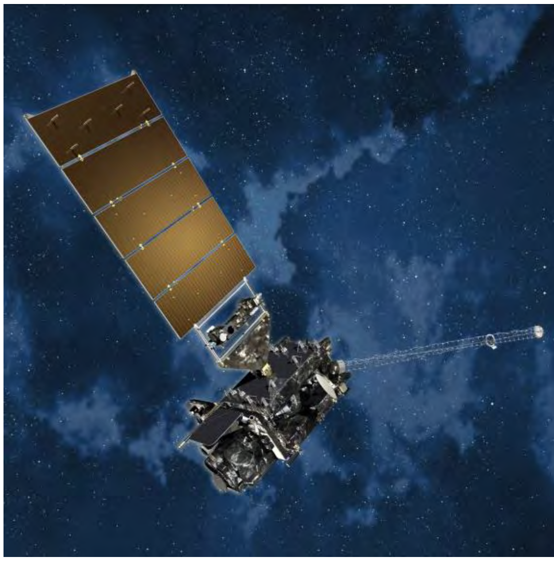


GOES-R JPSS

COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report
VOLUME II: CICS-MD TASK REPORTS

For the period:
April 1, 2016 – March 31, 2017
NOAA Grant NA14NES4320003

Dr. Fernando Miralles-Wilhelm, Director
April 30, 2017

CICS
Cooperative Institute for Climate and Satellites

TABLE OF CONTENTS

2 CICS-MD PROJECTS

2.1 Data Fusion and Algorithm Development

Validation of Operational AMSR2 SSTs	
Task Leader	Andy Harris
Task Code	AHAH_AMSR_14 Year 3
NOAA Sponsor	Mitch Goldberg
NOAA Office	NESDIS/JPSS
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: The 4^{th} version of the GAASP product has been used as the basis for development of a GHRSST Level-2P AMSR-2 product which will commence production in the NDE. This has required the development of a sensor-specific error statistics function, which reduces regional biases and improves accuracy. is based on and results are now much improved.

Background

The ability to retrieve SSTs even with 100% cloud cover is an invaluable asset for ocean forecasting and numerical weather prediction, especially during winter months. For example, the ability to observe rapidly varying SSTs due to strong mixing during the passage of hurricanes is especially useful during the high activity phases of the hurricane season. The AMSR-2 microwave imaging instrument can retrieve SSTs through clouds, and product is impervious to aerosol contamination. In addition, AMSR-2 carries a new channel at 7.33 GHz that has the potential to assist in regions of light precipitation and in mitigating the effect of RFI contamination on the retrieval. It is for these reasons that the timely provision of AMSR-2 SST observations is a highly desirable goal for a number of oceanographic, climate and weather applications.

Accomplishments

The initial, and most important, aspect of the work was to conduct an independent evaluation of the GAASP AMSR-2 SST product prior to operations. This:

a) Serves as validation of the end-product, and provides feedback for further adjustment and improvement, as required
b) We found that comparison against Level-4 analyses is a very powerful tool to identify potential anomalies.
c) Cross-comparison of errors identified in (d) against other derived parameters (wind speed, precipitation, cloud liquid water and water vapor) aids in discernment of cross-product feedback.

In response to our feedback and suggestions, the GAASP algorithm team developed a 4th version of the product, which has recently been validated and is a substantial improvement (0.62 K rms), with error characteristics that are broadly similar to those observed in other SST products. Some residual bias dependencies remain and these findings have been passed back to the team. In addition, a template for the GHRSST L2P product was provided, along with assistance in implementation and debugging. Most critically, the bias and uncertainty of the SST product has been characterized as a function of observational parameters. The application of this results in a modest reduction in RMS of ~0.02 K, and is illustrated in Figure 1. The geographical distribution of this improvement can be discerned from the "before and after" plots of bias versus latitude shown in Figure 2. The substantial increase in spread at southerly

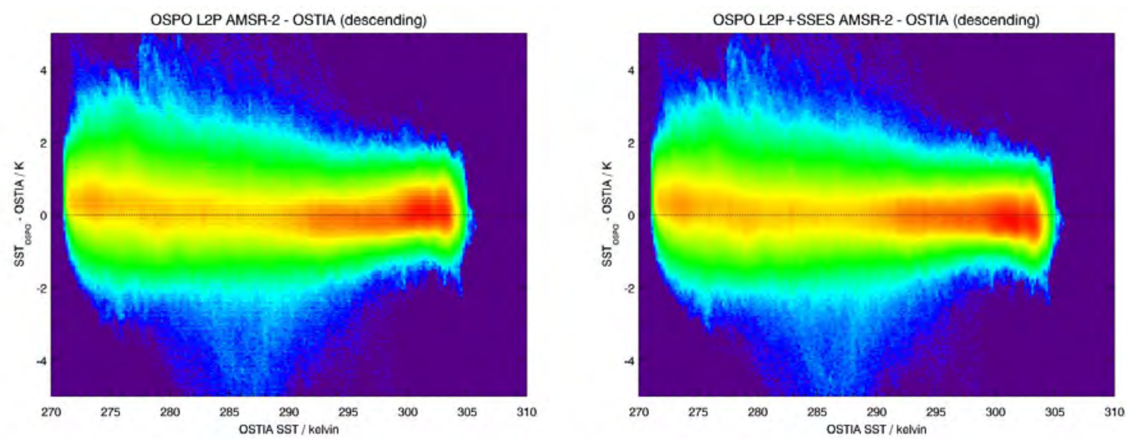


Figure 1. GAASP AMSR-2 GHRSST L2P SST (descending passes) - OSTIA SST analysis vs SST. The left-hand panel shows the uncorrected product, while the right-hand panel shows the effect of applying the Sensor Specific Error Statistic (SSES) bias adjustment (N.B. SST is not used as a predictor). The result is a reduction of bias at warmer temperatures and an overall reduction in curvature of the retrieval w.r.t. SST. Recent evidence indicates that the remaining warm bias at low temperatures is geophysical

latitudes merits further investigation.

Planned Work

Below are the planned activities on this project. Additional progress is anticipated on some of the following tasks, since they are being undertaken/completed this year (*i.e.* intended by end-June 2016)

- Refine GHRSST Level-2P Sensor Specific Error Statistics algorithm to account for residual errors in the GAASP AMSR-2 SST product
- Continue to provide feedback on further revisions to the GAASP AMSR-2 SST product development team

Products

- Report on GAASP AMSR-2 SST product accuracy;
- Contribution of materials to NOAA design reviews.

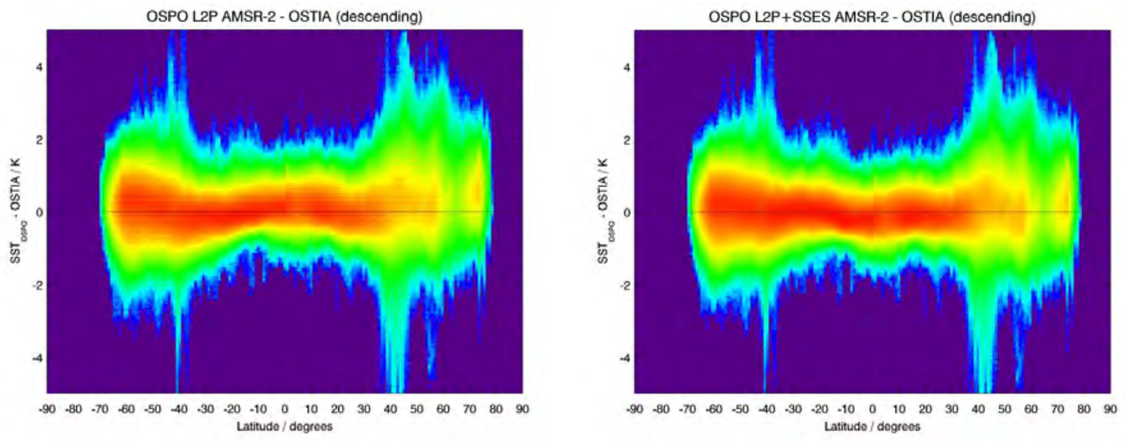


Figure 2. As for Figure 1, except showing dependence against latitude. As before, the left-hand panel shows the uncorrected product, while the right-hand panel shows the effect of applying the SSES. The reduction of warm bias at low latitudes coincides with the improvement at warmer temperatures shown in Figure 1. The larger spread at southerly latitudes remains an issue for further investigation.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

This task is only part of a major NOAA effort to produce SSTs (and other geophysical products) from AMSR-2 data. The provision of information (GHRSST L2P template) and development of the necessary SSES estimation algorithm are essential components for the “value-added” GHRSST L2P version of the basic GAASP AMSR-2 SST product.

Incorporation of Himawari-8 SST into 5-km Blended SST Analysis

Task Leader	Andy Harris
Task Code	AHAH_HSST_15 Year 2
NOAA Sponsor	Tom Schott
NOAA Office	NESDIS/OSGS
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Investigations continue on the available version of the ACSPO Himawari-8 SST, which has been successfully incorporated into the Geo-Polar Blended SST analysis. Tests have included the effect of a diurnal adjustment for the H-8 SSTs during the input gridding. Since the SPO retrieval algorithm utilizes direct regression, patterns of bias are somewhat different from the previous MTSAT-2 Imager. However, the AHI instrument has more channels, lower noise, improved spatial resolution and better calibration. This permits a more linear solution and makes the choice of algorithm less critical. The results are encouraging for the prospect of including data from the GOES-R ABI and, in the future, Meteosat Third Generation.

Background

NESDIS have been in the process of developing a new high-resolution (0.1°×0.1° and 0.05°×0.05°) global SST analyses to replace the previous 100-km, 50-km and 14-km (regional) products. The new scheme, which uses a recursive estimator to emulate the Kalman filter, also provides continuously updated uncertainty estimates for each analysis grid point. Since the analysis is entirely satellite-based, there is no explicit attempt to correct regional biases to an in situ standard. However, biases between individual datasets are corrected in a statistical manner, with certain assumptions of persistence and correlation length scale.

Improvements have been made to the analysis by assimilating a thinned version of the OSTIA as the bias-free dataset to which others are adjusted. The impact of the OSTIA data is negligible where there is adequate density of other observation. The intent is to move to a fully-independent revised bias correction scheme to take advantage of SST data from the recently-launched Sentinel-3 SLSTR instrument.

Substantial coverage gains have been afforded by utilizing carefully bias-corrected geostationary data. These benefits have been realized for many important regions of the world's oceans, include critical ecological areas such as the Coral Triangle and Great Barrier Reef. In the latter regions, much of the input data came from the MTSAT-2 instrument, which has now been replaced by the "next-generation" Himawari-8 platform. In order to continue to service the region, and maximize the benefit of the AHI imager, which should be capable of producing more accurate SSTs than its predecessor, it is important to adapt the Blended SST Analysis system to incorporate SST data from Himawari-8.

Accomplishments

The most important aspect of the work is to incorporate SST data derived from Himawari-8 radiances into the Geo-Polar Blended SST analysis. Ideally, the SST data should be from an operational source in order to ensure continuity. The following stages have been identified:

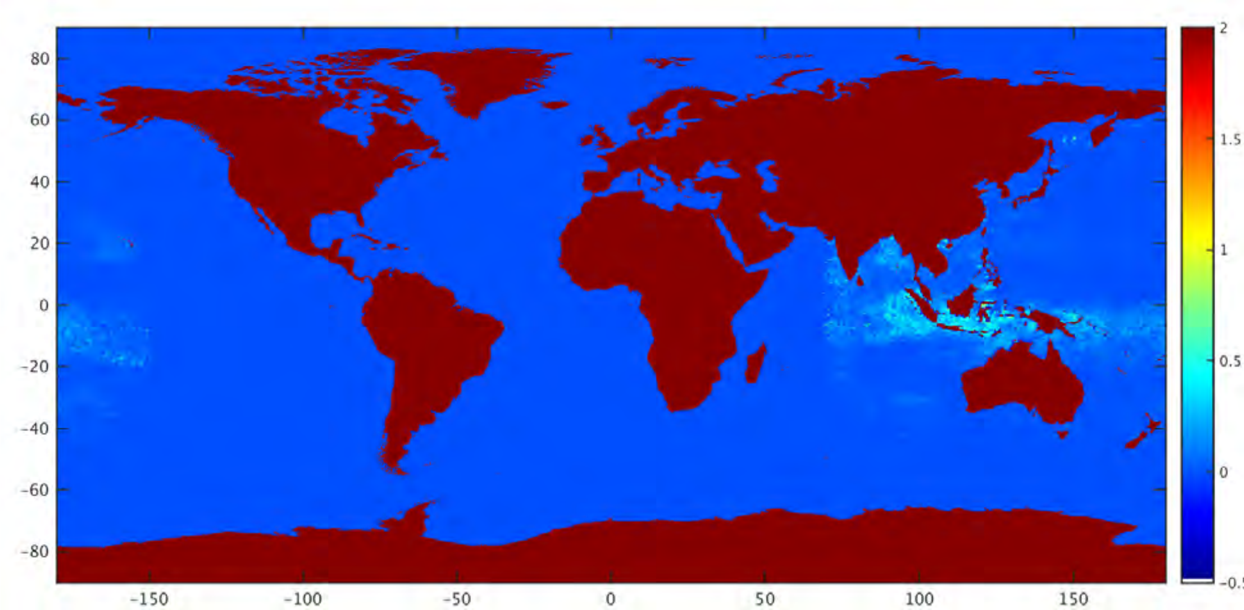


Figure 1: Average diurnal warming adjustment applied to Himawari-8 daytime data for March 2016. The scale is in kelvin. Note that the AHI field-of-view ranges from 65°E – 150°W.

d) Adapt blended SST ingestion software and incorporate experimental version of ACSPO Himawari-8 SST product into operational Geo-Polar Blended SST analysis. This is essential to maintain product accuracy in the W Pacific;
e) Ingest the BoM operational Himawari-8 SST in a parallel trial of the Geo-Polar Blended SST analysis;
f) Compare the accuracies of the Blended SST analyses using ACSPO and BoM Himawari-8 data, and switch to BoM data if product accuracy is not degraded;
g) Make refinements to analysis software to include operational version of ACSPO Himawari-8 SST data when those become available

Stage 1 has been successfully completed in order to provide continuity of coverage for the W Pacific. Since the BoM Himawari-8 SST is still undergoing refinement, and the operational version of the Himawari-8 SST product is not yet available, we have continued investigations into the currently available ACSPO product. Assimilation has now been performed to assess the impact of diurnal adjustment of the individual observations on the gridded superob field and concomitant change in the bias adjustment field. Figure 1 shows the mean diurnal adjustment applied to the Himawari-8 daytime SST data for March 2016. Figure 2 (top panel) shows the mean bias correction field for the same month, along with the bias correction field without diurnal adjustment (bottom panel). It can be seen that there appears to be some over-correction from warm bias to cool bias near the Equator (Indonesia & Philippines). These may be partly due to regional biases in the retrieval algorithm, which are typically somewhat more pronounced than those observed for other geostationary SST products that employ physical retrieval. Another obvious feature is a persistent warm bias around the edge of the AHI field-of-view. However, the water vapor burdens in the W Pacific are particularly high, and the current ACSPO algorithm does not utilize the 3.9 µm channel, so this behavior is not entirely unexpected. Another possibility is that the diurnal warming amplitudes may be overestimated. We have recently started developing and testing a new insolation parameterization that results in smaller diurnal amplitudes in tropical conditions. However, inspection of individual scenes revealed that the stronger diurnal events are often masked, and therefore do not contribute to the bias correction calculation, whereas the diurnal adjustment is only calculated on a 0.5°×0.5° grid and therefore spread the mean adjustment outside of these local maxima.

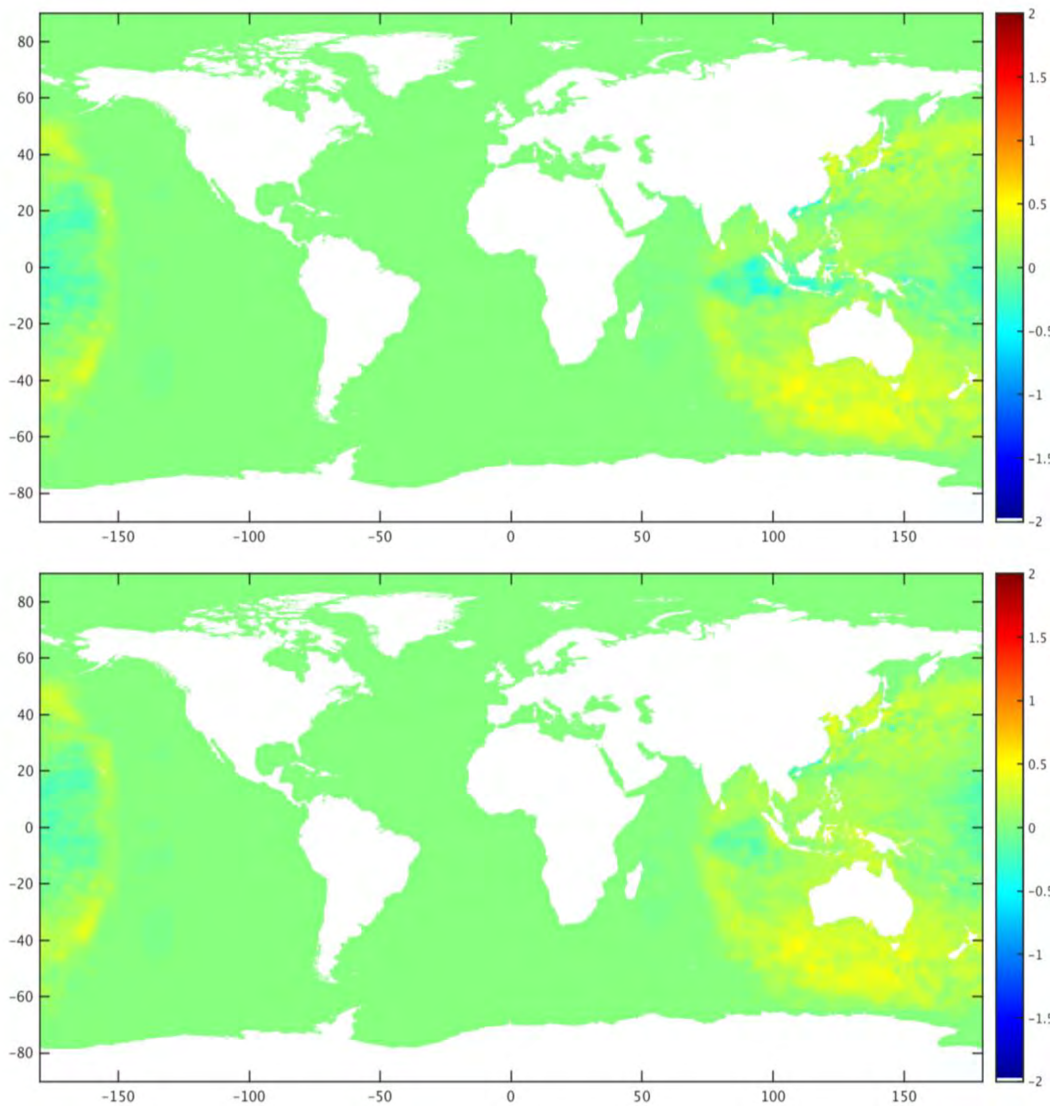


Figure 2. Top panel shows the average stochastic bias correction field for diurnally-adjusted Himawari-8 daytime SSTs for March 2016. The corresponding field for data that were not adjusted for diurnal effects prior to superob gridding is shown in the bottom panel.

Planned Work

Below are the planned activities on this project 'til end-June 2017.

- Assimilate the Australian Bureau of Meteorology (BoM) operational Himawari-8 SST product into a parallel version of the Geo-Polar Blended SST analysis
- Perform comparisons between blended SSTs using experimental ACSPO and BoM operational Himawari-8 SSTs
- Refine scheme to use operational ACSPO Himawari-8 SSTs when those become available

Deliverables

- Update documentation to reflect use of ACSPO and/or BoM Himawari SSTs as needed;
- Updates to code for ingestion of Himawari-8 SSTs as needed.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Himawari-8 SSTs are now being ingested into the NOAA Operational Geo-Polar Blended SST analysis. The code has been ported to NOAA Operations (OSPO).

An Investigation into the Feasibility of Accurate Lake Surface Temperatures

Task Leader	Andy Harris
Task Code	AHAH_LAKE_16
NOAA Sponsor	Paul DiGiacomo
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: Investigations into the utility of the existing ACSPO VIIRS SST product show that, for the Great Lakes, using only data defined with a quality level of "good" results in the exclusion of large areas of observations that are actually valid. This exclusion is both substantial and asymmetric, *i.e.* use of "good" data results in coverage that is both poor and biased warm with respect to the full distribution of valid temperatures. In order to allow the many good observations of cooler water, it is necessary to relax the quality level to include data flagged as "bad" which means that some truly cloud-contaminated observations are also allowed to pass the threshold. Further investigations into coverage for a representative target lake show that observations are almost absent during winter-time. Optimization of the cloud detection will be the first step in obtaining a viable automated lake surface temperature product from the VIIRS mission.

Background

NESDIS has long provided surface temperatures for the Great Lakes region as part of the CoastWatch suite of products. However, there has been no specific attempt to tailor these products to ensure that accuracy and coverage requirements are being met. Furthermore, there are many other lakes in North America for which end users desire accurate surface temperatures, but which have received scant attention. One prime indication of the need to increase work in this area is the User Request put in by NWS to the NESDIS Satellite Products and Services Review Board some two years ago that stated their need for accurate lake water temperatures. In their User Request, NWS went on to outline some of the problems that they perceive to exist in current lake surface temperature products, including inadequate cloud masking, biases due to anomalous atmospheric conditions, and water turbidity. Similar issues are highlighted in reports of the GHRSST Inland Water Working Group (e.g. GHRSST, 2012). Most of the problems in existing NESDIS satellite-based lake temperature products are due to the simple fact that the processing methodologies for cloud detection and temperature retrieval (e.g. Advanced Clear-Sky Processor for Oceans, ACSPO) have been optimized for the open ocean, where the atmosphere is usually close to equilibrium with the water surface, and the target is far from the disrupting influence of land.

The project evaluates the feasibility of utilizing the ACSPO product for lake surface temperatures. This initially requires the evaluation of ACSPO level-2 data over selected lake targets in North America. A subset of these are lakes for which suitable validation data exist (mostly *in situ* buoy measurements, such as are present in the Great Lakes). The key metrics that need to be evaluated are coverage and accuracy. Since the ACSPO cloud mask has not been optimized to function over inland water targets, the feasibility of relaxing the cloud mask in order to obtain adequate coverage is investigated. Such approaches usually result in a trade-off in accuracy, which can be evaluated by validation against *in situ*, where such data exist. Reduction of the cloud mask is likely to require at least some additional filters to be utilized in order to avoid excessive contamination. Furthermore, suitability of the ocean-trained temperature retrieval algorithm under genuinely cloud-free conditions can be assessed. Finally, the prospects for optimizing temperature retrievals for lake water temperatures should be assessed.

Accomplishments

An obvious first step is to assess how much tuning is likely to be necessary in order to adapt the current ACSPO Level 2 temperature product to provide usable lake temperatures (*i.e*. adequate accuracy and coverage). Following on from this, initial investigations into the prospects for improving both of these aspects should also be investigated.

Methodology

The primary purpose of this project is to assess the feasibility of adapting existing data products (ACSPO) to obtain lake water temperatures that meet coverage and accuracy requirements. In order to accomplish this, a number of tasks eventually need to be performed:

1) Establish a high-resolution land/lake mask that identifies an appropriate range of lake targets in North America. These targets should include lakes of appropriate size range and representative distribution across differing retrieval environments (altitude, continental & maritime environments, etc.). Some lakes need to contain validation data in order to assess product accuracy. All lakes can be used to assess coverage performance (i.e. frequency of obtaining temperatures that are deemed cloud-free);
2) Perform matches of ACSPO swath data against the lake targets and analyze statistics, including samples of accuracy of geolocation, percentage of lake that is deemed cloud-free, and range of temperatures within each lake (an indication of structure, which is a measure of how important the % coverage metric – lakes which are uniform in temperature need only be partially clear in order to obtain a representative temperature);
3) Assess increase in coverage when relaxing the ACSPO cloud mask, and the concomitant impact on accuracy of the lake temperature retrievals; and
4) Investigate possible ways to improve the product, such as application of tailored QC filters to mitigate the effect of increased retrieval error with a relaxed cloud mask. Such effects are likely to be regional and seasonal. Also investigate prospects for reducing error due to anomalous atmospheres (*e.g.* cool lake surrounded by warm land, or vice versa), emissivity differences, diurnal warming (water turbidity, wind speed, insolation). In this regard, addition of NCEP NAM surface and upper air data to the matches that include in situ validation will be invaluable. This will allow testing of the MTLS retrieval algorithm to see if local atmospheric conditions can be accounted for. The MTLS algorithm is also quite tolerant of other errors, such as residual cloud.

Sample Findings

The most important aspect of investigating suitability of the current ACSPO VIIRS product for lake surface temperatures is to assess the coverage. If good data which can provide valid observations are being erroneously masked by a cloud detection scheme that has been designed to function over the open ocean, the question of algorithm retrieval accuracy becomes moot. In such circumstances, it might be possible to relax the data quality in order to allow more good observations through, although care must be taken to ensure that bad data are still excluded.

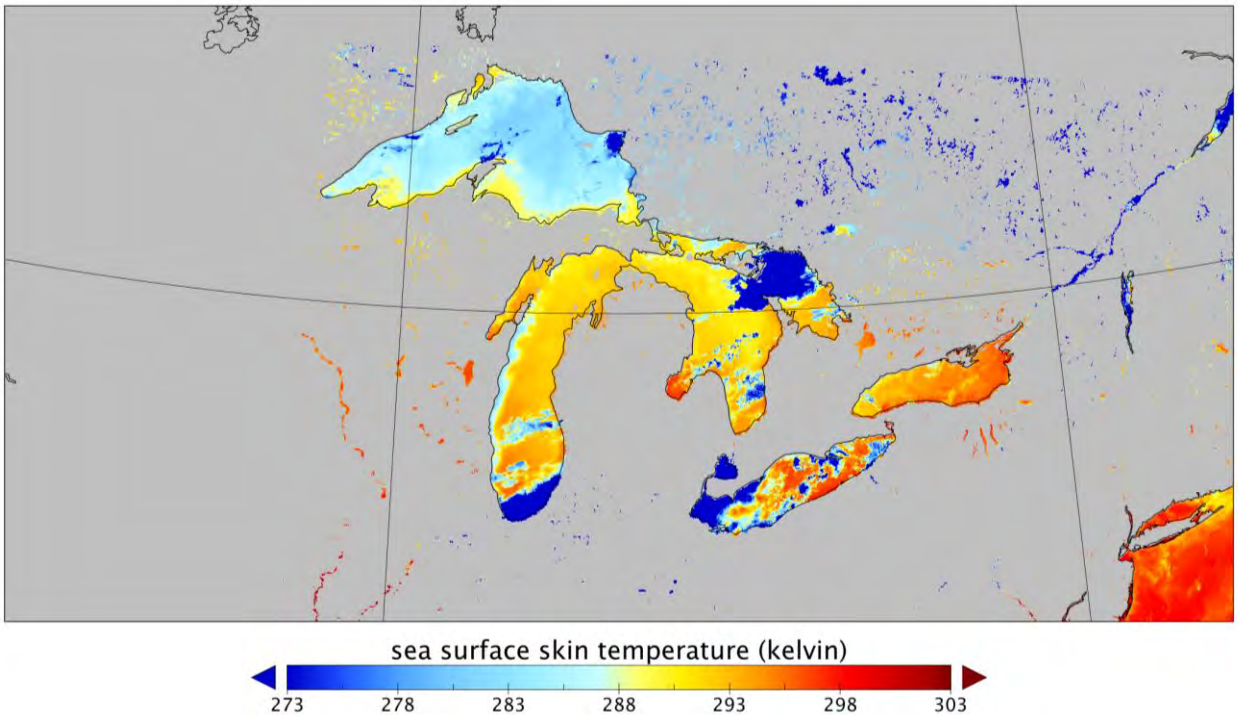


Figure 1. ACSPO VIIRS water temperatures for inland water bodies in North America.

Figure 2 shows an example of ACSPO VIIRS temperature retrievals for the Great Lakes and nearby inland water bodies. It is straightforward to discern by eye that, while there are some cloud-contaminated observations, much of Superior, Michigan, Huron and Ontario are cloud-free and, even with a 30 kelvin stretch, characteristic geophysical fluid dynamics patterns are visible in all of these lakes. The corresponding quality masking is shown in Figure 3, with “good” data shown in white, “bad” data shown as dark red, and some “suspect” pixels shown in a lighter red. The most obvious feature is the masking of virtually all cooler water as “bad”, such as the majority of Lake Superior, which has a characteristic thermal bar with only the southern shore waters getting significantly above ~280 K. The cooler water on the western side of Lake Michigan is also thereabouts entirely masked as “bad”. Furthermore, it is evident that relaxing the quality threshold to allow “suspect” data through has little impact on cov erage, while relaxing further to allow “bad” data also permits significantly cloud contaminated observations (e.g. the cloud bank at the southern end of Michigan). Finally, it can be seen that the vast majority of the smaller lakes to the north of the Great Lakes are completely masked as “bad”.

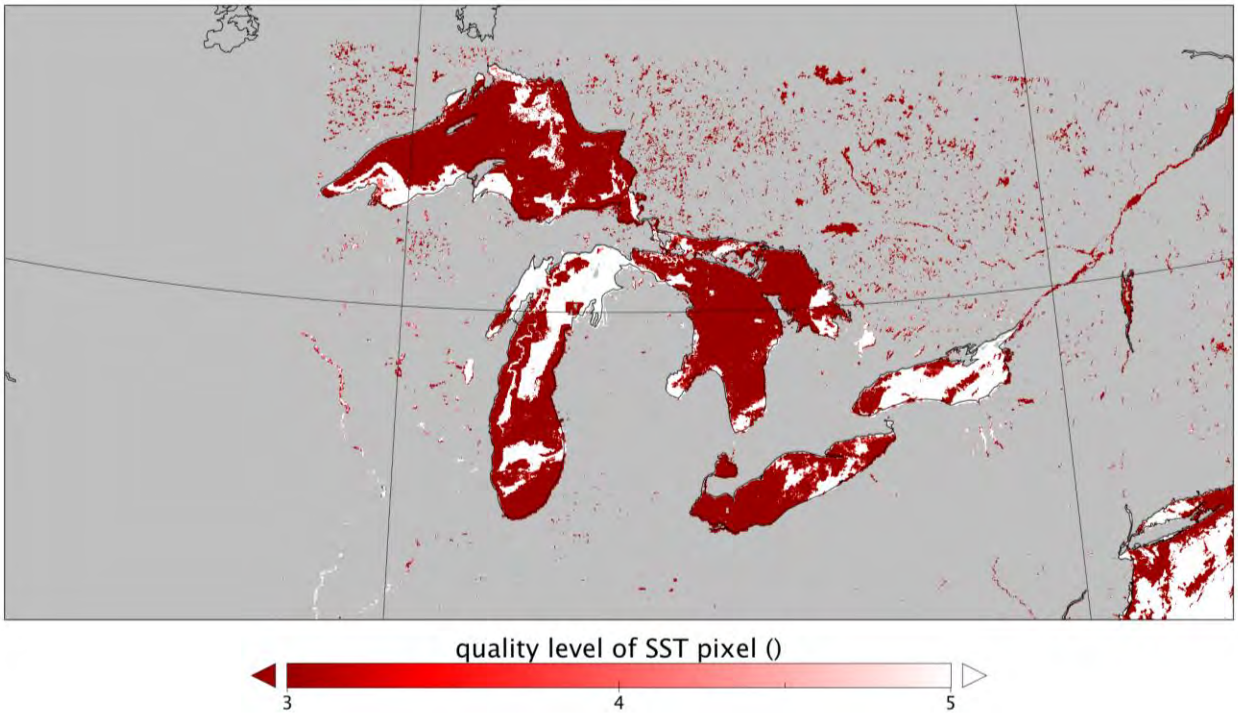


Figure 2. *As Figure 1, but showing ACSPO VIIRS quality levels (3 = "bad", 5 = "good")*

In addition, preliminary work has been performed on investigating the coverage statistics for a modest-sized lake target. This has involved collection of ACSPO v2.4 L2P products (*i.e.* the current algorithm) from May 2015 – end-2016. The results for retrieved temperature and standard deviation can be seen in Figure 3. The comparison for temperatures using QL=4 and QL=5 are shown. It can be seen that, not unexpectedly, the QL=4 temperatures display significantly more variability, but do add somewhat to the coverage. The retrieved temperatures from the two quality levels do, however, track each other. While the overall seasonal pattern is certainly geophysical, the shorter-term variability (and increased noise) may not be. It is also notable that there is a period around winter (approximately 3 months' duration) where there are almost no observations. While it might be expected that this would occur when the lake is frozen, the observation frequency does not pick up until the *retrieved* temperature is at least ~5°C.

Summary

It is clear that using only data defined with a quality level of "good" results in the exclusion of large areas of observations that are actually valid. This exclusion is both substantial and asymmetric, i.e. use of "good" data results in coverage that is both poor and biased warm with respect to the full distribution of valid temperatures. In order to allow the many good observations of cooler water, it is necessary to relax the quality level to include data flagged as "bad". Unfortunately, this means that truly cloud-contaminated observations are also allowed to pass the threshold.

Although the ACSPO VIIRS products have been developed for the open ocean, it might have been hoped that they would still function fairly well over large bodies of water such as the Great Lakes. It is quite evident that this is not actually the case, and there is not a simple solution. With such poor performance over large water bodies, the lack of coverage observed over smaller lakes was perhaps inevitable. Optimization of the cloud detection will be the first step in obtaining a viable automated lake surface temperature product from the VIIRS mission.

Planned Work

Below are the planned activities on this project, subject to ongoing funding. Additional progress is anticipated on some of the following tasks, since they are being undertaken/completed this year (*i.e.* intended by end-June 2016)

- Accuracy metrics for sample targets
- Feasibility of adapting existing ACSPO cloud masking
- Investigation of feasibility for localized adaptation of processing

Products

- Report on feasibility of lake surface temperature product from Polar Orbiting sensors;

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

The purpose of this task was to assess the feasibility of using (or adapting) existing NOAA products for the purpose of providing lake surface temperature products of sufficient accuracy and coverage for NWS needs. The work done illustrates the need for adaptation at least, which implies a new product will be forthcoming if the recommendations are acted upon.

An Assessment of Existing 1-km Sea Surface Temperature Analyses

Task Leader	Andy Harris
Task Code	AHAH_RSST_16
NOAA Sponsor	Paul DiGiacomo
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Investigations into the utility of the existing ~1-km SST analyses demonstrate that accuracy and coverage are likely to be significantly worse than obtained for the current ~5-km Geo-Polar Blended SST analysis. The anticipated benefit of moving to a higher resolution SST analysis is therefore unlikely to be realized without dedicated effort into development of regional analyses tailored to the needs of Coral Reef Watch.

Background

NESDIS generates an operational Geo-Polar Blended 5-km Sea Surface Temperature (SST) analysis that provides daily global coverage. There are many applications for this high-resolution analysis, one of which is for NOAA Coral Reef Watch's (CRW) next-generation coral bleaching thermal stress monitoring products. CRW's users (marine resource managers, scientists, and other coral reef stakeholders) need consistent global monitoring of temperatures that vary across reefs at sub-km scales. Satellite monitoring at these finer scales is critical to understand thermal conditions controlled by highly dynamic physical processes in the near-shore/shelf shallow waters where influences of tidal currents and bottom topography are significant. The development of a blended SST analysis at the resolution of 1/80° is expected to yield benefits. Data at this scale should allow users to take timely and effective management actions such as moving tourist visitation from reef areas experiencing high thermal stress to nearby sites experiencing lower stress, and coordinating in situ surveys of coral biological responses.

Availability of the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) SST data that provide much finer, sub-km spatial resolution makes the needed remote monitoring possible. To provide the accuracy of an SST analysis at sub-km scales applicable to CRW's coral reef management products, more frequent observations at higher resolution than polar-orbiting satellites (Suomi NPP, NOAA-19, Metop-B) are also needed, as the polar-orbiting satellites do not provide the frequency of observations required for reliable sub-km scale thermal stress data in the coastal zone, especially in cloudy regions. The Himawari-8 satellite will provide high frequency geostationary (Geo) SST observations at 2-km resolution. The blending of the VIIRS SST and the Himawari-8 SST would allow the generation of a new high-resolution SST analysis with the data density needed to produce reliable, gap-filled SST-based products for applications like CRW's.

Accomplishments

While it currently is not feasible to generate a high-resolution resolution SST analysis for the entire globe, the prospect of doing so for targeted regions of end-user interest is quite feasible. The complementary existence of the eReefs hydrodynamic model for Australia's Great Barrier Reef (GBR) offers the prospect of evaluating both the need for, and the output of, a higher resolution SST analysis. The GBR is also extensively instrumented. Since there are not comprehensive hydrodynamic models for the majority of the world's coral reef systems, improved coral reef monitoring capability through the provision of higher resolution SST analyses represents the only feasible solution for at least the next several years. The availability of high-quality high-resolution SST data from NPP VIIRS (and METOP-A/B) should be exploited for this purpose. As a supplement, ~2-km SST data from the Himawari-8 platform (a valid proxy for GOES-R), can serve to improve data coverage. The argument is as follows:

1. High-resolution SST analyses (at a finer resolution than the existing 5-km geo-polar blended SST analysis) should be developed for coral reef regions to improve temperature monitoring at the reef-scale;
2. "Next-generation" satellite SST data sources (VIIRS, Himawari-8, and eventually GOES-R imagers) will provide the necessary input data for the analysis; and
3. Fine-scale near shore data from in situ ocean temperature sensors and output from the eReefs hydrodynamic model will help to: a) validate the SST analysis (test/refine the gap-filling capability); b) refine interpretation of the SST analysis (particularly with respect to tides, temperature at reef depth); and c) ascertain the benefits of coral monitoring products derived from the high-resolution SST analysis *cf*. a full hydrodynamic model.

Methodology

One major advantage of adapting the current blended SST analysis system to produce high-resolution analyses for the regions of interest is the novel methodology of this technique for preserving feature resolution without introducing excessive noise. This is achieved by utilizing short, intermediate and long correlation length scales, and interpolating the final result based on local data density. Thus, the analysis only gives high resolution where adequate data are available to support it. Furthermore, regional analyses can be nested inside the existing global analysis, providing well-matched boundary conditions.

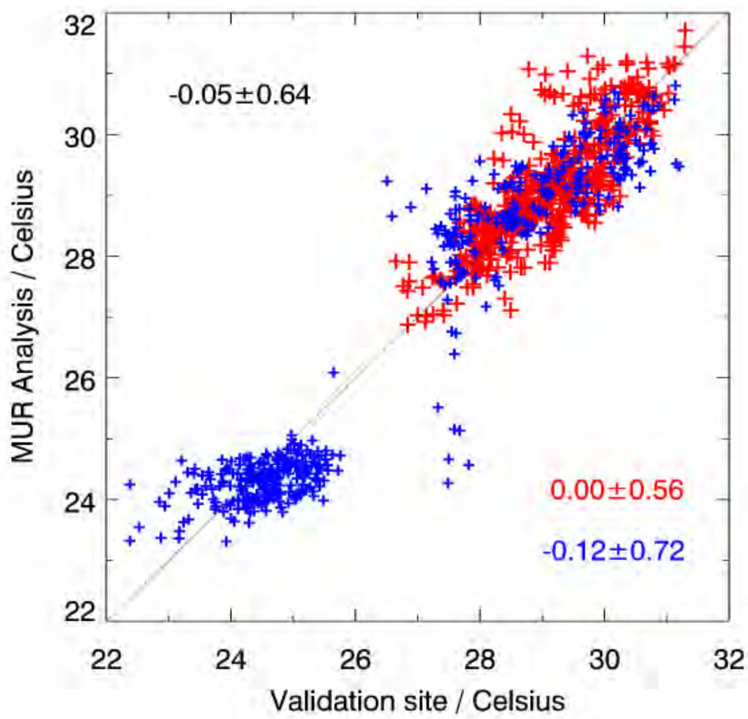
As a preliminary step to ascertain the feasibility and utility of using high-resolution SST analysis data, we have assessed existing high-resolution blended SST data for various test regions, such as:

- Great Barrier Reef
- Guam and Commonwealth of the Northern Mariana Islands (CNMI)
- Coral Triangle
- Caribbean
- Hawai'i (potentially)

This has included the following sub-tasks:

a. Gathering necessary test data (satellite and ancillary) and comparison data (eReefs, *in situ* temperatures);
b. Generating and validating test output in coral reef regions (*e.g.* monitoring stations), coastal sites (moorings), and the open ocean (buoys); and
c. Provision of sample ~1-km SST datasets to CRW.

Figure 1. MUR SSTs vs AIMS (red) and PAC (blue) monitoring sites for Jan – Mar 2015. The relatively restricted range of temperatures is due to the selection of S.H. summer (peak bleaching period) and the tropical nature of the validation sites. The regional nature of the validation statistics is evident. *N.B.* 23% of validation points had no corresponding MUR SST value, and therefore do not contribute to this figure.



Sample findings

There are only two ultra-high resolution global SST analyses retrievals available – namely the G1SST and MUR SST. Preliminary investigations revealed that, while there have been some improvements in the former, it remains a significantly more noisy product than the MUR, thus quantitative investigations have concentrated on the latter. Figure 1 shows validation results for the MUR SST compared with AIMS (Australian Institute of Marine Sciences) monitoring stations (predominantly in the Great Barrier Reef region), and PAC monitoring stations (distributed among coral reef sites throughout the W Pacific). It is evident that, even though the overall accuracies are not particularly good *cf.* expectations, there are distinct regional variations in data quality, especially for the PAC sites. Errors for the latter may be a few kelvin in magnitude, which is somewhat disappointing since the validation in only for a restricted time period and the accuracy of the input products are usually quite good for tropical regions.

Figure 2 shows a subscene of the MUR SST global analysis for January 1, 2015, overlaid with a corresponding snapshot of surface temperature for the eReefs model domain. It is evident that the hydrodynamic model information is substantially more detailed than the MUR SST analysis. Another key point of note, however, is the temperature offset (particularly evident at the model boundary), since the eReefs output does not include SST assimilation.

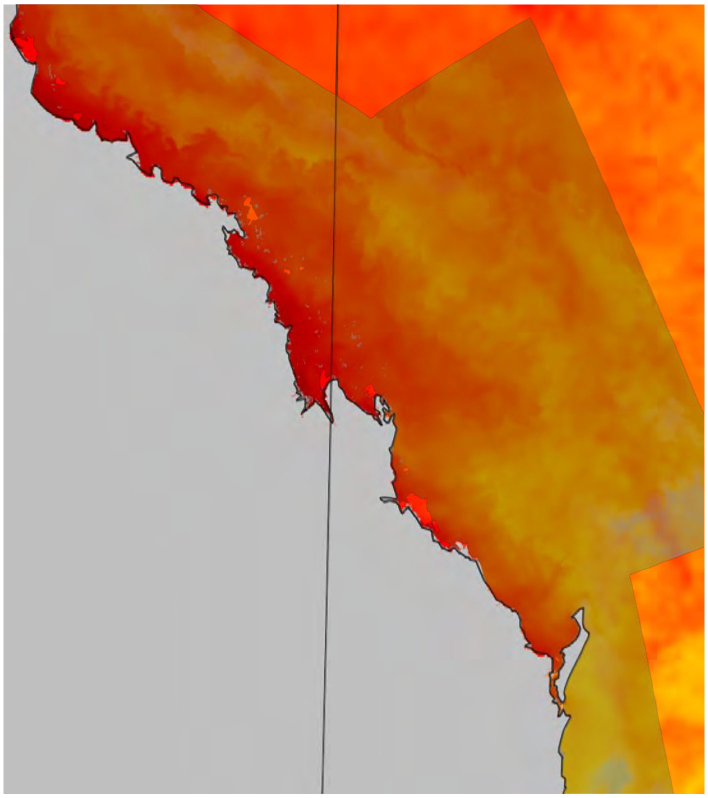


Figure 2. Composite image of 1-km resolution SST fields off Queensland coast for January 1, 2015. SSTs from the eReefs model domain are overlaid on the MUR SST analysis product. A marked decrease in feature resolution is evident outside the model domain.

Planned Work

In order to further NOAA mission goals, the following work should be carried out in Year 2, subject to funding:

1. Define test regions for high-resolution analyses
2. Begin collecting satellite data for test period and locations
3. Establish collaborative effort with eReefs (AIMS, CSIRO), including data exchange
4. Develop & test ingester for 10-minute Himawari-8 AHI, including QC
5. Develop & test ingester for GOES-R ABI, including QC
6. Initial configuration for 1/80° version of analysis (tiling, nesting, length scales, bias correction scales, land mask)
7. Obtain BoM ACCESS-R and NCEP NAM NWP flux data to run diurnal model
8. Experimental system that can ingest GOES-R ABI SSTs and Himawari-8 AHI SSTs and produce analysis at 1/80 resolution for test region(s)
9. Produce sample high-resolution analyses for test regions

Products

- Report on feasibility of using existing SST analysis for reef-scale CRW monitoring products;

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

The purpose of this task was to assess the feasibility of using (or adapting) existing ultra-high resolution SST analysis products for the purpose of providing Coral Reef Watch monitoring products at the reef-scale. Since the assessment showed that existing products were unlikely to meet requirements, there should be new NOAA products forthcoming, if the recommendations are acted upon.

Development of Global Soil Moisture Product System (SMOPS)

Task Leader	Dr. Christopher Hain, Dr. Mitchell Schull
Task Code	CHCH_SMOP_16
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 55%; Goal 2: 35%; Goal 3: 10%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight : We have finished ingesting NOAA AMSR2 and NASA SMAP soil moisture data into SMOPS, ingesting NRT SMOS, GMI and SMAP brightness temperatures into SMOPS for its own soil moisture retrievals and the new SMOPS version (V3.0) has been under testing at OSPO. The new version of SMOPS is expected to go operational in the summer of 2017.

Link to a research web page http://www.ospo.noaa.gov/Products/land/smops/index.html (SMOPS operational status monitoring site at OSPO).

Background

SMOPS went operational in late 2012 with external soil moisture product inputs from SMOS, ASCAT-A, and WindSat. It grids all the orbital soil moisture orbits from these sensors and output a global gridded soil moisture map for each sensor at a quarter degree resolution every 6 hours. In addition to the gridded soil moisture layers, SMOPS also generates a blended soil moisture layer that merges all the available soil moisture values using a cumulative distribution function (CDF) approach. As soil moisture data became available from MetOp-B ASCAT, MetOp-B ASCAT soil moisture has been added in SMOPS V1.3 in 2015. After the successful launch of JAXA's GCOM-W1 satellite May 18, 2012, a soil moisture environmental data record (EDR) from Advanced Microwave Scanning Radiometer (AMSR2) onboard GCOM-W1 is now being generated at NOAA. This product has also been ingested in SMOPS V2.0 in 2016. To improve the data latency of SMOS soil moisture generation, a new layer of SMOS soil moisture is now being generated inside SMOPS (V2.0).

As Soil Moisture Passive and Active (SMAP) satellite data became available in April of 2015, efforts have been made to include SMAP observations in SMOPS. In SMOPS V3.0, not only is the NASA official SMAP soil moisture layer included, but also a separate layer of SMAP soil moisture layer is generated inside SMOPS to make SMAP soil moisture data available in SMOPS 6-hour products. To take advantage of Global Precipitation Measurement (GMP) Microwave Imager (GMI)'s observation coverage around the equator, another soil moisture layer has also made available inside SMOPS V3.0.

Accomplishments

SMOPS Version 2.0 code with GCOME-W1 AMSR2 soil moisture and SMOS NRT soil moisture retrieved by SMOPS algorithm has been delivered to OSPO and has been operationally running since September, 2016. Because of the data quality and life cycle issues, WindSat soil moisture layer has been eliminated from SMOPS Version 2.0 and will not be produced operationally once this new version goes operational.

SMOPS Version 3.0 code with NASA SMAP soil moisture and SMOPS own retrievals from NRT SMAP brightness temperature and GMI temperature has been delivered to OSPO. It is now under testing on the operational system and will go operational in the coming months. Table 1 shows the data layers for different versions of SMOPS.

Table 1. Soil Moisture data layers from different version of SMOPS.

Soil Moisture Product	SMOPS Version 1.3	SMOPS Version 2.0	SMOPS Version 3.0
SMOPS Blended	**√**	**√**	**√ (1)**
NOAA AMSR-E	**√**	×	×
NRT SMOS	×	**√**	**√ (2)**
ESA SMOS	**√**	**√**	**√ (3)**
EUMETSAT ASCAT-A	**√**	**√**	**√ (4)**
EUMETSAT ASCAT-B	**√**	**√**	**√ (5)**
NOAA WindSat	**√**	×	×
NOAA AMSR2	×	**√**	**√ (6)**
GMI	×	×	**√ (7)**
NRT SMAP	×	×	**√ (8)**
NASA SMAP	×	×	**√ (9)**

Table 2 shows the contributions from newly added GMI and SMAP soil moisture data layers to the Blended Soil Moisture layer in SMOPS.

Table 2. Percentages in the Blended Product from individual sensors**.**

Date	NRT SMOS	ASCAT-A	ASCAT-B	AMSR2	GMI	NRT SMAP
8/29/2016	46	27	28	28	62	51
8/30/2016	48	29	29	33	60	54
8/31/2016	46	23	27	27	63	60
Average	**47**	**26**	**28**	**29**	**61**	**55**

Planned work

- Work with OSPO to test the updated SMOPS V3.0 code and make it operational.

Products

- SMOPS V3.0 code.

Presentations

- “NOAA Soil Moisture Operational Product System (SMOPS): Version 3.0”, Jicheng Liu, Xiwu Zhan, Limin Zhao, Christopher R. Hain, Li Fang, and Jifu Yin, Weizhong Zheng, and Micheal Ek, *CICS-MD Science Meeting*, December, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

JPSS Microwave Integrated Retrieval System (MiRS) Calibration and Validation

Task Leader:	Christopher Grassotti
Task Code:	EBCG_JMIR_15 Year 2 & EBCG_JMIR_16
NOAA Sponsor:	Quanhua (Mark) Liu
NOAA Office:	NESDIS/STAR/SMCD/SCDAB
Contribution to CICS Research Themes (%):	Theme 1: 20%, Theme 2: 80%.
Main CICS Research Topic:	Data Fusion and Algorithm Development
Contribution to NOAA goals (%):	Goal 1: 0%, Goal 2: 100%, Goal 3: 0%,
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Delivery of updated MiRS Version 11.2 to NOAA operations for all NOAA operational microwave satellites/sensors. The primary enhancement in V11.2 is the extension of operational processing capability to GPM/GMI measurements. V11.2 is also backwards compatible with all other operational satellites.

Link to a research web page: http://www.star.nesdis.noaa.gov/mirs

Developing and Refining Microwave Integrated Retrieval System (MiRS) High Resolution Snow/Ice Products

Task Leader:	Christopher Grassotti
Task Code:	EBCG_PMIR_16
NOAA Sponsor:	Quanhua (Mark) Liu
NOAA Office:	NESDIS/STAR/SMCD/SCDAB
Contribution to CICS Research Themes (%):	Theme 1: 20%, Theme 2: 80%.
Main CICS Research Topic:	Data Fusion and Algorithm Development,
Contribution to NOAA goals (%):	Goal 1: 0%, Goal 2: 100%, Goal 3: 0%,
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Significant update to snow water equivalent (SWE) algorithm for all ATMS and AMSU/MHS satellites, which optionally allows for the use of a vegetated forest fraction correction. Validation results over the U.S. using SNODAS analyses show significant improvements in snow cover detection and SWE, particularly over forested regions of eastern and northern U.S.

Link to a research web page: http://www.star.nesdis.noaa.gov/mirs

Background

This report summarizes work performed on the Microwave Integrated Retrieval System (MiRS) for the period April 1, 2016 through March 31, 2017. The Microwave Integrated Retrieval System (MiRS) has been the NOAA official operational microwave retrieval algorithm since 2007 and is currently run operationally on microwave data from NOAA, Metop, DMSP and Suomi-NPP polar orbiting satellites, and on data from Megha-Tropics/SAPHIR. In 2017, MIRS was also extended to process data from GPM/GMI and delivered to NOAA operations. It has also been run experimentally on data from TRMM/TMI, Aqua/AMSR-E, GCOM-W1/AMSR2. The inversion within MiRS follows a 1D-variational methodology, in which the fundamental physical attributes affecting the microwave observations are retrieved physically, including the profile of atmospheric temperature, water vapor, hydrometeors, as well as surface emissivity and temperature. The community radiative transfer model (CRTM) is used as the forward and Jacobian operator to simulate the radiances at each iteration prior to fitting the measurements to within the noise level. The retrieved surface properties are then used to determine surface physical characteristics, including, when appropriate, cryospheric parameters such as sea ice concentration, ice age, and snow water amount, and snow grain size, using pre-determined relationships that link emissivity and effective skin temperature to these parameters. These links are based, in part, on physical modeling of snow and ice radiative properties. MiRS is has also been integrated into the Community Satellite Processing Package (CSPP), developed at the University of Wisconsin/Space Science and Engineering Center.

Accomplishments

Note: all efforts funded at approximately 25% by PSDI and 75% by JPSS ADP

04-15-2016

Addition of Forest Fraction Correction to Snow Cover Retrieval (Chris Grassotti)

Detection and retrieval of snow cover and snow amount using satellite microwave measurements can be challenging when the snow cover signal is partially or completely masked by overlying vegetation such as evergreen forests. Based on experimentation and testing, an empirical correction was developed and implemented in MiRS that utilizes a static analysis of forest fraction. The forest fraction is derived from the global VIRSS high resolution vegetation type dataset. Validation against the SNODAS daily operational analysis shows significant improvement (see Figure 1). This correction has been implemented as a user-specified option in the latest working version of MiRS.

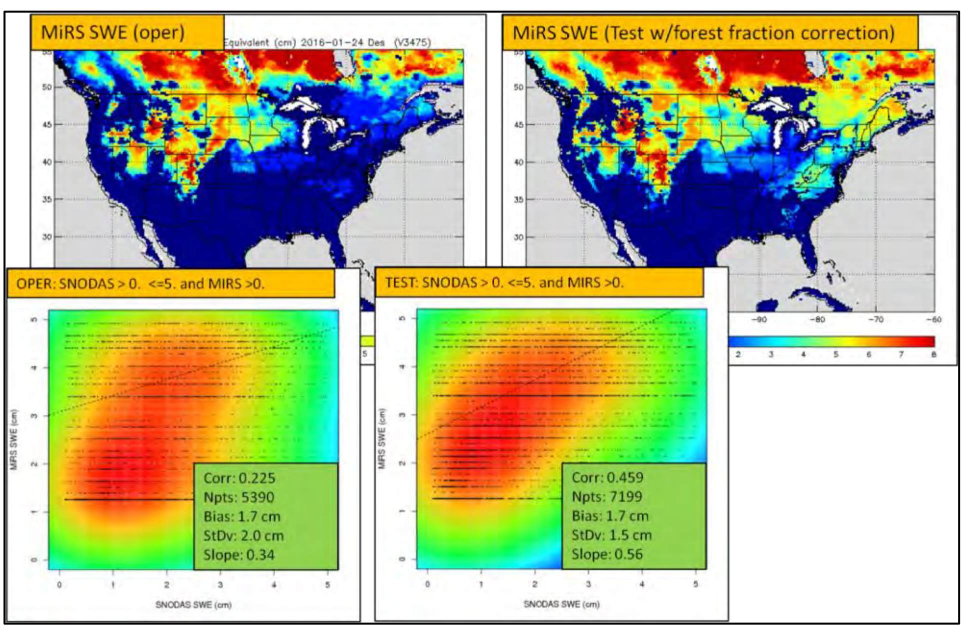


Figure 1. Comparison of MiRS Snow Water Equivalent (mm) from ATMS on 24 January 2016 for the case of the East Coast Blizzard. Comparison of the operational (left) with experimental retrievals (right) show much better detection of snow cover and estimation of SWE when compared with SNODAS.

05-10-2016

Missing Scan Line Issue in MiRS ATMS Products (Junye Chen)

An issue was resolved in which occasional scan lines were missing in MiRS ATMS products but not in the input ATMS TDR data. The problem was persistent and present several times per day. Further investigation by Dr. Chen showed that the cause of the problem was twofold. First, the MiRS footprint matching program inadvertently expanded the missing values not only in the granule in which it is located but also into the previous and following granules. Second, there were three abnormal situations in ATMS TDR and GEO files could trigger the MiRS program to set the MiRS internal quality control flag to bad and the TBs to missing values for that scan line. Code modifications were implemented to handle the various cases that lead to these artifacts, and the missing scan lines were removed. A patch to the MiRS operational software was generated and sent to OSPO and NDE. Figure 2 shows an example of the impact of implementing the software fix.

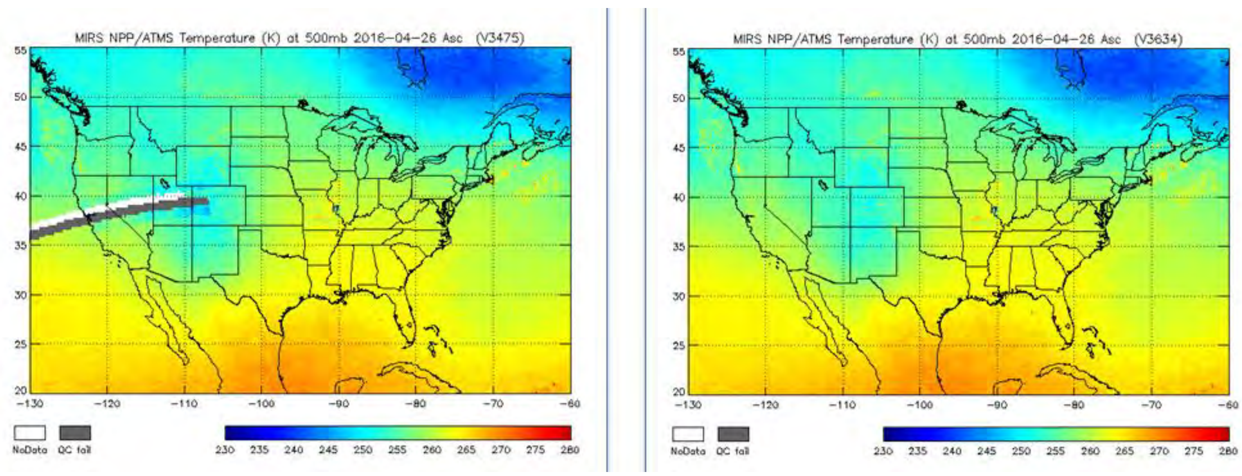


Figure 2. Comparison of MiRS 500mb Temperature over the US before (left) and after (right) the scan line issue was solved.

06-29-2016

MiRS Algorithm Readiness Review (GPM/GMI Extension) (Chris Grassotti, Junye Chen)

Planned and led an important Algorithm Readiness Review (ARR) presentation to NOAA management and stakeholders. This was a significant milestone, in which a new version of MiRS was presented (v11.12) in preparation for delivery to operational use. The primary change to MiRS in this version of MIRS was the extension of operation processing capability to data from the NASA GPM/GMI mission. The official operational products available from MiRS for GPM/GMI are: rain rate, total precipitable water, rain water path, ice water path, cloud liquid water and snow water equivalent. Figure 3 shows an example of the hourly rain rate produced from MiRS GPM/GMI compared with the rain gauge adjusted radar estimate from the operational Stage IV analysis. Figure 4 shows the positive impact of tuning the algorithm on total precipitable water vapor via adjustment of the channel radiometric and forward model noise. Version 11.2 was delivered to operations in Summer 2016, and running in operations in January 2017.

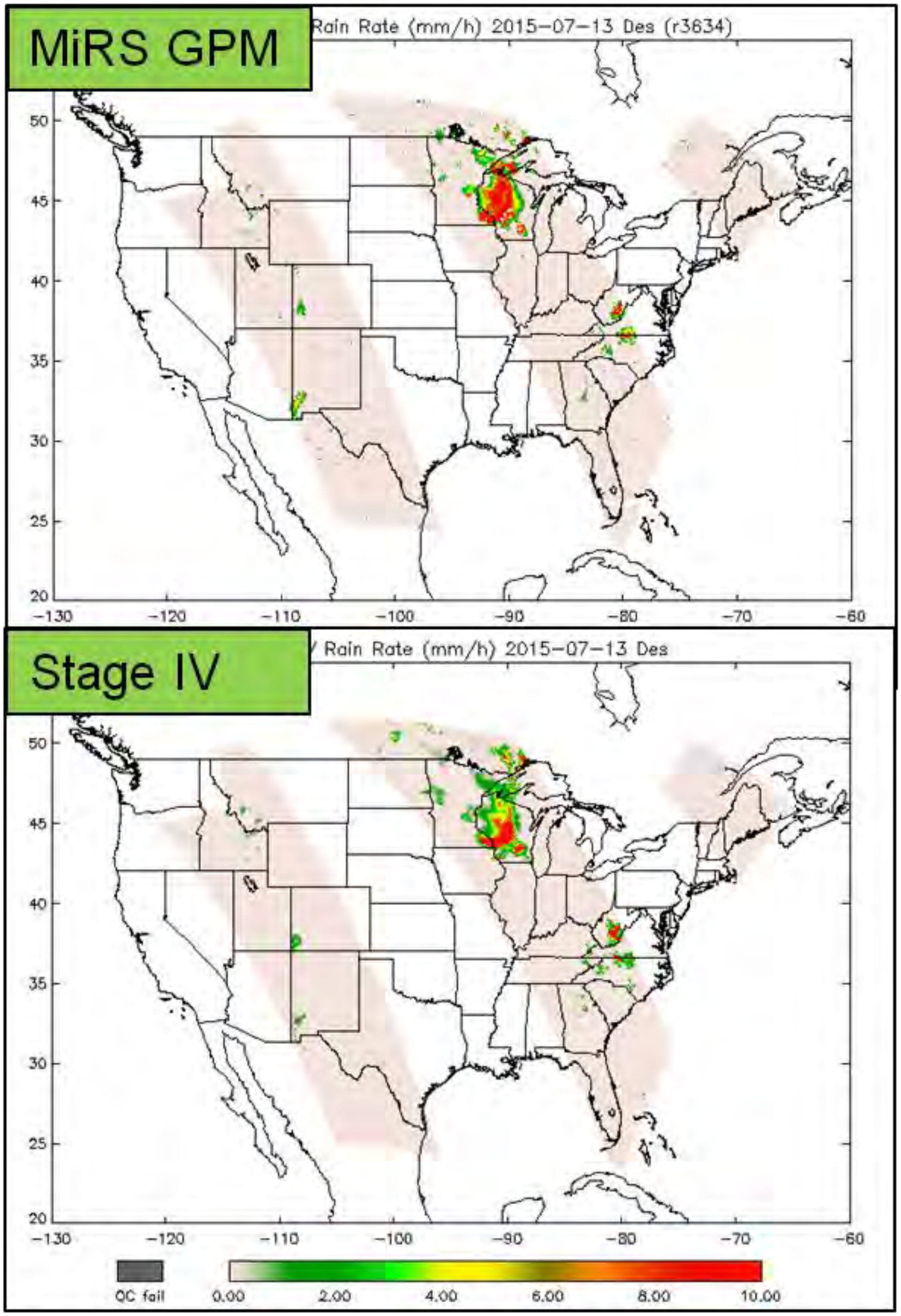


Figure 3. Comparison of rain rate (mm/h) produced from MiRS GPM/GMI (top) with the operational Stage IV analysis (bottom) on 13 July 2015.

