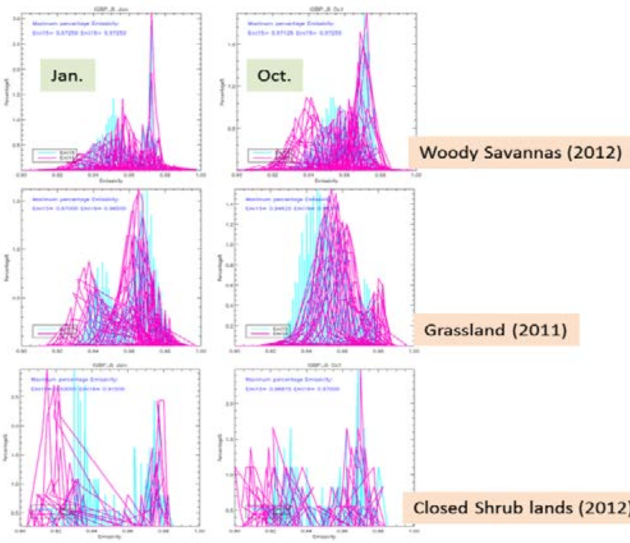


The images above from Suomi-NPP and MODIS scans 25 minutes apart are used to illustrate the difficulty of comparing two measurements from different time samples. Due to changing atmospheric conditions, a scan between Suomi-NPP, MODIS and/or GOES are not comparable as the surface features observed by each satellite are different.

Aside from these spatial and temporal challenges, atmospheric conditions are constantly changing. Cloud cover and precipitation can have a direct impact on LST. Frontal passages with rapidly rising or falling temperatures also can cause changes in LST. Thus, even very small intervals between satellite scans can pose significant challenges when comparing the observed radiances. Such significant spatial and temporal variation features not only restrict some retrieval approaches that can be applied for SST derivation, but also make the LST in-situ validation more difficult.

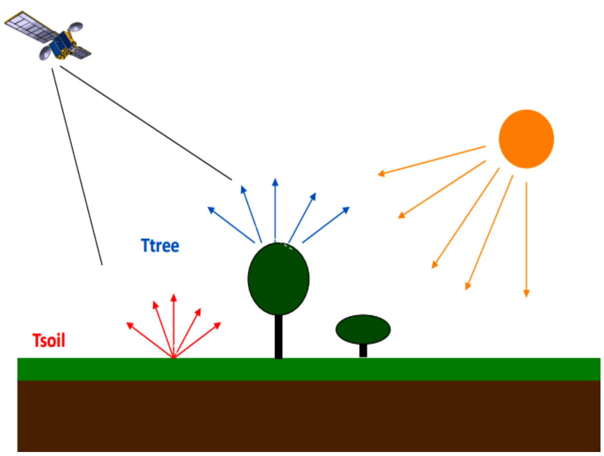
Emissivity Sensitivity

Emissivity is the ability of a surface to emit radiant energy compared to that of a black body at the same temperature and wavelength and under the same viewing condition. LST and emissivity are coupled in the surface-to-sensor radiative transfer problem; Satellite LST retrieval requires knowledge of land surface emissivity at satellite footprint explicitly or implicitly. Since the land surface is usually composed of different materials with various emission features, it is very hard to obtain the accurate emissivity information at satellite footprint. Most LST algorithms are sensitive to emissivity so even a small amount of uncertainty in emissivity may cause significant amount of LST uncertainty. In the current VIIRS LST algorithm, surface type information is applied as implicit knowledge of emissivity. Because emissivity may vary significantly in certain surface types along the seasons, this also degrades the VIIRS LST retrieval quality.



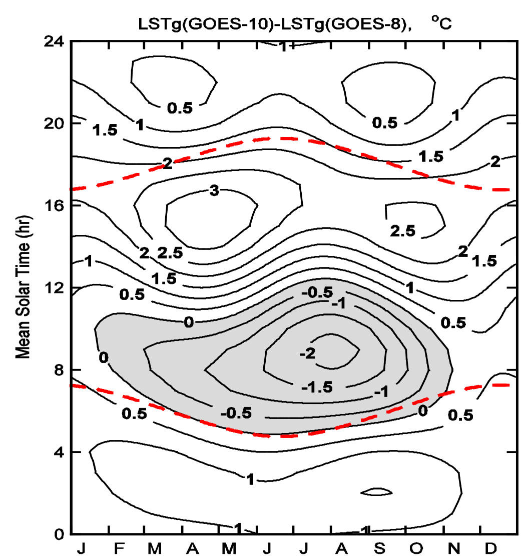
The sample plots on the right show considerable seasonal emissivity variation over some surface types. They also show that emissivity may vary significantly within a surface type.

Satellite Viewing Angle Sensitivities



Another challenge in LST algorithm development is that emissivity varies with view geometry, which can result in major differences in the properties observed by the satellite. When a satellite views the earth surface at different angles, the satellite scene will change, i.e. the component of land materials will be different. In addition, due to the surface emission anisotropic feature, the LST observed by a satellite may differ significantly from one viewing angle to another.

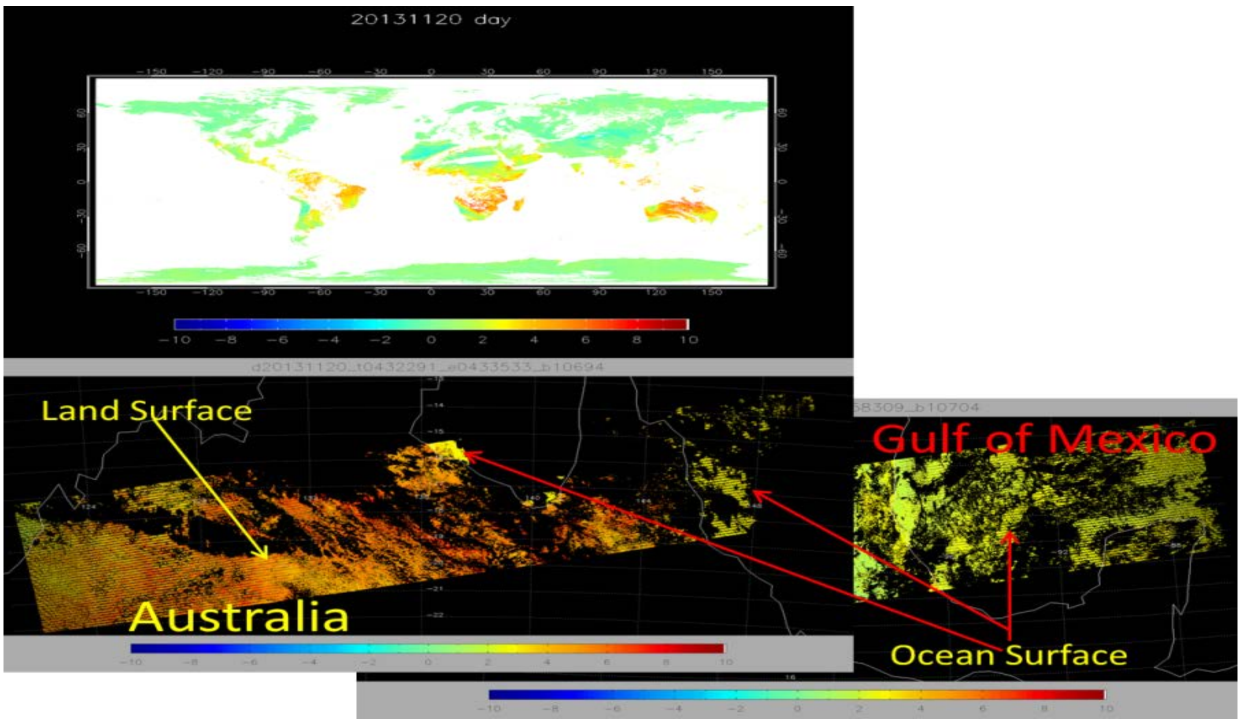
For example, the figure on the right shows the difference of LSTs observed from the imagers on GOES-8 (which operated in the East) and GOES-10 (which operated in the West) at the same location of a SURFRAD station at 36.63ºN and 116.02ºW in Desert Rock, NV. There were about 2096 simultaneous observation data pairs between the two imagers. The view zenith of GOES-8 is 60.14 degrees, while that of GOES 10 is 46.81 degrees.



The satellite viewing directional effects are more pronounced over areas of sparse vegetation and forested areas as the radiometric contributions from soil and vegetation vary with the sun and viewing geometry.

Atmospheric Correction

Many algorithms, including single and multi-channel, have been developed for LST retrieval. Among these, regression algorithms based on the split window (SW) technique have been the most widely used due to their simplicity, effectiveness and robustness. Principally, the SW algorithm employs the brightness temperature (**BT**) 11 μm spectrum as first guess of LST and BT difference at 11 and 12 μm as a correction to atmospheric absorption. Note that the infrared spectrum LST retrieval, such as VIIRS LST, is only available under clear sky condition.



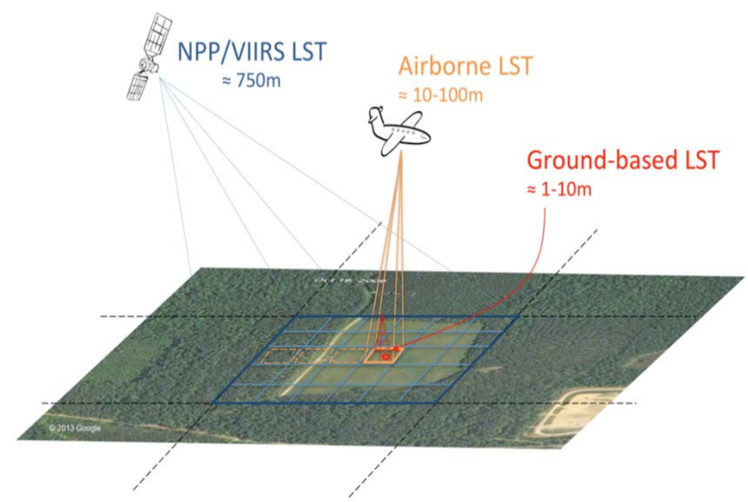
Top: BT difference at daytime. Split-window algorithm feature: brightness temperature (BT) difference at 11 and 12 mm. Bottom left: Significant BT differences over land and sea water surface. However, the BT difference is much smaller over sea surface

Atmospheric correction helps to compensate the atmospheric absorbed surface emission in the LST derivation. The SW approach was first developed for SST retrieval and then inherited for LST retrieval. Results from several studies indicate that the atmospheric correction done by the BT difference in LST retrieval does not work as well as in SST retrieval. Due to emission differences between the ocean surface and land surface, the BT difference over land can be much higher than that over ocean. A big difference in BT can cause the atmospheric correction term in the LST algorithm to introduce significant errors. In this regard, a better atmospheric correction method is needed.

Challenges in LST Product Validation

Validation of satellite-derived LST is often a challenge, so aside from issues in algorithm development, scientists must also contend with those encountered during validation. Validation assures that a product, service or system meets the needs of the customer and other identified stakeholders. It is therefore a very important task because without it, the uncertainty and accuracy of satellite-derived data cannot be verified. Moreover, this data cannot be used with confidence to gauge their closeness to ground observations.

[24]*In-Situ Validation*

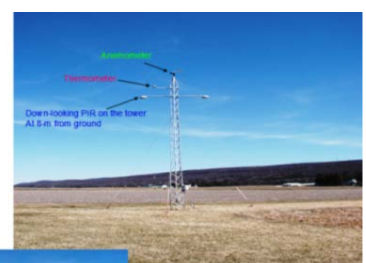


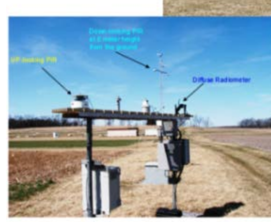
Impact of the spatial resolution on the LST derived from satellite, aircraft and ground station measurements.
The up-scaling approach is based on a physically based land surface model that uses ground measurements and within pixel information to describe satellite footprints over ground stations. Guillevic et al., RSE, 2012

Traditionally, validation of satellite LST products is performed by comparing the LSTs derived from satellite data to the LSTs estimated from ground in situ measurements. However, due to a small scale variation feature of the LST over most land surfaces, the satellite derived LSTs tend to differ significantly from in-situ LSTs. The challenge then becomes how to link ground-based measurements and satellite products at moderate resolution. LST can vary significantly within a pixel area and change within relatively a short time period, which complicates the validation process even further.

Scaling Issues

Additional issues encountered in validating satellite-derived LST using in-situ data include measurement difficulties, emissivity directional impact, and the effect of cloud contamination; and spatial and temporal variations which can lead to inaccurate emissivity information. But still more problematic is that the number of high quality in-situ observations that match satellite observations in both time and space is very limited. Shown on the right is an illustration of spot-pixel measurement difference. For ground sites the LST measured by a station at a specific location does not represent the surrounding area that is part of the coarser satellite sensor footprint. In-situ LSTs are usually collected over a significantly small and homogeneous area that's roughly 0.01 km, whereas





Surface heterogeneity is shown in a 4km x 4km Google map (1km x 1km, in the center box) around the Bondville station area

[24] *Guillevic, Pierre C.; Privette, Jeffrey L.; Coudert, Benoit; Palecki, Michael A.; Demarty, Jerome; Ottlé, Catherine; and Augustine, John A., "Land Surface Temperature product validation using NOAA's surface climate observation networks—Scaling methodology for the Visible Infrared Imager Radiometer Suite (VIIRS)" (2012). Publications, Agencies and Staff of the U.S. Department of Commerce. Paper 381.* http://digitalcommons.unl.edu/usdeptcommercepub/381

satellite-derived LSTs are collected over areas that range anywhere from 1 km and above. Therefore validation sites have to be carefully selected and characterized at the scale of the pixel with ground-reference measurements as well as on the scale of the satellite pixel area.

