NOAA / NESDIS / STAR

Satellite Meteorology and Climatology Division

2015 Annual Report

Photo Credit: The Suomi NPP Blue Marble, NASA/NOAA

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1. Message from the Division Chief

In 2015, the Center for Satellite Applications and Research (STAR) Satellite Meteorology and Climatology Division (SMCD) supported Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite R-Series (GOES-R) programs for mission-critical operations and scientific research. The division submitted ten projects as part of the STAR Annual Operating Plan (AOP). Some of these projects have resulted in far-reaching impacts on broader user communities, including

Dr. Fuzhong Weng, Chief of STAR's Satellite Meteorology and Climatology Division

1) Demonstration of the Suomi NPP Cross-Track Infrared Sounder (CrIS) full spectral resolution sensor data record (SDR) products through STAR offline processing system;
2) Demonstration of uses of Advanced Himawari-8 Imager (AHI) data for GOES-R Advanced Baseline Imager (ABI) calibration risk reduction; and
3) Delivery of AHI Level 1B radiance and Level 2 atmospheric motion wind Binary Universal Form for the Representation of meteorological data (BUFR) files to National Weather Service (NWS).

CrIS full spectral resolution SDR data will enable NWS to assimilate the infrared (IR) radiance data with more channels at midwave water vapor band, and also will allow for accurate retrievals of greenhouse gases. AHI Level 1B radiances are utilized for GOES-R algorithm tests and product demonstration. Both L1B radiances and L2 wind products are being assimilated through National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) gridpoint statistical interpretation (GSI).

The achievements made by the division federal employees and contractors were highly appreciated and recognized by NOAA, NESDIS, and STAR senior managements. The CrIS SDR team lead, Dr. Yong Han, received the NOAA Administrator's Award for developing state-of-the-art processing, calibration, and monitoring of CrIS full spectral resolution data for weather and climate applications. Dr. Felix Kogan received his distinguished career award in scientific achievement for applying NOAA satellite data to monitor global land surface conditions and for providing data for critical applications worldwide. The Visible Infrared Imaging Radiometer Suite (VIIRS) SDR science team, led by Dr. Changyong Cao, received the 2015 NESDIS award for achieving significant advances in critical areas of VIIRS Day/Night Band (DNB) development, including JPSS-1 waiver mitigation, operational straylight correction, and geolocation capability development and validation.

SMCD also had another record year in scientific publications and outreach activities. A total of 34 papers have been published in various American Meteorological Society (AMS), American Geophysical Union (AGU), and Institute of Electrical and Electronics Engineers (IEEE) journals. For example, Ken Pryor had his unique study on "Progress and Developments of Downburst Prediction Applications of GOES" published in the journal of AMS Weather and Forecasting.

The existing suite of downburst prediction algorithms employs the GOES sounder to calculate risk based on conceptual models of favorable environmental thermodynamic profiles for downburst occurrence. A diagnostic nowcasting product, the Microburst Windspeed Potential Index, is designed to identify attributes of a favorable downburst environment in the presence of large convective available potential energy (CAPE) and in the presence of a surface-based or elevated mixed layer with a large temperature lapse rate.

SMCD also submitted 15 new milestones as part of the STAR FY16 Annual Operating Plan. Three of them are elevated to NESDIS and higher levels, including

1) Complete and deliver a report on a pilot simulation to assess NOAA benefits and readiness to utilize a commercial small-sat constellation of IR hyperspectral and microwave sounding sensors;
2) Deliver the GOES Evapotranspiration and Drought product system to NCEP Climate Prediction Center and Environmental Modeling Center (EMC) for pre-operational assessment in land surface modeling and drought monitoring operations; and
3) Complete reprocessing of GOES-13 atmospheric motion vectors (AMVs) using the GOES-R winds algorithm over the lifetimes of seven historical Hurricanes for use in GSI/Hurricane Weather Research and Forecasting (HWRF) assimilation experiment.

Four SMCD federal employees (Ivan Csiszar, Xiwu (Jerry) Zhan, Shobha Kondragunta, and Istvan Laszlo) were nominated by the NESDIS Assistant Administrator to support the National Research Council decadal survey as members of the Decadal Survey Support Team (DSST). This survey will generate consensus recommendations on the U.S. government's civilian space-based Earth system science programs over the decade 2017-2027. The DSST will provide support to the decadal survey steering committee and panels in their hearings and other interactive fact finding activities to ensure that NOAA interests are addressed by the decadal survey committee.

Dr. Fuzhong Weng
Chief, Satellite Meteorology and Climatology Division
NOAA/NESDIS/Center for Satellite Applications and Research

2. Welcome New SMCD Staff

SMCD would like to warmly welcome the following staff to our team…

Yvette Jones-Bell: Budget Analyst

- Joined SMCD October 2015
- Primary duties: Budget and spending, C-requests, contracts/grant processing, and MOU's

Clarissa Bennett: Administrative Assistant Contractor (1st Choice)

- Joined SMCD September 2015
- Primary duties: Travel arrangements, supply management, office space, and administrative processes

Lisa Huxtable: Support Scientist Contractor (IMSG, Inc.)

- Joined SMCD March 2015
- Primary duties: Publications, scientific documentation, and division milestone/annual reports

3. SMCD Overview

3.1. Satellite Meteorology and Climatology Division Mission Statement

SMCD conducts research and develops new satellite products to improve and expand the use of satellite data for monitoring global meteorological, environmental, and climatological conditions. The Division conducts an end-to-end program ranging from planning new satellite instruments to developing new satellite products and applications and transitioning these developments to operations in NOAA's weather, climate, and environmental monitoring and prediction systems.

SMCD's Science Priorities include the following:

- *Calibrate and intercalibrate all instruments to meet SI traceable standard*
- *Improve and enhance calibration and retrieval algorithms*
- *Develop the suite of products through common algorithms and blended techniques*
- *Strengthen climate studies using satellite instruments and products*
- *Improve uses of satellite data in numerical weather prediction (NWP) models*
- *Promote collaboration with international space agencies*

Satellite sensor data and products developed in SMCD fall in the following discipline areas:

- *Advanced Technology Microwave Sounder (ATMS) sensor data record*
- *Cross-Track Infrared Sounder (CrIS) sensor data record*
- *Visible Infrared Imaging Radiometer Suite (VIIRS) sensor data record*
- *Ozone Mapping and Profiler Suite (OMPS) sensor data record*
- *GOES imager/sounder products*
- *GOES-R Advanced Baseline Imager (ABI) level 1 and 2 products*
- *Advanced Microwave Sounding Unit level 1 and level 2 products*
- *Advanced Very High Resolution Radiometer (AVHRR) level 1 and 2 products*
- *Reference environmental (climate) data records from satellites (e.g., MSU/SSU and SBUV2)*

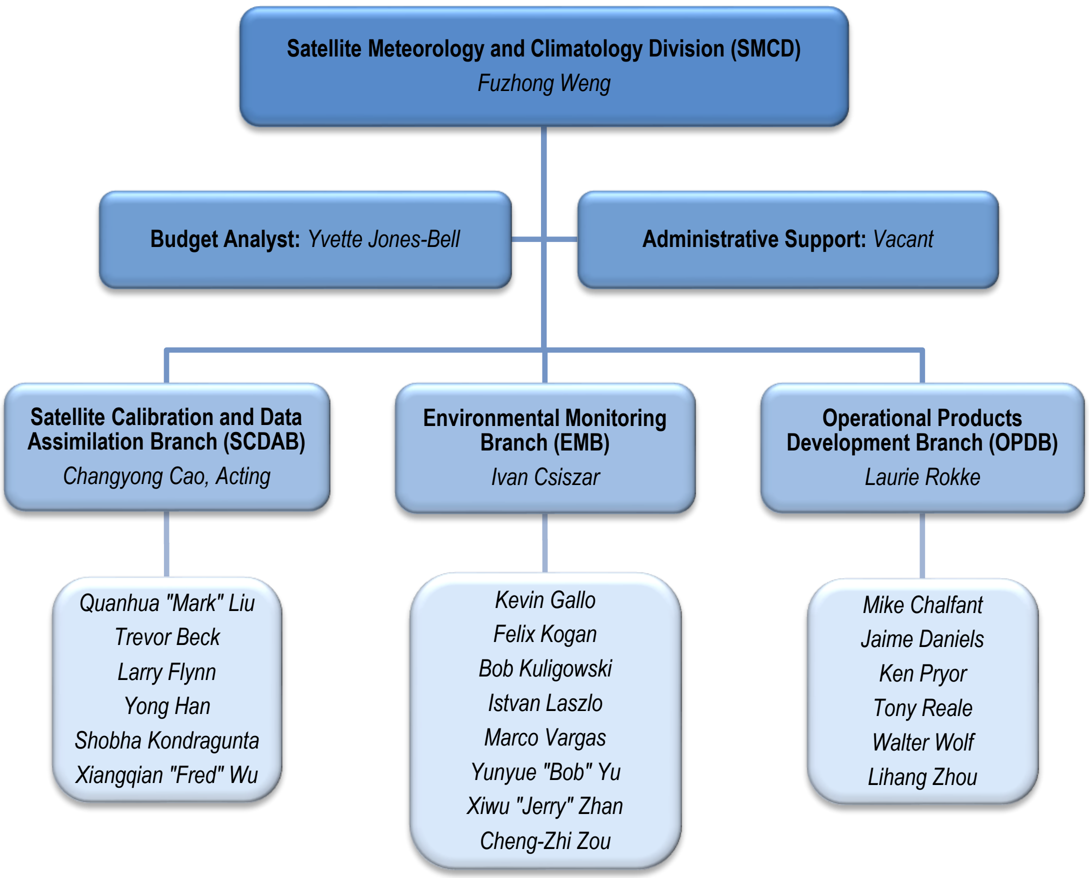
Satellite environmental data and products developed in SMCD fall in the following discipline areas:

- *Atmospheric variables – temperature, humidity, winds*
- *Land surface variables – soil moisture, vegetation, surface temperature, surface albedo, surface type*
- *Hydrological variables – precipitation, cloud water, rain water, graupel, hail, snow, total water*
- *Environmental hazards – aviation hazards, air quality, fires, flash floods, drought*
- *Climate variables – ozone, Earth radiation budget, aerosols, greenhouse gases*

In addition to developing new and improved sensor and environmental products, SMCD also conducts the following crosscutting activities to support the broad NOAA missions:

- *Community Radiative Transfer Model (CRTM)*
- *Global Space-based Inter-Calibration System (GSICS)*
- *Integrated Calibration and Validation System (ICVS)*
- *Enterprise Algorithm for Satellite Common Ground System*

3.2. SMCD Organization Chart



3.3. SMCD Branches

Satellite Calibration and Data Assimilation Branch (SCDAB)

- SCDAB's mission is to:
    - Provide lifecycle instrument calibration/validation support to NOAA's operational environmental satellites in both polar-orbiting and geostationary orbits by:
        - Providing technical oversight on the development of future satellite instruments; supporting pre-launch testing of instrument performance; investigating instrument performance waivers as well as impacts on users, and developing mitigation strategies;
        - Leading satellite post-launch calibration/validation; maintaining and improving the radiometric and geolocation accuracy of operational satellite radiometer to ensure data quality for all applications;
        - Performing long-term monitoring of instrument performance and participating in anomaly resolution;
        - Supporting recalibration for climate studies.
    - Develop radiative transfer models for satellite data assimilation used in numerical weather predictions.
    - Foster international collaboration for mutual benefits through bilateral and multilateral agreements.

Operational Products Development Branch (OPDB)

- OPDB's mission is to:
    - Develop and transition products into NOAA Operations, with its primary goal to reduce the time to transition products into operations.
    - Conduct applied research on the use of geostationary and polar-orbiting satellite data for the analysis of significant meteorological and surface-based phenomena; work in tandem with NESDIS operations to implement scientific techniques developed within NESDIS and elsewhere to produce quantitative, derived products, such as subjective pattern recognition techniques as well as long-term science maintenance of operational products.
    - Help improve short-range warnings and forecasts in support of NOAA's mission, the highest priority of OPDB's research and development activity. As a result, the principal customer is the National Weather Service. Other important users are the U.S. Department of Defense, the Department of Agriculture, and international agencies such as the World Meteorological Organization and foreign weather services.
    - Provide support in training NWS and Department of Defense (DoD) forecasters through the development of in-residence and distance learning courses at the Cooperative Program for Meteorological Education and Training (COMET) in Boulder, Colorado.
    - Lead the strategic objective of the STAR enterprise approach to enable cost-effective development of interoperable multi-sensor and multiplatform

algorithms, pre- and post-launch instrument calibration and validation, long-term science maintenance, user outreach, and value-added applications.
    - Provide project management for algorithm science and related activities that include support for both the GOES-R and JPSS satellite programs.
    - Through OPDB satellite project managers working across the STAR divisions, organize, lead, and integrate the science teams, resources, and tools to collaborate effectively to provide reliable deliveries and algorithm stewardship in support of NOAA goals. For further information go to www.star.nesdis.noaa.gov/jpss/index.php (JPSS Project) and www.star.nesdis.noaa.gov/goesr/ (GOES-R AWG Project).