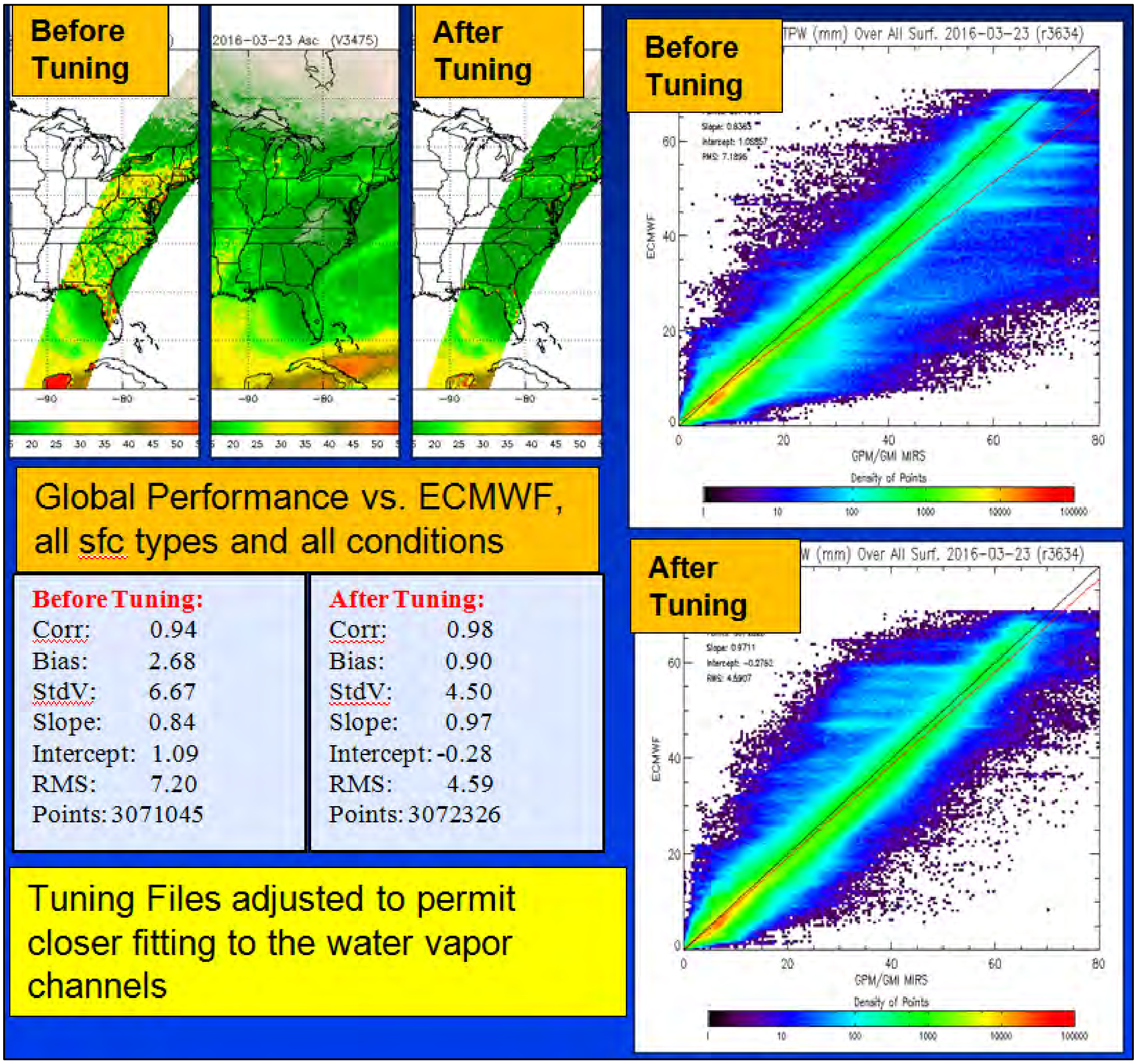


Figure 4. Comparison of MiRS TPW retrieval based on GPM/GMI data before and after tuning of the channel radiometric uncertainties.

08-10-2016

MiRS Presentation at the JPSS Science Meeting (Chris Grassotti)

The STAR JPSS 2016 Annual Science Team Meeting was held August 8-12 2016 at NCWCP in College Park, MD. Chris Grassotti gave a talk entitled “MiRS: Products Overview and Potential Improvements.”

09-06-2016

Microwave Integrated Retrieval System (MiRS) Using S-NPP/ATMS Data Observes Tropical Storm Hermine off Florida Coast (Chris Grassotti)

Tropical Storm Hermine, which briefly intensified to hurricane strength before making landfall, was observed in microwave satellite data from S-NPP/ATMS over the Gulf of Mexico on September 1, 2016 (Fig. 3). The NOAA Microwave Integrated Retrieval System (MiRS) retrieved surface rain rates in and around the storm at 1910 UCT (approximately 310 pm local time) as the storm was intensifying just a few hours prior to landfall on the west coast of Florida. As shown in Figure 5, maximum rain rates were estimated to exceed 15 mm/h (0.6 in/h). Comparison with the operational Stage IV radar-gauge analysis at the same time show good qualitative agreement.

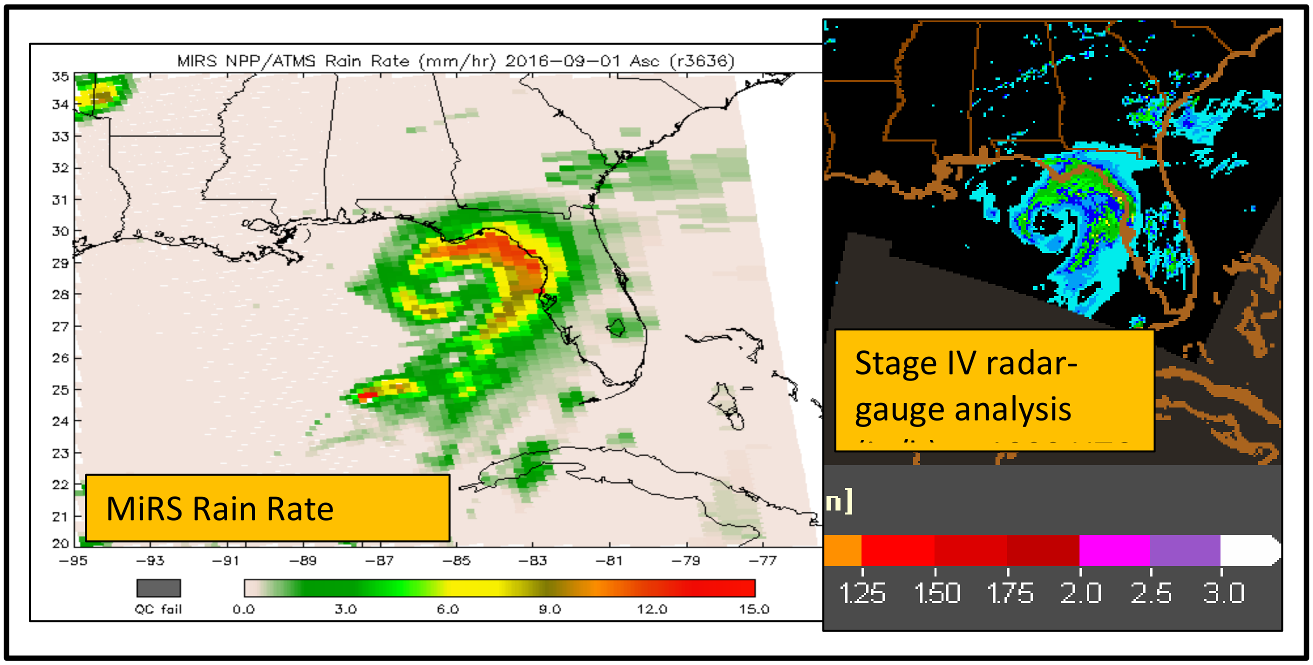


Figure 5. MiRS retrievals of rain rate (mm/h) around Tropical Storm Hermine from Suomi-NPP/ATMS microwave observations at 1910 UTC on 1 September 2016. Panels show MiRS surface rain rate (left), and Stage IV radar-gauge analysis (right). Maximum MiRS rain rain rates of 15 mm/h correspond to 0.6 in/h, in agreement with Stage IV.

09-16-2016

MiRS Team Presenters at the NASA Sounder Science Team Meeting (Chris Grassotti, Junye Chen)

The NASA Sounder Science Team Meeting was held 13-16 September 2016 in Greenbelt, MD. Chris Grassotti gave a talk entitled "Microwave Integrated Retrieval System: Algorithm Overview, Performance, and Application of Sounding Products." Dr. Junye Chen also gave a talk entitled "Validation and Recent Scientific Improvements in Temperature and Moisture Sounding on NOAA Microwave Integrated Retrieval System (MiRS)"

09-26-2016

J. Chen Gives an Oral Presentation at SPIE Remote Sensing Conference (Junye Chen)

Dr. Junye Chen gave an oral presentation on the impact of upgrading the background covariance matrices in NOAA Microwave Integrated Retrieval System (MIRS) at SPIE Remote Sensing Conference in Edinburgh, UK. Figure 6 shows summary results of the impact on global temperature retrievals for one full day. Over ocean bias and standard deviation are reduced using an updated background covariance matrix.

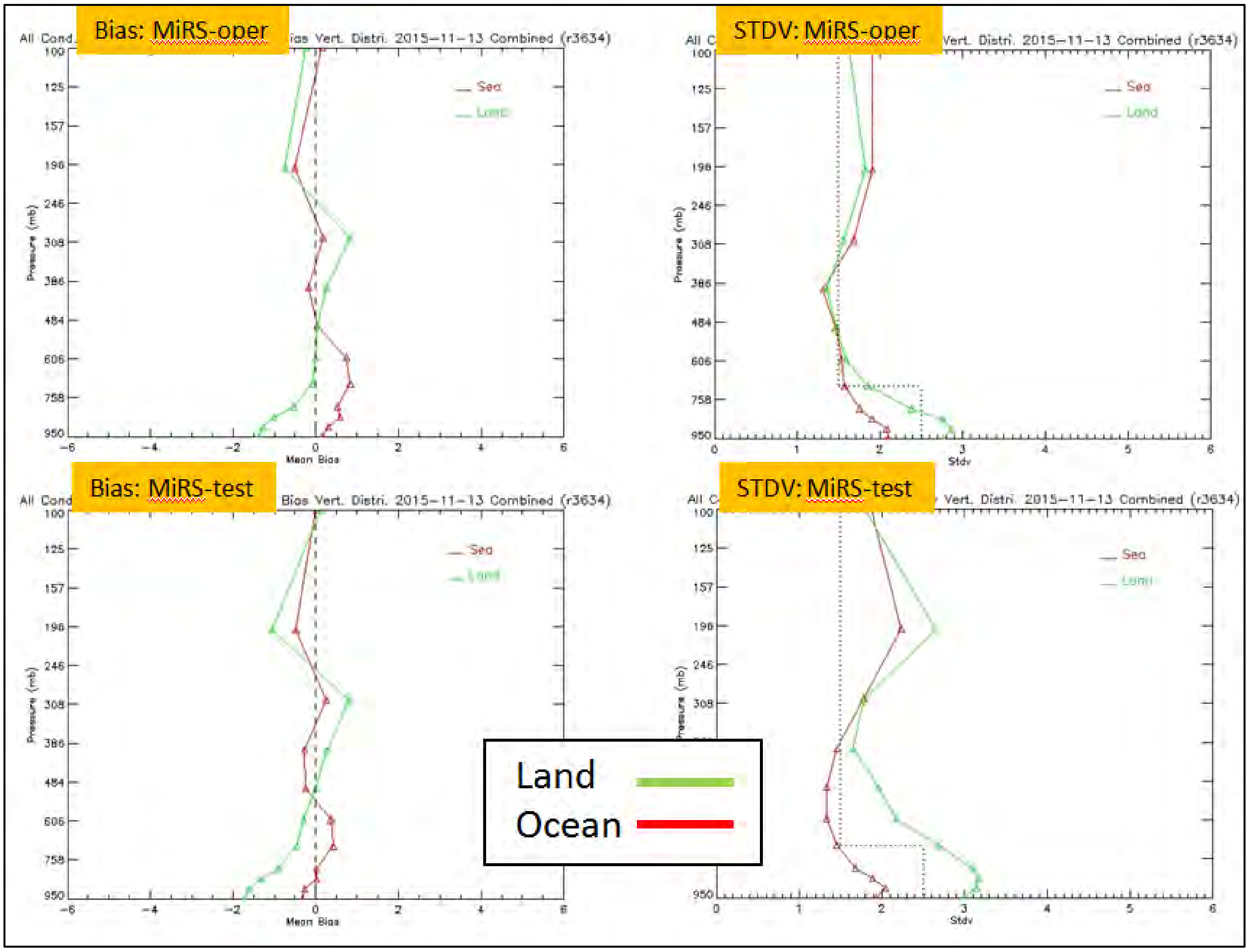


Figure 6. Comparison of global temperature retrieval performance (relative to ECMWF analyses) for a single day, for operational MiRS (top), and a test version (bottom) in which an updated background covariance matrix was used. Improvement in both bias and standard deviation is seen over ocean surfaces.

10-05-2016

C. Grassotti Presents MiRS Poster at 8th IPWG Meeting (Chris Grassotti)

Chris Grassotti attended the 8th International Precipitation Working Group meeting in Bologna, Italy from October 3-7. This year the meeting was jointly held with the International Workshop on Space-Based Snowfall Measurement. Research results were presented in a poster entitled: "Development and Assessment of Precipitation Products from the Microwave Integrated Retrieval System (MiRS)".

10-15-2016

New MiRS Website Goes Live (Chris Grassotti)

A completely overhauled and redesigned website for the MIRS project was officially launched on 1 October 2016. This was the first major update to the website since 2007, and involved 2-3 months of work with in collaboration to the NESDIS/STAR webmaster. Major updates included updated IT security features, smoother browsing experience, and easier maintainability.

10-18-2016
MiRS Passes JPSS Validated Maturity Review (Chris Grassotti , Junye Chen)
On 18 October 2016, MiRS presented validation results for the following official products: temperature profile, water vapor profile, total precipitable water, and rain rate. Detailed comparisons of MiRS retrieved products with various reference data were presented. The objective is to demonstrate that retrieval performance in terms of accuracy and precision meets the specified requirements. Following the review, the decision of JPSS management was to approve all the above products as having a status of officially validated.

11-18-2016
Improved MiRS Rain Rate Retrievals Over Land Using Cloud Liquid Water as an Input (Chris Grassotti)
Experimental retrievals of rainfall over land that include retrieved cloud liquid water were shown to improve the detection and estimation of light rainfall amounts. Figure 7 shows an intercomparison of operational and experimental rain rates, along with the operational Q3 gauge-adjusted analysis.

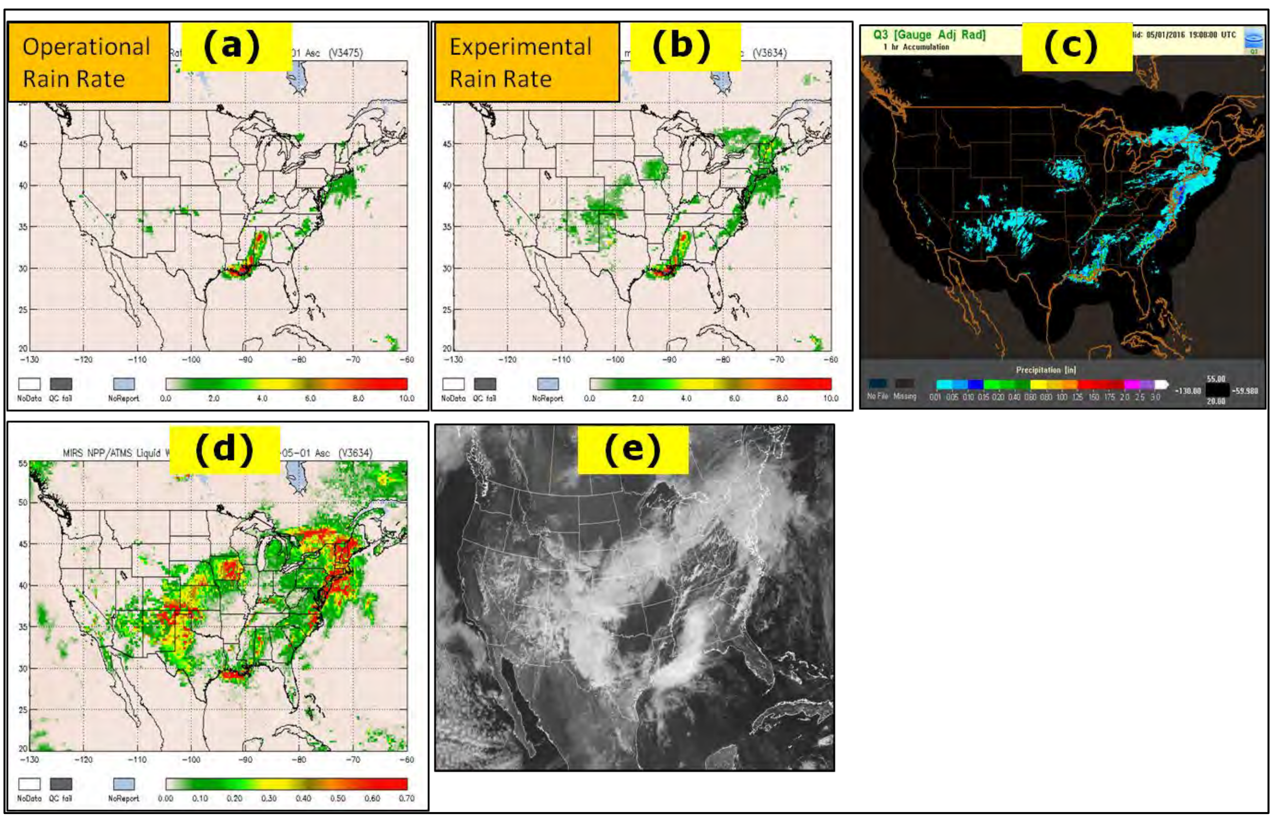


Figure 7. Example of impact of using retrieved CLW over land in the land precipitation estimation from SNPP/ATMS on 01 May 2016. Shown are (a) MiRS operational RR (mm/h), (b) MiRS RR using CLW, (c) MRMS Q3 radar-gauge analysis valid at 1900 UTC (units in inches), (d) MiRS Liquid Water Path (LWP=RWP+CLW, mm), and (e) visible satellite image from GOES-East valid at 1915 UTC.

11-29-2016

MiRS Team Presentations at CICS Science Meeting (Chris Grassotti, Junye Chen)

Chris Grassotti presented a poster summarizing improvements and validation of MiRS precipitation products, and Dr. Junye Chen gave an oral presentation on the impact of upgrading the background co-variance matrices in NOAA Microwave Integrated Retrieval System (MIRS).

12-12-2016

J. Chen Presents MiRS poster at AGU 2016 (Junye Chen)

Dr. Junye Chen presented a poster on the Advance of Atmospheric Sounding in NOAA Microwave Integrated Retrieval System (MIRS) in the JPSS Era.

01-25-2017

C. Grassotti Presents MiRS Poster at Annual AMS Meeting (Chris Grassotti)

Chris Grassotti attended the 97th AMS Annual Meeting, 31st Conference on Hydrology from January 22-26. Research results were presented in a poster entitled: " Precipitation Products from the Microwave Integrated Retrieval System: Recents Developments, Improvements, and Validation ".

03-01-2017

Initial MiRS Extension to JPSS1/ATMS Data Completed (Junye Chen)

Dr. Junye Chen extended MiRS to process ATMS data from the upcoming JPSS-1 mission and tested with proxy data.

03-10-2017

Improved Sounding in Tropical Cyclone Environment (Chris Grassotti)

The MiRS team is collaborating with the tropical cyclone (TC) team at the Cooperative Institute for Research in the Atmosphere (CIRA). The team at CIRA has developed an algorithm that is used operationally at the National Hurricane Center to estimate and predict TC intensity, and accurate temperature and water vapor profile retrievals are keys to an accurate intensity estimate. Figure 8 shows a comparison from Hurricane Edouard which shows temperature anomaly cross-sections from the operational MiRS, and an experimental version that used a TC climatology of temperature and water vapor as a background a priori constraint. In the experimental version the low level warm anomaly which is due to contamination from heavy rain and ice that was seen in the operational version is eliminated and replaced with a cold anomaly, which is much more consistent with known temperature structures of TCs.

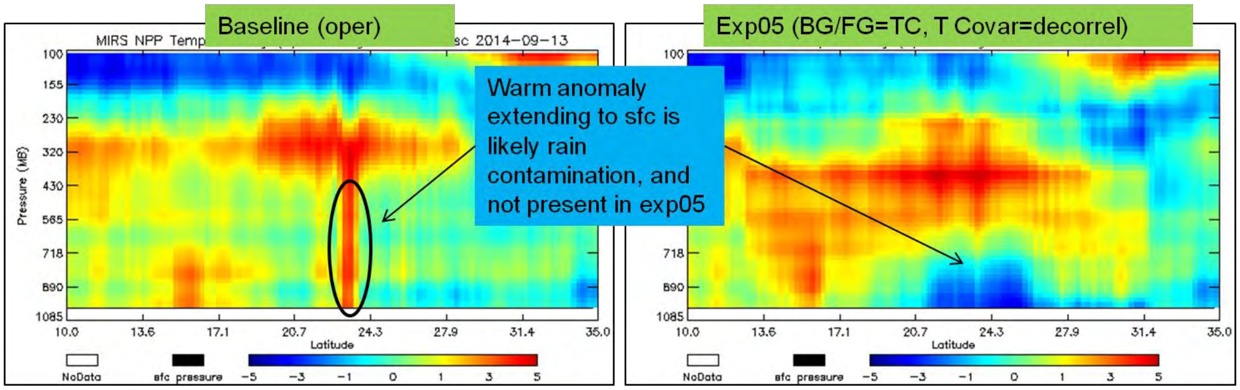


Figure 8. Comparison retrieved vertical temperature anomaly cross-sections through the center (22.2 N, 46.9 W) of HurricaneEdouard (13 September 2014) from operational (left) and experimental (right) MiRS. The upper level warm and lower level cold anomalies are better depicted in the experimental retrieval, while the operational retrieval contains contamination from heavy rain and ice.

Planned work

- Extend MiRS to process data from the upcoming JPSS-1/ATMS mission (launch now planned for 23 September 2017). Validate products.
- Conduct Algorithm Readiness Review for JPSS-1/ATMS after calibration/validation period, and deliver updated MiRS package to NESDIS operations (OSPO/NDE).
- Integrate snowfall rate (SFR) algorithm for SNPP and JPSS-1/ATMS (provided by H. Meng) into the MiRS package.
- Continue to explore and develop methods of improving MiRS temperature and water vapor retrievals in rainy conditions, including intense precipitation associated with tropical cyclones.
- Continue calibration/validation activities for all ATMS products.

Publications

- Die Wang, Catherine Prigent, Lise Kilic, Stuart Fox, Chawn Harlow, Carlos Jiménez, Filipe Aires, **Christopher Grassotti**, and Fatima Karbou, “Surface emissivity at microwaves to millimeter waves over polar regions: parameterization and evaluation with aircraft experiments”, 2017, accepted to Journal of Atmospheric and Oceanic Technology, ***in press***.
- Ralph Ferraro, Patrick Meyers, Paul Chang, Zorana Jelenak, **Christopher Grassotti**, and Shuyan Liu, “Application of GCOM-W AMSR2 and S-NPP ATMS Hydrological Products to a Flooding Event in the United States”, 2017, accepted to IEEE Journal of Selected Topics in Applied Observations and Remote Sensing (JSTARS), ***in press***.
- Shuyan Liu, **Christopher Grassotti, Junye Chen**, and Quanhua Liu, “GPM Products from the Microwave Integrated Retrieval System (MiRS)”, IEEE Journal of Selected Topics in Applied Observations and Remote Sensing (JSTARS), ***submitted, reviewed, undergoing second round of revisions***.

Products

The table below lists the official operational products generated routinely by the MIRS algorithm.

MiRS Operational Products
Atmospheric Temperature profile
Atmospheric Water Vapor profile
Total Precipitable Water
Land Surface Temperature
Surface Emissivity Spectrum
Total SeaIce Concentration
First Year Sea Ice Concentration
Multiyear Sea Ice Concentration
Snow Cover Extent
Snow-Water Equivalent
Snow Grain Size
Integrated Cloud Liquid Water
Integrated Graupel Water Path
Integrated Rain Water Path
Rainfall Rate
Snowfall Rate (AMSU/MHS only, ATMS in progress)

Presentations

- Grassotti, Christopher (invited)
  Microwave Integrated Retrieval System: Products Overview and Potential Improvements
  STAR JPSS Annual Science Team Meeting
  College Park, MD
  8-12 August 2016

- Grassotti, Christopher
  Microwave Integrated Retrieval System: Algorithm Overview, Performance, and Application of Sounding Products
  Sounder Science Team Meeting
  Greenbelt, MD
  13-16 September 2016

- Chen, Junye
  A Comprehensive validation of temperature and moisture sounding in NOAA Microwave Integrated Retrieval System (MIRS)
  Sounder Science Team Meeting
  Greenbelt, MD
  13-16 September 2016

- Grassotti, Christopher
  Development and Assessment of Precipitation Products from the Microwave Integrated Retrieval System
  8th International Precipitation Working Group Meeting
  Bologna, Italy
  3-7 October 2016

- Chen, Junye
  The impact of upgrading the background covariance matrices in NOAA Microwave Integrated Retrieval System (MiRS)
  ERS16 SPIE Remote Sensing Meeting
  Edinburgh, United Kingdom
  26 - 29 September 2016

- Grassotti, Christopher
  Development and Assessment of Precipitation Products from the Microwave Integrated Retrieval System
  CICS-MD Science Meeting
  College Park, MD
  29 November – 1 December 2016

- Chen, Junye
  The impact of upgrading the background covariance matrices in NOAA Microwave Integrated Retrieval System (MiRS)
  CICS-MD Science Meeting
  College Park, MD
  29 November – 1 December 2016

- Chen, Junye
  The Advance of Atmospheric Sounding in NOAA Microwave Integrated Retrieval System (MIRS) in the JPSS Era
  AGU Fall Meeting
  San Francisco, CA
  12-16 December 2016

- Grassotti, Christopher
  Precipitation Products from the Microwave Integrated Retrieval System: Recents Developments, Improvements, and Validation
  AMS Annual Meeting, 31st Conference on Hydrology
  Seattle, WA
  22-26 January 2017

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	7
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	3
# of NOAA technical reports	
# of presentations	9
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

New or Improved Products Developed – All are produced in operations

- Integrated Water Vapor, TPW (Improved, i.e. new product from GPM/GMI)
- Rain Rate (Improved, i.e. new product from GPM/GMI, and Improved over Land for other satellites)
- Cloud Liquid Water (Improved, i.e. new product from GPM/GMI)
- Rain Water Path (Improved, i.e. new product from GPM/GMI)
- Graupel Water Path (Improved, i.e. new product from GPM/GMI)
- Snow Water Equivalent (Improved, i.e. new product from GPM/GMI, and improved for AMSU/MHS and ATMS)
- Snowfall Rate (New for AMSU/MHS, integrated existing external algorithm developed by H. Meng)

CUNY-CREST Sea Surface Temperature -MODIS-like VIIRS product; Pattern Recognition Analyses; Ocean Fronts; ACSPO Regional Monitor (ARM)	
Task Leader	Irina Gladkova
Task Code	IGIG_SSTM_16
NOAA Sponsor	Alexander Ignatov
NOAA Office	STAR
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 2: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

Visible Infrared Imaging Radiometer Suite (VIIRS) radiometer, flown onboard S-NPP JPSS satellite, is capable of providing superior sea surface temperature (SST) imagery. However, the swath data is subject to several artifacts including bow-tie distortions and striping, and require special pre-processing steps. VIIRS also has two irreversible data reduction steps onboard: pixel aggregation (to reduce resolution changes across the swath) and pixel deletion, which complicate both bow-tie correction and destriping. We have developed an algorithm, adopted in the National Oceanic and Atmospheric Administration (NOAA) Advanced Clear-Sky Processor for Oceans (ACSPO) SST system, to minimize the bow-tie artifacts in the SST imagery and facilitate application of the pattern recognition algorithms for improved separation of ocean from cloud and mapping fine SST structure, especially in the dynamic, coastal and high-latitude regions of the ocean. The algorithm is based on a computationally fast re-sampling procedure that ensures a continuity of corresponding latitude and longitude arrays.

The cloud mask employed in the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) SST system, is most liberal among the community SST products. Yet, false alarms do occasionally occur in ACSPO, especially in the dynamic oceanic regions. Performing front detection at the stage of cloud masking improves both fronts and mask. We plan to output the frontal product as an extra layer of the ACSPO SST product, which can be directly used in the composition process.

Accomplishments

- We have developed the algorithm and initial implementation (in C++) for the SST Level 3 (L3U) product (“U” stands for “uncollated”, where multiple passes over the same grid are independently saved). It is a gridded version of L2P SST product, using equiangular 0.02º grid. Similarly to the L2P, the L3U data are also reported in 10-min granules, but with daily volume <1 GB. Currently, the NOAA VIIRS L3U SST product is operationally used or tested in several major international numerical weather prediction centers. Paper describing the algorithm has been submitted.
- We have previously developed a pre-processing procedure – resampling – which corrects the bow-tie distortions, typical for polar orbiting instrument. This step is needed for spatial continuity of satellite imagery (c.f. Figure 1), which is critically important for users interested in Level 2

satellite imagery. During the reporting period, the bow-tie correction algorithm has been implemented and tested for both, VIIRS and MODIS instruments.

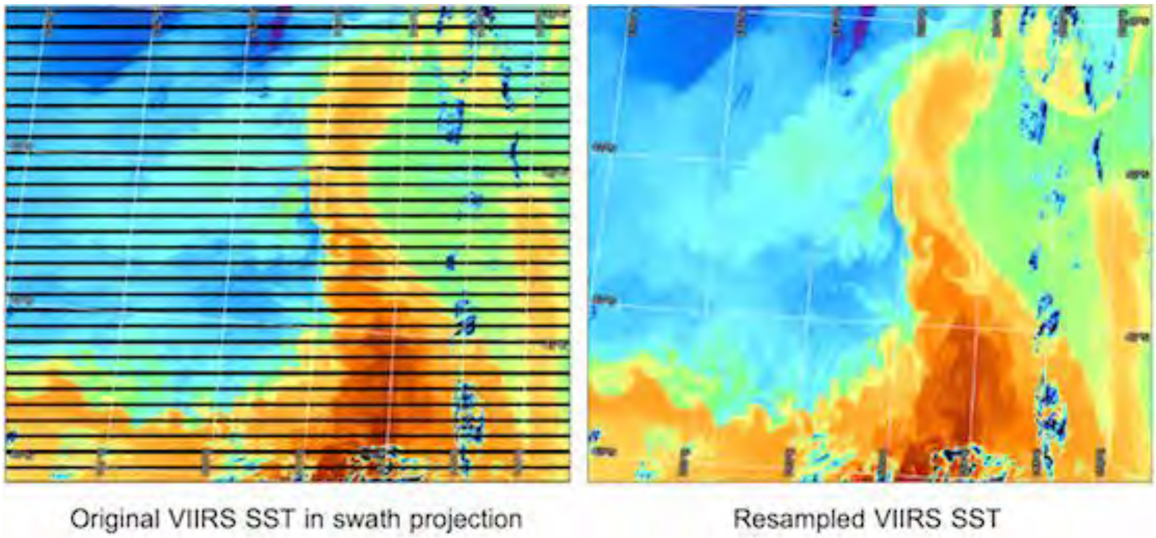


Figure 1. Left: Example of bow-tie deletions when the Visible Infrared Imaging Radiometer Suite (VIIRS) sea surface temperature (SST) image is displayed in the original swath projection. Right: Corresponding resampled SST ACSPO v2.5 imagery.

- The previously introduced automated SST Pattern Test first identifies ocean thermal fronts and adjacent contiguous areas with uniform SSTs, and then makes ocean vs. cloud decision based on the statistics of the whole regions. During the reporting period we have significantly improved the major component of our earlier developed algorithm. These enhancements will be incorporated in the future versions of the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) SST system, to generate a new product – ocean fronts (which can be used to validate the gradients in various L4 analyses); and improve VIIRS clear-sky mask (especially in the dynamic areas of the ocean, in coastal zones, and in the high-latitude regions).

- We have significantly improved the thermal front identification. The front detection uses the gradient behavior of the SST field, connectivity of the fronts, and bi-modality of the SST distribution in the vicinity of the thermal fronts. Since ocean thermal fronts have significant variation in gradient strength, we have introduced several front enhancements pre-processing procedures. Our multi-scale approach is based on the derivative of a Gaussian kernel at various scales, as well as eigenvalues of the Hessian matrix. We plan to output the frontal product as an extra layer of the ACSPO SST product, which can be directly used in applications which require the estimation of thermal fronts, for example derivation of thermal front composite maps, validation of aggregated L4 products and physical models in terms of frontal locations, comparison with other related phenomena such as changes in chlorophyll, ocean salinity, sea surface height etc.

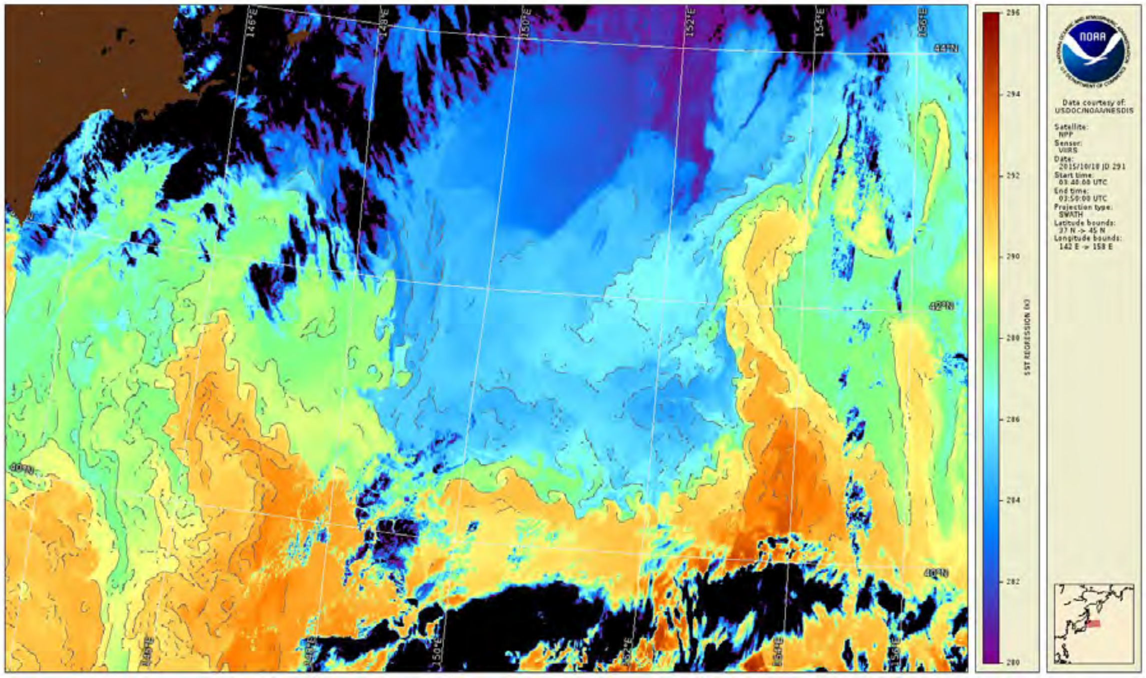


Figure 2. Example of SST image with thermal fronts overlaid (rendered in gray).

Planned work

- Continue improving clear sky domain detection algorithm
- Continue developing and testing thermal front detection algorithm
- Continue developing the code that outputs thermal fronts as an extra layer of the ACSPO SST L2 product, which can be directly used in the front composition process and in assimilation of L2 product in higher level products.

Publications

Alexander Ignatov, Irina Gladkova, Yanni Ding, Fazlul Shahriar, Yury Kihai, Xinjia Zhou, JPSS VIIRS Level 3 Uncollated SST Product at NOAA, submitted to Journal of Applied Remote Sensing

Products

JPSS VIIRS Level 3 Uncollated SST Product

Presentations

Irina Gladkova, Alexander Ignatov, Fazlul Shahriar, Yury Kihai, Towards High Resolution Ocean Thermal Fronts Product from JPSS VIIRS, 17th GHRSST Meeting, June 2017, Washington DC

Alexander Ignatov, Irina Gladkova, Yury Kihai, Boris Petrenko, Fazlul Shahriar, ACSPO v2.5 & upcoming improvements in v2.6, JPSS 2016 Annual Science Team Meeting, August, College Park

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	1
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	2
# of undergraduate students mentored during the year	

- Developed the algorithm and initial implementation of L3U SST NOAA product. It has been tested and optimized at NOAA and now operational.
- Improved SST imagery has been tested and now in a process of being incorporated in the version 2.5 of the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) SST system.
- Thermal Front layer will be added in NOAA ACSPO version 2.6

GCOM-W1 Soil Moisture Product Development and Validation

Task Leader	Dr. Jicheng Liu
Task Code	JLJL_GCOM_16
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: We have finished the development of GCOM-W1 AMSR2 soil moisture EDR product algorithm. The science code of the algorithm has been completed and delivered to GCOM-W1 team at NOAA/NESDIS/STAR. The code is now operationally running there. A re-run of the production code has been done over the whole AMSR2 data period using the most recent version of brightness temperature inputs. This historical data set will be used for the validation work using the in-situ measurements. This product has been ingested into SMOPS Version 2.0 and after. Algorithm refinement has been intensively conducted to improve both the spatial coverage and the quality of the retrievals.

Background

The Global Change Observation Mission-Water (GCOM-W1) satellite, as part of the Joint Polar Satellite Program (JPSS), has been in orbit since its launch in May, 2012. The Advanced Microwave Scanning Radiometer follow on instrument (AMSR2) on GCOM-W1 will provide a majority of global water cycle Environmental Data Records (EDR). One set of these EDRs are the Land-surface parameters (i.e. land surface soil moisture and land surface type) while soil moisture EDR is one of these EDRs. The main goal of the soil moisture EDR task is to ensure that the tools and capabilities are in place to efficiently generate and validate the Soil Moisture EDR from AMSR2 observations.

The GCOM-W1 AMSR2 Algorithm System Package (GAASP) is designed to produce all Level 2 AMSR2 products at NOAA, and went operational in later 2014 for Day 1 products and in 2016 for Day 2 products, respectively. AMSR2 Soil Moisture EDR is one of the Day 2 products.

Accomplishments

The Single Channel Retrieval algorithm (SCR) for soil moisture is selected as the primary algorithm to retrieve soil moisture values using microwave observations from AMSR2. This algorithm has been heavily tested and some of the major parameters have been tuned for better retrieval results. The science code of this algorithm has been completed and delivered to GCOM-W1 team. The integration of the science code into the GAASP has been completed and the system went operational in later 2016.

AMSR2 SM EDR has been successfully ingested in SMOPS 2.0, which went operational in September, 2016. Table 1 shows that AMSR2 SM EDR product plays a major role in the SMOPS blended product.

In-situ soil moisture observation data has been collected from a number of ground observation networks and product validation has been conducted using this observations. Table 2 shows the validation results of AMSR2 SM EDR along with other products from SMOPS.

Table 1: Percentages in the Blended Product from individual sensors

Date	NRT SMOS	ASCAT-A	ASCAT-B	AMSR2	GMI	NRT SMAP
8/29/2016	46	27	28	28	62	51
8/30/2016	48	29	29	33	60	54
8/31/2016	46	23	27	27	63	60
Average	47	26	28	29	61	55

Table 2. Validation results of Unbiased Root Mean Square Error (ubRMSE) for different SM products.

In situ Sites	SMOS	NSMOS	ASCAT-A	ASCAT-B	AMSR2	Blended
Mason, IL	0.062	0.193	0.094	0.097	0.040	0.046
Torrington, WY	0.062	0.037	0.070	0.071	0.049	0.054
LittleRiver, GA	0.076	0.130	0.079	0.076	0.029	0.040
Lehman, TX	0.062	0.048	0.113	0.116	0.055	0.057
CPER, CO	0.047	0.048	0.082	0.079	0.056	0.056
Phillipsburg, KS	0.050	0.054	0.083	0.084	0.064	0.068
Maqu, CN	0.106	0.109	0.074	0.084	0.093	0.084
Naqu, CN	0.106	0.056	0.067	0.078	0.046	0.044
Average	0.071	0.084	0.083	0.086	0.054	0.056

Planned work

- Continue working on collecting and processing in-situ soil moisture data.
- Continue working on SM EDR algorithm validation effort using the collected data sets.
- Continue working on retrieval algorithm refinement based on the validation results.
- Deliver the refined algorithm.

Products

- GAASP soil moisture EDR operational code.
- Documents related GAASP SM EDR code.
- Collection of processors for in-situ soil moisture observations.
- Validation results for the SM EDR product using field measurements.

Presentations

- "NOAA Soil Moisture Operational Product System (SMOPS): Version 3.0", Jicheng Liu, Xiwu Zhan, Limin Zhao, Christopher R. Hain, Li Fang, and Jifu Yin, Weizhong Zheng, and Micheal Ek, *CICS-MD Science Meeting*, December, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

The new GAASP SM EDR code has been delivered to NOAA/NESDIS/STAR. It's now running operationally. Newly generated Cumulative Distribution Functions (CDF) used in the algorithm will increase the spatial coverage and data quality.

Mapping Altimeter Sea Level at High Latitude	
Task Leader	Semyon Grodsky
Task Code	SGSG_MALT_16
NOAA Sponsor	Laury Miller & Eric Leuliette
NOAA Office	NESDIS/STAR/SOCD/Laboratory for Satellite Altimetry
Contribution to CICS Research Themes (%)	Theme 1: Climate and Satellite Research and Applications (100%)
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 2: To share that knowledge and information with others (100%)
Strategic Research Guidance Memorandum:	2. Environmental Observations
Highlight : OI algorithm to merge different altimeters	

Background

Seasonal variability of major Arctic environmental parameters is very large and sea level (SL) seasonal variations of 20 - 30 cm in magnitude reflect this. Seasonal changes in Arctic SL are affected by sea level pressure (IBE), wind regime, river runoff, and steric effects associated with water temperature and salinity. All these factors have been identified as major forcing components influencing the seasonal cycle of SL. A significant portion of interannual variations is wind-driven and is related to alternates between anticyclonic and cyclonic atmospheric regimes. Switches between them lead to significant differences in the ocean state corresponding to each regime.

For better representation of Arctic sea level and other operations, the Laboratory for Satellite Altimetry needs an operational routine that allows combining measurements from different satellites. This routine should allow for minimization of inter-satellite biases, which otherwise would result in stripe-like patterns of gridded altimetry that reflect differences among along track data from different altimeter missions.

Although the original task was formulated for regional, high-latitude studies, the final altimeter gridding procedure was designed for the globe.

Accomplishments

OI altimeter gridding procedure mimics similar procedure developed for the European AVISO project. The AVISO codes are considered as proprietary and are not available. Our implementation of the procedure accounts for the recent observation based radii of correlation and propagation speed of sea level anomalies (update of the original data of Jacobs et al., 2001, Gregg Jacobs (NRL/SSC) personal communication, 2016). Matrix inversion performance is optimized for symmetric and positively defined matrices. Although the original task was formulated for regional, high-latitude studies, the final altimeter gridding procedure has been designed for the globe. It effectively eliminates stripes between tracks from different missions due to the application of the long wave error covariance formalism. Gridded altimeter fields developed using this OI procedure are used for an online quick view of the most recent sea level fields.

The developed gridded altimeter data were used by Grodsky et al. (2017) to interpret interannual sea surface salinity (SSS) variations on the northwestern Atlantic shelf. SSS data from the Aquarius and SMOS satellite missions display a steady increase of ~1psu over the entire northwestern Atlantic shelf south of Nova Scotia during the 2011-2015. Put in the context of longer ocean profile data the results suggest that mixed layer salinity and temperature north of the Gulf Stream experience positively correlated shelf-wide interannual oscillations (1psu/2degC). Salty and warm events occur coincident with anomalous easterly-southeasterly winds and Ekman transport counteracting the mean southwestward shelf currents. They are coincident with the weakening of both branches of the Scotian Shelf Current (SSC), which is evident in altimetry data. This suggests that salt advection by anomalous SSC acting on the mean salinity gradient is the primary driver regulating the transport of fresh/cold water from high latitudes. The advection mechanism imposes a connectedness of the larger-scale interannual variability in this region and its tie to atmospheric oscillations. G. A. Jacobs, C. N. Barron, and R. C. Rhodes (2001), Mesoscale characteristics, *J. Geophys. Res*, **106**(9), 19581–19595.

Publications

Grodsky, S.A., N. Reul, J. A. Carton, B. Chapron, and F.O. Bryan (2017), Interannual surface salinity in Northwest Atlantic shelf, *J. Geophys. Res. Oceans,* **122**, doi:10.1002/2016JC012580

Products

OI algorithm to merge and grid different altimeter along track data.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	X
# of peer reviewed papers	1
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Science and Technology Infusion Strategy for the Next-Generation Global Prediction System (NGGPS) Planning: Strategic Plan (Part 1 of 2)

Task Leader	Stephen Lord
Task Code	SLSL_NWS_15 Year 2
NOAA Sponsor	Fred Toepfer
NOAA Office	NWS Office of Science and Technology Integration
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: A successful Science and Technology Infusion Strategy for the NGGPS planning involves strategic issues for model and data assimilation development and an explicit community-based plan for advanced physical (scale-aware) parameterizations with improved coupling of physical processes across radiation, boundary layer, deep and shallow convection and surface fluxes. Mentoring current NWS and other NOAA staff is an important contribution to add perspective to a very complex undertaking. Moreover, efficient and effective use of High Performance Computing (HPC) resources through careful software design and HPC system planning is essential for providing new and improved products to users through the NGGPS Program.

Background

Science and technology infusion from external research into NWS operational numerical forecast systems is a key driver of expanded services to the public. Successful Research to Operations (R2O) provides a 'conveyor belt' of improved operational systems for the NWS to keep pace with expanding needs of society for weather-related threats. Evolution of the numerical forecast systems in the NCEP Production Suite (NPS) requires considerable planning, requirements gathering and software development by qualified community scientists and software engineers to ensure services are optimized and meeting user needs. Continued strategic procurement of High Performance Computing (HPC) resources is vital to progress both for operations and for software development. This proposal seeks to improve R2O strategies and processes for NCEP.

Accomplishments

Dr. Lord contributed to writing the Next Generation Global Prediction System (NGGPS) Physics Plan and a planning document for the Unified Global Coupled System (UGCS) for Weather and Climate Prediction. He also mentored both NWS and OAR employees in programs such as the Consumer Option for an Alternative System to Allocate Losses (COASTAL Act), the NWS Aircraft Program and reporting on the "Sandy Supplement" progress and accomplishments. These activities supported the NWS Science and Technology Integration (STI) Program. Dr. Lord wrote an informal manuscript entitled "Operational High Performance Computing at the National Weather Service, NOAA," which is under review. The basic thesis of this manuscript is that HPC system availability to developers is a key, and under-emphasized, factor in facilitating S&T infusion and that HPC components are becoming more vulnerable to system Input/Output (I/O) efficiency, necessitating new strategies for operational software design and development.

Planned work

The HPC manuscript will continue to be refined and then submitted to the NGGPS and Environmental Modeling Center (EMC) management. Mentoring will continue.

Publications

Lord, Stephen J. *et al*., 2016: Analysis of an Observing System Experiment for the Joint Polar Satellite System, Bulletin American Meteorological Society, August 2016, 1409-1425.

Products

e.g., documented instrument development, algorithm development, numerical model development and data set generation

Other

Mentoring and advising: Six federal staff were mentored throughout the past year (Ek, Tallapragada, Marshall, Kurkowski, Fritz, Louis)

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of ~~NOAA~~ informal technical reports	1
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of ~~undergraduate students~~ Federal employees mentored during the year	6

Peer-reviewed publication completes 2016 task (**Analysis of an Observing System Experiment for the Joint Polar Satellite System**); technical report is currently unreviewed draft; mentored personnel are Federal employees.

Science and Technology Infusion Strategy for the Next-Generation Global Prediction System (NGGPS) Planning: Diagnostic System (Part 2 of 2)

Task Leader	Stephen Lord
Task Code	SLSL_NWS_15 Year 2
NOAA Sponsor	Fred Toepfer
NOAA Office	NWS Office of Science and Technology Integration
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: A comprehensive diagnostic system is essential to identifying systematic forecast errors and to measuring progress toward minimizing these errors. This project contributes to building such a system.

Background

A comprehensive diagnostic system is essential to identifying systematic forecast errors and to measuring progress toward minimizing these errors. NCEP has an extensive on-line archive of its Global Forecast System (GFS) analyses and forecasts and another on-line archive of forecasts and analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF). Comparisons of error geographical patterns and magnitudes between these two systems can provide insight into model-induced and possibly data assimilation errors and their evolution in time and space. Such a system does not formally exist at NCEP at this time, although individual investigators have developed detailed analysis tools for their own use. The envisioned diagnostic system is being developed with community access in mind, and it is focused on being a tool for both model diagnosticians and model developers.

Accomplishments

In Phase 1 of this work, Dr. Lord has developed a prototype version of an atmospheric forecast Diagnostic System (DS). Acting as a data access tool for the NCEP GFS and the ECMWF data, the DS calculates and displays forecast errors for individual verification days, monthly (and longer) mean errors (also known as “bias”) and case studies of arbitrarily chosen initial conditions. The DS accesses a huge on-line archive of forecast and analysis data from the GFS and ECMWF systems. An example is shown in Fig. 1. In the month of December 2015, mean analysis differences show large values over Greenland and elevated topography in Antarctica, North and South America as well as eastern Brazil and China-Southeast Asia regions. In addition, the DS can easily access “parallel” GFS output to compare new developmental runs with operational runs. An example is shown in Fig. 2.

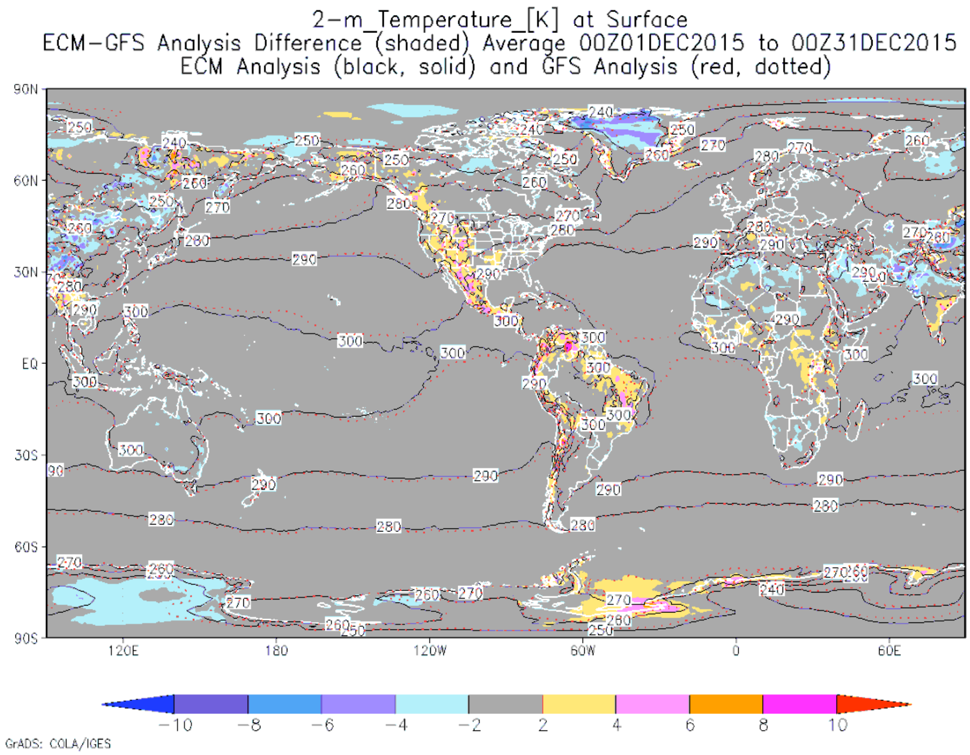


Figure 1. Monthly mean analysis differences in GFS and ECMWF 2-m temperature for December 2015.

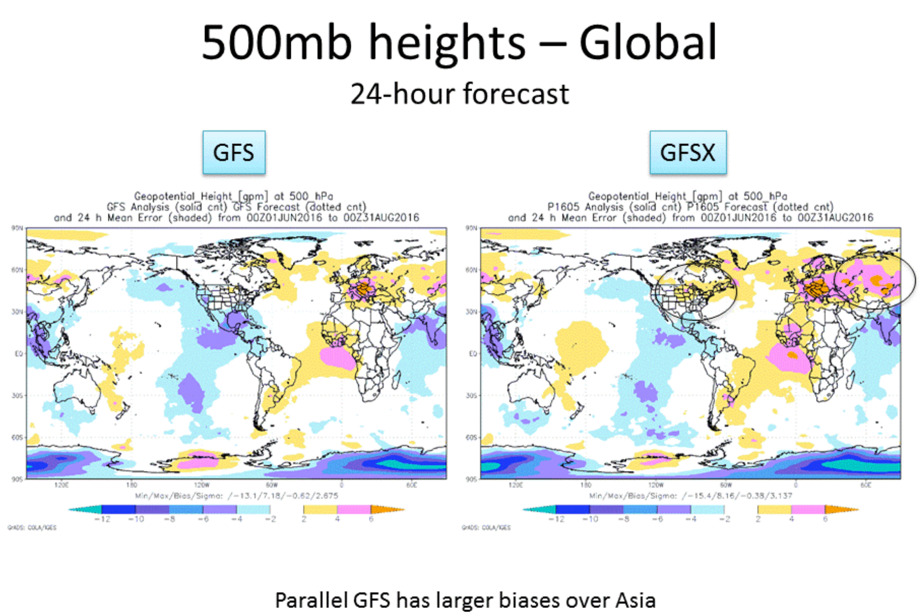


Figure 2. Operational (GFS) and parallel (GFSX) 3 month biases of 24 h forecast 500 hPa Geopotential Height for June-August 2016 (figure courtesy of Tracey Dorian, Environmental Modeling Center).

Planned work

Work accomplished in Phase 1 will be expanded in ***Phase 2*** and ***Phase 3*** as follows.

Phase 2

- Adding verification against aircraft observations
    - Aircraft observations are about as accurate as rawinsonde soundings, but are at single levels following the flight path. When aircraft are taking off or landing, the observations resemble soundings (from the ground to cruise level) but are not processed as such due to the larger horizontal distance between aircraft observations compared to rawinsondes. Nevertheless, aircraft observations can provide information on the vertical distribution of forecast errors on scales equal to or less than the PBG files (~100 km). Some innovative displays are planned.
- Error analysis of surface pressure, temperature and moisture fields
    - The DS can diagnose forecast errors in the atmospheric boundary layer and at the surface. The amount of observations at low levels in the atmosphere is likely to increase due to addition of TAMDAR data, so the DS should be able to use these valuable observations for model forecast verification.
- Adding access to precipitation data and adding forecast error diagnostic capability to the GFS high resolution Gaussian Grid (GG) data
    - The precipitation forecast grids are on a high-resolution Gaussian Grid (GG) that provides more detail than the standard Pressure Grib (PGB) files that are currently subject to DS analysis. The capability to seamlessly diagnose and display both GG and PGB files is important for the DS capability to display errors from the entire model output stream. Future GFS output will be in GG format for all variables on model levels in a sigma-pressure coordinate. When the GFDL "Finite-Volume" dynamics is implemented a similar format will be used.
    - While PGB files are used in monthly groups, the GG files will be used in a case-study mode to investigate details of physics interactions. The GG data closely approximate the actual model calculations and aren't interpolated to pressure surfaces and a latitude-longitude grid like the PGB grids. Furthermore, GG files are much larger than PGB files and cannot practically be stored on-line.

Phase 3

While the acid test of any model improvements is a controlled GFS parallel that uses the entire system (data assimilation, model forecast and post-processing), a simplified system that uses a Single-Column Model (SCM) containing the model physical parameterization codes should be helpful in diagnosis, understanding error generation, and testing and tuning proposed changes. The emphasis in Phase 3 is to integrate un-interpolated GG model data, a SCM and the current DS display and diagnosis capability; this upgrade should provide a powerful tool for GFS improvements.

- Adding capability for diagnosis of model physical parameterizations using a SCM and GG data

- A SCM is a tool that can be used to approximate the interactions of model physical parameterizations. It is derived from the model codes and should be executable from the DS using GG vertical column data, given sufficient development of an interface. Case study GG data from the DS will be ingested by the SCM and tendencies of model variables will be calculated and returned to the DS.

Publications

No peer-reviewed publications are planned at this time, although if some interesting and publication-worthy results are discovered, they will be published. Non-peer reviewed publications will include:

1) “README”-level documentation of the DS and its component parts
2) A user’s guide containing instructions for key processes
3) Various presentations and tutorials

Products

Graphical products similar to those shown above are output from the DS. In addition, several large files containing error data could be produced.

Presentations

1) A Diagnostic System for the GFS – 9 September 2016
2) Continued Development of a Diagnostic System for GFS (and ECMWF) Forecasts and Analyses (V2.0.0) – 12 January 2017

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	(1 or 2 planned)
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

The Diagnostic System (DS) is being used routinely to evaluate new GFS software development and will a candidate for becoming part of the operational forecast system diagnostic package.

GOES-R Surface Albedo Project	
Task Leader	Shunlin Liang & Tao He
Task Code	SLTH_GOER_15 Year 2
NOAA Sponsor	Yunyue Yu
NOAA Office	STAR Algorithm Information Team
Contribution to CICS Research Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

Surface albedo and reflectance product suite is the operational product proposed in GOES-R surface albedo project, which will be implemented in the GOES-R product chain to help with downstream GOES-R products (e.g., snow cover product). This product suite will also play an important role for driving climate, mesoscale, atmospheric, hydrological, and land surface models.

The goal of this task is to develop algorithms and software packages to generate GOES-R land surface albedo (LSA) and spectral directional reflectance product. Previously, we have conducted some preliminary work on developing the prototype algorithms and software packages with proxy datasets: 1) we refined our prototype algorithms develop with MSG/SEVIRI data and applied them to Himawari AHI; 2) tested datasets from AHI were prepared and extracted for the year of 2015; 3) ground measurements were collected at the Australian flux observation sites to help with validations of AHI-based surface albedo; 4) we also started to collect fine resolution satellite data such as Landsat-8 data to investigate the spatial representativeness of ground measurements and to help bridge the spatial scale difference between satellite pixel and ground measurement footprint; 5) other existing satellite products (e.g., MODIS albedo/BRDF product) were collected for inter-comparison and validation of AHI-based surface albedo and surface reflectance products. With the developed Version 6 software package that implemented the LSA algorithm with AHI data, we plan to validate the software package using actual AHI data, identify potential issues, and further improve the software package. Since AHI is very similar to ABI in terms of the sensor's spectral, spatial, and temporal characteristics, we will apply and refine the software package to the simulated/actual ABI data. This report summarizes our main accomplishments in algorithm and software development and products validation during the past year.

Accomplishments

During the past year, our primary task is algorithm development/maintenance and software testing /validation. Our efforts to accomplish this goal include the following specific tasks:

1) Version 6 software package preparation and delivery

In Version 6 software package, we switched from using SEVIRI data to AHI data as a proxy, the latter with very similar data structure and band design to that of the GOES-R ABI. All the ancillary data used in the software package have been updated, which include atmospheric lookup-table, narrow-to-broadband conversion, and shortwave albedo climatologies. We extracted the AHI L1B data and cloud mask data for the several periods in 2015 as the sample input data for Version 6 software.

The software package has been tested against the sample input data and generated outputs including surface albedo and spectral reflectance data. We delivered the Version 6 software package with sample test datasets to AIT in the 1st quarter of 2016. An example of the software output with AHI data is shown in Fig.1.

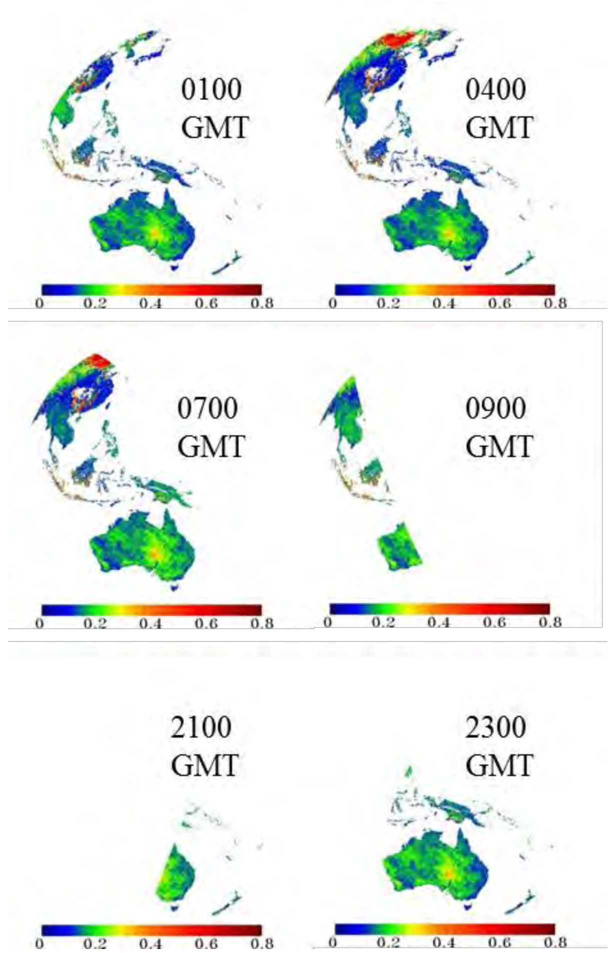


Figure 1. Surface albedo maps generated from AHI data on December 1st, 2015.

2) Algorithm development/maintenance: cloud masking

The AHI cloud mask data generated at NOAA STAR is only available from the second half of 2015; however, there are few ground measurements available for the same period. To validate the surface albedo estimation from the LSA software algorithm, we need to develop a cloud masking algorithm for the AHI L1B data.

For albedo estimation, the Top-of-Atmosphere (TOA) observation used in the retrieval procedure needs to have a minimal cloud contamination. To achieve this purpose, we developed a thresholding algorithm to derive the cloud mask from AHI data, in which we tend to exclude the cloud-contaminated observations.

3) Software testing and validation
   a. To test the performance of the delivered algorithm, we conducted validations of surface albedo derived from the AHI proxy data at Australian OzFlux sites using both ground measurements (Table 1) and MODIS products (Table 2). Results showed that our algorithm generated surface albedo with RMSEs up to 0.022 and 0.013 compared with ground measurements and MODIS albedo products. The larger difference found between AHI albedo and ground measurements can be explained by the scale difference between satellite pixels and footprints of ground observations.

Table 1. Validation of AHI-based albedo against ground measurements

Time period (year/month)	Bias	RMSE	R^2	N
2015/04	-0.005	0.022	0.420	2214
2015/07	-0.013	0.021	0.566	2283
2015/11	0.002	0.022	0.652	837
2016/01	0.009	0.021	0.677	1977

Table 2. Validation of AHI-based albedo against MODIS albedo products

Time period (year/month)	Bias	RMSE	R^2	N
2015/04	-0.001	0.013	0.746	2493
2015/07	0.002	0.012	0.758	2297
2015/11	0.001	0.013	0.814	1023
2016/01	0.011	0.021	0.662	1998

   b. We also conducted validations for the two algorithms used in our retrievals process. Results from the optimization algorithm (primary algorithm) and direct estimation algorithm (back up algorithm) are comparable; the former outperformed the latter with smaller RMSE and higher R^2. The result indicates that direct estimation approach is a little sensitive to the cloud-contaminated TOA observations with a slightly larger bias; whereas the optimization method can be a bit more tolerant to the cloud contamination with multiple observations as the input. Comparison with MODIS albedo is much better, suggesting that considering scale difference between satellite pixel and ground measurement footprint remains necessary for the validation of AHI albedo estimation.

c. We compared the surface reflectance and albedo product with MODIS surface albedo and reflectance products. We used MCD41 BRDF parameter product to calculate band albedo and used MOD/MYD 09 CMG data for surface reflectance. Fig. 2 shows the comparison result between AHI and MODIS on DOY 11, 2016. The biases from product inter-comparisons meet the requirement of the algorithm (less than 0.08).