Cloud Contamination

Clouds affect the retrieval of LST from the infrared channel. LST cannot be calculated under cloudy conditions. Hence most studies focus on its retrieval under cloud-free conditions. A bigger concern however, is for cloud-contaminated pixels, i.e., those pixels that are significantly biased because the LST is retrieved under partial cloudy condition but ends up flagged as cloud-free condition. This limitations stems from the current cloud filtering process, which uses a generic cloud mask product due to its utility in a variety of applications. This calls for better quality of LST retrieval. Thus, a better cloud filtering process is needed for surface temperature retrieval as has been done for SST retrieval. In the presence of clouds, satellite measurements will reflect a combined signature from both clouds and the underlying surface, thus cloudy data must be removed prior to the retrieval of LST.

All the above difficulties must be considered for a reliable satellite LST validation process.

LST from NOAA's Next-Gen Polar Orbiters

LST is one of the land Environmental Data Records (EDRs) for the JPSS mission. The Suomi-NPP VIIRS provides measurements of EDRs – atmospheric, land, and oceanic parameters. The VIIRS LST EDR measures how hot the 'surface' of the earth over global land areas including coastal and inland- water locations to provide key information for monitoring Earth surface energy and water fluxes. VIIRS was designed to improve upon the capabilities of AVHRR, thus the products generated from VIIRS data provide a new source of LST for many applications, including weather forecasting, active fire applications, drought monitoring and land cover mapping.

LST validation is pertinent to product accuracy and to helping understand the limitations and potential of satellite-derived LST. As the VIIRS LST algorithm moves towards operational evaluation by the user community, NOAA scientists are making continuous improvements to it, and monitoring and assessing its performance. This has included global cross satellite comparisons at various spatial and temporal frames between the Suomi-NPP VIIRS and NASA's MODIS-AQUA; and ground in-situ evaluation with the data from the Surface Radiation Budget Network (SURFRAD), as well as ground observations from global sites including Africa. Although there has been significant progress in the JPSS LST product development and validation, complex challenges remain in its development. Several of the issues found are under investigation. Currently, the VIIRS LST is only validated in the U.S. Along the path to operational status, NOAA scientists plan to also perform VIIRS LST validation globally. They also plan to improve the currently implicit LST algorithm to be emissivity explicit, develop an independent emissivity data product (for the emissivity-explicit VIIRS LST retrieval), and perform consistent data product development (i.e. re-process of the VIIRS LST data). While the assessments of the VIIRS LST have not been without challenges, their outcomes have rendered more opportunities for further improvements of the VIIRS LST algorithm. More importantly, they have yielded a new source of satellite derived LST for use in many applications, including weather forecasting and drought monitoring.

Summary

LST plays a key role in many meteorological, hydrological, and climatology applications. It is a key indicator of the Earth's net radiation budget at surface as well as an important indicator of both the greenhouse effect and the energy flux between the atmosphere and the land. It is also used to monitor the state of crops and vegetation on the planet. LST can be derived directly from ground measurements or remotely from satellite measurements. However, high-quality LST from ground measurements, and especially in remote areas in remote areas, suffer from operational constraints, and remain scarce due to the sparse density and uneven distribution of ground stations. These circumstances make it practically impossible to measure LST from ground-based instruments at the regional and global scales. Thus, satellites provide the most practical means of obtaining LST on such scales. Notwithstanding, there are enormous challenges to overcome before an accurate LST can be derived from satellite measurements. Retrieving and validating LST remains challenging tasks. Not to mention, satellite derived LST has shown to have much greater uncertainty than SST, making it harder to use within forecasting operations. Nonetheless, satellite-derived LST products have significant utility in applications of hydrology, meteorology, and climatology.

The accurate measurement of LST from satellites requires the effective removal of cloudy radiances (cloud clearing), compensation for the attenuation introduced by the atmosphere, and some consideration for the spectral variation of surface emissivity for different surface types. For LST data from the VIIRS sensor, future improvements are planned to further enhance its utility. These include a global VIIRS LST validation, and emissivity explicit algorithm, an independent emissivity data product, and consistent data product development. More importantly, because LST is one of the key products in both the JPSS and GOES-R missions, it is crucial to keep improving the retrieval algorithm and monitor the LST product once it is in operational mode. The VIIRS LST product is expected to be used in various applications including, weather forecasting models, agriculture monitoring, drought prediction and monitoring, ecosystem monitoring, and climate studies.

JPSS Science Feature Articles: Communicating the Benefits and Performance of JPSS Data, Algorithms, and Products

*This article is based in part on the **September 28, 2015** JPSS science seminar presented by Julie Price, Science and Technology Corporation (STC).*

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

Satellite data has become a critical component of both today's forecasts from numerical weather prediction models and long-term monitoring of climate. Data from the NOAA satellites have made essential contributions to the nation's weather and climate monitoring capabilities. The resulting data from satellites provide a wealth of observations that have been used in a broad range of applications including weather analysis and forecasting, monitoring air quality, coral reefs, harmful algal blooms, wildfires, and volcanic ash; global vegetation analysis, and ocean dynamics research. They have even been used to predict potential outbreaks of vector-borne diseases like malaria. To capture this wide range of capabilities and their applications, the Joint Polar Satellite System (JPSS) Program publishes user-focused articles that are shared broadly with the public. The goal of these feature articles is to heighten awareness of the societal benefits derived from applications that utilize JPSS data. This goal is motivated by the NOAA mission statements to "understand and predict changes in climate, weather, oceans, and coasts; and, to share that knowledge and information with others". And to better understand the value of these feature articles, and how they connect to NOAA's mission, it is necessary to start with the JPSS Program and its current satellite the Suomi National Polar-orbiting Partnership (Suomi NPP).

The Suomi NPP Satellite – the first next generation spacecraft in the JPSS series – was launched in Oct 2011. It was declared NOAA's primary weather satellite in May 2014. In all, JPSS is equipped with five state-of-the-art instruments: the Visible Infrared Imaging Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS), the Ozone Mapping and Profiler Suite (OMPS), and the Clouds and the Earth's Radiant Energy System (CERES). Data from the CrIS and the ATMS are assimilated

These seminars are a useful mechanism for NOAA scientists and their affiliates to present their JPSS PGRR science activities, including scientific results, issues and related success stories. A question and answer session at the end of each presentation encourages ongoing reflection and engagement with the diverse audience participating in person or via a web collaboration tool.

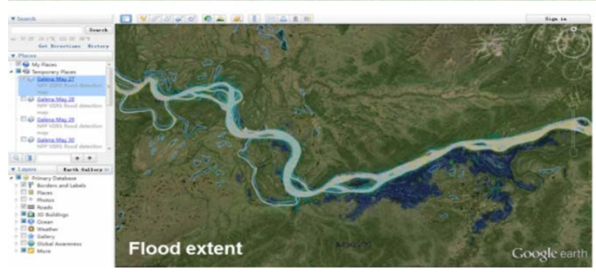
The science seminar webpage (screenshot shown right) provides information on upcoming seminars, featured speakers, and discussion topics. It provides an abstract with details of each seminar, and instructions on how to participate either in person or remotely. In addition, the slides from each completed seminar are then made available for download.

Screenshot of the science seminar webpage
http://www.jpss.noaa.gov/science-seminars.html

To date, opening up the JPSS science seminars to a wide and diverse external audience, has become an increasingly popular means of ensuring access, to the science taking place in the PGRR Program.

Science Feature Articles

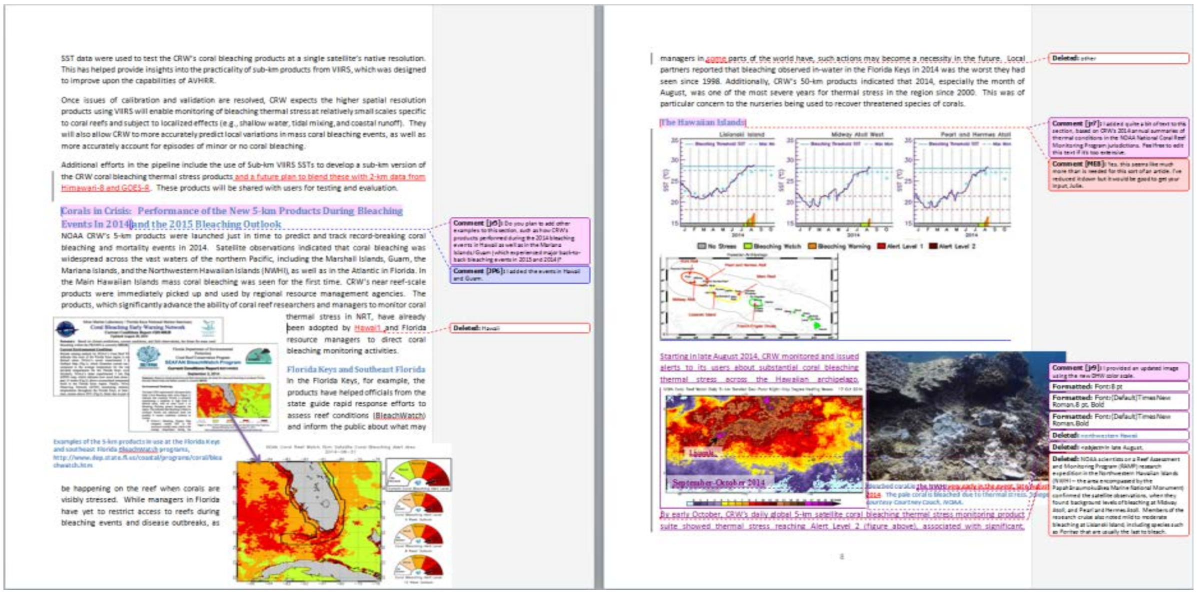
Shortly after the advent of the Science Seminars another communication initiative was begun. Using the information from the Science Seminars as a foundation, Program Science feature articles were created to enable the JPSS Program to build awareness and facilitate public understanding of the JPSS PGRR through science discussions, and descriptions of the instruments such as VIIRS, ATMS and CrIS. Societal benefits are sometimes conveyed through examples of the operational use of sensor capabilities. Prominent examples include the VIIRS DNB, which leverages reflected moonlight, in addition to emitted light from cities and fires, to sense clouds, fog, and other Earth features such as snow cover; or ATMS which can view inside and below clouds, and therefore and can be used to produce images inside storms, including hurricanes. These articles are designed to provide an easy-to-read reference on PGRR activities, and document the societal benefits demonstrated by the operational use of JPSS data. The feature articles serve as a source of information for various audiences ranging from Congress, DOC, and NOAA to a science-interested public. They are also key distribution documents at national and international conferences including the American Meteorological Society (AMS) annual meetings, and the biennial NOAA Satellite Conference (NSC).



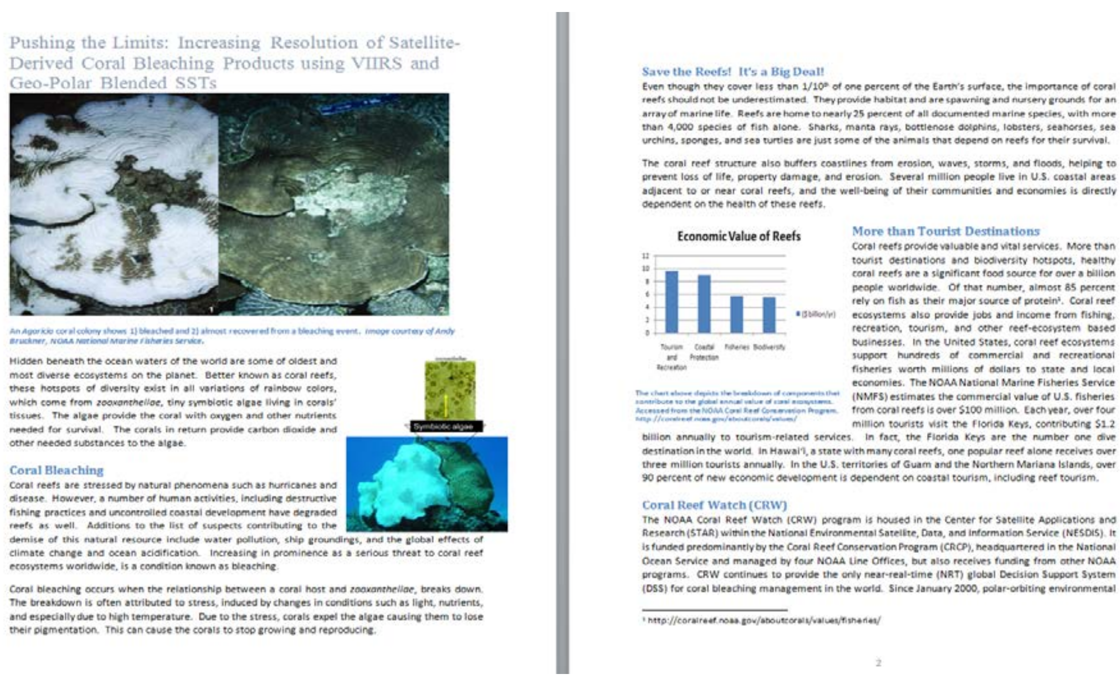
The feature articles contribute to the discussion of science through concrete examples from real people. For example, in May 2013 during river ice breakup, the VIIRS false-color and reflectance imagery was extremely helpful in identification of river flooding due to ice jams along the Yukon River. A colossal ice jam formed

along Bishop Rock – a sharp "S" bend in the river -- downstream of village of Galena on the Yukon River. This caused the waters to rise above the river banks, and ultimately led to historic record flooding that devastated the village. VIIRS can identify river ice jams which can lead to large flood events. Moreover, flooding from ice jams can occur in a very short span of time.