Environmental Monitoring Branch (EMB)

- EMB's mission is to:
    - Develop, evaluate, and transition to operation satellite-based products that quantify geophysical environmental variables that characterize the state of the solid surface and the atmosphere of the Earth and its radiant energy budget.
    - Conduct an end-to-end program that includes:
        - Development, enhancement, and maintenance of products from current operational environmental satellite systems;
        - Studies supporting the planning of new satellite instruments for developing new satellite products and applications for current and next generation instruments;
        - Transition of these developments to operations in NOAA's weather, climate, and environmental monitoring and prediction systems.
    - Conduct research and development falling in the following discipline areas:
        - Atmospheric variables – aerosols, deep-layer temperatures, cloud properties;
        - Land surface variables – vegetation, snow, and ice cover;
        - Hydrological and Energy Cycle variables – precipitation, Earth radiation budget;
        - Environmental hazards – fires, heavy rainfall and flash floods, drought.

4. Accomplishment Summaries

4.1. *Feasibility Study with NIST on SI Traceable Active Light Source for VIIRS DNB*

POC: Changyong Cao

The calibration uncertainty of the VIIRS DNB at low-light radiances is on the order of 30%-100%, which has become a major impediment to the quantitative use of the low light radiance data at night. The large uncertainty is due to the very large dynamic range of the DNB, which spans seven orders of magnitude. As a result, the uncertainty significantly increases when the calibration is transferred from the solar diffuser at low gain stage to the night light observations at high gain stage. The objective of this study is to perform a feasibility study of developing a vicarious calibration source for the calibration of the high gain stage of the DNB, which would enable more quantitative applications of the DNB data at night.

This study is challenging because the calibration of the VIIRS DNB relies on the same solar diffuser that is onboard for the other reflective solar bands for which the signal can be seven orders of magnitude greater than the DNB observations at night. As a result, when the calibration is transferred from the low gain to the high gain through the medium gain, the uncertainty has increased from 2% to 30% (up to 100% at large scan angles). This challenge cannot be met with the onboard calibration alone. Therefore, an alternative to improve the calibration uncertainty is to use a vicarious SI traceable calibration source at night, which is the focus of this study.

The project involves a close collaboration between NOAA and National Institute of Standards and Technology (NIST) scientists. In 2014, NIST scientists were invited to NOAA to discuss the needs for an active light source, and the uncertainties achievable at NIST laboratories. Based on experience with existing laboratory integrating sphere technologies at NIST, the concept of a vicarious active light source was developed. It was recognized that a large integrating sphere, which can achieve an uncertainty of sub percent, when developed and deployed to the field, can achieve the low uncertainty requirements as an active light source. Further collaborative work with NIST was presented at the NCC-NIST calibration workshop held on July 10, 2015, at NIST, which also led to the publication of the SPIE conference paper on this topic.

To demonstrate the feasibility of the active night light source, we performed an extensive study by selecting existing night light point sources from the Suomi NPP VIIRS DNB observations. This included distinct sources such as lights from bridges, oil platforms, gas flares, and volcanoes. Results show that the bridge lights are the most stable compared to the rest. In particular, the San Mateo bridge lights are the best choice because of the favorable weather conditions in the region, and also because of the stability of the LEDs according to the California Department of Transportation. The time series in Figure 1 shows the overall stability of the VIIRS DNB observations over the San Mateo bridge. In general, the radiance is between 2-5 nW/cm^2-sr. Further investigation reveals that the high radiance values are mostly due to a combination of clouds and lunar illumination. To further diagnose the large variability of the radiances, we compared the radiances produced by two independent producers, the NOAA

Interface Data Processing Segment (IDPS) and NASA LandPeate, and found that while in general the LandPeate radiances are ~15% high than the IDPS version, there is good consistency between these two versions over time. However, it is not clear which one is closer to the true radiance values because there is no ground truth to use as a standard. This led us to believe that the solution is to develop an active light source and deploy it to the field. Ideal sources would be broad band source covering the spectral response region of the 0.5-0.9µm. The study based on Suomi NPP demonstrates that the use of an active night light source is quite feasible. With rigorous characterization of the ground-based light source and time series analysis, the SI traceability of the VIIRS DNB can be established. Furthermore, light sources with different spectral characteristics (such as red LED) can be used to expand its potential use to make DNB a user-customizable band, which will enable such applications as aerosol retrievals at night. This feasibility study has been completed successfully. Going forward, we will continue this effort toward the implementation of the active light source, in collaboration with NIST, and leveraging the NOAA SBIR 2014 project for this topic.

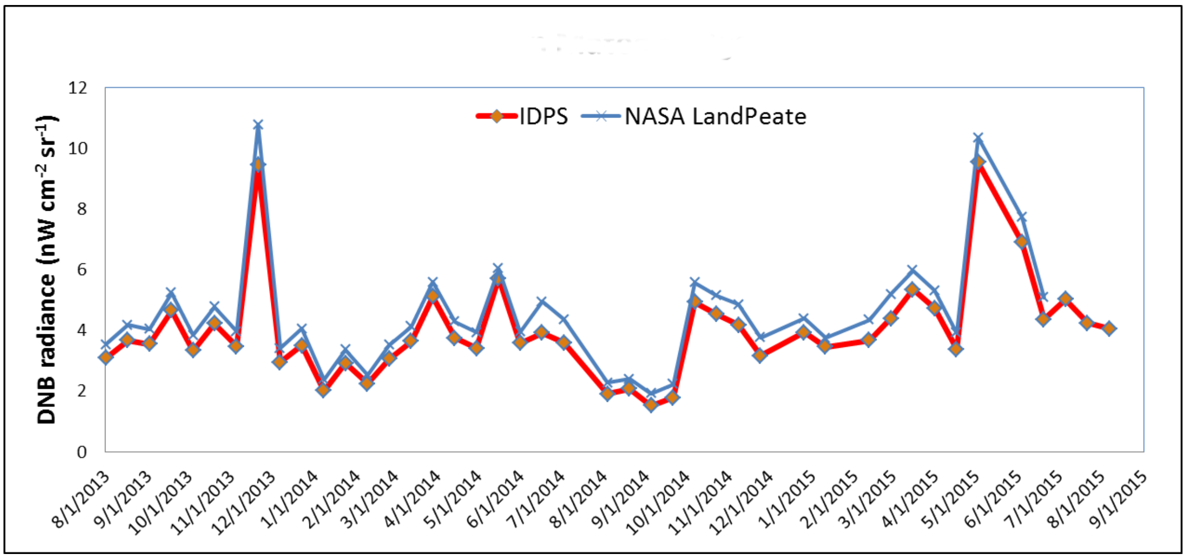


Figure 1. VIIRS observation time series of the San Mateo bridge lights and comparison between IDPS and LandPeate radiances

4.2. Establish the Routine Generation and Validation of the Derived Motion Wind Product from Himawari-8 Data

POC: Jaime Daniels

The Japan Meteorological Agency (JMA) successfully launched their next generation geostationary satellite, Himawari-8, on October 7, 2014. The Himawari-8 satellite carries the AHI, which is a 16-channel multi-spectral imager that has spectral and spatial characteristics that are very similar to the future GOES-R ABI.

The availability of Himawari-8/AHI datasets brings an unprecedented opportunity to exercise many of the Level-2 algorithms developed for GOES-R and validate the performance of the derived products. One such product is the derived motion winds. There is also an operational requirement for NOAA/NESDIS to generate derived motion winds products from JMA's geostationary satellite and distribute them to the NWS Telecommunication Gateway (NWSTG) so they can be distributed out to NWS Weather Forecast Offices (WFOs) in the Western Pacific. NESDIS operations currently produce derived motion winds from JMA's Multi-functional Transport Satellite (MTSAT) series of geostationary satellites and will switch over to Himawari-8 when it becomes JMA's primary geostationary satellite. NESDIS/STAR/SMCD is developing the capability to generate winds from Himawari-8 using the latest GOES-R algorithms and plans to deliver this capability to NESDIS operations in October 2015.

Wind products are being routinely generated on an hourly basis from Himawari-8 bands 3 (0.64µm), 7 (3.9µm), 8 (6.2µm), 9 (7µm), 10 (7.3µm), and 14 (11.2µm). Figure 2 shows an example of the Himawari-8 winds derived from Band 14 (11.2µm) 10-minute Full Disk imagery on May 18, 2015. Near the center of the image is Typhoon Dolphin, which was a Category 4 (131-155 mph) storm at this point in time. It did reach Super Typhoon status just prior to this image when maximum sustained winds reached 150 mph. This period of intensification occurred after the typhoon cleared both Guam and Rota (45 miles NE of Guam).

The Himawari-8 wind products are being routinely validated on a daily basis using radiosonde wind observations and Aircraft Communications Addressing and Reporting System (ACARS) Wind Observations. Figure 3 shows a time series of the Mean Vector Difference (MVD) and speed bias between upper level (100-400 mb) Himawari-8 winds derived using Band 14 (11.2µm) and ACARS winds over the period August 30 - September 17, 2015. This time series of comparison statistics indicates that the GOES-R derived motion winds algorithm is performing extremely well and provides high confidence that winds derived from the GOES-R ABI will meet the performance specifications for the derived motion winds product.

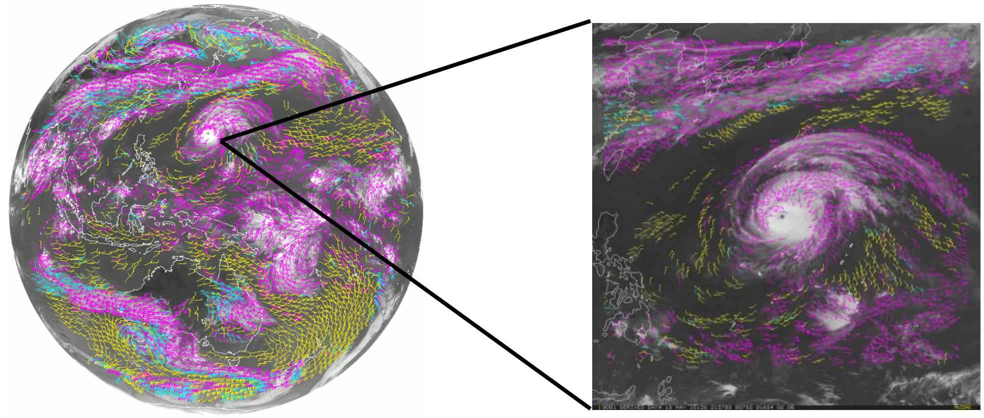


Figure 2. Winds derived from full disk 10-minute Himawari-8 band 14 (11.2 µm) imagery on May 18, 2015. Typhoon Dolphin can be seen near the top center of the full disk image on the left and is blown up in the image on the right. These winds are derived from tracking cloud features using the 11.2 µm band. High level (100-400 mb) winds are shown in violet; mid-level (400-700 mb) are shown in cyan; and low level (below 700mb) are shown in yellow.

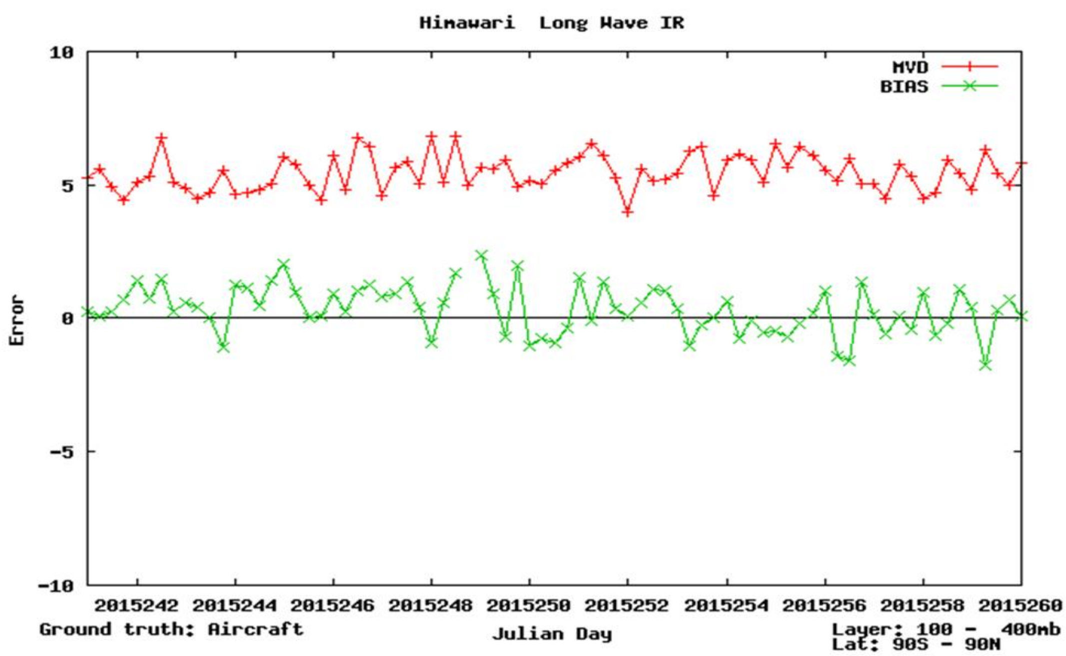


Figure 3. Time series of Mean Vector Difference (MVD) and speed bias between upper level (100-400mb) Himawari-8 winds derived using band 14 (11.2 µm) and collocated aircraft winds for the period August 30 - September 17, 2015.