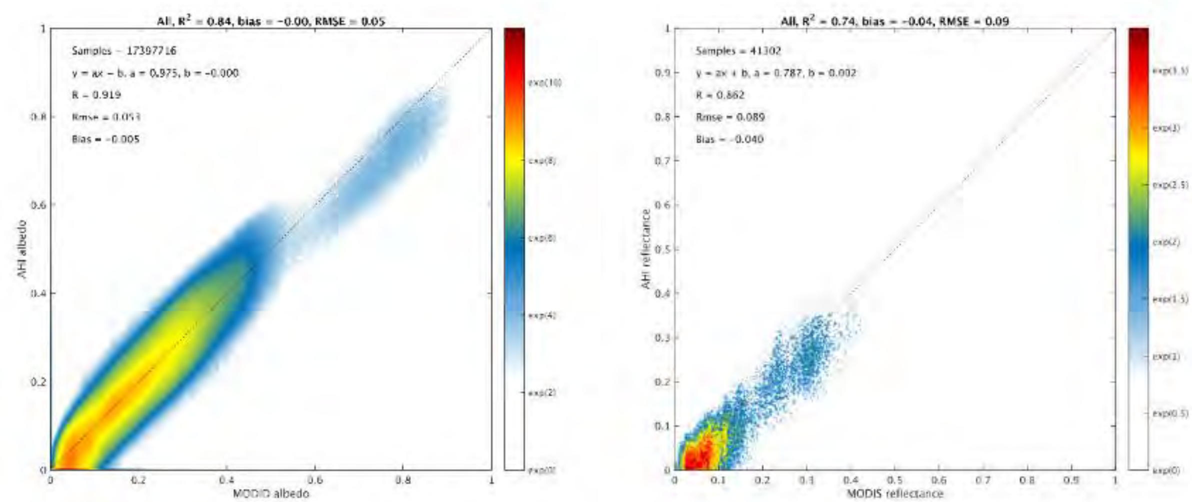


Figure 2. Surface reflectance/albedo comparison between MODIS and AHI

4) Critical Design Review preparation

To prepare for the CDR materials, we first updated the algorithm theoretical basis in the slides prepared for the CDR four our previous GOES-R albedo project in 2009. Compared to the proposed algorithm in 2009, the current algorithm is an optimization algorithm without separating the surfaces into dark or bright targets, which follows the logic of VIIRS algorithm.

Also, we were actively working with the STAR and Harris staff in outlining the delivered software structure, input and output specifications, and other ancillary information for them to prepare for the software design part of the CDR materials. The CDR meeting was held successfully on Sep 26th, 2016.

5) Version 7 Code and ATBD delivery

In Version 7 software package, we switched from using AHI data to simulated ABI data. We prepared simulated ABI data from DOY 019 to DOY 029 as the sample input data for Version 7 software. The algorithm was tested and compared with MODIS products.

The software package has been tested against the sample input data and generated outputs including surface albedo and spectral reflectance data. We delivered Version 7 software and corresponding ATBD to algorithm implementation team (AIT) for software implementation in the first quarter of 2017.

Planned work

- Task 1 - Algorithm Development
  - The snow mask from NWP will be used in broadband albedo estimation to improve the accuracy.
  - Albedo climatology database will be updated to guarantee that the results have no missing value.

- Task 2 - Product validation against ground measurements
  - We will continually collect ground measurements of LSA at sites in the United States and South America, and validate GOES-R albedo retrievals using the actual ABI data against those ground measurements.

- Task 3 - Inter-comparison between GOES-R albedo and other satellite products
  - Validations and inter-comparison of the actual ABI-based LSA and reflectance will be made against other satellite products, such as MODIS, VIIRS, and Landsat.

- Task 4 - Software/Algorithm Integration and Testing
  - With an extensive evaluation of the AHI-based and ABI-based algorithms, we will update our software package and ATBD accordingly and deliver them to AIT for testing. Also, we will collect more test data and evaluate the stability and accuracy of the algorithm software.

- Task 5 - Algorithm Maintenance
  - Based on the algorithm refinement progress and feedbacks from AIT on the test version software package, our efforts will be made to maintain the software algorithm by updating the parameters and ancillary data.
  - We will continue to support the algorithm through tests made against simulated data from future satellites in GOES-R series, i.e., GOES-S.

- Task 6 – Algorithm Application and Demonstration
  - We will demonstrate the albedo product can detect climate events such as drought, snow-fall, fire, land cover change and so on.
  - We will help snow cover team to utilize the reflectance data in the estimation of snow cov-er.

Publications

[1] He, T., S. Liang, and D. Wang, (2017). Improving albedo estimation using simultaneous multi-angle MISR data. *IEEE Transactions on Geoscience and Remote Sensing, 55(5), 2605-2617*

[2] Liang, S., D. Wang, T. He, Y. Zhang and Y. Yu, (2017). GOES-R Advanced Baseline Imager (ABI) algorithm theoretical basis document for surface albedo. NOAA/NESDIS, Version 2.2

Products

GOES-R surface albedo and reflectance products will be generated from this project.

Other

Graduate Students, Yi Zhang, Han Ma, and Hongmin Zhou, are currently supported and advised under this project

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	2
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of NOAA technical reports	1
# of presentations	2
# of graduate students supported by your CICS task	2
# of graduate students formally advised	3
# of undergraduate students mentored during the year	

GOES-R surface albedo and reflectance products will be generated from this project.

Retrieving Cloud Base Height and Updraft Speed for Shallow Convective Clouds and Boundary-Layer Moisture from VIIRS for Improving the NCEP GFS

Task Leader:	Zhanqing Li
Task Code:	ZLZL_RCBH_16
NOAA Sponsor:	Mitchell Goldberg
NOAA Office:	NESDIS/JPSSO
Contribution to CICS Research Themes (%)	Theme 1: 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 100%
trategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions
Link to a research web page	www.atmos.umd.edu/~zli

Background

The planetary boundary layer (PBL) height, moisture in the PBL, cloud base height (H_b), and updraft speed at cloud bases (W_b) are all important meteorological variables that influence cloud, precipitation and air pollution transportation, etc. They are thus crucial for numerical weather and environmental prediction (NWP and NEP), quantitative precipitation forecasting (QPF), and the prediction of severe convective storms (SCS). Despite their importance, we don't have a good knowledge about these variables, which is especially poor, if there is any, at high spatial resolution on large scales obtained real-time or near real-time, which could only be feasible from satellites if there are sound approaches to derive them.

Retrieval from satellite would be most desired, if there is any new information pertaining the variables that can be extracted from the satellite data. Besides its unique advantage of large and routine coverage, there would be great potential application in combination with the existing retrievals such as cloud parameters, e.g., COD, cloud effective radius (CER), and liquid water path (LWP). Together, they are not only helpful for NWP/QPF, but also for a wide range of climate studies such as understanding of aerosol-cloud interactions (ACI) as envisioned by the CHASER (Clouds, Hazards, and Aerosols Survey for Earth Researchers) satellite mission (Rosenfeld et al. 2012b; Rennó et al. 2013). CHASER is based on the notion of using the base of convective clouds as CCN chambers to retrieve activated CCN at convective cloud base. Rosenfeld et al. (2014) combined satellite and radar measurements to estimate the CCN at convective cloud base, while Zheng et al. (2015) developed a pilot approach to estimate updraft at the base of convective clouds.

The purpose of this project is to develop satellite-based method of retrieving the above-noted physical quantifies, validate them, understand the uncertainties using numerical simulation models and generate products for numerical weather prediction (NWP) models.

Accomplishments

The accomplishments can be divided into two components:

1. Algorithm development and validations

We propose a method of retrieving the Wb for marine stratocumulus based on a simple relationship between Wb and cloud top radiative cooling (CTRC) using the ground-based measurements from DOE/ARM MAGIC filed campaign and Graciosa Island (GRW) site. Figure 1 shows the Wb-CTRC relationship for the combined datasets from MAGIC and GRW site, with a correlation coefficient of -0.68 and RSD of ~13 cm/s. When we compare the Wb-CTRC relationship between MAGIC and GRW cases, we found that, compared with the result from MAGIC, the scatter is much greater even for GRW cases. There are two possible reasons. First, the cliffs to the north of the AMF site may bring additional upward wind in NBLWs condition, which adds noise to the relationship. Second, considering the small range of the Wb (20 ~ 100 cm/s), any island disturbance will considerably affect the relation, even if such disturbance is minimized in NBLWs condition.

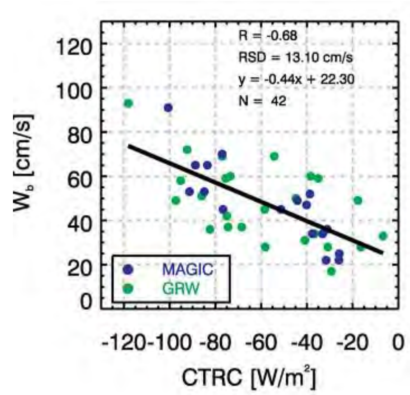


Figure 1: Variation of W_b with cloud top radiative cooling for MAGIC and GRW cases. The blue and green dots represent the MAGIC and GRW cases, respectively.

Based on the W_b-CTRC relationship, we apply it to satellite remote sensing of W_b. We use the GOES-derived cloud parameters in combination with soundings from ECMWF reanalysis as input to the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model to compute the CTRC. Validations against ground-based measurements of W_b by W-band cloud radar show a good agreement.

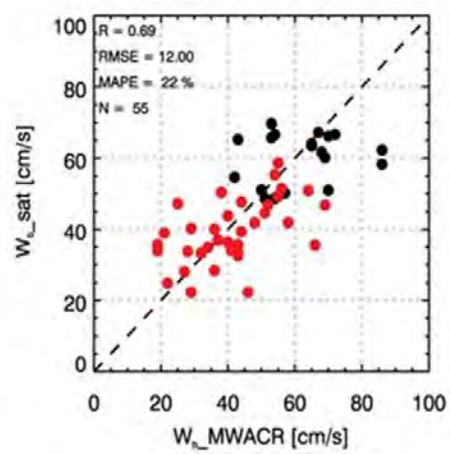


Figure2 Validations of satellite-retrieved cloud base updrafts for marine stratocumulus. The black and red points stand for nighttime and daytime cases over MAGIC, respectively.

2. Modeling

The formulations and the algorithms of Zhu et al. (2014) and Zheng et al. (2015) are simple but promising to obtain the cloud variables (e.g., cloud base updraft (W_b) and the maximum updraft (W_{max})). Inevitably, they are derived for certain cloud types under certain meteorological conditions or assumptions:

1. Non-precipitating clouds or clouds with no cooling from rain evaporation
2. Homogeneous surface property or land use.
3. Well-mixed PBL with dry adiabatic lapse rate and constant water mixing ratio
4. No wind shear effects on evaporation, turbulence and subsequent updrafts
5. Free convection.

By performing simulations using a cloud-resolving model (CRM), we evaluate these assumptions. Through this evaluation, we can identify certain assumption or assumptions that affect the cloud variables more significantly than other assumptions.

To evaluate the assumption 1, we performed the control run for a shallow-cumulus case and then we repeated the control run by turning off cooling from rain evaporation. This repeated run is referred to as the noevp run. Note that in the control run, cooling from rain evaporation is present. Comparisons between the noevp run and the control run evaluate how the assumption 1 affects the cloud variables. Then, to evaluate the assumption 2, we repeat the control run with the homogeneous surface property or with no variation of the surface property over the whole domain. This repeated run is referred to as the homo run. Note that in the control run, there are ten different types of the surface property, hence, there is a high-level inhomogeneity of the surface property or the land use. In the homo run, the surface property is assumed to be one type that is pasture over the whole domain.
Comparisons between the homo run and the control run evaluate how the assumption 2 affects the cloud variables. Table 1 shows the averaged W_b and W_{max}, which are two important cloud variables that are supposed to be derived from the algorithms, over cloudy areas for the three runs.

Simulations	W_b (m s^{-1})	W_{max} (m s^{-1})
Control run	0.34	1.44
Noevp run	0.33	1.44
Homo run	0.32	1.50

Table 1. The averaged W_b and W_{max} over the cloudy areas

As seen in Table 1, the variation of W_b and W_{max} among the simulations is not significant. This demonstrates that assumptions 1 and 2 do not play an important role in the determination of those cloud variables and thus, adopting these assumptions for the algorithms is not likely to cause a serious deviation of the derived cloud variables by the algorithms from the real values.

Planned work

1. Evaluate the rest three assumptions by repeating the control run for the shallow-cumulus case.

2. In addition to the shallow-cumulus case, we plan to collect five more cases of warm cumulus clouds at Southern Great Plain (SGP) from June to August, 2015.
3. By combining simulations for these six cases, we can perform more generalized evaluation of the assumptions.
4. Further improve the algorithms based on the modeling results
5. Generate experimental products and test their applications in NWP

Publications

Zheng, Y., D. Rosenfeld and Z. Li (2017), Satellite remote sensing of cloud-based updrafts for marine stratocumulus, to be submitted to GRL.

Zheng, Y., D. Rosenfeld and Z. Li (2016), Quantifying cloud base updraft speeds of marine stratocumulus based on cloud top radiative cooling, *Geophys. Res. Lett.,* 2016GL071185, doi: 10.1002/2016GL071185.

Products

e.g., documented instrument development, algorithm development, numerical model development and data set generation

Presentations

Z. Li, et al., “Cloud base and Atmospheric Profile Parameters from Passive Satellite Sensors and Their Applications in Weather and Climate”, EUMESAT Annual Conference, 2016.

Zheng Y., et al, **invited seminar**, “Satellite retrieval of updrafts and cloud condensation nuclei concentration at convective cloud base”, Chinese Academy of Meteorological Sciences, Beijing, China, July, 2016.

Zheng Y., et al, **invited seminar**, “Quantifying cloud base updraft speeds of marine stratocumulus based on cloud top radiative cooling”, Meteorological Institute of Shaanxi Province, Xi’an, China, August, 2016.

Zheng Y., et al, **oral presentation**, “Second half of the story: satellite remote sensing of cloud-base updrafts for marine stratocumulus”, workshop “Satellite retrieval of cloud droplet number concentration”, University of Leipzig, Leipzig, Germany, October, 2016.

Zheng Y., et al, **invited seminar**, “Satellite retrieval of cloud-base updrafts and CCN”, Max Planck Institute for Meteorology, Hamburg, Germany, January, 2017.

Zheng Y., et al, **invited seminar**, “Satellite retrieval of ‘supersaturation’ at cloud base”, Max Planck Institute for Chemistry, Mainz, Germany, January, 2017.

Zheng Y., et al, **oral presentation**, “Satellite remote sensing of cloud-based updrafts for marine stratocumulus”, AMS 97th Annual Meeting, Seattle, Washington, January, 2017.

Other

Awards:

2017 Ann G. Wylie Dissertation Fellowship, UMCP
2017 Chinese Government Award for Outstanding Students Abroad, China Scholarship Council
2016 Jacob Goldhaber Travel Award, UMCP
2016 Outstanding Graduate Assistant Award (top 2% of graduate assistants), UMCP
2016 Ann Wylie Green Fund Scholarship Award, UMCP

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	2
# of NOAA technical reports	
# of presentations	6
# of graduate students supported by your CICS task	1
# of graduate students formally advised	6
# of undergraduate students mentored during the year	

2.2 Calibration and Validation

NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Science and Management Support for NPP VIIRS Surface Type EDR

Task Leader	Chengquan Huang
Task Code	CHCH_VIRS_15 Year 2
NOAA Sponsor	Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%;
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight : Passed Validated 1 maturity review
Link to a research web page: http://vct.geog.umd.edu/st/

Background
This report summarizes the work of ongoing NOAA project entitled "NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Science and Management Support for NPP VIIRS Surface Type EDR". The purpose of this project is to develop the surface type environmental data record products using the VIIRS sensor onboard the JPSS/NPP satellite, which represents the continuity of the POES AVHRR and EOS MODIS land cover products. In this year, a new version of global surface type classification map using 2015 observational data has been created and delivered to NOAA. The validation of this new map suggests the surface type product continuously exceeds the requirement of the classification accuracy. The 2015 surface type classification map is the first product using the support vector machines (SVM) as the main classification algorithm to produce the global 1-km land cover product, which replaced the C5.0 decision tree classification framework used by previous submissions. Based on the work using SVM to produce VIIRS surface type map, a peer-reviewed journal paper has been submitted and accepted. Besides the required surface type map in IGBP classification legend, other classification system, such as biome types and NCEP 20-type are further explored during this year. Our works have also been presented at AMS, and ESA's Living Planet Symposium, and NOAA's science meetings.

Accomplishments
A new version of global surface type map based on 2015 VIIRS observations have been generated and delivered during this report period. There are two major changes compared to last year's product. First, the main classification algorithm has been changed from the C5.0 to the SVM. Second, all NOAA data sources have been used for generating this version, instead of partial outside data sources. The main classification algorithm change comes from the preliminary comparisons and experiments results between the old C5.0 and SVM, which suggested the SVM could potentially further improve the classification accuracy, and fewer post-classification steps are needed, which is also preferred to save processing time. In order to switch classification algorithm, new software packages have been implemented and parallel cluster has also been used to speed up the SVM classification process. Our visual comparison

suggested the initial classification result from the SVM is superior to that of C5.0, which leads to fewer post-processing steps, and shorter overall time on the map production. The quantitative validation results, which are from our validation software and dataset, showed consistent overall classification accuracy compared to the last year's result, which exceeds the project's requirement on classification accuracy. The new 2015 global surface type map is shown in Figure 1 below.

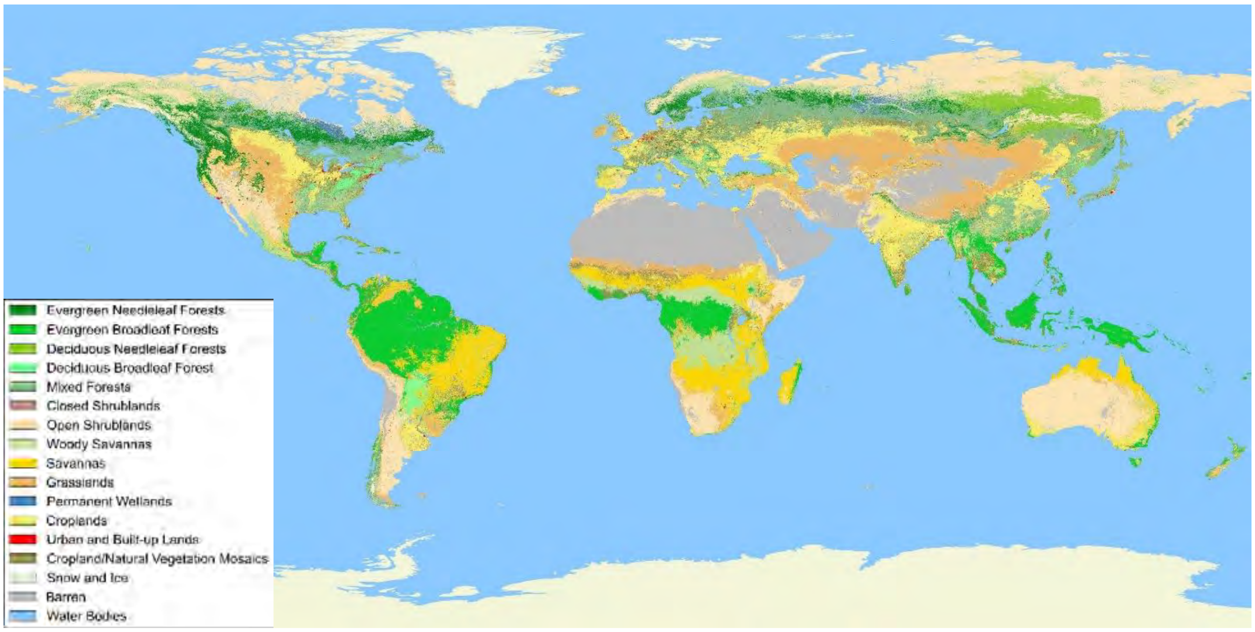


Figure 1: 2015 Global Surface Type Map

Based on the study on SVM and its use in the production of VIIRS global surface type map, a peer-reviewed journal paper has been submitted and accepted by the International Journal of Digital Earth. The paper is expected to publish soon. Another major achievement is further exploration of other classification scheme. Specific users may require different classification legend other than IGBP. For example, the National Centers for Environment Prediction (NCEP) needs a 20-type global surface type classification map, which consists of the abovementioned 17-type IGBP map plus three additional tundra types. Those results have been presented in various scientific conferences and meetings.

In addition to providing basic global surface type map, the team also investigated the use of annually updated surface type maps, and discovered potential surface type changes, typically caused by flooding, burning, deforestation, reforestation, or urbanization, over annual maps. Although some of these changes take place over a multi-year timescale, others may take place in just a few days. While the VIIRS annual global surface type product may not capture the short term surface type changes, it may illustrate their consequences by detecting burn scars or flooded areas. An example of large scale surface type changes is the consequence of the Rim fire of 2013 in California. The global surface type products generated with 2012 and 2014 VIIRS data demonstrated that the region marked with the red polygon in the enlarged areas in the middle of the figure shown below has surface type changed from Woody Savannas to Shrubland. This study may also be used as a basis to further investigate long term surface type changes, and their implications.

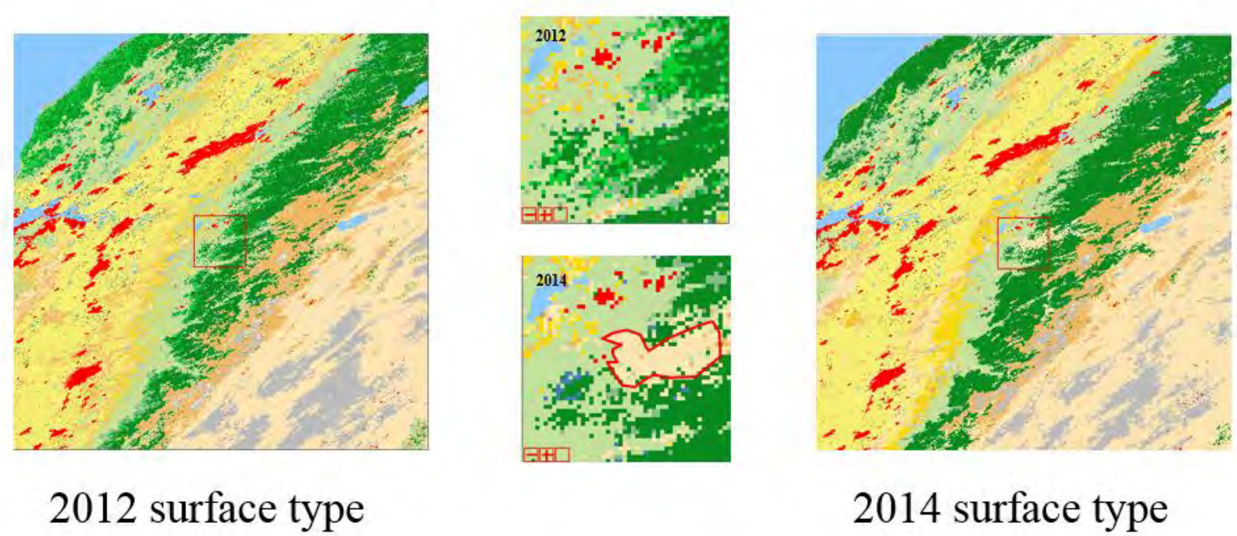


Figure 2. The fire caused the surface type changes from woody savannas to open shrubland. This result has been highlighted in the JPSS 2016 science seminar annual digest presented during 2017 AMS meeting.

Planned work

- Continue working on algorithm refinement of the global surface type products, including collecting more representative training samples globally, and assessing individual annual metrics.
- Improve the whole surface type classification algorithm, including how to use the SVM classifier, and subsequent post-classification processing.
- Generate 2016 global surface type map.
- Generate new land/water mask product for other downstream users.
- Study daily surface type change products, such as snow/ice, flood, burn areas.

Publications

- Rui Zhang, Chengquan Huang, Xiwu Zhan, Huiran Jin, and Xiao-Peng Song. Development of S-NPP VIIRS global surface type classification map using support vector machines. *International Journal of Digital Earth*. In press.

Products

- 2015 Global surface type classification map.
- New SVM based software suite for the surface type products.

Presentations

- Xiwu Zhan, Rui Zhang, Jicheng Liu, Chengquan Huang, Huiran Jin, Ivan Csiszar. 2016. Monitoring Land Surface Type Changes Using Satellite Observations from S-NPP/JPSS VIIRS and GCOM-W1 AMSR2. 2016 Living Planet Symposium. Prague, Czech Republic. May 9-13, 2016.
- Rui Zhang, Chengquan Huang, Xiwu Zhan, Huiran Jin. 2016. Development of new global surface type maps from VIIRS data. 2016 Living Planet Symposium. Prague, Czech Republic. May 9-13, 2016. (Full paper)

- Rui Zhang, Chengquan Huang, Xiwu Zhan, Huiran Jin. 2016. Developing land surface type map with biome classification scheme using Suomi NPP/JPSS VIIRS data. 2016 JPSS annual science meeting. College Park, MD. Aug. 8-11, 2016
- Rui Zhang, Chengquan Huang, Xiwu Zhan, Huiran Jin. 2017. Development of new global surface type maps from VIIRS data. 97th American Meteorological Society annual meeting. Seattle, WA. Jan. 22-26, 2017.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	1
# of NOAA technical reports	1
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

This year, the 2015 VIIRS global surface type map has been developed and validated. The data has been delivered to NOAA, and is public available in our website. One paper has been accepted by the International Journal of Digital Earth. Four poster have been presented in AMS, ESA's Living Planet Symposium, and NOAA's JPSS annual science meeting, in which one full paper has been released by the LPS.

Suomi NPP (SNPP) Visible Infrared Imager Radiometer Suite (VIIRS) Active Fire Products Applications for Fire Management

Task Leader	Evan Ellicott
Task Code	EEEE_VIRS_16
NOAA Sponsor	Mitch Goldberg
NOAA Office	Joint Polar Satellite SystemOffice
Contribution to CICS Research Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	3. Decision Science, Risk Assessment and Risk Communication

Highlight: 2015 was successful in advancing our goals to leverage SNPP VIIRS AF products for operational use of active and post-fire management and research. In addition, the past year saw numerous opportunities realized for the purposes of quality assessment (QA) and validation of the VIIRS AF data. We were engaged with the role out of AWIPS II and assisted with understanding the implementation of the VIIRS AF product. Outreach and education was, and still is, a strong component of this project and 2015 witnessed growth in our U.S. and international communication and training. New VIIRS AF products, including fire radiative power (FRP) and fire mask for the M-band product and the testing and eventual roll-out of the I-band fire product has expanded the end-users' interest in the VIIRS fire capabilities. Therefore, we have pursued promoting and educating users about these new datasets. Finally, we continue to employ our website to provide highlights of fire data and imagery from VIIRS while offering clear and succinct information for the public.

Link to a research web page: http://viirsfire.geog.umd.edu

Background

Wildfire potential has been predicted to increase in the coming decades across the globe with changing climate (Liu, Stanturf and Goodrick 2010). Fire monitoring from satellites has a long history. Flannigan and Haar (1986) discussed the feasibility of using AVHRR to identify and track hot spots from fires in Alberta, Canada. Twenty-five years later the launch of the Suomi National Polar-orbiting Partnership (SNPP) insured continuity of remote sensing data for fire applications. Aboard SNPP is the Visible Infrared Imager Radiometer Suite (VIIRS) from which the Active Fire (AF) product was developed. This product plays a strategic role in wildfire monitoring and modeling, providing synoptic and timely data critical for disaster and resource management. The VIIRS AF Proving Ground and Risk Reduction (PGRR) project was established by NOAA to ensure maximum benefit for downstream users through outreach and education and product evaluation and improvement. The goal of this project is to leverage the VIIRS AF products for active and post-fire management and NOAA operations to improve research and decision making.

Accomplishments

Outreach:
User outreach and capacity building is an important component of this PGRR project and 2016 saw another successful year for this project. Interaction with data users and suppliers is important to insure transparency about the AF product, updates and changes to the data itself and underlying algorithm, and sources of data. We've maintained on-going and frequent discussions with our partners in the USFS, Interagency Coordination Centers, NOAA, and Direct Readout/Broadcast community.

International Outreach:
In January 2016 we attended a conference in Yangon, Myanmar where we presented information about VIIRS AF detections with our GOFC-GOLD regional partners and their constituents. We had several opportunities to provide hands-on educational demonstrations to improve their understanding of the data, products, and availability.

Along a similar line, we had several in-person meetings with Washington DC NGO, World Resources Institute, to help implement the VIIRS I-band fire product into their Global Forest Watch – Fires website (http://fires.globalforestwatch.org/home/). There website is an important tool for monitoring fires, in particular in Indonesia, and now includes the VIIRS AF product(s).

We attended the Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) Fire Implementation Team (IT) meeting in Santiago, Chile, in November where several fruitful days of discussions provided insight to current limitations in data usage and understanding among users. This has led to strategies to close this gap of data availability, understanding, and application which we will address in the coming months.

Alaska Outreach:
Building off of our communication and outreach over the past several years, we travelled to Fairbanks, Alaska, in March 2016 to meet with our end-users to discuss VIIRS data (including the AOD products being displayed through the eIDEA website, another PGRR project). Our audience included the National Weather Service (NWS), Geographical Information Network of Alaska (GINA), Alaska Interagency Coordination Center (AICC), Alaska Fire Service (AFS), and the Alaska Fire Science Consortium. We had numerous round table discussions about VIIRS data availability from the GINA DB systems, AWIPS 2, and AFS website. The meetings were very hands on, looking at current and potential data and systems. We also provided a presentation about VIIRS products at the AFS to a broad audience of data users.

In July, we returned to Fairbanks, Alaska to revisit the issue of near-real time (NRT) data availability from the Geographical Information Network of Alaska (GINA) to the fire management agencies, Alaska Fire Service (AFS) and the Alaska Interagency Coordination Center (AICC). Once again, we provided a training seminar about VIIRS at AFS/AICC and the University of Alaska (UAF). The talks covered the above topic of future improvements to the AF product as well as where this product would be available (NOAA CLASS/NDE). In addition, we met with individuals from the NWS, UAF, State Department of Forestry, and Alaska Fire Science Consortium (Fig. 1). It was at AFSC that we were asked to be apart of a steering committee to help organize and facilitate a workshop on fire management and remote sensing specifically geared for high latitudes. Thus, since July 2016 we have helped organize the Alaska Fire Science Consortium Remote Sensing workshop which will be held in Fairbanks in April 2017.

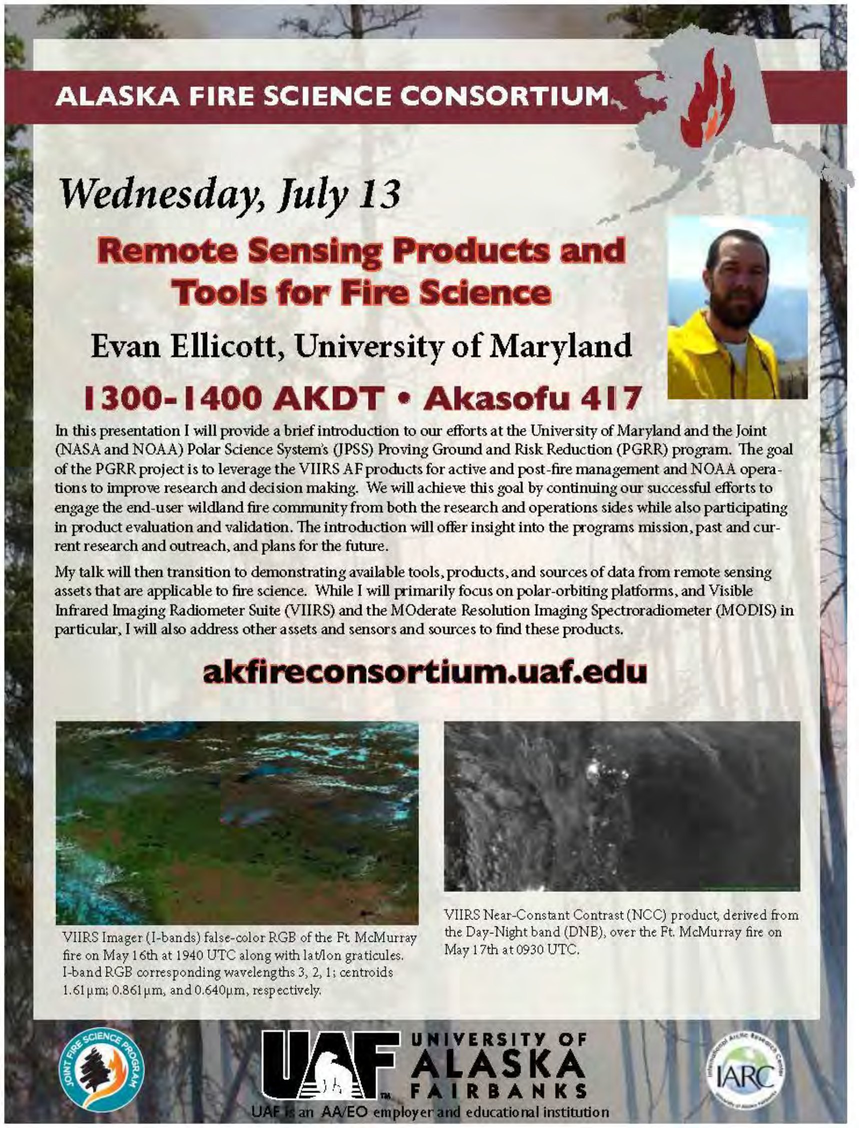


Figure 1. Flyer circulated by the Alaska Fire Science Consortium to raise awareness of our visit and scheduled seminar.

Peer Stakeholders:

NOAA's Fire & Smoke Initiative, was started in May 2014, to identify current and next generation NOAA polar-orbiting and geostationary satellite products that are applicable for analyzing fires and smoke, and then getting those products in the hands of users. As a member of the Fire & Smoke initiative we have participated in monthly telecons with stakeholders to keep them abreast of outreach efforts and product development. This platform offers a chance to communicate with peers in various disciplines (e.g. smoke transport, aerosol production) related to VIIRS and wildland fires.

For much of 2016 we organized a training section on VIIRS fire & smoke products that was delivered at the American Meteorological Societies annual meeting short course section in January 2017. Similarly,

Evaluation: An additional key component for the VIIRS AF PGRR project is product evaluation. In 2016 we continued to monitor the distribution of VIIRS I-band data from various sources including NRT from the NASA LANCE and NOAA CLASS systems (Fig. 2). We also evaluated VIIRS products against MODIS to insure consistency among the products. There are various sources of satellite derived products, such as Worldview (https://worldview.earthdata.nasa.gov/) and the RealEarth site (http://realearth.ssec.wisc.edu/). The latter provides numerous products from polar-orbiting and geostationary assets, but data is often not available and not being produced internally (i.e. the RealEarth site grabs products from other websites or data portals and is simply reflecting them on their site). The need for “one-stop-shopping” may not completely viable, but this continued to be a target for this project and our partners in the Fire & Smoke Initiative.

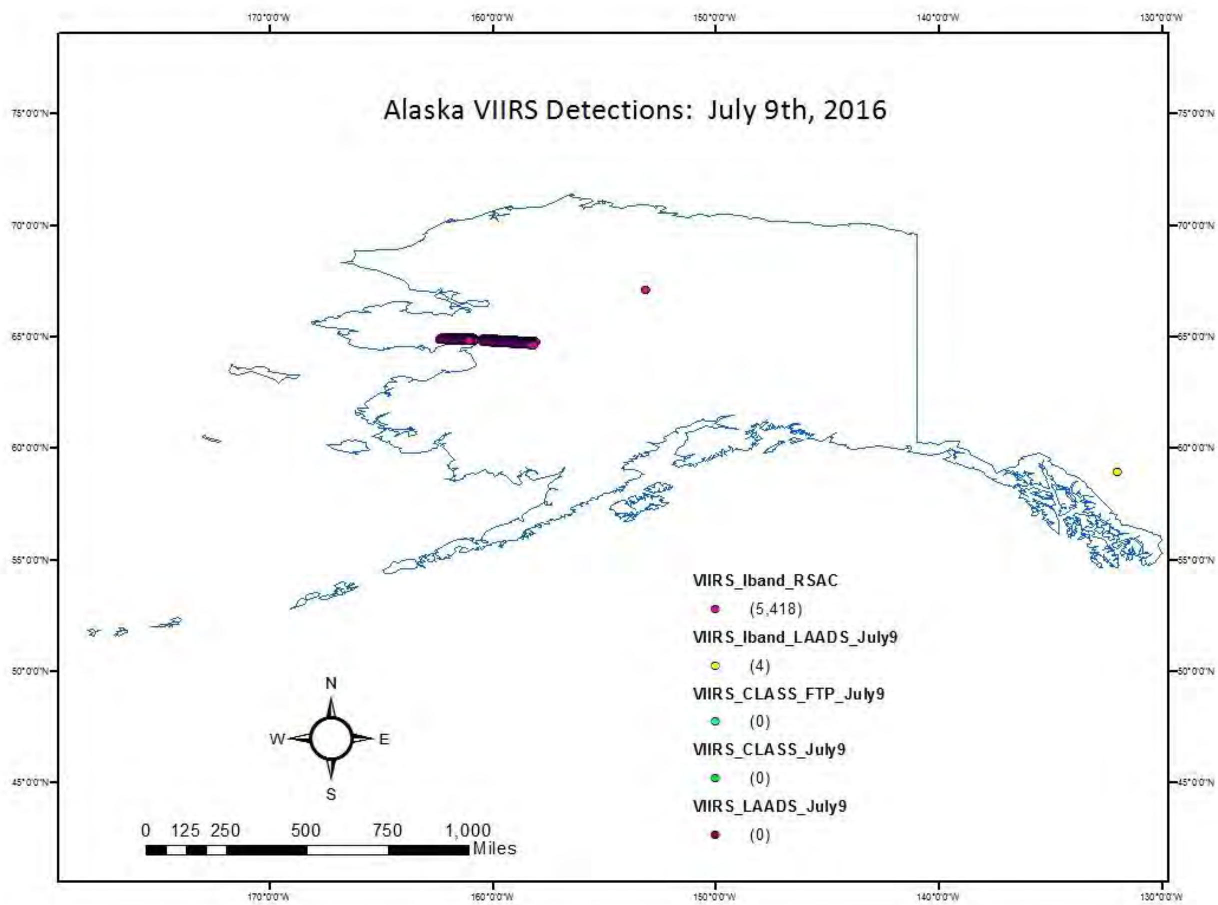


Figure 2. Spurious detections were generated in the RSAC’s DB processing chain which are not present from the NOAA (CLASS) or NASA (LAADS) distributions.

The development and dissemination of the NOAA Data Exploitation (NDE) Level 2 AF product means a mature, robust product available to end-users (Fig. 3). The NDE VIIRS active fire product passed the Operational Readiness Review December 16, 2015 and declared operational January 20, 2016. The product (AF_v1r0_npp*) was made available was made available via web and FTP download during the spring/summer 2016 and was being incorporated into the HRRR-smoke model. In the mold of the successful MODIS AF product, VIIRS now offers such attributes as brightness temperatures, fire radiative power (FRP), and quality flags. In addition, a fire mask means that users can numerically and visually inspect fire detections and areas of fire activity for omission/commission errors. For example, missing detections from cloud obscuration can now be visualized with the NDE AF product. Evaluation of this product, specifically compared to the previous AVAFO standard product, as well as MODIS, was started in late-2016 and will continue into 2017.

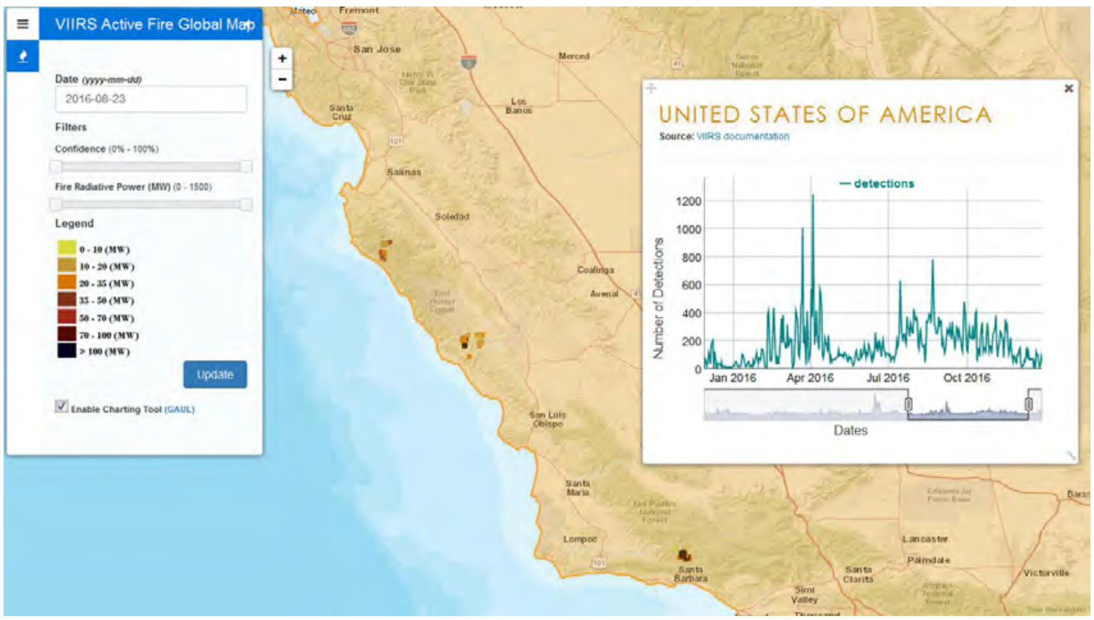


Figure 3. The *beta* VIIRS website that uses NOAA Exploitation Data (NDE) which has decreased latency and greater fire characteristic information. The above example is centered on California on August 23rd, 2016 and shows the Fire Radiative Power (FRP). The new website will also included statistical information, in this case a graph of fire counts for each day.

During the spring of 2016 we conducted numerous laboratory tests and deployed our radiometers in the field in conjunction with Maryland DNR's spring prescribed burning season. We used these burns to take advantage of SNPP overpasses for validation purposes (Fig. 4).

a


Alton Rd
Artie Kemp Rd
11449 Alton Rd
Town Branch
Linganore Creek

b

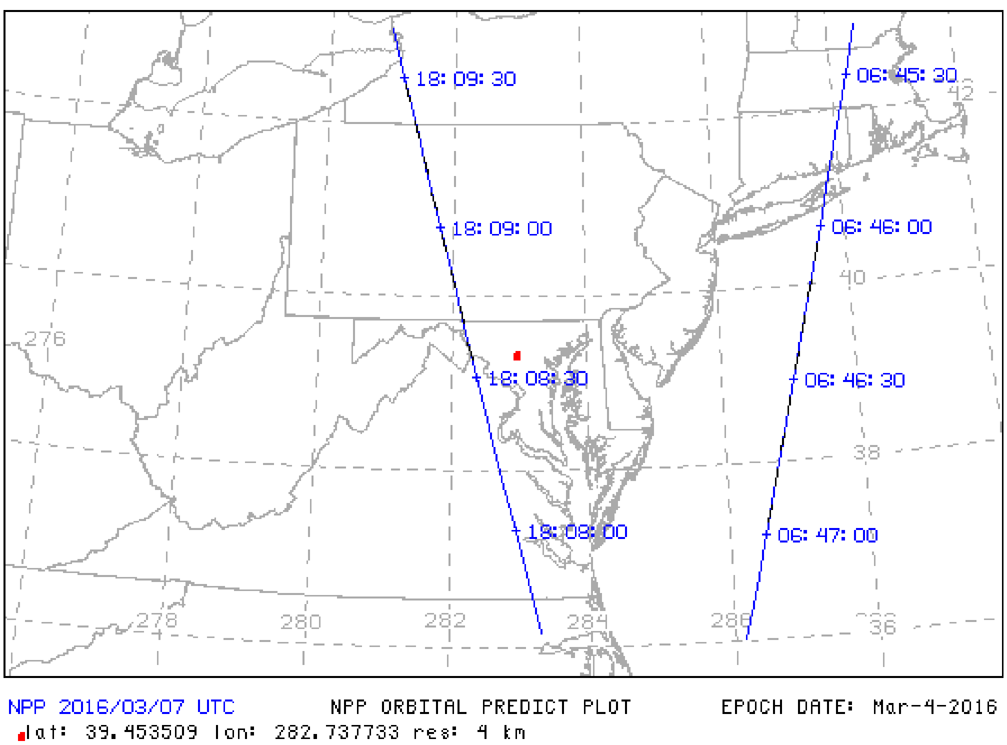

18:09:30
18:09:00
18:08:30
18:08:00
06:45:30
06:46:00
06:46:30
06:47:00
42
40
38
36
276
278
280
282
284
286
NPP 2016/03/07 UTC
NPP ORBITAL PREDICT PLOT
EPOCH DATE: Mar-4-2016
lat: 39.453509 lon: 282.737733 res: 4 km

Figure 4. (a) Site of prescribed fire conducted by Maryland DNR and Wildlife departments on 07 March 2016 (39.454, -77.262) as shown in Google Maps; (b) Overpass schedule for NPP coinciding with the location of the fire; (c) photo of one of the radiometer towers as the fire passes underneath and SNPP was passing overhead.

Planned work

With the public release of the NOAA Data Exploitation (NDE) product we will to evaluate against the previous standard product from CLASS (AVAFO). We have developed code to download, process, and populated our website with the NDE product (Fig. 3) and continue to use this tool to evaluate the VIIRS product(s). In addition, evaluation against the MODIS FRP is on-going and we are planning spring and summer prescribed fires for validation purposes.

We will continue to engage NWS personnel to support the ingestion and display of VIIRS AF products in AWIPS 2. In the previous funding period we had several opportunities to sit down at WFOs to see the use of AWIPS and understand what the forecasters need and want. We will continue to get such input and offer feedback to the necessary channels working on getting VIIRS data in AWIPS.

We have promoted the use VIIRS AF products through NGO partners and will continue to expand our portfolio of NGO participation. For example, through several in-person and phone meetings with personnel from World Resources Institute (WRI) we helped insure a stable, consistent product and message was being disseminated from their web portal (Fig. 5).

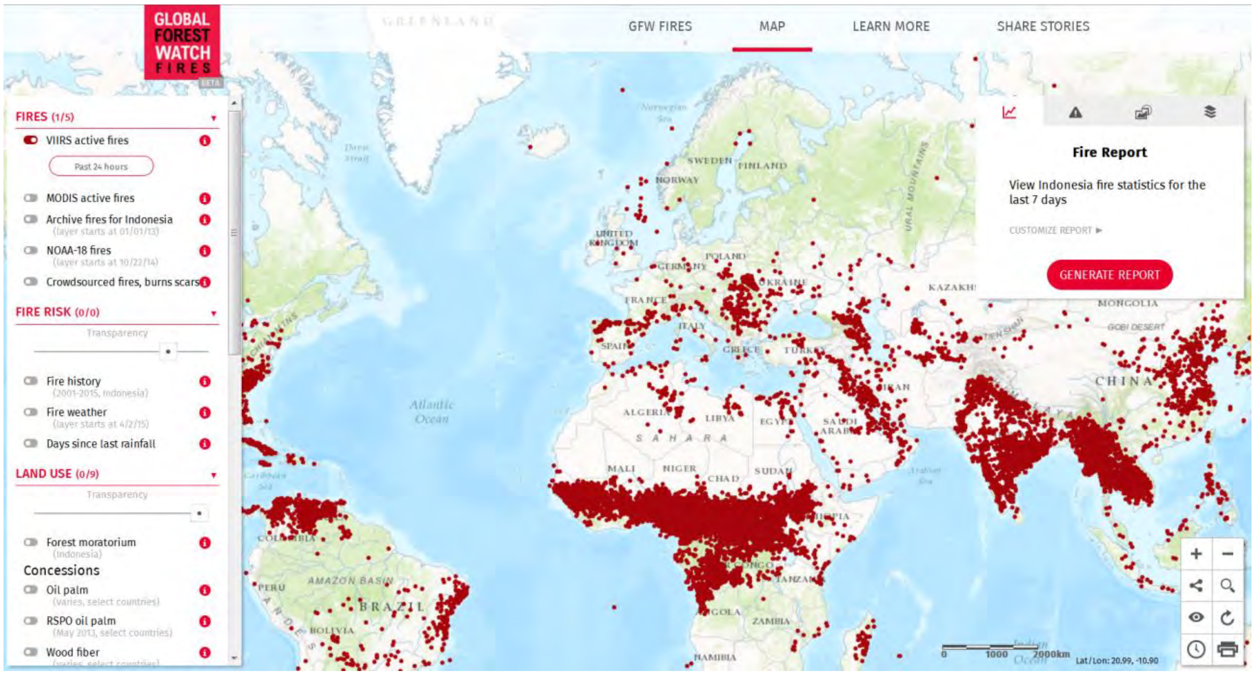


Figure 5: Screen capture of WRI's Global Forest Watch Fires interactive web map showing VIIRS fire detection for the past 24 hours.

Qualitative and quantitative assessment of product consistency among primary sources of product retrieval among end-users (e.g. CLASS vs. CIMSS vs. RSAC). Improved UMD VIIRS web-site to include NDE FRP product and statistical analysis tools (Fig 3.) and continue to monitor insure continuity between data sources, for example Direct Broadcast systems (IPOPP and CSPP) or LAADS (NASA) and CLASS (NOAA).

Finally, we will continue to promote data and knowledge sharing via our website (http://viirsfire.geog.umd.edu/). As shown above in Fig. 3, the website continues to evolve with the VIIRS AF product. We regularly communicate and share data with research and operations personnel. However, since our website is intended for product awareness and instruction, we encourage users to download data from operational data sources managed via NOAA (e.g. CLASS NDE) and the DB community (e.g. Geographical Information Network of Alaska, GINA).

Publications

- Csiszar, W. Schroeder, L. Giglio, E. Ellicott, B. Wind, K. Prasad Vadrevu, and C. Justice, (2014) Active Fires from the Suomi NPP Visible Infrared Imager Radiometer Suite: Product status and first evaluation results. J. Geophys. Res. Atmos., 119, doi: 10.1002/2013JD020453.
- W. Schroeder, E. Ellicott, C. Ichoku, L. Ellison, M. Dickinson, R. Ottmar, C. Clements, D. Hall, V. Ambrosia, and R. Kremens, (2014), Integrated active fire retrievals and biomass burning emissions using complementary near-coincident ground, airborne and spaceborne sensor data. Remote Sensing Environment. doi: http://dx.doi.org/10.1016/j.rse.2013.10.010.

Presentations

Presentations have included, but limited to:

- In January 2016, Dr. Ellicott presented research related to VIIRS validation at the GOFC-GOLD meeting in Yangon, Myanmar.
- March, 2016, Dr. Ellicott provided several talks in Fairbanks, Alaska, covering product details, availability, and evaluation efforts. Talks were given at the Alaska Interagency Coordination Center and the University of Alaska, Fairbanks.
- Dr. Ellicott presented VIIRS-related research findings at the International Association of Wildland Fire's (IAWF) spring conference, April 2016, in Portland, Oregon.
- Dr. Ellicott returned to Fairbanks, Alaska in July 2016 for outreach and education. At this time he provided another presentation at the Alaska Interagency Coordination Center to personnel from the Alaska Fire Service, BLM, and State Forestry.
- At the NOAA Aerosol Workshop in September 2016, Dr. Csiszar gave a talk about the VIIRS AF products.
- Dr. Ellicott gave a presentation at the GOFC-IT meeting in Santiago, Chile, on November 17th, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	2
# of presentations	4
# of graduate students supported by your CICS task	1
# of graduate students formally advised	
# of undergraduate students mentored during the year	1

This year our emphasis continued to be outreach and communication, with a strong, collaborative working with the VIIRS AF cal/val team on VIIRS AF evaluation. We provide numerous presentations, many invited, as well as hands on demonstration and training about VIIRS, data access, and applications. Two papers were published demonstrating satellite active fire applications, validation, and in particular, VIIRS early maturity status.

Continued Expansion, Enhancement and Evolution of the NESDIS Snowfall Rate Product to Support Weather Forecasting

Task Leader	Jun Dong
Task Code	JDCK_FCST_15 Year 2
NOAA Sponsor	Huan Meng
NOAA Office	NESDIS/STAR/SCSB
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 70%; Goal 2: 30%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: A new Snowfall Detection algorithm was developed, which combines current operational algorithm and weather forecast model; Supercool liquid water effect was modeled in the 1D VAR satellite snowfall rate retrieval algorithm.

Link to a research web page: http://cics.umd.edu/sfr; http://cics.umd.edu/~jdong/data

Background

An ATMS snowfall rate (SFR) algorithm including an embedded snowfall detection algorithm was developed in the past year. The ATMS and the operational MHS SFR products have demonstrated their utility in weather forecasting through product assessment at several WFOs. The benefit is most evident in areas with limited or no ground observations and radar coverage. During the past year, the SFR algorithm has been improved in two major aspects: new combined Snowfall detection and adding supercooled liquid water in the forward simulation model. In addition, the current SFR is generated from five satellites so large time gaps exist between observations. SFR products from more satellites are required to reduce the gaps. Finally, the SFR algorithms are only applicable to over land. An ocean SFR product will be able to provide information on approaching snowstorms for coastal communities, and to expand the product to global scale to benefit hydrological applications such as blended global precipitation analysis.

Accomplishments

1. New Combined snowfall detection algorithm

A combined Snowfall Detection (SD) algorithm based on both satellite and NWP model data had been developed. It improves detection of snowfall from both shallow and deep clouds. The algorithm and some modified snowfall screenings were integrated in the SFR test processing system. As a measure of quality assurance, the results from the test system and those from the CONUS direct broadcast (DB) data-based system were compared for a few weeks against NEXRAD radar reflectivity to ensure that the new SD algorithm performs as expected. Figure 1 shows the combined SD algorithm improves both probability of detection (POD) and false alarm rate (FAR). After the test period ended with satisfactory results, the combined SD algorithm was implemented in the DB-based SFR system.

2. Modeling Supercool Liquid Water effect

The snowfall rate retrieval component uses an Inverse method that involves forward modeling of brightness temperature. In this reporting period, the radiative transfer model (RTM) used for brightness temperature simulation has been modified to incorporate the effect of supercooled cloud liquid water.

After the model was constructed, it was tested with a few case studies to ensure that the RTM functioned properly. The SFR algorithm with supercooled liquid water is improved by reducing negative bias. However, the SFR estimates appear to be sensitive to the initialization of the retrieval vector in the new model. It is under further development for the optimal application of the new RTM.

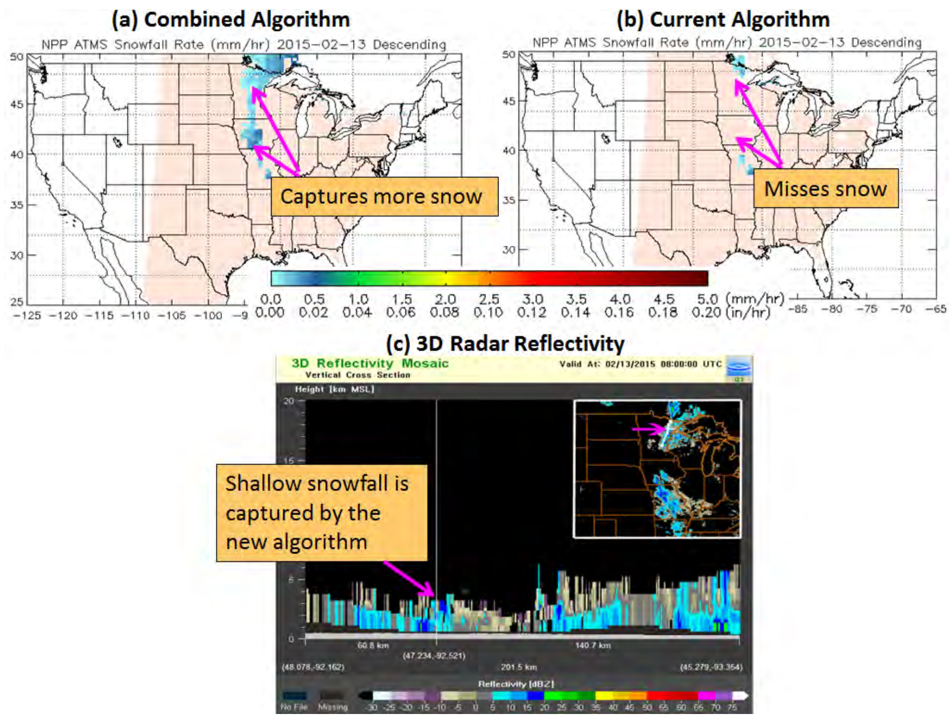


Figure 1. The combined snowfall detection algorithm detects more shallow snowfall (a) than the existing algorithm (b). The 3D radar reflectivity (c) shows the shallow cloud in Minnesota.

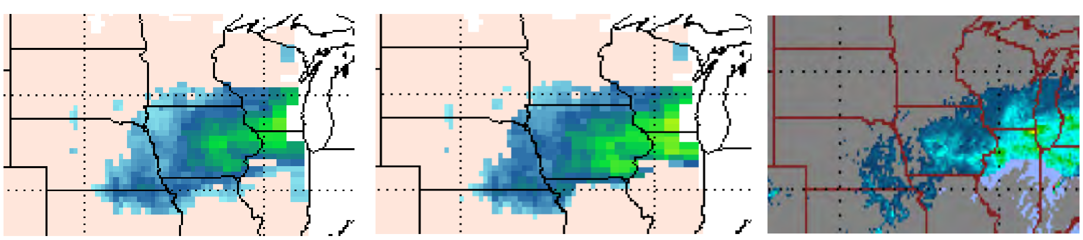


Figure 2. Case study of the cloud water effect in SFR algorithm. Left: ice-only model (correlation 0.44); middle: ice-water mixed model (correlation 0.50); right: corresponding MRMS radar observation.

Planned work

- More new SD validation using ground station observation and radar data (MRMS);
- Develop more appropriate initialization for supercooled liquid water;

- Cal/Val new SFR algorithm using MRMS radar data;
- Develop SD and snowfall rate algorithms for SSMIS sensor;

Publications

Meng, H., J. Dong, R. Ferraro, B. Yan, L. Zhao, C. Kongoli, N. Wang, B. Zavodsky. A 1DVAR-based snowfall rate retrieval algorithm for passive microwave radiometer. Journal of Geophysical Research: Atmosphere, in review.

Products

- New combined snowfall detection algorithm;
- New radiative transfer model with supercooled water integrated.

Presentations

Dong, J., H. Meng, C. Kongoli, R. Ferraro, B. Yan, L. Zhao, N. Wang, B. Zavodsky; Snowfall Detection and Rate Retrieval from ATMS; 2016 CICS Annual Meeting
Dong, J., H. Meng, C. Kongoli, R. Ferraro, B. Yan, L. Zhao, N. Wang, B. Zavodsky; New Improvements of Snowfall Detection and Rate Retrieval from ATMS; AGU Fall Meeting, 12/2016

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of NOAA technical reports	
# of presentations	2
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Transition and Enhancement of ATMS Snowfall Rate Product and its Fusion with Weather Radar Data

Task Leader	Jun Dong
Task Code	JDJD_ATMS_15 Year 2
NOAA Sponsor	Huan Meng
NOAA Office	NESDIS/STAR/SCSD
Contribution to CICS Research Themes (%)	Theme 1: 30%; Theme 2: 70%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 70%; Goal 2: 30%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: The ATMS snowfall rate algorithm was updated with the new snowfall detection algorithm.
Link to a research web page: http://cics.umd.edu/sfr; http://cics.umd.edu/~jdong/data

Background

Forecast and analysis of snowfall rate remain a challenge for National Weather Service (NWS) Weather Forecast Offices (WFOs). An ATMS SFR algorithm was developed based on NOAA operational AMSU/MHS SFR product, and is running near real-time. This SFR system uses Direct-Broad (DB) data to reduce latency. A merged SFR (mSFR) system was also developed to combine satellite SFR and Multi-Radar Multi-Sensor (MRMS) data. Once the SFR product is generated, it is disseminated to NASA/SPoRT where the product is formatted for AWIPS and delivered to local WFOs for evaluation. In the past year, the SFR system was updated based on new development of snowfall detection snowfall rate algorithm. More calibration, validation and assessment are needed.

Accomplishments

1. Implementation of combined snowfall detection algorithm

The new combined Snowfall Detection (SD) algorithm based on both satellite and NWP model data had been developed and were integrated in a near real-time SFR processing system. After the new SFR product is generated, it is disseminated to NASA/SPoRT who converts the data to AWIPS and serve to several WFOs and WPC.

2. Product assessment

Several WFOs participated in the SFR assessment in the past two winters through NASA/SPoRT. We received positive feedback from WFOs. For instance, forecasters from the Sterling, VA WFOs have contacted the SFR development team twice this winter with questions about the SFR and MRMS merged product. Figure 1 is a Forecast Discussion issued by the Sterling, VA WFO on January, which showed the improvement of the new SD algorithm.

The SFR product is being utilized at WPC Hydrometeorological Testbed's WWE 2016/2017 winter for daily verification of Probabilistic Snowfall Rate Forecasts. In addition, case studies will be conducted at WPC and potentially SPC to examine the performance of the product.

Planned work

- This project is officially over. However, we will continue the following tasks will continue in preparation for SFR assessment in winter 2017-2018.
- Move real-time SFR system to new CICS computer cluster;
- Maintain and update SFR-DB system;
- Maintain and update merged SFR product.

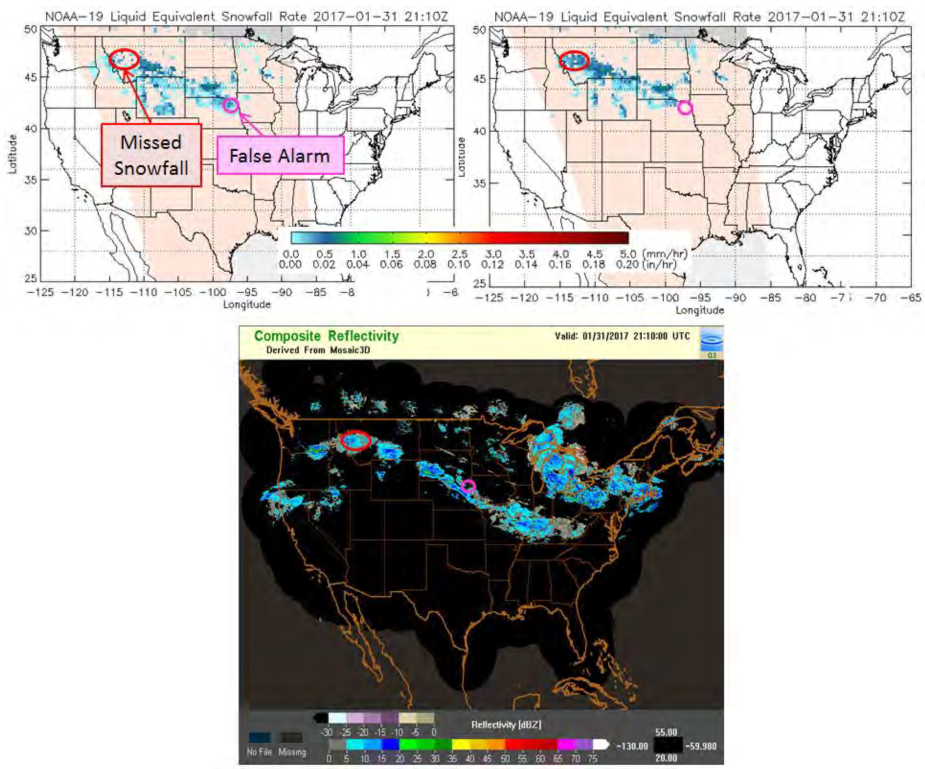


Figure 1. Top left: Snowfall detected by the satellite single-module SD algorithm; top right: snowfall detected by the satellite and model combined SD algorithm; bottom: NEXRAD composite radar reflectivity. Ground observations also confirm the missed snowfall and false alarms noted in the top left images compared to the top right image.