From Rough Draft to the Annual Digests



The Feature articles are developed by JPSS Program Science Staff in collaboration with PGRR principal investigators and staff. As with any writing process, the first step in developing the articles involves gathering source information, which includes a review of existing literature. The primary material comes from the seminar briefings, while secondary material comes from various sources including PGRR project information, journal articles, textbook material, the internet, and Subject Matter Expert (SME) blogs. The program science writers then write the first draft for review. During this review phase the writers consult the experts, brainstorm within the program science staff, and write text with SME input and guidelines. Above and below are screenshot examples of an article in the draft and press-ready formats.



This particular article "Pushing the Limits: Increasing Resolution of Satellite-Derived Coral Bleaching Products Using VIIRS and Geo-Polar Blended SSTs" showcased the NOAA Coral Reef Watch (CRW) program, which provides bleaching alerts that help support management responses to one of the greatest threats facing coral reef ecosystems – coral bleaching. This article also highlighted how NOAA CRW's 5-km products – derived using SST measurements from various sensors including VIIRS – were launched just in time to predict and track record-breaking coral bleaching and mortality events in 2014.

The first Program Science feature article made its debut in 2013. Since then 35 features stories have been produced. Even though the articles exist as discrete units, they are also the building blocks of the JPSS annual science digests. Every December, the articles created during the year, are synthesized into an annual science digest. These digests communicate the importance of JPSS for user applications, and also allow readers to further explore the JPSS PGRR. To maximize their utility these digests are freely available to all.

Summary

The successful launch of Suomi NPP has led to massive amounts of innovative new data becoming available to agencies and organizations in the U.S. and around the world. The JPSS PGRR Program has been highly successful in bringing program scientists and data users together to optimize the use of current capabilities and identify new ways of using this data. The JPSS science seminars and feature articles have proven critical to communicating the effectiveness of these applications. Through the monthly Science Seminars, NOAA scientists and their affiliates are able to present their JPSS PGRR science activities. This forum generates important interaction between the JPSS Program, its PGRR Projects, interested scientists and the public. The feature articles, which build upon the information presented in the seminars, seek to reach an even wider audience base and further promote the message presented in the science seminars. The associate feature articles detail and describe how the wealth of data from JPSS is used to respond to high-visibility, rapidly changing environmental crises. They also give readers (often the general public) some "behind the scenes" insight into science processes that are typically restricted to the PGRR. This insight, along with the illustrative examples of the positive impact JPSS has on users' problem scenarios, have become key Program Science contributors of essential information in support of NOAA's mission to share environmental knowledge and information with others. A steady rise in seminar attendance, positive audience feedback, along with an increase in demand for the feature articles and annual digests confirm that they are and will remain important communication channels for years to come.

Seminar briefings from November 2012 to the present are available at http://www.jpss.noaa.gov/science-seminars-archive.html. In addition, copies of the annual science digests are also are available for download at http://www.jpss.noaa.gov/science_digest.html.

Web Features

March 31, 2015

Preserving Our Coral Reefs

How NOAA's Polar-orbiting Satellite Data are used to Help Reef Conservation Around the World

The NOAA/NASA Suomi NPP satellite's Visible Infrared Imaging Radiometer Suite (VIIRS) instrument helps improve NOAA's ability to track coral reef health.

The National Environmental Satellite Data Information Service's (NESDIS) Coral Reef Watch (CRW) effort, with support from the NOAA Coral Reef Conservation Program, produces information to help protect coral reefs. CRW uses remote sensing and in-situ tools for near-real-time and long term monitoring, modeling and reporting of physical environmental conditions of coral reef ecosystems.

Credit: NOAA

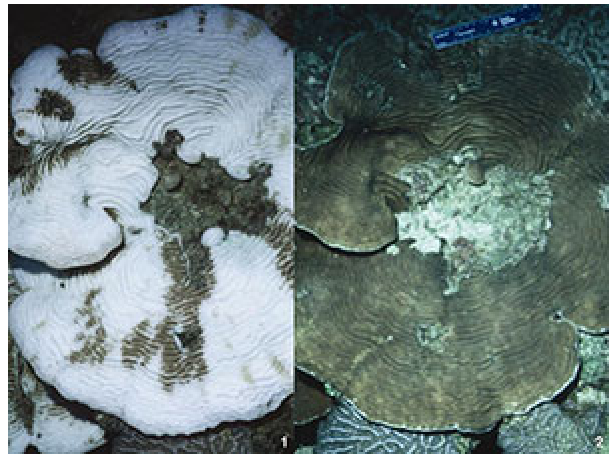
CRW is using a blend of polar-orbing satellite data from NOAA POES, VIIRS data and NOAA GOES satellite data for Sea Surface Temperature (SST) analysis. This provides a 100-fold improvement in spatial resolution over earlier products, giving scientists crucial information to track reef health around the globe. For the past 15 years, CRW has provided coral reef managers, scientists, and the public with satellite-based products, maps, and alerts when high SST are present, a key cause of coral bleaching. CRW recently released its Coral Bleaching Thermal Stress Outlook which forecasts the potential for coral bleaching up to four months in the future.

The new products were made available to users in the summer of 2014, just in time to document record-breaking coral bleaching on the Main and Northwestern Hawaiian Islands, Commonwealth of the Northern Marianas Islands, and significant bleaching in Guam and Florida and were immediately picked up and used by regional resource management agencies.

These new blended SST products help reduce missing data caused by cloud coverage over the oceans. This is particularly vital in areas such as the "Coral Triangle," which consists of the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon

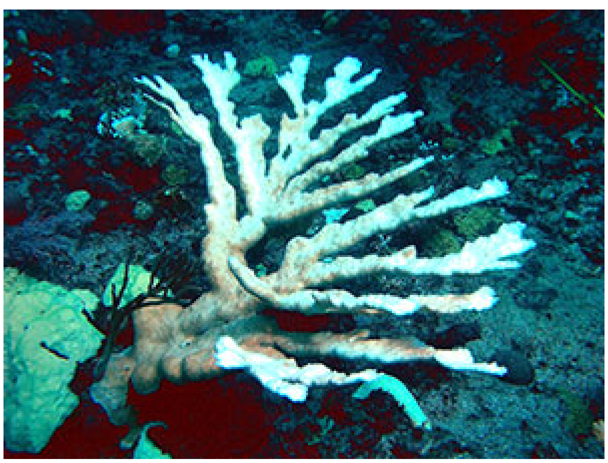
Islands and Timor-Leste that had six months of persistent cloud cover in 2010. The VIIRS instrument provides data for the ocean, land, aerosol, and cloud research and offers improved spatial resolution, which is a substantial improvement for coastal and estuarine areas in particular.

Coral reefs are often called the "rainforests of the sea," as they are some of the most biodiverse and productive ecosystems on earth, occupying only 0.1 percent of the ocean, yet home to a quarter of all marine species. Crustaceans, reptiles, seaweeds, bacteria, fungi and over 4000 species of fish call coral reefs home. Coral reefs are estimated at an annual global economic value of $375 billion, and provide food and resources for over 500 million people in 94 countries and territories[25].



An Agaricia coral colony shown: 1) bleached, and 2) almost fully recovered, from a bleaching event. Credit: Andy Bruckner, NOAA's National Marine Fisheries Service.

Coral bleaching occurs when corals are stressed by changes in conditions such as temperature, light, or nutrients, and they expel the symbiotic algae living in their tissues, causing them to turn completely white. As temperatures rise[26], mass bleaching and infectious disease outbreaks are a potential consequence that could become more frequent. In 2005, the U.S. lost half of its coral reefs in the Caribbean in one year due to a massive bleaching event[27].



Bleached Elkhorn Coral
Credit: NOAA

Coral reefs are also affected directly by changes in carbon dioxide (CO_2). When CO_2 is absorbed into the ocean from the atmosphere, it alters seawater chemistry through decreases in pH (ocean acidification). This slows the rate at which corals and other reef-building organisms can build their skeletons and shells.

With 75 percent of the world's coral reefs at risk from local and global stresses, and 10 percent already damaged beyond repair, JPSS data are critical for researchers to understand and better manage the complex interactions leading to coral bleaching[28]. When bleaching conditions

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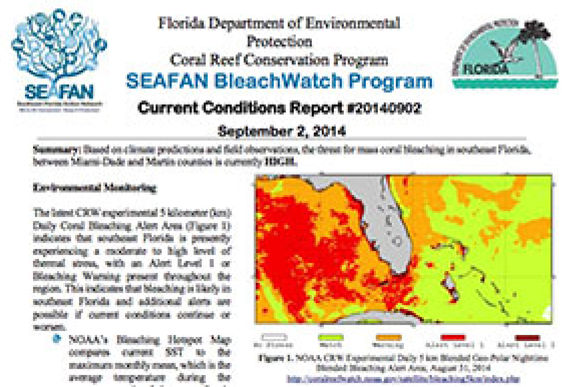
25 http://www.wri.org/publication/reefs-risk-revisited
26 The U.S. Global Change Research Program, National Climate Assessment, 2014 http://nca2014.globalchange.gov/highlights/report-findings/oceans#intro-section-2
27 http://oceanservice.noaa.gov/facts/coral_bleach.html
28 http://www.wri.org/publication/reefs-risk-revisited

occur, these tools can be used to trigger bleaching response plans and support appropriate management decisions.

JPSS represents significant technological and scientific advances in environmental monitoring and will help advance weather, climate, environmental and oceanographic forecasting and monitoring. JPSS delivers key observations for the Nation's essential products and services, including forecasting severe weather like hurricanes, tornadoes and blizzards days in advance, and assessing environmental hazards such as sea ice, droughts, forest fires, floods, poor air quality and harmful algal blooms in coastal waters, helping to secure a more "Weather-Ready Nation."

JPSS enables scientists and forecasters to monitor and predict weather patterns with greater accuracy and to study long-term climate trends by extending the more than 30-year satellite data record. NOAA is responsible for managing and operating the JPSS program, while NASA is responsible for developing and building the JPSS satellite and ground system.


Florida Department of Environmental Protection
Coral Reef Conservation Program
SEAFAN BleachWatch Program
Current Conditions Report #20140902
September 2, 2014

Summary: Based on climate predictions and field observations, the threat for mass coral bleaching in southeast Florida, between Miami-Dade and Martin counties is currently HIGH.

Environmental Monitoring

The latest CRW experimental 5 kilometer (km) Daily Coral Bleaching Alert Area (Figure 1) indicates that southeast Florida is presently experiencing a moderate to high level of thermal stress, with an Alert Level 1 or Bleaching Warning present throughout the region. This indicates that bleaching is likely in southeast Florida and additional alerts are possible if current conditions continue or worsen.

- NOAA's Bleaching Hotspot Map compares current SST to the maximum monthly mean, which is the average temperature during the

A Coral Reef Conservation Program Warning Report from September 2014 sent to regional resource management agencies. Credit: Coral Reef Watch

To learn more about the Coral Reef Watch and their use of JPSS data visit, "Pushing the Limits" Increasing Resolution of Satellite Derived Coral Bleaching Products using VIIRS and Geo-Polar Blended Sea Surface Temperatures.

Full story can be read online at this link:
http://www.jpss.noaa.gov/news_archive.html?story=news-59&year=2015

June 9, 2015

JPSS Data Used for Predicting and Monitoring Atmospheric Rivers

Severe rainfall events have the potential to result in loss of life and destruction of homes and property. A flood occurs somewhere in the United States or its territories nearly every day of the year[29]. The past 30 years of flood data has shown an average of 82 fatalities and $7.98 billion in damages per year[30]. Flooding occurs when water enters watersheds too quickly for the land to absorb it or managed reservoirs to store it, which can be particularly treacherous following drought conditions.

The impact of severe weather events like droughts and subsequent floods and landslides during heavy rain show that the ability to predict and track weather systems is becoming more critical than ever. The NOAA/NASA Suomi NPP satellite's Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) instruments help forecasters and scientists to monitor and predict drought related weather patterns like Atmospheric Rivers (AR) with greater accuracy. Recent studies have shown that ARs have broken 40 percent of California droughts since 1950[31]. In February 2015, Northern California was barraged by ARs known as the Pineapple Express. The storms caused heavy rains, damaged trees and power lines and impacted travel.

A home damaged by a mudflow is pictured in the area of the 2013 Springs Fire, in Camarillo, California, Dec. 2, 2014. The area was under mandatory evacuation as a powerful winter storm brought heavy rain to southern California burn areas in Ventura, Los Angeles, Orange and San Diego counties.

CREDIT: Jonathan Alcorn/Reuters

ARs are relatively narrow regions in the atmosphere that are responsible for most of the horizontal transport of water vapor outside of the tropics. ARs that contain the largest amounts of water vapor, the strongest winds, and stall over watersheds vulnerable to flooding can create extreme rainfall, and floods causing landslides. Aerosols from local sources (such as dust and

[29] http://www.nws.noaa.gov/com/weatherreadynation/news/140314_flood.html#.VVuU3flViko
[30] http://www.nws.noaa.gov/hic/
[31] http://journals.ametsoc.org/doi/abs/10.1175/JHM-D-13-02.1

pollution) as well as those transported from remote continents can enhance storm development and influence western U.S. precipitation.

The National Weather Service (NWS) can identify the AR phenomena in current numerical forecast models that utilize CrIS and ATMS data, providing forecasters the capability to give advanced warning of potential heavy rain up to five to seven days in advance. NOAA's Unique CrIS/ATMS Processing System (NUCAPS) is an operational algorithm to retrieve temperature, water vapor, and trace gases from the Suomi NPP CrIS and ATMS instruments. Monitoring ATMS microwave satellite imagery provides from JPSS satellites provides advanced warning of the presence and movement of these phenomena in the Pacific. For example, during the winters of 2014 and 2015, with the development of AR observatories, a unique collection of ground-based instruments designed to measure the key atmospheric variables in ARs (e.g., wind profiles and column integrated water vapor content), forecasters have been able to monitor their strength and location as they make landfall, thereby improving short-term rainfall forecasts for flash flooding.