4.3. Validation of OMPS Nadir Ozone Profile and Total Column Ozone EDRs

POC: Lawrence Flynn

The Suomi National Polar-orbiting Partnership (S-NPP) Ozone Mapping and Profiler Suite (OMPS) is designed to take measurements to continue and improve upon the ozone records from NOAA Polar Operational Environmental Satellites (POES) Solar Backscatter Ultraviolet Instrument (SBUV/2) and NASA Earth Observing System (EOS) Aura missions. The validation of these products demonstrates the capability to continue providing the estimates needed to monitor the Ozone Layer for the nation.

There are two principal challenges to attaining our goal. The first challenge is that the OMPS SDR has been a moving target. This means that the validation results for the Environmental Data Records (EDRs) have to be reproduced for each new version of the SDRs. This is actually good news as the SDR Team has been implementing a wide range of improvements and adjustments to the measurements that will result in better performance for the EDRs. These improvements and adjustments include implementation of weekly updates to the Dark Current Look Up Tables (LUTs), adjustments of the Day 1 Solar Spectra values and wavelength scales using in-orbit measurements, addition of code modules to perform measurement-based stray light corrections and intra-orbit wavelength scale adjustments to meet performance requirements, and reanalysis and implementation of more consistent radiance and irradiance calibration coefficient LUTs. The last of these changes took place on September 9, 2015, and provided better values for six SDR LUTs (three each for the Nadir Mapper and Nadir Profiler).

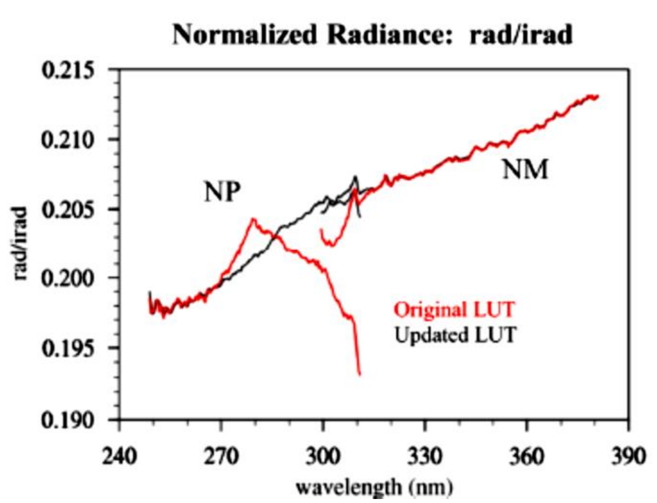


Figure 4. (Provided by C. Pan) Changes in the radiance/ irradiance calibration coefficients with the latest delivery of SDR LUTs.

In Figure 4, notice that the changes for the Nadir Profiler are greater than 2%, which is the required accuracy for the SDR. These changes have not been validated. There are also differential changes for the Nadir Mapper between the reflectivity channel at 331 nm and the main ozone channel at 318 nm that are 1%, which is the required accuracy for such changes.

The second challenge is that we are in the process of switching from the retrieval algorithms in place for OMPS at launch to the heritage/enterprise Version 8 algorithms. The V8 Ozone Profile Algorithm (V8Pro) has been implemented in IDPS and will become operational as part of the Mx8.11 Build. This algorithm is NOAA's current operational algorithm to process the POES SBUV/2 measurements. The Version 8 Total Column Ozone Algorithm (V8TOz) was delivered to Data Products Engineering (DPE) at the start of summer (2015) for implementation in IDPS. We hope it will be a component of the Mx8.12 build, but it may be held back until the Block 2.0

implementation. This algorithm is NOAA's current operational algorithm to process the MetOP GOME-2 measurements to create total ozone maps. It is also used to process the NASA EOS Aura OMI measurements.

In order to speed the validation of the V8 EDRs, we have developed processing/reprocessing capabilities for both of the V8 algorithms at STAR. Unfortunately, these require the input of the updated SDRs and our reprocessing capabilities are more limited for those products.

For the OMPS Nadir Ozone Profile EDR, we are using our offline capabilities to process the operational flow of the SDRs (with the six new LUTs) from IDPS with the V8Pro algorithm. We have also used the six new LUTs to reprocess a golden day (May 20, 2013) when there was a "Chasing Orbit" match up with the NOAA-19 SBUV/2. The main change in the latest processing is in the absolute calibration of the radiance/irradiance ratios. We are analyzing the initial measurement residuals from the V8Pro to see if we need to provide Calibration Factor Earth LUTs adjustments to the SDR team. Our preliminary results show that these adjustments will be necessary to generate ozone profile products meeting the accuracy requirements.

For the OMPS Total Ozone EDR, we are using our offline capabilities to process the operational flow of the SDRs (with the three new LUTs) from IDPS with the V8TOz algorithms. The main changes are in the SDR intra-orbit wavelength scales. Therefore, we are generating weekly ICVS ozone product monitoring results to check the absolute and relative calibration, and need three weeks of data to get good analysis for this evaluation. We will determine whether we need to provide Calibration Factor Earth LUT adjustments to the SDR team. Preliminary evaluations and analysis show that we will need to adjust the reflectivity, ozone, and aerosol channels to meet the requirements.

Given our extensive validation studies and the stability of the OMPS instruments, we expect to be able to move directly to Validated Stage 3 Maturity for the EDRs with the implementation of these soft calibration adjustments by the SDR team. The adjustments will ensure agreement for the OMPS Ozone EDRs with other well-validated satellite instrument ozone products (NOAA POES SBUV/2 and EOS Aura OMI).

4.4. Demonstrate the Suomi NPP CrIS Full Spectral Resolution SDR Products Using STAR Offline Processing System

POC: Yong Han

NOAA/STAR has developed a ground processing system to generate the full spectral resolution (FSR) Sensor Data Records for the CrIS instrument onboard the S-NPP satellite. This achievement laid the ground work for the data production, and demonstrated the S-NPP FSR SDR products. Started on December 4, 2014, when the CrIS was commanded to the FSR mode operation from the normal spectral resolution (NSR) mode operation, STAR routinely produces the FSR SDRs, available to the public via the STAR FTP site with a data latency of less than 12 hours. The FSR SDR includes a total of 2,211 spectral channels, a substantial increase from the 1,305 channels of the NSR SDRs, which continue to be generated by the NOAA operational processing system after the CrIS FSR transition. Figure 5 shows an example of the FSR and NSR spectra. The spectral resolutions of the FSR mid-wave and shortwave bands are increased by factors 2 and 4, respectively, in comparison to those of the NSR SDRs. The FSR radiance data are critical for retrieving carbonate products such as carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4). In addition, the increase of the information content from the FSR radiance data on atmospheric temperature and water vapor improves the NWP. STAR is utilizing the CrIS FSR data in the NOAA-Unique CrIS/ATMS Processing System to generate carbonate products.

The development of the FSR SDR processing system was challenging in both algorithm and software because the current SDR algorithms designed for the NSR SDRs do not work correctly for the FSR SDR processing and the current SDR software was not scalable to accommodate the increased dimensions of the FSR data. The new and improved algorithms include self-apodization correction, spectrum resampling, radiance noise estimation, and dynamic update of the Correction Matrix Operator (CMO). A modification of the self-apodization correction algorithm was made in order to remove large radiance ringing artifacts in the shortwave band due to an inappropriate expansion factor, which results in the breakdown of energy conservation when applied to the FSR SDR processing. The resampling matrix calculation is reformulated in the undecimated spectral domain rather than decimated domain to avoid the negative impact of the guard bands in which the signals are contaminated with noise. The FSR noise calculation includes the spectral calibration, which is ignored in the NSR processing, to take into account the noise contributions from spectral calibration in the mid- and shortwave bands due to increased spectral resolutions in these two bands. The new CMO handling algorithm is developed to improve spectral accuracy by more frequent updates of the CMO matrix since the spectra with increased spectral resolution is more sensitive to spectral calibration uncertainty.

Substantial work was done to upgrade the SDR software and create a computational environment within which the FSR processing is automatic and efficient. The FSR SDR software includes a new framework that resolves the key issue of the backward compatibility and one source code for both FSR and NSR SDR processing. The STAR FSR SDR processing system is required to process the data in near real-time on an ordinary Linux computer. To meet this requirement, an efficient computational environment was developed to manage input and output data and data processing in a parallel computing fashion.

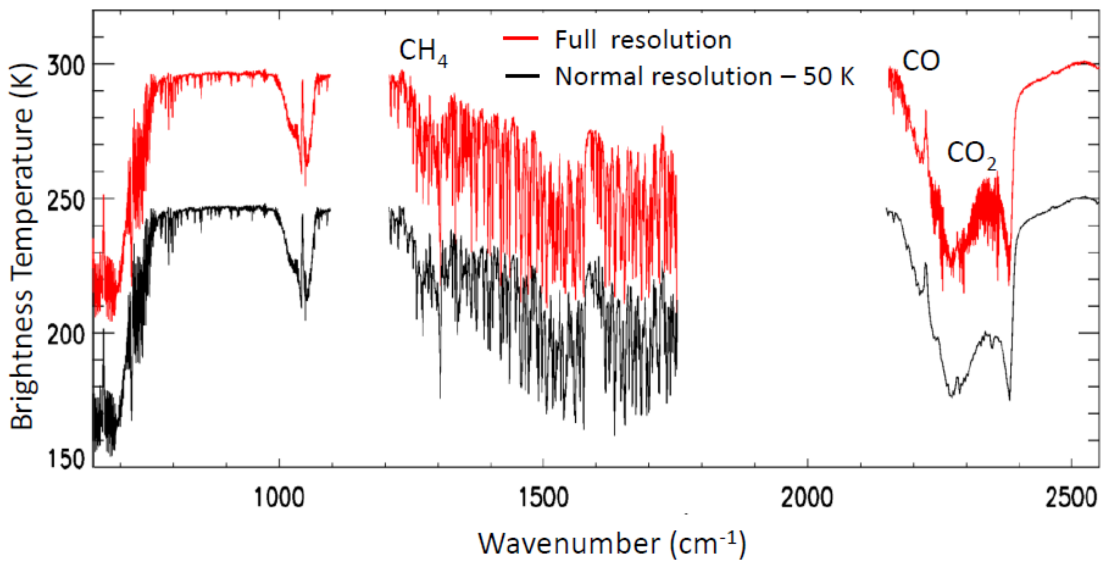


Figure 5. An example of CrIS FSR (red line) and NSR (black line, offset by 50 K) spectra. The spectral resolutions of the FSR mid-wave and shortwave bands are increased by factors 2 and 4, respectively, in comparison to those of the NSR SDRs. Channels sensitive to the carbonate gases in the two bands are labeled with CH_4 (1210-1400 cm^{-1}), CO (2155-2190 cm^{-1}), and CO_2 (2300-2370 cm^{-1}).

4.5. *Develop 36-year VIIRS-AVHRR NDVI and Brightness Temperature Time Series*

POC: Felix Kogan

In the last two decades, the role of satellite observations in climate and land services has increased considerably, especially with the introduction in 2011 of the new generation of NOAA's polar-orbiting satellites known as the JPSS, beginning with the S-NPP satellite. In the past four years, the S-NPP VIIRS instrument helped to improve early drought detection, monitoring (intensity, duration, area, etc.), and impact assessment. Another important role of the new sensor is to continue long-term environmental data records, enhancing their ability to estimate climate warming and land cover changes. This project demonstrates how the new data continue more than three decades of Normalized Difference Vegetation Index (NDVI) and Brightness temperature (BT) from Advanced Very High Resolution Radiometer (AVHRR) data records to the new era of S-NPP/VIIRS for climate and land cover change studies. These results will be extended through the JPSS lifetime.

Some challenges in achieving these goals are huge differences between AVHRR and VIIRS NDVI and BT. NDVI differences are due to strong differences in the NIR spectral response function between AVHRR and VIIRS, resulting in 30% higher NDVI values for VIIRS relative to AVHRR. BT differences are due to VIIRS collecting high-resolution IR data from the 10-12 µm infrared window, which is contaminated with water vapor in the 11-12 µm region, while AVHRR collects from the 10-11 µm spectral range (which has less water vapor contamination), resulting in lower BT for VIIRS relative to AVHRR.