Publications

Meng, H., J. Dong, R. Ferraro, B. Yan, L. Zhao, C. Kongoli, N. Wang, B. Zavodsky. A 1DVAR-based snowfall rate retrieval algorithm for passive microwave radiometer. Journal of Geophysical Research: Atmosphere, in review.

Products

- Updated snowfall rate product with new combined snowfall detection algorithm;
- Maintain and update merged SFR product;
- The SFR retrieval system was rewrite to handle GFS data with different resolution.

Presentations

Dong, J., H. Meng, C. Kongoli, R. Ferraro, B. Yan, L. Zhao, N. Wang, B. Zavodsky; Snowfall Detection and Rate Retrieval from ATMS; CICS Annual Meeting, 11/2016;

Dong, J., H. Meng, C. Kongoli, R. Ferraro, B. Yan, L. Zhao, N. Wang, B. Zavodsky; New Improvements of Snowfall Detection and Rate Retrieval from ATMS; AGU Fall Meeting, 12/2016;

Meng, H., J. Dong, C. Kongoli, R. Ferraro; Development and Applications of the SFR product; 8th International Precipitation WG; 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of NOAA technical reports	
# of presentations	3
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Science and Management Support for S-NPP VIIRS Aerosol Optical Thickness (AOT), Aerosol Particle Size Parameter (APSP), and Suspended Matter (SM)

Task Leader	Jingfeng Huang
Task Code	EBJH_JPSS_14 Year 3 & JHJH_JPSS_16
NOAA Sponsor	Shobha Kongdragunta, Istvan Laszlo
NOAA Office	NESDIS
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: We have maintained and improved the S-NPP VIIRS Operational Aerosol Algorithm on the NOAA IDPS, conducted intensive Calibration and Validation of the VIIRS Aerosol Products, and provided the validated Products of daily global aerosol observations to user communities to support research and operational activities in weather, climate, and air quality.

Link to a research web page: **http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/**

Background

The Suomi National Polar-orbiting Partnership (S-NPP), the first satellite of the Joint Polar Satellite System (JPSS), was launched on October 28, 2011. Critical daily global aerosol products are now being produced from the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard S-NPP, as the vanguard of the next generation of operational satellite sensors capable of providing daily global aerosol observations for research and operational activities in weather, climate and air quality. The VIIRS aerosol products include Aerosol Optical Thickness (AOT) and Aerosol Particle Size Parameter (APSP), and Suspended Matter (SM). The operational S-NPP VIIRS aerosol products are publicly accessible from NOAA's Comprehensive Large Array-data Stewardship System (CLASS, http://www.class.ngdc.noaa.gov).

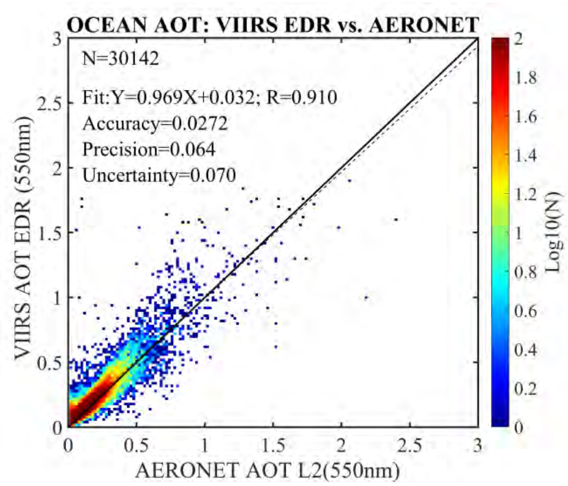
The S-NPP VIIRS aerosol products are maintained and improved by NOAA's Center for Satellite Applications and Research (STAR) Aerosol Calibration/Validation (Cal/Val) Team led by Shobha Kondragunta and Istvan Laszlo. The scientists at the University of Maryland Cooperative Institute for Climate studies (CICS-MD) are aimed to conduct continued research and data management work on the S-NPP VIIRS aerosol algorithm maintenance and improvements. CICS-MD scientists will also support future JPSS1 VIIRS aerosol algorithm development, improvement, code change testing, and prelaunch Cal/Val activities with the transition of the new VIIRS enterprise aerosol algorithms to the JPSS1 satellite observations.

This task mainly aims for supporting the NOAA STAR scientists in conducting calibration and validation of the S-NPP and JPSS1 VIIRS aerosol products, maintaining both the science and operational aerosol algorithms, developing alternative algorithms, and improving the algorithms in accuracy and precision to meet the needs of user communities.

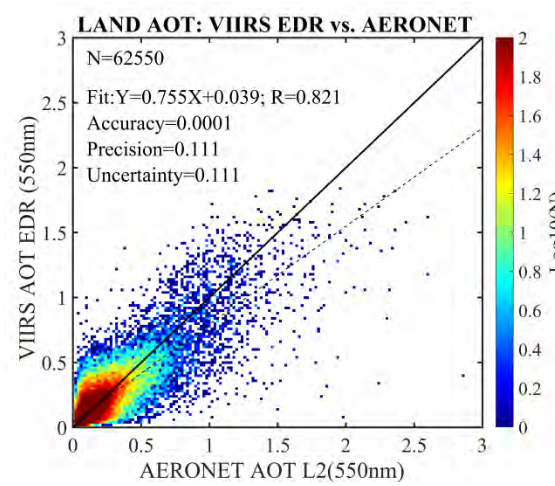
Accomplishments

Supported by the task, the CICS Scientists conducted the Intensive Calibration and Validation (ICV) on the S-NPP VIIRS aerosol products with extended validation data period. The VIIRS aerosol products were compared to collocated AERONET measurements from May 2, 2012 to Dec 31, 2016. Over land, the VIIRS Aerosol Optical Thickness (AOT) Environmental Data Record (EDR) exhibits an overall global bias against AERONET of 0.0001 with an uncertainty of 0.11. Over ocean, the mean bias of VIIRS AOT EDR is 0.0272 with an uncertainty of 0.07. The mean bias of VIIRS Ocean Ångström Exponent (AE) EDR is 0.11 with an uncertainty of 0.57 (Figure 1).

(a)



(b)



(c)

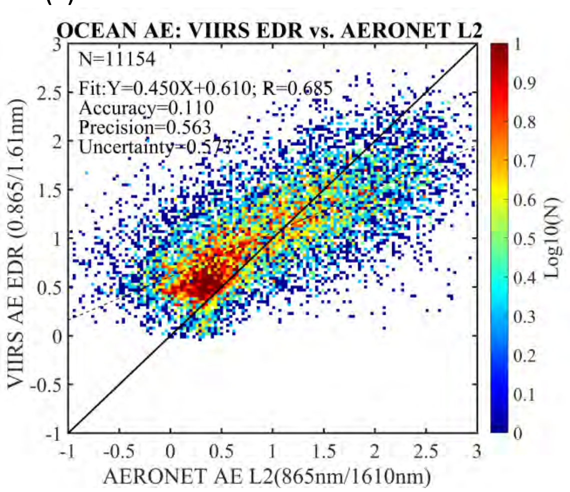


Figure 1. Density plots of high quality VIIRS AOT and AE EDR vs. AERONET: (a) VIIRS Land AOT EDR 550 nm vs. AERONET; (b) VIIRS Ocean AOT EDR 550 nm vs. AERONET; and (c) VIIRS Ocean AE EDR vs. AERONET

Increased uncertainty in the retrieval is linked to specific regions, seasons, surface characteristics and aerosol types, suggesting opportunity for future modifications as understanding of algorithm assumptions improves. These findings demonstrate the integrity and usefulness of the VIIRS aerosol products that will transition from S-NPP to JPSS1. The findings were summarized in the Huang et al. (2016) paper.

CICS Scientists also performed large data array management of the VIIRS aerosol products to support data use activities of the NOAA STAR VIIRS aerosol team. This includes maintaining and improving an automated data archiving and processing system that can automatically fetch, process, and archive VIIRS aerosol EDR on local disk storage, and to generate daily global images of the VIIRS aerosol products for validation and monitoring purposes. The website can be found at: http://www.star.nesdis.noaa.gov/smcd/viirs_aerosol/WEB/html/nesdis.viirs.web.html. This system supports the daily activities of data visualization, event monitoring, data reprocessing, and calibration/validation currently performed by members of the NOAA STAR VIIRS aerosol team.

The CICS scientists also support the entire VIIRS aerosol team by monitoring and reorganizing the structure of data storage at local data servers. The archived datasets and any other special requested datasets were used to support other team members for their scientific and operational needs to develop and test new aerosol algorithms, such as the new algorithm developed in Zhang et al. (2016) and the upcoming new Enterprise VIIRS aerosol algorithm in the Enterprise Processing System (EPS).

CICS scientists also conducted scientific research on new aerosol retrieval and internal testing schemes to further improve the operational NOAA VIIRS aerosol products (research to operation product #1). CICS scientists used the Algorithm Development Library (ADL) to run and test aerosol algorithms. The ADL testing was used to assess the impacts from code improvements, such as LUT and PCT updates, ocean model update and snow detection scheme update etc. for CICS scientists to support Discrepancy Report (DR), Problem Change Request (PCR) and Configuration Change Request (CCR) submissions. As part of the Cal/Val activities, CICS scientists participated in the Factory Baseline Tests (FBT) regularly to ensure correct implementation of code changes in the VIIRS algorithms from Mx8.9 to Mx8.11.

In the past year, CICS Scientists successfully transferred the following internal test scheme to the operation during the past year (techniques for NOAA's operational use #1): adjusting the thresholds in the snow and snowmelt screening scheme in the EPS VIIRS aerosol algorithm to help regain aerosol retrievals over heavy smog events and to keep same level of snow and snowmelt screening as in the IDPS algorithm. New thresholds for normalized difference snow index (NDSI) and spatial filter were proposed, evaluated and implemented in the EPS VIIRS aerosol algorithm that will become operational soon in 2017. With the new thresholds, the EPS algorithm was able to successfully regain high quality AOT retrievals over Eastern China during smog prevalent season (Figure 2).

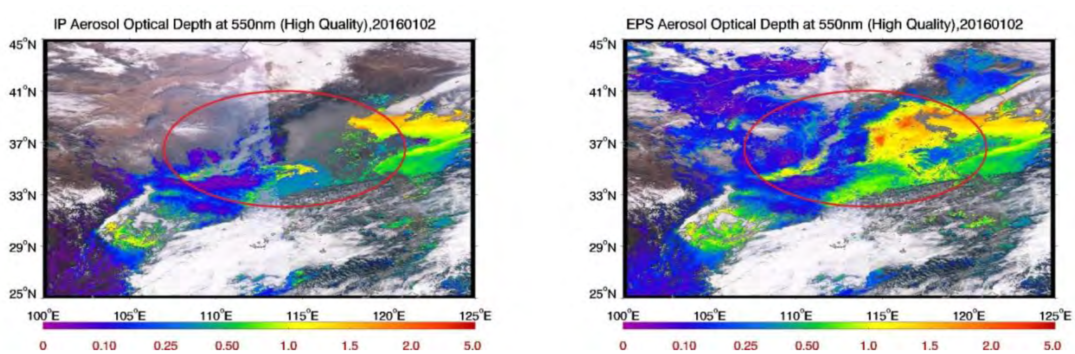


Figure 2. (a) the missing high quality AOT retrievals of China smog in Eastern China on Jan 2, 2016, produced by the IDPS VIIRS aerosol algorithm; and (b) the regained high quality AOT retrievals of China smog on the same day, produced by the EPS VIIRS aerosol algorithm.

To meet the user needs from global climate modelers, CICS scientists maintain the daily data processing of the gridded VIIRS aerosol 0.25°X0.25° resolution products and provide data support through the NOAA STAR website (research to operation product #2).

Planned work

CICS scientists will continue working with the NOAA STAR scientists and the VIIRS aerosol science team to conduct the Calibration/Validation activities to further improve the VIIRS aerosol algorithm, to provide data support to the data user communities, and to support the prelaunch Calibration/Validation activities for JPSS 1.

This includes but not limited to:

1) Maintaining the daily VIIRS Aerosol EDR data ingesting, data analysis, data visualization, and data display on the group website;
2) Conducting Large Array Data Management to facilitate science team algorithm development and testing activities;
3) Participating in the operational and scientific algorithm code change processes;
4) Monitoring long term performance of the S-NPP VIIRS aerosol products;
5) Evaluating the VIIRS aerosol products for higher validated stages;
6) Supporting the transition of the VIIRS aerosol algorithm from S-NPP to JPSS 1;
7) Conducting the prelaunch calibration and validation of the JPSS 1 VIIRS aerosol products;
8) Writing up journal papers to publish and report scientific results in journals and at conferences.

Publications

Peer-Reviewed:

1. Zhang, H., S. Kondragunta, I. Laszlo, H. Liu, L. A. Remer, **J. Huang**, S. Superczynski, and C. Pubu (**2016**), An enhanced VIIRS aerosol optical thickness (AOT) retrieval algorithm over land using a global surface reflectance ratio database, J. Geophys. Res. Atmos., 121, doi:10.1002/2016JD024859.

2. **Huang, J.,** S. Kondragunta, I. Laszlo, H. Liu, L. A. Remer, H. Zhang, S. Superczynski, P. Ciren, B. N. Holben, and M. Petrenko (**2016**), Validation and expected error estimation of Suomi-NPP VIIRS aerosol optical thickness and Ångström exponent with AERONET, J. Geophys. Res. Atmos., 121, 7139–7160, doi:10.1002/2016JD024834.

Products

1. NPP/VIIRS Operational Aerosol Products: include aerosol optical depth (AOD) at 11 wavelengths, aerosol size parameter (Angstrom Exponent, AE) and type-related information (Suspended Matter).
2. 0.25°X0.25° gridded high quality AOD datasets.

Presentations

1. **Huang, J.,** H. Liu, H. Zhang, S. Kondragunta, I. Laszlo, P. Ciren, L. Remer, and S. Superczynski, Detecting Air Pollution Events Over China Using Two Different Aerosol Optical Thickness Products Derived from S-NPP VIIRS Observations, Abstract #303078, 13th Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS Annual Meeting 2017, Seattle, 22-26, January **2017**

2. **Huang, J.,** H. Liu, H. Zhang, S. Kondragunta, I. Laszlo, P. Ciren, L. Remer, and S. Superczynski, AOT retrievals of China Smog Events (winter 2015-2016) Using Two Different VIIRS Aerosol Algorithms, CICS Annual Science Meeting, College Park, MD, November 30, **2016**
3. Liu, H., Hai Zhang, I. Laszlo, S. Kondragunta, L. A. Remer, P. Ciren, **J. Huang**, and S. Superczynski, NOAA VIIRS Dark Target-Bright Surface Aerosol Optical Depth Algorithm, 4th AeroSat Workshop, Beijing, 19-23 September, **2016**
4. Remer, L. A., H. Liu, P. Ciren, S. Kondragunta, H. Zhang, **J. Huang**, S. Superczynski and I. Laszlo, The NOAA VIIRS aerosol products and applications for air quality applications, 4th AeroSat Workshop, Beijing, 19-23 September, **2016**

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	2*
# of products or techniques submitted to NOAA for consideration in operations use	1**
# of peer reviewed papers	2***
# of NOAA technical reports	
# of presentations	4****
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

*: The improved products include the operational S-NPP VIIRS Aerosol Products and the 0.25°X0.25° gridded datasets.
**: The threshold adjustments in the snow and snowmelt screening scheme to regain smog AOT retrievals but keep the same level of snow and snowmelt screening
***: The two peer reviewed papers (Huang et al., 2016 and Zhang et al., 2016) were published in JGR-Atmosphere.
****: The presentations were listed in the above presentation list.

CUNY Scientific Support for S-NPP Snow Cover Products

Task Leader	Peter Romanov
Task Code	PRPR_VIRS_16
NOAA Sponsor	Jeff Key
NOAA Office	STAR
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 2: 100%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight : We have continued working on calibration, validation and improvement of snow cover products generated from VIIRS instrument onboard S-NPP satellite. Routine evaluation of the retrievals has demonstrated a close to optimal performance of the algorithm and the product with over 92% yearly mean accuracy of snow identification under clear sky conditions. An improved version of the algorithm has been developed and delivered for operational implementation**.**

Link to a research web page:
https://www.star.nesdis.noaa.gov/smcd/emb/snow/viirs/viirs-snow-fraction.html

Background

Global observations with the VIIRS instrument onboard Suomi-NPP satellite have been conducted since early 2012. Outgoing radiances in the visible and infrared spectral bands measured by VIIRS are used to derive a large number of environmental parameters, characterizing the state of the Earth's atmosphere, land surface and cryosphere. The binary snow cover map and the fractional snow cover map are among the cryosphere products inferred from VIIRS observations.

The objective of this project consists, first, in maintaining of the current VIIRS snow mapping algorithms as well as in the assessment of the performance of these algorithms and in evaluation of the accuracy of snow cover maps derived from VIIRS/JPSS within the IDPS. The second objective consists in evaluation of performance of new NDE algorithms. The performance of both algorithms will be assessed by comparing snow maps with other independent sources of information on the snow cover properties and distribution and by visual analysis of original satellite imagery and corresponding derived remote-sensing product. The results of this analysis will be used to identify possible weaknesses in the NDE algorithms and to determine ways for possible improvement of the VIIRS NDE snow cover products. Recommended improvements to the algorithm will be tested on local servers and then proposed for implementation in the operational routine.

Accomplishments

We continue evaluating the new VIIRS NDE (Enterprise) snow cover product and comparing it with the IDPS binary snow cover product. Since October 2016 global gridded VIIRS NDE snow cover maps are generated daily at two-three weeks delay. The maps are produced on a geographical grid with 0.01 degree grid cell size. Daily NDE snow maps have also been generated for two periods in March 2016 and in May-June 2016. At this time VIIRS NDE Cloud mask is not generated routinely therefore both snow cover maps (IDPS and NDE) are produced with the IDPS cloud mask.

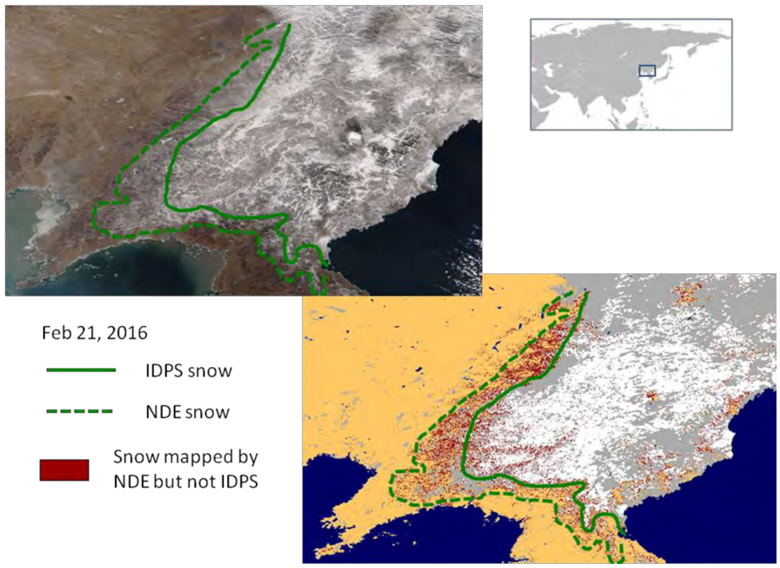


Figure 1. Bottom: VIIRS IDPS and NDE snow maps overlaid. February 21, 2016. Top: True color image

Comparison of IDPS and NDE snow retrievals with the true color imagery demonstrates somewhat better identification of partially snow covered scenes with the NDE algorithm (see example in Fig.1).

The graph in Fig.2 present daily estimates of the rate of agreement between IDPS and NDE daily snow maps with the IMS daily product for North America and Eurasia in 2016. The new NDE algorithm demonstrates a small, mostly within 2%, but consistent improvement of the retrieval accuracy as compared to NDE. Part of this increase is due to additional consistency tests in the NDE algorithm which labels all “questionable” snow identifications as “cloudy”.

The comparison is performed only in cloud-clear areas. All land grid cells in the Northern Hemisphere are used in the comparison, which explains a high rate of agreement. Limiting the comparison to the area of “climatologically variable snow cover”, i.e. to the area where snow cover may or may not be present at the given time of the year reduces the estimated agreement by 3-5%.

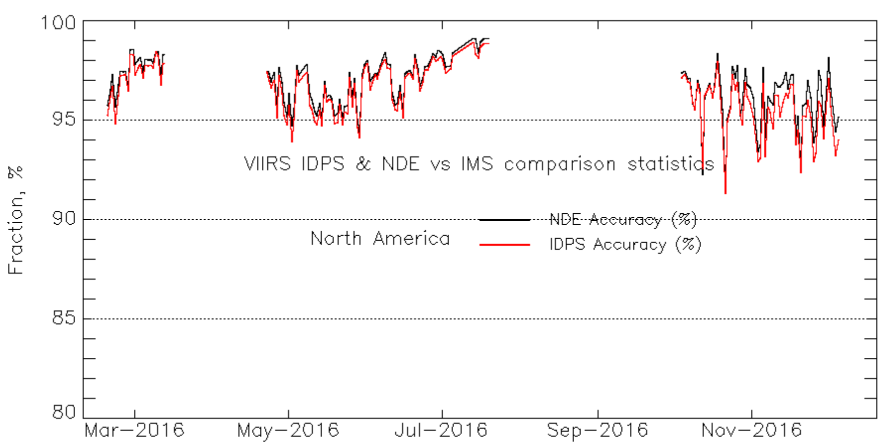


Figure 2. Fraction of correct snow/no-snow identification by IDPS (operational) and NDE(experimental) algorithms.

Planned work

- Continued monitoring/validation of the snow cover products derived from S-NPP VIIRS data within the IDPS system.
- Evaluate snow cover retrievals with the new algorithm within the NDE system. Prepare information for the product maturity review.

Presentations

VIIRS Snow Cover Products: Current Status and Plans, STAR JPSS 2016 Annual Science Meeting, 8-12 August, College Park, MD

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

NPP/VIIRS Land Surface Albedo Validation Research and Algorithm Refinement

Task Leader	Shunlin Liang & Dongdong Wang
Task Code	SLDW_VIRS_15 Year 2
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD/EMB
Percent contribution to CICS Themes	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
Main CICS Research Topic	Calibration and Validation
Percent contribution to NOAA Goals	Goal 1: 60%; Goal 2: 40%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: We developed an algorithm to estimate daily mean albedo from VIIRS. We developed a new VIIRS gridded product of land surface albedo. We comprehensively evaluated VIIRS albedo data using newly collected data and we have also been routinely monitoring VIIRS albedo product.

Background

Land surface albedo (LSA), defined as the ratio between solar radiation reflected by Earth's land surface and solar radiation incident at the surface, is a function of both solar illumination and the reflective properties of land. Remote sensing is an efficient tool for mapping LSA globally on a regular basis. Attempts to generate global maps of LSA can be traced back to the early meteorological satellites. Since then, a series of optical sensors have been applied to derive global data on LSA. The launch of the Moderate Resolution Imaging Spectroradiometer (MODIS) began a new era of monitoring LSA with satellites. As its successor, the Visible Infrared Imaging Radiometer Suite (VIIRS) from the Suomi National Polar-orbiting Partnership (Suomi NPP) and future Joint Polar Satellite System (JPSS) missions provide us a continued opportunity to map LSA from space. Currently, surface albedo data is produced as one of VIIRS Environmental Data Records (EDRs). It is a granule-based product, containing albedo parameter over land and sea ice surfaces. A direct estimation algorithm was developed to estimate instantaneous blue-sky albedo from clear-sky VIIRS observations over land and sea ice pixels.

Accomplishments

1. Developing a new method for daily mean albedo from VIIRS

Existing satellite products of land surface albedo typically provide only instantaneous values of black-or white-sky albedo, or sometimes blue-sky albedo. Such data are usually not suitable for directly calculating surface shortwave net radiation because of differences in the definition of various albedo terms and diurnal variations of their values. Differences between black-sky and blue-sky albedo, which result from atmospheric effects, can be as large as 20%. In addition, diurnal variations in illuminating conditions may lead to a difference of 15% between daily mean albedo and instantaneous albedo.

A direct estimation algorithm was used to retrieve instantaneous blue-sky albedo at the satellite overpass time from Visible Infrared Imaging Radiometer Suite (VIIRS) top-of-atmosphere (TOA) reflectance data. We extended the instantaneous algorithm to infer daily values of broadband blue-sky albedo directly from TOA observations under the assumption that atmospheric conditions at the overpass time represent their daily average. The direct estimation method does not require surface reflectance or

BRDF data as inputs and retrieves daily albedo in one step, avoiding propagation of uncertainty by multiple steps of atmospheric correction, BRDF modeling, and narrow-to-broadband conversion.
Field measurements from 2012 and 2013 collected at SURFRAD and GC-Net sites were used to validate the presented method.

Validation results of snow-free cases
All valid clear-sky retrievals of daily albedo were compared with corresponding SURFRAD measurements. The two datasets generally show good agreement with an R^2 of 0.839, a negligible underestimation, and an overall RMSE of 0.056. The accuracy is comparable to previous results for retrieving instantaneous albedo. Compared to the data retrieved with BRDF LUT, the results for Lambertian LUT are slightly worse. Together with the following results for the GC-Net stations, we will discuss the pros and cons of incorporating surface anisotropy in estimating daily albedo. For both BRDF and Lambertian results, larger discrepancies are mainly observed for the snow-covered cases. Due to a mixture of snow and vegetation, even the relatively homogenous SURFRAD sites will have less spatial representativeness for snow-covered albedo. To reduce errors caused by partial snow coverage, we used the data for permanent snow cover from GC-Net stations to assess the quality of snow albedo retrievals.

The direct estimation method uses one single observation to retrieve daily albedo. In nature, such retrievals will reflect internal and external effects such as intra-daily variations due to subpixel clouds and shadows as well as differences in atmospheric conditions and viewing geometry. To reduce the impacts of these factors, we calculated 16-day averaged values of daily albedo and compared them with field measurements for snow-free days. The 16-day averaged retrievals generally show improved quality. The RMSE from BRDF LUT is as small as 0.018. This accuracy is even higher than what we previously obtained for instantaneous albedo, mainly due to the use of aerosol-specific LUT for the desert cases.

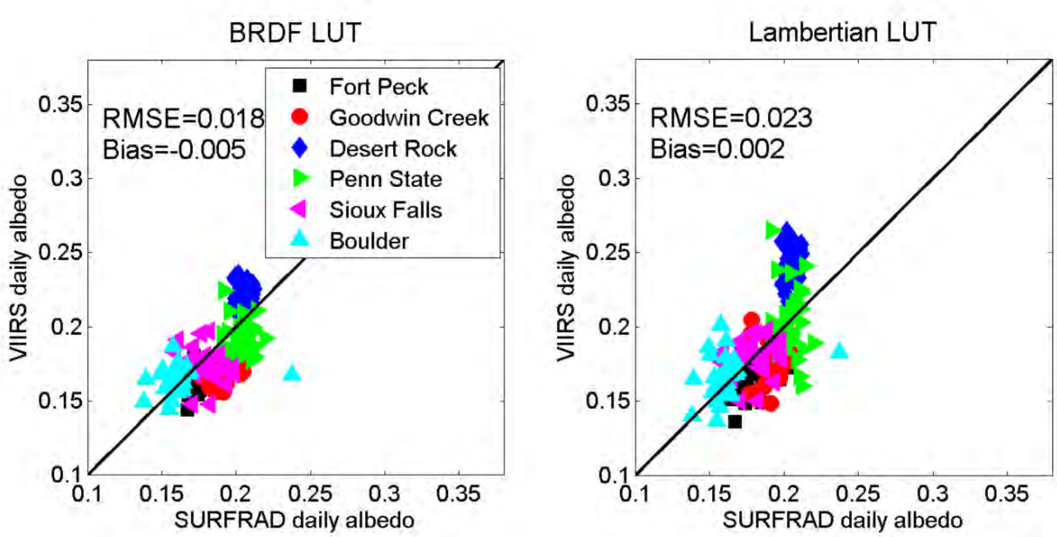


Figure 1. Comparison results between VIIRS-retrieved daily albedo and that measured at SURFRAD sites. Only snow-free data are used.

Validation results of snow-covered cases

Uncertainties of snow albedo are generally larger, especially for cases with long oblique view path or large SZA values. Scatterplots of snow albedo retrievals were made by excluding far off-nadir observations (SZA >55° or VZA >30°) with three different LUTs. It is interesting to note that the Lambertian LUT generates the best results with the smallest RMSE. Correlations between retrieved daily albedo and measured daily albedo are similar amongst the three LUTs, and the generic BRDF LUT has a slightly higher R^2. However, due to the existence of a non-identity slope, the generic BRDF LUT underestimates daily mean albedo with the largest bias of 0.047. The snow-specific BRDF LUT reduces the bias, but the non-identity slope still exists. It implies that BRDF information used in training the models has uncertainties and is not able to sufficiently duplicate the actual angular distribution of snow reflectance. With such inaccurate information about snow BRDF, the BRDF version of LUT fails to outperform the model with the Lambertian assumption. The Lambertian LUT was trained with surface spectra where complete information about surface spectral reflectance was available and nine VIIRS bands were used to derive the model. The BRDF LUT obtains the spectral BRDF information from the MODIS BRDF database. To reduce the correlation among bands, only one of the three blue bands were used in the BRDF model construction. In addition, the broadband albedo of the BRDF data was empirically converted from the narrowband albedo and the narrow-to-broadband conversion may have caused additional uncertainties.

Results for retrievals from SURFRAD and GC-Net stations were combined to evaluate the overall quality of daily mean albedo. The results for GC-Net surfaces are based on the Lambertian LUT and limited to near-nadir observations (SZA >55° and VZA >30°). The overall accuracy of retrieving daily albedo has a bias of 0.003 and RMSE of 0.055. Large discrepancies exist over snow cases, particularly seasonal snow at the SURFRAD stations. In addition to the complexity of snow albedo, which will be discussed in the following section, the use of a single observation in retrieving daily albedo will also lead to some level of random errors. After excluding the seasonal snow results from the SURFRAD stations, the validation results of 16-day mean albedo are improved to R^2 of 0.996 and RMSE of 0.024.

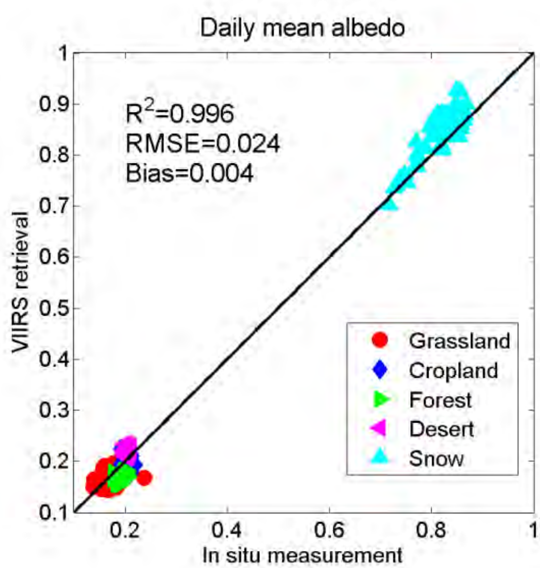


Figure 2. Validation results of 16-day averaged daily albedo. Snow-free albedo retrieved with BRDF LUT and snow albedo from Lambertian LUT.

2. Generating gridded VIIRS albedo product

This newly designed enterprise algorithm is based on the daily algorithm we previously proposed. It will generate gap-filled and noise-reduced gridded albedo product. The improved algorithm includes three major components:

- Instant Retrieval: retrieving albedo at granule level
- Gridding: gridding retrieved albedo granules and cutting gridded data into tiles
- Temporal filtering: temporal noise correction and filling data gap filling

We evaluated the abovementioned prototype system with the global data and the results were compared with existing albedo product. The test period is from Jul 09th to 25th, 2015. The test used 4316 files with a data volume of 1.32TB. The global maps both before and after temporal filtering were shown in Figures 3. This can be better illustrated with data from one tile as example. Quantitatively, the data after filtering have improved accuracy because the random noises are reduced and the impacts caused by undetected cloud and cloud shadow are mitigated (Figure 4).

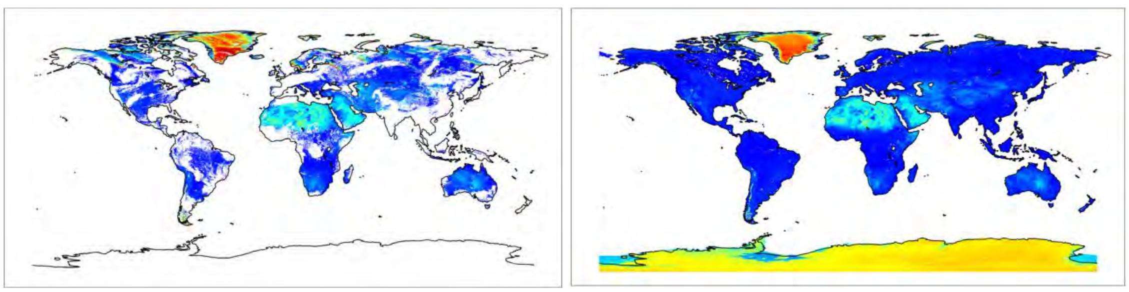


Figure 3. Global map of the original VIIRS albedo before and after temporal filtering on Jul 17th, 2015

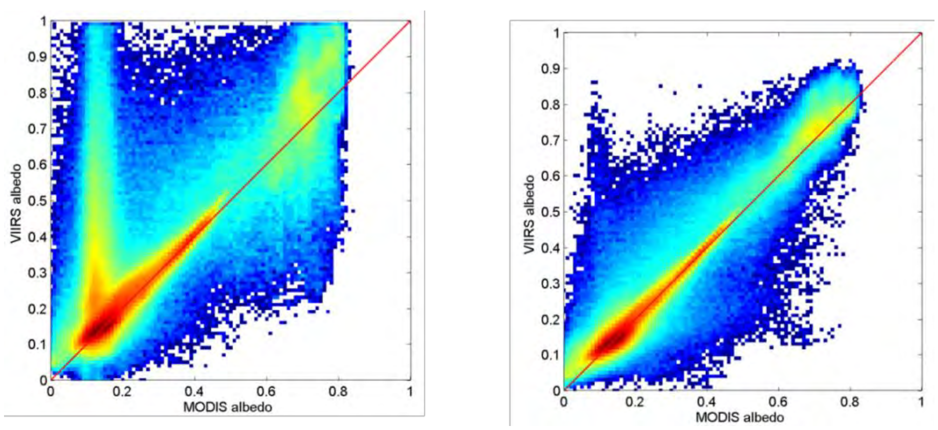


Figure 4. Comparison of VIIRS albedo before and after filtering with MODIS albedo data

Planned work

- Refining gridded albedo product;
- VIIRS albedo product assessment and monitoring;

- Updating data set of albedo climatology;
- Developing J1 land surface albedo algorithm.

Publications

Wang, D., Liang, S., Zhou, Y., He, T. & Yu, Y. (2017). A new method for retrieving daily land surface albedo from VIIRS data. *IEEE Transactions on Geoscience and Remote Sensing*, **55**(3), 1765-1775, doi: 10.1109/tgrs.2016.2632624.

He, T., Liang, S. & Wang, D. (2017). Direct estimation of land surface albedo from simultaneous MISR data. *IEEE Transactions on Geoscience and Remote Sensing*, **55**(5), 2605 - 2617, doi: 10.1109/TGRS.2017.2648847.

Zhou, Y., Wang, D., Liang, S., & He, T. (2016). Assessment of the Suomi NPP VIIRS land surface albedo data using station measurements and high-resolution albedo maps. *Remote Sensing*, **8**, 137, doi: 10.3390/rs8020137.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	3
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	2
# of graduate students formally advised	2
# of undergraduate students mentored during the year	

GOES-R Active Fire/Hot Spot Characterization: Validation and Refinement of GOES-R/ABI Fire Detection Capabilities

Task Leader	Wilfrid Schroeder
Task Code	WSWS_ABI_14 Year 3 & WSWS_ABI_16
NOAA Sponsor	Jaime Daniels
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 70%, Theme 2: 30%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 50%, Goal 2: 50%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: *Deep-dive* fire validation tool was expanded, tested with DOE data and applied to post-launch ABI data

Background

The GOES-R Advanced Baseline Imager (ABI) fire detection and characterization (FDC) algorithm builds on the Wildfire Automated Biomass Burning Algorithm (WF-ABBA), which originated from GOES Visible Infrared Spin Scan Radiometer Atmospheric Sounder (VAS) data applications [Prins and Menzel, 1992]. The WF-ABBA product provides routine detection and characterization of sub-pixel active fires, serving the fire management community as well as the scientific community.

Assessment of satellite active fire detection and characterization products requires simultaneous observations in order to reduce the effects of short-term variations in fire conditions [Csiszar and Schroeder, 2008]. Previous studies have used higher spatial resolution satellite data to validate moderate-to-coarse resolution fire products derived from sensors aboard the same orbital platform (e.g., Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER))as well as on separate platforms by limiting the time difference between acquisitions (e.g, GOES and Landsat Enhanced Thematic Mapper Plus (ETM+) [Schroeder et al., 2008a, b].

This project uses USGS/Landsat-8 and ESA/Sentinel-2 reference fire data to assess and validate the ABI FDC algorithm, adapting the validation methods developed for GOES and MODIS fire products to work with GOES-R/ABI data. The data processing routines are grouped into one software package describing the GOES-R/ABI *deep-dive* active fire validation tool.

This project is considered highly relevant to the GOES-R mission, as it will allow the refinement of ABI's fire detection product by means of algorithm fine-tuning using independent higher spatial resolution reference data.

Accomplishments

A new reference fire data set was developed using 20 m resolution data derived from the Multispectral Instrument (MSI) aboard the ESA/Sentinel-2a satellite. That data set builds on the Schroeder *et al*. [2016] methodology, which was originally developed for the Landsat-8 Operational Land Imager (OLI) data. Those two reference fire data sets constitute the primary inputs to the *deep-dive* tool. The *deep-*

dive tool was tested using Landsat-8/OLI and Sentinel-2a/MSI data paired to pre-launch GOES-R Data Operations Exercise (DOE). Issues affecting the FDC data product were identified, including inconsistent data attributes and incoherent fire size, temperature and intensity retrievals. Those issues were communicated back to the GOES-R Algorithm Working Group and the Algorithm Scientific Software Integration and System Transition Team (ASSISTT).

The consistency between Landsat-8/OLI and Sentinel-2a/MSI reference fire data was analyzed using hundreds of near-coincident data pairs. Overall, OLI and MSI fire detection data showed strong agreement (Figure 1). Short-term variations in fire behavior were reflected in the summary fire statistics derived from each data set when temporal separation >10 min was observed.

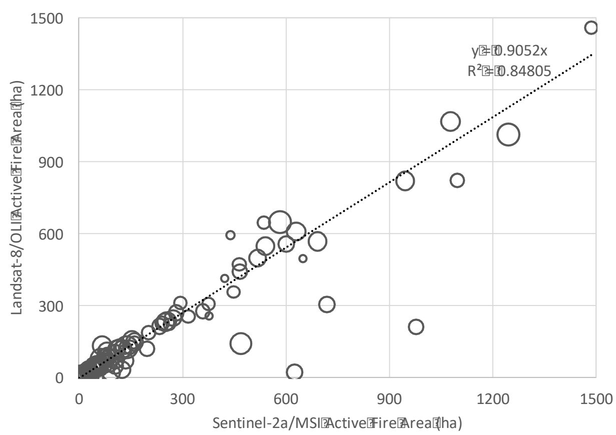


Figure 1: Near-coincident Landsat-8/OLI and Sentinel-2a/MSI active fire areas collected over a wide range of fire regimes globally. Sentinel-2/MSI observations were made 3-28 min after Landsat-8/OLI (time separation reflected on size of data points), therefore may show systematic fire size growth as a function of diurnal cycle.

Post-launch GOES-16/ABI fire data were analyzed using both Landsat-8/OLI and Sentinel-2a/MSI reference fire data distributed across the full disk sampling area. Early-orbit ABI data showed data navigation errors, resulting in measurable spatial offset when overlaid to the reference fire data (Figure 2). Subsequent analysis of ABI data following rectification of the Image Navigation and Registration (INR) procedures showed noticeable improvement in geolocation quality relative to the reference fire data sets. A set of 120 Landsat-8/OLI reference images were paired to ABI data (Figure 3), and used to assess fire product quality. Preliminary ABI fire detection commission error rate was estimated to be 20%.

Outstanding ABI fire product inconsistencies were also found in the post-launch data, including the inconsistent file attributes and fire retrievals identified with the pre-launch DOE. Additional anomalies were identified in the post-launch data resulting from the ABI data gridding scheme. The latter causes noticeable smearing of gridded radiances, and subsequent misclassification of fire-free pixels neighboring fire-affected pixels leading to artificially higher commission error rates. Those findings have been shared with the algorithm's principal investigator.

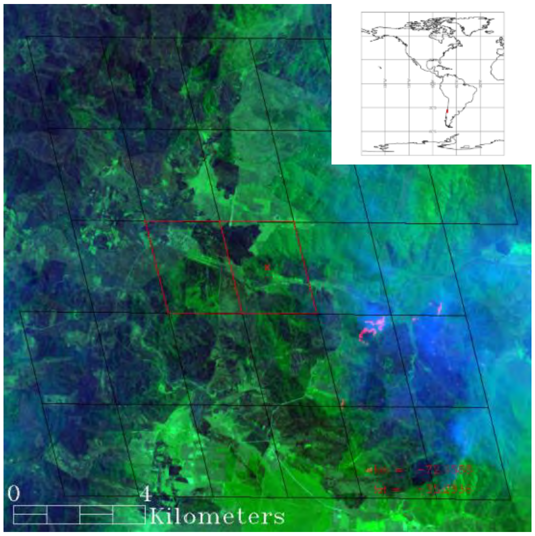


Figure 2. GOES-16/ABI effective pixel footprints (grid) acquired on 29 Jan 2017 @1429UTC south of Santiago/Chile, overlaid on near-coincident Sentinel-2a/MSI false-color composite image subset. ABI fire pixels are colored red; spatial offset relative to reference data describes lower accuracy geolocation impacting early-orbit data.

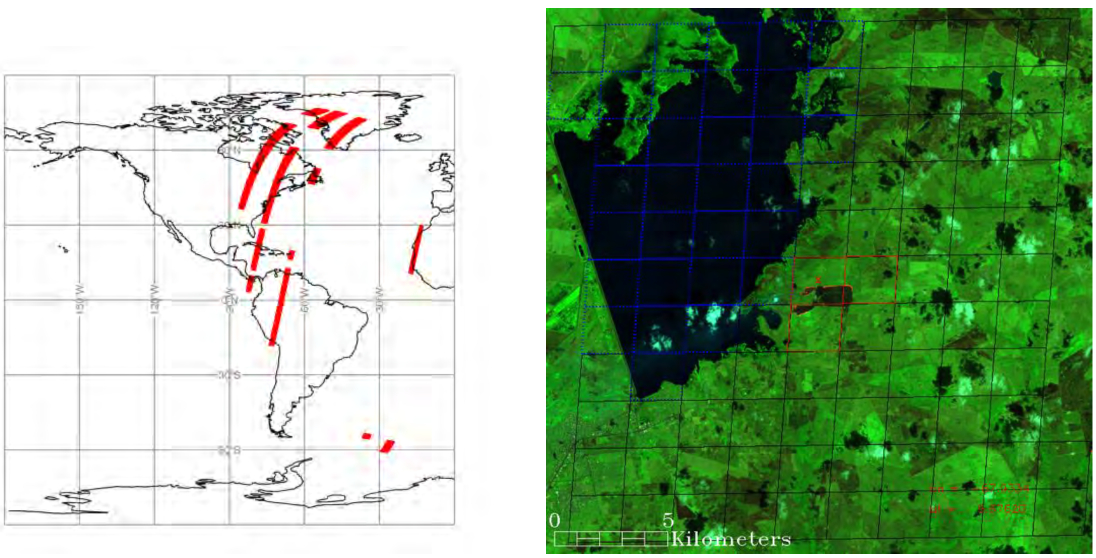


Figure 3. Sampling of GOES-16/ABI fire detection product using 120 Landsat-8/OLI reference images distributed across the full disk observation cone (left). GOES-16/ABI effective pixel footprints (grid) acquired on 03 Mar 2017 @1441UTC over Venezuela, overlaid on near-coincident Landsat-8/OLI false-color composite image subset. ABI fire pixels (red) are found to align well with fire-affected area on OLI image.

Planned work

- Maintain/refine GOES-16/ABI deep-dive fire validation tool (July 2017 – March 2018)
- Run deep-dive fire detection validation using provisional-maturity ABI data and Landsat-8 and/or Sentinel-2/MSI reference data (July 2017 – March 2018)
- Report validation results to appropriate ABI Land/Fire Product leads (July 2017 – March 2018)
- Support verification and inspection of updated ABI Level-2 fire algorithm outputs generated by the Algorithm Integration Team (ASSISTT) (July 2017 – March 2018)

- Run deep-dive sub-pixel fire characterization validation (i.e., fire area, temperature, radiative power) using available airborne reference data (dependent on USDA Forest Service and NASA airborne data acquisition schedules) (July 2017 – Mar 2018)
- Generate draft manuscript for peer-reviewed publication describing fire detection validation metrics (omission & commission errors) for provisional-maturity data (December 2017 – March 2018)
- Support GOES-R Product User Guide reviews
- Prepare quarterly reports to Land AWG Chair

Publications

Schroeder, W., Oliva, P., Giglio, L., Quayle, B., Lorenz, E., and Morelli, F. (2016). Active fire detection using Landsat-8/OLI data. *Remote Sensing of Environment*, doi: 10.1016/j.rse.2015.08.032.

Products

Operational implementation of Landsat-8/OLI active fire data set at the USDA Forest Service Remote Sensing Applications Center (RSAC) was expanded during the 2016 fire season, including provisions for processing of on-demand nighttime data acquisitions.

Presentations

Schroeder, W., Giglio, L., Walsh, W., Csiszar, I., Ellicott, E., Oliva, P., Guillevic, P., Lima, A. (2016). VIIRS (and Landsat-class) active fire products. GOFC/GOLD Fire Implementation Team and ForestSat meeting, Santiago/Chile, 14-18 November (http://forestsat2016.com/).

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**1**
# of NOAA technical reports	
# of presentations	**1**
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Expanded Landsat-8/OLI fire data processing implemented operationally at USDA/RSAC

Radiometric Calibration for Jason 2 and 3 Advanced Microwave Radiometer

Task Leader	Xi Shao and Bin Zhang
Task Code	XSBZ_JAS3_16
NOAA Sponsor	Laury Miller / Eric Leuliette
NOAA Office	NESDIS/STAR/SOCD
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation;
Contribution to NOAA Goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: We have monitored the stability of Jason-3 Advanced Microwave Radiometer by comparing with Jason-2 AMR using vicarious site methods, SNO method, and coldest ocean method. A comparison of AMR radiance at 23.8 GHZ between Jason-3 and ATMS is also carried out.

Background

Jason-3 is a follow-on Altimetry mission of Jason-2, led by NOAA, EUMSAT and CNES. Jason-3 is launched on January 17th, 2016. It will provide continuous measurements of sea surface height as an addition to the global ocean surface time series datasets from previous altimetry missions: TOPEX/Poseidon, Jason-1, Jason-2 and ESA series satellite missions. The measured sea surface height time series are being used by the scientific community for study the global and regional ocean circulation patterns, the global sea level rise and hence global climate change. With more than two decades of measurements of the sea level height, the abundant data set can give us a confident estimation of the global sea level rise rate (Beckley et al. 2007; Cazenave et al., 2009; Nerem et al., 2010) with highly accurate inter-satellite calibration. However, any long term sea level change determination using different satellites must undergo the scrutiny of sensor stability and consistency. After all, the sea level rise derived from the previous satellites has a rate of 3.4 mm/year (Beckley et al., 2007; Nerem et al., 2010), and instruments often display on-orbit drifts, step jump and irregularities which can result in height rate errors comparable to sea level rise rate (Cao et al., 2011). To be sure the sea level rise is not mixed with calibration errors, instrument drifts have to be minimized at a level significantly less than this rise.

In this study, we monitor the stability of the Jason-3 AMR radiometric calibration using different methods. During the first 9 months period after launch, Jason-3 and Jason-2 flight on the same orbit with Jason-3 leading 80 seconds. Then Jason-2 was moved to another orbit on Oct. 3rd, 2016. Co-flight on the same orbit gave us a great opportunity to monitoring the Jason-3 radiometric measurements stability by comparing with Jason-2 measurements since both AMRs have nearly identical design. We have used various methods, such as comparing brightness temperature over selected sites, over SNO between Jason-2 and Jason-3, coldest ocean method as well as comparing with other satellite (ATMS/SNPP) over SNOs.

Accomplishments

1. **Jason-3 AMR Comparison with Jason-2 AMR over different sites**

Some land sites, such as Amazon site1 (5.9326N, 68.0263W), Libyan (29.7401N, 24.0944E) have very uniform radiance observations on the Microwave water vapor band with very small spatial variation. Therefore, these sites are usually used to calibrate the satellite sensors on these bands, though seasonal and diurnal variations are strong usually, but can be easily predicted from historical observations. Due to the small observational time difference (80S) between Jason3 and Jason2 on the same sites, it can be expected the observation difference are mainly due to the calibration difference between the two AMRs on the two satellites. Figure 1 shows the time series of the brightness temperature ratio at two sites. We can see the brightness temperature ratio (J3/J2) is shifted with time. Initially, there is a positive bias and then the bias is gradually reduced over the two sites consistently towards one. Usually, there exists brightness temperature dependency in the ratio time series due to calibration errors. Since the brightness temperature over land surface is usually much higher than the ocean surface, if there is BT dependency in the ratio time series, the trend we see in the land site time series is not necessarily the same trend over the ocean surface. A website has been set to show the time series: https://ncc.nesdis.noaa.gov/JASON3.php

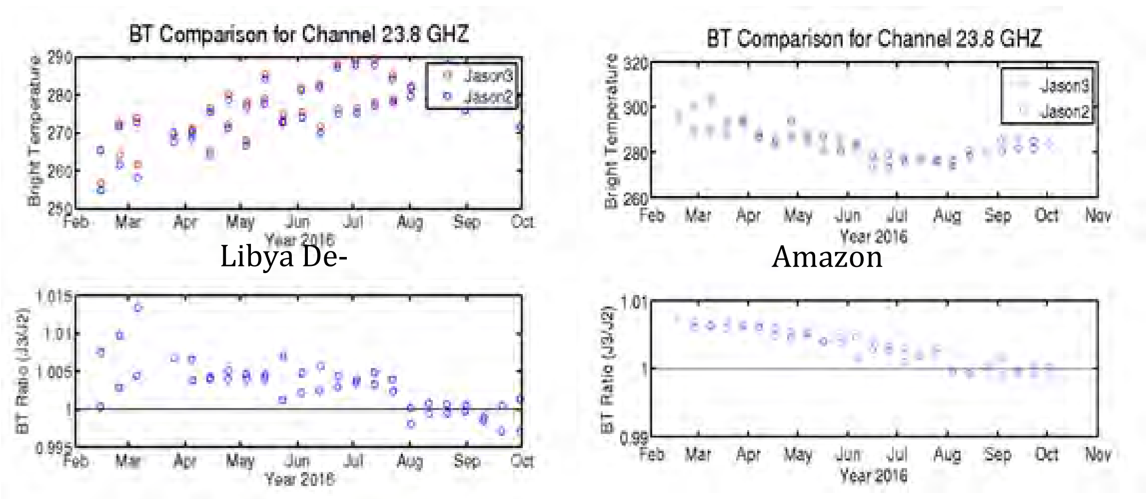


Figure 1 Brightness temperature comparison between Jason3/AMR and Jason2/AMR at channel 23.8 GHZ at site Amazon and Libya desert.

2. **Jason-3 AMR Comparison with Jason-2 AMR over global SNOs**

Co-flight of Jason-3 and Jason-2 gave us the great opportunity for calibration/validation of Jason-3 measurements from Jason-2. With 80 seconds time lag, we searched all Jason-3 and Jason-2 pixels within 1 km distance globally, and the averaged brightness temperature ratio over ocean pixels over each flight cycle is shown in Figure 2. Clearly, the pattern of trend is in the same direction as seen in the land site. An initial positive BT bias (J3-J2) becomes negative along with time and then becomes relative stable. This similar trend but with different ratios over ocean comparing to land sites indicates possible brightness temperature dependency. Usually, on the 23.8 GHZ channel, the brightness temperature over ocean is less than 200K, while the brightness temperature at Amazon and Libya desert can be easily more than 250 K. Both ocean and land time series indicate that changes/adjustment happened near the end of July, 2016 (Jason-3 cycle 17) consistently.

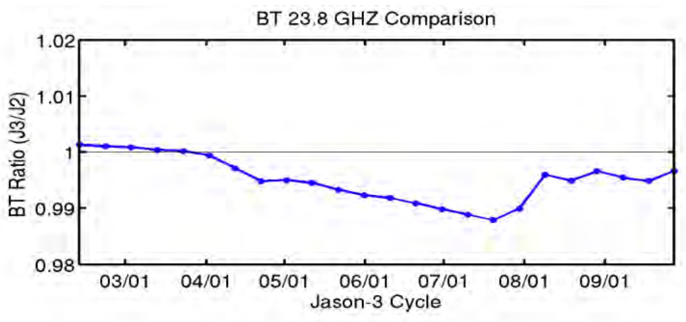


Figure 2. Global Water Vapor Band Brightness Temperature Ratio (mean) Between Jason-3 and Jason-2 over time for the first 8 months

3. **Brightness temperature dependency in the brightness temperature ratio between Jason 3 and Jason-2**
   Usually, brightness temperature dependency indicates possible systematic error in the calibration. Figure 3 shows the BT ratio between Jason-3 and Jason-2 versus the Jason-2 brightness temperature over different Jason-3 cycles. This brightness temperature dependency explains why different bias occurs over land and ocean. Also the dependency separation in cycle 17 indicates calibration adjustment. After that, the BT dependency becomes less and the ratio less depends on the brightness temperature.

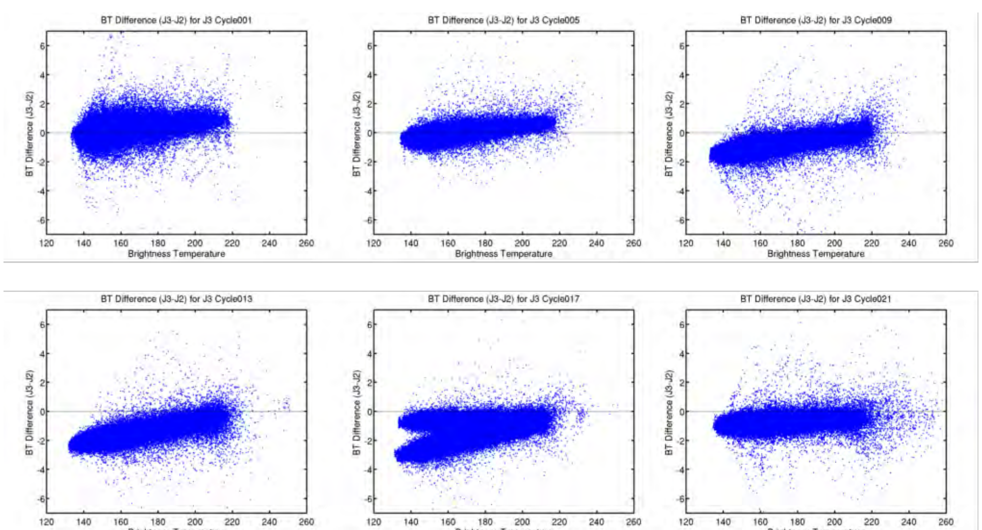


Figure 3. Strong bias dependency on brightness temperature can be seen between Jason-3 and Jason-2. This dependency has been reduced after cycle 17.

4. Coldest Ocean Brightness Temperature Time Series

The coldest ocean method looks at the histograms of all the brightness temperatures measured over ocean surface and determines the coldest brightness temperature by extrapolating the fitted line in the range of 0.5%-1% to 0% and analyzes the time series variation. It *shows relative stable for Jason-2 and negative trend for Jason3 in the first 6 months and back to follow Jason-2 later (Fig.4). Usually the long term trend can be detected in this time series, but there exists seasonal variation inside needs to be removed.*

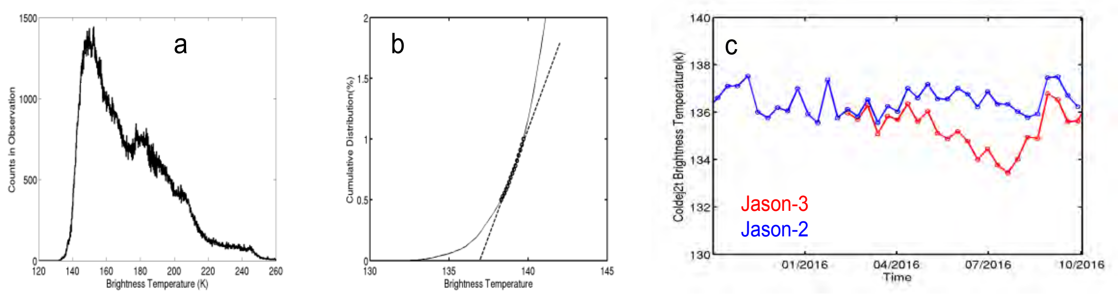


Figure 4. The coldest ocean method and its application to Jason-2 and Jason3 AMR BT dataset for each cycle. It looks the BT histogram (a) of each cycle and derives the coldest ocean BT (b), then the time series is constructed (C).

5. Jason-3 AMR Brightness Temperature Comparison with ATMS/SNPP over Simultaneous Nadir Overpass

The Advanced Technology Microwave Sounder (ATMS) onboard Suomi-NPP satellite has 22 channels. Channel 1 is the water vapor channel with frequency of 23.8 GHZ. It has a larger footprint at nadir of 74.8 km than Jason-3 AMR foot print of 26 km. ATMS has a scan period of 8/3 seconds, while Jason-3 has a scan rate of 1 Hz. The ATMS has 1.1^o spatial sampling along swath, while Jason-3 only scans nadir. Since the SNPP flys polar-orbiting sun synchronized with inclination angle of 98.79^o and Jason-3 flys with 9.9 days repeat cycle with inclination angle of 66.05^o, they always have SNO within given distance and time criteria. Figure 5 shows SNO location between the SNPP and Jason-3 over the Jason-3 first 8 months. The time series comparison is being evaluated.

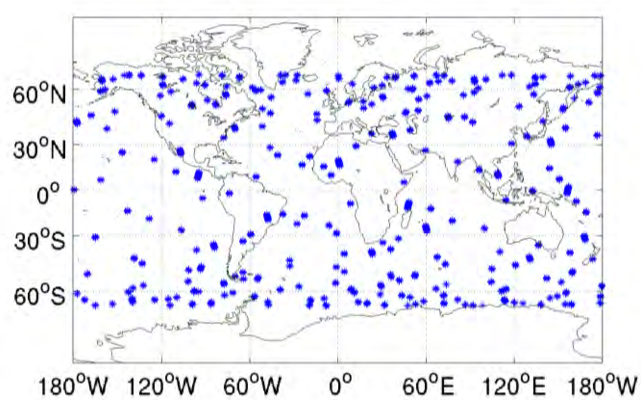


Figure 5 SNO locations between Jason-3 and SNPP during period 02/2016-08/2016

Planned work:

We will continue the monitoring using the site and cold ocean methods and will keep working on comparisons over SNO locations between Jason-3 and other satellites (SNPP/ATMS, SARAL/ALTIKA, Sentinel-3 etc). We will monitor/analyze the cold-space view calibration of the Jason-3 AMR since first time on the Jason satellite, pitch maneuver has been carried out for cold-space view to get a absolute calibration reference. We will continue update the website and prepare our findings into presentations/papers for conference and publications.

Presentations:

Zhang, B. etc, Monitoring the Stability of the Advanced Microwave Radiometer onboard Jasaon-3, Nov., 2016, CICS Annual Science Meeting, College Park, MD

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Lunar and Stellar Calibration for GOES-R Advanced Baseline Imager (ABI) in support of the Calibration Working Group

Task Leader	Xi Shao
Task Code	XSXS_ABI_14 Year 3
NOAA Sponsor	Changyong Cao
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 80%; Theme 2: 20%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation;
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS scientists support Calibration and Validation work for GOES-R Advanced Baseline Imager (ABI) instrument through lunar calibration, stellar calibration, and Imagery Navigation and Registration (INR) of GOES-R ABI.

Background

The Geostationary Operational Environmental Satellite-R Series (GOES-R) satellite was successfully launched in November, 2016 and it provides continuous imagery and atmospheric measurements of Earth's western hemisphere and space weather monitoring. The Advanced Baseline Imager (ABI) is the primary instrument on GOES-R for imaging Earth's weather, climate, and environment. ABI is able to view the Earth with 16 different spectral bands, including two visible channels, four near-infrared channels, and ten infrared channels. The ABI has two main scan modes. The continuous full disk mode will provide uninterrupted scans of the full disk every 5 minutes, while the flex mode will concurrently allow full disk imagery every 15 minutes, the continental US every 5 minutes, and a mesoscale region as often as every 30 seconds. The requirement for the ABI calibration is to an accuracy of 3% (1 σ) reflectance for visible and near-infrared wavelengths. For infrared channels, the ABI will be accurate to 1K (1 σ) at 300K.

Instrument calibration, characterization, and validation are essential to GOES-R mission success and the production of high-quality data products. To ensure the mission requirements are met, the ABI sensor radiometric calibration will utilize onboard calibration devices, including a solar diffuser (SD) for solar reflective channels and a blackbody for the infrared bands. Due to the partial aperture used on GOES-R for solar diffuser (SD) calibration and no on-board SD stability monitor, the in-flight calibration process will also make extensive use of views of the Moon and stars. We perform lunar and stellar calibration, and support imagery navigation and registration (INR) for GOES-R ABI. Since the ABI onboard the GOES-R satellite has very similar spectral and spatial characteristics as Himawari-8 Advanced Himawari Imager (AHI), we also performed characterization of AHI stray light, and comparison the ability of observing heat sources in MWIR band between SNPP VIIRS and AHI which helps support post-launch calibration activities of ABI.

Accomplishments

Our work to support calibration and validation work for GOES-R Advanced Baseline Imager (ABI) instrument can be summarized as following.

1. Solar avoidance zone prediction tool development and testing with AHI observations

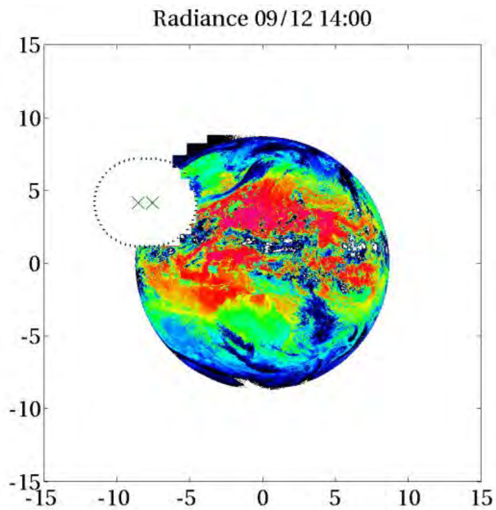


Figure 1: Validation of Solar Avoidance Zone Prediction Tool with HIMAWARI-8 AHI 3.9 um Channel Observation on Sept. 12, 2015.

We developed code for predicting solar avoidance zone (SAZ) position in fixed grid of GOES-R ABI and used AHI imagery as an example to validate the tool. Figure 1 shows the overlaid solar avoidance zone with AHI image on 09/12/2015 which validates our tool.

2. Developed tool to predict Moon appearance in GOES-R ABI FOV to support post-launch scheduling of lunar calibration of GOES-R ABI
3. Validated Lunar Selenographic Mapping tool with the Moon chasing observations by AHI
4. Continue to evaluate Himawari-8 AHI Geospatial calibration using GEO-LEO SNO data with SNPP VIIRS.