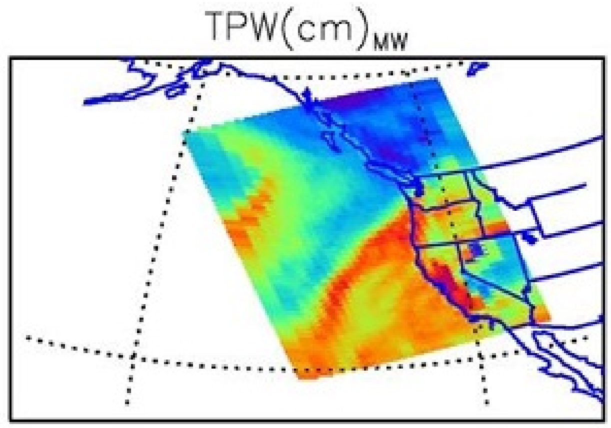
Predicting rainfall totals in these events can be challenging as models must identify the details of the duration, timing, and location of AR's as they make landfall. Developing a better understanding of ARs may help to reduce uncertainties in weather predictions and climate projections of extreme precipitation and its effects, including the status of water supply following drought conditions.

Atmospheric River Observatory, Bodega Bay, California.
CREDIT: Clark King, NOAA

From January- March 2015, NOAA, U.S. Department of Energy (DOE), Scripps Institution of Oceanography, NASA, the U.S. Naval Research Laboratory, and the U.S. National Science Foundation engaged in a field campaign focusing on AR's and aerosols known as CalWater 2015.

CalWater 2015 studies AR and aerosol phenomena through a three-prong coordinated approach, including the deployment of state-of-the art monitoring equipment on-board NOAA Research Vessel Ronald H. Brown, airplanes, and at field sites across California through NOAA's Hydrometeorology Testbeds (HMT) to study water supply availability and the incidence of extreme precipitation events along the West Coast of the United States. The data collected from this experiment will be analyzed and used to help improve precipitation predictions.

CalWater 2015 also benefits from Suomi NPP's satellite data. JPSS program's participation in last year's CalWater campaign suggested that the NUCAPS data from CrIS and ATMS could improve AR forecasts. JPSS provided NUCAPS temperature and moisture data from CrIS and ATMS data to the 2015 CalWater campaign. The data was acquired by direct broadcast antennas in Corvallis, Oregon and Honolulu, Hawaii, which, due to their proximity, enabled the NUCAPS products to show the context of the entire CalWater field campaign region while the aircraft were in flight in near real-time.



Example of the NUCAPS microwave-only total precipitable water for Jan 27, 2015 using data provided by the Oregon State University direct broadcast site in Corvallis. NOAA P-3 was in the air when these data were acquired.

The CalWater 2015 campaign proved that data collected through direct broadcast from Suomi NPP could be used to support future campaign flight operations. More importantly, NUCAPS data will help the CalWater science community to more accurately understand the complex weather system activities associated with the development and landfall of AR phenomena, benefiting weather forecasting.

The full direct broadcast antenna network covers all of North America and provides reliable data to NOAA's National Center for Environmental Prediction to assist in meeting the nation's environmental challenges while also allowing local markets to collect data directly from Suomi NPP.

JPSS represents significant technological and scientific advances in environmental monitoring and will help advance weather, climate, environmental and oceanographic forecasting and monitoring with greater accuracy. JPSS delivers key observations for the Nation's essential products and services, including forecasting severe weather like hurricanes, tornadoes, and blizzards days in advance, and assessing environmental hazards such as, droughts, forest fires, poor air quality and harmful coastal waters, helping to secure a more "Weather-Ready Nation." NOAA is responsible for managing and operating the JPSS program, while NASA is responsible for developing and building the JPSS instruments, spacecraft, and ground system.

For more information on the CalWater Initiatives: http://www.esrl.noaa.gov/psd/calwater.

Full story can be read online at this link:
http://www.jpss.noaa.gov/news_archive.html?story=news-61&year=2015

June 15, 2015

From Sea to Shining Sea: How JPSS Data Support Ocean Ecosystem Health

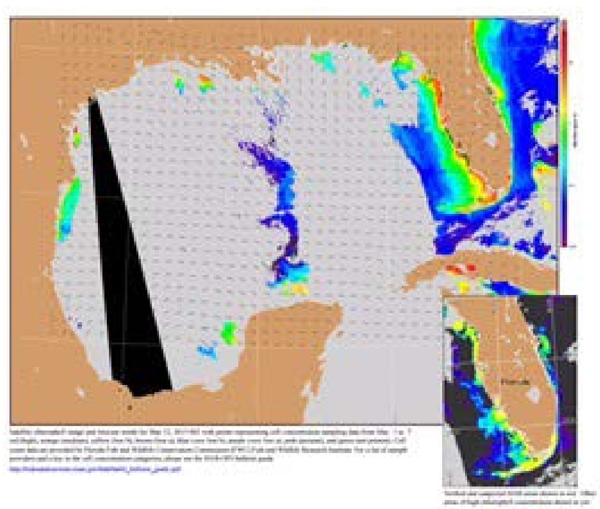
Covering 70 percent of the earth surface, the ocean plays a critical role in shaping our weather patterns and climate, as well as providing vital food resources and global transportation. The global ocean data from Joint Polar Satellite System (JPSS) satellites aid not only in critical weather forecasting, but in the monitoring of oceanic variables and changes. NOAA uses these data to help protect human life, property and endangered aquatic species.

Monitoring Harmful Algal Blooms

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on board JPSS satellites can identify large fields of microscopic algae, which bloom in the ocean surface layer.

When naturally occurring microscopic algae rapidly develop under certain temperature and seasonal conditions, the resulting algal blooms can grow to vast proportions.

Some of these blooms can contain toxins that are harmful to the marine environment. When this occurs, these blooms are called Harmful Algal Blooms (HAB). HABs are known to have devastating impacts on both aquatic and coastal ecosystems.



Gulf of Mexico Harmful Algal Bloom Bulletin, May 11, 2015. CREDIT: NOAA

Significant fish, shellfish, marine mammal and bird morbidity can occur and illness in people can result from breathing toxic air from the blooms or from eating contaminated fish and shellfish. As a result, coastal HAB events cost an estimated at $82 million a year, impacting commercial and recreational fishing, tourism and valued habitats. These impacts affect local economies and the livelihood of coastal residents.

Using JPSS satellite data, NOAA's National Ocean Service (NOS) has created the NOAA HAB Operational Forecast System to provide specific tools and information on localized HAB events.

The program focuses on the Gulf of Mexico, but NOS additionally monitors blooms in the Great Lakes, Northeast, Pacific Coast, Mid-Atlantic/Southeast, and Caribbean/Pacific Islands.

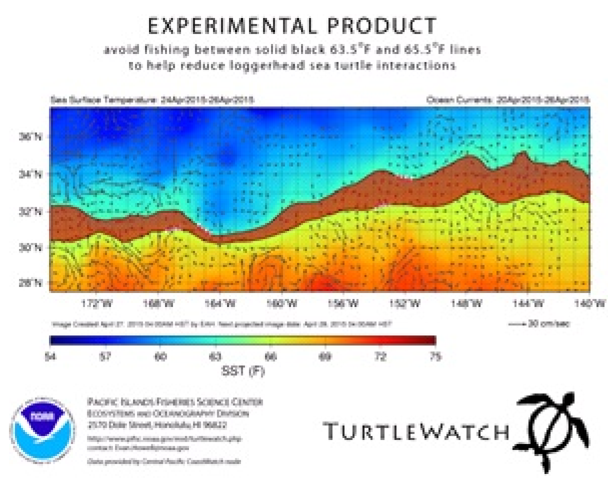
Helping to Protect Endangered Species

JPSS VIIRS data also feeds NOAA's operational global Sea Surface Temperature (SST) data product, which blends data from all active Polar-orbiting Operational Environmental Satellites and Geostationary Operational Environmental Satellites.

Loggerhead Turtle escaping a net equipped with turtle excluder device.
CREDIT: NOAA

Sea surface temperature data are essential to understanding the state of the Earth's weather and climate system, and allow for the monitoring of global marine ecosystems and species. SST data compiled over time reveal surface currents which allows for estimations of the ocean-to- atmosphere exchange of heat, momentum and gases, a critical parameter in both oceanic and atmospheric forecasting. Moreover, this compiled data can be used to monitor anomalies or trends in SST which helps scientists to characterize threats such as coral bleaching or track the habitat of species, such as sea turtles.

Endangered loggerhead sea turtles have been found to prefer temperate waters from 63.5 – 65.5°F. SST information is used to help reduce inadvertent interactions between Hawaii-based longline fishing vessels and the endangered loggerhead turtles as part of NOAA's National Marine Fisheries Service (NMFS) TurtleWatch program. This program provides up-to-date information about the location of this narrow band of loggerhead sea turtle habitat in the Pacific Ocean north of the Hawaiian Islands.

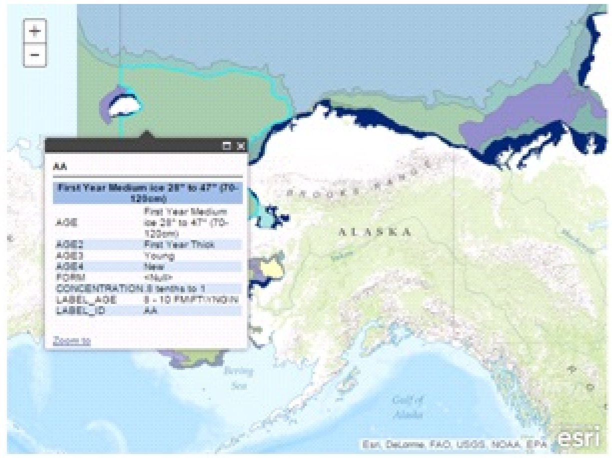


The TurtleWatch product is a composite image of remotely-sensed sea surface temperature (SST) data and derived ocean current vectors. The mapped temperature values represent averages of SST information for the most recently available 3-day period.
CREDIT: Pacific Islands Fisheries Science Center, NOAA

The *TurtleWatch* map displays SST and ocean current conditions and the predicted location of waters preferred by the turtles to help fishermen avoid potentially deadly interactions. NMFS expects these TurtleWatch maps to help reduce the accidental capture of loggerheads by longline fishing vessels pursuing swordfish or other species. Fishermen operate under strict limits on fishing interactions with the turtles, so this helps them as well.

Identifying Safe Passages

The NOAA National Weather Service (NWS) [Weather Forecast Offices](#) (WFOs) in Alaska use VIIRS data to routinely monitor potentially threatening conditions around the arctic ice pack.

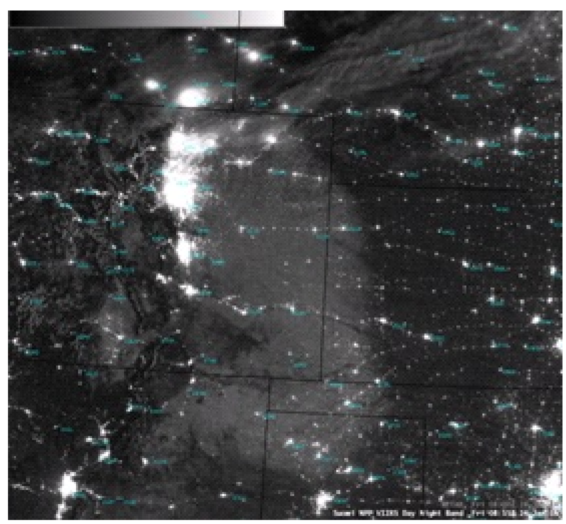


Sea Ice Map.
CREDIT: NOAA

With one of the most productive and sustainable fisheries in the world, the Alaskan marine ecosystem harvests almost six billion pounds of seafood per year. Alaskan residents hold 7,000 commercial fishing permits and nearly 12,000 full-year crew member licenses, meaning many Alaskan lives and livelihoods are dependent upon accurate forecasting of oceanic conditions. With estimated total earnings of $681 million from the fishing industry, monitoring and supporting navigation around sea ice is critical to protecting life and property around the vast Alaskan coastline.

JPSS data are critical to the NWS ice operations, which uses imagery to monitor ice extent as well as potential hazards throughout the region. Forecasters produce graphic analyses of SST, sea ice and five-day sea ice forecasts year-round as a public service to public and private maritime operations. This ice forecast assists fishing and commercial vessels in determining the safest and most efficient route.

JPSS satellite data have also become invaluable to NWS operations because in the arctic winter, it provides Day/Night Band imagery at night using the light of the moon. This type of high- resolution satellite imagery is not available from any other satellite. Imagery from the Day/Night Band on VIIRS instrument enables Alaska WFOs to clearly see high-resolution features throughout the year without sunlight.

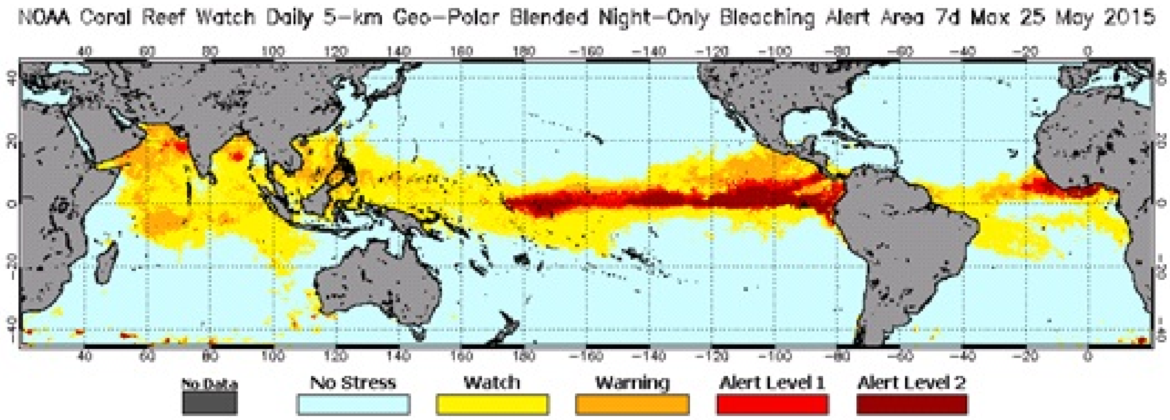


Suomi NPP VIIRS Day/Night Band image shows a broad area of snow cover over parts of the High Plains and Foothills regions of the US.
CREDIT: CIMSS

Monitoring Global Coral Reef Health

The [Coral Reef Watch (CRW) program](#), uses JPSS satellite and in-situ data for near-real-time and long term monitoring of environmental conditions of coral reef ecosystems. Since 2000, CRW has produced satellite-based products, maps, and alerts that identify high SSTs on coral reefs – a key cause of coral bleaching. When bleaching conditions occur that endanger coral health, these tools can be used to support bleaching response plans.