These challenges were overcome with the application of an algorithm designed to estimate Vegetation Health of land. The algorithm consists of the following steps: retrieving channel radiances in the visible and emissive intervals of solar spectrum, testing the stability of the radiances, mapping them to a standard geographic projection, producing NDVI and BT, adjusting the VIIRS NDVI and BT to AVHRR-equivalent values using correlation and regression analysis, testing the stability of the resulting Pearson correlation coefficient and regression parameters (slope and intercept), and producing VIIRS-adjusted NDVI and BT. Figure 6 demonstrates that the adjusted S-NPP/VIIRS NDVI and BT are consistent with the AVHRR-based time series.

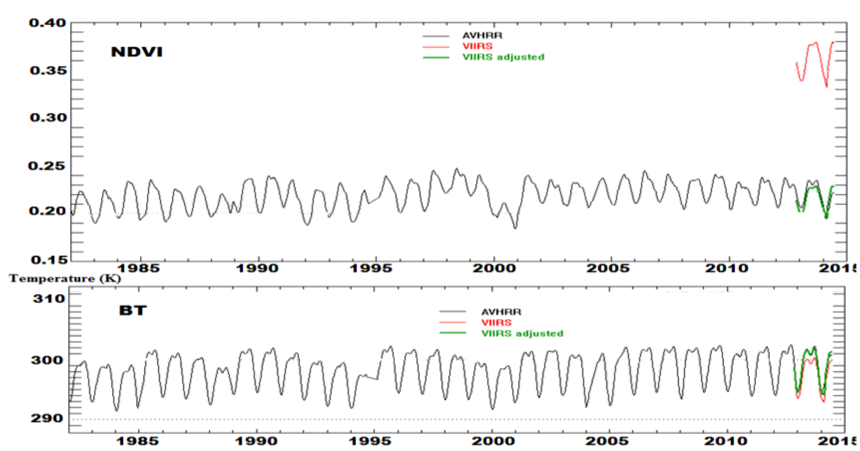


Figure 6. 36-year (1981-2015) NDVI and BT from AVHRR and VIIRS (actual and adjusted) for dry grassland area in Saratov region of Russia.

4.6. *Demonstration of S-NPP VIIRS Fire and Aerosol Product Applications for NWS Applications through "Fire and Smoke" Initiative*

POC: Shobha Kondragunta

The S-NPP VIIRS fire and smoke products are currently distributed to operational users, including air quality forecasters, through the IDEA (Infusing satellite Data into Environmental Applications) website that includes products generated from Direct Broadcast (DB) data. Under the *Fire and Smoke Initiative*, the objective is to enhance the IDEA display system with targeted regions as a focus and interactive zoom capability to the city level so that Incident Meteorologists can use the system while on the ground using their device of choice (e.g., smartphones). Products to be displayed are fire hot spots, fire radiative power from the new VIIRS operational fire product, proxy burned area computed from regression models, and areal extent of smoke and dust plumes. This web-based dissemination system reaches out to many operational users, in particular air quality forecasters. However, forecasters at WFOs often have limited time to access multiple web-based data and, therefore, rely on data coming into their Advanced Weather Interactive Processing System (AWIPS) monitors. To facilitate the WFOs, the plan is to reformat VIIRS fire and smoke products available on the IDEA website and make them available for AWIPS-II applications. As the first phase of this project, STAR aerosol team gave seminars, interactive tutorials, and live demos to introduce S-NPP VIIRS fire and aerosol products that are available on the IDEA website.

The summer 2015 was a very active fire season in the western region, Alaska, and Canada. Figure 7 shows S-NPP VIIRS fire hot spots and smoke mask overlaid on true color image over CONUS (Contiguous United States) for August 14, 2015. The smoke mask flag (shown in magenta-pink color), along with aerosol optical thickness (AOT) product, provides the forecasters with information on not only the amount of aerosol in the atmosphere, but also the type of aerosol. The smoke and dust mask from the operational product stream generated by the IDPS system is not operational as its quality is not good. STAR aerosol team developed an alternate algorithm that runs on the DB data and provides it along with AOT product. These satellite-derived products are the staple for air quality forecasters who are well trained on how to use these products in their daily air quality forecasts. However, the weather forecasters, especially in the western region, who are increasingly being asked to address the smoke forecasting needs, are not familiar with satellite-derived aerosol products. To address this, a presentation by an air quality forecaster was given to participants of the *Fire and Smoke Initiative* on the case study of June 9, 2015, involving the transport of smoke from fires in Alaska and Canada and how the smoke led to air quality standard violations for the eastern United States. This presentation, along with other informal teleconferences, was used to expose the forecasters in the Western Region and Alaska to S-NPP VIIRS aerosol products.

As a result of various meetings, including a one-day satellite air quality proving ground workshop on September 9, 2015, the VIIRS *Fire and Smoke* team obtained valuable feedback to revise the dissemination of the products. Although forecasters use products from different satellites, some of them prefer a blended product. This blended product of fire and smoke aerosols needs to inform them where the hot spots are, where the smoke is now, and where the smoke is headed. In particular, they are not concerned about which specific satellite has provided this information. Contrary to this, air quality forecasters well trained in the use of satellite data prefer observations from different satellites at different times to capture diurnal variability in aerosols and changes to cloud cover. To meet these two diverse requirements, the IDEA website will be modified to have one-stop information on fires and smoke for different regions (e.g., NWS Alaska, NWS Western Region, etc.). The blended version of the product display system will also be ported to AWIPS-II.

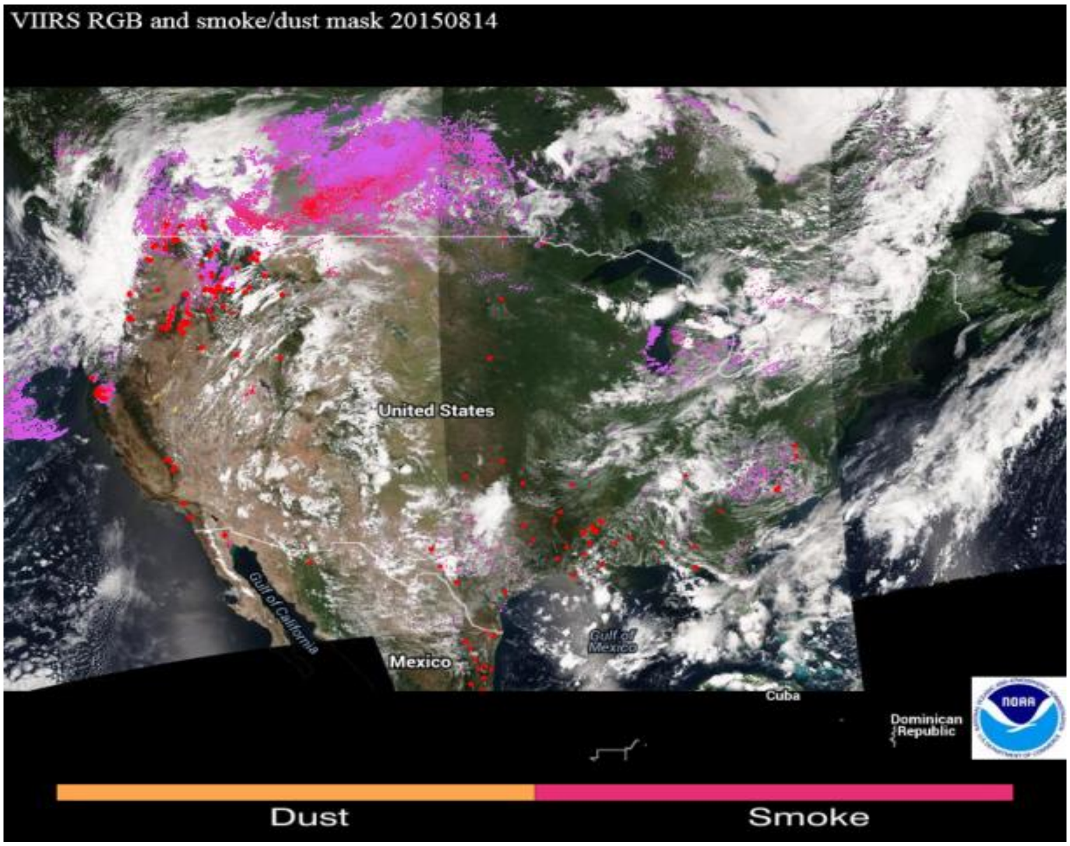


Figure 7. S-NPP VIIRS fire hot spots (red dots) and smoke mask (magenta-pink) overlaid on true color image for August 14, 2015. Image generated using SDRs from direct broadcast data downloaded at University of Wisconsin–Madison. The algorithm that generated the smoke mask is a research algorithm that is being tested on the DB data. The granules from CONUS and Alaska are processed daily and images distributed through IDEA (http: www.star.nesdis.noaa.gov/smcd/spb/aq).

4.7. Incorporating Rainfall Rates from the Advanced Technology Microwave Sounder into the Operational Ensemble Tropical Rainfall Potential Suite

POC: Robert J. Kuligowski

Tropical Rainfall Potential (TRaP) is a gridded forecast of rainfall from a tropical cyclone during the next 24 hours; it has been produced operationally at Office of Satellite and Product Operations (OSPO) for every tropical system worldwide for more than a decade. A TRaP is produced by extrapolating the current rain rate field for the storm (estimated from satellite data) along the official predicted storm track, often from the National Hurricane Center, for 24 hours (assuming that the rain rates do not change with time) and accumulating the rainfall to get a predicted total. More recently, an enhancement called Ensemble Tropical Rainfall Potential (eTRaP) was put into operations at OSPO. In the ensemble, all of the TRaPs in 6-hour segments (i.e., lead times of 0-6, 6-12, 12-18, and 18-24 hours) are organized by time period (e.g., all of the TRaP segments covering 12 to 18 UTC on a particular date) and combined into a weighted ensemble. The weights are based on the satellite instrument used to produce the rain rates (since the accuracy varies from one instrument to the next) and on the lead time of the TRaP segment (for instance, a TRaP that represents an 18-24 hour forecast will receive less weight than one that represents a 0-6 hour forecast). The TRaPs from each instrument are also adjusted so that there are no significant differences in bias from one instrument to the next. The weighted ensemble is used to produce total accumulations for 0-24 hours and the four 6-hour segments, plus probabilities that the rainfall accumulation at each pixel will exceed a given amount.

As old satellites are retired, rain rates from new satellites must be brought into the ensemble to replace them; otherwise, there will not be enough TRaPs to form the basis for an ensemble forecast. This became an acute problem in the Atlantic Basin several years ago; at one point eTRaPs were available only 50% of the time because of a lack of TRaPs. To solve this problem, several new rain rate estimates have been added to the ensemble in recent years, most recently the ATMS onboard the S-NPP satellite, using rain rates by the Microwave Integrated Retrieval System (MIRS). Before a TRaP from a new satellite can be added to the ensemble, its accuracy relative to the other TRaPs needs to be evaluated so that it can be weighted appropriately in the ensemble. This was done by comparing the accuracy of TRaPs from ATMS data to TRaPs produced by other satellites. Four tropical systems that made landfall over the CONUS during 2012-2013 were evaluated for 17 different time periods and it was found that the skill of the ATMS TRaPS was very similar to that of the TRaPs from other microwave instruments (the Tropical Rainfall Measuring Mission and the Advanced Microwave Sounding Unit/Microwave Humidity Sounder), so the weight of the ATMS TRaPs in the ensemble was set at 1; in addition, it was found that no bias adjustment was needed.

The resulting ATMS TRaPS were then incorporated into eTRaP, and the results showed that the skill of eTRaP actually increased slightly (Figure 8), and the wet bias decreased slightly. These improvements were considered a secondary benefit to ensuring continuity of the eTRaP product, but were nonetheless a welcome result. The code for including the ATMS TRaPs in eTRaP was delivered to OSPO in 2015 and is being transitioned into operations there.

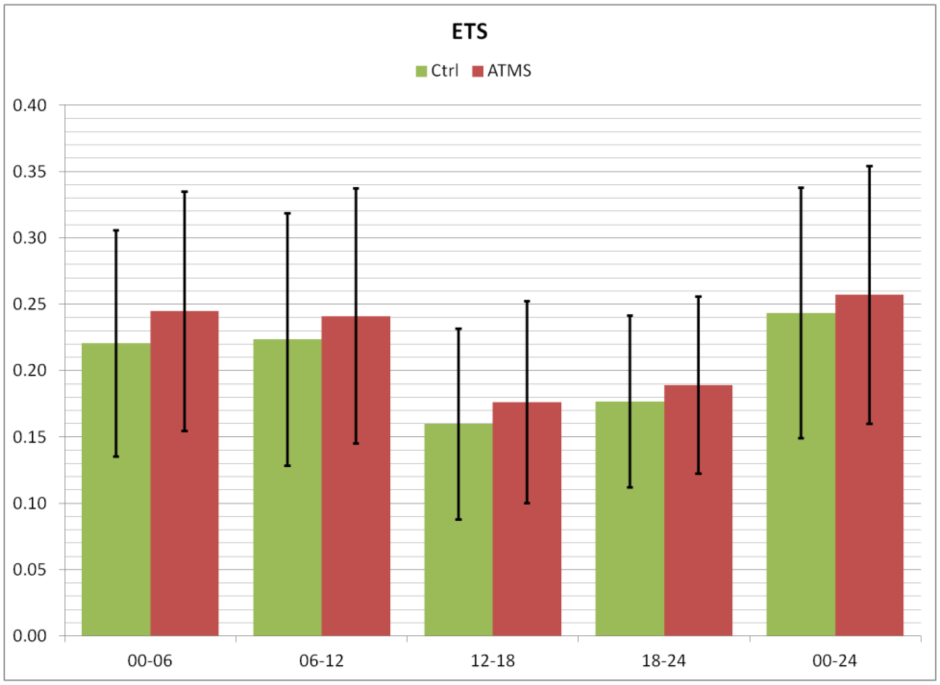


Figure 8. Equitable Threat Score (0=no skill relative to chance, 1=perfect skill) for eTRaP without ("Ctrl") and with ("ATMS") ATMS TRaPs included for 18 different predictions during the 2012-2013 Atlantic hurricane seasons. The bars indicate the 95% confidence interval.