Our study evaluated the navigation and co-registration accuracies of three AHI bands from the three FPMs using the simultaneous nadir observations (SNO) of SNPP-VIIRS I-band images [Yu et al., 2016]. This prepares for post-launch INR validation of ABI.

5. Developed Control Point Matching method for INR monitoring of GOES-R ABI Channel 2 and tested the tool by evaluating INR performance of HIMAWARI AHI Channel 3.

This tool is optimized in processing speed for the fix-grid nature of ABI L1B data, which enables monitoring diurnal variation of ABI INR accuracy.

6. Cross-comparison of Suomi-NPP VIIRS and Himarwari-8 AHI MWIR observations

Comparison of the mid-wavelength infrared (MWIR) imageries of Suomi-NPP Visible Infrared Imaging Radiometer Suite (VIIRS) and HIMAWARI-8 AHI enables assessment of sensor radiometric performance in monitoring temperature variation of heat sources such as hot spots and urban heat islands. The 3.75 um band of VIIRS provides imagery in high spatial resolution (~375 m) twice a day. The 3.9 um channel of AHI imagery in 10-minute time resolution enables continuous monitoring of temporal variation of heat source temperature. Using imageries of VIIRS and AHI MWIR channel, we compared their performance in monitoring both spatial distribution and temporal (seasonal and diurnal) variation of heat sources. As an example, Figure 2 shows the comparison of temperature variation at the two sites in Shanghai Region. In general, the T_B at Shanghai City center is higher than the T_B at rural Island and the TB difference varies from 4 k and 8 k. The peak difference occurred near local noon. Comparing the ability of observing heat sources in MWIR band between VIIRS and AHI supports post-launch calibration activities of ABI. This work is published in Shao et al. [2016a].

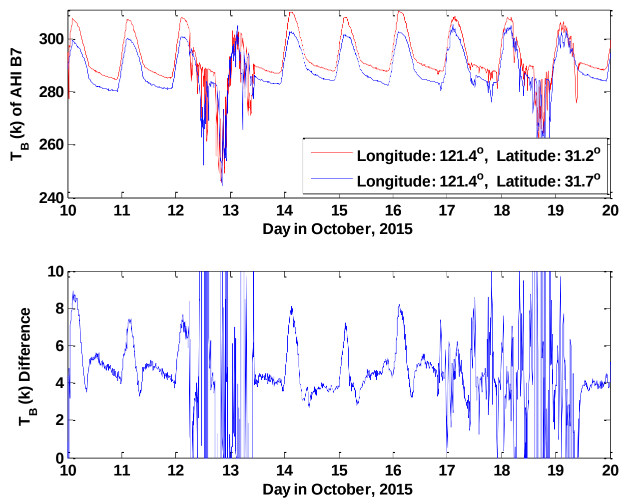
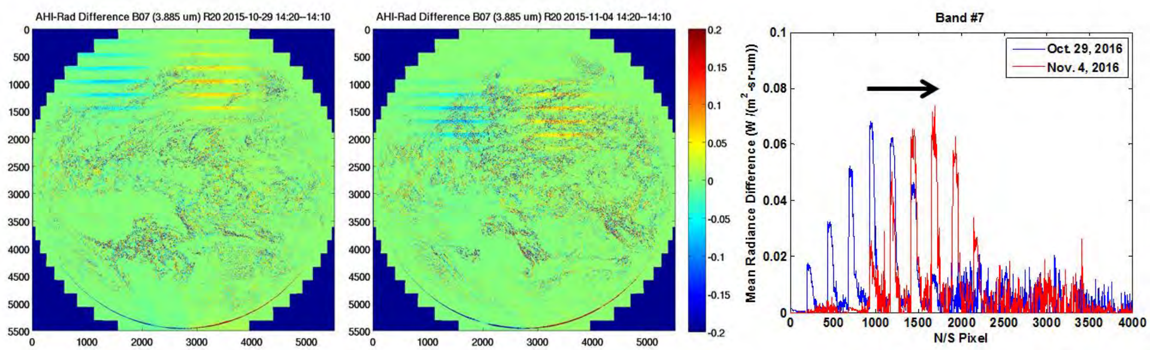


Figure 2: Top panel shows the time series of T_B of Shanghai City center (red line) and reference site on Chongming Island measured by 3.9 um channel of AHI during October, 2015. Bottom panel shows the T_B difference between two sites.

7. Stray Light Monitoring Tool Development and Testing with Himawari-8 AHI

There have been stray light observed in the full disk imagery of the AHI 3.9-µm channel over a few weeks around February and October-November when the line of sight of the sun is at ~10 to ~20 degrees south of the nadir of the Himawari-8. Difference data between consecutive AHI 3.9-µm images have been processed to quantitatively characterize and monitor the AHI stray light. Stray light indices are also developed to trend the occurrence, position and magnitude of the stray light in the AHI 3.9-µm imageries. It is also found that the stray light is the greatest in the AHI 3.9-µm band but also is detectable in other Mid-Wavelength IR channels. Analysis of the ratio of stray light magnitude between AHI 3.9-µm and 6.2-µm band indicates that it is consistent with the ratio of solar radiance for these two bands. This suggests that the stray light is mainly due to direct illumination of the attenuated solar radiation on the AHI detector rather than from onboard thermal body emission due to heating. The ABI onboard the GOES-R satellite has very similar spectral and spatial characteristics as AHI. Therefore, characterizing the stray light in the 3.9-µm channel of AHI helps support post-launch calibration activities of ABI. This work is published in Shao et al. [2016b].



(a) (b) (c)

Figure 5: Panel (a) and (b) show frame-to-frame radiance difference image between UT 14:10 and 14: 20 on Oct. 29 and Nov. 2, 2015, respectively, for the AHI 3.9 um channel. Panel (c) shows the mean radiance difference along the N/S direction as derived from Panel (a-b).

Planned work:

We will continue to support calibration and validation work for GOES-R Advanced Baseline Imager (ABI) through

- Support lunar calibration for GOES-R ABI through
  - Analysis and comparison of Himawari-8 AHI and ABI lunar observation data and perform lunar radiance calibration for ABI
- Develop tools to support radiometric calibration of GOES-R ABI through
  - *Cross-comparison of stellar radiometric trending with calibration from other methods such as lunar, solar diffuser*
- Develop tools to support Imagery Navigation and Registration (INR) of GOES-R ABI through
  - Use Control Point Matching method to perform INR monitoring of GOES-R ABI Channel 2

Publications: (Non-peer reviewed)

1. Yu, F., Wu, Xiangqian, Shao, X. and Kondratovich, V., "Evaluation of Himawari-8 AHI geospatial calibration accuracy using SNPP VIIRS SNO data," *IEEE International Geoscience and Remote Sensing Symposium*, TUP.P32.169, Beijing, (2016).
2. X. Shao, C. Cao, B. Zhang, Y. Bai, X. Wu and F. Yu, "Comparison of Suomi-NPP VIIRS and HIMARWARI-8 AHI MWIR observations for hot spot and heat island studies," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016, pp. 1954-1957. doi: 10.1109/IGARSS.2016.7729503
3. Shao, X., Xiangqian Wu and Fangfang Yu, Characterization of Himawari-8 AHI 3.9-um channel stray light , *Proc. SPIE* 9972, Earth Observing Systems XXI, 99720R (September 19, 2016); doi:10.1117/12.2237052, (2016b).

Presentations:

1. Shao, X., Cao, Changyong, Zhang, B., Bai, Y., Wu, Xiangqian and Yu, Fangfang, "Comparison of Suomi-NPP VIIRS and HIMAWARI-8 AHI MWIR observations for hot spot and heat island studies," *IEEE International Geoscience and Remote Sensing Symposium*, TU3.L8.4, Beijing, (2016).

2. Shao, X., Xiangqian Wu and Fangfang Yu, Characterization of Himawari-8 AHI 3.9-um channel stray light , *Proc. SPIE* 9972, Earth Observing Systems XXI, 99720R (September 19, 2016); doi:10.1117/12.2237052.

Products:

GOES ABI Solar Avoidance Zone Prediction Tool

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	3
# of presentations	2
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	1

Pre- and Post-Launch Calibration/Validation Support for J1 and Suomi-NPP VIIRS

Task Leader	Xi Shao
Task Code	XSXS_CLVL_16
NOAA Sponsor	Changyong Cao
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 90%; Theme 2: 10%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation;
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS scientists provide operational science support for Suomi-NPP and J1 VIIRS instrument through support radiometric calibration and validation of VIIRS by providing pre-launch Support for J1 VIIRS, performing lunar calibration, characterizing spectral degradation of solar diffuser due to space radiation exposure, supporting DNB radiometric validation with nightlight sources for SNPP VIIRS, DNB stray light correction LUT generation tool development for Suomi-NPP and J1 VIIRS, and supporting VIIRS SDR team management and coordination.

Background

The Suomi-NPP satellite was successfully launched on October 28, 2011. The Visible Infrared Imaging Radiometer Suite (VIIRS) is one of five instruments onboard the Suomi-NPP (SNPP) satellite and acquired its first measurements in November 2011 [*Cao et al.*, 2013, 2014]. The SNPP VIIRS instrument has undergone a period of intensive cal/val and the instrument on-orbit performances are stable. As the follow up mission, JPSS-1 (J1) is the second spacecraft in the NOAA's next generation of polar-orbiting satellites. It is scheduled to launch in early 2017. The primary objective of the J1 mission is to provide a continuation of the NOAA heritage polar-orbiters in the afternoon orbit. The VIIRS onboard both SNPP and J1 is designed to provide moderate-resolution, radiometrically accurate images of the globe twice daily and has 22 spectral bands covering the spectrum between 0.41 µm and 12 µm, including 14 reflective solar bands (RSB), 7 thermal emissive bands (TEB), and 1 day-night band (DNB). It collects visible and infrared imagery and global observations of land, atmosphere, cryosphere, oceans, primarily focused on clouds, Earth surface variables, Sea Surface Temperature (SST) and Imagery.

This work supports post-launch and pre/post-launch calibration/validation work for SNPP and J1 VIIRS, respectively. The goal of pre-launch period of J1 VIIRS is to characterize J1 VIIRS instrument using prelaunch test data. Pre-launch tasks include VIIRS performance verification, performance waiver studies, and pre-launch calibration look-up-table (LUT) development and testing. The post-launch period of J1 VIIRS covers three phases: Post-Launch Tests (PLT), aka, early orbit instrument checkout (EOC), intensive calibration/validation (ICV), and long-term monitoring (LTM). Our tasks focus on supporting long term monitoring of SNPP VIIRS, pre-launch calibration/validation and prepare for PLT of J1 VIIRS.

Accomplishments

We supported the Suomi-NPP VIIRS calibration in a broad scope by:

1. Long term monitoring of the DNB geolocation accuracy/stability and validation of terrain correction

We selected ground based night light source such as Lhasa airport on the Tibetan Plateau at high elevation and oil platform Holly which is a ground point source at sea level to validate the DNB geolocation accuracy at different scan angles with terrain correction [Figure 1]. The result showed that before and after terrain correction (TC) for Lhasa airport, the geolocation errors at nadir are small both before and after TC [Figure 2]. However, before TC, the error greatly increases with scan angle and can be up to nearly 10km at high scan angles. At sea level, we used about one year DNB data over oil platform Holly and the result showed terrain correction near sea level has very small effects [Figure 2].

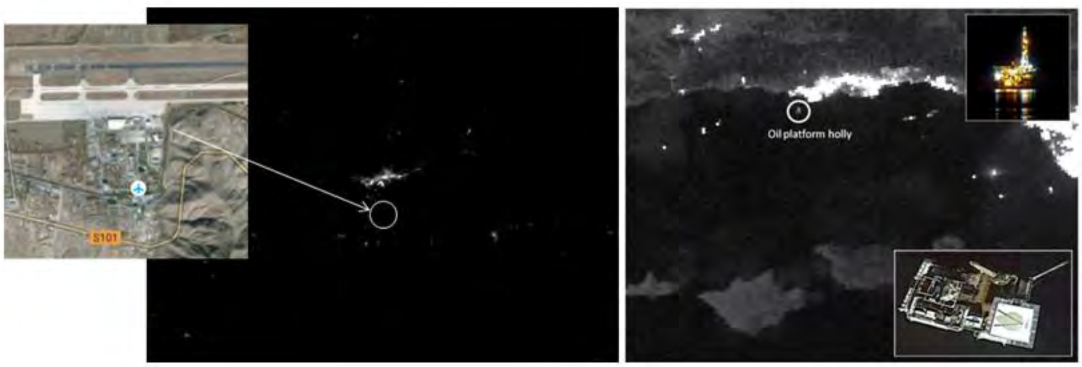


Figure 1. DNB image of the Lhasa airport, Tibet, China (left), and Oil platform Holly, California (right)

2. Comparison of NOAA VIIRS IDPS SDR Operational and Reprocessed Data

Since VIIRS was launched on October 28, 2011, there have been many updates in the NOAA operational processing of VIIRS Sensor Data Record (SDR), which lead to inconsistencies in the long-term data records. In order to generate a complete set of long-term data, the VIIRS SDR needs to be reprocessed using the new coefficients and updated algorithms. We supported preparation of LUTS for VIIRS SDR reprocessing and compared the VIIRS operational IDPS and reprocessed SDR data. The improved LUTs incorporated into the VIIRS SDR reprocessing are

- Thermal Emissive Bands (TEB): Ltracer method during WUCD period.
- Reflective Solar Bands (RSB): Using RSB F factors provided by Ocean Color team.
- Day Night Band: DN0 and Gain ratio LUT updates and stray light correction.

Figure 3 shows the comparison between IDPS and reprocessed SDR for M1-M4 band. It can be seen that RSB radiance ratio is generally consistent with the ratio of Ocean Color team provided-F factor to the RSBAutoCal F-Factor. Small spatial variations of radiance ratio could be the results of different gain stages in RSB bands. In general, M2 band has the largest radiance ratio, while M1 band has the smallest ratio.

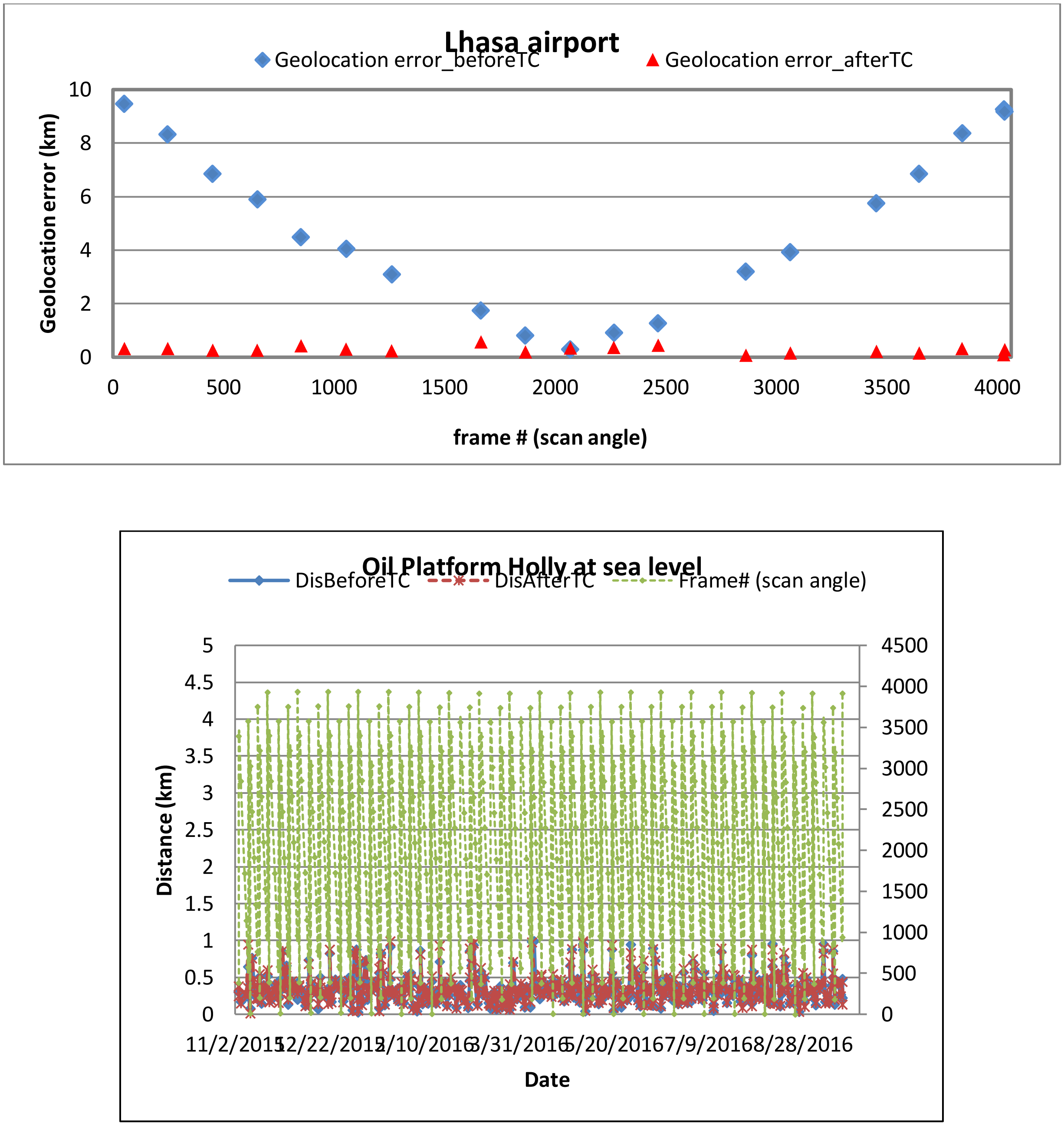


Figure 2. (Top) Geolocation error of Lhasa airport before and after terrain correction; (Bottom) Geolocation error vs scan angle (frame number) from November 2015 to September 2016 for Oil Platform Holly.

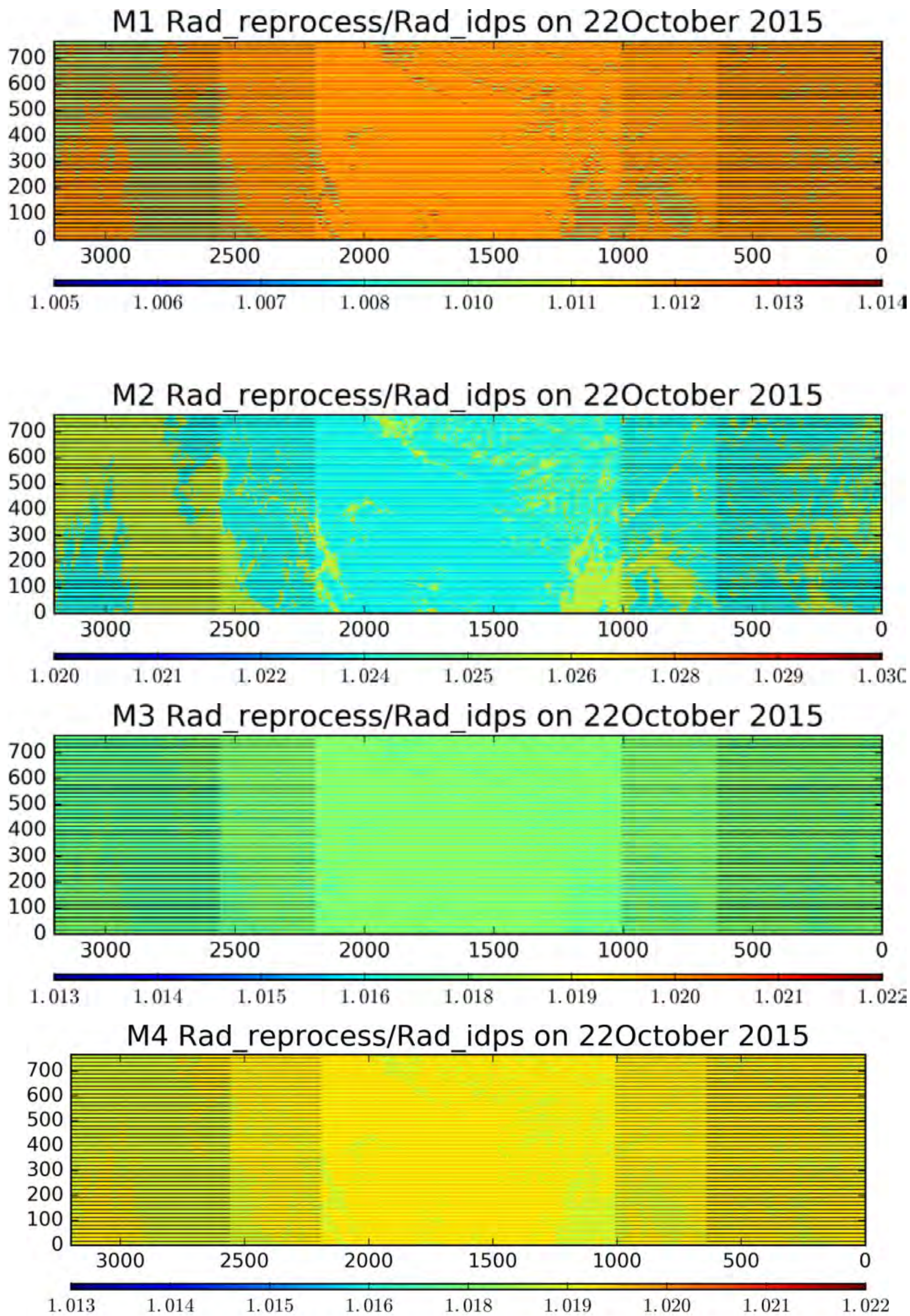


Figure 3. The ratio of reprocessed radiance to IDPS radiance for RSB bands M1, M2, M3, and M4 over Gulf of Mexico.

3. Support DNB stray light correction LUT generation tool development for J1 VIIRS

The SNPP VIIRS DNB sensor is affected by terminator stray light which is due to solar illumination on the instrument after the satellite passes through the day-night terminator projected on Earth's surface. For DNB of J1 VIIRS, similar stray light can occur. Stray light in the DNB imagery can be seen on the night side of the terminator that causes a positive offset in radiance when the satellite moves from day to night in the northern hemisphere. In the southern hemisphere, it starts at the penumbra and becomes insignificant as the spacecraft heads into the day side of the orbit. To minimize the stray light effect, stray light LUTs are generated to remove the offset for pixels that are affected. Each LUT is generated by using radiance data from terminator crossings close to the time of a new moon phase that are not contaminated by aurorae or lights related to human activities. We support the DNB stray light correction software development for J1 VIIRS. In particular, we developed semi-automatic selection algorithm for granular selection with minimum auroral or artificial light contamination.

4. Support feasibility assessment of replacing one of VIIRS M band with water vapor band

Existing VIIRS bands do not cover the water vapor band around 6.53 um. The closest band to this frequency is M13 (with central wavelength at 4.05um) and M14 (central wavelength at 8.55um). In the future VIIRS onboard JPSS series satellites it will be ideal if a water vapor channel can be added to VIIRS so that tropospheric water vapor can be observed at spatial and temporal resolution of VIIRS. With the added water vapor channel VIIRS can supplement the temporal coverage of MODIS especially for regions where GOES series satellites do not cover, such as Alaska and near polar area for better weather forecasting and analysis. However, due to heritage design of VIIRS there is no space left for addition of a new channel. An alternative is to replace an existing channel. Some options are considered; one is to remove M10 because it has very similar spectral response function to that of the imagery band I03 centered at 1.61um. Assessment of the radiance difference from the two bands has been studied to estimate the impact on replacing of M10 using I03 observations. It is found that the detector (at M10) level responsivity to a new water vapor channel at 6.7um is low, which makes placing the water vapor at M10 not a good choice. We also evaluate the other option to remove a long wave infrared channel M16B. M16B and M16A have very similar spectrum response function. They are redundant and combined on orbit and mainly used in SST algorithm. So it is possible to replace M16B with a water vapor channel.

5. Supported DNB radiometric validation with nightlight sources and developed a new capability to monitor VIIRS DNB calibration with lunar radiance reflected from deep convective cloud (DCC)

The deep convective cloud (DCC) is known to have a stable reflectance in the visible spectral range. Therefore, the reflected lunar radiance from the DCC provides a unique dataset of lunar radiance changes with phase angle. We developed a new capability to monitor VIIRS DNB using DCC reflected lunar radiance data at various phase angles and compared the results to those from lunar model predictions. This is useful not only for monitoring the DNB calibration stability, but also may help validate lunar models independently.

6. Performed comparison between SNPP VIIRS Block2 System output with IDPS operational output.

This comparison validates the SNPP VIIRS Block2 System and enables the migration to Block2 System for SNPP VIIRS SDR production.

7. Coordinate the publication of special issue "Calibration/Validation of Visible Infrared Imaging Radiometers and Applications" for VIIRS.

We also provided figure editing and graphic design for the special issue.

8. Support VIIRS SDR Team Management and Coordination

a. Organize and archive weekly and monthly status reports on task activities and presentation materials, and technical reports.
b. Update and maintain the NOAA calibration center calibration knowledge base online
c. Document the VIIRS sensor status, calibration and validation progress, and the recommendation on the VIIRS sensor operation, software change, and look-up table update to NPP/JPSS management.
d. Maintain computer servers at UMD for VIIRS data processing for the VIIRS SDR team

Planned work

1. Perform lunar calibration for SNPP and J1 VIIRS
2. Validate the VIIRS Day/Night Band geolocation accuracy at different scan angles
3. Support DNB stray light correction LUT generation tool development for J1 VIIRS
4. Support DNB radiometric validation with nightlight sources
5. Support Inter-satellite calibration between VIIRS and instrument on other satellites
6. Continue to develop a method to reduce striping in VIIRS SDR Products
7. Develop the calibration/validation knowledge base for JPSS J1 VIIRS and make it available on the website at https://ncc.nesdis.noaa.gov. We have previously developed a similar knowledge base for Suomi NPP and it has been used extensively by both the program and users worldwide. We will expand this capability to JPSS J1 and maintain the website.
8. Other tasks include maintaining computer servers at UMD for VIIRS data processing for the VIIRS SDR Team; support VIIRS SDR team calibration and validation activities; work with all VIIRS teams on future planning, execution, and reporting; Support coordination of the interaction between the VIIRS SDR, CrIS SDR, and VIIRS EDR teams.

Publications:

Non-Peer-Reviewed:

1. X. Shao, C. Cao, B. Zhang, Y. Bai, X. Wu and F. Yu, "Comparison of Suomi-NPP VIIRS and HIMARWARI-8 AHI MWIR observations for hot spot and heat island studies," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016a, pp. 1954-1957. doi: 10.1109/IGARSS.2016.7729503

Presentations:

1. Wang, Zhuo, Wenhui Wang, and Changyong Cao: Feasibility study of VIIRS detector-level spectral response SDR processing and calibration, University of Maryland CICS Annual Meeting, College Park, Maryland, 2016.
2. Bai. Y., C. Cao, X. Shao, and B. Zhang, Validating the VIIRS Day/Night Band geolocation accuracy at different scan angles with terrain correction, EUMETSAT Meteorological Satellite conference, 26-30, September 2016.

3. B. Zhang and C. Cao, "A preliminary study of aggregating VIIRS I3 to generate M10 for adding a future water vapor band," NOAA JPSS Annual Review Meeting, College Park, MD, 2016. (Poster)
4. Shao, X., Cao, Changyong, Zhang, B., Bai, Y., Wu, Xiangqian and Yu, Fangfang, "Comparison of Suomi-NPP VIIRS and HIMAWARI-8 AHI MWIR observations for hot spot and heat island studies," IEEE International Geoscience and Remote Sensing Symposium, TU3.L8.4, Beijing, (2016).

Other

Award: Xi Shao received NOAA/NESDIS/STAR Innovative Research Award for the publication of the research work on "Shao, X.; Cao, C.; Liu, T.-C. , Spectral Dependent Degradation of the Solar Diffuser on Suomi-NPP VIIRS Due to Surface Roughness-Induced Rayleigh Scattering, *Remote Sens.* 2016, *8*, 254."

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	1
# of presentations	4
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

J1-VIIRS and SNPP-VIIRS Calibration Support

Task Leader	Xi Shao
Task Code	XSXS_J1VI_15 Year 2
NOAA Sponsor	Changyong Cao
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 90%; Theme 2: 10%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation;
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS scientists provide prelaunch science support for JPSS-1 (J1) VIIRS instrument through support J1-VIIRS SDR look-up-tables (LUTs) validation, analysis of J1-VIIRS DNB scan mode change, developed tool to validate the VIIRS Day/Night Band geolocation accuracy and for DNB radiometric validation with nightlight sources, and support J1-VIIRS TEB band calibration/calibration.

Background

JPSS-1 (J1) is the second spacecraft within NOAA's next generation of polar-orbiting satellites. It is scheduled to launch in early 2017. The primary objectives of the J1 mission is to provide a continuation of the group of Earth system observations initiated by the Earth Observing System Terra, Aqua, Aura, and Suomi-NPP missions. VIIRS (Visible Infrared Imaging Radiometer Suite) onboard J1 is designed to provide moderate-resolution, radiometrically accurate images of the globe twice daily. It collects visible and infrared imagery and global observations of land, atmosphere, cryosphere and oceans. Similar to SNPP VIIRS, J1-VIIRS has 22 spectral bands covering the spectrum between 0.41 µm and 12 µm, including 14 reflective solar bands (RSB), 7 thermal emissive bands (TEB), and 1 day-night band (DNB). J1-VIIRS generates many critical environmental products about snow and ice cover, clouds, fog, aerosols, fire, smoke plumes, dust, vegetation health, phytoplankton abundance and chlorophyll.

Our team at University of Maryland has been supporting Sensor Data Record (SDR) calibration and validation of SNPP VIIRS instrument since its launch. As a continuation of our support for the calibration/validation of SNPP VIIRS, we will provide critical support for the SDR calibration/validation of J1-VIIRS to ensure the success of J1-VIIRS. To ensure that the J1-VIIRS mission requirements are met, we will provide expertise/technical support for J1-VIIRS SDR look-up-tables (LUTs) preparation/testing/validation, for analysis of J1-VIIRS DNB scan mode change due to DNB nonlinearity. We will also support J1-VIIRS TEB band calibration/calibration and calibration of J1-VIIRS SWIR band nonlinearity.

Accomplishments

We supported the J1 VIIRS calibration in a broad scope by :

1. **Performed feasibility study of VIIRS detector-level spectral response SDR processing and calibration**

Since each detector of VIIRS has its own relative spectral response (RSR) and they are not identical, ideally, SDR or level 1B data should be generated for each detector as if it is an independent detector. However, this is computationally complex and expensive, and the current SDR data is generated based on the band-averaged RSR, treating multiple detectors as one average virtual detector, at the expense of accuracy. We investigated the impacts of detector level RSR difference on VIIRS SDRs in both thermal emissive bands (TEB) and reflective solar bands (RSB) and the feasibility to use detector level RSR in VIIRS SDR processing and calibration. Atmospheric dependencies at detector level top of atmosphere reflectance and brightness temperature differences were observed in the NOAA operational VIIRS SDRs, especially over tropical oceans. Striping is also related to the difference between band-averaged and detector-level RSR.

Using TEB as an example, new TEB radiance-temperature conversion look-up-tables (LUT) were generated using the detector-level RSR, and the corresponding science code change was studied. The detector-level and band-averaged LUTs were used to generate sample SDR data over the uniform clear-sky ocean surface near tropical and polar regions. Bands M15 and M16 of VIIRS brightness temperatures were analyzed using the sample cases to study the influence of detector-level RSR on TEB striping patterns. In general, the detector-level processing generates more realistic SDR products, but it also may lead to more striping (Figure 1).

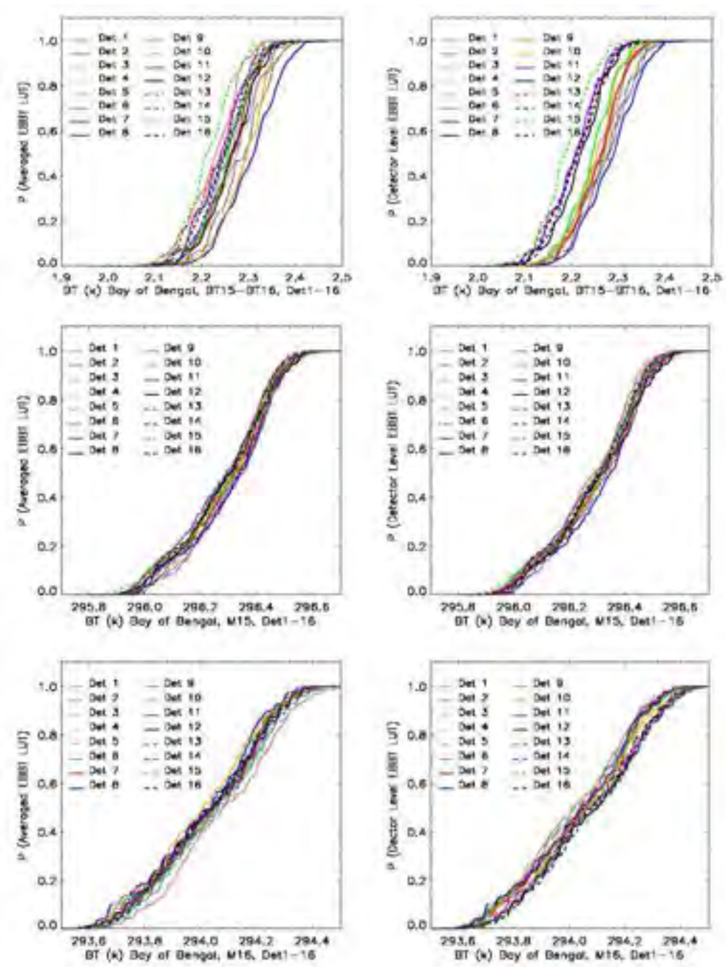


Figure 1. The cumulative histogram for Bay of Bengal over tropical region on 22 June 2014 using the band-averaged RSR (Left) and detector-level RSR (Right) in M15 – M16 (Top), M15 (Middle), and M16 (Bottom).

2. Support J1-VIIRS SDR look-up-tables (LUTs) validation

We validated the J1 VIIRS LUTs including OBCBB Emitted Radiance, OBCBB Reflected Radiance, Radiance to Effective Blackbody Temperature (EBBT), HAM Emitted Radiance, RTA Emitted Radiance, Common Geolocation LUT, and South Atlantic LUT.

3. Supported comparison between ADL Block 2 (version 5.2) results and IDPS results (ADL version 4.2).

This prepares the implementation of ADL Block 2 for J1 VIIRS SDR production.

4. Performed analysis of aggregating VIIRS I3 products and comparison with M10 data.

Water vapor observation at channels with central wavelength around 6.5 um is of great importance in weather forecasting and climate change detection, such as in MODIS, GOES, and GOES-R series of satellites. The VIIRS onboard Suomi NPP has 22 bands, however, does not have a water vapor sensing band, and the current VIIRS design cannot make space for additional band. Since the high resolution (375m) imagery band I03 and moderate resolution (750m) band M10, have very similar Spectral Response Functions centered at 1.61 um, it is possible to replace M10 observations with that from I03 to make space for a new water vapor band. However, the impact of removing M10 on different users should be assessed thoroughly.

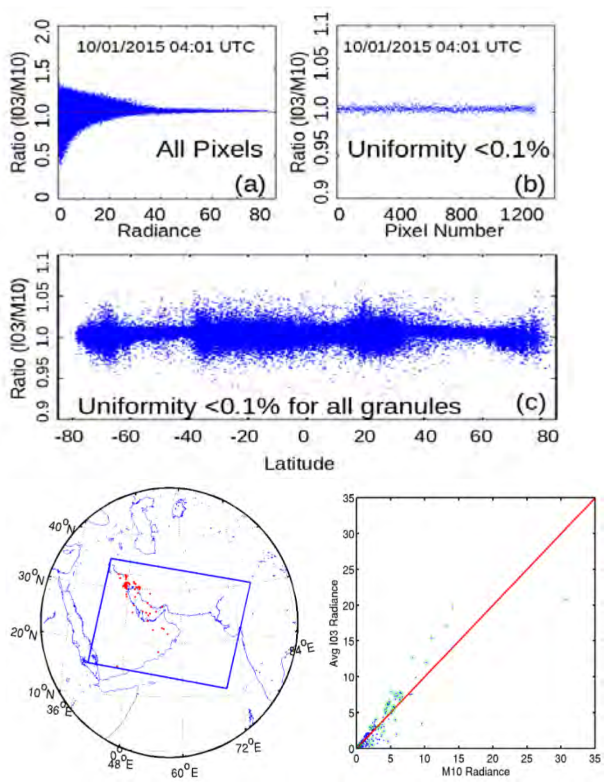


Figure 2: Radiance ratio between aggregated I03 and M10. (a) Ratio of all valid M10 pixels for one granule. (b) Ratio for uniformity less than 0.1% for one granule. (c) Ratio for uniformity less than 0.1% for all granules on Oct.1st, 2015. Bottom right: Scatter plots of aggregated I03 radiance and M10 radiance at 06/12/2014 21:54. Bottom left: for radiance more than 1 W/m2/sr/um and their locations (red dots in bottom right panel). The green circles indicate fire pixels detected. Blue box marks granule boundaries.

M10 and I03 are mainly used for obtaining surface reflectance at different resolution and for snow detection. M10 can also be used in cloud and aerosol detection, and in detecting night fire from gas flares and combustion sources. We examined the VIIRS SDR dataset and compared the radiance from M10 and aggregated I03 (to M10) with different earth observations [Figure 2]. At day time, the M10 and I03 have very good agreement, but the radiance ratio between them is affected mainly by the uniformity of I03 pixels and different surface types. Over snow surface, the radiance scatterplot shows less scattered than that with no snow, indicating I03 has similar ability as M10 in snow detection. Limited night datasets indicate radiance of I03 and M10 are different, but I03 may also have superior ability in detecting night fire from gas flares and combustion sources. This study provides an early assessment of the feasibility of aggregating I03 to M10 in order to replace the M10 with a water vapor band.

5. **Developed tool to validate the VIIRS Day/Night Band geolocation accuracy at different scan angles, and evaluate the effect of terrain correction**

We have performed preliminary studies by selecting validation sites at different altitudes, such as the Oil Platform Holly at sea level, and isolated nightlights on the Qinghai-Tibet Plateau at > 3 km altitude as primary validation point sources. By comparing the geolocation errors before and after terrain correction of these sites, we found that geolocation errors at the Qinghai-Tibet plateau are greatly reduced from more than 1 km to within 200 meters after terrain correction. This suggests that terrain correction greatly increased geolocation accuracy at high elevations. On the other hand, at sea level, terrain correction has little impact on geolocation accuracy as expected. In addition, we also found that the geolocation errors are not correlated with scan angle or frame# for the validation sites. This validation capability of scan angle dependency and terrain correction is especially important for VIIRS DNB on JPSS J1 due to the changes of its onboard aggregation scheme at high scan angles.

6. **Developed tool for DNB radiometric validation with nightlight sources.**

The radiometric calibration of low gain stage (LGS) of VIIRS Day/Night Band (DNB) onboard Suomi-NPP is performed using onboard solar diffuser. In operations, the high gain stage (HGS) values of DNB are determined by multiplying the LGS gain gains with the HGS/LGS ratio determined from the data collected along solar terminator region. The transfer of DNB calibration from LGS to HGS causes increase of uncertainties and affects the accuracy of the low light radiances at night for DNB. We supported monitoring the stability of the low radiance observations at night by DNB through analyzing and trending DNB observations of stable night lights such as over bridge and power plant and identified and characterize stable these light sources.

7. **Monitoring VIIRS DNB calibration with lunar radiance reflected from deep convective cloud (DCC)**

The deep convective clouds (DCC) are known to have a stable reflectance in the visible spectral range. Therefore, the reflected lunar radiance from the DCC provides a unique dataset of lunar radiance changes with phase angle. We developed a new capability to monitor VIIRS DNB using DCC reflected lunar radiance data at various phase angles and compared the results to those from lunar model predictions. This is useful not only for monitoring the DNB calibration stability, but also may help validate lunar models independently. This will be used monitor J1 VIIRS DNB calibration stability.

Planned work

We will continue to perform the following work to support calibration and validation for J1 VIIRS.

- Expand the validate capabilities by including more validation sites, and perform additional statistical analysis. A complete system will be developed for the validation of JPSS J1 VIIRS DNB by its launch in 2017
- Support post-launch J1-VIIRS SDR look-up-tables (LUTs) validation
- Subtract radiances due to lunar illumination on the sites of interest based on predictions from lunar irradiance model and apply cloud screening using VIIRS cloud mask product. The VIIRS DNB data from two sources such as IDPS and NASA Land Peate will be compared at the monitoring sites, which can revealed some differences possibly due to difference in the calibration algorithm implementation.
- Develop a new capability to monitor VIIRS DNB using DCC reflected lunar radiance data at various phase angles and compared the results to those from lunar model predictions. This is useful not only for monitoring the DNB calibration stability, but also may help validate lunar models independently. This will be done for both Suomi NPP and J1 VIIRS DNB.

Publications

Non-Peer-Reviewed:

1. B. Zhang and C. Cao, "A preliminary study of aggregating VIIRS I3 to generate M10 for adding a future water vapor band," *2016 IEEE international Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016, pp. 3017-3020. doi: 10.1109/IGARSS.2016.7729780

Presentations:

1. B. Zhang and C. Cao, "A preliminary study of aggregating VIIRS I3 to generate M10 for adding a future water vapor band," *2016 IEEE international Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016, (POSTER)
2. Bai. Y., C. Cao, X. Shao, and B. Zhang, Validating the VIIRS Day/Night Band geolocation accuracy at different scan angles with terrain correction, JPSS 2016 Annual Science Team Meeting, College Park, MD, 8 - 12 August, 2016.
3. Wang, Zhuo, Wenhui Wang, and Changyong Cao: Feasibility study of VIIRS detector-level spectral response SDR processing and calibration, EUMETSAT 2016 - Meteorological Satellite Conference, Darmstadt, Germany, 26 - 30 September 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	1
# of presentations	3
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support of SNPP VIIRS SDR Calibration and Team Management/Coordination	
Task Leader	Xi Shao
Task Code	XSXS_SNPP_15 Year 2
NOAA Sponsor	Changyong Cao
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 90%; Theme 2: 10%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation;
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS scientists provide operational science support for Suomi-NPP VIIRS instrument through support radiometric calibration of VIIRS by trending with lunar model and vicarious methods; perform VIIRS IDPS data quality assessment; perform DNB stray light correction assessment with DNB observation under moon-light; support DNB radiometric and geolocation validation with nightlight sources and support VIIRS SDR team management and coordination.

Background

The Suomi-NPP satellite was successfully launched on October 28, 2011. VIIRS (Visible Infrared Imaging Radiometer Suite) onboard the Suomi-NPP satellite is designed to provide moderate-resolution, radiometrically accurate images of the globe twice daily and primarily focus on clouds, Earth surface variables, Sea Surface Temperature (SST) and Imagery. It has 22 spectral bands covering the spectrum between 0.412 µm and 12.01 µm, including 14 reflective solar bands (RSB), 7 thermal emissive bands (TEB), and 1 day-night band (DNB).

The VIIRS instrument has undergone a period of intensive calibration/validation and the instrument on-orbit performances are stable. For the RSBs, the calibration uncertainty in spectral reflectance for a scene at typical radiance is expected to be less than 2%. For DNB, when the Suomi-NPP moves from day to night in the northern **hemisphere** and from night to day in the southern hemisphere, stray light occurs and contaminates the DNB imagery and straylight correction are required. To meet these requirements, We support radiometric calibration for VIIRS through vicarious calibration of VIIRS RSB bands, assessment of VIIRS stability through comparing lunar, solar diffuser and vicarious calibration, inter-satellite calibration between VIIRS and instrument on other satellite, investigating effects of space radiation on VIIRS stability (SDSM spectral degradation), and performing lunar calibration for VIIRS. We also support the assessment of DNB stray light correction.

The work help to ensure the production of high quality radiometrically and geometrically corrected sensor data records for Suomi-NPP VIIRS; update and improve SNPP VIIRS calibration and validation; establish and maintain SI traceability for SNPP/JPSS VIIRS, reduce their measurement uncertainties, and assure data quality with best calibration practices.

ACCOMPLISHMENTS

We supported the Suomi-NPP VIIRS calibration in a broad scope by

1. **Developed online tool to monitor the DNB geolocation accuracy and stability to provide long term support on DNB geolocation validation.**

An interactive online tool has been developed to validate DNB geolocation error using night light sources. The VIIRS DNB geolocation at night is evaluated using point sources such as lights from oil platforms. We generated the error assessments DNB geolocation and made the results available on line (https://ncc.nesdis.noaa.gov/VIIRS/VIIRSGeoErrors.php). This provides long term support on DNB geolocation validation.

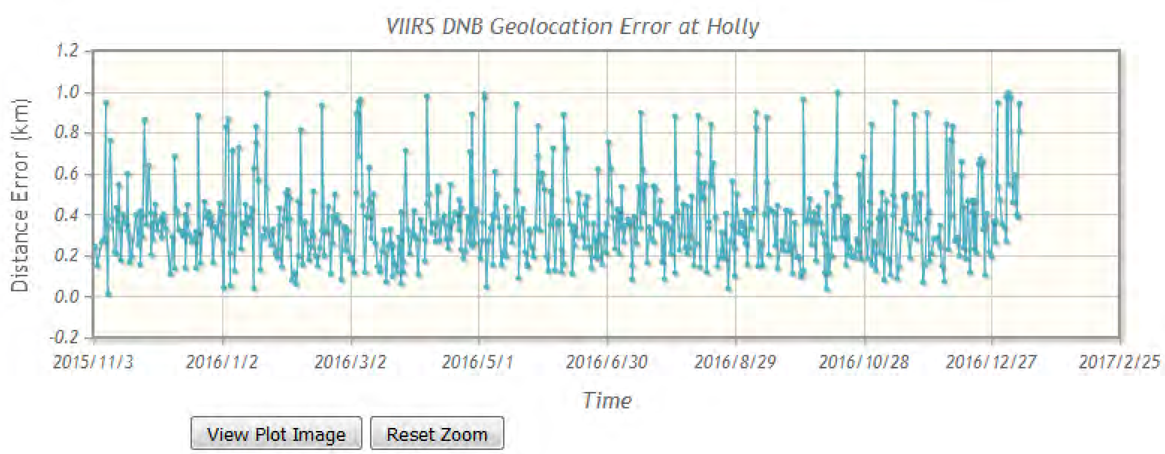


Figure 1: Example of the online monitoring of DNB geolocation error from night light source at oil platform Holly.

2. **Comparison of NOAA Operational and NASA Land SIPS Reprocessed Suomi NPP VIIRS SDR Products**

The purpose of this study is to investigate the difference between NOAA operational and NASA Land SIPS (Science Investigator Processing System) SDR products over the well-established validation site MOBY in Hawaii. The primary area of interest of this study is area over the Marine Optical BuoY (MOBY), located at (20°49’ N, 157° 11.5’ W), which is the primary ocean measurement site for vicarious calibration of satellite ocean color sensors. The comparisons were performed for bands M1-M7 and M15 from January 2012 to December 2015. Our results quantified difference in radiance between IDPS and NASA reprocessed data for bands M1– M3 for the entire study period [Figure 2]. Large differences are observed in M4 from 2012 to 2014 [Figure 2], as well as for band M5-M7 in 2012. There is no significantly radiance difference in M15 band. This comparison helps trace the difference back to the differences and updates in calibration algorithm and prepares for the reprocessing of VIIRS SDR data.

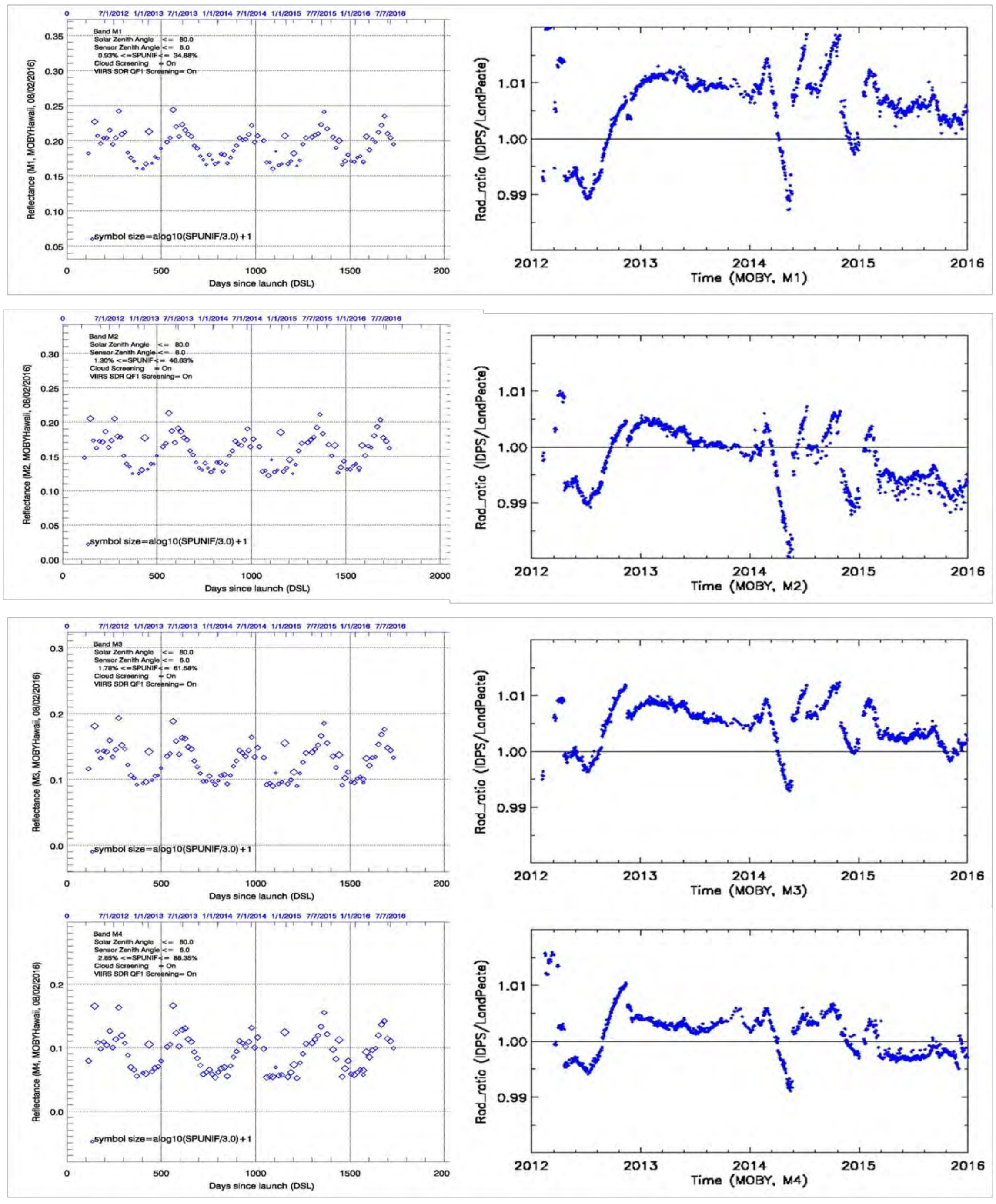


Figure 2. NOAA operational VIIRS SDR data on IDPS over MOBY Hawaii site (Left panel); Right: Radiance ratio of NOAA operational IDPS data to NASA Land PEATE /SIPS VIIRS SDR data for bands M1 to M4.

3. We performed assessment of straylight correction performance for VIIRS day/night band.

We used Dome-C and Greenland under lunar illumination and compared the straylight correction performance between the NOAA IDPS and the NASA Land PEATE data. The straylight effect was observed in the DNB band which appeared as gray haze in radiance images. Straylight correction techniques have been implemented to remove this effect. This study presented an effective method to assess performance of straylight correction for VIIRS DNB band using DNB observations over Dome C in the Antarctic and Greenland in the Arctic under lunar illumination. Through cross-comparison between lunar-phase dependence of DNB observations of events with straylight correction and those without straylight, the quality of straylight correction has been assessed. Using this method, DNB radiance data from two different sources, i.e. the NOAA IDPS and the NASA Land PEATE data, are compared for their performance in straylight correction.

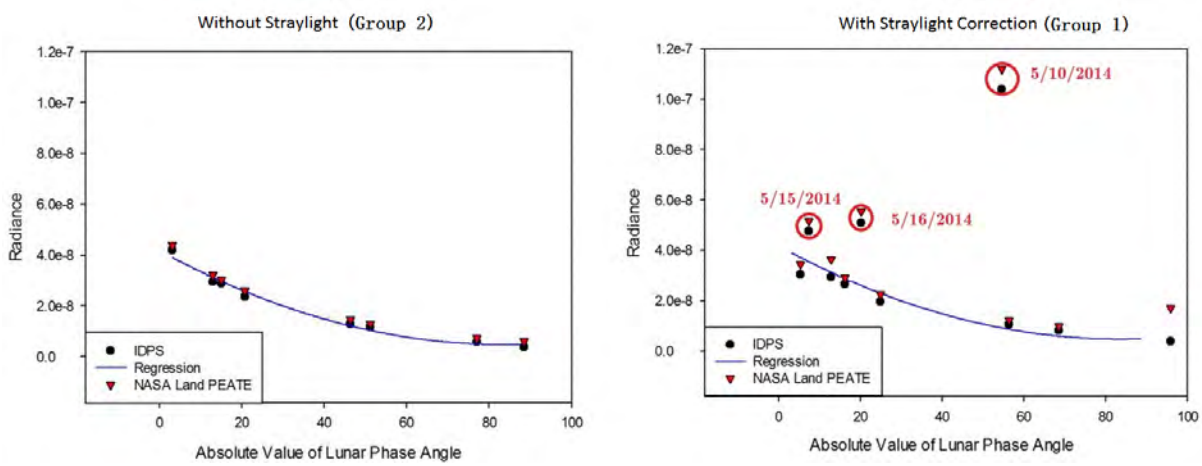


Figure 3: Cross-comparison between lunar-phase dependence of DNB observations of DOME C under Moon light for events without straylight (left) and those with straylight correction (Right). The performance of straylight correction in both NOAA IDPS and the NASA Land PEATE data has been assessed.

4. We developed a new capability to monitor VIIRS DNB calibration with lunar radiance reflected from deep convective cloud (DCC).

The deep convective cloud (DCC) is known to have a stable reflectance in the visible spectral range. Therefore, the reflected lunar radiance from the DCC provides a unique dataset of lunar radiance changes with phase angle. We developed a new capability to monitor VIIRS DNB using DCC reflected lunar radiance data at various phase angles and compared the results to those from lunar model predictions. This is useful not only for monitoring the DNB calibration stability, but also may help validate lunar models independently.

5. We performed comparison between SNPP VIIRS Block2 System output with IDPS operational output.

This validates the SNPP VIIRS Block2 System and enables the migration to Block2 System for SNPP VIIRS SDR production.

6. We performed comparison of Suomi-NPP VIIRS and Himarwari-8 AHI MWIR observations for hot spot and heat island studies.

The results were published in Shao et al. [2016a].

7. We continued to update the VIIRS event database.

The Event log database has been updated by archiving events that occurred to Suomi NPP VIIRS since launch. This includes major events such as sync loss, single event upset outage, as well as planned events such as lunar maneuvers, blackbody warm-up cool-down (WUCD), star tracker realignment, etc. This is very useful for instrument diagnoses, time series trending and analysis, and future reanalysis and recalibration. We have used the Event log database to collect lunar maneuver data which has been used for the lunar band ratio analysis. It is also used to correlate the time and location of the single event upset outage in instrument anomaly and diagnosis. While the database mainly includes instrument related events, the ground processing related events such as MX updates are being added.

8. We support VIIRS SDR team management and coordination

a. *Organize and archive weekly and monthly meeting and status reports.*
b. *Update VIIRS knowledge-base for the dissemination of NPP VIIRS cal/val information and parameters online*
c. *Document the VIIRS sensor status, calibration and validation progress, and the recommendation on the VIIRS sensor operation, software change, and look-up table update to NPP/JPSS management.*
d. *Maintain computer server at UMD for VIIRS data processing for the VIIRS SDR team*

Planned work:

- Continue to study VIIRS DNB calibration with lunar radiance reflected from deep convective cloud (DCC) by analyzing more DNB data.
- Perform radiometric calibration for VIIRS through vicarious calibration of VIIRS RSB bands
- Perform assessment of VIIRS stability through comparing lunar, solar diffuser and vicarious calibration, inter-satellite calibration between VIIRS and instrument on other satellite,
- Continue to perform assessment of DNB stray light correction.

Publications:

Peer-Reviewed:

1. Wang, L., B. Zhang, D. Tremblay, and Y. Han (2017), Improved scheme for Cross-track Infrared Sounder geolocation assessment and optimization, J. Geophys. Res. Atmos., 122, 519–536, doi:10.1002/2016JD025812.

Non-Peer-Reviewed:

2. X. Shao, C. Cao, B. Zhang, Y. Bai, X. Wu and F. Yu, "Comparison of Suomi-NPP VIIRS and HIMARWARI-8 AHI MWIR observations for hot spot and heat island studies," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016a, pp. 1954-1957. doi: 10.1109/IGARSS.2016.7729503
3. X. Shao, C. Cao, T. c. Liu, B. Zhang, S. F. Fung and A. S. Sharma, "VIIRS Day/Night Band observations of auroral activity during a 2015 severe geomagnetic storm," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016b, pp. 3021-3024. doi: 10.1109/IGARSS.2016.7729781

Presentations:

1. Wang, Zhuo, Wenhui Wang, Changyong Cao, and Sirish Uprety: Comparison of NOAA Operational and NASA Land SIPS Reprocessed Suomi NPP VIIRS SDR Products, JPSS 2016 Annual Science Team Meeting, College Park, MD, 8 - 12 August, 2016.
2. Bai. Y., C. Cao, X. Shao, and B. Zhang, Validating the VIIRS Day/Night Band geolocation accuracy at different scan angles with terrain correction, EUMETSAT Meteorological Satellite conference, 26-30, September 2016.
3. B. Zhang and C. Cao, "A preliminary study of aggregating VIIRS I3 to generate M10 for adding a future water vapor band," NOAA JPSS Annual Review Meeting, College Park, MD, 2016. (Poster)
4. Shao, X., Cao, Changyong, Zhang, B., Bai, Y., Wu, Xiangqian and Yu, Fangfang, "Comparison of Suomi-NPP VIIRS and HIMAWARI-8 AHI MWIR observations for hot spot and heat island studies," *IEEE International Geoscience and Remote Sensing Symposium*, TU3.L8.4, Beijing, (2016).
5. X. Shao, C. Cao, T. c. Liu, B. Zhang, S. F. Fung and A. S. Sharma, "VIIRS Day/Night Band observations of auroral activity during a 2015 severe geomagnetic storm," *IEEE International Geoscience and Remote Sensing Symposium*, Beijing, (2016).

Others:

Award: Xi Shao received NOAA/NESDIS/STAR Innovative Research Award for the publication of the research work on “Shao, X.; Cao, C.; Liu, T.-C. , Spectral Dependent Degradation of the Solar Diffuser on Suomi-NPP VIIRS Due to Surface Roughness-Induced Rayleigh Scattering, *Remote Sens.* 2016, *8*, 254.”

Products:

- Online monitoring of VIIRS DNB geolocation accuracy: https://ncc.nesdis.noaa.gov/VIIRS/VIIRSGeoErrors.php

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of NOAA technical reports	2
# of presentations	5
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

GOES-R Near-Surface Unmanned Aircraft System (UAS) Feasibility Demonstration Study

Task Leader	Xi Shao
Task Code	XSXS_UAS_15
NOAA Sponsor	Changyong Cao
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 90%; Theme 2: 10%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation;
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight CICS scientists provide science, engineering and testing support for GOES-R near-surface Unmanned Aircraft System (UAS) feasibility demonstration study. In particular, this project supports GOES-R near-surface UAS design, performs hardware procurement for the prototype UASs, and supports the integration, initial testing and field campaign of GOES-R UAS.

Background

The Geostationary Operational Environmental Satellites – R Series (GOES-R) is the next generation of geostationary Earth-observing systems. The advanced spacecraft and instrument technology employed by the GOES-R series will provide significant improvements in the detection and observations of environmental phenomena that directly affect public safety, protection of property and our nation's economic health and prosperity. The first satellite in the GOES-R is launched in 2016. Instrument calibration, characterization, and validation are essential to GOES-R mission success and the production of high-quality data products. The Advanced Baseline Imager (ABI) is a critical instrument onboard GOES-R and was designed to provide high quality data with radiometric uncertainties within 3% for the Reflective Solar Bands (RSB), and within 1 K for the Thermal Emissive Bands (TEB). Unlike the heritage GOES imagers, the SI traceability of ABI was established during pre-launch testing.

As part of the comprehensive GOES-R ABI post-launch validation activities, a GOES-R field campaign is planned to support the validation of ABI L1b & L2+ products. In particular, the campaign is focused to provide an independent validation of the SI traceability of ABI L1b spectral radiance observations, as well as, provide surface and atmospheric geo-physical measurements in support of L1b & L2+ product validation. Current operational validation capabilities to collect high quality reference observations of extended areas and surface bi-directional reflectance distribution function (BRDF) over regions comparable to environmental satellite observations are very limited. Given the recent technological advance of low-cost commercially available Unmanned Aerial Vehicles (UAV) and compact sensors a great opportunity exists to leverage these technologies as a critical part of the GOES-R field campaign activities. During the GOES-R near-surface Unmanned Aircraft System (UAS) feasibility demonstration study phase, we will support UAS design, perform hardware procurement for the prototype UAS, support the integration and initial testing of GOES-R UAS and support GOES-R UAS field campaign.

Accomplishments

Our work on GOES-R near-surface unmanned aircraft system feasibility demonstration study can be summarized as following.

1. System design and procurement

The system includes an UAS, a UAS flight controller (Pixhawk) to control the path and record geology related metadata, UAS sensor suite which includes Raspberry Pi to handle the data acquisition process and various sensors and parts. The design integrates various sensors on the UAS including visible-and-near-infrared (VNIR) spectrometer, shortwave-infrared (SWIR) spectrometer, temperature and humidity sensor, barometer, etc. We arranged procurement of rotary UAV from UAV Solutions, VNIR spectrometer (Ocean Optics, model Flame-S-VIS-NIR-ES), SWIR spectrometer (ArcOptics, model Rocket 0.9-2.6 w/ DSP), thermopile sensor (Apogee, model SI-411), several lab equipment and accessories from Thorlabs, TE Technology, BBN, and InterMet, etc.