With 75 percent of the world's coral reefs at risk from local and global stresses and 10 percent already damaged beyond repair, JPSS data are critical for researchers to understand and better manage the complex interactions leading to coral bleaching.



Daily 5-km Bleaching Alert Area (7-day max) product for May 25, 2015
CREDIT: NOAA Coral Reef Watch

JPSS data products are an important asset to monitoring and protecting our oceans' ecosystem and global economy by providing timely and high quality data for decision support through significant technological and scientific advances.

JPSS' work to identify HABs and coral bleaching events, assisting in protecting endangered species and monitoring threats around Alaska are just the tip of the iceberg to what JPSS data can help accomplish. JPSS also delivers key observations for the Nation's essential products and services, including forecasting severe weather like hurricanes, tornadoes, and blizzards days in advance, and assessing environmental hazards such as, droughts, forest fires, poor air quality and harmful coastal waters, helping to secure a more "Weather-Ready Nation."

JPSS enables forecasters and scientists to monitor and predict weather patterns with greater accuracy and to study long-term climate trends by extending the more than 30-year satellite data record. NOAA is responsible for managing the JPSS program science, operations and developing parts of the ground segment. NASA is responsible for developing and building the JPSS instruments, spacecraft and ground system.

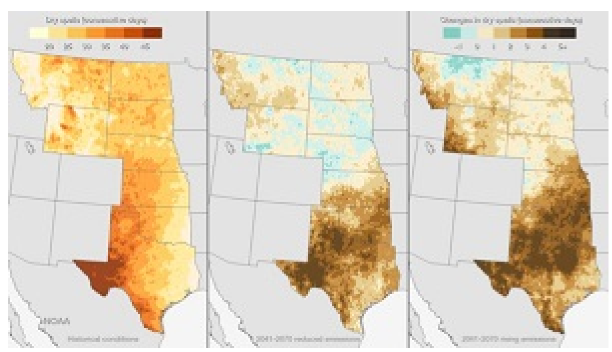
Full story can be read online at this link:
http://www.jpss.noaa.gov/news_archive.html?story=news-62&year=2015

August 4, 2015

During Historic Droughts, JPSS Data Proves Vital

In recent years, droughts have become both more prevalent and severe, wreaking havoc in all 50 states and costing billions of dollars of damage with the heaviest impact to the mid-west, southwest and western regions.

NOAA's National Centers for Environmental Information (NCEI) which monitors and tracks severe weather and climate events dating back to 1980, have recorded 21 droughts in the past 23 years that have exceeded $1 billion in losses. NOAA and its interagency partners are committed to predicting and monitoring drought location, intensity and duration to mitigate such extensive losses. Emergency managers use data from NOAA's Joint Polar Satellite System (JPSS) to plan, predict, and respond to dangerous drought conditions in the United States and throughout the world because of their global coverage.



These maps, adapted from the U.S. National Climate Assessment issued in May 2014, show historical and projected patterns in the number of consecutive dry days experienced in different parts of the Great Plains. The historical map (left) shows the average annual maximum number of consecutive dry days during 1971-2000. Darker shades of orange signify longer dry spells. The projected maps show changes in consecutive dry days for 2041-2070, compared to 1971-2000. One scenario (center) assumes substantial reductions in emissions, and the other scenario (right) assumes continued rising emissions. Credit: NOAA

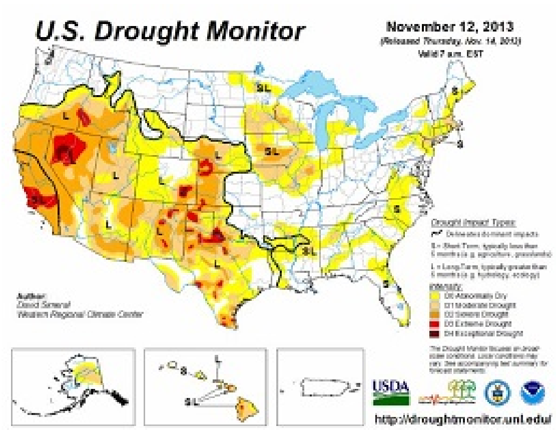
The 2012 drought was the most severe drought in the United States since the 1930's, with 80 percent of agricultural land experiencing drought conditions resulting in costly widespread harvest failure for corn, sorghum and soybean crops[32]. 2013 was less severe yet caused $10 billion in damages and drought conditions have continued with historical severity. For instance, it affected the majority of California for all of 2014, making it the worst drought on record for the state. Surrounding states and parts of Texas, Oklahoma and Kansas also experienced severe drought conditions.

The damage from droughts also causes dry conditions that are prime for wildfires. Drought

[32] http://www.ers.usda.gov/topics/in-the-news/us-drought-2012-farm-and-food-impacts.aspx#.VAYSZDKwL7I

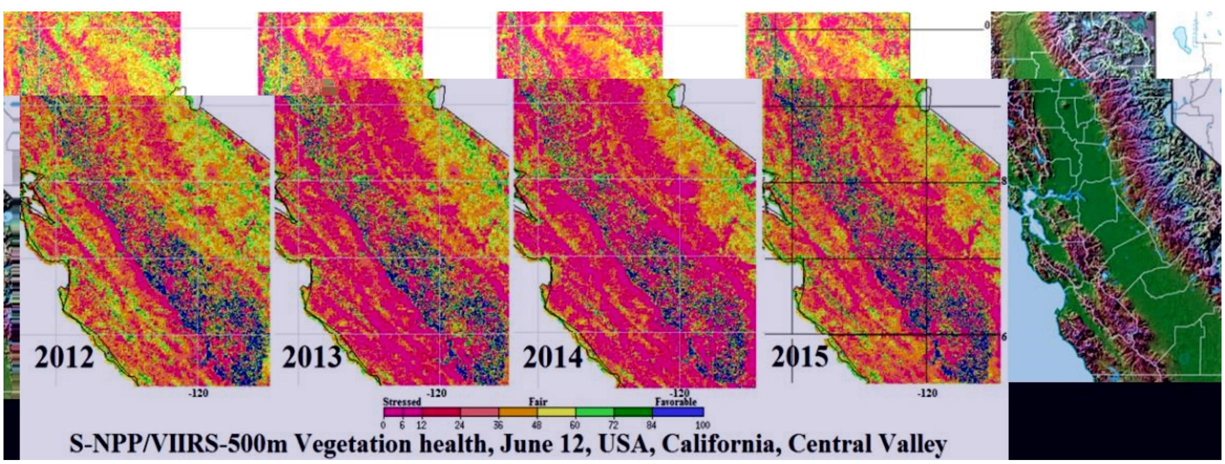
conditions have increased the quantity and magnitude of wildfires in western U.S. forests since the 1970s[33]. The 2012 drought left dry ground conditions that combined with extreme heat and human error caused wildfires that devastated Colorado with fire sizes 1.5 times the 10-year average.

To help monitor and predict drought conditions, scientists will use a complement of JPSS land surface temperature, soil moisture and vegetation products derived from multiple instruments which are assimilated into the Global Land Data Assimilation System (GLDAS) and North America Land Data Assimilation System (NLDAS) systems. The NLDAS is the main information source for the current U.S. Drought Monitor.



“During eight of the last fifteen years large-scale droughts were responsible for huge losses of grain resulting in global production falling below steadily growing consumption,” said Felix Kogan, NOAA Environmental Monitoring Branch Research Scientist. “Since drought prediction is very challenging, drought monitoring and impact assessment are very important to address food security."

There are currently many drought detection and monitoring methods to include the U.S. Drought Monitor, which provide large-scale drought assessments, which media use in discussions of drought and policy makers can use in allocating drought relief. Consistent measurements of drought conditions provide the necessary environmental intelligence data needed to make accurate forecasts and educated decisions.



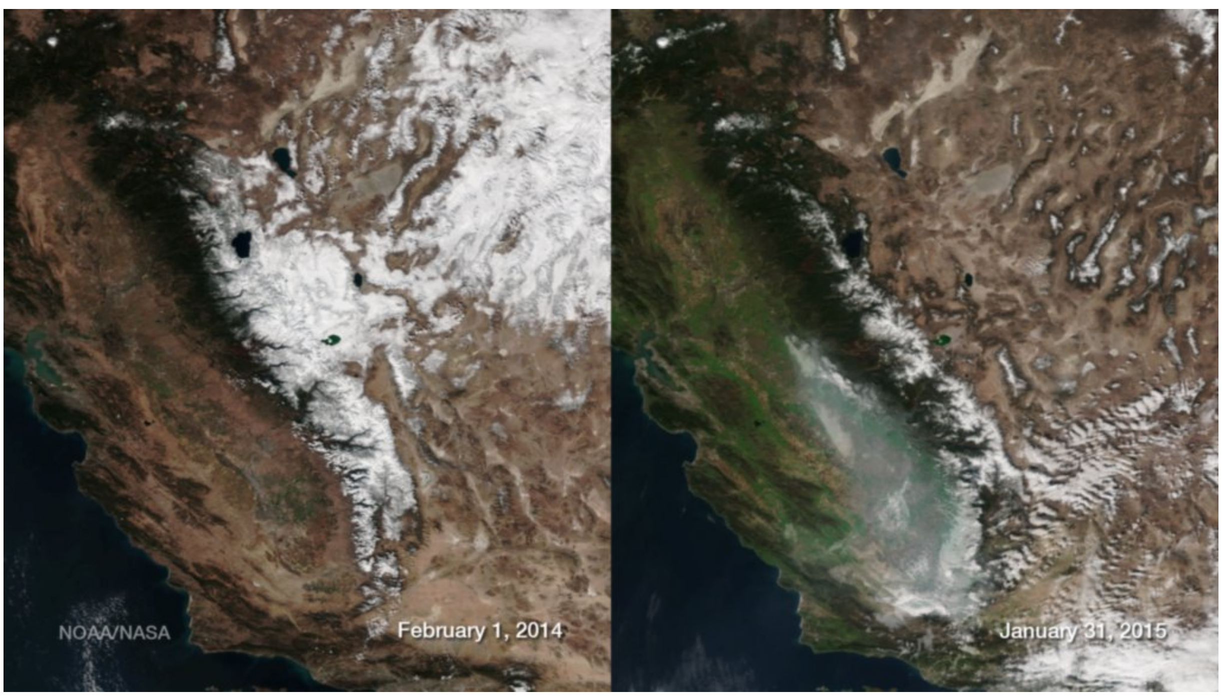
The 2015 drought affected large part of Central Valley, which is the principal agricultural area of California. The image above shows levels of vegetation health and stress in June of each year. The blue areas show where the vegetation is very healthy. These areas are agricultural farms in the central valley being supported by irrigation. The bright pink regions are where the vegetation is in extreme stress and/or the surface temperature is much higher than normal. The map on the far right is a false color topographic reference map, which clearly defines the central valley region. From the images, you can see the effect of late spring 2015 rains which temporarily improved the vegetation condition slightly when compared to June 2013 and June 2014.

[33] http://nca2014.globalchange.gov/report/regions/northwest#narrative-page-17006

Satellites have unique advantages over conventional observations of drought, due to their ability to acquire information over large geographical areas, measure and analyze key features of droughts routinely with relatively high repetition rates, and increased spatial detail of vegetation conditions.

The next-generation instruments aboard satellites in the JPSS constellation provide critical information for drought forecasts that assist in monitoring and predicting drought severity as well as wildfire conditions. Proper drought predictions and monitoring assist farmers in scheduling and maximizing crops, preparing for water conservation actions and securing a more "Weather-Ready Nation."

JPSS' Visible Infrared Imaging Radiometer Suite (VIIRS) instrument will enable the monitoring of the Earth's surface and its surrounding environment. These features in combination with new vegetation health[34] methodologies provide highly valuable assessments of drought start and monitor drought area intensity, duration and impacts on agriculture, forestry, rangeland and other resources and activities. This is very important for such regions as California, where agricultural crops are irrigated. The image below demonstrates observation of changes in vegetation health during June 2015, the tenth year of mega-drought in the western U.S.



Credit: NOAA

A series of atmospheric rivers in December 2014 brought much needed precipitation to a drought-stricken California. The result is a visibly greener land cover in early 2015 compared to the same time the previous year, as seen in these Suomi NPP satellite images. The state, however, is still in an extreme drought, having received very little rain or snow since. This lack of precipitation, along with warmer than normal temperatures, has resulted in much lower

[34] FKI1. http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/index.php

snowpack in the Sierra Nevada Mountains between the two years. Analysis by NOAA confirms that the extent and depth of the snowpack is much less in 2015 compared to 2014 along with higher snowpack temperatures (i.e., melting).

The VIIRS' swath is 1.3 times wider than that of its operational predecessors, has a sharper view of the swath edge, excellent radiometric features, faster data processing and availability, higher resolution of 375m, and more satellite channels across the spectrum. VIIRS is able to provide vegetation health data, with eight times more detail, and at a much higher and more consistent quality. In addition, VIIRS provides multi-year services vital for land cover and climate change detection.