4.8. Complete Implementation of New Modules in the JPSS Risk Reduction Aerosol Retrieval Algorithm That Are Expected to Improve Retrieval of High Optical Thickness

POC: Istvan Laszlo

Under the JPSS Risk Reduction (RR) program, a physical algorithm has been developed for the retrieval of AOT from the measurements of the VIIRS. Similar to the current operational algorithm in the IDPS, the VIIRS RR algorithm (VRR) uses the 488 nm (band M3) VIIRS reflectance to retrieve the AOT via estimating the M3 surface reflectance from that derived from the 672 nm (M5) band. Evaluation of the AOT product with ground-based retrievals of aerosol from the Aerosol Robotic Network (AERONET) showed compliance with requirements; however, there was an indication of underestimation of AOT for high AERONET values. The top panel of Figure 9, which plots the IDPS AOT versus the AERONET AOT from two years of satellite-ground matchup data, clearly shows several significantly lower IDPS retrievals beyond about 1.5 AERONET AOT.

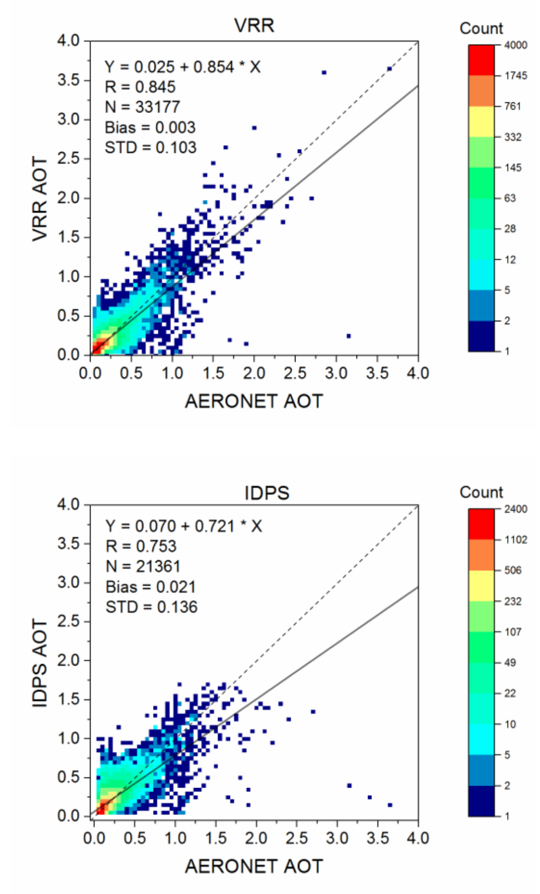


Figure 9. Comparison of satellite-derived AOT from the IDPS algorithm (top) and that from the VRR algorithm (bottom) with ground-based aerosol retrieval from AERONET. Note the decrease in underestimation in VRR for high AOT, reduction in bias and standard deviation (STD), and increase in correlation (R) and number of retrievals (N). Two years of satellite-AERONET AOT matchup data were used. Solid line represents the linear fit Y=a+bX; dotted line is the 1:1 line.

The IDPS approach is expected to work reasonably well for low AOT since a low AOT presents a relatively optimal condition for estimating the M5 surface reflectance. However, when the AOT increases, much of the radiation “seen” by the satellite comes from scattering by aerosols, so the uncertainty in the estimated M5 (and thus the M3) surface reflectance can become significant. In contrast, the M11 band at 2250 nm remains relatively transparent for most (small-size) aerosols, and presents a chance to estimate a potentially accurate M11 surface reflectance from which a less uncertain M5 value can be estimated. This latter approach has also been implemented in the VRR algorithm.

But since we do not know the AOT magnitude when we start the retrieval, how do we choose the channel (M5 or M11) for estimating the M3 surface reflectance? Theoretically, the M3 surface reflectances should be the same regardless of whether they are estimated from M5 or M11. In practice, however, they are different due to uncertainties in the relationship between them, and because high AOT makes the M5 value more prone to errors. When the difference between the two M3 values (retrieved from M5 and M11, respectively) is larger than a threshold, the VRR algorithm chooses the M11 band. The bottom panel of Figure 9 shows the evaluation of VRR retrievals with AERONET values. Comparing it to the top panel, it is evident that much of the underestimation seen in the IDPS at high AERONET AOT value is gone, and the bias and standard deviation (STD) also improved.

4.9. Generate NOAA Operational Atmospheric Trace Gas Products (CO, CO_2, and CH_4) (AC3) from S-NPP CrIS Full Spectral Resolution Data

POC: Quanhua (Mark) Liu

Atmospheric carbon CO, CO_2, and CH_4 (AC3) environmental data records are important parameters for air quality forecasting and climate studies. The U.S. Environment Protection Agency (EPA) has set National Ambient Air Quality Standards for six principal pollutants. Carbon monoxide is one of the six principal pollutants that are harmful to public health and the environment. Carbon monoxide is also a good indicator for monitoring wildfires. Carbon dioxide is a greenhouse gas that is used in climate studies. Methane is a much stronger greenhouse gas than carbon dioxide. The information on CO_2 and CH_4 can also be useful to radiance assimilation in support of weather forecasting. In radiance assimilation, temperatures are derived from CO_2-affected channels and water vapors are inverted from water vapor channels overlapped by CH_4 absorption.

The NOAA JPSS mission is going to generate AC3 EDRs from CrIS full spectral resolution data. The full spectral data will be operational and the NOAA/NESDIS/STAR sounding team is working on the algorithm development. As a demonstration, NASA/Langley Research Center and NOAA/STAR sounding teams have worked together and conducted the global retrievals of AC3 using the NASA algorithm. Figure 10 shows the retrieval of global CO at 300 hPa by using the CrIS full spectral data generated at NOAA/NESDIS/STAR. CO at this layer can reflect the CO emission source and transportation. We can see the large CO emission source in East Asia and Africa. The orange and red color part over the northern Pacific Ocean indicates the CO transportation from East Asia to the west of North America.

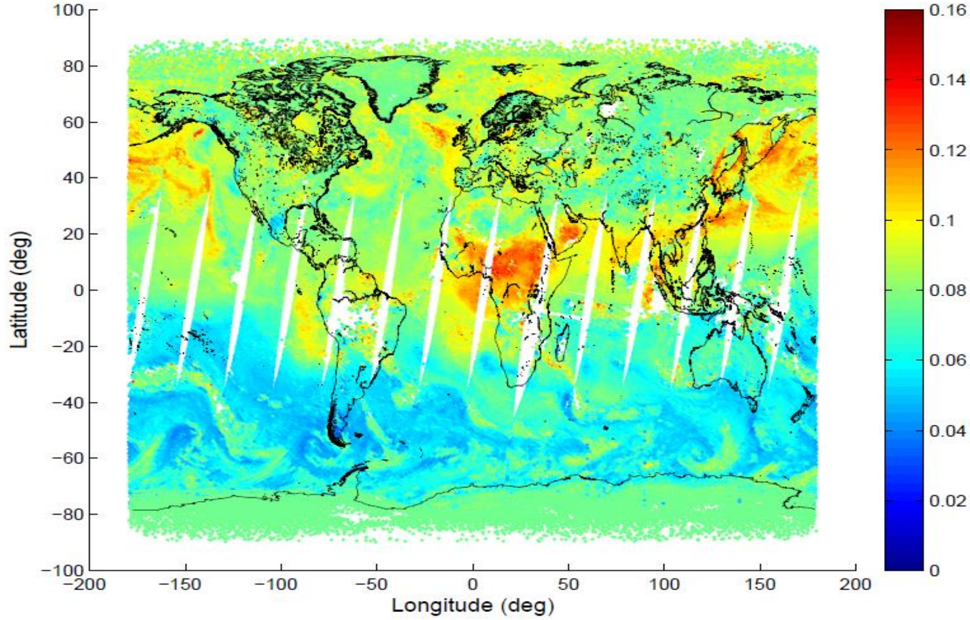


Figure 10. Retrieved carbon monoxide (in ppmv) at 300 hPa by using CrIS full spectral data on February 17, 2015.

4.10. Delivery of High-resolution, Global Geostationary Full-disk Composite Product to Support NWS/EMC's Global Aircraft Icing Validation

POC: Kenneth L. Pryor

A recently developed suite of global geostationary satellite image mosaics has been implemented in the NESDIS/OSPO. New software merges visible, thermal infrared, and shortwave infrared full-disk image datasets from Geostationary Operational Environmental Satellites (GOES)-13 and 15, Meteosat Second Generation (MSG) Spinning Enhanced Visible and InfraRed Imager (SEVIRI), and MTSAT into a global composite image dataset. The global mosaic images are generated at high resolution, 8 km, and extend coverage to the polar circles (67° latitude) to satisfy a request from the NCEP/EMC. Pre-operational product datasets are available for testing and evaluation via the OSPO FTP server: ftp://satepsanone.nesdis.noaa.gov/2day/gmosaic/.

In order to maximize dataset usage, and minimize overlap and geodistortion error, generation of the new composite image suite entails the following steps:

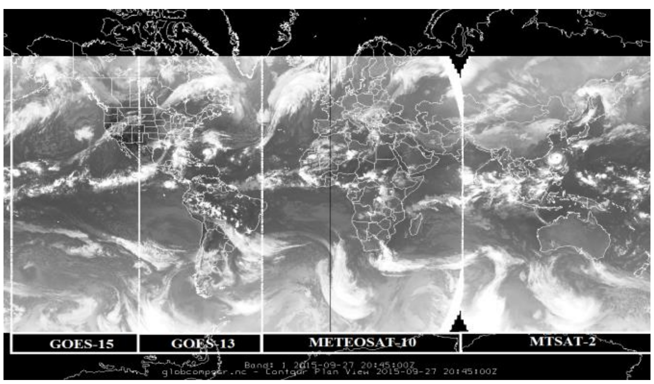


Figure 11. Global image mosaic of GOES, Meteosat SEVIRI, and MTSAT longwave infrared imagery at 2100 UTC on September 27, 2015, with satellite sensor source marked by white partitions.

1) Generation of 8-band image data files

2) Generation of image files containing brightness values

3) Generation of new remapped images with 8-km resolution

4) Generation of image files containing the distance to nadir for each respective satellite

5) Merging the four images with the same projection into a composite image

An important step in the generation of this high-quality global mosaic dataset is taken in areas overlapped by two satellites, where pixels with a shorter distance to its own nadir are selected to generate the composite image, resulting in higher resolution and less distortion. The global image mosaic software passed a code review in June 2015. Nearly complete global coverage at 8 km resolution between Arctic (Latitude 67°N) and Antarctic (Latitude 67°S) circles is demonstrated in Figure 11. Overlap between geostationary satellite image sectors is minimized, thereby eliminating geodistortion (i.e., displacement, limb darkening) errors. Global mosaic satellite data allows for improved indication of icing potential, especially in the vicinity of icing pilot reports (PIREPs). In addition, GCIP (GEWEX [Global Energy and Water Cycle Exchanges Project] Continental-scale International Projects) derived from satellite mosaic data is more consistent with the operational regional CIP product, which shows that satellite data improves the GCIP product.

4.11. *Routine Collocation of GPM Dual-frequency Precipitation Radar and S-NPP Advanced Technology Microwave Sounder in Precipitating Regions*

POC: Anthony L. Reale

Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR), a follow-up to the NASA Tropical Rainfall Measuring Mission (TRMM), was launched February 27, 2014. GPM provides advanced precipitation measurements from space using a combination of active and passive remote sensing techniques. These data are useful to calibrate, unify, and improve precipitation measurements among research and operational satellites with microwave sensors. The data are also useful to better understand the impacts of precipitation in the microwave bands in order to better calculate radiance in precipitating regions for possible inclusion in NWP forecast assimilation. Precipitating regions are a critical component of weather forecast information that currently do not benefit from direct satellite inputs to reconcile the temperature and moisture fields. The compilation of a dataset to better understand how precipitation impacts the microwave sensors in the 50 GHz and 183 GHz frequency range, with the goal of developing RT model enhancements to allow the assimilation of these data in precipitating regions, was the motivation for this work.