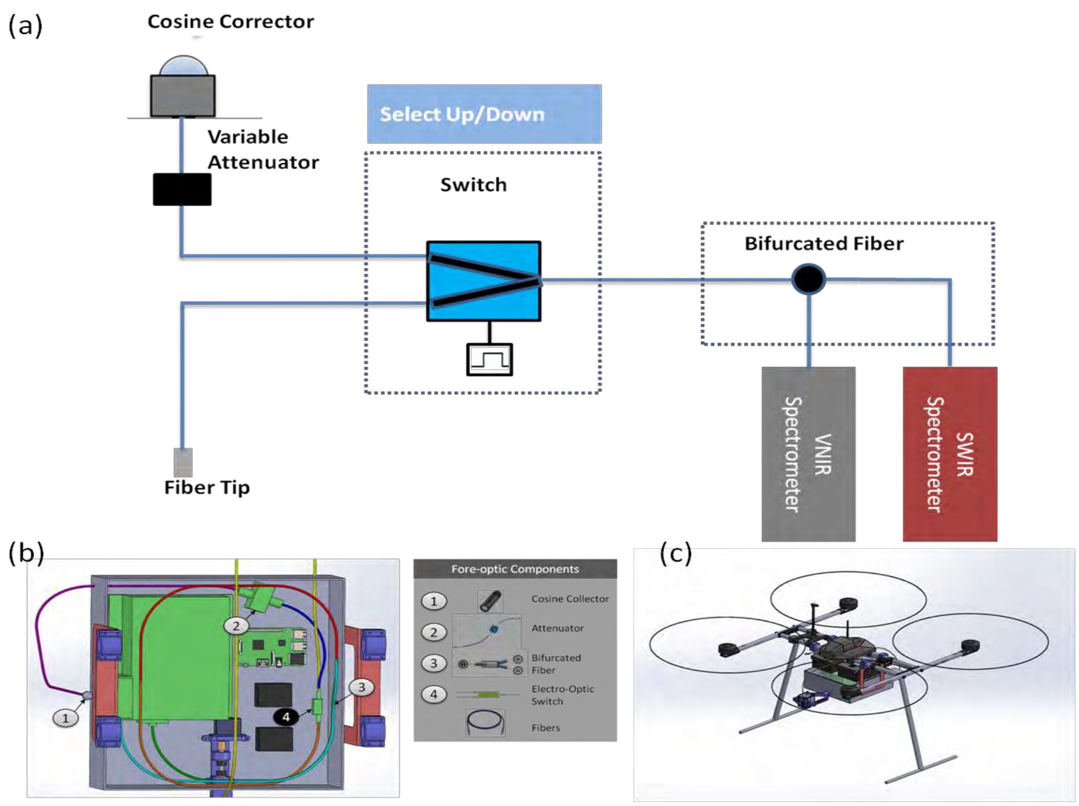


Figure 1. (a) Basic schematic of the UAS reflective solar band sensor suite (b & c) Designed UAS sensor suite with a custom enclosure that accounts for fiber length and bending radius requirements and UAS platform (courtesy of UAV Solutions)

2. Support UAS sensor suite design and integration

We supported the sensor suite design to meet the challenges of integrating the two different spectrometers on the same platform so that both upward and downward measurements could be made. The design achieves this objective with a customized fiber-optics based design that enables the core-bore sighting of both spectrometers that are either pointed in an upward or gimbaled downward direction (controlled by an electro-optic switch) through common fibers. This allows the same spectrometers to be used for both measurement directions, which reduces complexity and minimizes system weight. The fiber-based design poses some challenges, however, due to the physical constraints such as maintaining fiber bend radius, minimizing fiber bend changes, as well as the availability of fibers and fiber components that have low loss across wavelengths from 0.4-2.38 µm and can be customized to the minimum lengths necessary. Figure 1 shows a schematic of the design. A cosine corrector points upward to collect the total sky irradiance, which propagates through a variable attenuator to prevent saturation. The downward radiance is collected through a bare fiber. Both fibers are connected to a custom electro-optic switch to select either an upward or downward measurement based on the electronic trigger. Once the radiation exits the switch, it will be split with a bifurcated fiber such that half the signal will propagate to each spectrometer. Each leg of the bifurcated fiber is designed to minimize loss for the wavelength range matching each spectrometer. Figure 1 shows the system inside the custom enclosure where the fibers are placed so that they meet the fiber bending and minimum fiber length requirements. Although fiber bend changes were minimized in the design, some will exist when the angle of the pointing on the gimbal changes (as the gimbal can be autonomously controlled to point at any angle). Preliminary measurements of a similar fiber (same fiber core diameter) show that this bending has negligible impacts.

3. Completed successful functional test flights with the GOES-R Near-Surface UAS System

Teamed with Maryland UAS test site, we completed several UAS functional test flights and successful data acquisitions (Figure 2 and Figure 3):

- Locations & Dates:

  Fixed-wing UAS - Successful test flights and generation of products: 2D & 3D geo-referenced maps
  - University of Maryland (UMD) UAS test site in Bushwood, MD on August 3, 2016
  - NOAA National Estuary Research Reserve (NERR) in Jug Bay, MD on August 8, 2016 – UAS test data provided to NOAA NERR as operational data

  Rotary UAS - Successful Rotary UAS functional performance demonstrations
  - NOAA National Estuary Research Reserve (NERR) in Jug Bay, MD on November 11, 2016
  - University of Maryland (UMD) UAS test site in Bushwood, MD on January 13, 2017
- Demonstrated functional performance of UAS and payload:
  - Aircraft/payload integration testing successful
  - Stable gimbal pointing and goniometric maneuvers to accomplish required ABI validation flights
    - Stabilized hover over a tarp to establish sensor baselines
    - 1km straight line flight while holding an alternate heading and continuous altitude
    - Orbiting a specific point while the aircraft maintained a heading aligned with the center point of the orbit (critical for data collection)
  - Command and data handling with time synchronization between all sensors
    - Several collection runs automated into a single operation
    - Ability to collect sensor data from a single location at precise altitudes
  - Reflectance data acquired in-flight and on ground:

  - VNIR spectra acquired correlate with reference instrument
  - SWIR spectra acquired in-flight and on-ground (spectra suffered from low SNR)
    - New configuration found to boost SNR – modification identified and implemented
- Thermal infrared radiometer data and context imagery acquired in-flight
- Performed endurance testing to further refine mission limits
- Some data outages occurred during flight testing:
  - Root cause found: Loose power cable connection
  - Corrective action taken: Cables replaced and connections hardened

Figure 2: Various field testing flights and data acquisitions performed with the GOES-R Near-Surface Unmanned Aircraft System.

4. **Supporting GOES-R field campaign deployment in Red Lake, AZ during April, 2017, which will complete the near surface UAS feasibility demonstration study.**

Planned work

We will continue to support the GOES-R near-surface Unmanned Aircraft System (UAS) feasibility demonstration study. Our remaining task is to support GOES-R field campaign deployment in Red Lake, AZ during April, 2017, which will complete the near surface UAS feasibility demonstration study.

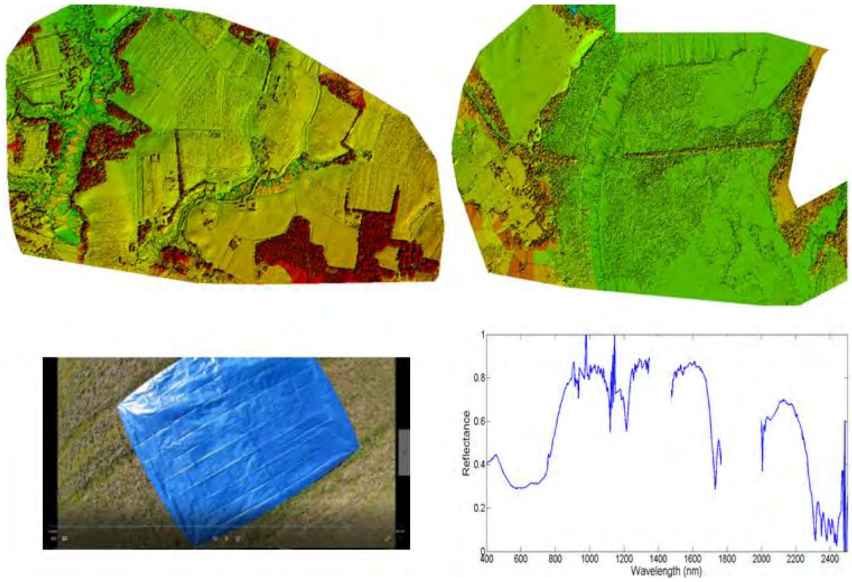


Figure 3: Top: 3D geo-referenced maps generated from the test flights; Bottom: In-Flight Photo of blue tarp used as reference and Hyperspectral Spectra of the reference blue trap measured by the UAS sensor suite.

Publications

Non-peer reviewed paper

Aaron J. Pearlman ; Francis Padula ; Xi Shao ; Changyong Cao and Steven J. Goodman " Initial design and performance of the near surface unmanned aircraft system sensor suite in support of the GOES-R field campaign ", *Proc. SPIE* 9972, Earth Observing Systems XXI, 99720U (September 19, 2016); doi:10.1117/12.2238178.

Presentations

Aaron J. Pearlman ; Francis Padula ; Xi Shao ; Changyong Cao and Steven J. Goodman " Initial design and performance of the near surface unmanned aircraft system sensor suite in support of the GOES-R field campaign ", *Proc. SPIE* 9972, Earth Observing Systems XXI, 99720U (September 19, 2016); doi:10.1117/12.2238178.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	1
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	1

New Product:
GOES-R Near-Surface Unmanned Aircraft System

Developing Front-End-Processing for Mitigating JPSS ATMS Radiance Striping and Radio- Frequency Interference

Task Leader:	Xiaolei Zou
Task Code:	XZXZ_ATMS_16
NOAA Sponsor:	Lihang Zou
NOAA Office:	NESDIS/STAR
Contribution to CICS Research Themes (%):	Theme 1: 100%
Main CICS Research Topic:	Calibration and Validation
Contribution to NOAA goals (%):	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

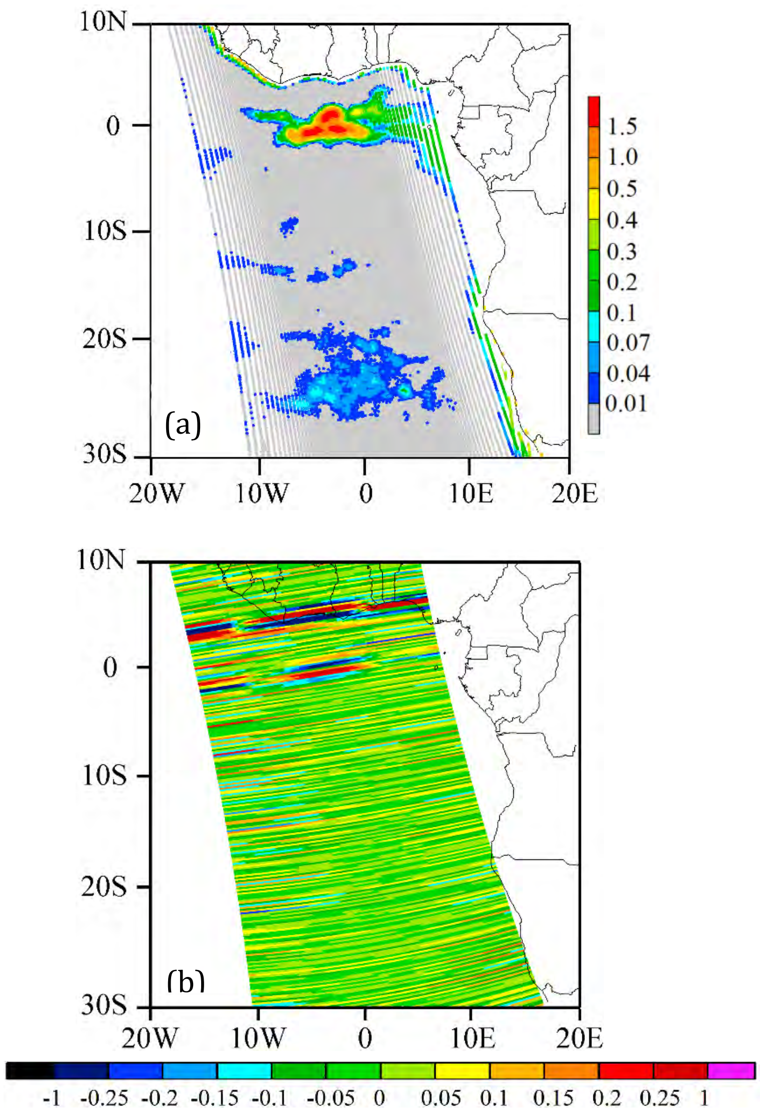
Highlight: A modification successfully made to the striping noise mitigation algorithm, which worked for ATMS sounding channels, so that artefacts generated by the striping noise mitigation in the window channels are successfully removed while the striping noise is mitigated as desired.

Background

From the on-orbit ATMS data, this 1/f noise can manifest itself a striping noise pattern in NWP O-B fields (Bormann et al., 2013; Qin et al., 2013) at ATMS upper level air temperature sounding channels. However, the striping noise was not shown in any AMSU-A channels. Qin et al. (2013) and Ma and Zou (2015) proposed and tested two methods for mitigating the striping noise in ATMS brightness temperature measurements. Both methods performed well for the striping noise mitigation of ATMS sounding channels without altering important small-scale weather signals. However, problems were encountered when the same method was applied to ATMS window channels. Specifically, the striping noise mitigation generates artefacts over places where ATMS scanlines are aligned with coastline and at the edges of deep clouds and heavy precipitation in the de-striped dataset of window channels. This deficiency was raised at "NOAA Worksop on JPSS Life-Cycle Data Reprocessing to Advance Weather and Climate Applications" (Heather Lawrence at ECMWF, Personal Communication, 2016). Thus, mitigation of the striping noise at ATMS window channels is a necessary step to ensure high quality data.

Accomplishments

The S-NPP ATMS upper air temperature sounding channels display a clear across-track striping noise in the NWP O-B fields. The striping magnitude variation is much more significant in ATMS along-track directions. Such a striping feature is also visible at brightness temperature fields at all 22 channels during an ATMS on-orbit pitch maneuver period. An algorithm was developed earlier by combining a principal component analysis (PCA) and ensemble empirical mode Decomposition (EEMD) and worked well for reducing the striping noise at ATMS upper air temperature sounding channels. However, at ATMS window channels (channels 1 and 2), artefacts were generated in the destriped observations at places where ATMS scanlines are aligned with either coastlines curves or the edges of deep clouds. They are caused by the along-track sharp gradients of brightness temperatures at window channels when ATMS earth scenes change from ocean to land or clear-sky to deep clouds and vice versa. Thus, an additional step is added to the PCA/EEMD method to eliminate such impacts. The modified de-striping method performs well for reducing the striping noise at ATMS window channels without introducing the artefacts to the de-striped brightness temperature fields. Figure 1a shows a presence of clouds with LWP greater than 1.5 kg m^{-2} that is aligned zonally and parallels to ATMS scanlines. The brightness temperature observations of both channels 1 and 2 over cloudy regions are much higher than their surrounding oceanic environment (figures omitted). In other words, the ATMS observed brightness temperatures have a sharp along-track gradient at the cloud edge over several FOVs over the same scanline. This situation is similar to the sharp along-track gradient of brightness temperatures at the coastal line. In fact, the striping noise extract by the original method confirm the presence of artefacts not only near the coastal lines, but also near the cloud edge (Fig. 1b). Such artefacts in ATMS window channelsare eliminated from the striping noise extracted by the newly proposed modified method (Fig. 1c).



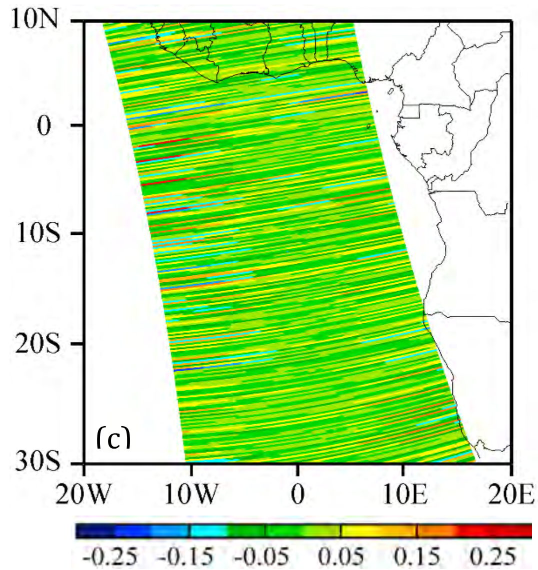


Figure 1. (a) cloud liquid water path, (b) striping noise extract by the original method, and (c) striping noise extracted by the modified method of channel 1 for ATMS data on January 2, 2013 obtained by the PCA/EEMD method.

Planned work

- Publish the work on ATMS window channels striping noise mitigation in refereed journal
- Implement the striping noise mitigation for all the five years of S-NPP ATMS data of all channels
- J1 ATMS Ku-Band radio-frequency interference studies
- J1 ATMS striping noise analysis
- Absolute calibration/validation for SNPP and J1 ATMS sounding channels by using GPS RO measurements

Publications

Dong, H., X. Zou and Z. Qin, 2017: Striping noise reduction at ATMS window channels. *Quart. J. Roy. Meteor. Soc.*, (submitted)

Presentations

The 2016 STAR JPSS Annual Science Team Meeting, August 8-12, 2016, NOAA Center for Weather and Climate Prediction, College Park, Maryland. An oral presentation entitled “Re-evaluation of Suomi NPP ATMS Destriping Algorithm for Surface-Sensitive Channels.”

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	1
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	1
# of graduate students formally advised	1
# of undergraduate students mentored during the year	

Scientific Support for JPSS CrIS Calibration and Validation: Yong Chen (Part 1 of 4)

Task Leader:	Yong Chen
Task Code:	YCYC_JPSS_14 Year 3
NOAA Sponsor:	Fuzhong Weng
NOAA Office:	NESDIS/STAR
Contribution to CICS Themes (%):	60% Theme 1 and 40% Theme 2
Main CICS Research Topic:	Calibration and Validation
Contribution to NOAA goals (%):	Goal 1: 30%; Goal 2: 70%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS Scientist Yong Chen continue work to improve the calibration algorithms, including optimization of the calibration equation, implement ringing artifact reduction algorithm updates into FSR-ADL software, further assess the spectral and radiometric accuracies of the SDR product from the FSR processing system, and analyze JPSS-1 pre-launch test data and derive parameters for CrIS spectral and radiometric calibration.

Background

This report summarizes the third year work of the ongoing NOAA project entitled "Scientific Support for Joint Polar Satellite System (JPSS) CrIS Calibration and Validation". CrIS on S-NPP is a Fourier transform spectrometer. It provides a total of 1305 channels in the normal mode for sounding the atmosphere. CrIS can also be operated in the full spectral resolution (FSR) mode with spectral resolution of 0.625 cm^{-1} for all three bands (total 2211 channels). NOAA operated CrIS in FSR mode from normal mode on December 4, 2014 for S-NPP, and will operate CrIS in FSR mode for the Joint Polar Satellite System (JPSS). Based on CrIS Algorithm Development Library (ADL), we have develop a state-of-art system for processing and calibrating the NSR and FSR with the best calibration algorithm to improve the scientific results. The code was the baseline code for JPSS-1, and now already transition to operational on March 8, 2017. Below are the accomplishments of this year, followed by future plans.

Accomplishments

05-25-16 **June Delivery of Operational CrIS SDR Algorithm Updates** Yong Chen

The baseline code is ADL5.3.1 (PSAT-16, Block 2.0), received in April 2016. We have updated this code with new calibration algorithm A4 with more data points, and applying non-circular FIR filter correction as well as additional algorithms included. All the algorithm parameters are controlled by Processing Control Table (PCT) files and corresponding XML files: (1) each algorithm has its own Algorithm_ID; (2) post filter/cosine filter parameters; (3) decimated interferogram points/truncated decimated interferogram points. The Geolocation algorithm is also updated: modified the geolocation algorithm to correct the FOV position errors and improved S-NPP mapping parameters. In this code, it only include fringe count error (FCE) correction algorithm. The final package is delivered on June 30, 3016.

and LBLRTM simulations. Algorithm 4 (A4) shows the smallest ringing artifact at both band 1 edges.

06-20-16 **CrIS ADL Code for Reprocessing CrIS SDR** Yong Chen
We have created one specific code for CrIS SDR reprocessing. This code is based on ADL5.3.1 PSAT16 with updates for geolocation, non-linearity, and calibration algorithm to improve the scientific results. The default calibration algorithm for both normal and full resolution is A4 instead of A1 (IDPS type). The reprocessed SDR for band 1 will be exactly the same from normal and full resolution. The calibration coefficients are refined with the latest updates based on the work from CrIS science team, and replaced these in the Engineering Packet in the RDR data stream. The resampling wavelength will be updated based on the metrology laser wavelength and resulting in zero sampling error in the spectral calibration. All the SDRs will be generated with the same calibration coefficients, resulting in improved consistency during the CrIS life-time mission.

08-3-16 **Oral Presentation at 13th Asia Oceania Geosciences Society Annual Meeting** Yong Chen
CICS-MD Scientist Yong Chen presented a talk titled “Hyper-spectral Infrared Sensor CrIS Sensor Data Record Long-term Spectral Accuracy and Stability” at 2016 AOGS Conference. In this study, we use LBLRTM and ECMWF forecast fields to systematically evaluate the spectral accuracy of CrIS SDR at different spectral ranges for all three bands. Based on these results, the best spectral ranges can be chosen to evaluate the spectral accuracy and stability for CrIS, IASI and future FTS infrared instruments. Long-term CrIS spectral accuracy and spectral stability from the operational CrIS SDR was presented.

08-16-16 **Oral Presentation at AMS 21th Conference on Satellite Meteorology** Yong Chen
CICS-MD Scientist Yong Chen presented a talk titled “Hyper-spectral Infrared Sensor CrIS Sensor Data Record Long-term Radiometric and Spectral Accuracy and Stability” at 2016 AMS 21th Cnference on Satellite Conference. In this study, the accuracy of CrIS radiometric and spectral calibration and its stability are assessed using the operational SDR data. Overall radiometric biases (O-S) are small and stable over time, FOV-2-FOV differences are less than ~20 mK. It is shown that CrIS metrology laser wavelength varies within 3 ppm as measured by the Neon calibration subsystem. While the current CrIS operational algorithm is designed to have a spectra error less than 2 ppm, the actual spectral errors are about 4 ppm. The CrIS SDR radiometric and spectral accuracy will be further improved for climate applications with its fine-tuning of calibration coefficients and improved calibration algorithm in NOAA reprocessing project.

11-30-16 **Oral presentation at 2016 CICS Science Conference** Yong Chen
CICS-MD Scientist Yong Chen presented a talk titled “Suomi NPP CrIS Reprocessed SDR Long-term Accuracy and Stability” at 2016 CICS Science Conference. In this study, the accuracy of CrIS radiometric and spectral calibration and its stability are assessed using the reprocessed SDR and compared to the operational SDR data. Overall radiometric biases (O-S) are small and stable over time, FOV-2-FOV differences are less than ~10 mK, and much better than that from the operational SDR. It is shown that CrIS metrology laser wavelength varies within 3 ppm as measured by the Neon calibration subsystem. The reprocessed SDR have spectral errors less than 0.5 ppm, is much better than the operational SDR with about 4 ppm. Reprocessed CrIS SDR will benefit GSICS inter-calibration capabilities and climate applications, in terms of better radiometric and spectral calibration accuracy, and consistence calibration and performance based on the same software and calibration parameters.

01-24-17 **Oral presentation at 2017 AMS Annual Meeting** Yong Chen

CICS-MD Scientist Yong Chen presented a talk titled "Suomi NPP CrIS Reprocessed SDR Long-term Accuracy and Stability" at 2017 AMS annual meeting. Using the reprocessed CrIS SDR data, we have evaluated the long-term radiometric and spectral accuracy and stability during the CrIS observed period 2012-2016, and results show that both radiometric and spectral accuracy and stability are greatly improved.

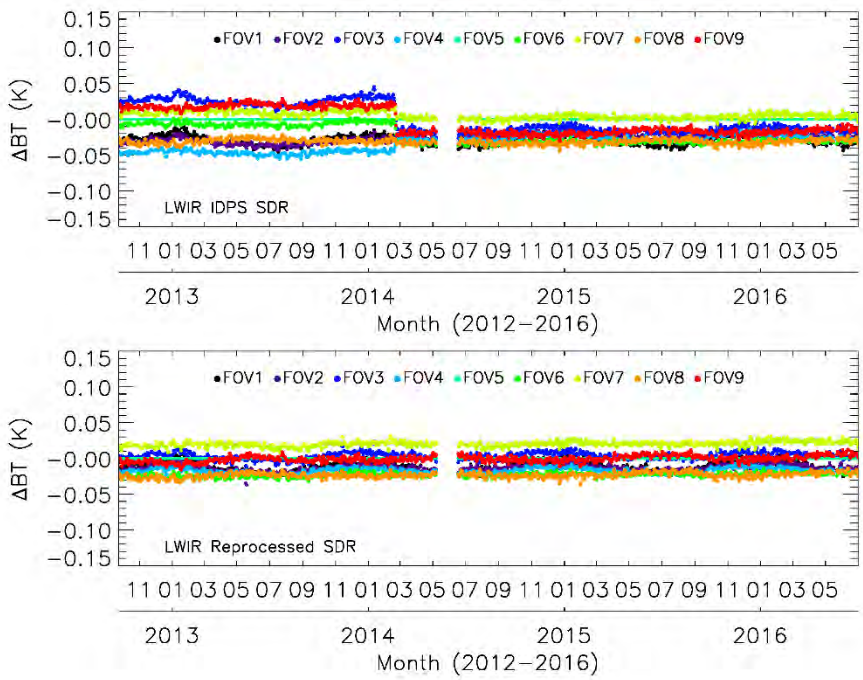


Figure 1. Time series of the longwave daily mean FOV to FOV difference (16 channels averaged from 672 to 682 cm^{-1}) with respect to the center FOV 5 for clear sky over ocean.

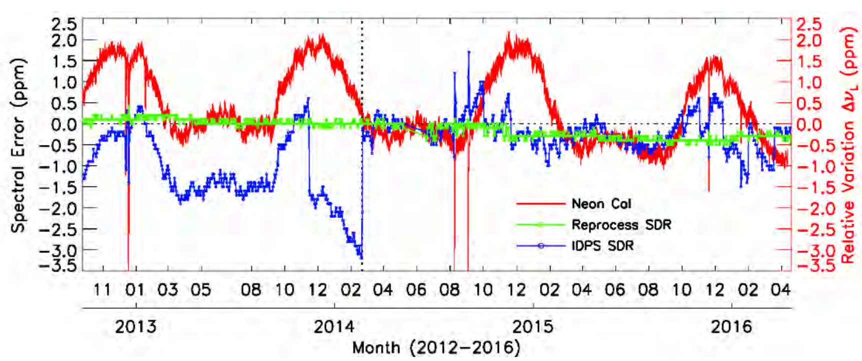


Figure 2. Comparison of the Neon subsystem spectral calibration versus calibration using the upwelling radiances for IDPS and reprocessed SDRs from September 22, 2012 to April 19, 2016.

Feb 2017 Paper on **Characterization of Long-Term Stability of Suomi NPP Cross-Track Infrared Sounder Spectral Calibration** Yong Chen

CICS-MD Scientist Yong Chen has published an article in IEEE Transactions on Geoscience and Remote Sensing. Since CrIS radiometric accuracy depends on the accurate spectral calibration, it is important to reduce the spectral uncertainty and increase the calibration stability for weather and climate applications. In this paper, the accuracy of CrIS spectral calibration and its stability are assessed using the operational sensor data record (SDR) data generated by the interface data processing segment (IDPS). A spectral validation method is developed and applied to clear scene data over ocean from September 22, 2012, to April 19, 2016. It is shown that CrIS metrology laser wavelength varies within 3 ppm, as measured by the Neon calibration subsystem. While the current CrIS operational algorithm is designed to have a spectra error less than 2 ppm, the actual spectral errors are about 4 ppm due to the IDPS software bugs. A new correction method is applied to fix the bugs and to further improve CrIS spectral calibration. It is found that the CrIS spectral calibration accuracy is less than 1 ppm in both normal and full spectral resolution SDR data sets.

11-21-16 Presentation on "Evaluation of ADL FCE Detection/Correction Algorithm Using J1 TVAC FCE Data" at CrIS science team meeting
01-18-17 Presentation on "RDR Leap Second Error" at CrIS science team meeting
03-29-17 Presentation on "Block 2.0 CrIS Update" at CrIS science team meeting

Planned work

- Further assess the spectral and radiometric accuracies of the SDR product from the reprocessing CrIS life-cycle SDR data
- Improve the CrIS calibration algorithm in Block 2.0 software for JPSS-1
- Transit algorithm to operations for JPSS-1
- Evaluation the SDRs generated from JPSS Block 2.0
- Analyze JPSS-1 pre-launch test data and derive parameters for CrIS spectral and radiometric calibration
- Refine the JPSS-1 post-launch spectral and radiometric calibration coefficients

Publications

Peer-Reviewed

Yong Chen, Yong Han, and Fuzhong Weng, Characterization of long-term stability of Suomi NPP Cross-Track Infrared Sounder (CrIS) spectral calibration, IEEE Transact. Geosci. Remote Sensing, 55, 1147-1159. doi:10.1109/TGRS.2016.2620438, (2017).

Likun Wang, Yong Chen, and Yong Han, Impacts of field of view configurations of Cross-track Infrared Sounder on clear-sky observations, Appl. Opt., 55, 7113–7119. doi: 10.1364/AO.55.007113 (2016).

Products

- CrIS FSR-ADL SDR processing system for S-NPP and baseline for JPSS1
- CrIS SDR reprocessing system for S-NPP life-mission
- FSR SDR products to the user community since 12/4/2014

Presentations

Likun Wang, Denis Tremblay, Yong Chen, and Yong Han: Scientific benefits of spatial resolution for next generation infrared hyperspectral sounder instruments, IASI 2016 Conference, Antibes Juan-les-Pins, France, 11-15 April, 2016 (poster).

Yong Chen, Yong Han, Likun Wang, Denis Tremblay, and Xiaozhen Xiong: Calibration accuracy improvements for CrIS on JPSS, IASI 2016 Conference, Antibes Juan-les-Pins, France, 11-15 April, 2016 (poster).

Likun Wang, Yong Han, and Yong Chen: Combination of VIIRS measurements and products with CrIS toward extending data utilization, 2016 IEEE International Geoscience and Remote Sensing Symposium, Beijing, China, 10-15 July, 2016 (oral).

Yong Chen, Yong Han, and Fuzhong Weng: Hyper-spectral infrared sensor CrIS sensor data record long-term spectral accuracy and stability, the 13th Annual Meeting Asia Oceania Geosciences Society, Beijing, China, 31 July to 5 August, 2016 (oral).

Yong Chen, Yong Han, and Fuzhong Weng: Hyper-spectral infrared sensor CrIS sensor data record long-term radiometric and spectral accuracy and stability, the AMS 21st Conference on Satellite Meteorology, Madison, WI, 15-19 August, 2016 (oral).

Denis Tremblay, Yong Han, Yong Chen, Likun Wang, and Xin Jin: Lunar intrusion detection algorithm for the Cross-track Infrared Sounder (CrIS) instrument on S-NPP satellite, Conference on Characterization and Radiometric Calibration for Remote Sensing, Logan, UT, 22-25 August, 2016 (oral).

Denis Tremblay, Yong Han, Yong Chen, Likun Wang, and Xin Jin: Lunar intrusion detection algorithm adapted for the Cross-track Infrared Sounder (CrIS) instrument on S-NPP satellite, The 2016 Eumetsat Meteorological Satellite Conference, Darmstadt, Germany, 26-30 September, 2016 (poster).

Yong Chen, Yong Han, Likun Wang, Fuzhong Weng, and Ninghai Sun: Suomi NPP CrIS reprocessed SDR long-term accuracy and stability, The 97th Meteorological Society Annual Meeting, Seattle, WA, 22-26 January, 2017 (oral).

Likun Wang, Yong Chen, Denis Tremblay, and Yong Han: VIIRS radiance cluster analysis under CrIS field of views, The 97th Meteorological Society Annual Meeting, Seattle, WA, 22-26 January, 2017 (oral).

Other

May 2016, Dr. Yong Chen was awarded the 2016 Individual Technology Award by NOAA/NESDIS/STAR for developing a state-of-art system for processing, calibrating and validating Cross-track Infrared Sounder (CrIS) full spectral resolution data for weather and climate applications.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	2
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Scientific Support for JPSS CrIS Calibration and Validation: Likun Wang (Part 2 of 4)

Task Leader	Yong Chen
Task Code	YCYC_JPSS_14 Year 3
NOAA Sponsor	Lihang Zhou
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 30%; Goal 2: 70%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS scientists evaluate radiometric, spectral, and geometric calibration accuracy of Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR) on Suomi NPP and future JPSS satellites, improve the data quality, and support operational use of numerical weather predication (NWP) data assimilation and Environmental data record (EDR) Team.

Background

This work is part of the project “Scientific Support for Joint Polar Satellite System (JPSS) CrIS, VIIRS and OMPS Calibration” but emphasizes more on Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR). The goal of this project is to focus on NOAA operational calibration support for CrIS and development of innovative techniques to improve the calibration of JPSS instruments for advanced applications. The CrIS SDR calibration and validation (Cal/Val) process includes both prelaunch and postlaunch activities. Radiometrically, spectrally, and geolocated calibrated radiances with annotated quality indicators from CrIS SDR are used not only to provide improved atmospheric temperature and humidity profiles information, but are also used extensively by the scientific community for global measurements of trace gases, land surface properties, cloud properties, and medium-term climate trending. The CICS scientist – Likun Wang – uses inter-sensor calibration techniques to evaluating spectral, radiometric, and geolocation calibration accuracy of CrIS SDR, to improve and ensure the data quality of CrIS SDR, and to support operational use of NWP data assimilation and EDR team.

Accomplishments

1. Improving Geolocation Accuracy of CrIS SDR Products

An improved scheme for Cross-track Infrared Sounder (CrIS) geolocation assessment for all scan angles (from −48.5° to 48.5°) is developed in this study. The method uses spatially collocated radiance measurements from the Visible Infrared Imaging Radiometer Suite (VIIRS) image band I5 to evaluate the geolocation performance of the CrIS Sensor Data Records (SDR) by taking advantage of its high spatial resolution (375 m at nadir) and accurate geolocation. The basic idea is to perturb CrIS line-of-sight vectors along the in-track and cross-track directions to find a position where CrIS and VIIRS data matches more closely. The perturbation angles at this best matched position are then used to evaluate the CrIS geolocation accuracy. More importantly, the new method is capable of performing postlaunch on-orbit geometric calibration by optimizing mapping angle parameters based on the assessment results and thus can be further extended to the following CrIS sensors on new satellites. Finally, the proposed method is employed to evaluate the CrIS geolocation accuracy on current Suomi National Polar-orbiting Partnership satellite. The error characteristics are revealed along the scan positions in the in-track and cross-track directions. It is found that there are relatively large errors (~4 km) in the cross-track direction close to the end of scan positions. With newly updated mapping angles, the geolocation accuracy is greatly improved for all scan positions (less than 0.3 km). This makes CrIS and VIIRS spatially align together and thus benefits the application that needs combination of CrIS and VIIRS measurements and products.

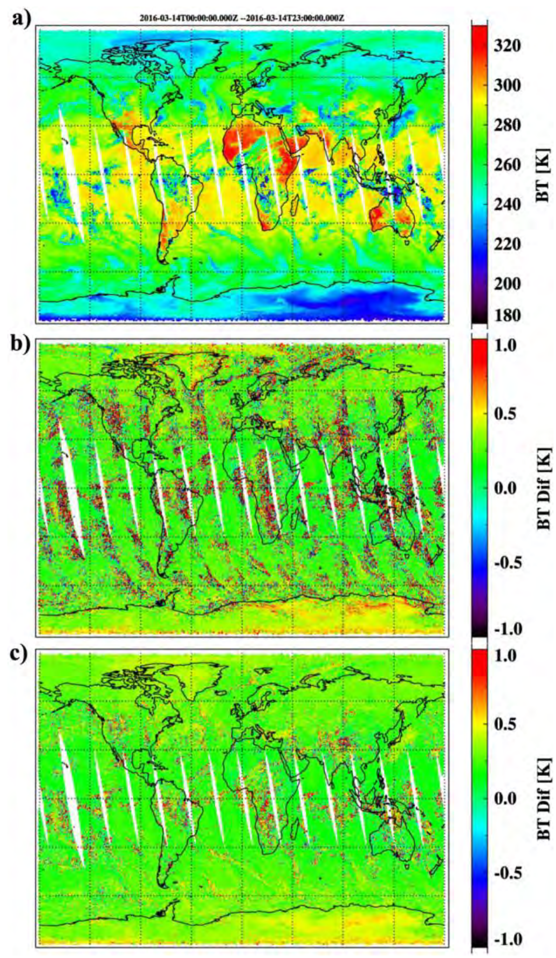


Figure 1. The effects of CrIS geolocation accuracy improvements on CrIS-VIIRS BT differences, including (a) CrIS image at 900 cm−1 on 14 March 2016 as well as (b) CrIS-VIIRS BT difference images for original CrIS IDPS geolocation data sets and (c) and reproduced.

2. Evaluating Impacts of Field of View Configuration of Future CrIS Instrument

Hyperspectral infrared radiance measurements from satellite sensors contain valuable information on atmospheric temperature and humidity profiles and greenhouse gases, and therefore are directly assimilated into numerical weather prediction (NWP) models as inputs for weather forecasting. However, data assimilations in current operational NWP models still mainly rely on cloud-free observations due to the challenge of simulating cloud-contaminated radiances when using hyperspectral radiances. The limited spatial coverage of the 3×3 field of views (FOVs) in one field of regard (FOR) (i.e., spatial gap among

FOVs) as well as relatively large footprint size (14 km) in current Cross-track Infrared Sounder (CrIS) instruments limits the amount of clear-sky observations. This study explores the potential impacts of future CrIS FOV configuration (including FOV size and spatial coverage) on the amount of clear-sky observations by simulation experiments. The radiance measurements and cloud mask products (VCM) from the Visible Infrared Imager Radiometer Suite (VIIRS) are used to simulate CrIS clear-sky observation under different FOV configurations. The results indicate that, given the same FOV coverage (e.g., 3×3), the percentage of clear-sky FOVs and the percentage of clear-sky FORs (that contain at least one clear-sky FOV) both increase as the FOV size decreases. In particular, if the CrIS FOV size were reduced from 14 km to 7 km, the percentage of clear-sky FOVs increases from 9.02% to 13.51% and the percentage of clear-sky FORs increases from 18.24% to 27.51%. Given the same FOV size but with increasing FOV coverage in each FOR, the clear-sky FOV observations increases proportionally with the increasing sampling FOVs. Both reducing FOV size and increasing FOV coverage can result in more clear-sky FORs, which benefit data utilization of NWP data assimilation.

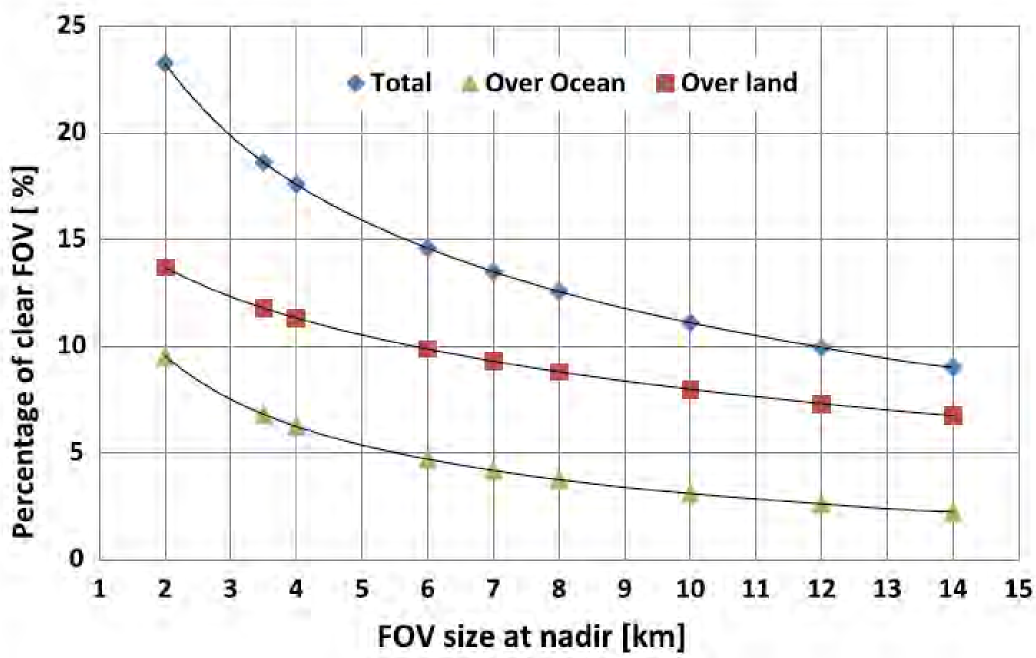


Figure 2: Percentage of CrIS clear-sky FOVs in total FOV number, varying the FOV size. For all the simulations, each FOR contains 3 × 3 FOVs with different FOV size.

Planned work

- Computing the mounting Matrix for JPSS-1 CrIS Sofeware
- Preparing the software for post-launched geolocation assessment for JPSS-1 CrIS

Publications

Peer-reviewed Journal Papers

Wang, L., D. A. Tremblay, B. Zhang, and Y. Han, 2017: Improved scheme for Cross-track Infrared Sounder geolocation assessment and optimization. *Journal of Geophysical Research – Atmosphere,* **122**, 519-536, doi:10.1002/2016JD025812.

Wang, L., Y. Chen, and, Y. Han, 2016: Impacts of Field of View Configuration of Crosstrack Infrared Sounder on Clear Sky Observations, *Applied Optics,* **55**, 7113-7119, doi:10.1364/AO.55.007113.

Wang, L., D. A. Tremblay, B. Zhang, and Y. Han, 2016: Fast and Accurate Collocation of the Visible Infrared Imaging Radiometer Suite Measurements and Cross-track Infrared Sounder Measurements. *Remote Sensing*, ***8***, 76; doi:10.3390/rs8010076.

Non-Peer-reviewed Conference Proceedings

Wang L. and Y. Han, 2016: Using Collocated VIIRS Observations for CrIS Scene Characterization toward Extending Data Utilization," in *Light, Energy and the Environment*, OSA Technical Digest (online) (Optical Society of America, 2016), paper JW4A.11, doi: 10.1364/FTS.2016.JW4A.11

Products

- CrIS SDR Geolocation Products
- CrIS Standalone Geolocation Python Software

Presentations

Wang, L., Y. Chen, D. Tremblay, and Y. Han, 2017: VIIRS Radiance Cluster Analysis under CrIS Field of View. *97th AMS Annual Meeting*, Seattle, WA, USA, January 23-26 2017.

Wang, L., Y. Chen, D. Tremblay, and Y. Han, 2017: VIIRS Radiance Cluster Analysis under CrIS Field of View. *2016 Annual CICS Science Conference*, College Park, MD, November 29- December 1, 2016.

Wang, L., Y. Chen, D. Tremblay, and Y. Han, 2016: Combination of VIIRS with CrIS toward Extending Data Utilization. *2016 STAR JPSS Annual Science Team Meeting*, College Park, MD, August 8-12 2016.

Wang, L., Y. Han, and Y. Chen, 2016: Combination of VIIRS Measurements and Products with CrIS toward Extending Data Utilization, *2016 IEEE International Geoscience and Remote Sensing Symposium*, Beijing, July 10-15 2016.

Wang, L., Y. Chen, D. Tremblay, and Y. Han, 2016: Uses of CrIS SDR as GSICS Reference. *NOAA Workshop on JPSS Life-Cycle Data Reprocessing to Advance Weather and Climate Applications*, College Park, MD, May 17-18 2016,

Wang, L., D. Tremblay, Y. Chen, and Y. Han, 2016: Scientific Benefits of Spatial Resolution for Next Generation Infrared Hyperspectral Sounder Instruments. *2016 IASI Conference*, Antibes Juan-les-Pins, France, April 11-15, 2016.

Wang, L., 2016: Combination of VIIRS Measurements and Products with CrIS toward Extending Data Utilization. *2016 ESSIC Seminar*, College Park, MD, March 21 2016.

Wang, L., B. Zhang, D. Tremblay, and Y. Han, 2016: Fast and accurate collocation of CrIS and VIIRS. *2016 GSICS Annual Meeting*, Tsukuba Japan, February 29-March 4, 2016.

Wang, L., and T. Hewison, 2016: Hyperspectral infrared sounder traceability and uncertainty. *2016 GSICS Annual Meeting*, Tsukuba Japan, February 29-March 4, 2016.

Wang, L., 2016: Combination of VIIRS Measurements and Products with CrIS toward Extending Data Utilization. *Navy Research Laboratory Marine Meteorology Division Seminar*, Monterey, CA, February 24 2016.

Wang, L., B. Zhang, Y. Han, X. Jin, Y. Chen, and D. Tremblay, 2016: Geolocation Assessment Tool and Correction Model for JPSS CrIS. *96th AMS Annual Meeting*, New Orleans, LA, USA, January 10-14 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	3
# of NOAA technical reports	
# of presentations	11
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Three peer-reviewed papers (3) have been published this year. Nine presentations (9) have been presented in the domestic and international conferences and two seminars (2) have been give in ESSIC and NRL, respectively. We improved the NPP CrIS geometric calibration algorithms as well as operational geolocation products.

Scientific Support for JPSS CrIS Calibration and Validation: Chunqiang Wu (Part 3 of 4)

Task Leader:	Yong Chen
Task Code:	YCYC_JPSS_14 Year 3
NOAA Sponsor:	Fuzhong Weng
NOAA Office:	NESDIS/STAR
Contribution to CICS Themes (%):	100% Theme 2
Main CICS Research Topic:	Calibration and Validation
Contribution to NOAA goals (%):	Goal 2: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Chunqiang Wu is a visiting research scholar from China under the support of Dr Yong Chen. Dr Wu mainly focus on the field of nonlinear (NL) correction in the Cross-track infrared Sounder (CrIS) related calibration procedure. Some tools to derive NL parameters from various data sets are developed , which would benefit the optimization of the calibration of J1 Cris.

Background

This report summarizes the work of first half year during my visiting to the University of Maryland under the support of Dr Yong Chen. During my visit, I focus on the field of nonlinear (NL) correction in the Cross-track infrared Sounder (CrIS) related calibration procedure. CrIS on S-NPP is a Fourier transform spectrometer. It provides a total of 1305 channels in the normal mode for sounding the atmosphere. Data analysis indicated that some of the CrIS HgCdTe detectors have significant NL, which is dominated by the second order term. Determination of the NL parameter (a_2) values for each FOV is one of the major efforts in CrIS SDR calibration and validation process. There are three methods for determinations of a_2 values, which have been applied to S-NPP CrIS data, each with advantages and disadvantages. Method 1 is based on the information of low frequency out band signal. The advantage of the method is that it can be applied to identify the NL detectors and derive a_2 parameters from both prelaunch ground testing and in-orbit DM data. The disadvantage is the large uncertainty due to the low signal-to-noise ratio. Method 2 is to use an external blackbody calibration target (ECT) during prelaunch ground thermal vacuum tests. The a_2 value is determined from the spectra when the instrument views the ECT at a set of temperatures. The advantage of this method is the good signal-to-noise ratio. The disadvantage is the difficulty to have a uniform ETC temperature across the 9 FOVs and know exactly the ECT radiance. Method 3 relies on a reference FOV which has the lowest NL among the 9 FOVs and derives a_2 parameters for the other 8 FOVs relative to the reference FOV. This method is very useful for minimizing the FOV-to-FOV difference, important for NWP and profile retrieval applications, and can be applied for both prelaunch and in-orbit calibrations. For in-orbit calibrations, the method determines the a_2 parameters with data collected from near nadir measurements, screened to remove those from horizontally non-uniform scenes. As J1 will launch in September 2017, tools to generate NL parameters are needed. Below are the accomplishments of this year on this topic.

Accomplishments

10-15-2016 **Derive NL parameter from Diagnostic data** Chunqiang Wu

Nonlinearity in an interferometer spectrum is manifest by second and higher order harmonics in the spectrum as show by U Wisc. The second order harmonic would produce signals at twice the nominal wavenumber of the in band spectra and the low frequency out-band. Due to the second order harmonic at double pass contributions and is not useful for determining nonlinearity. The nonlinearity for wave-numbers near the DC level is much more useful and forms the basis for estimating nonlinearity constant. There are two types of non-linear correction equations; one is based on the physics of nonlinearity and the real interferogram is expressed by linear interferogram and its second harmonics, the other is on the basis of mathematic and the linear interferogram is expressed by the observed nonlinear interferogram and its second harmonics. These two types of correction methods are both coded in python and implemented to CriS Diagnostic data. The correction effects are compared, and it shows that if the DC level would be estimated precisely, the results from method 1 are a little bit better than those of the second method.

11-25-2016 **Derive NL parameters from operational data by adjusting** Chunqiang Wu
In the in-orbit calibration process, the NL coefficient a_2 values are refined with the two-step approach. In the first step, the DM interferogram data collected during the instrument early check out period were used to derive the a_2 parameters. The fractional change in the parameters from prelaunch to in-orbit is therefore accurately estimated from the ratio of these DM derived in-orbit and prelaunch a_2 values. The results verified the prelaunch findings that all the SWIR FOVs are linear and MWIR FOVs 6 and 9 are highly linear. The results also verified for the LWIR band that FOV 5 has the lowest nonlinearity among the 9 FOVs. In the second step, the MWIR FOV 9 and LWIR FOV 5 were used as the reference FOVs for the MWIR and LWIR bands, respectively, to determine the a_2 parameters for other FOVs by minimizing the their radiance brightness temperature differences from the reference for a large set of near nadir Earth observations for spectral regions which have high sensitivity to nonlinearity and low spatial variability. Based on 3 days of operational data, the a2 values of other 8 FOVs are adjusted by a ratio in steps of 0.05 from 0.0 to 1.5 to minimize their difference compared to the reference FOV, which shows low nonlinearity. The RMS averages of the difference of BT spectrum over the fitting intervals are used as a metric to constrain adjust. Also, the spectrum domains and data set to perform this minimization are examined. The results show that the derived a2 values is consistent with those used in the operational software, indicate that these methods work well.

12-20-2016 **Estimate the effect of uncertainty in DC level on correction precision** Chunqiang Wu
As discussed above, there are many methods to derive a2 values from various data sets and many of them can be used together to get a final value, which will benefit the nonlinear correction. Also, during the correction, the DC level is as important as that of a2. The DC level is monitored by CrIS, but the recent analysis from TVAC data shows that it would be varies during the testing. In addition, for some instrument the DC level is unknown and it would be parameterized by other observation. Based on the simulation data, in which the truth is known, the effect of changing DC level is examined. It shows that a change of DC level by 10% would affect the calibration precise to an extent of requirement. In addition, if the DC level is not well estimated, and the a2 values are derived based on multiple external blackbody calibration targets, the calibration precision would be achieved due to the offset between DC level and a2 values.

Planned work

- work on SA correction
- work on SNO and inter-satellite comparison

Products

Two tools are developed to derive a2 values from diagnostic data and operational data.

Scientific Support for JPSS CrIS Calibration and Validation: Hui Xu (Part 4 of 4)

Task Leader:	Yong Chen
Task Code:	YCYC_JPSS_14 Year 3
NOAA Sponsor:	Fuzhong Weng
NOAA Office:	NESDIS/STAR
Contribution to CICS Themes (%):	60% Theme 1 and 40% Theme 2
Main CICS Research Topic:	Calibration and Validation
Contribution to NOAA goals (%):	Goal 1: 30%; Goal 2: 70%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight CICS Scientist Hui Xu works to improve the calibration algorithms, including assess the accuracies of CrIS algorithms and updates CrIS SDR algorithms into ADL software.

Background

In this report, we focus on the Cross-track infrared Sounder (CrIS) related calibration and validate activities. CrIS on S-NPP is a Fourier transform spectrometer. It provides a total of 2211 channels in the full spectral resolution (FSR) mode with spectral resolution of 0.625 cm^{-1} for sounding the atmosphere. Below are the accomplishments of this year, followed by future plans.

Accomplishments

NPP-CrIS polarization radiometric correction and assessment

The Scene Selection Mirror (SSM) polarization couples with the polarization of the CrIS interferometer, producing a small radiometric offset which is Field of View (FOV), Field of Regard (FOR) and band dependent. This small but detectable offset need to be corrected in CrIS Algorithms. To assess the polarization correction algorithm, the CrIS SDRs with and without polarization correction are compared to IASI and AIRS on SNO events. Figure 1 shows the shows the spectrum difference between CrIS and IASI-A in the nadir view. The CrIS spectrum is generally higher than IASI-A before the polarization correction. However, after the polarization correction, the mean bias between CrIS and IASI has been obviously reduced, even though the correction results are very small in some of the long and middle wave channels. Similar results are also found between CrIS and IASI-B and AIRS. However, in the tropical region, the polarization correction seems enhance the mean difference between CrIS and AIRS.

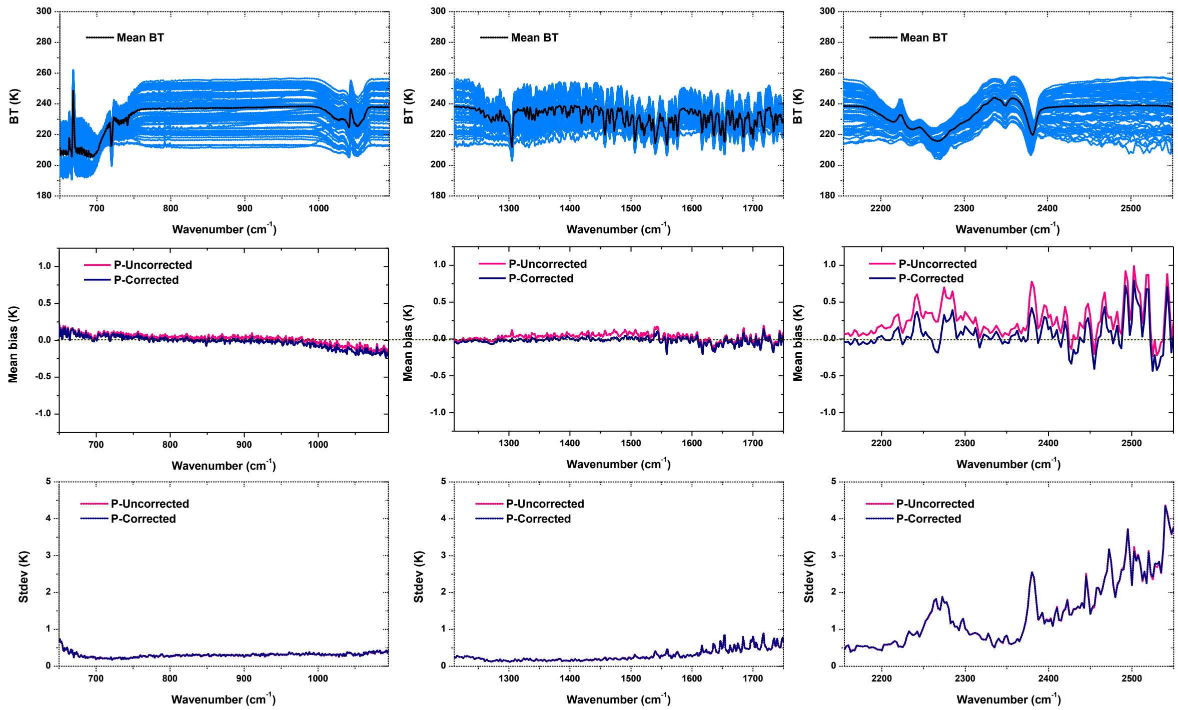


Figure 1. CrIS spectral distribution (top) for CrIS–IASI/A nighttime SNOs and the mean (middle) and standard deviation (bottom) of CrIS–IASI/A brightness temperature differences in long, middle and short wave band from left to right. The solid black lines in top figures represent the average spectrum from all the samples. The solid pink and blue lines in bottom figures represent polarization uncorrected and corrected CrIS–IASI/A brightness temperature differences respectively.

Planned work

(1) NPP-CrIS gap channel prediction and application

CrIS measures the earth scene over three different wavelength ranges: long-wave infrared (650~1095 cm-1), middle-wave infrared (1210~1750) and short-wave infrared (2155-2550 cm-1). There are some spectral gaps among the above three wave bands, such as the spectrum from 1095 to 1210 cm-1. To some extent, the gap channels limit the use of CrIS, e.g., the intercomparison between CrIS and other broad-band instruments. Thus, it will enhance the usage of CrIS if we could accurately predicate the gap channels. IASI with 8461 spectral channels sampled every 0.25 cm-1, covering the region from 645-2760 cm-1, which may help us do the predication work.

(2) CrIS Interferogram Spike Detection and Correction Algorithm Assessment

Detectors are subject to impulse spike due to direct bombardment of detector by high energy particles hitting spacecraft, and then emitting numerous X-rays that can excite detectors. The large area CrIS detectors be vulnerable to single event upset and the spikes can be present anywhere in the interferogram. Therefore, it is essential to do the spike corrections to suppress the effects of cosmic particle interaction with sensitive detector and associated electronics.

(3) CrIS SDR non-linearity correction

Non-linearity levels in the LWIR and MWIR detectors are high enough to require application of a non-linearity correction to the uncalibrated spectra in order to reduce the radiometric error introduced by the detector non-linearity. So, we need to further optimize the current non-linearity correction algorithm and transit it to operations for JPSS-1.

2.3 Surface Observation Networks

Howard University Support of NOAA's Commitment to the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)

Task Leader	Belay B. Demoz and Ricardo Sakai
Task Code	BDBD_GCOS_15 Year 2
NOAA Sponsor	Mitch Goldberg
NOAA Office	NESDIS/JPSSO
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations
Link to a research web page	www.gruan.org

Background

Lack of proper documentation of upper air atmospheric state variable errors has hampered accuracy of derived climate trend estimates. To mitigate this issue, the GCOS Reference Upper Air Network (GRUAN) sites have started a rigorous documentation of highly accurate upper air soundings on periodic intervals. The Howard University Beltsville Research Site as part of the NOAA Center for Atmospheric Studies (NCAS: http://ncas.howard.edu) is one of these sites (http://gruan.org) which is making dedicated measurements of upper air radiosondes during the NPP overpass times and archiving the data sets. This proposal seeks to continue the US NOAA commitment for GRUAN by launching weekly Vaisala RS-92 and monthly CFH launches, coincident with the overpass of the (S-NPP). The data will be processed in a highly quality controlled, internationally agreed manner where data and associated metadata are stored at the GRUAN Lead Center in Lindenberg, Germany, and NOAA's National Center for Environmental Information (NCEI). By using these GRUAN certified data sets in NUCAPS cal/Val – this task directly addresses the user engagement for data enhancement/improvement as well as the detailed data characterization part of the objective for JPSS PGRR. A conducive arrangement has been made with our NOAA STAR collaborators for dedicated NUCAPS and other cal/val activities and feedback – which address another of the primary JPSS PGRR objectives. These data sets will be used by NOAA STAR scientists in data validation and testing and debugging the NOAA Products Validation System (NPROVS+). Further, the data will aid in forming the Site Atmospheric State Best Estimate (SASBE), useful for a through validation of the NOAA Unique CrIS/ATMS processing System (NUCAPS).

Accomplishments

Activities that fall under this task and completed within this quarterly reporting period are (1) preparations of extended data collection at the NWS site in Sterling, VA, HUBR, and the planned NWS experiment in Wallops, VA. (2) Certification of the HUBR site as a full GRUAN site by the GRUAN-working group; (3) coordination establishment of the GRUAN Mid-Atlantic Consortium (G-MAC) activities, and (4) satellite validation activities towards an establishment of a Site Atmospheric State Best Estimate (SASBE) product. A quarterly meeting was held to plan and coordinate related activities between consortium members; Students, NWS Sterling Field Support Center (SFSC) staff and scientists at NOAA-STAR and

NASA-NDACC researchers. The meeting focused on lessons learned and expectations from the G-MAC and DWD's Lindenbeg, Germany lead center as well as a planned validation study at Wallops, VA by NWS-SFSC. As in the past, an improvement in data delivery, data quality and flags in the primary goals of this funding continues. These goals are (1) weekly and monthly RS92 and CFH launches and associated activities and calibration continued; (2) Coordinated sonde launches by NWS-SFSC and HUBR continued at or near the time of satellite overpass; (3) Analysis of SASBE related sonde and lidar data has continued.

Planned work

- Continue the weekly Vaisala RS-92 and monthly CFH launches, coincident with the overpass of the Suomi National Polar-orbiting Partnership satellite (NPP).
- Continue data sharing with NESDIS/STAR personnel for NPROV+.
- Continue collaboration with GRUAN and submission of all previous radiosonde data sets and continue quality controlling the data archive.
- Continue collaboration with STAR personnel for validation of the EDRs, contributing to and the NOAA/NWS Sterling Testing Facility scientists on CFH training.
- Continue the monthly CFH launches and contribute for the development of the CFH GRUAN data product.
- Continue with SASBE analysis and submit a paper for peer-reviewed journal.

Products

- Trained NWS-Sterling office employee on proper handling and launch of CFH sondes for the NWS-Wallops Field Experiment.
- Assisted in planning and execution of the field campaign.

Presentations

Monique Walker, M., B. B. Demoz, R. K. Sakai, N. R. Nalli, T. Reale, D. Venable, L. Cooper Jr., M. K. Payne, and M. I. Oyola (2017): Inter-Comparison and Validation of NOAA-Unique Combined Atmospheric Processing System Water Vapor Retrievals and Case Study on Howard University Beltsville Site State Best Estimate

Other

A graduate student, Megan Payne (now Megan Lataille) completed her Ph.D. Defense and have been employed by NOAA-NWS, Sterling test Center as an upper air expert.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	12[1]
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	1
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	2[+]
# of undergraduate students mentored during the year	2

- [1]This task operates upper air sondes out to f the Howard University Beltsville campus. The grant covers the resources necessary for calibration of NUCAPS by the NPROVS team at STAR and is submitted as part of the GRUAN network.
- [+]Two Howard University graduate students are assisting with launch of the upper air products at Beltsville. Two undergraduate students at UMBC are working on analysis of data from this grant.

Support for Air Quality Projects at ARL: Daniel Tong (Part 1 of 10)

Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: 1) CICS scientists generated high-quality emission products to major updates in the NOAA O_3 and $PM_{2.5}$ forecasts; 2) CICS scientists conducted validation of VIIRS isoprene product using measurements from two new cruises; 3) CICS scientists investigated the impact of the 2008 economic recession on US air quality; 4) CICS scientist co-authored UN report on global assessment of sand and dust storms.

Background

This work is part of the collaboration between NOAA Air Resources Laboratory (ARL) with UMD to advance climate research. The specific task is to develop high-quality emission datasets and emission algorithms to support the national air quality forecasting capability (NAQFC) and climate models.

Accomplishments

In the past year, Daniel Tong has completed the following tasks:

1. NOAA National Air Quality Forecasting Research and Operation:

Daniel led the team's efforts to generate high quality emission data products to support day-to-day operations of the NOAA National Air Quality Forecast Capability (NAQFC). In addition, Daniel has generated new emission dataset to support a major update of NAQFC to CMAQ version 5.02. Products generated from this effort include four large datasets required by the National Weather Service (NWS) to NOAA air quality forecast operations and research:

a) *Operational CONUS Emissions:* Generated emission files for the CONUS domain, including 365-D area source files, 365-D mobile files, ~30 point source files and other ancillary emission files;
b) *Experimental CONUS Emissions:* Generated the similar emission datasets for the Experimental run with CB05 chemical mechanism (total of ~760 files);
c) *Operational Hawaii Emissions:* Generated emission files for the Hawaii domain, including 365-D area source files, 365-D mobile files, ~30 point source files and other ancillary emission files;
d) *Operational Alaska Emissions:* Generated emission files for the Hawaii domain, including 365-D area source files, 365-D mobile files, ~30 point source files and other ancillary emission files;

2. Validation of S-NPP VIIRS marine isoprene product

Daniel serves as the PI to a NOAA Joint Polar Satellite System (JPSS) project that aims to derive real-time marine isoprene emissions using multiple JPSS ocean products and NWS global meteorology. He continues working with NESDIS scientists to validate the VIIRS isoprene product. Daniel used new isoprene measurements from the SPACES/OASIS (June– July 2014, Indian Ocean) and ASTRA-OMZ (October 2015, eastern Pacific Ocean) cruises to compare the JPSS emission method and three of other models employed by previous scientists (Palmer et al., 205; Arnold et al., 2009; and Gantt et al., 2009)

3. Impact of economic recession on US air quality
In a series of studies using the NAQFC modeling system and satellite observations, we have examined the impact the 2008 economic recession on air quality over the Untied States. First, we examines the long-term NO_x trends derived from satellite and ground observations are compared and used to evaluate the updates of NO_x emission data by the US National Air Quality Forecast Capability (NAQFC) for next-day ozone prediction during the Recession. Over the eight large US cities examined, both the Ozone Monitoring Instrument (OMI) and the Air Quality System (AQS) detect substantial downward trends from 2005 to 2012, with a seven-year total of -35% according to OMI and -38% according to AQS. The NO_x emission projection adopted by NAQFC tends to be in the right direction, but at a slower reduction rate (-25% from 2005 to 2012), due likely to the unaccounted effects of the 2008 economic recession. Both OMI and AQS datasets display distinct emission reduction rates before, during, and after the 2008 global recession in some cities, although the detailed changing rates vary from city to city. Our findings demonstrate the feasibility of using space and ground observations to detect the impact of the Recession on urban air pollution, and the trend can be used to evaluate major updates of emission inventories objectively.