With extreme drought conditions expected to continue, JPSS data is vital for monitoring and understanding drought conditions, aiding forecaster's ability to detect drought events earlier and predict intensity, duration and impacts. Earlier and more accurate predictions help Nation's leaders, decision makers, emergency managers and media to better provide increased warnings to the public-at-large.

For more information about current drought outlooks, visit http://www.climate.gov/news-features/featured-images/data-snapshots-drought-outlook-september-2014.

Full story can be read online at this link:
http://www.jpss.noaa.gov/news_archive.html?story=news-63&year=2015

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Kogan, F., W. Guo, A. Strashnaia, A. Kleshenko, O. Chub, O. Virchenko, 2015, *Modeling and prediction crop losses from NOAA polar-orbiting operational satellites. Geomatics, Natural Hazards and Risk, DOI: 10.1080/19475705.2015.1009178.*
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Kogan, F. and W.Guo 2014, *Early twenty-first-century droughts during the warmest climate. Geomatics, Natural Hazards and Risk.*
http://dx.doi.org/10.1080/19475705.2013.878399 [1]

August 14, 2015

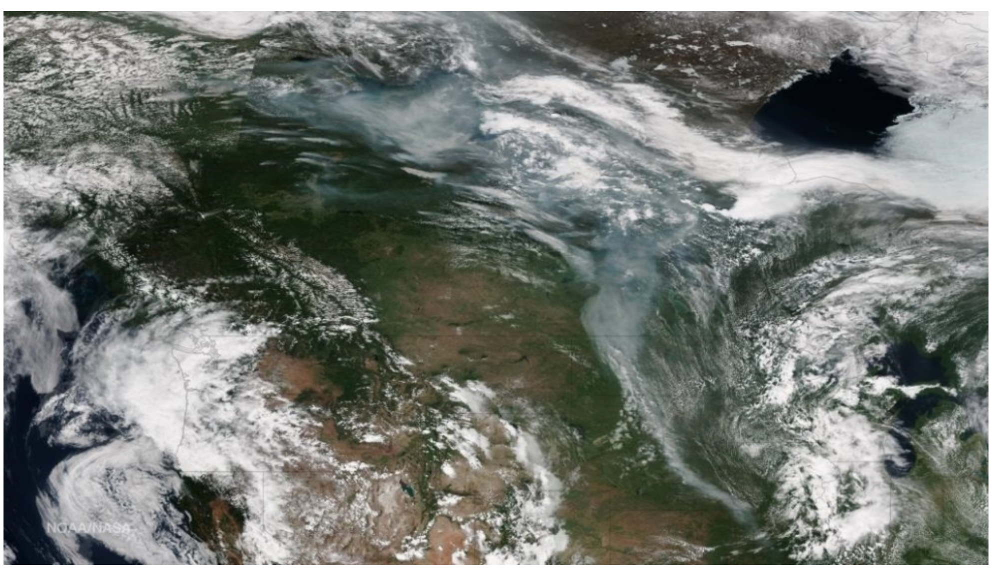
Alaska Firefighters Get Help from NOAA Satellites

5.1 million acres have burned in Alaska in 2015. It's the second highest total on record, eclipsed only by the devastating 2004 fire season, which left more than six million acres burned. And the number of acres burned keeps climbing.

Firefighters with the Alaska Fire Service (AFS) are having a rough time of it, to say the least. With few roads to reach many remote areas, the AFS has to use aircraft to provide supplies to ground crews. But the large drifting smoke plumes can make air travel a hazard, further complicating the ability to deliver supplies to areas in need. **That is why forecasters, using data from JPSS satellites, are helping the AFS stay on top of weather conditions that trigger fires and track the resulting smoke drifting across the state.**

For two weeks during the month of July, JPSS satellite liaison Eric Stevens from the Geographic Information Network of Alaska (GINA) was embedded with AFS.

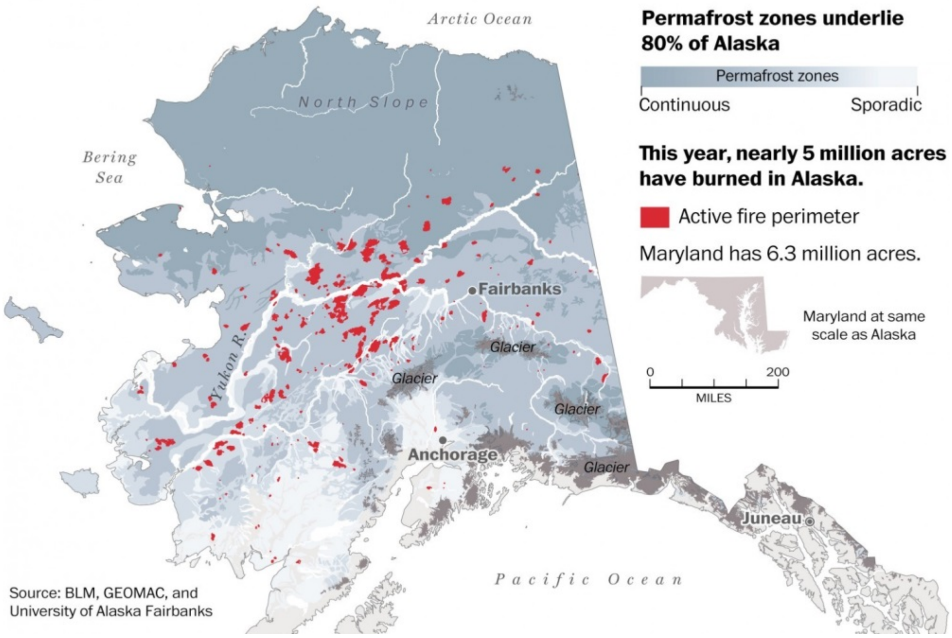
"Alaska is very data-sparse, so imagery from satellites helps fill an important need," said Stevens. "Polar-orbiting satellites like the JPSS series provide very frequent coverage at high-latitude locations like Alaska, so there is a lot of good data to work with."



This image of smoke stretching from fires in Alaska and Canada was captured by the VIIRS instrument on the NOAA/NASA Suomi NPP satellites on June 29, 2015.
Credit: NOAA Visualization Lab.

Because of the

close working relationship between JPSS and AFS, access to operational NOAA satellite data today is better than ever before. In fact, the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument that flies on satellites in the JPSS constellation is now a key contributor to the satellite data products that provide critical observations of fire and smoke across the state.



Credit: University of Alaska, Fairbanks

Full story can be read online at this link: http://www.jpss.noaa.gov/media.html?story=news-64

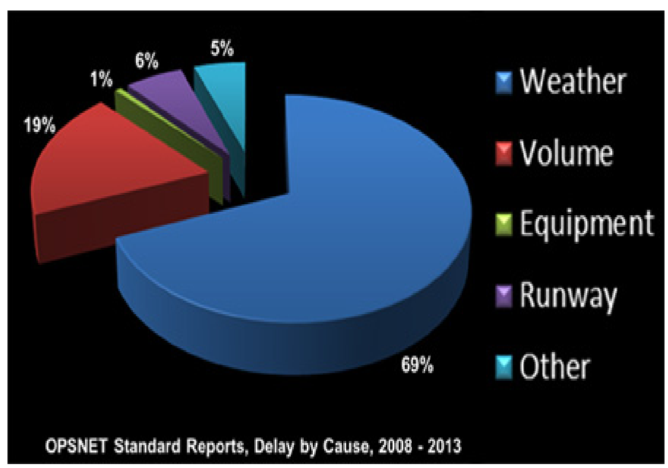
August 18, 2015

NOAA Weather Satellites' Eye on the Sky

August 19th marks National Aviation Day, a United States national observation originally established in 1939 by President Franklin Delano Roosevelt in honor of Orville Wright's birthday. Orville and his brother Wilbur are credited with inventing and building the world's first successful airplane and making the first controlled, powered and sustained heavier-than-air human flight, on December 17, 1903. To prepare for their historic flight, the Wrights contacted the U.S. Weather Bureau, the precursor to NOAA's National Weather Service (NWS), seeking information on locations with sufficient wind conditions to suit their needs.

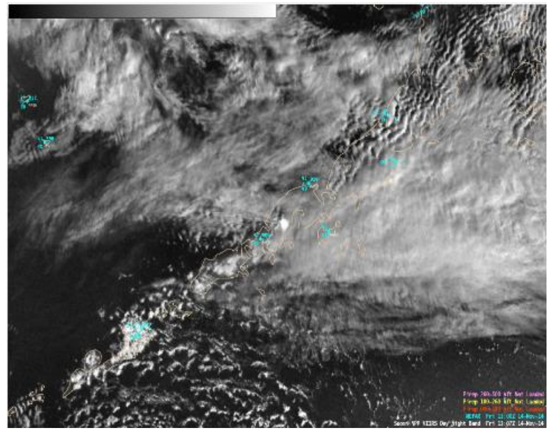
The U.S. Weather Bureau created the first official aviation weather forecast for the Aerial Mail Service route from New York to Chicago on December 1, 1918. In the early years of forecasting, meteorologists used basic tools like kites and balloons flown with instruments attached to forecast temperature and wind direction to create aviation forecasts. NOAA's NWS now uses advanced satellite data to support all aspects of flight, from planning, takeoff and departure, en route, and through arrival and landing.

NOAA's polar orbiting environmental satellites (POES) and geostationary operational environmental satellites (GOES) weather satellites, like the Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellites – R Series (GOES-R), will provide vital observations of issues such as turbulence, icing, thunderstorms, and low ceilings and visibility as inputs to NWS aviation weather analyses and forecasts. Airline delays in the National Airspace System due to these weather issues have steadily decreased over the last five years but still constitute the majority of all delays with over 192,000 weather delays occurring last year. The data from NOAA weather satellites are used to create products for specific conditions and locations to predict and monitor dangerous weather conditions.



Causes of air traffic delay in the National Airspace System. Credit: Federal Aviation Administration

Observing Alaska



Nighttime images of Suomi NPP VIIRS Day/Night Band of an eruption of the Pavlof Volcano on November 13, 2014.

In Alaska, JPSS provides critical data for nearly all of the weather forecasting for aviation, filling gaps over areas that are not adequately covered by conventional observing systems. Aviation touches all aspects of life in Alaska, and is a basic mode of transportation because approximately 90% of Alaska is not served by roads. Alaska has six times as many pilots per capita and 16 times as many aircraft per capita when compared to the rest of the United States[35].

The north Pacific air routes connecting Alaska to the Far East carry 10,000 people per day and up to 50,000 aircrafts per year.

Polar-orbiting satellite products enable forecasters at NOAA's Alaska Aviation Weather Unit to provide critical aviation forecasts and more effective aviation warning support. Alaska's high latitude location ensures that it receives data from multiple polar-orbiting passes every day, helping this critical data offset the lack of ground-based and radar observations. Aviation in Alaska is impacted by everything from low cloud and fog, icing, turbulence, extremely cold temperatures, and volcanic ash. The Suomi-NPP satellite, with its advanced imager and sounder products, has proven to be a vital information source for Alaskan aviation forecasters.

Monitoring Volcanos and Volcanic Ash

Only 10 percent of the world's volcanoes are routinely monitored from the ground, making satellites the only frequently available tool that can reliably identify volcanic eruptions anywhere in the world. Advanced analysis of data from polar orbiting and geostationary satellites reduces the probability of a disastrous and/or costly aircraft encounter with volcanic ash and helps to minimize the cost associated with avoiding volcanic ash. Volcanic ash is extremely harmful to jet engines, and can melt and congeal within turbines and other parts, causing rapid engine failure. For this reason it is vital that the height and extent of volcanic ash be accurately forecast. Tools from new, high-resolution satellite instruments like those on GOES-R and JPSS will help make this possible.

Aircraft damage due to volcanic ash.
Credit: NOAA National Weather Service, Gary Hufford

Volcanic ash is often spread far beyond the erupting volcano, leading to airline delays and cancellations. In 2010 the Eyjafjallajökull volcano in Iceland erupted,

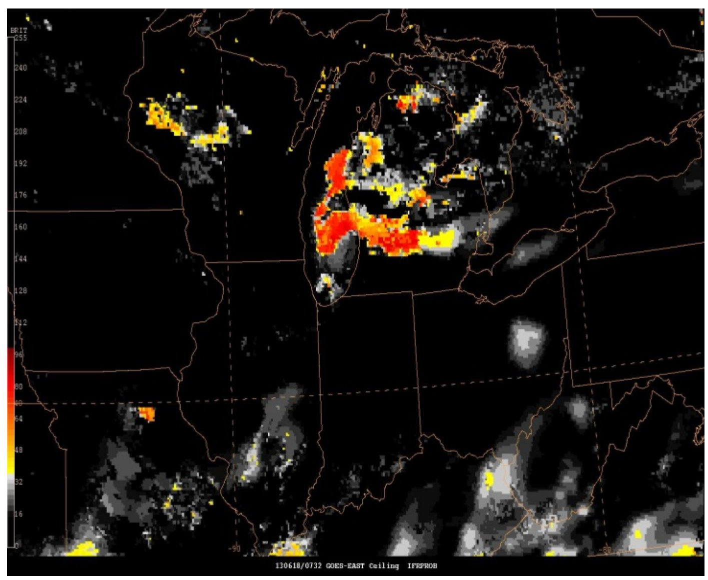
[35] *"Flying in Alaska" from The Ninety-Nines, Inc. Alaska Chapter. http://www.ak99s.org/flyalaska.html*

causing a six-day travel ban over the controlled airspace of many European countries. The data given to the air traffic control organizations provided the information they needed to make the decision to divert and ground more than 4,000 flights. The ban was in effect to address the possibility of volcanic ash ejection causing damage to aircraft engines and risking human life. This was the largest air-traffic shutdown since World War II, costing $1.7 billion in losses for the airline industry, as well as innumerable losses within freight imports and exports; tourism industries and the access to fresh food and essential goods.