The task was focused on collocating GPM/DPR with S-NPP ATMS microwave data in the 183 GHz region and was divided into two basic parts. First, the orbital geometries of the respective DPR and ATMS had to be integrated into a single processing capability capable of comparing the observations on each day to determine the occurrence of co-located DPR and ATMS observations. A collocation is initially defined as a DPR observation(s) falling within +/- 15 minutes and about 10km from the center of a given ATMS 183 GHz footprint. Once a series of collocated observations is determined, the second step is to determine if the DPR indicates that precipitation is occurring; if yes, then all of the collocated DPR and ATMS observations are retained on a special file. Processing of these collocations was initiated early in 2015 and continues through the present day.

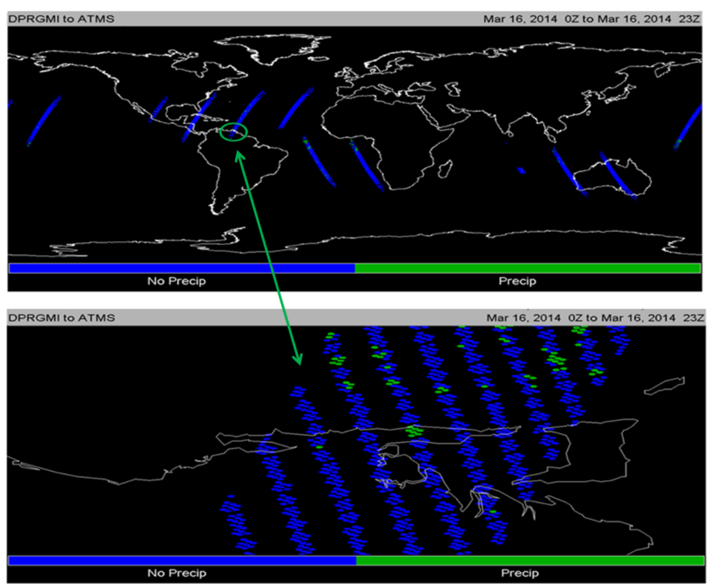


Figure 12. Global distribution of GPM and S-NPP ATMS observations.

The upper panel of Figure 12 shows a typical global distribution of GPM and S-NPP ATMS observations on a day when sizable numbers of collocated observations are observed. Blue areas indicate precipitation-free zones and the green areas designate precipitating regions based on the DPR. Overall, the GPM and ATMS satellites have approximately 18-day collocation cycles in which the number of collocated observations varies from the distribution as shown in the upper panel to no collocations equator-ward of 50N. The lower panel shows the distribution of precipitating DPR clusters collocated within 10 km and 15 minutes of the center of the ATMS footprint (not shown) corresponding to the circled area in the upper panel. On a good day, about 5% of the ATMS observations are collocated with GPM/DPR, with typically less than 0.5% indicating precipitation. Although a very small number of collocated precipitating observations are observed on any given day, when accumulated over several years, these can provide a significant sample of the rare and potentially critical data for improving weather forecast when precipitation is occurring.

4.12. *Initiate the Discussion with NESDIS Big Data Efforts and Hold STAR Big Data Workshop*

POC: Laurie Rokke

NOAA's historical satellite programs combined with the current satellite production of operational products and the upcoming launches of the next generation of satellite sensors (JPSS, GOES-R) will provide a vast lake of data. This data has the potential to provide improved information for understanding and protecting our ecosystems, supporting improved Weather Service forecasts, and refining and adding value to Earth System Science. The amount of data being collected, the speed at which it is needed, and the quality of the data produced make it optimal for Big Data applications. Within NOAA data sets there exists valuable patterns and information, which is difficult to detect due to the excessive amount of work to extract them. The intent of the milestone is to introduce big data and its analytical applications to STAR to improve satellite applications.

STAR involvement in Big Data is focused on using predictive modeling techniques to characterize instrument noise and applications of background error covariance modeling. The environment and process needed to do predictive modeling is shown in Figure 13, and is being

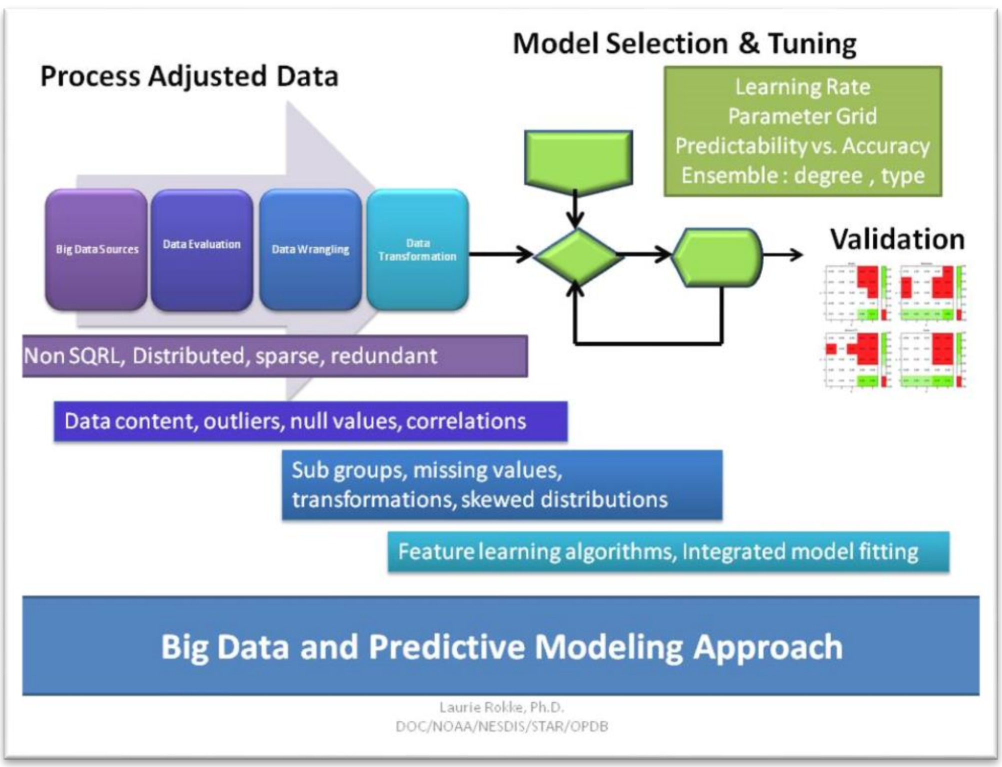


Figure 13. Predictive Modeling Fundamentals.

implemented at STAR. A Big Data Workshop is scheduled for February 11, 2016, with speakers from NOAA, University researchers, and Industry to discuss new and innovative applications.

STAR is contributing to the NOAA Science Advisory Board working group on Data Archiving and Access Requirements, working with them on STAR activities and with the team from the NESDIS Big Data Initiative. The NOAA Big Data Project was initiated due to the fact that the existing NOAA infrastructure and funding cannot support the amount of data and level of demand. The NOAA Big Data project was designed so see if the value inherent in NOAA's Data sets could support the cost of their distribution. A huge response to the Request for Information released in February 2014 prompted NOAA to initiate a research and prototyping phase to explore technologies and methods, incubate ideas for new business models, and to prove whether self-sustainability was possible. To this end, NOAA created the NOAA BIG Data Project with initial outreach to companies that serve as project anchors (Infrastructure as a Service institutions) to build Data alliances that create market ecosystems. The intent is to demonstrate the value of the proposition and self-sustainability of the project. Project anchors and data alliances define their own goals in concordance with the NOAA statement of objectives:

1. Transparency and open standards
2. Equal access and no privileged access to data
3. Technical touch points with NOAA
4. Common data catalogs

The value of this effort is to combine the best of NOAA environmental data with business technical applications that would be self-sustaining and improve our understanding and use of the Earth's Environmental data.

4.13. Development of the JPSS-1 Top of Canopy NDVI (J1 Upper)

POC: Marco Vargas

The JPSS will provide operational continuity of satellite-based observations and products for NOAA's POES and the S-NPP satellite. S-NPP was launched in October 2011, and JPSS-1 (J1) is planned for launch in 2017. Certain level 1 requirements were exempted for S-NPP, but will be implemented in the J1 era, including the JPSS-1 Top of Canopy (TOC) NDVI. Vegetation Indices derived from satellite measurements are used to monitor the environment, including drought, land degradation, deforestation, the health of ecosystems, forest fires, crop monitoring, land cover classification, as well as for weather forecasting and climate research. In addition, the TOC NDVI is a critical upstream product for various derived variables needed by the NWS NCEP, including Leaf Area Index, Vegetation Health, and Vegetation Phenology.

The current operational S-NPP VIIRS Vegetation Index EDR includes two vegetation indices: the Top of the Atmosphere NDVI and the TOC Enhanced Vegetation Index. For JPSS-1, the S-NPP Vegetation Index EDR algorithm has been updated to include the TOC NDVI, additional quality flags, and improved high-quality definitions for the three indices. The new J1 TOC NDVI was developed using S-NPP VIIRS Surface Reflectance (SR) input bands (SR bands I1 and I2). The JPSS Algorithm Change Process (ACP) was followed during development and implementation of the new vegetation index. The ACP included a Critical Design Review, a Test Readiness Review, and an Algorithm Readiness Review (ARR).

The JPSS-1 TOC NDVI was validated against MODerate resolution Imaging Spectroradiometer (MODIS) TOC NDVI data, and the calculated Accuracy, Precision, and Uncertainty performance parameters were below the specification parameters listed in the JPSS Level 1 Requirements Document Supplement. The final validation results were presented at the ARR. The JPSS Algorithm Engineering Review Board approved the code change (CCR 474-CCR-15-2382) on July 15, 2015. The JPSS-1 TOC NDVI code change has been released to Raytheon for integration into the IDPS Block 2.0 PRO code. The new JPSS-1 Vegetation Index EDR algorithm will be deployed and transitioned to operations within the JPSS Ground System before JPSS-1 launch.

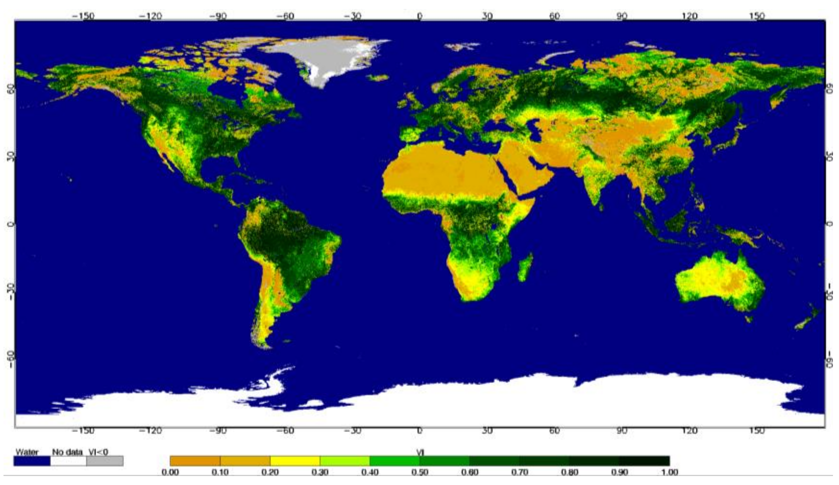


Figure 14. JPSS VIIRS TOC NDVI (June 25 – July 1, 2015)

4.14. Provide Himawari-8 Level 1B Radiance BUFR and Level 2 Derived Motion Wind BUFR files to the NWS

POC: Walter Wolf

Equipped with vital sounder instruments, the JPSS-1 satellite is not expected to launch before early 2017. Given the time required for in-orbit checkout of the system, calibration, and other commissioning activities, NWS operational users will not expect to have access to JPSS-1 data until late in 2017. NOAA has identified a potential data gap between current sources of polar sounder data in the afternoon orbit and the future operations of JPSS-1. To mitigate this data gap, the "Sandy Supplemental Himawari-8 (H8) Product Development Project" was implemented. The primary function of the project is to provide the services needed to ingest data from the H8 satellite, process these data into reformatted Level 1b (L1b) and Level 2 (L2) products, and distribute these products to the NWS. The products requested by the NWS are original Level 1b Advanced Himawari Imager radiances, L1b Radiance data for all 16 AHI channels in BUFR, and the Level 2 Derived Motion Winds (DMW), in both BUFR and Network Common Data Form (NetCDF) 4 formats.