Next, we combines observed NO_x trends and a regional chemical transport model to quantify the impact of the recession on surface ozone (O_3) levels over the continental United States. The impact is quantified by simulating O_3 concentrations under two emission scenarios: business-as-usual (BAU) and recession. In the BAU case, the emission projection from the Cross-State Air Pollution Rule (CSAPR) is used to estimate the “would-be” NO_x emission level in 2011. In the recession case, the actual NO_2 trends observed from Air Quality System (AQS) ground monitors and the Ozone Monitoring Instrument (OMI) on the Aura satellite are used to obtain “realistic” changes in NO_x emissions. The model prediction with the recession effect agrees better with ground O_3 observations over time and space than the prediction with the BAU emission. The results show that the recession caused a 1-2 ppbv decrease in surface O_3 concentration over the eastern United States, a slight increase (0.5-1 ppbv) over the Rocky Mountain region, and mixed changes in the Pacific West. The gain in air quality benefits during the recession, however, could be quickly offset by the much slower emission reduction rate during the post-recession period.

4. Contribution to UN Report on Sand and Dust Storms
Daniel Tong co-authored a recent United Nations (UN) Report titled “Global Assessment of Sand and Dust Storms”, jointly published by United Nations Environmental Programme (UNEP), The World Meteorology Organization (WMO), and United Nations Convention to Combat Desertification (UNCCD). This report, with a Foreword by UN Secretary General Ban Ki-Moon, discussed the state and trend of global sand dust storms, the drivers behind the trend, societal impacts and possible solutions to combat increasing desertification around the globe. Several papers authored by our team members were cited to support the report.

Planned work

- Continue working on emission modeling research data to support NOAA NAQFC operation;
- Continue working on multiple research projects on air quality forecasting, satellite remote sensing and applications.

Publications

1. Huang J, McQueen J, Wilczak J, Djalalova I, Stajner I, Shafran P, Allured D, Lee P, Pan L, Tong D, Huang HC. Improving NOAA NAQFC $PM_{2.5}$ predictions with a bias correction approach. Weather and Forecasting. 2016 Dec 21(2016).
2. Zhang, X., Zhao, L., Tong, D. Q., Wu, G., Dan, M., & Teng, B. (2016). A Systematic Review of Global Desert Dust and Associated Human Health Effects. *Atmosphere*, *7*(12), 158.
3. Tong, D.Q., L. Pan, W. Chen, L. Lamsal, P. Lee, Y. Tang, H. Kim, S. Kondragunta, I. Stajner, 2016. Impact of the 2008 Global Recession on air quality over the United States: Implications for surface ozone levels from changes in NO_x emissions. Geophysical Research Letter, 43(17), 9280-9288, doi: 10.1002/2016GL069885.
4. Lee, Pius, Jeffery McQueen, Ivanka Stajner, Jianping Huang, Li Pan, Daniel Tong, Hyuncheol Kim, Youhua Tang, Shobha Kondragunta, Mark Ruminski, Sarah Lu, Eric Rogers, Rick Saylor, Perry Shafran, Ho-Chun Huang, Jerry Gorline, Sikchya Upadhayay, and Richard Artz (2017). NAQFC developmental forecast guidance for fine particulate matter ($PM_{2.5}$), Weather and Forecasting, 32(1), 343–360.
5. Shepherd, Gemma, Enric Terradellas, Alexander Baklanov , Utchang Kang , William A. Sprigg , Slobodan Nickovic , Ali Darvishi Boloorani , Ali Al-Dousari , Sara Basart , Angela Benedetti, Andrea Sealy, Daniel Tong, Xiaoye Zhang, Joy Shumake-Guillemot , Zhang Kebin, Peter Knippertz, Abdulkareem A. A. Mohammed, Moutaz Al-Dabbas, Leilei Cheng, Shinji Otani, Feng Wang, Chengyi Zhang, Sang Boom Ryoo, and Joowan Cha, Gemma Shepherd, editor (2016). Global Assessment of Sand and Dust Storms. United Nations Environment Programme, Nairobi. Retrieved from uneplive.unep.org.
6. Richard Artz, Pius Lee, Rick Saylor, Ariel Stein & Daniel Tong, 2016. Introduction to a Special Issue of *JA&WMA* on NOAA's 7th International Workshop on Air Quality Forecasting Research (IWAQFR). *Journal of Air and Waste Management Association*, 66, 815-818.
7. Dong, X., Fu, J. S., Huang, K., Tong, D. and G. Zhuang: Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and its application over East Asia, Atmos. Chem. Phys., 16, 8157–8180, 2016.
8. Battye, W. H., Bray, C. D., Aneja, V. P., Tong, D., Lee, P., & Tang, Y. (2016). Evaluating ammonia (NH 3) predictions in the NOAA National Air Quality Forecast Capability (NAQFC) using in situ aircraft, ground-level, and satellite measurements from the DISCOVER-AQ Colorado campaign. *Atmos. Environ*. doi: 10.1016/j.atmosenv.2016.06.021.
9. Zhao, Hongmei, Daniel Q. Tong, Pius Lee, Hyuncheol Kim and Hang Lei, 2016: Reconstructing Fire Records from Ground-Based Routine Aerosol Monitoring, *Atmosphere*, **7**, 43, doi:10.3390/atmos7030043.
10. Lei, Hang, Julian XL Wang, Daniel Q. Tong, and Pius Lee. "Merged dust climatology in Phoenix, Arizona based on satellite and station data." *Climate Dynamics* (2016): 1-15.
11. Tang, Y., L. Pan, P. Lee, D. Tong, D., H. C. Kim, J. Wang and S. Lu. The Performance and Issues of a Regional Chemical Transport Model During Discover-AQ 2014 Aircraft Measurements Over Colorado. In *Air Pollution Modeling and its Application XXIV* (pp. 635-640, Chapter 103). *ISBN:978-3-319-24476-1*, Springer International Publishing, 2016.
12. Lee, P., Atlas, R., Carmichael, G., Tang, Y., Pierce, B., Biazar, A.P., Pan, L., Kim, H., Tong, D. and Chen, W., 2016. Observing System Simulation Experiments (OSSEs) Using a Regional Air Quality Application for Evaluation. In *Air Pollution Modeling and its Application XXIV* (pp. 599-605). Springer International Publishing.

Presentations

Daniel gave ten presentations at national and international conferences.

Other

1. Grants Received
    - US Weather Research Program (USWRP) 2016. Towards the improvement of chemical lateral boundary conditions for the National Air Quality Forecasting Capability. Role: Co-PI, with Zhining Tao of NASA, $400,000 (UMD portion $205,000), 2016-2019.

2. Community Services
    - Daniel co-chaired two sessions on dust trends and societal impacts at the 2016 AGU Fall Meeting in San Francisco, CA;
    - Daniel co-chaired the emission forecasting session at the 8th International Workshop on Air Quality Forecasting Research (IWAQFR) held on Jan, 2017 in Toronto, Canada.

Support for Air Quality Projects at ARL: Youhua Tang (Part 2 of 10)	
Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

My major task at NOAA Air Resources Laboratory is conducting air quality modeling research, including air quality re-analysis and support NOAA/NCEP operational air quality forecasting, and model development.

Accomplishments

In the period from April 2016 to March 2017, I developed the method of using GSI/CRTM's GOCART aerosol module to handle the CMAQ's AOD calculation, so that GSI can assimilate CMAQ aerosol with satellite AOD data. I presented this result in 2016 Annual CMAS conference and the corresponding paper is submitted.

In order to support a USWRP project of updating lateral boundary condition (LBC) for NAQFC, I build a LBC interface to extract NASA's GEOS-5 output. If the new LBC shows better result, we will use it to replace the existing operational NAQFC's LBC.

The surface chemical reanalysis data for U.S. CONUS domain is rolled out using optional interpolating method (Tang et al., 2015). The healthy-study scientists are looking at it in their projects.

Planned work

1. I plan to expand GSI to assimilate more species, e.g. O3 etc, and put it for operational usage. It should improve the NAQFC's day-1 PM and ozone predictions.
2. Reanalysis data process. I will continue working on reanalyzing air quality data, and collaborate with healthy-study scientists. Currently I am using hourly optimal interpolation method for this process, which can be tested with GSI method in the future.
3. We will continue testing the GEOS-5 LBC for improving the chemical lateral boundary condition of NAQFC. If the result is encouraging, I will work on implementing it.
4. Explore the CMAQ linkage with FV3. I plan to re-write the meteorological pre-processor and overhaul PreMAQ as it is too old and too slow for NAQFC usage.
5. High-resolution prediction. We have a plan for 3km simulation over Northeastern USA, and I will work on it.
6. I will also support emission-related activities, including the point source annual update, and mobile emission update and ammonia emission study.

Publications

Tang, Y., M. Pagowski, T. Chai, L. Pan, P. Lee, B. Baker, R. Kumar, L. Delle Monache, D. Tong and H.-C. Kim, Aerosol Assimilation Based on NCEP's GSI Compared to Optimal Interpolation Method. Submitted to Geoscientific Model Development.

Battye, W. H., C. D. Bray, V. P. Aneja, D. Tong, P. Lee, and **Y. Tang**, Evaluating ammonia (NH3) predictions in the NOAA National Air Quality Forecast Capability (NAQFC) using in situ aircraft, ground-level, and satellite measurements from the DISCOVER-AQ Colorado campaign. Atmos. Environ., 140, 342-351, DOI:10.1016/j.atmosenv.2016.06.021, 2016.

Tong, D., L. Pan, W. Chen, L. Lamsal, P. Lee, **Y. Tang**, H. Kim, S. Kondragunta, and I. Stajner, Impact of the 2008 Global Recession on air quality over the United States: Implications for surface ozone levels from changes in NOx emissions, Geophys. Res. Let., 43(17), 9280-9288, DOI:10.1002/2016GL069885. 2016.

Lee, P., J. McQueen, I. Stajner, J. Huang, L. Pan, D. Tong, H. Kim, **Y. Tang**, S. Kondragunta, M. Ruminski, and S. Lu, NAQFC developmental forecast guidance for fine particulate matter (PM2. 5). Weather and Forecasting, DOI: 10.1175/WAF-D-15-0163.1, 2017.

Lu, C.-H., A. da Silva, J. Wang, S. Moorthi, M. Chin, P. Colarco, **Y. Tang**, P. S. Bhattacharjee, S.-P. Chen, H.-Y. Chuang, H.-M. Juang, J. McQueen and M. Iredell, The implementation of NEMS GFS Aerosol Component (NGAC) Version 1.0 for global dust forecasting at NOAA/NCEP. Geosci. Model Dev., 9, 1905–1919, doi:10.5194/gmd-9-1905-2016, 2016.

Hong, C., Q. Zhang, Y. Zhang, **Y. Tang**, D. Tong, and K. He. Multi-year Downscaling Application of Online Coupled WRF-CMAQ over East Asia for Regional Climate and Air Quality Modeling: Model Evaluation and Aerosol Direct Effects. Submitted to Geoscientific Model Development.

Presentations

Y. Tang, et al., Assimilation Based on NCEP's GSI Compared to Optimal Interpolation Method, 15th Annual CMAS Conference, Chapel Hill, NC, Oct 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	2
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	4
# of NOAA technical reports	1
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support for Air Quality Projects at ARL: Xinrong Ren (Part 3 of 10)	
Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz & W. T. Luke
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 100%, Theme 3: 0%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 0%, Goal 2: 80%, Goal 3: 20%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

Mercury (Hg) is a neurotoxic pollutant and exists in the environment for long periods by cycling between the air, water, and soil in different chemical forms. Atmospheric emissions of mercury are important, as atmospheric deposition is the most significant loading pathway for many ecosystems. After deposition to watersheds and receiving waters, mercury can be converted to methylmercury, a highly toxic form. Methylmercury is incorporated into the food chain and increases with trophic levels through bioaccumulation. Humans are exposed to methylmercury primarily through consuming contaminated fish and other aquatic organisms. Methylmercury can adversely affect the nervous system, particularly those of fetuses and young children.

Gaseous elemental mercury (GEM) is observed ubiquitously in the troposphere. The distributions of two other forms of mercury species, gaseous oxidized mercury (GOM) and particulate bound mercury (PBM), are not well documented. It is highly desirable to conduct measurements of a variety of trace gases along with atmospheric mercury to facilitate source identification.

Accomplishments

With the support from this project, Xinrong Ren has been working primarily on the atmospheric mercury monitoring project at NOAA Air Resources Laboratory. Below is a summary of the accomplishments in the past year:

(1) Support of on-going long-term atmospheric mercury measurements

Xinrong Ren provided technical and scientific support of weekly/monthly/quarterly maintenance for a long-term atmospheric mercury monitoring site located in Beltsville, Maryland. The atmospheric mercury monitor is operated by NOAA Air Resources Laboratory (ARL) according to EPA Atmospheric Mercury Network (AMNet) protocols. He also provided support for the operation of other two AMNet sites located in Grand Bay, Mississippi and Hilo, Hawaii.

a. In September 2016, Xinrong Ren, together with Winston Luke and Paul Kelley, travel to Mauna Loa Observatory (MLO) on the island of Hawaii. They perform a scheduled maintenance visit to the MLO AMNet mercury monitoring site and deployed additional instrumentation for the measurement of total reactive mercury, and for the testing of gaseous oxidized mercury and gaseous elemental mercury calibration sources designed to improve the accuracy and robustness of atmospheric mercury measurements. Testing of the additional instrumentation and calibration devices continued for approximately 4 months until early 2017.

b. In late January and early February 2017, Xinrong Ren together with Winston Luke and Paul Kelley, traveled to the Grand Bay National Estuarine Research Reserve (NERR) in Moss Point, Mississippi and performed a scheduled maintenance visit to the Grand Bay AMNet mercury monitoring site, to deploy additional instrumentation for the calibrations of trace gas measurement, and to train new site operators.

(2) Data analyses for atmospheric mercury process studies

Xinrong Ren worked on the data analysis for the two atmospheric mercury process studies: (a) Inter-annual, seasonal and diurnal variations of atmospheric mercury species and source -receptor correlation the Beltsville site, and (b) Long-term trends of atmospheric mercury species at a coastal site in the northern Gulf of Mexico. One paper has been published based on the results from the first study. A second paper based on the results from the second study is in preparation.

Planned work

- To continue the monitoring of mercury compounds (GEM, GOM, and PBM) at the three EPA Atmospheric Mercury Network (AMNet) sites operated by NOAA ARL.
- To conduct data analysis for the atmospheric mercury observations at the Grand Bay and Mauna Loa AMNet sites made over the past 9 years.

Publications

Peer-reviewed

1. **Ren, X.**, D. L. Hall, T. Vinciguerra, S. E. Benish, P. R. Stratton, D. Ahn, J. R. Hansford, M. D. Cohen, S. Sahu, H. He, C. Grimes, R. J. Salawitch, S. H. Ehrman, and R. R. Dickerson, Methane Emissions from the Marcellus Shale in Southwestern Pennsylvania and Northern West Virginia Based on Airborne Measurements, *J. Geophys. Res.*, in press, 2017.
2. Martin, C. R., N. Zeng, A. Karion, R. R. Dickerson, **X. Ren**, B. N. Turpie, K. J. Weber, Evaluation and enhancement of a low-cost NDIR CO_2 sensor, *Atmos. Meas. Tech. Discuss.*, doi:10.5194/amt-2016-396, 2017.
3. Bieser, J., F. Slemr, J. Ambrose, C. Brenningkmeijer, S. Brooks, A. Dastoor, F. DeSimone, R. Ebinghaus, C. N. Gencarelli, B. Geyer, L. E. Gratz, I. M. Hedgecock, D. Jaffe, P. Kelley, C. Lin, V. Matthias, A. Ryjkov, N. E. Selin, S. Song, O. Travnikov, A. Weigelt, W. Luke, **X. Ren**, A. Zahn, X. Yang, Y. Zhu, N. Pirrone, Multi-model study of mercury dispersion in the atmosphere: Vertical distribution of mercury species, *Atmos. Chem. Phys. Discuss.*, doi:10.5194/acp-2016-1074, 2016.
4. **Ren, X.**, W. T. Luke, P. Kelley, M. D. Cohen, R. Artz, M. L. Olson, D. Schmeltz, M. Puchalski, D. L. Goldberg, A. Ring, G. M. Mazzuca, K. A. Cummings, L. Wojdan, S. Preaux, and J. W. Stehr, Atmospheric mercury measurements at a suburban site in the Mid-Atlantic United States: Inter-annual, seasonal and diurnal variations and source-receptor relationships, *Atmos. Environ.*, 146, 141-152, doi: 10.1016/j.atmosenv.2016.08.028, 2016.
5. Mazzuca, G. M., **X. Ren**, C. P. Loughner, M. Estes, J. H. Crawford, K. E. Pickering, and R. R. Dickerson, Ozone production and its sensitivity to NOx and VOCs: results from the DISCOVER-AQ field experiment, Houston 2013, *Atmos. Chem. Phys.*, 16, 14,463–14,474, doi: 10.5194/acp-16-14463-2016, 2016.

6. Ma, Y., Y. Diao, B. Zhang, W. Wang, **X. Ren**, D. Yang, M. Wang, X. Shi, and J. Zheng, Detection of formaldehyde emissions from an industrial zone in the Yangtze-River-Delta region of China using a proton transfer reaction ion-drift chemical ionization mass spectrometer, *Atmos. Meas. Tech.*, 9, 6101-6116, doi: 10.5194/amt-9-6101-2016, 2016.
7. Lyman, S., C. Jones, T. O'Neil, T. Allen, M. Miller, M. S. Gustin, A. M. Pierce, W. Luke, **X. Ren**, P. Kelley, Automated calibration of atmospheric oxidized mercury measurements, *Environ. Sci. Technol.*, 50, 12,921−12,927, doi: 10.1021/acs.est.6b04211, 2016.
8. Mok, J., N. A. Krotkov, A. Arola, O. Torres, H. Jethva, M. Andrade, G. Labow, T. F. Eck, Z. Li, R. R. Dickerson, G. L. Stenchikov, S. Osipov, and **X. Ren**, Impacts of brown carbon from biomass burning on surface UV and ozone photochemistry in the Amazon Basin. *Sci. Rep.*, 6, 36940, doi: 10.1038/srep36940, 2016.
9. Cohen, M. D., R. R. Draxler, R. S. Artz, C. Banic, P. Blanchard, M. S. Gustin, Y.-J. Han, T. M. Holsen, D. A. Jaffe, P. Kelley, H. Lei, C. P. Loughner, W. T. Luke, S. N. Lyman, D. Niemi, J. M. Pacyna, M. Pilote, L. Poissant, D. Ratte, **X. Ren**, F. Steenhuisen, A. Steffen, R. Tordon, and S. Wilson, Modeling the global atmospheric transport and deposition of mercury to the Great Lakes, *Elementa*, 4: 000118, doi: 10.12952/journal.elementa.000118, 2016.
10. Barth, M. C., M. M. Bela, A. Fried, P. O. Wennberg, J. D. Crounse, J. M. St. Clair, N. J. Blake, D. R. Blake, C. R. Homeyer, W. H. Brune, L. Zhang, J. Mao, **X. Ren**, T. B. Ryerson, I. B. Pollack, J. Peischl, R. C. Cohen, B. A. Nault, L. G. Huey, X. Liu and C. A. Cantrell, Convective Transport of Peroxides by Thunderstorms Observed over the Central U.S. during DC3, *J. Geophys. Res.-Atmos.*, 121 (8), 4272–4295, 2016, doi: 10.1002/2015JD024570.
11. Brune, W. H., B. C. Baier, J. Thomas, **X. Ren**, R. C. Cohen, S. E. Pusede, E. Browne, A.H. Goldstein, D. R. Gentner, F. N. Keutsch, J. Thornton, S. Harrold, F. Lopez-Hilfiker, P. O. Wennberg, Ozone Production Chemistry in the Presence of Urban Plumes, *Faraday Discuss.,* 189, 169-189, 2016, doi: 10.1039/c5fd00204d.
12. Nowlan, C. R., X. Liu, J. W. Leitch, K. Chance, G. González Abad, C. Liu, P. Zoogman, J. Cole, T. Delker, W. Good, F. Murcray, L. Ruppert, D. Soo, M. B. Follette-Cook, S. Janz, M. Kowalewski, C. Loughner, K. Pickering, J. Herman, M. Beaver, R. Long, J. Szykman, L. Judd, **X. Ren**, W. Luke, P. Kelley, and J. Al-Saadi, Nitrogen dioxide observations from the Geostationary Trace gas and Aerosol Sensor Optimization airborne instrument: Retrieval algorithm and measurements during DISCOVER-AQ Texas 2013, *Atmos. Meas. Tech.* 9, 2647–2668, doi:10.5194/amt-9-2647-2016, 2016.

Presentations

1. Ren, X. and R. R. Dickerson, Estimate of Methane Emissions from the Marcellus Shale in Southwest Pennsylvania and Northern West Virginia Using Aircraft Observations, Abstract #7.2, AMS the 19th Conference on Atmospheric Chemistry, Seattle, WA, January 23-26, 2017.
2. Luke, Winston, Paul Kelley, Xinrong Ren et al., Assessment of Gaseous Oxidized Mercury Measurement Accuracy at an Atmospheric Mercury Network (AMNet) Site, Abstract # B33D-0642, AGU Fall Meeting, San Francisco, CA, December 11-16, 2016.
3. Dickerson, R. R. et al. (including X. Ren), Determination and Evaluation of Greenhouse Gas and Pollutant Flux Estimates for the Baltimore/Washington Area, Abstract #11.3, AMS the 19th Conference on Atmospheric Chemistry, Seattle, WA, January 23-26, 2017.
4. Dickerson, R. R. et al. (including X. Ren), Measurements and models of greenhouse gas emissions and pollutant fluxes in the Baltimore/Washington Area, Abstract # A13J-01, AGU Fall

Meeting, San Francisco, CA, December 11-16, 2016
5. Salmon, O. E. et al. (including X. Ren), Wintertime Emission Ratios of CO2 and NOy from Washington, D.C.-Baltimore, Abstract # A13J-06, AGU Fall Meeting, San Francisco, CA, December 11-16, 2016
6. Ren, X. et al., Ozone production and its sensitivity to NOx and VOCs: Results from the DISCOVER-AQ field experiment, Houston 2013, Abstract # A14A-01, AGU Fall Meeting, San Francisco, December 11-16, 2016
7. Ahn, D. et al. (including X. Ren), Quantifying Fluxes of Greenhouse Gases in Baltimore-Washington Metropolitan Area from Airborne Measurements, Abstract # A21C-0040, AGU Fall Meeting, San Francisco, CA, December 11-16, 2016
8. He, H. et al. (including X. Ren), Numerical simulations of Aerosol and Trace Gas Emissions and Transformations over the North China Plain, , Abstract # A21C-0060, AGU Fall Meeting, San Francisco, CA, December 11-16, 2016
9. Brune, W. H. et al. (including X. Ren), Building Confidence in the Understanding of Atmospheric Oxidation Capacity, Abstract # A41I-01, AGU Fall Meeting, San Francisco, CA, December 11-16, 2016
10. Luke, Winston, Paul Kelley, Xinrong Ren, Richard Artz, Mark Olson, David Schmeltz, and Nash Kobayashi, Evaluation of GOM Measurement Artifacts at the Mauna Loa AMNet Site, the National Atmospheric Deposition Program Annual Meeting, Santa Fe, NM, October 31-November 4, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers on mercury (total)	4(12)
# of NOAA technical reports	
# of presentations	10
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support for Air Quality Projects at ARL: Li Pan (Part 4 of 10)	
Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

The National Air Quality Forecasting Capability (NAQFC) provides air quality forecast (Ozone and PM2.5) and issues a numerical guidance to warning public when poor air quality conditions occur. NOAA/OAR Air Resources Laboratory (ARL) is continuing cooperating with NOAA National Weather Service (NWS) to support NAQFC in 2016. This support includes two aspects: operation and system upgrading. In operation, ARL is responsible for providing operationally needed monthly anthropogenic surface emissions and yearly point emissions and JTABLE. ARL is also responsible for finding a quick solution in case of operational emergency. In system upgrading, ARL is responsible for developing a new system based on the state of the art sciences and technologies to improve the accuracy of current NAQFC forecasting and delivering codes to EMC through EMC designated SVN after testing and evaluations.

Accomplishments

- **Upgraded operational CMAQ version in NAQFC from 4.6 to 5.0.2**

  The current CMAQ operation version in NAQFC is CMAQ4.6 that was firstly released by US EPA in October, 2006. CMAQ version 5.0.2 was released by US EPA in May 2014. Compared with CMAQ version 4.6, in gas-phase chemistry, CMAQ 5.0.2 includes the updated toluene chemistry in CB05 mechanism and on-line photolysis rate module; in aerosol chemistry, CMAQ 5.0.2 enhances more sophisticated aerosol module as well as speciation. CMAQ5.0.2 also enables in-line biogenic emission calculation and in-line dry deposition velocity calculation.

- **Upgraded PREMAQ to enable CMAQ5.0.2 coupling with NAM**

  PREMAQ is acting as an interface between meteorology model and chemical transport model converting NAM outputs into CMAQ ready inputs. Since CMAQ5.0.2 activates more in-line functions and includes more gas and aerosol species, it requires that PREMAQ has to be modified accordingly. Ten more variables are added to metcro2d file. They are listed as SNOCOV (snow coverage), VEG (vegetation), SEAICE (sea ice), WR (canopy moisture content), SOIM1 (soil moisture in top CM), SOIM2 (soil moisture in top M), SOIT1 (soil temperature in top CM), SOIT2 (soil temperature in top M), SLTYP(soil texture type by USDA category) and Q2(mixing ration at 2m). We add USGS 24 category land using typing fractions (LUFRAC) and land-water mask (LWMASK) into grdcro2d file. We add UWINDC (C-staggered U-comp of true wind at W-E faces) and VWINDC (C-staggered V-comp of true wind at S-N faces) into metdot3d file. We also add CFRAC_3D (3d cloud fraction) into metcro3d file.

- **Upgraded PREMAQ to read NAM GRIB2 output format**
  The format of NAM output has been changed from GRIB1 to GRIB2. NAM reader in PREMAQ has been modified to read GRIB2. During testing, we found several bugs in GRIB2 library (g2_c) and reported it to NCO.

- **Upgraded wind blowing dust code to be compatible to CMAQ5.0.2 aerosol species list**
  In the wind blowing dust code used for CMAQ4.6, crustal species are not explicitly represented. However, for CMAQ5.0.2, crustal emissions are subdivided to Al, Ca, Cl, Fe, K, Mg, Mn, Na, Si and Ti. Meanwhile, several bugs in old wind blowing dust code had been fixed.

- **Upgraded NGAC species mapping table to be compatible to CMAQ5.0.2 aerosol species list**
  NGAC species mapping table has been changed according to new CMAQ5.0.2 aerosol species and the number concentration for each aerosol size bin has been added into CMAQ boundary condition.

- **New BlueSky fire emission in NAQFC**
  Wildfire emissions are calculated in the newly updated BlueSky model. The fire emission processing codes in NAQFC has been overhauled to enable directly reading BlueSky wildfire emissions. The previous code is through SMOKE, which needs to convert fire emission information to SMOKE inventory format. The wildfire fire plume rising height is also calculated based on BlueSky calculated heat flux. This change not only saves PREMAQ processing time but also enable CMAQ 5.0.2 utilized the wildfire diurnal profile derived from BlueSky.

- **24-hour CMAQ retrospective run to provide an initial condition for next 48-hour forecasting**
  Due to time consumed processes in wildfire detecting and following data quality control, the wildfire information used in today's NAQFC is usually one day old. A CMAQ retrospective run uses yesterday wildfire information to rerun yesterday forecasting 24 hours. In this run, more wildfire information from HMS is used such as fire starting time, duration and fire ending time. Therefore, this run represented the best available wildfire prediction in NAQFC and is acting as an initial condition for next 48-hour forecasting. This setting significantly benefits NAQFC model performance especially in a fire season over CONUS, which usually occurs in summer time and at a same time as ozone season.

- **Completed NAQFC CMAQ5.0.2 suite testing using new NAM**
  EMC updated NAM microphysics to improve stratiform precipitation, changed land-surface physics and radiation to improve cool and warm season surface temperature bias and changed convective parameterization to improve cool season dry bias. Under new NAM, NAQFC CMAQ5.0.2 suite has been tested and predicted ozone and PM have been evaluated.

- **Completed NAQFC CMAQ5.0.2 evaluations**
  We run two months CMAQ5.0.2 simulations in winter (January and February) and three months CMAQ5.0.2 simulations in summer (June, August and September) for evaluation testing. We use AIRNOW data to evaluated CMAQ5.0.2 predicted ozone and PM2.5. CMAQ5.0.2 reduces ozone positive bias and PM2.5 negative bias in summer. CMAQ5.0.2 also reduces ozone negative bias and PM2.5 positive bias in winter.

- **Tested NOx emission adjustment**
  Using observed NOx trends from AQS ground stations and OMI NO2 column from 2011 to 2015, we got NOx emission adjustment factor on a state level basis. We interpolated this trend and applied it 2016 NOx emission. The new NOx emission was simulated in CMAQ5.0.2 and results have been evaluated. Ozone positive bias in summer had been significantly reduced. It means that the ozone false alarm in NAQFC had been reduced.

- **Transferred NAQFC CMAQ5.0.2 suite code from WCOSS to CRAY**
  NWS decided that CMAQ5.0.2 will run on CRAY instead of WCOSS. We completed codes transfer from WCOSS to CRAY. Each code has to be recompiled based on CRAY environmental setting. CMAQ results on WCOSS and on CRAY had been checked for consistency.

- **Delivered NAQFC CMAQ5.0.2 suite code to EMC**
  We delivered CMAQ5.0.2 code to EMC through SVN. The code delivered to EMC is capable of four cycles forecasting simulation (00, 06, 12 and 18). EMC run 4-cycle forecasting while we do one cycle parallel forecasting on 12z.

Planned work

- Unify as much as possible AK, HI NAQFC code with that for CONUS;
- Extend NAQFC forecasting from 48 hours to 72 hours;
- Apply updated point source emission, EPA emission-release projected for2017 and MOVES to NAQFC;
- Apply new static lateral boundary condition for NAQFC;
- Include fire boundary condition from NGAC into NAQFC;
- Set a NAQFC parallel run with GSI and process analysis included.

Publications:

- Huang, J., McQueen, J., Wilczak, J., Djalalova, I., Stajner, I., Shafran, P., Allured, D., Lee, P., **Pan, L**., Tong, D. and Huang, H.C., 2016. Improving NOAA NAQFC PM2. 5 predictions with a bias correction approach. *Weather and Forecasting*, (2016).
- Lee, P., McQueen, J., Stajner, I., Huang, J., **Pan, L**., Tong, D., Kim, H., Tang, Y., Kondragunta, S., Ruminski, M. and Lu, S., 2016. NAQFC developmental forecast guidance for fine particulate matter (PM2. 5). *Weather and Forecasting*, (2016).
- Tong, D., **Pan, L.**, Chen, W., Lamsal, L., Lee, P., Tang, Y., Kim, H., Kondragunta, S. and Stajner, I., 2016. Impact of the 2008 Global Recession on air quality over the United States: Implications for surface ozone levels from changes in NOx emissions. *Geophysical Research Letters*, *43*(17), pp.9280-9288.
- Kim, H.C., Lee, P., Judd, L., **Pan, L**. and Lefer, B., 2016. OMI NO2 column densities over North American urban cities: the effect of satellite footprint resolution. *Geoscientific Model Development*, *9*(3), pp.1111-1123.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	3
# of products or techniques submitted to NOAA for consideration in operations use	7
# of peer reviewed papers	4
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

New and Improved Products:

1. NAQFC CMAQ 5.0.2 forecasting system;
2. 24-hour CMAQ retrospective run using newest wildfire information from HMS;
3. New fire emission scheme for NAQFC;

Support for Air Quality Projects at ARL: Fong Ngan (Part 5 of 10)

Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz & Ariel Stein
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 0%, Theme 3: 100%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: CICS Scientist Fong Ngan **d**eveloped and evaluated WRF-HYSPLIT inline coupling and a long-term WRF meteorological archive for dispersion simulations.
Link to a research web page: http://www.arl.noaa.gov/WRF_inline.php

Background

1. **Development and evaluation of WRF-HYSPLIT inline coupling**

NOAA/ARL's dispersion (HYSPLIT) has been inline coupled to the Advanced Research WRF meteorological model. The inline coupling approach takes advantage of the higher temporal frequency of the meteorological variables, avoids temporal and vertical interpolation of the data, and uses WRF's vertical coordinate. The inline HYSPLIT is available on ARL's web site (http://www.arl.noaa.gov/WRF_inline.php) to provide information and instructions of using the inline HYSPLIT. The WRF-ARW user web page (http://www2.mmm.ucar.edu/wrf/users/) also has a link to direct users to the inline HYSPLIT. Dr. Ngan updated the inline model with new features and evaluated with measurements from Sagebrush tracer experiment in a fine scale resolution.

2. **A long-term WRF meteorological archive for dispersion simulations**

ARL's Data Archive of Tracer Experiment and Meteorology (DETEM) provides a platform for HYSPLIT's verification and development. To support DATEM by providing meteorological data, Dr. Ngan ran the WRF model to create a long-term archive to provide meteorological data compatible with the HYSPLIT dispersion model and to serve as initial and boundary conditions for WRF simulations at a finer resolution for dynamic downscaling.

Accomplishments:

1. **Development and evaluation of WRF-HYSPLIT inline coupling**

The transfer coefficient matrix (TCM) capability available in the offline HYSPLIT was added to the inline system. TCM simulation treats the emission as a unit source and the result is multiplied by a factor file which contains the time-varying emission rates and radioactive decay constant to compute the actual air concentrations and depositions. A few parameters were added to the Registery file in WRF and variable arrays were modified in HYSPLIT subroutines for the TCM implementation. The inline HYSPLIT with TCM feature was tested for a subset of the Fukushima accident with the time varying emission rate for Cs-

137. The TCM simulation had very similar concentration and deposition results compared to the run using an emission file. The inline HYSPLIT was updated with new options including the transfer coefficient matrix (ICHEM=10), concentration output written in mixing ratio (ICHEM=6) and input/output height using mean sea level (KMSL=1). It comes with WRF version 3.7 and version 3.8.1 in two separate packages. Both packaged were tested for CAPTEX #2 episode (input files available for users to download). Inline and offline HYSPLIT simulations were conducted for Sagebrush tracer experiment and results were evaluated against tracer measurements. Dr. Ngan used two sets of WRF data generated with MYJ and YSU boundary layer parameterizations to drive the dispersion simulations for four tracer releases (IOP #2- #5) during the experiment. Three out of four releases (except IOP #2), the inline results outperformed offline simulations. For the statistical evaluation, inline plumes had better coverage and cumulative distribution of concentration than offline plumes. The spatial plots of tracer concentration show that the inline HYSPLIT generated higher concentrations than the offline approach in the area close to the release location.

2. A long-term WRF meteorological archive for dispersion simulations

Based on these WRF data generated with a variety of PBL schemes and nudging options, Dr. Ngan ran the HYSPLIT model to simulate four controlled tracer experiments – CAPTEX, ANATEX, and OKC80, and METREX - covering different time periods with diverse durations including a summer day, several days in the fall, three months during winter, and one full year, respectively. The evaluation of the WRF results utilizing conventional observations showed a similar statistical performance for the different PBL schemes. Given the limited information the meteorological evaluation alone can provide, Dr. Ngan used the dispersion evaluation with measurements from multiple tracer experiments to gain further insight into the most appropriate WRF configuration to generate reasonable data for dispersion applications. The dispersion simulations based on WRF data generated equal or slightly better statistical performance than those driven by the NARR dataset. The statistical comparison showed a mix impact for the dispersion results driven by the non-nudged and nudged WRF data. This work was written in a manuscript submitted to Journal of Applied Meteorology and Climate and is now under the second round of review. The main advantage of using the WRF dataset is that it provides additional variables relevant to atmospheric dispersion that are not available from NARR, such as friction velocity, turbulent kinetic energy, and time-averaged wind fields. With this new WRF meteorological data, HYSPLIT can calculate the dispersion using different options for mixing estimations available in the model. Furthermore, for applications requiring precipitation data (e.g. involving wet deposition processes) the WRF dataset provides hourly precipitation while NARR only includes three-hourly data. The WRF dataset covering years 1980 – 2016 will be added to the DATEM expanding the capabilities for using different meteorological inputs and a variety of options to compute the HYSPLIT mixing parameters. It can provide users the capability to generate dispersion ensembles with variations in meteorological inputs and diverse configurations of the dispersion simulations.

Planned work

- Update and maintain the inline HYSPLIT coupling with WRF. Evaluate the inline and offline dispersion results for the Sagebrush experiment.
- Use in-situ measurements for mixing parameters such as the turbulent velocity variance to understand the dispersion process, evaluate inline and offline HYSPLIT results and investigate the estimation of mixing parameters in the model.

- Simulate meteorological data and dispersion results for Idaho Field Experiment and evaluate the results with measured concentrations taken during the experiment.

Publications

Peer previewed publications

Crawford, A. M., B. J. Stunder, **F. Ngan** and M. J. Pavolonis, 2016: Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption. *J. Geophys. Res.*, 121, 10786-10803.

Eslinger, Paul and co-author, **F. Ngan**, 2016: International Challenge to Predict the Impact of Radioxenon Releases from Medical Isotope Production on a Comprehensive Nuclear Test Ban Treaty Sampling Station. Journal of Environmental Radioactivity, 157, 41-51.

Presentations

Ngan, F. and A. Stein, 2016: Dispersion simulations of inline HYSPLIT for Sagebrush tracer experiment. 20th Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling, Fairfax, VA, George Mason University.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	2
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support for Air Quality Projects at ARL: Hyun Cheol Kim (Part 6 of 10)	
Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz & Ariel Stein
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 0%, Theme 3: 100%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

Smokes from wildfires are significant source of air pollution affecting regional air quality, biosphere, and human health. Modeling the transport of smoke form large wildfires has been one of important activity of NOAA Air Resources Laboratory (ARL). However, forecasting the transport and dispersion of particular matter originated from forest fires has been very challenging task mostly due to high uncertainties in their location, timing and vertical allocation of wildfire emissions. NOAA ARL and Cooperative Institute for Climate and Satellites (CICS) at University of Maryland, College Park support Dr. Hyun-Cheol Kim to work on source term inverse problems using HYSPLIT model to estimate emissions from wildfires. Dr. Kim also develop model, satellite and observational data visualization and analysis tool to support HYSPLIT and the National Air Quality Forecast Capability (NAQFC) for data analysis and model input improvement.

Accomplishments

Dr. Hyun Cheol Kim has worked on inverse modeling of wildfire emission using HYSPLIT, satellite-based NO_x emission assimilation, and visualization/analysis tool development for HYSPLIT and CMAQ. Detailed descriptions are provided below:

(1) Development of data handling tools: Tools to generate data for model inputs and verification were developed. Data are available from multiple agencies in various data format, including MODIS AOD (hdf), GASP total AOD (binary), GASP smoke AOD (i.e. ASDTA product, grib/hdf), HMS fire emission (ASCII) and HMS smoke plume (GIS shapefile).

(2) Identification of wildfire events: For detailed study of inverse approach, wildfire events during 2015 & 2016 have been fully investigated and documented. For those fire events, multiple data to detect high aerosol (MODIS, GASP and AERONET) and smoke (GASP ASDTA and HMS) were intercompared and evaluated.

(3) Algorithms and tools for cost function minimization in emission inverse modeling is being developed in collaboration with Dr. Tianfeng Chai.

(4) A new technique for satellite-based NO_x emission monitoring (e.g. observations of NO_2 vertical column densities) was developed and utilized for the comparison with NAQFC model. Model experiment using adjusted NO_x emission based on space-borne monitoring is being conducted.

(5) Development of IDL tools: Dr. Kim has developed visualization and analysis tools for HYSPLIT and NAQFC products. Interactive Data Language (IDL, Harris Geospatial Solutions) based data processing and visualization tools have been developed to utilize model outputs (e.g. trajectory or dispersion concentration files from HYSPLIT and M3IOAPI grid data for CMAQ), surface-based observations (e.g. EPA AQS, AIRNow and AERONET), and space-borne instruments (e.g. MODIS AOD, NESDIS GASP AOD, OMI/GOME-2 NO2). Dr. Kim is collaborating with ARL scientist to incorporate these graphics to the Real-time Environmental Applications and Display sYstem (READY).

Planned work

- Test of Inverse modelling tools and construction of smoke inverse system.
- Top-down Inverse modeling of anthropogenic emissions using space-borne monitoring and air pollutants precursors for NAQFC.
- Development of IDL-based visualization and analysis tools for HYSPLIT and CMAQ.

Publications

Kim, S., C. Bae, B.-U. Kim, and **H. Kim**, 2017: PM2.5 Simulations for the Seoul Metropolitan Area: (I) Contributions of Precursor Emissions in the 2013 CAPSS Emission Inventory, *Korean Society for Atmospheric Environment*, Accepted

Kim, S., O. Kim, B.-U. Kim, and **H. Kim**, 2017: Impact of Emissions from Major Point Sources in Chungcheongnam-do on Surface Fine Particulate Matter Concentration in the Surrounding Area, *Korean Society for Atmospheric Environment*, Accepted

Lee, P., J. McQueen, I. Stajner, J. Huang, L. Pan, D. Tong, **H. Kim**, Y. Tang, S. Kondragunta, M. Ruminski, S. Lu, E. Rogers, R. Saylor, P. Shafran, H.-C. Huang, J. Gorline, S. Upadhayay, S. Upadhayay, and R. Artz, 2017: NAQFC developmental forecast guidance for fine particulate matter (PM2.5), *Weather and Forecasting*, doi:10.1175/WAF-D-15-0163.1

Kim, E., C. Bae, **H. C. Kim**, J. H. Cho, B.-U. Kim, and S. Kim, 0271: Regional Contributions to Particulate Matter Concentration in the Seoul Metropolitan Area, Korea: Seasonal Variation and Sensitivity to Meteorology and Emissions Inventory, *Atmospheric Chemistry and Physics Discussion,* doi:10.5194/acp-2016-1114

Pan, S., Y. Choi, W. Jeon, A. Roy, D. A. Westenbarger, **H. C. Kim**, 2016: Impact of high-resolution sea surface temperature, emission spikes and wind on simulated surface ozone in Houston, Texas during a high ozone episode, *Atmos. Env*., doi:10.1016/j.atmosenv.2016.12.030

Kim, H. C., S. Kim, S. Son, P. Lee, C.-S. Jin, E. Kim, B.-U. Kim, F. Ngan, C. Bae, C.-S. Jin, C.-K. Song, and A. Stein, 2016: Synoptic perspectives on pollutant-transport patterns observed by satellites over East Asia: Case studies with a conceptual model, *Atmospheric Chemistry and Physics Discussion,* doi:10.5194/acp-2016-673

Tong, D., L. Pan, W. Chan, L. Lamsal, P. Lee, Y. Tang, **H. Kim**, S. Kondragunta, and I. Stajner, 2016: Impact of the 2008 Global Recession on air quality over United States: Implications for surface ozone levels from changes in NOx emissions, *Geophys. Res. Lett.*, 43, DOI: 10.1002/2016GL069885

Kim, B.-U., O. Kim, **H. Kim**, and S. Kim, 2016: Influence of fossil-fuel power plant emissions on the surface PM2.5 in the Seoul Capital Area, South Korea, *J. of Air & Waste Manage. Assoc*., 66:9, 863-873, DOI:10.1080/10962247.2016.1175392

Chang, C.-Y., E. Faust, X. Hou, P. Lee, **H. C. Kim**, B. C. Hedquist, and K.-J. Liao, 2016: Investigating Ambient Ozone Formation Regimes in Neighboring Cities of Shale Plays in Northeast United States using Photochemical Modeling and Satellite Retrievals, *Atmos. Env.*, 142, 152-170 , doi:10.1016/j.atmosenv.2016.06.058

Kim, H. C., P. Lee, L. Judd, L. Pan, and B. Lefer, 2016: OMI NO2 column densities over North American urban cities: the effect of satellite footprint resolution, *Geosci. Model Dev.*, 9, 1111-1123, doi:10.5194/gmd-9-1111-2016

Tang, Y., L. Pan, P. Lee, D. Tong, **H. C. Kim**, J. Wang, S. Lu, 2016: The Performance and Issues of a Regional Chemical Transport Model During Discover-AQ 2014 Aircraft Measurements Over Colorado, Air Pollution Modeling and its Application XXIV, Springer International Publishing, 635-640, 10.1007/978-3-319-24478-5_103

Lee, P., R. Atlas, G. Carmichael, Y. Tang, B. Pierce, A. P. Biazar, L. Pan, **H. Kim**, D. Tong, W. Chen, 2016: Observing System Simulation Experiments (OSSEs) Using a Regional Air Quality Application for Evaluation, Air Pollution Modeling and its Application XXIV, Springer International Publishing, 599-605, 10.1007/978-3-319-24478-5_97

Zhao, H., D. Q. Tong, P. Lee, **H. Kim**, and H. Lei, 2016: Reconstructing Fire Records from Ground-Based Routine Aerosol Monitoring, Atmosphere, 7(3), 43,doi:10.3390/atmos7030043

Li, Xiangshang, Y. Choi, B. Czader, **H. Kim**, B. Lefer, and S. Pan, 2016: The impact of observation nudging on simulated meteorology and ozone concentrations during DISCOVER-AQ 2013 Texas campaign, *Atmos. Chem. Phys.,* 16, 3127-3144, doi:10.5194/acp-16-3127-2016

Presentations

Kim, E., S. Kim, **H. C. Kim**, B.-U. Kim and J. Cho, 2016: Detailed Contributions of Foreign and Domestic Emissions to Particulate Matter over South Korea Forecasted with WRF and UM models, *16th Annual EMS conference*, Trieste, Italy

Kim, S., E. Kim, C. Park, C. Bae, H. C. Kim, and B. U. Kim, B. U., 2016: Prototype of CMAQ Toxic Simulations over the Seoul Metropolitan Area. *The 3rd International Energy & Environment Conference*

Kim, S., B.-U. Kim, **H.C. Kim**, C. Bae, E. Kim, S. You, M. Bae, O. Kim, and C. Park, 2016: Interpreting Particulate Matters and Ozone Forecasts based on Instrumented 3-Dimensional Photochemical Grid Models for South Korea, *17th IUAPPA Conference*, Busan, South Korea

Kim, S., C. Bae, E. Kim, S. You, M. Bae, O. Kim, C. Park, **H. C. Kim**, and B.-U. Kim, B. U., 2016: CMAQ Simulation Study to Analyze the Long-term Variations of Criteria Air Pollutants in the Seoul Metropolitan Area, South Korea, during 2004~2015, *17th IUAPPA Conference*, Busan, South Korea

Kim, H. C., O. Kim, C. Bae, B.-U. Kim, and S. Kim, 2016: Space-borne Monitoring of NOx Emissions from Cement Kilns in South Korea, *17th IUAPPA Conference*, Busan, South Korea

Bae, C. H., **H. C. Kim**, B.-U. Kim, and S. Kim, 2016: Implementation of Near Real-Time Fire and Dust Emissions in Air Quality Forecast over Northeast Asia, *17th IUAPPA Conference*, Busan, South Korea

Park, C. S. Kim, **H. C. Kim**, and B.-U. Kim, 2016: Analysis of Ozone and NOx Simulation concentration in metropolitan area of the photochemical model by KV scheme, *17th IUAPPA Conference*, Busan, South Korea

Bae, M., **H. C. Kim**, B.-U. Kim, and S. Kim, 2016: Tracking Chemical Histories of Pollutant Plumes Using a Lagrangian-Eulerian Hybrid System, *17th IUAPPA Conference*, Busan, South Korea

You, S. B.-U. Kim, **H. C. Kim**, Y. Lim, I. Suh, C.-K. Song, N. Moon, and S. Kim, 2016: Impact of Planetary Boundary Layer Schemes on Modeled Surface Ozone Concentrations in the Seoul Metropolitan Area, South Korea: Long-range Transport Cast Study, *17th IUAPPA Conference*, Busan, South Korea

Kim, O., B.-U. Kim, **H. C. Kim**, and S. Kim, 2016: Impact of Emissions from Large Point Sources in the Chungcheongnam-do in the Surround Area, *17th IUAPPA Conference*, Busan, South Korea

Kim, B.-U., **H. C. Kim**, and S. Kim, 2016: Application and Evaluation of Particulate Source Apportionment Technique for a PM Forecasting System: A Case Study, *17th IUAPPA Conference*, Busan, South Korea

Kim, E., **H. C. Kim**, B.-U. Kim, J. H. Cho, and S. Kim, 2016: Ozone Simulations over the Seoul Metropolitan Area for a 2014 May Episode, *17th IUAPPA Conference*, Busan, South Korea

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	12
# of NOAA technical reports	2
# of presentations	12
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support for Air Quality Projects at ARL: Paul Kelly (Part 7 of 10)	
Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

Mr. Kelley is working to support two atmospheric chemists at ARL (Drs. Luke and Ren) and to provide data for model validation for a global mercury model written by Dr. Cohen, also at ARL. One of the major long-term goals is to understand how gaseous elemental mercury (GEM) in the atmosphere is transformed into more highly bio-available reactive gaseous mercury (RGM) and fine particulate mercury (FPM). This involves a complicated cycle of convection of anthropogenic GEM into the free troposphere and lower stratosphere, subsequent oxidation into RGM and FPM, and then wet deposition by deep convective thunderstorms or dry deposition following strong post-frontal subsidence.

Accomplishments:

1. Support of on-going long-term atmospheric mercury measurements

NOAA / ARL has installed and maintained three ground stations that are devoted to long term monitoring of speciated atmospheric mercury and operates them according to National Atmospheric Deposition Program sampling protocols (AMNET). The site in Beltsville, MD has a speciated mercury instrument with an inlet at 10 meters. Another site in the Grand Bay National Research Reserve in Grand Bay, MS has a speciated atmospheric mercury instrument, as well as a range of other trace gas instruments (SO_2, CO, O_3, black carbon) and standard meteorology instruments. The third site is at the Mauna Loa Observatory (MLO) on the island of Hawaii. ARL currently operates two speciated atmospheric mercury systems there and CO, SO_2 and O_3 trace gas instruments.

Mr. Kelley performs weekly maintenance and repair at the Beltsville, MD site to keep it operating according to AMNET protocols. One trip in 2016 was made to the Grand Bay, MS site and another to our Mauna Loa, HI site to repair instruments and perform calibrations.

2. Improved Mercury Calibration Techniques.

A Gaseous Oxidized Mercury Standard Addition (GOMsa) system was developed to inject $HgBr_2$ into the inlet of a speciated mercury analyzer to test the denuder capture efficiency. This system was deployed at Mauna Loa in September 2016 and showed GOM capture efficiency falls to less than 20% during periods when water vapor mixing ratios are above 5 gm/kg.

Using similar instrumentation, a Gaseous Elemental Mercury Standard Addition (GEMsa) system has been developed and deployed long term at our Beltsville site. Correcting each five-minute measurement of GEM by the standard addition response improves precision by reducing within-hour standard deviation by 30% and indicates that ambient GEM may be under-reported by 4-6%.

Planned work

- Continue support for long-term Hg monitoring at NOAA's three AMNET sites.
- Improve GOMsa system by simplifying plumbing to reduce delivery nozzle size.
- Continue deployment of GEMsa system at Beltsville site and monitor results.

Publications:

C. R. Nowlan, X. Liu, J. W. Leitch, K. Chance, G. González Abad, C. Liu, P. Zoogman, J. Cole, T. Delker, W. Good, F. Murcray, L. Ruppert, D. Soo, M. B. Follette-Cook, S. J. Janz, M. G. Kowalewski4 , Christopher P. Loughner, K. E. Pickering, J. R. Herman, M. R. Beaver, R. W. Long, J. J. Szykman, L. M. Judd, P. Kelley, W. T. Luke, X. Ren, J. A. Al-Saadi: Nitrogen dioxide observations from the Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) airborne instrument: Retrieval algorithm and measurements during DISCOVER-AQ Texas 2013, Atmos. Meas. Tech., 9, 2647–2668 doi:10.5194/amt-9-2647-2016.

S. Lyman, C. Jones, T. O'Neil, T. Allen, M. Miller, M. S. Gustin, A. M. Pierce, W. T. Luke, X. Ren, P. Kelley: Automated Calibration of Atmospheric Oxidized Mercury Measurements, Environmental Science & Technology, 50, 23, 12921, 2016.

X. Ren, W. T. Luke, P. Kelley, M. D. Cohen, R. Artz, M. L. Olson, D. Schmeltz, M. Puchalski, D. L. Goldberg, A. Ring, G. M. Mazzuca, K. A. Cummings, L. Wojdan, S. Preaux, J. W. Stehr: Atmospheric mercury measurements at a suburban site in the Mid-Atlantic United States: Inter-annual, seasonal and diurnal variations and source-receptor relationships. Atmospheric Environment, 146, 141, 2016.

Cohen, M. D., R. R. Draxler, R. S. Artz, P. Blanchard, M. S. Gustin, Y. Han, T. A. Holsen, D. A. Jaffe, P. Kelley, H. Lei, C. P. Loughner, W. T. Luke, S. L. Lyman, D. Niemi, J. M. Pacyna, M. Pilote, L. Poissant, D. Ratte, X. Ren, F. Steenhuisen, A. Steffen, R. Tordon and S. Wilson. Modeling the global atmospheric transport and deposition of mercury to the Great Lakes. Elementa Science of the Anthropocene 4: 000118. doi: 10.12952/journal.elementa.000118, 2016

Bieser, J., F. Slemr, J. Ambrose, C. Brenningkmeijer, S. Brooks, A. Dastoor, F. DeSimone, R. Ebinghaus, C. N. Gencarelli, B. Geyer, L. E. Gratz, I. M. Hedgecock, D. Jaffe, P. Kelley, C. Lin, V. Matthias, A. Ryjkov, N. E. Selin, S. Song, O. Travnikov, A. Weigelt, W. Luke, **X. Ren**, A. Zahn, X. Yang, Y. Zhu, N. Pirrone, Multi-model study of mercury dispersion in the atmosphere: Vertical distribution of mercury species, *Atmos. Chem. Phys. Discuss.*, doi:10.5194/acp-2016-1074, 2016.

Presentations:

Luke, Winston, Paul Kelley, Xinrong Ren, Richard Artz, Mark Olson, David Schmeltz, and Nash Kobayashi, Evaluation of GOM Measurement Artifacts at the Mauna Loa AMNet Site, the National Atmospheric Deposition Program Annual Meeting, Santa Fe, NM, October 31-November 4, 2016.

Luke, Winston, Paul Kelley, Xinrong Ren et al., Assessment of Gaseous Oxidized Mercury Measurement Accuracy at an Atmospheric Mercury Network (AMNet) Site, Abstract # B33D-0642, AGU Fall Meeting, San Francisco, CA, December 11-16, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	5
# of NOAA technical reports	
# of presentations	2
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support for Air Quality Projects at ARL: Alice Crawford (Part 8 of 10)

Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 0%, Theme 3: 100%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions
Link to a research web page	https://www.arl.noaa.gov/HYSPLIT_info.php

Background

Dr. Alice Crawford works on volcanic ash applications for the HYSPLIT pollutant transport and dispersion model. One application of HYSPLIT is to produce forecasts of dust concentrations due to the suspension of dust by wind. Deposits of volcanic ash are also subject to resuspension and ash concentrations from resuspension can be high enough that they are of concern for aviation, health, and hazard assessments. For instance, a deposit of volcanic ash in Alaska is the source of resuspension events which are detectable by satellite based instruments and have caused the Anchorage VAAC to issue volcanic ash advisories. The mechanism for resuspension of any material is the transfer of momentum from the atmosphere to the deposited material. Dust emission schemes in transport and dispersion models (including HYPSLIT) calculate the mass flux of material based on the friction velocity (obtained from a meteorological model), an empirically determined threshold friction velocity (below which no mass flux is observed), and an empirical parameter representing deposit characteristics, such as particle size and density distribution, soil moisture and roughness. These empirical parameters, as well as the functional form of the dependence on friction velocity must be determined for each type of material.

Accomplishments

The first year of a two year project to assess the impact of a potential volcanic eruption of Mt. St. Helens on the nuclear waste management facility at Hanford, WA was completed. This project is a collaboration between DOE, USGS, DRI and NOAA/ARL. For this project Dr. Crawford is developing and testing new ash re-suspension algorithms that will be incorporated into the HYSPLIT modeling system. Work to date has included the following:

(1) Collaborated with the project partners to determine scope of work, information flow, and procedures. NOAA / ARL will use empirical data collected by DRI to develop the resuspension algorithm. NOAA / ARL will use model outputs produced by USGS on possible ash deposit footprints as inputs into the HYSPLIT model.

(2) TSP measurements from Washington State in the year 1980 were collected. PM10 measurements for later years were downloaded from an EPA website. These PM10 measurements show the temporal evolution of dust storms in some years which should be similar to the temporal evolution of an ash resuspension event.

(4) A white paper detailing NOAA's approach to the problem was written. Dr. Crawford developed software which will create many HYSPLIT runs with unit mass releases. The software will then perform post-processing which will combine results from the HYSPLIT. This design allows the HYSPLIT runs to be performed before inputs from DRI and USGS are available.
(5) Preliminary HYSPLIT runs were done to test the approach and gauge sensitivity to some of the input parameters such as number of particles used in the simulations.
(6) Quality assurance procedures were developed in conjunction with DOE.

Planned work

(1) Complete the hazard assessment for DOE. Production runs of HYSPLIT are expected to start in April and continue through October 2017. Results from DRI and USGS should be available by then to be applied in the post processing.
(2) Write a peer reviewed journal article with results from the ash resuspension project.
(3) Create generalized ash resuspension algorithm for HYSPLIT
(4) Apply some of the methods in the DOE work to fire smoke and or dust applications.

Publications

Crawford, Stunder, Ngan, Pavolonis, (2016) Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption *J. of Geophysical Research: Atmospheres,* 121, p 10,786, doi:10.1002/2016D024779

Chai, Crawford, Stunder, Pavolonis, Draxler, Stein, (2017) Improving volcanic ash predictions with the HYSPLIT dispersion model by assimilating MODIS satellite retrievals *Atmos. Chem. Phys.,* **17**, 1-15, doi:10.5194/acp-17-1-2017

Presentations

Alice Crawford gave a presentation, "Modeling Ash Resuspended by Wind," at the DOE ashfall research project planning meeting In Hanford, WA from Nov2-3.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**2**
# of NOAA technical reports	
# of presentations	**1**
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Support for Air Quality Projects at ARL: Tianfeng Chai (Part 9 of 10)

Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz & Ariel Stein
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background:

The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed at NOAA Air Resources Laboratory has been widely used to study the atmospheric pollutant transport and dispersion in both forward and backward modes. Among those applications, the backward trajectory of a single pollutant particle is often used to identify the potential source locations. An improvement can be made by employing the dispersion module to quantify the source strength by utilizing the concentration information.

The operational smoke forecasts using the NOAA Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPIT) model in support of the National Air Quality Forecast Capability (NAQFC) are greatly hindered by the large uncertainties of the smoke emission estimates. While most wild fire locations are well identified by the NOAA NESDIS Hazardous Mapping System (HMS), the current US Forest Service (USFS) BlueSky emission prediction may produce large uncertainties. This research aims to objectively and optimally estimate the wildfire smoke source strengths, vertical distribution and temporal variations by applying an observation-modeling inversion technique based on NOAA NESDIS GOES Aerosol/Smoke products (GASP) and HYSPLIT simulations.

Accomplishments:

1. A HYSPLIT inverse system to assimilate MODIS satellite retrieval of ash cloud top height and mass loading has been developed. Using the 2008 Kasatochi eruption as an example, the system can estimate the volcanic ash emissions as a function of time and height. Results are published at *Atmos. Chem. Phys.* (doi:10.5194/acp-17-2865-2017)
2. CAPTEX Cross Appalachian Tracer Experiment (CAPTEX) measurements are used to estimate the known point source strength. By having ensemble HYSPLIT runs, the inverse system is capable of estimating the strength with known release time information. Results have been presented at 2016 AGU Fall meeting
3. Uncertainties of GASP observations have been evaluated against MODIS, VIIRS, and AERONET measurements. A smoke event in November 2016 has been identified for tests.
4. HYSPLIT source estimate code has been developed and tested for pseudo observations.

Planned Work:

Continue to develop the HYSPLIT inverse system and implement the improved system to more applications. The features that will be added to the current system would include uncertainty analysis of the source terms and locate the source location and release times. The use of the ensemble runs will be further explored. The potential applications will include Aliso Canyon methane leak incident, CAPTEX, Fluxes of Atmospheric Greenhouse Gases in Maryland (FLAGG-MD) and the Wintertime Investigation of Emissions, Reactivity, and Transport (WINTER) campaigns, 2nd ATM challenge.Top-down estimation of wildfire smoke emissions based on HYSPLIT model and NOAA NESDIS GOES Aerosol/Smoke products (GASP) to improve smoke forecasts in the US -- USWRP project (NOAA Award NA16OAR4590121)Tianfeng Chai (PI), Ariel Stein (Co-PI), Shobha Kondragunta (Co-PI) Hyun Cheol Kim (Co-I)

HYSPLIT inverse system will be continuously developed, tested, and improved. The HYSPLIT inverse system will be used to test the identified wildfire smoke event in November 2016.

Publications:

1. Impact of Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol optical depth (AOD) and AirNow PM2.5 assimilation on Community Multi-scale Air Quality (CMAQ) aerosol predictions over the contiguous United States T Chai, H. Kim, P. Lee, and D. Tong, *J. Geophys. Res*., in review

2. Improving volcanic ash predictions with the HYSPLIT dispersion model by assimilating MODIS satellite retrievals, T Chai, A Crawford, B Stunder, MJ Pavolonis, R Draxler, A Stein, *Atmos. Chem. Phys.* 17, 2865-2879, doi:10.5194/acp-17-2865-2017, 2017

3. Reply to Comment on 'Premature deaths attributed to source-specific BC emissions in six urban US regions' MD Turner, et al., and T. Chai Environmental Research Letters 11 (9), *Environ. Res. Lett*., doi:10.1088/1748-9326/11/9/098002

4. International challenge to predict the impact of radioxenon releases from medical isotope production on a comprehensive nuclear test ban treaty sampling station PW Eslinger, TW Bowyer, P Achim, T Chai, B Deconninck, K Freeman, *Journal of environmental radioactivity* 157, 41-51

Presentations:

1. Estimating volcanic ash emissions by assimilating satellite observations with the HYSPLIT dispersion model, Tianfeng Chai, First TEMPO Applications Workshop, Huntsville, AL, USA, July 12-13, 2016

2. Inverse modeling with HYSPLIT Lagrangian Dispersion Model - Tests and Evaluation using the Cross Appalachian Tracer Experiment (CAPTEX) data, T. Chai, A. Stein, F. Ngan, and R. Draxler, San Francisco, CA, USA, December 12-16, 2016

3. Quantifying co-benefits of source-specific CO2 emission reductions in Canada and the US: An adjoint sensitivity analysis, M. Soltanzadeh, et al., and T. Chai 2016 AGU Fall Meeting, San Francisco, CA, USA, December 12-16, 2016

4. Using HYSPLIT Generated Ensembles to Improve the Simulation of Plume Dispersion and Assess Model Uncertainty, A. Stein, F. Ngan, and T. Chai, 2016 AGU Fall Meeting, San Francisco, CA, USA, December 12-16, 2016

Other

Reviews:

- Journal papers reviewed: 13
- NOAA ARL internal review: 2
- Number of reviewed proposals: 14

Support for Air Quality Projects at ARL: Barry Baker (Part 10 of 10)	
Task Leader	R. R. Dickerson
Task Code	RDRD_AQS_14 Year 3 & RDRD_AQS_16
NOAA Sponsor	Richard Artz
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic:	Surface Observation Networks
Contribution to NOAA goals (%)	Goal 1: 25%, Goal 2: 50%, Goal 3: 25%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

The National Air Quality Forecast Capability (NAQFC) provides air quality forecast and numerical guidance for issuance of warnings to the public when poor air quality conditions arise. The NOAA/OAR Air Resources Laboratory (ARL) cooperated with the NOAA National Weather Service (NWS) to support NAQFC in 2015.