Data from NOAA satellites are used to create volcanic ask detection and property products for the Volcanic Ash Advisory Centers (VAAC). The VAAC advisory data is given to the air traffic control organizations to determine when it is necessary to divert and ground flights. For example, data from the Ozone Mapping and Profiler Suite (OMPS) onboard the Suomi-NPP satellite is used to track and monitor volcanic emissions that may impact aviation. Researchers at the University of Wisconsin-Madison Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies have designed a series of operational products utilizing satellite data that derive the height and particle size of volcanic ash, while also accurately showing its spread.

Capturing Fog Conditions

Fog conditions occur when clouds begin within 50 feet of the surface which impacts visibility and can affect a pilot’s ability to take off or land safely, causing delays and lost revenue. Data from polar-orbiting and geostationary satellites data are combined with models and used to create a joint Fog and Low Stratus (cloud) product to provide a probability of Instrument Flight Rule (IFR) conditions. IFR conditions are regulations established by the Federal Aviation Administration (FAA) to govern flight conditions in which flight by outside visual reference is not safe.



June 18th, 2013 – Fog and Low Stratus over Chicago O’Hare Airport

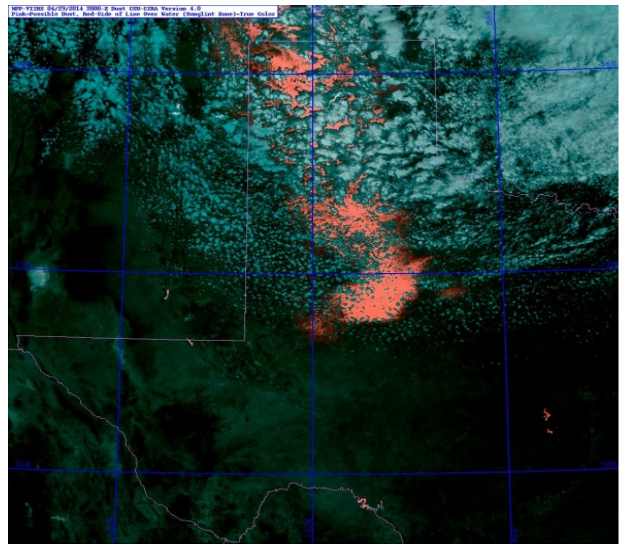
The Fog and Low Stratus product proved effective early in the morning of June 18th, 2013, where it showed IFR probabilities greater than 80% over Lake Michigan and moving southwest towards Chicago airspace.

A National Aviation Meteorologist was monitoring Fog and Low Stratus product and noticed low ceilings would begin to impact the airspace around the Chicago Midway International and Chicago O’Hare International Airports. These conditions were not reflected in other forecasts which showed clear skies. The National Aviation Meteorologist shared the critical information from the Fog and Low Stratus product with the FAA.

Using the new information, the FAA, airports and airlines were able to create a new plan of action for air traffic. This information allowed the airlines to stagger plane arrival windows and increase the amount of fuel onboard, to allow for extra holding time to avoid causing planes to divert and waste more fuel. Roughly 60 flights were able to land under these conditions without diversions, saving around $600,000.

Predicting Thunderstorms

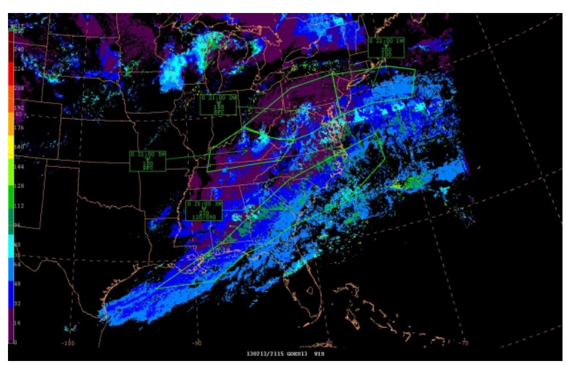
During the summer months thunderstorms affect air travel the most[36]. When air traffic managers are dealing with thunderstorms impacting airspace, one of the most important things that they consider is where the top of these storms are located. Currently they rely on tools like a radar echo tops algorithm, which determines the top of the precipitation within the core of a thunderstorm). However, this is difficult in radar sparse areas and areas with few observations (i.e. over large bodies of water) where the satellite derived cloud altitudes or tops become very useful. Using cloud property retrievals from geostationary satellite data, the algorithm estimates the top of the convective cloud and is not hampered by the same radar and observation limitations, helping to predict and monitor dangerous storms.



VIIRS/MODIS dust enhancement imagery over Eastern Colorado and Northern Texas.

Calculating Dust Storms

While blowing dust events are not a frequent occurrence over the U.S., they can cause significant impact to aviation. Dust reduces visibilities just as much as a snowstorm, but while snow is easy to identify on radar, dust is not. It is even more difficult to detect using generic satellite imagery. However, high-resolution satellite imagery from JPSS has changed this.



Feb. 13th, 2013 Icing bases

Using visible and infrared bands from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument, researchers from the Cooperative Institute for Research in the Atmosphere (CIRA) developed an algorithm to differentiate between cloud and dust, and enhance the latter. In April of 2014, a weekend-long dust event occurred over eastern Colorado and northern Texas. With a strong low pressure system moving across the center of the country and winds in excess of 70 mph, coupled with an

[36] http://www.faa.gov/nextgen/programs/weather/faq/

ongoing drought, dust was immediately lofted. However, given existing cloud cover and the fine particles of the dust, it was extremely difficult to see on satellite imagery. Subsequently it was very difficult for aviation forecasters to issue advisories for the blowing dust. Using the CIRA algorithm they were able to take a look at the dust enhancement and easily determine the location of the dust, confirming the location to issue the advisory and adjust accordingly.

Forecasting Icing Conditions

Icing conditions can also be very treacherous to aircrafts. Satellite data provides vital information to the forecasting process for finding icing conditions. In assessing current icing conditions, visible and infrared satellite imagery provides an excellent overall picture of what to expect. Cloud parameters derived from geostationary satellite data help to better define the potential icing threat to aircraft and improve icing forecasts.

When an aircraft encounters icing in flight it is important that pilots know how thick that the cloud layer producing the icing is. When ice begins to build up, pilots need to know how high or low they must descend to escape it, or how far they need to divert to fly out of and around it. An experimental product, using geostationary satellite data, and soon JPSS data, to estimate the tops and bases of the icing layer has the potential to provide valuable information to forecasters at the NWS Aviation Weather Center. This will allow forecasters to more accurately predict tops and bases in their products.

Looking to the Future

As the nation's aviation system continues to grow, and a greater number of people are expected to fly more miles each year, accurate and timely aviation forecasts are critical. NOAA's satellite data continues to provide vital observations of unfavorable weather issues protecting life and property and helping to secure a more "Weather-Ready Nation." NOAA satellites represent significant technological and scientific advances in environmental monitoring and will help advance weather, climate, environmental and oceanographic forecasting and monitoring with greater accuracy.

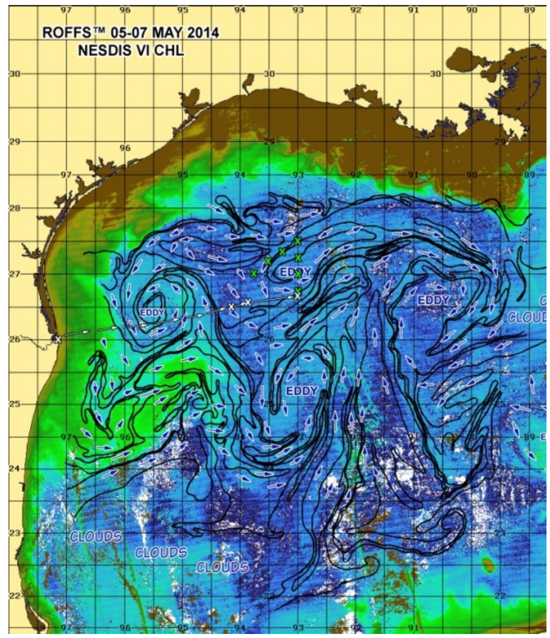
To view exciting satellite imagery, and experience the science behind the satellites please visit www.jpss.noaa.gov and www.goes-r.gov.

Full story can be read online at this link: http://www.jpss.noaa.gov/media.html?story=news-65

October 23, 2015

JPSS Data Aids Bluefin Tuna Research

Did you know that satellite data products from the Joint Polar Satellite System (JPSS) Program are helping scientists study Atlantic bluefin tuna larval ecology? NOAA's National Marine Fisheries Service (NMFS) uses satellite observations such as topography, sea surface temperature, and ocean color in their studies of highly migratory fish species like the bluefin tuna. Bluefin tuna is one of the most highly evolved fish species and is in danger of overfishing. Prized as sushi, one bluefin tuna can sell for tens of thousands of dollars.



Oceanographic analyses including ocean color from Visible Infrared Imaging Radiometer Suite (VIIRS).
Credit: Roffer's Ocean Fishing Forecasting Service, Inc. (ROFFS™)

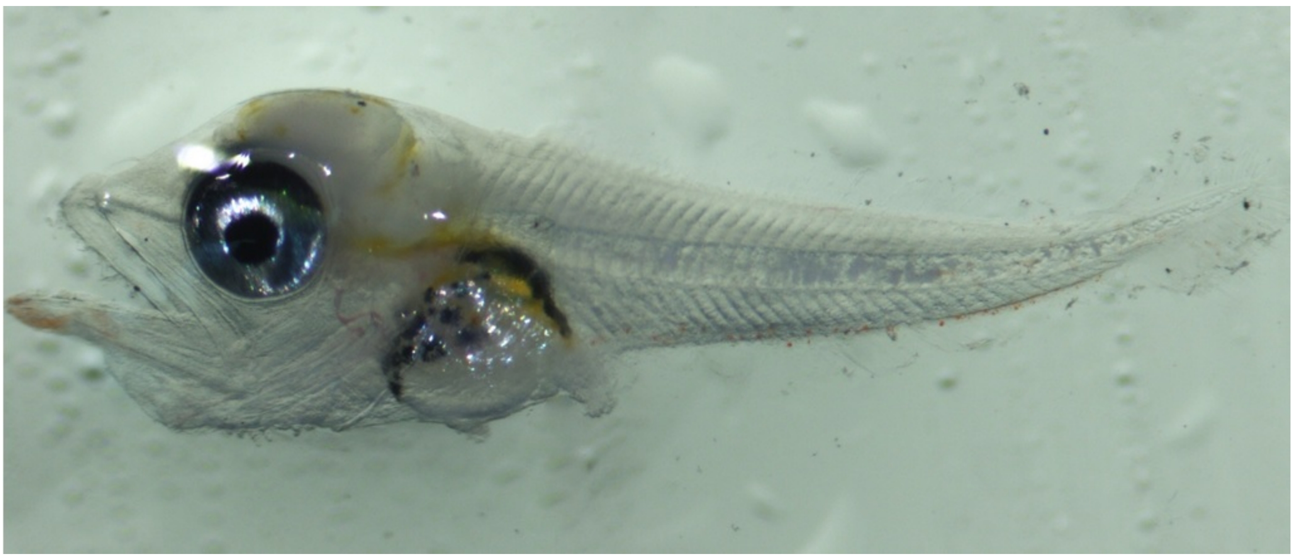
Satellite data has helped researchers gain a better understanding of the migratory patterns of the bluefin tuna. This information assists researchers in understanding the spawning patterns and life cycle, and is used to formulate policies to help prevent overfishing. JPSS data products are an important asset to monitoring and protecting the oceans' ecosystem and global economy by providing timely and high quality data for decision support through significant technological and scientific advances.

NOAA Ship Nancy Foster
Credit: NOAA

NMFS participated in two consecutive 4-year studies in the Gulf of Mexico and Northern Caribbean focusing on the larval ecology of the Atlantic bluefin tuna, in relation to environmental conditions and climate.

During a recent cruise on board the NOAA Ship Nancy Foster from April 27- June 5, 2015, NOAA's Center for Satellite Applications and Research (STAR) team members, Mengua Wang and Lide Jiang, provided near-real-time data from JPSS' Visible Infrared Imaging Radiometer Suite (VIIRS) instrument to Dr. Mitchell Roffer, founder of Roffer's Ocean Fishing Forecasting Service, Inc. where the satellite data was integrated into daily oceanographic analyses that included sea surface temperature and color, water mass identification, current direction and relative speed and ocean frontal boundaries to guide the shipboard sampling strategy sent to Dr. John Lamkin of NMFS' Southeast Fisheries Science Center and helped determine if it was necessary to change the location of the sampling stations to increase the chances of finding bluefin tuna larvae.

"This data allows the research team to be able to model how habitats might change in the next 100 years. Their work would not be possible without satellite data," said Dr. John Lamkin, NMFS Team Leader for the Early Life History Laboratory. "These models will aid in creating reliable forecasting of tuna habitats and give researchers and decision-makers better tools for understanding living ecosystems and are invaluable to fisheries oceanography research."



Larval bluefin tuna.
Credit: NOAA

In addition to aiding in oceanographic studies, JPSS delivers key observations for the Nation's essential products and services, including forecasting severe weather like hurricanes, tornadoes, and blizzards days in advance, and assessing environmental hazards such as, droughts, forest fires, poor air quality and harmful coastal waters, helping to secure a more "Weather-Ready Nation."

To learn more about these efforts by the National Marine Fisheries Service (NMFS), visit www.nmfs.noaa.gov and visit www.jpss.noaa.gov to experience the science behind the satellites.