To meet the NWS requests, STAR had to first gain access to the AHI data in near real-time. To do so, STAR worked with the Japan Meteorological Agency through the NESDIS International and Interagency Affairs Division to access the JMA Himawari Cloud. STAR was given an account from which we download the 16-channel full disk L1b data every 10 minutes. These data are then saved in the STAR Central Data Repository (SCDR) in the original Himawari Standard Data (HSD) format. These HSD files, ten files per full disk per channel, are then copied to the STAR ftp server where NWS, DoD, and the Joint Center for Satellite Data Assimilation can download the data. The HSD files have been available on the STAR ftp server since March 2015. STAR also pushes the data to two of its cooperative institutes: Cooperative Institute for Meteorological Satellite Studies (CIMSS) and Cooperative Institute for Research in the Atmosphere (CIRA).

Because of the similarity of the H8 AHI to the GOES-R ABI, the software to provide both the subset of H8 AHI data and the DMW needed by the NWS for data assimilation was leveraged from the other STAR work. This work included leveraging the improved product processing system developed by the GOES-R Algorithm Working Group (AWG), providing NESDIS operations with a flexible system framework and allowing for easy integration of new Level 2 product algorithms and data sharing between algorithms. This enabled the advanced GOES-R algorithms to be applied to the AHI data, thereby enabling early experience with the GOES-R algorithms in operations. This BUFR conversion software leveraged the existing NetCDF4 to BUFR Reformatting Toolkit (N4BRT).

By leveraging the AWG framework, STAR was able to implement an AHI Cloud Mask algorithm, Cloud Phase algorithm, Cloud Height algorithm, and DMW algorithm. The algorithms were implemented over the summer of 2015 and the NetCDF4 DMW product is being produced in near real-time at STAR since September 2015. By leveraging the N4BRT, the L1b AHI BUFR files were made available to NWS and DoD in May 2015 and the DMW BUFR file was made available in September 2015.

4.15. Demonstrate Uses of Himawari-8 AHI Data for GOES-R ABI Calibration Risk Reduction

POC: Xiangqian Wu

After the Japan Meteorological Agency decided to launch the Advanced Himawari Imager (similar to Advanced Baseline Imager), it was recognized that NOAA's experience with ABI development, in particular instrument calibration and validation (cal/val) and meteorological product algorithms, would be invaluable for JMA. Meanwhile, AHI would be launched 12 months before ABI, allowing NOAA to learn from early AHI data to reduce ABI risks. These mutual benefits led to the NOAA-JMA collaboration on respective advanced geostationary meteorological satellite systems, which was formalized in January 2012. As part of this collaboration, we were tasked to demonstrate, by June 2015, the use of AHI data for GOES-R ABI risk reduction.

Figure 15. True color image by AHI on January 15, 2015, 02:30 UTC. [Courtesy of JMA for data and of S. Miller (CIRA) for true color scheme.]

A major challenge we faced was the limited available knowledge we had on AHI, the first of a new generation. While we were experienced with GOES calibration in general and ABI pre-launch tests in particular, we had just started to plan for ABI post-launch tests and there was no precedence for AHI on-orbit performance. Differences also exist in spacecraft, instrument, cal/val and Image Navigation and Registration (INR) algorithms, and data format between AHI and ABI. To meet these challenges, we studied AHI design and data format, and developed the AHI and ABI post-launch test plans in parallel while keeping JMA well informed. We strived to benefit JMA with NOAA expertise without violating International Traffic in Arms Regulations (ITAR) and other regulations. In February 2015, a NOAA delegation visited JMA and shared our expertise through extensive discussions on various aspects of AHI cal/val and INR. This visit, and the follow-up side meetings in March and April and web meetings in May and August, greatly helped both NOAA and JMA to understand AHI performance. As another result of this collaboration, NOAA received early AHI data that have been a tremendous help to educate users of ABI potentials, to fine tune product algorithms, and to test ground system processing.

We also had a number of unexpected challenges during the collaboration. In December 2014, shortly after the instrument saw the first light, it was discovered that the scan mirror encoder malfunctioned occasionally, causing excessive shutdowns. In January 2015, it was found that AHI INR had unacceptable errors, putting many cal/val activities on hold. In February 2015, unexpected stray light was found around satellite midnight. With our effort and through collaboration with JMA, NASA, and Harris Corporation, we overcame all of these obstacles. All of these experiences, including the hardware and software modifications by Harris, reduced the risks for ABI.

We shared our experience widely within the GOES-R Program (NESDIS, NWS, NASA, Harris, and contractors) through briefings to GOES-R personnel and to the GOES-R Independent Advisory Committee in February, a Milestone summary to STAR in June, and the distribution of early data to 118 users in 17 organizations. The benefits of NOAA-JMA collaboration for ABI risk reduction have been appreciated repeatedly. Most recently, at the ABI Flight Model 4 (FM4) Pre-environmental Review (PER), the only recommendation by the Integrated Independent Review Team (IIRT) was to continue using AHI experience to reduce ABI risk. This milestone was achieved with support by STAR GOES-R Calibration Working group (CWG) and Algorithm Working Group (AWG) teams, the GOES-R Program, NESDIS International and Interagency Affairs Division (IIAD), and JMA.

4.16. A Vegetation Phenology Webpage Developed for Foliage Near-real-time Monitoring and Prediction over the CONUS

POC: Yunyue Yu

Patterns in land surface phenology at global scales reflect complex interactions among atmospheric, biospheric, and soil biogeochemical processes, and are particularly sensitive to climate changes**.** Near-real-time monitoring and short-term forecasting of vegetation phenology have a wide social, cultural, and economic significance to people on this planet, including for food supply, human health, species invasions, droughts, and disease outbreaks. However, in order to characterize and understand interannual-to-decadal scale changes in ecosystem response to climate change, a well-calibrated long-term phenology data record spanning the AVHRR, MODIS, and VIIRS era is required. While long-term phenology data serves the investigation of climate change, the VIIRS phenological metrics in near real-time will provide relatively realistic data to the land model in the NOAA Numerical Weather Prediction Systems and will assist the crop growth monitoring in the U.S. Department of Agriculture.

Prediction of the vegetation phenology is based on a high-quality four-phase vegetation development model and current vegetation observations. Such observations are available by polar-orbiting satellite sensors from AVHRR, MODIS, and VIIRS era; inconsistency of the observations from different satellite missions must be resolved. In this project, an improved vegetation phenology model and vegetation index computation model have been developed, which then is applied for the near-real-time vegetation phenology monitoring. Further, a climatologically database is developed based on a large amount of historical data computation, which then is applied for the near-future vegetation phenology prediction.

The near-real-time foliage monitoring and near-future prediction results are published at one of the STAR websites: http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Foliage.php. The phenology monitoring and prediction results have been used and cited by universities, research institutes, government agencies, and international organizations.

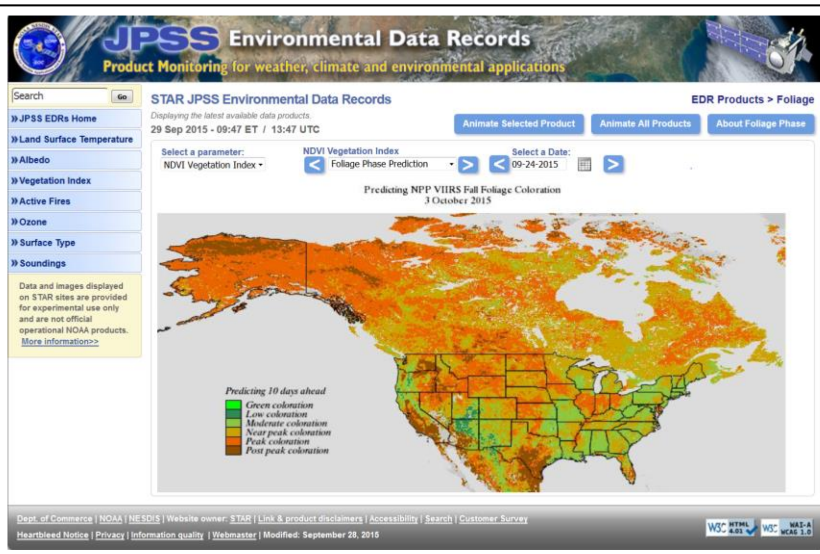


Figure 16. Near-real-time foliage monitoring and near-future prediction results.

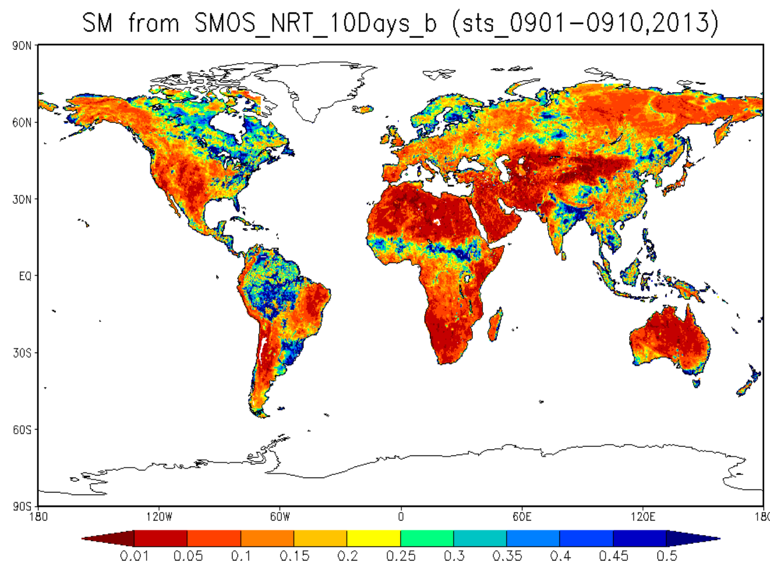
4.17. Update and Make Operational SMOPS with Observations from GCOM-W/AMSR2 and Near-real-time SMOS

POC: Xiwu Zhan

The Soil Moisture Operational Products System (SMOPS) is NESDIS' operational global system for providing reliable soil moisture data to the experimental and operational numerical weather prediction models of the NWS NCEP. SMOPS currently uses data from the Advanced Scatterometer (ASCAT) on MetOp-A and -B of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Soil Moisture and Ocean Salinity (SMOS) of the European Space Agency (ESA), and WindSat of the DoD Naval Research Laboratory (NRL). The SMOS soil moisture data feed has roughly 12-hour latency, but SMOS Level-1 brightness temperature data latency is less than 3 hours. Since 12-hour latency is too long for use in operational numerical weather models, one of the FY15 tasks of the SMOPS project was to use the SMOPS retrieval algorithm to retrieve soil moisture with latency significantly shorter (about 5 hours) than the official SMOS soil moisture product latency.

To obtain an observation of brightness temperature, ESA uses a complicated antenna model with heavy computational costs, which is the main reason why the SMOS official soil moisture product latency is so long. To speed up the retrieval process, we developed a quadratic regression equation to fit the distribution of the brightness temperature as a function of incidence angle in order to obtain fixed-angle near-real-time (NRT) theoretical baselines (TBs). This simplified approach produced NRT TB fields similar to ESA SMOS official SMOS L2 TB products in a fraction of the time.

To retrieve soil moisture, surface temperature (Ts) is also required in addition to the optical depth (τ) of the vegetation cover. SMOPS ingests Ts data from the NCEP GFS and interpolates them to each grid for the time when the TB data are acquired from SMOS. The value of τ is estimated from Enhanced Vegetation Index, which is in turn obtained from the S-NPP VIIRS. Using the Single Channel Algorithm, SMOPS could retrieve soil moisture for an orbit file within two hours after it arrives. The final SMOS soil moisture products obtained from our NRT TB data are also similar to the ESA SMOS official Level 2 soil moisture data products with significantly shorter latency (Figure 17). In addition, SMOPS has been updated with data from the Japan Aerospace Exploration Agency's Global Change Observation Mission (GCOM)-Water 1 (W1) Advanced Microwave Scanning Radiometer-2 (AMSR2). The Level 2 soil moisture retrievals in swath files are obtained from NESDIS GAAPS (GEWEX Aerosol Assessment Panel), which is developed by the NESDIS GCOM-W1/AMSR2 project team. The additional sensor improves spatial coverage of the available soil moisture fields, especially for the 6-hour images.



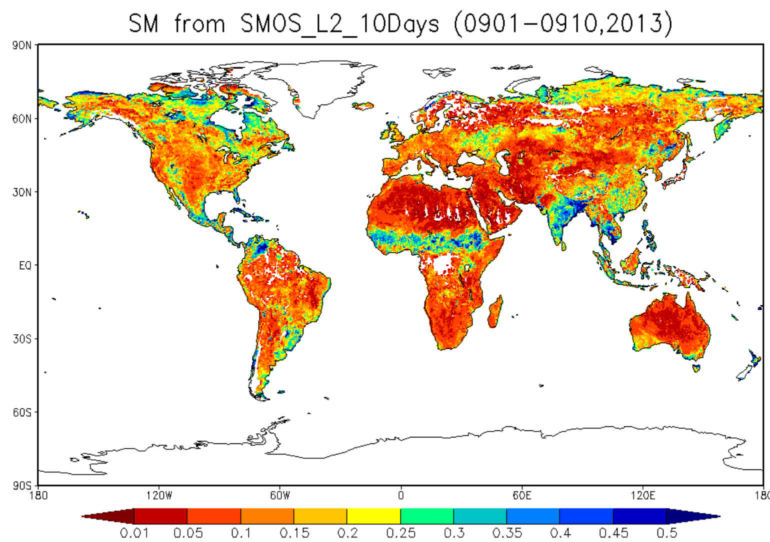


Figure 17. NRT SMOS soil moisture retrieved from SMOPS NRT SMOS TB data are comparable with the ESA SMOS Level 2 soil moisture product. SMOPS NRT SMOS soil moisture data has a latency of less than 6 hours, while the official ESA SMOS soil moisture products are mostly 12 hours late.

4.18. STAR JPSS Annual Science Meeting

POC: Lihang Zhou

The JPSS-STAR (JSTAR) Program organized the second STAR JPSS 2015 Annual Science Team Meeting. The meeting was successfully held August 24-28, 2015, at NOAA's Center for Weather and Climate Prediction (NCWCP) in College Park, MD. The meeting was well attended, with more than 300 virtual and in person attendees, including academic and industry partners, as well as users from NOAA and around the world.

Leveraging on hundreds of scientists from NOAA, NASA, DOC, industry, and academic partners, the goal of the JSTAR program is to provide robust, affordable, and flexible state-of-the-art scientific solutions to meet the NOAA JPSS requirements. With the coming JPSS-1 Launch and NESDIS reorganization, it is essential to share with the teams the vision and mission of the program. There are also changes on JPSS-1 sensor properties and capabilities (such as CrIS full spectral resolution, OMPS higher spectral and spatial resolution, VIIRS DNB non-linearity, etc.). The challenge is to keep all team members informed of changes, including SDR and EDR teams, as well as the operational users, to ensure their preparation and readiness for JPSS-1.

The annual meeting included detailed talks on the status of the SDR and EDR products, and their progress toward preparing for JPSS-1. The meeting also featured sessions detailing user engagement with JPSS products, cutting-edge applications being produced with JPSS data, and the details of data access and reprocessing schemes. Additionally, the event allowed teams to hold rare face-to-face side meetings and discussions. The meeting also produced critical recommendations from users and the broader JPSS community.

STAR has received positive feedback on the annual meeting and was able to share the vision and mission of both NESDIS and the JPSS Program, as well as the JSTAR program. Lastly, it provided an opportunity to collect users' feedback on products and algorithms, which will further benefit future improvements.

Details and all of the meeting presentations are available on the STAR JPSS webpage. http://www.star.nesdis.noaa.gov/star/meeting_2015JPSSAnnual_agenda.php

An executive summary of the meeting is also available upon request. For more information, please contact: Lihang.Zhou@noaa.gov

4.19. Developing Algorithms to Merge SSU and AMSU Observations for the Generation of Stratospheric Temperature Climate Data Record from 1979 to Present

POC: Cheng-Zhi Zou

The stratospheric temperature trends are one of the central indicators for anthropogenic global warming. Observations from the Stratospheric Sounding Unit (SSU) onboard NOAA historical polar-orbiting satellites have been playing a vital role in detecting the long-term trends and variability in the middle and upper stratospheric temperatures during 1979-2006. The SSU successor is the Advanced Microwave Sounding Unit-A (AMSU-A), starting from 1998 until present. It is desirable to merge the two observations together to extend the SSU data record to provide continued monitoring of changes in the stratospheric temperatures from 1979 to present. Unfortunately, the two observations came from different atmospheric layers, with the SSU weighting functions covering atmospheric layers much thicker than those of the AMSU-A channels. In addition, the SSU weighting function varies with time and locations, posing a challenge to merge with AMSU-A with accuracy high enough for development of climate-quality data record.

In 2015, STAR scientists developed a novel variational approach for the SSU and AMSU-A merging, accounting for matching in both of their temperatures and weighting functions. The approach solves for time- and latitudinal-dependent merging coefficients from a variational equation specifically designed for this problem, and it yields zero mean inter-satellite biases with small standard deviation and negligible bias drift over time between SSU and its derived AMSU-A equivalent during their overlapping period (see Figure 18 below). The solution satisfies the necessary condition for the merged time series to reliably detect long-term climate trend. Meanwhile, their weighting functions were matched with reasonably good accuracy, ensuring that the merging is physically sound.

The global mean temperature trends during 1979-2015 derived from the merged time series were -0.64, -0.69, -0.77 K/Dec, respectively, for the three extended SSU channels, representing layer mean temperatures of the mid-stratosphere, upper-stratosphere, and top-stratosphere. This cooling effect is consistent with predictions from the anthropogenic global warming theories that both increases of carbon dioxide (and other greenhouse gases) and ozone depletion will cause a cooling response in the stratospheric temperatures. The merged observations were also compared with climate model simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP-5). Excellent agreement was found for global as well as latitudinal mean trends.

In conclusion, the extended SSU time series was demonstrated to be a credible dataset in monitoring changes in the stratospheric temperatures and verifying climate model simulations of the anthropogenic global warming effect.

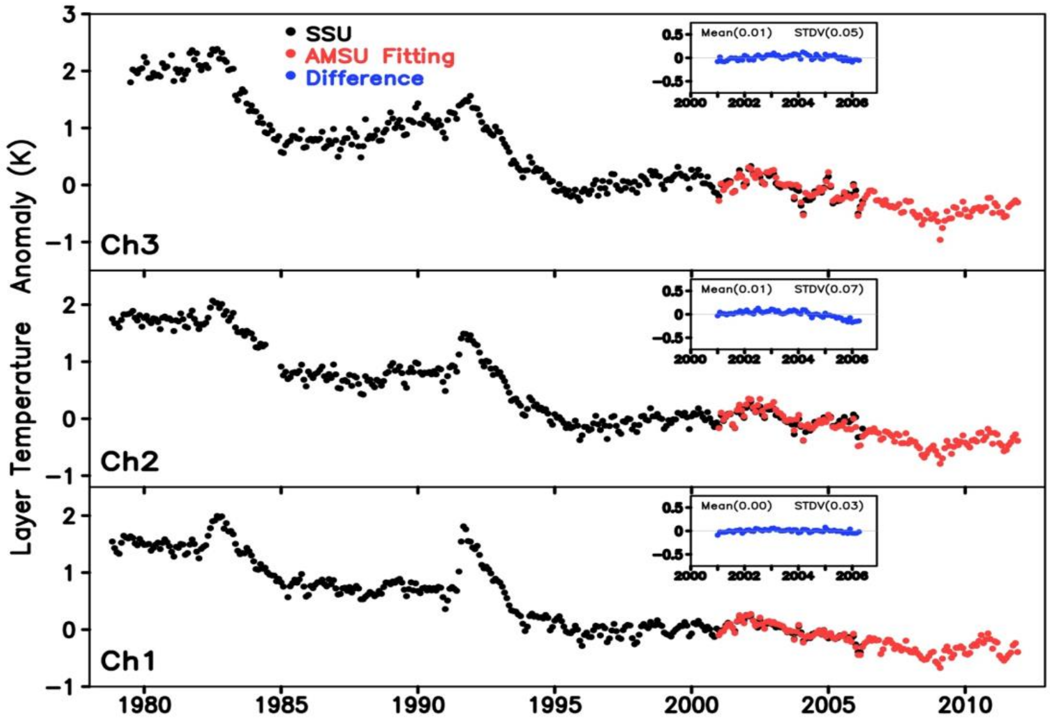


Figure 18. Global mean anomaly time series for the three SSU channels and their AMSU-A equivalents after applying the merging algorithms. The blue lines in the inserted boxes are the difference time series between SSU channels and their AMSU-A equivalents derived from the merging algorithms during their overlapping observations.

5. Awards

The following awards stand out and proudly demonstrate SMCD's hard work and dedication to the NOAA satellite program. These awards allow STAR/SMCD outstanding performers to shine amongst their peers and co-workers. Congratulations on your achievements!

NOAA Administrator's Award 2015

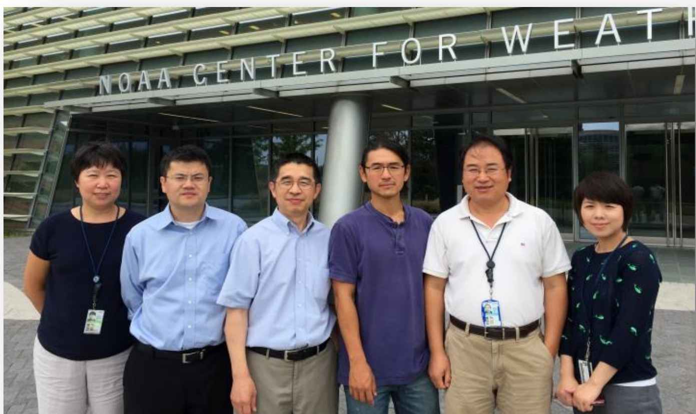
Recipient: **Yong Han** – CrIS SDR Science Team Lead

"For developing state-of-the-art processing, calibration, and monitoring of Cross-track Infrared Sounder (CrIS) full spectral resolution data for weather and climate applications."

Pictured (from left to right): VADM Michael Devany (NOAA's Deputy Under Secretary for Operations), Yong Han (STAR), and Thomas Burns (NESDIS Deputy Assistant Administrator for Satellites).

NESDIS Award 2015

Recipients: **Changyong Cao** – VIIRS SDR Science Team Lead; VIIRS SDR Science Team [**Wenhui Wang** (ERT), **ShihYan Lee** (ERT), **Yan Bai** (University of Maryland), **Xi Shao** (University of Maryland), and **Bin Zhang** (ERT)]



"For achieving significant advances in critical areas of Visible Infrared Imaging Radiometer Suite Day/Night Band development, including JPSS-1 waiver mitigation, operational straylight correction, and geolocation capability development and validation."

Pictured (from left to right): Wenhui Wang (ERT), Xi Shao (UMD), Changyong Cao (STAR), ShihYan Lee (ERT), Bin Zhang (ERT), and Yan Bai (UMD).

STAR Science Award 2015 – Innovation

Recipients: **Shobha Kondragunta** and **Istvan Laszlo** – Aerosol Team Leads; Aerosol Team [**Pubu Ciren** (IMSG), **Jingfeng Huang** (CICS), **Hongqing Liu** (IMSG), **Steven Superszynski** (SRG), and **Hai Zhang** (IMSG)]

"Winners of the annual STAR Innovation Award for enhancing the accuracy of Suomi NPP VIIRS aerosol products and ensuring that those products reach the user community with reduced latency to achieve their best value."

Pictured (from left to right): Stephen Volz (NESDIS Assistant Administrator), Hui Xu (IMSG), Hongqing Liu (IMSG), Steven Superszynski (SRG), Hai Zhang (IMSG), Pubu Ciren (IMSG), Jingfeng Huang (CICS), Ivan Csiszar (SMCD), and Mike Kalb (STAR Director, Acting). *Not pictured: Shobha Kondragunta (SMCD) and Istvan Laszlo (SMCD).*

STAR Science Award 2015 – Science

Recipients: NPROVS Team [**Charles Brown** (IMSG), **Michael Petty** (IMSG), **Bomin Sun** (IMSG), and **Frank Tilley** (IMSG)]

"Winners of the annual STAR Science Award for leadership and support for the development and continuous operation of the STAR NOAA Products Validation System (NPROVS)."

Pictured (from left to right): Stephen Volz (NESDIS Assistant Administrator), Hui Xu (IMSG), Tony Reale (SMCD), Frank Tilley (IMSG), Michael Petty (IMSG), Charles Brown (IMSG), Ivan Csiszar (SMCD), and Mike Kalb (STAR Director, Acting). *Not pictured: Bomin Sun (IMSG).*

STAR Science Award 2015 – Program/Project Management

Recipients: Algorithm Scientific Software Integration and System Transition Team (ASSISTT) [**Bigyani Das** (IMSG), **Tom King** (IMSG), and **Shanna Sampson** (IMSG)]

“Winners of the annual STAR Program/Project Management Award for coordinating the activities across the STAR Science Teams, enabling the implementation of the Enterprise Algorithms across satellite platforms.”

Pictured (from left to right): Stephen Volz (NESDIS Assistant Administrator), Hui Xu (IMSG), Tom King (IMSG), Mike Kalb (STAR Director, Acting), Walter Wolf (SMCD), and Ivan Csiszar (SMCD). *Not pictured: Bigyani Das (IMSG) and Shanna Sampson (IMSG).*

6. Publications

1. **Cao, C**, & **Bai**, **Y.** (2014). Quantitative analysis of VIIRS DNB nightlight point source for light power estimation and stability monitoring. Remote sensing. 6(12):11915-11935.

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4. Dai, Q., Han, D., Zhuo, L., **Huang, J.**, Islam, T., & Srivastava, P. K. (2015). Impact of complexity of radar rainfall uncertainty model on flow simulation. *Atmospheric Research*, 161, 93-101. [10.1016/j.atmosres.2015.04.002]

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