Full story can be read online at this link: http://www.jpss.noaa.gov/media.html?story=news-68

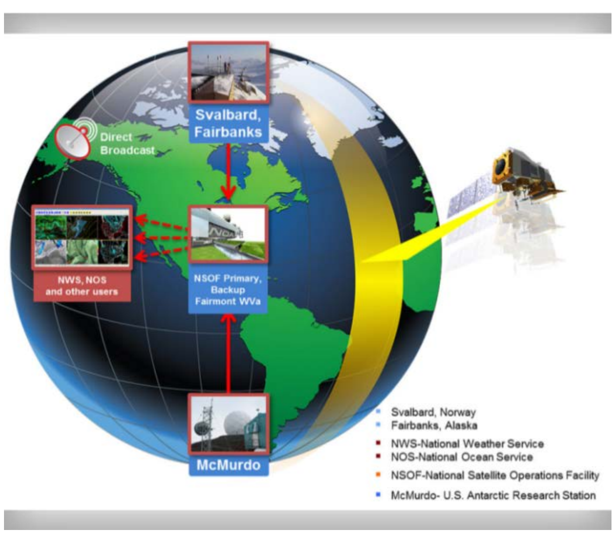
October 28, 2015

NOAA Celebrates Four-Year Anniversary of Suomi NPP Launch

NOAA Celebrates Four-Year Anniversary of Suomi NPP Launch

October 28, 2015 marked the fourth anniversary of the launch of the NOAA/NASA Suomi National Polar-orbiting Partnership (Suomi NPP) satellite. The Suomi NPP satellite is the bridge between NOAA's legacy Polar Orbiting Environmental Satellites (POES) and NOAA's next generation Joint Polar Satellite System (JPSS) weather satellites. Suomi NPP is the first satellite in the JPSS Program and is currently NOAA's primary polar-orbiting weather satellite.

Since Suomi NPP launched four years ago, it has orbited Earth over 20,000 times.



This image show the Suomi NPP versatile ground system that controls the spacecraft, ingests and processes data and provides information to users more quickly than ever before.

The weather data produced by Suomi NPP is derived from the next generation instruments that fly on the JPSS series satellites: Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), and Ozone Mapping and Profiler Suite (OMPS). Suomi NPP provides the first mission using these instruments, and also flies the 5th flight model of the Cloud and Earth Radiant Energy System (CERES).

These sensors represent substantial advances over NOAA's legacy Polar-orbiting Operational Environmental Satellites and build on some of the capabilities pioneered by the NASA's Earth Observing System Satellites and the Department of Defense's Defense Meteorological Satellite Program (DMSP).

Suomi NPP data is collected by a ground station in Svalbard, Norway, and is then routed to the NOAA Satellite Operations Facility in Suitland, Maryland where it is processed and distributed. In addition, Suomi NPP data are accessed by users through the use of direct broadcast antennas to quickly access Suomi NPP observations made while in view of each direct broadcast antenna to support critical missions.

NOAA’s National Weather Service (NWS) incorporates Suomi NPP data into its weather prediction models that help generate medium-to-long range forecasts to better predict medium- and long-term weather, including severe weather phenomena. These data are also provided fully and openly to other Federal, State and local users; commercial weather sector; and international partners.

Suomi NPP has resulted in an improved quality of weather and environmental observations from its sophisticated instruments.

Suomi NPP is critical for weather forecasts beyond 48 hours and increase the consistency and accuracy of forecasts three to seven days in advance of a severe weather event.

This advanced notice greatly aids our Nation's leaders, decision makers, emergency managers, and media to better provide increased warnings to the public-at-large. VIIRS imagery has become a staple of weather forecast offices in Alaska and the Pacific, and provides high resolution details to the NWS National Centers for Environmental Prediction to help forecast tropical and mid-latitude storms.

Suomi VIIRS observed with exceptional detail three tropical storms in the Western Hemisphere on the evening of August 27, 2015. Hurricane Ignacio in the Central Pacific, Hurricane Jimena in the Eastern Pacific, along with Tropical Storm Erika in the Atlantic Caribbean Sea are shown from west to east. Credit: NOAA

Suomi NPP data are used to generate dozens of environmental data products, including measurements of clouds, vegetation, ocean color, and land and sea surface temperatures.

Suomi NPP products are available via **NOAA's Comprehensive Large Array-Data Stewardship (CLASS) website**, which currently houses more than 4.88 petabytes (equivalent to 305,000 16 GB smartphones) of data from the satellite, typically receiving 2.1 terabytes of data a day. Currently VIIRS data is the most frequently accessed environmental data from CLASS. In addition, NOAA’s partner NASA is using Suomi NPP data to create multi-decadal climate quality data records begun under the Earth Observing Program in the early 2000’s. NOAA and other research scientists throughout the U.S. and the world use Suomi NPP data as they study severe weather, atmospheric and oceanographic phenomena, and climate.

Enhanced data products include:

- Atmospheric temperature/moisture profiles
- Hurricane intensity and position
- Thunderstorms, tornado potential
- Alaska “nowcasting” (e.g. ice detection)
- Significant precipitation and floods
- Dense fog
- Volcanic ash
- Fire and smoke
- Sea surface temperature, ocean color
- Sea ice extent and snow cover /depth
- Polar satellite derived winds (speed/direction/height)
- Vegetation greenness indices and health
- Ozone
- Oil spills

The swirling of sea surface waters is shown in this thermal infrared image from the Suomi NPP spacecraft in an area just southeast of Cape Cod, Massachusetts on April 21, 2015. The VIIRS sensors can detect slight differences in temperature at a resolution of 375 meters per pixel, and here they are colored – blue for cold, and red for warm. The warm waters of the Gulf Stream meet and mix with the much cooler surface waters from the North Atlantic. An incredibly tight gradient between these two masses of water is especially evident on the left side of the image, where the area of white is very fine between cool and warm. These boundaries are often ecological hot spots, especially for fisheries. Credit: NOAA/NASA

Suomi NPP is also the primary weather observation satellite system for Alaska and the Polar Regions.

In Alaska, Suomi NPP provides critical data for aviation weather forecasting as well as for the economically vital maritime, oil and gas industries. Aviation touches all aspects of life in Alaska, and is a basic mode of transportation because approximately 90% of Alaska is not served by roads.

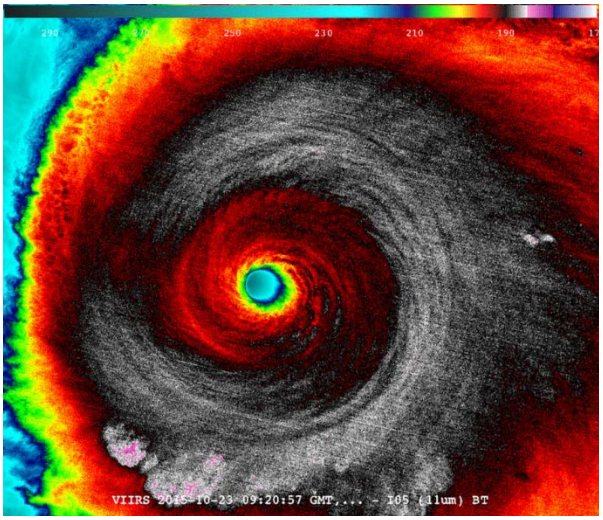
Data from Suomi NPP also contribute to the U.S National Ice Center, which provides snow and ice products to support the military as well as the transportation and energy sectors.

The NWS Weather Forecast Offices in Alaska uses the data from the next generation VIIRS instrument on-board Suomi NPP to produce graphic analyses of sea surface temperatures and sea ice, as well as five day sea ice forecasts year round. The VIIRS instrument is also a key contributor to the satellite data products that provide critical observations of fire and smoke across the state.

This image highlights the difference between the VIIRS Thermal Infrared and the VIIRS Day/Night Band of Alaska's sea ice at night. The cirrus clouds, which are semi-transparent at visible light wavelengths, are often opaque at nighttime infrared wavelengths. Credit: Steve Miller, Colorado State University/CIRA

Learn more about how Suomi NPP data has aided **firefighters** and the **United States Coast Guard** in Alaska to reduce the potential loss of human life and property.

Suomi NPP serves as the primary tool for predicting weather in locations that are not visible to conventional observing systems.



In the Pacific region, another data sparse area, Suomi NPP data provides information to accurately track and predict severe weather events. The region's distinctive geography has a high vulnerability to hazards and climate variables such as typhoons, heavy rains, droughts and tropical cyclones that threaten island wildlife and ecosystems. The VIIRS day/night band is sensitive enough to provide storm information even under limited moonlight conditions, a major advancement for storm analysis.

This image shows Hurricane Patricia, the strongest land-falling Pacific hurricane in recorded history as the historic storm bore down on Mexico's Pacific coast. The VIIRS instrument aboard Suomi NPP captured an infrared image of the typhoon on October 23, 2015. Credit: William Straka III, University of Wisconsin-Madison, CIMSS

Satellites in the JPSS Program will continue to build on the success of Suomi NPP.

Building on the success of Suomi NPP, NOAA is on track for the launch of the second satellite in the JPSS program in early 2017, called JPSS-1. Every indication is that Suomi NPP will provide the critical time for its successor, JPSS-1 to be thoroughly tested during post-launch. The orbital position of JPSS-1 relative to Suomi NPP will allow data from both spacecraft to be used more advantageously in the national weather prediction models. At the time of this publication four of the five sensors have been fully integrated onto the JPSS-1 satellite bus and the last sensor, ATMS, is expected to be available for integration by the end of the 2015. JPSS is planning future satellite missions to ensure that forecasters have the data they need without interruption.

JPSS is a collaborative program between the NOAA and its acquisition agent, NASA. NOAA is responsible for total funding and managing JPSS program, operations, and science products, while NASA supports NOAA by developing and building the JPSS instruments, spacecraft, and ground system. This interagency effort (JPSS) is the latest generation of U.S. polar-orbiting satellites.

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

This image is a rendering of JPSS-1, built by Ball Aerospace & Technologies Corp. in Boulder, Colorado. Credit: Ball Aerospace & Technologies Corp.

Full story can be read online at this link: http://www.jpss.noaa.gov/media.html?story=news-69#

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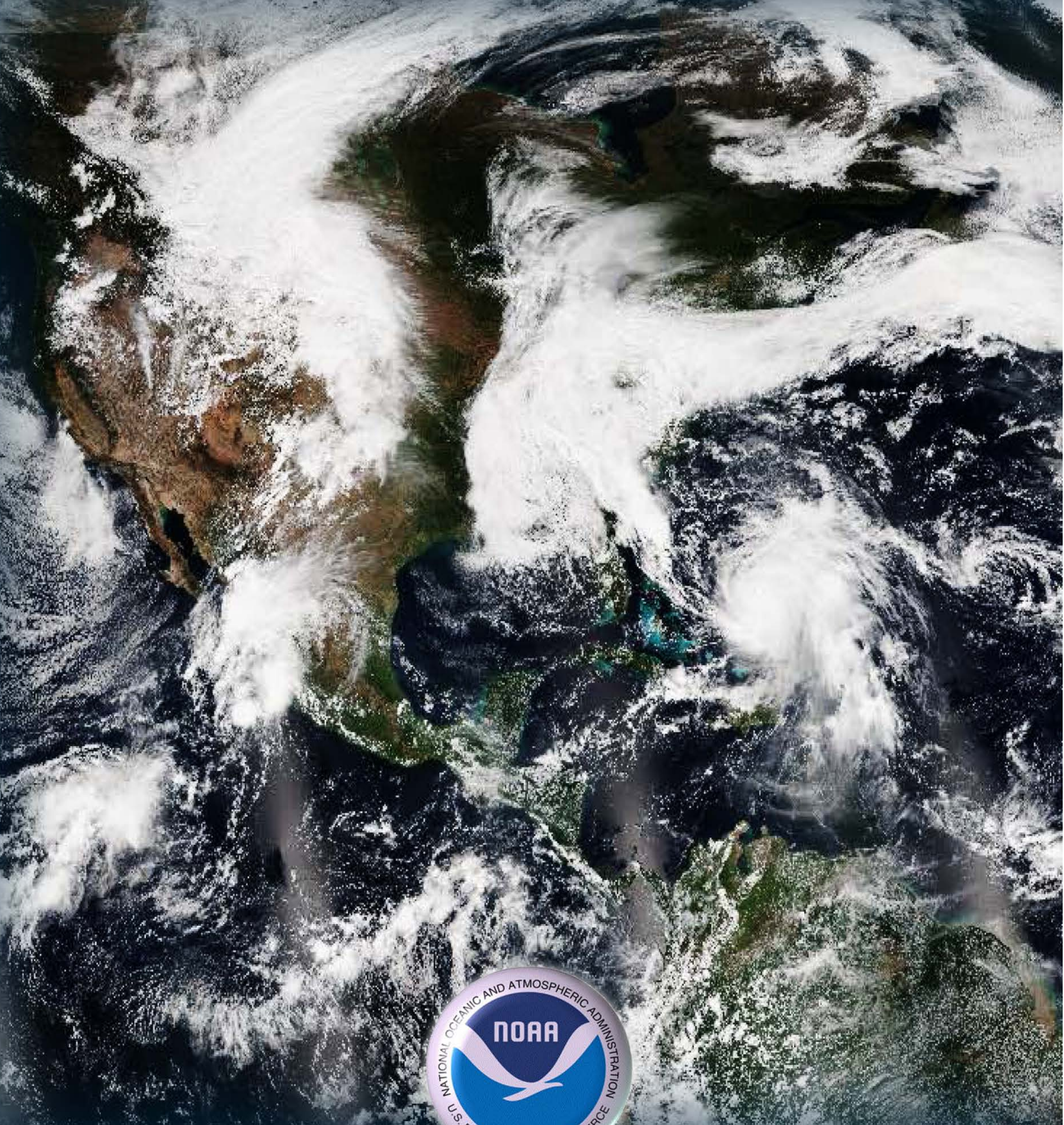

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