Accomplishments

CMAQ is currently run operationally at NOAA in an offline mode where the meteorology is first run using the North American Mesoscale Model on the B-grid (NMMB). The output from the meteorology is then processed into CMAQ ready input using PREMAQ (Lee et al., Weather and Forecasting 2016). CMAQ was demonstrated as a component in the National Unified Operational Prediction Capability (NUOPC) and Earth System Modeling Framework (ESMF). NUOPC allows CMAQ to be coupled with a variety of meteorological models such as NMMB and the soon-to-become National Weather Service (NWS) operation Next Generation Global Prediction System (NGGPS) without modification to the CMAQ code itself and minimal changes to the ESMF layer. Additionally, it gives the ability to couple with other types of models such as land surface and ocean models. ESMF allows each model to reside on their own grid. In this case NMMB is on the Arakawa B-grid and CMAQ is on the Arakawa C-grid. Currently, the data is only brought into CMAQ and so there are no direct or indirect effects being fed into the meteorology, however, in the future this feature could easily be added into the ESMF layer. A test case of a May 11, 2014 dust event was presented at the 2016 CMAS conference with a coupling timestep of five minutes.

A new verification package, the Model and ObservatioN Evaluation Tool (MONET) has been developed to quickly evaluate chemical transport models. MONET is designed to be a modularized Python package for 1) pairing model output to observational data in space and time, 2) leveraging the pandas Python package for easy searching and grouping, and 3) analyzing and visualizing data. A convenient method for evaluating model output is introduced through this process. Data processed by MONET is easily searchable and can be grouped using meta-data found within the observational datasets. Included in the package are common statistical metrics (e.g. bias, correlation, and skill scores), plotting routines such as scatter plots, time-series, spatial plots, and more. MONET is well modularized and effortlessly able to add further observational datasets and different models. In the future, satellite observations, additional networks such as FLUXNET and the Integrated Surface Database, and flight data are essential to further expand our understanding of the NAQFC. A paper is currently under review in *Environmental Modelling and Software*.

Planned work

- Dust analysis, modeling and evaluation, including incorporating satellite products (LAI, soil moisture, NDVI etc) in FENGSHA.
- Help with the lateral boundary condition project.
- Continue to improve verification of NAQFC within NOAA using MONET along side the IMPROVE, AQS and AIRNOW networks.

Publications

1. Barry Baker and Pius Lee, "Overview of the Model and ObservatioN Evaluation Tool (MONET) version 1.0 for evaluating chemical transport models." Submitted to *Environmental Modelling and Software*. Currently under review
2. Youhua Tang, Mariusz Pagowski, Tianfeng Chai, Li Pan, Pius Lee, Barry Baker, Rajesh Kumar, Luca Delle Monache, Daniel Tong, and Hyun-Cheol Kim, "Aerosol Assimilation Based on NCEP's GSI Compared to Optimal Interpolation Method." Submitted to *Geoscientific Model Development.* Currently under Review

Presentations

1. "Applications of satellite NO2 observations in US National Air Quality Forecasting Capability," Barry Baker, Pius Lee, Daniel Tong, Lok Lamsal, Li Pan, Charles Ding, Hyuncheol Kim, Tianfeng Chai, Kenneth E. Pickering, Shobha Kondragunta, and Ivanka Stajner. JPSS meeting, College Park, MD 2016
2. "In-Line Coupling of the NMMB and CMAQ Models through NCEPs ESMF and NUOPC Framework," Barry Baker, Pius Lee, Dusan Jovic, Li Pan, Youhua Tang and Daniel Tong. CMAS 2016

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	2
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

2.4 Advanced Satellite Programs

Year 6 GOES-R/JPSS Visiting Proving Ground Scientist Program

Task Leader:	Michael J. Folmer
Task Code:	EBMF_GOESR_16/ EBMF_JPSS_16
NOAA Sponsors:	Steve Goodman & Mitch Goldberg
NOAA Offices:	GOESPO & JPSSO
Percent contribution to CICS Themes:	Theme 1: 20%; Theme 2: 80%; Theme 3: 0%.
Main CICS Research Topics:	Advanced Satellite Programs (GOES-R and JPSS)
Percent contribution to NOAA Goals:	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%
Strategic Research Guidance Memorandum:	3. Decision Science, Risk Assessment and Risk Communication

Highlight: A CICS visiting scientist (VS) has lead the GOES-R and JPSS Proving Ground activities at the NOAA Center for Weather and Climate Prediction and the Tropical Analysis Branch of the National Hurricane Center since May 2011. These proving grounds allow forecasters and researchers the opportunity to evaluate new satellite technologies in every day operations.

Background

The Geostationary Operational Environmental Satellite R-Series (GOES-R) and Joint Polar Satellite System (JPSS) Satellite Proving Ground (PG) is a collaborative effort among the GOES-R Program Office, JPSS Program Office, and the National Oceanic and Atmospheric Administration (NOAA) Cooperative Institutes, Weather Forecast Offices, National Centers for Environmental Prediction (NCEP) National Centers, and Experimental Testbeds. The Proving Ground is a project in which proxy GOES-R and JPSS products can be tested and evaluated before launch of the GOES-R series and JPSS 1 & 2. Proxy GOES-R and JPSS products are generated using combinations of currently available GOES data and higher-resolution data provided by instruments on polar-orbiting satellites (e.g., MODIS) and S-NPP as well as model synthetic satellite data. Now that GOES-R has been launched (November 19, 2016), the GOES-16 products and algorithms can now be evaluated and tested in the PG.

A full-time visiting scientist (VS) is required for the GOES-R and JPSS PG efforts based at the NOAA National Weather Service (NWS) Weather Prediction Center (WPC), Ocean Prediction Center (OPC), National Hurricane Center (NHC) Tropical Analysis and Forecast Branch (TAFB), and the National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Analysis Branch (SAB) in College Park, Maryland as part of the Marine, Precipitation, and Satellite Analysis Proving Ground (MPS PG). The GOES-R and JPSS VS coordinates the evaluation effort, helps facilitate product availability, generates combined reports, trains forecasters on product applications, provides feedback to product developers, and coordinates local GOES-R and JPSS Day 1 Readiness.

Accomplishments

The 2016 demonstrations featured a gradual transition from focusing on GOES-R proxy products to preparing for real-time data ingest and display of GOES-R (GOES-16) data. The overarching theme of the PG continued to focus on heavy rainfall, explosive cyclogenesis, maritime convection, extratropical transition of tropical cyclones, and fog/low stratus. The Overshooting Top Detection (OTD), GLD-360 Lightning Density, GOES-R Convective Initiation, CIRA Layered Precipitable Water, and Nearcast Model were used for convective monitoring and heavy rainfall. The multispectral or RGB imagery, convective products, and NOAA Unique Combined Atmospheric Profiles (NUCAPS) were used for analyzing and forecasting explosive cyclones and extratropical transition. The Fog/Low Status, GeoColor, and Night-time Microphysics products were used for monitoring and forecasting fog formation in the marine zones of OPC and TAFB. Many forecasters found the products to be beneficial to their operations and continue to use them along with the successful implementation of the Air Mass RGB products into daily forecast routines. The GOES-14 super rapid scan operations for GOES-R (SRSOR) have been a major success in the MPS PG since about 2012 and this continued in February, April, May, and August 2016. There were many examples of use for diagnosing some heavy rain events associated with deep convection in the southern U.S., fire monitoring for SAB, and even the rapid intensification of an extratropical cyclone off the southeast U.S. coast in early February.

The following are some projects that were started or completed in 2016:

- The collaboration among OPC, WPC, and AK region continued into 2016 and focused on how the centers can effectively communicate to AK region how they are utilizing the Air Mass RGB for analyzing hurricane-force extratropical storms. The CICS RA had to postpone travel to Juneau and Anchorage due to the impacts of Hurricane Matthew (2016), but has rescheduled for spring 2017. A student intern was tasked with identifying representative events and analyzing and documenting how multiple products may lead to earlier diagnosis of a significant hurricane-force event. The products that are being showcased in this project include the Air Mass RGB from Himawari-8, the 6.2µm, 6.9µm, and 7.3µm water vapor channels from Himawari-8 and the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Aqua and Terra satellites, along with scatterometer for winds, ozone products from the Infrared Atmospheric Sounding Interferometer (IASA) and NUCAPS, along with atmospheric profiles from NUCAPS.
- Himawari-8 imagery was first introduced experimentally to forecasters at OPC, SAB, and WPC in July 2015 and was made operationally available in early December 2015. Training on the Advanced Himawari Imager (AHI) was offered to forecasters of which 37 were successfully trained in a full-day workshop offered by the CICS RA.
- The MPS PG took a more active role in the HMT experiments in 2016 by introducing the NESDIS Snowfall Rate product during the WWE to verify snowfall rate forecasts made by participants. The CIRA Layered Precipitable Water product was introduced to the FFAIR experiment for monitoring pooling of precipitable water at upper levels or identifying possible atmospheric rivers.
- The CICS RA is also heavily involved in the Satellite Training Advisory Team (STAT) that was assembled to guide the various training partners on the future direction of GOES-R and eventually JPSS training for the National Weather Service (NWS).
- After the successful implementation of new satellite directories, projections, and resolution for GOES-13, GOES-15, Meteosat-10, Meteosat-7, and Himwari-8, the CICS RA has teamed up with a colleague at the National Hurricane Center to lead a team that will prepare for additional polar-orbiting and new GOES-16 imagery in N-AWIPS and AWIPS II. The focus of this team is on correcting color enhancement curves to match the bit-depth of the new imagery, transitioning all PG related satellite products and techniques to AWIPS II NCP, and investigate the option to produce multispectral and derived products “on-the-fly” in NCP.

- Finally, the CICS RA and OPC have been hosting interns that have studied offshore marine convection, fog and low stratus in marine zones, hurricane-force extratropical storms, and comparing the High Resolution Rapid Refresh (HRRR) model lightning threat algorithm against real time lightning detection in the offshore zones.

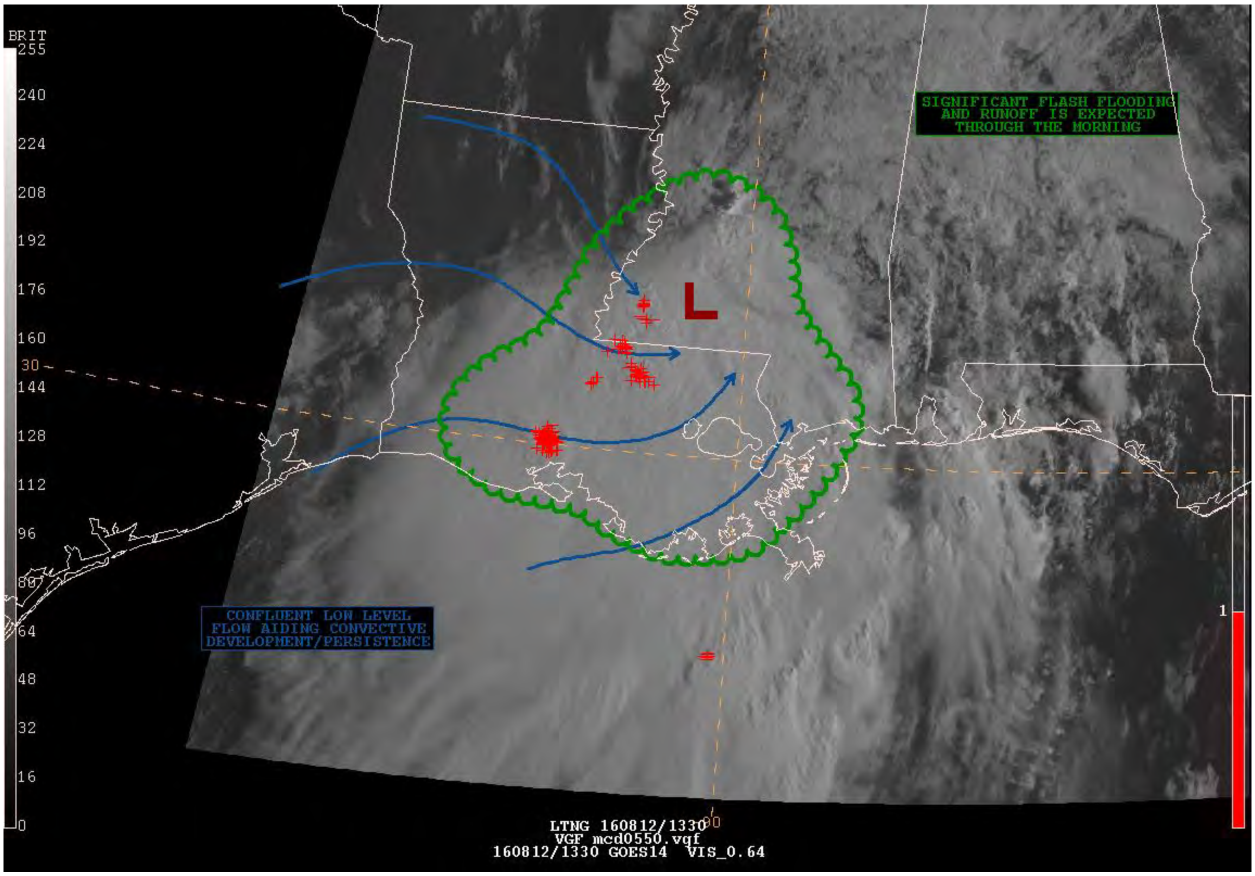


Figure 1: GOES-14 0.64 µm visible image during the August 2016 Super Rapid Scan Operations for GOES-R (SRSOR) demonstration. WPC found the 1-minute imagery quite useful during a severe/catastrophic flooding event that was unfolding in south/central Louisiana on 08/12/2016. The lightning data overlaid is from the Vaisala GLD-360 network and was also available at 1-minute increments. The forecaster on duty noted that the rapid refresh was very helpful in determining the strength and organization of the deeper thunderstorms, highlighting where the greatest flood threats were around sunrise.

The main goals of the proposed research and training for 2017-2018 are 1) training forecasters to use new products and become much more familiar with Himawari-8 and GOES-16; 2) identifying different applications for each product; 3) identifying weaknesses or errors for each product; and 4) gathering user feedback. The 2017 MPS PG will continue to focus on convection, explosive cyclones, heavy precipitation, and fog/low stratus with significant emphasis on GOES-16 channels, Level-2 derived products, and multispectral imagery. As part of the JPSS portion of the PG, additional S-NPP products will be identified and evaluated in preparation for JPSS-1. NUCAPS will be a major focus as the atmospheric profiles and planer products will provide added insight into the pre-convective environment. The new Global

Precipitation Monitoring (GPM) mission will add another level of support for the NOAA satellites program by helping users understand/validate products like the GOES-R rain rate and cloud properties products. As the onboarding of a new satellite ingest and dissemination system (ISatSS), additional polar-orbiting products from Sentinel, GPM, AMSR2, and others will become available to forecasters, therefore there will be a need to test the data, develop and disseminate training, and provide feedback as necessary. One very important goal is to transition the PG into the AWIPS II era in time for the OPC operational transition sometime in FY18 or FY19, which includes integrating the various GOES-R and JPSS products into the National Centers Perspective so the forecasters can continue to evaluate the products in their new setting. Finally, the CICS RA will continue to be involved in the development and roll-out of official NWS GOES-R and JPSS training now that GOES-16 is in orbit and JPSS-1 launches in September 2017.

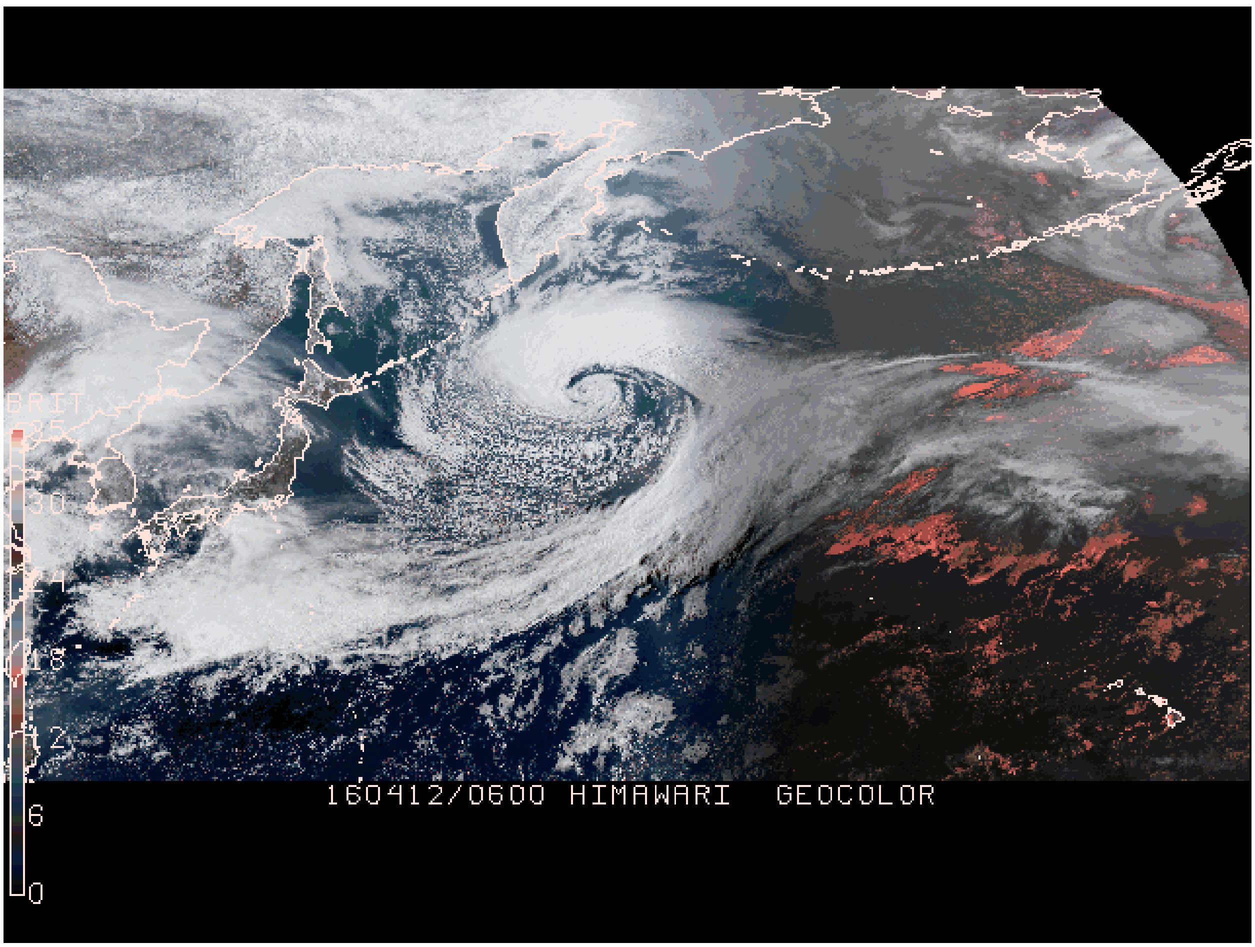


Figure 2: In December 2015, the first Himawari imagery was made available in a non-operational status for use by OPC and WPC. This GeoColor image courtesy of Steve Miller at CIRA, shows the contrast from the true color capability of the Advanced Himawari Imager along with the nighttime mode showing the 10.4-3.9 difference which depicts the low clouds and possible fog in pink. This product has been a huge hit at the centers and the forecasters look forward to a similar version of this product for GOES-16 in 2017!

Planned work

The 2017 MPS PG demonstrations will focus on the GOES-16 imagery and derived products (as they become available). Other activities from recent years will continue, but in a much more diminished state. The exception is JPSS where demonstrations will focus on the use of NUCAPS for various weather phenomena at each of the centers.

1. **Products to be Demonstrated:**
   a. GOES-16 L2 Imagery and Products (letter indicates center listed above in (1))
      i. Aerosol Detection (a, c, d)
      ii. Aerosol Optical Depth (a, c, d)
      iii. Cloud & Moisture Imagery (a, b, c, d)
      iv. Cloud Optical Depth (a, d)
      v. Cloud Particle Size Distribution (b, c)
      vi. Cloud Top Height (a, b, c, d)
      vii. Cloud Top Phase (a, b, c)
      viii. Cloud Top Pressure (a, b, c)
      ix. Cloud Top Temperature (a, b, c, d)
      x. Derived Motion Winds (a, b, c, d)
      xi. Derived Stability Indices (a, b, c, d)
      xii. Fire/Hot Spot Characterization (c, d)
      xiii. Hurricane Intensity Estimation (a, b, c, d)
      xiv. Land Surface Temperature (skin) (a, b, c, d)
      xv. Legacy Vertical Moisture Profile (a, b, c, d)
      xvi. Legacy Vertical Temperature Profile (a, b, c, d)
      xvii. Rainfall Rate / QPE (a, b, c, d)
      xviii. Sea Surface Temperature (skin) (a, b, c, d)
      xix. Snow Cover (a, b, c)
      xx. Total Precipitable Water (a, b, c, d)
      xxi. Volcanic Ash: Detection & Height (a, c, d)
      xxii. Lightning Detection: Events, Groups, Flashes (a, b, c, d)
   b. GOES-16 Future Capabilities
      i. GOES-R Lightning Detection (a, b, c, d)
      ii. Overshooting Tops Detection (a, b, c, d)
      iii. GOES-R Convective Initiation (a, b, c, d)
      iv. Multispectral Imagery
         1. Air Mass (a, b, c, d)
         2. GeoColor (a, b, c, d)
         3. Dust/SAL (c, d)
         4. DEBRA (c, d)
         5. Day Convection (a, b, c, d)
         6. Day/Night Microphysics (a, b, c, d)
   c. JPSS Products
      i. JPSS AIRS/IASI/NUCAPS Ozone Retrievals (a, b, c, d)
      ii. Day-Night Band (a, c, d)
      iii. NESDIS Snowfall Rate (b)

iv. CIRA Layered Precipitable Water (a, b, c, d)

2. **Project Schedule:**
   a. MPS Product Evaluation Schedule:
      i. GOES-16 Post Launch Product Testing (post-Feb 28, 2017; see below)
      ii. GOES-16 Future Capability evaluation (1 March – 31 December 2017)
      iii. JPSS Product evaluations (1 March – 31 December 2017)
      iv. HMT Winter Experiment (17 January – 17 February 2017)
         1. NESDIS Snowfall Rate
      v. HMT Summer Experiment (FFAIR) 2017 (July 2017)
         1. CIRA Layered Precipitable Water
         2. Rainfall Rate / QPE
   b. Use Case Development (Spring/Summer/Fall 2017):
      - Use Case Development (Summer-Fall 2017): At least one use case per center will focus initially on cloud and moisture imagery before it becomes provisional in May 2017. Additional use cases will be developed for each center addressing the various L2 products that will compliment forecast operations. Examples of possible uses cases include, but are not limited to:
         a. Unified Surface Analysis (OPC/TAFB)
         b. Wind/Wave (OPC/TAFB)
         c. North American Surface Analysis (WPC)
         d. Metwatch (Flash flood, excessive rain) (WPC)
         e. Model Diagnosis (WPC/OPC/TAFB)
         f. Fire/Smoke (SAB)
         g. Tropical Cyclone Classification (SAB)
         h. Volcanic Ash (OPC/TAFB/SAB)

Publications

Berndt, E. B., B. T. Zavodsky, and M. J. Folmer, 2016: Development and Application of Atmospheric Infrared Sounder Ozone Retrieval Products for Operational Meteorology, IEEE Transactions on Geoscience and Remote Sensing, vol. 54, issue 2, pp. 958-967

Folmer, M.J., R.W. Pasken, S. Chiao, J. Dunion, and J. Halverson, 2016: Modeling studies on the formation of Hurricane Helene: the impact of GPS dropwindsondes from the NAMMA 2006 field campaign. Meteorology and Atmospheric Physics, 1-18, DOI: 10.1007/s00703-016-0452-2.

Presentations **(* indicates invited)**

Folmer, M.J., J. Sienkiewicz, J. Clark, and S. Goodman, 2016: Year One of Himawari-8 Imagery in the Ocean Prediction Center: How AHI is Helping Prepare Forecasters for GOES-R. 41st National Weather Association Annual Meeting, Norfolk, VA.

Folmer, M.J., 2016: The Proving Ground for Marine, Precipitation, and Satellite Analysis: Forecasting in an OCONUS World. 2016 OCONUS Meeting, Honolulu, HI (remote).*

Folmer, M.J., 2016: GOES-R Series Program Update and User Readiness. GOES-R visits to Key West WFO, Melbourne WFO, Ruskin WFO, Upton WFO, and Eastern Region Headquarters.*

Folmer, M.J., J. Clark, J. Sienkiewicz, A. Orrison, M. Klein, J. Nelson, J. Kibler, N. Ramos, H. Cobb, M. DeMaria, E. Berndt, M. Goldberg, and S. Goodman, 2016: Addressing Forecast Challenges at the Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis. 21st AMS Satellite Meteorology, Oceanography, and Climatology Conference, Madison, WI.

Folmer, M.J., E.Berndt, J. Halverson, and J. Dunion, 2016: An Analysis of the Extratropical Transition of Hurricane Arthur (2014) from a JPSS Proving Ground Perspective. 32nd AMS Conference on Hurricanes and Tropical Meteorology, San Juan, PR.

Folmer, M.J., 2016: A Satellite Paradigm Shift: GOES-R and JPSS Shed New Light on Analyzing and Forecasting Heavy Precipitation, Marine Weather, and Tropical Cyclones. JPSS and GOES-R Seminar Series, Greenbelt, MD.*

Folmer, M.J., A. Terborg, A. Schumacher, and B. Line, 2016: NCEP Centers Preparation for the New JPSS Series: Current Polar-Orbiting Satellite Applications. 2016 Satellite Proving Ground and User Readiness Meeting, Norman, OK.*

Folmer, M.J., B. Ward, A. Terborg, and A. Schumacher, 2016: National Centers Perspective on Use and Training of Himawari Data. 2016 Satellite Proving Ground and User Readiness Meeting, Norman, OK.*

Folmer, M.J., E. Berndt, J. Halverson, and J. Dunion, 2016: An Analysis of the Extratropical Transition of Hurricane Arthur (2014) from a JPSS Proving Ground Perspective. 32nd AMS Conference on Hurricanes and Tropical Meteorology, San Juan, Puerto Rico.

Folmer, M.J., M.L. Bozeman, C. Mello, A.M. Terborg, G. Grosshans, M. Sardi, M. DeMaria, and S. Leyva, 2016: Preparing for GOES-R and JPSS in AWIPS II: National Centers Perspective. 96th American Meteorological Society Annual Meeting, New Orleans, LA.

Folmer, M.J., J.M. Sienkiewicz, J.D. Clark, H.D. Cobb III, N. Ramos, D.R. Novak, A. Orrison, J. Kibler, S.D. Rudlosky, S.J. Goodman, and M. Goldberg, 2016: Preparing for GOES-R and JPSS at the Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis: 2015 Demonstrations. 96th American Meteorological Society Annual Meeting, New Orleans, LA.

Outreach

- Co-mentoring a PhD student at the University of Alabama-Huntsville (UAH)
- Co-mentoring two University of Maryland Interns at OPC
- Visiting WFOs when possible to update on GOES-R and introduce the MPS PG
- Building a collaboration between the MPS PG and Alaska Region PG

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	5
# of peer reviewed papers	2
# of NOAA technical reports	
# of presentations	5
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Facilitating Direct CICS Support for Satellite Proving Ground Efforts

Task Leader:	E. Hugo Berbery
Task Code:	EBSR_GOES_14 Year 3 & EBEB_PGTC_15 Year 2
NOAA Sponsor:	Steven Goodman, Mitch Goldberg, and Mike Kalb
NOAA Office:	NESDIS/GOESPO & JPSSO & STAR
Contribution to CICS Research Themes (%):	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic:	Advanced Satellite Programs
Contribution to NOAA goals (%):	Goal 1: 25%; Goal 2: 75%; Goal 3: 0%
Strategic Research Guidance Memorandum:	Other–Scientific Outreach and Education

Highlight: Following nearly three years of effort, a NOAAPORT Satellite Broadcast Network (SBN) antenna, receiver, and server have been installed at CICS-MD. The NOAAPORT will provide nearly identical feeds to those received at National Weather Service (NWS) offices, allowing CICS-MD to simulate operational environments for the first time.

Link to a research web page: http://cicsmd.umd.edu/

Background

The JPSS and GOES-R programs have provided support for developing a CICS-MD Proving Ground and Training Center (PGTC). The PGTC is an operational framework that allows CICS-MD to maximize its satellite PG contributions. Infrastructure is being built to promote sustained interaction between JPSS/GOES-R algorithm developers and end users for training, product evaluation, and solicitation of user feedback. Many SCSB/CICS-MD scientists develop algorithms that have a variety of operational applications, but these scientists have limited channels for direct interaction with NWS forecasters. The proposed research will help bridge this gap by supporting an IT expert and several student liaisons. This effort will broaden the influence of CICS-MD within the satellite PGs, and bring operational meteorology into the classroom. Target products include ATMS and SSMIS snowfall rates, regional AMSR-2 products for the OCONUS, and lightning enhanced precipitation products. The PGTC will help with additional JPSS product lines being developed by NESDIS/STAR scientists located adjacent to SCSB/CICS-MD at the NCWCP (e.g., aerosol and fire products). The proposed research will develop satellite education and training materials through e-learning modules, seminars, weather event simulations, and special case studies. The PGTC seeks to produce graduates with remote sensing experience ready to staff future NESDIS activities as support contractors and civil servants.

Accomplishments

- A NOAAPORT Satellite Broadcast Network (SBN) antenna, receiver, and server were installed at CICS-MD. The NOAAPORT provides nearly identical feeds to those received at National Weather Service (NWS) offices, allowing CICS-MD to simulate operational environments. This equipment is integral to promoting interactions between scientists, students, and forecasters.

- AWIPS, WDSS, and McIDAS have been implemented to visualize real-time and archive data from satellite- and ground-based sensors.

- An LDM Server has been built to obtain experimental products from the other cooperative institutes. This server will eventually serve out demonstration products, and allowing CICS-MD scientists to help promote their smooth transition into operations.
- The CICS-MD PGTC has implemented its first STAR product in AWIPS. The NESDIS snowfall rate (SFR) product is produced at CICS-MD, converted to an AWIPS-readable format, and displayed on our AWIPS systems. These procedures have been running on our system routinely since Feb 2017, making us confident that our set of procedures are robust.

- We have developed and began implementing plans to renovate the room that houses our AWIPS machines. CICS-MD administrators saw the value in this facility, and purchased new furniture which has been installed. The room now houses five workstations, two equipped with 4-panel AWIPS machines, and a ceiling-mounted projector with an automatic screen.

- The addition of two new team members has put the team in a much better position. Mamoudou Ba (NWS/MDL) continues a one year rotational assignment helping to coordinate the PGTC activities and ensure that they fit within the broader PG efforts. Mamoudou has well established connections to the NWS MDL, which helps us to implement AWIPS, incorporate existing plug-ins, and develop new plug-ins. Mark Sannutti specializes in AWIPS implementation and keeps our AWIPS machines updated to the newest version.

- We have installed and implemented the Raytheon version of AWIPS, bringing us more in line with the operational users. A recent AWIPS upgrade now allows us to routinely display the new GOES-16 imagery in AWIPS.

- Doug Kahn, a senior at UMD/AOSC, worked as a student volunteer at the Sterling National Weather Service Weather Forecast Office under the supervision of forecaster Matthew Elliot. During summer 2016, Doug volunteered at the Sterling WFO two days per week and also worked at CICS-MD two days per week, allowing for close collaboration with the Sterling WFO.

Figure 1. SBN Antenna atop the M-Square research building that houses CICS-MD.

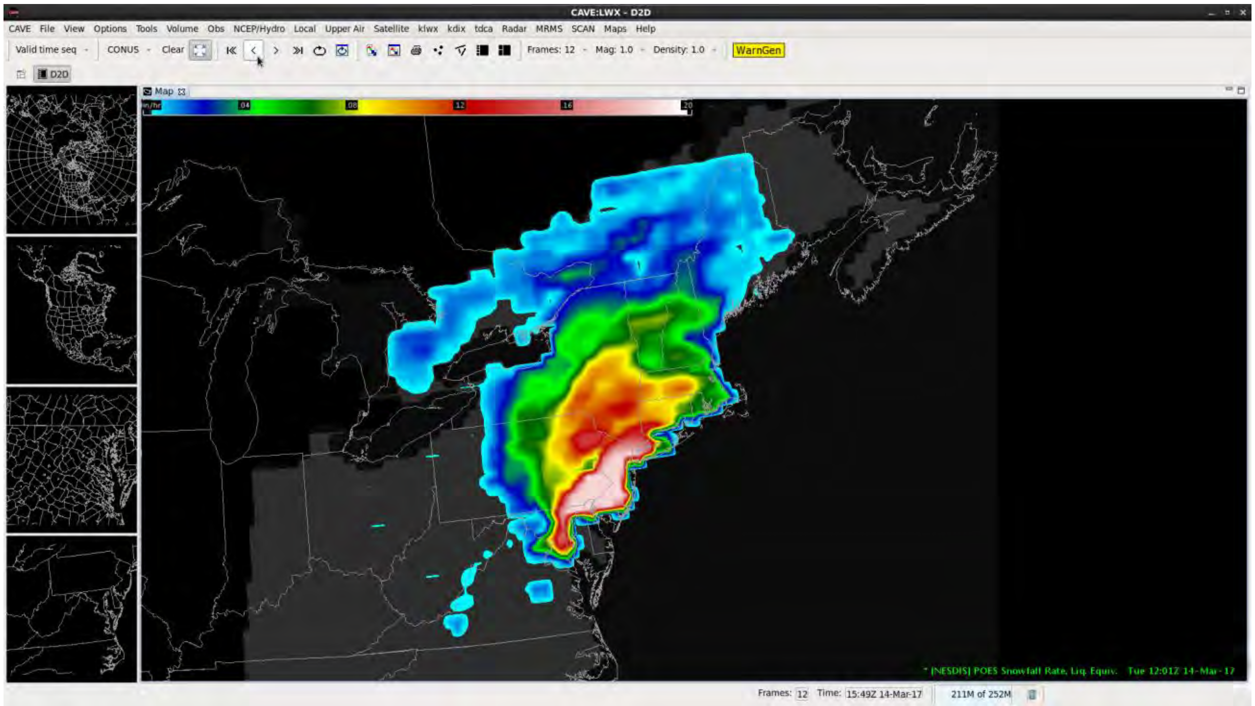


Figure 2. NESDIS/STAR snowfall rate product as viewed in AWIPS.

Planned work

- Develop AWIPS plug-in Capabilities – AWIPS will provide tremendous flexibility for developers in the form of plug-ins. These tools can be developed for implementation at WFOs and National Centers using existing data feeds.

- Continue to advise Shobha Kondragunta (NESDIS/STAR) and Ivan Csiszar (NESDIS/STAR) as they work to implement their aerosol and smoke products in NWS operations.

- Work with Huan Meng (NESDIS/STAR/SCSB) and NASA SPoRT as they investigate the visualization, training, and gathering of user feedback regarding the NESDIS/STAR snowfall rate product.

- Implement the Community Software Processing Package (CSPP) – Although the SBN is the main NWS data distribution tool, other (newer) data sets often must be gathered using different means. The CSPP provides a standardized means for interacting with the direct broadcast community, and thus provides an essential tool for product developers.

- Obtain/implement software for creating forecaster training modules

- Integrate the GOES-16 GLM into AWIPS to allow for the development of training materials

- We plan to add two additional 4-panel AWIPS machines along with three large television monitors to display various products in AWIPS. This new room will provide space for STAR and CICS-MD scientists to visualize their products as they will be seen by NWS forecasters.

Performance Metrics	
# of new or improved products developed (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	2

2.4a Scientific Support for the GOES-R Mission

GOES Evapotranspiration (ET) and Drought Product System (GET-D)

Task Leader	Mitchell Schull, Christopher Hain
Task Code	CHCH_GETD_14 Year 3
NOAA Sponsor	Xiwu Zhan
NOAA Office	NESDIS/STAR/SMCD/EMB
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Scientific Support for the GOES-R Mission
Contribution to NOAA Goals (%)	Goal 1: 70%; Goal 2: 30%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: We have developed an operational evapotranspiration and drought monitoring system using the GOES Land Surface Temperature product, meteorological data and other ancillary satellite remote sensing data. The GET-D product has been made operational at NOAA OSPO.

Link to Websites

NOAA/STAR: https://www.star.nesdis.noaa.gov/smcd/emb/droughtMon/products_droughtMon.php# ;

NOAA/OSPO: http://www.ospo.noaa.gov/Products/land/getd/

Background

The GOES ET and drought product system (GET-D) has been developed and made operational at the NOAA Office of Satellite and Product Operations (OSPO). The GET-D system is based on a surface energy balance model specifically adapted for geostationary satellite data to calculate the evapotranspiration (ET) and the potential ET (PET).

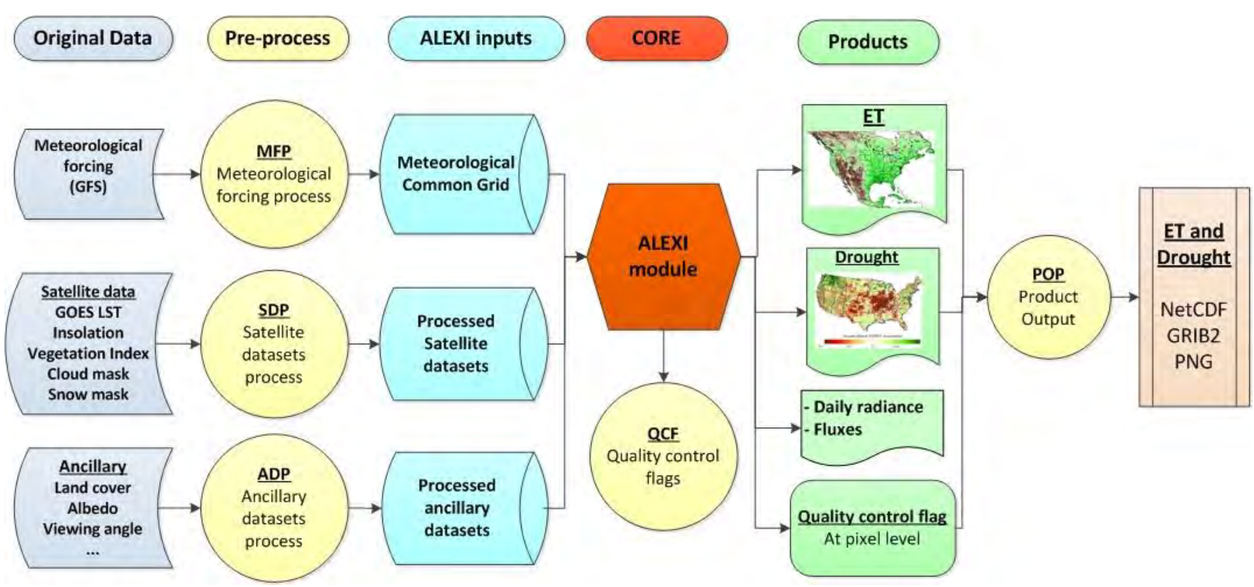


Figure 1. GOES Evapotranspiration and Drought Product (GET-D) system design.

Primary remote sensing inputs to the Atmosphere-Land Exchange Inverse (ALEXI) model are time-changes in land-surface temperature (LST), hourly down-welling short and long-wave radiation, and leaf area index (LAI). We have spearheaded the use of anomalies in the remotely sensed ET/PET fraction (f_{PET}) generated with ALEXI as a drought monitoring tool that samples variability in water use, and demonstrated complementary value in combination with standard drought indices that reflect water supply. ALEXI provides a framework for interpreting LST and vegetation index remote sensing drought signals within the context of a physically based energy balance model. This is the first ET and drought monitoring data product that are operationally supported at NESDIS from GOES. Figure 1 presents high-level design and data flow of the GET-D system.

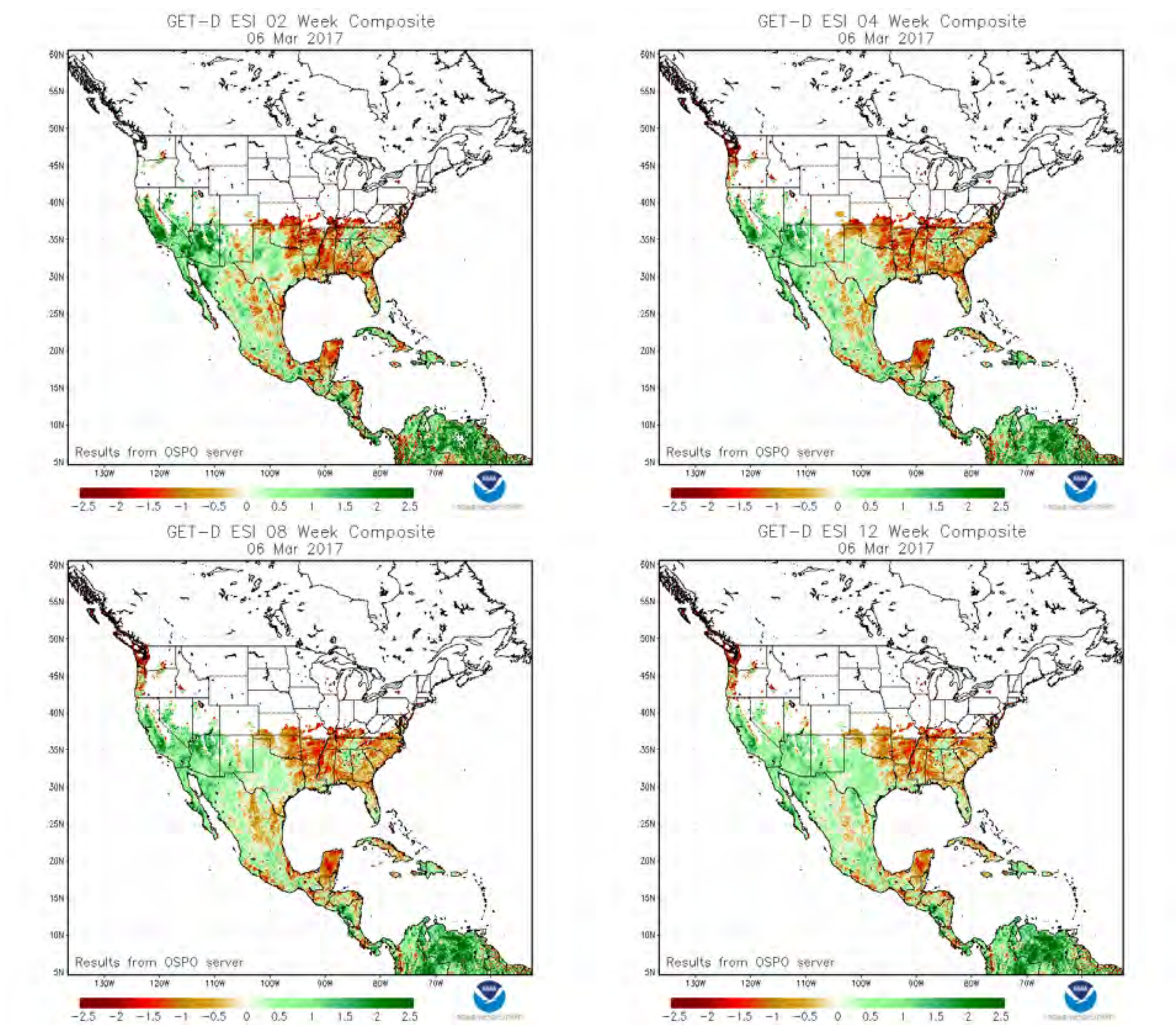


Figure 2. Example ESI composites from the GET-D system

Accomplishments

The GOES ET and drought product system (GET-D) has been developed and made operational at the NOAA Office of Satellite and Product Operations (OSPO). In the last funding cycle, we have finished system tests, system readiness review, operational readiness review and SPSRB briefing. We also updated the GETD Algorithm Theoretical Basis Document (ATBD) and relevant description documents. The project deliverables (documentation and software) and milestones have been accomplished as planned.

Figure 2 presents an example of 2/4/8/12-week composite of ESI generated from the GET-D system at 8km resolution over the North American domain **(March 06th, 2017)**.

Publications

Zhan, X., Chris Hain, Li Fang and Zhengpeng Li, GETD Algorithm Theoretical Basis Document (ATBD), version 1.0, 2014

Zhan, X., Hanjun Ding, Chris Hain, Li Fang, Zhengpeng Li and Priyanka Roy, GOES Evapotranspiration and Drought Product System (GET-D) , report prepared for the NESDIS SPSRB Critical Design Review (CDR), August 21, 2014.

Products

- Software system for the Atmosphere–Land Exchange Inversion MODEL (ALEXI).
- Software system for GOES Evapotranspiration (ET) and Drought Product System (GET-D).
- Documentation for the drought monitoring algorithm and software system.

Presentations

Chris Hain, M. C. Anderson, J. Otkin, T. R. H. Holmes, and W. T. Crow, Implementing the Remotely Sensed Evaporative Stress Index Globally Using MODIS Day/Night Land-surface Temperatures, poster in AMS 96th Annual Meeting, New Orleans, LA, 2016

Zhengpeng Li, C. Hain, L. Fang, X. Zhan, and M. C. Anderson, GOES Evapotranspiration and Drought Product System (GET-D), poster in AMS 96th Annual Meeting, New Orleans, LA, 2016

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	2
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

This year, we developed a new 8-km North American domain drought monitoring product (1) and the product has been operational. Two posters summarizing the product have been made in the AMS 96th Annual Meeting, LA, 2016.

Washington D.C. Lightning Mapping Array Maintenance and Outreach, Real-time Monitoring of Lightning Detection Network Performance, GOES-R GLM Validation and Application

Task Leader:	E. Hugo Berbery
Task Code:	EBSR_DCLM _14 Year 3, EBSR_RMLD_15 Year 2 & EBEB_GLM_16
NOAA Sponsor:	Steven Goodman & Jamie Daniels
NOAA Office:	NESDIS/GOESPO
Contribution to CICS Research Themes (%):	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic:	Scientific Support for the GOES-R Mission
Contribution to NOAA goals (%):	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Several recent projects have helped improve the visibility of the DCLMA and demonstrate its value for severe weather analysis and public outreach.

Link to a research web page: http://cicsmd.umd.edu/

Background

The Washington D.C. Lightning Mapping Array (DCLMA) is a joint demonstration project between the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), New Mexico Institute of Mining and Technology, and 10 local site hosts. The DCLMA has been operational since 2007, providing detailed 3D lightning observations that inform decision makers about the severe weather and lightning threats. The network consists of 10 sensors that monitor very high frequency (VHF; MHz) radio waves (radiation sources) emitted by lightning. These total lightning observations provide detailed insights into the structure and evolution of convective storms, and help protect lives and property. The DCLMA has many uses, including severe storm research, public safety outreach efforts, and preparations for the planned Geostationary Lightning Mapper (GLM).

Many meteorological applications use lightning observations from both ground- and space-based lightning detection systems. As the number of networks and variety of users expands, it becomes increasingly important to understand the detection capabilities of these networks. Both Rudlosky and Shea (2013) and Rudlosky (2015) evaluated the performance of ground-based lightning detection networks relative to observations from the Tropical Rainfall Measurement Mission (TRMM) Lightning Imaging Sensor (LIS). Moreover, Peterson et al. (2016) showed that LIS is capable of detecting some of the development of the lightning channel that is evident in LMA observations. The GOES-R Geostationary Lightning Mapper (GLM) Science Team also has developed several tools for validating lightning detection networks. This project will implement real-time lightning monitoring tools in support of operational GOES-R GLM users and long-term monitoring requirements. It then will composite inter-comparison and validation results from GLM Science Team members and identify the best means for disseminating this valuable information. Finally, it will improve our understanding of ground- and space-based lightning detection systems to better inform scientists and forecasters using these data for weather research, modeling, and forecasting applications.

Accomplishments

The DCLMA remained operational with at least 5 sensors reporting during all of calendar year 2015. These data were shared with operational users and also to develop training materials for National Weather Service (NWS) forecasters. An undergraduate student has been trained to work on the DCLMA sensors, and also to use the Warning Decision Support System – Integrated Information (WDSS-II) to interrogate these data alongside radar and model observations. This ongoing research uses the DCLMA and Global Lightning Dataset 360 (GLD360) along with WDSS-II which allows visualization and clustering of convective storms in an interactive, 3-D graphic display, to provide detailed insights into the structure and evolution of convective storms.

This project began by delving more deeply into the dataset created by Rudlosky (2015) to investigate the properties of lightning flashes that were observed by the LIS and those that were not. These results have been communicated to members of the GOES-R GLM science team to help with their investigation of the fraction of lightning flashes that come to ground. Current work is also examining the coincident LIS lightning and cloud property dataset used in Peterson et al. (2016) to identify lightning flash structure and morphology in the context of collocated precipitation radar, infrared, and passive microwave satellite measurements. CICS-MD connected to real-time lightning feeds (e.g., NLDN, ENTLN, DCLMA) via a new Satellite Broadcast Network (SBN) antenna. Data from private vendors is presently provided by commercial software systems that allow for the real-time visualization of these data. We attended a workshop in Huntsville, AL to explore lightning validation tools developed by other GLM Science Team members. We have begun the process of implementing these tools in real-time to determine which validation procedures are best for this purpose.

Planned Work

- Continue collaborations with scientists at the University of Alabama Huntsville and NASA Marshall Space Flight Center
- Take advantage of new LMA installment at Wallops Island for collaborations and to gain interesting insights into storms along the Delmarva Peninsula.
- Explore the potential for merging the D.C. and Wallops Island LMAs to cover a larger region.
- Compile a DCLMA archive and continue to document significant severe weather, lightning induced structural damage, and any lightning casualty events
- Support hourly undergraduate researchers who visit sensors that fail to bring them back online
- Continue exploring lightning validation tools developed by other GOES-R GLM Team Scientists to determine which procedures are best suited for real-time implementation.
- Implement selected procedures to compute performance statistics in near real-time for both the GOES-R GLM and ground-based networks (e.g., the National Lightning Detection Network - NLDN and Earth Networks Total Lightning Network - ENTLN).
- Composite these statistics over seasonal and annual periods, and report the findings periodically through manuscript publications and conference presentations.

- Merge the new procedures with the existing CICS-MD Cal/Val Center and planned PGTC. These capabilities will be developed in conjunction with the STAR/CICS-MD Precipitation Cal/Val Center and the newly emerging CICS-MD PGTC. Various paths will be explored to determine the optimal method for sharing these performance statistics with lightning data users.
- Determine the optimal method for sharing performance statistics with lightning data users. Data initially will be provided via a webpage modeled after the CICS-MD Precipitation Cal/Val Center. As the CICS-MD PGTC grows, additional tools will become available for distributing performance statistics in near real-time. We anticipate that this information will benefit both operational weather forecasters and numerical modelers.

Publications

Peterson, M., W. Deierling, C. Liu, D. Mach, and C. Kalb (2017), The properties of optical lightning flashes and the clouds they illuminate, *J. Geophys. Res. Atmos.*, **122**, 423–442, doi:10.1002/2016JD025312.

Presentations

Peterson, M. J. and S. Rudlosky, 2016: Optical and Radio Perspectives on Lightning Flash Propagation. *AGU Fall Meeting*, San Francisco, CA, 2016, oral.

Rudlosky, S., 2016: Lightning Observations and Applications. *UK Met Office*. Exeter, UK, 12 July. (Invited)

Kahn, D. T., S. D. Rudlosky, P. C. Meyers, and M. J. Pavolonis, 2017: Evaluating the ProbSevere Model Over the Atlantic Ocean Using WDSS-II, *7th Conference on Transition of Research to Operations*, Amer. Meteor. Soc., Seattle, WA, January 23-26, Poster 880.

Other

Interaction with operational partners –Doug Kahn, a senior at UMD/AOSC, worked as a student volunteer at the Sterling National Weather Service Weather Forecast Office under the supervision of forecaster Matthew Elliot. During summer 2016, Doug volunteered at the Sterling WFO two days per week and also worked at CICS-MD two days per week, allowing for close collaboration with the Sterling WFO. Doug is conducting his senior thesis research at CICS-MD investigating off-shore thunderstorms.

Performance Metrics	
# of new or improved products developed (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	3

Technical Support of GOES-R Land Surface Temperature Algorithms and Validation	
Task Leader:	Peng Yu
Task Code:	PYPY_GOES_14 Year 3 & PYPY_GOES_16
NOAA Sponsor:	Yunyue Yu
NOAA Office:	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%):	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic:	Scientific Support for the GOES-R Missions
Contribution to NOAA goals (%):	Goal 1: 40%; Goal 2: 60%; Goal 3: 0%; Goal 4: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

This report summarizes the ongoing NOAA project titled "Technical support for GOES-R land surface temperature algorithm and validation". The goal of this project is to continue performing the tasks determined at the AWG land team LST schedule and Validation Plan (updated in January 2015) and in GOES-R Land Surface Temperature (LST) Validation Readiness, Implementation and Management Plan (RIMP). Following the successful delivery of the 100% readiness Algorithm Package for ABI LST in September 2010, the revision validation tool delivery in 2013, the major works for FY16 are on the verification and validation of operational LST product, the algorithm improvement and maintenance, refurbishment and testing of the GOESR LST validation and monitoring tool, and emissivity product development and improvement. One of the key tasks is the testing of the validation tool with DOE data and AHI data and to get it ready for the operational production of the ABI LST. Most of the team efforts focus on the inspection and validation of the operational LST product once it becomes available and the readiness of multiple validation tools before GOESR launch.

Accomplishments

The GOES-R LST validation tool has been updated and tuned to better meet the requirement of operational LST validation. Additional functionalities were added to accommodate the characteristics of GOES-R LST product. As proposed in the FY16 work plan, it has been extended to an online validation and monitoring system for GOES-16 LSTs. The system consists of four different components following the needs determined at the GOES-R LST RIMP document, including the visualization module, which was run on a daily basis to produce LST snapshots for visual inspection, the metadata, quality flag, and statistics inspection system, which was run on a daily basis for product data inspection, the main processing component, which is run daily for LST data subset and matchup, and a monitoring and validation component, which was run every week. The complete system has been intensively tested with the DOE-3 and DOE-4 data (simulated ABI proxy) and is being automatically run via crontab. All modules were able to post the results on an FTP server, however, due to the data sharing restriction, the online result presentation were temporarily disabled at the current stage. The LST validation and monitoring component summarizes the validation results and passed the results to the group through email. Products currently being monitored and inspected include LSTs from Full Disk, CONUS, MESO1, and MESO2. The system will also serve the need for GOES-16 LST long term monitoring.

Multiple LST retrieval algorithms were evaluated and tested with proxy data from multiple sensors. An enterprise algorithm (1) has been proposed to the mission management.

$$T_s = C + A_1 T_{11} + A_2 (T_{11} - T_{12}) + A_3 \varepsilon + A_4 \varepsilon (T_{11} - T_{12}) + A_5 \Delta\varepsilon \qquad (1)$$

The algorithm is readily applicable to different satellite sensors. The enterprise version of the LST retrieval code has been completed, tested, verified, and submitted to AIT. Retrieval coefficients for HIMAWARI-8 AHI and GOES-16 ABI have been generated and implemented to the AIT's framework. A system has been established to monitor the baseline and enterprise AHI LSTs and their difference (Figure 1).

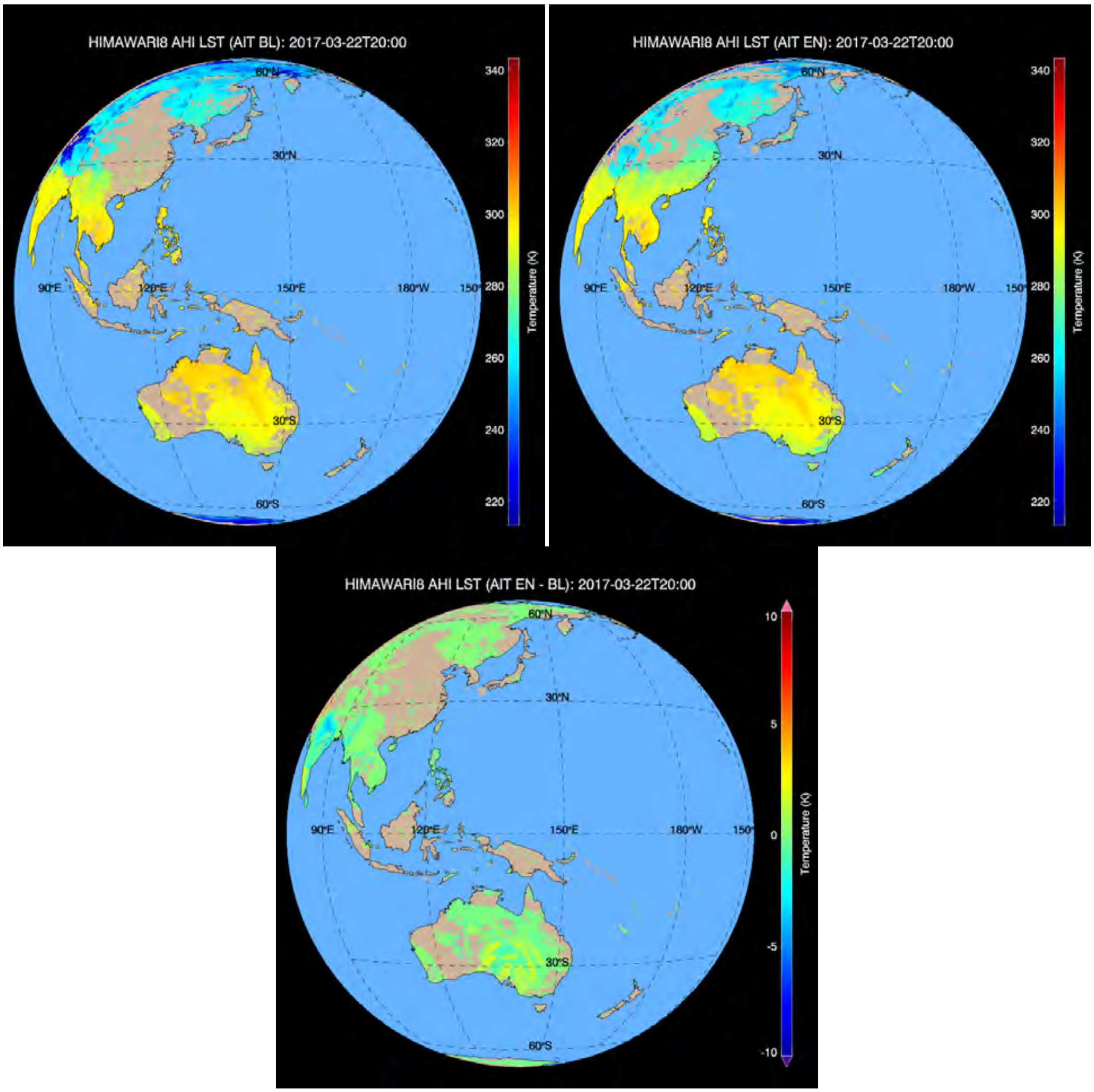


Figure 1. Baseline LST (upper left), Enterprise LST (upper right), and their difference (lower) at 2017-03-22 20:00 UTC.

GOES-16 was launched in November, 2016 and the data has been made available to LST AWG team since January, 2017. Most team efforts focused on the inspection of multiple LST products, including Full Disk (FD), CONUS, and two Mesoscale LST products, to ensure that no systematic errors exist and the product can reach its Beta maturity on May 22nd, 2017. All four components of the validation have been run for multiple purposes. Figure 2 shows an example of the LST snapshots for FD and CONUS LSTs on Mar. 16th, 2017.

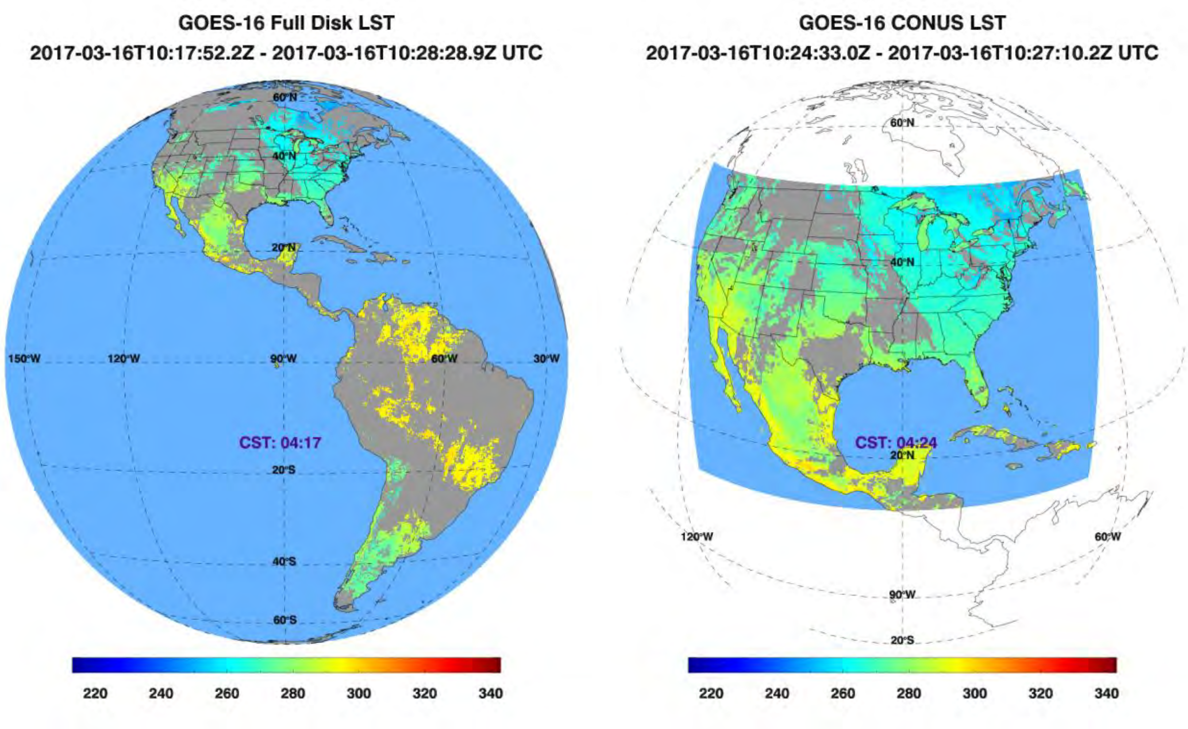


Figure 2. GOES-R ABI LST snapshots on Mar. 16th, 2017

Information being routinely checked includes the file content, metadata, LST visual images, and LST retrieval range. In addition, the main processing module is run for data subset and matchup with in-situ observations to get ready for the products quality/performance assessment. Issues have been found during this period, including calculation error of LST retrieval statistics, navigation/registration issue of SDR data, incorrect radiance to brightness temperature conversion parameters, issues on LST retrieval availability, inconsistency between the two LST quality flags (DQF and PQI), etc. A comprehensive analysis and report will be completed towards the baseline ABI LST product beta maturity.

Improvements have been made to enhance the quality of the emissivity product. The background emissivity has been updated, in which the land surface was classified to three major types, *e.g.*, soil, inland water and permanent snow/ice. Soil emissivity was derived from ASTER GED dataset based on the vegetation cover method and inland water was assigned according to the spectral library due to the stable emissivity value of water. As for snow and ice, large discrepancy between MODIS and ASTER product exists, the evaluation results indicated mean emissivity from MODIS worked better. A daily rolling snow fraction data was generated each day to account for the snow impact on emissivity. Long time series

VIIRS daily snow fraction data were used to build a gap-free gridded data, once there is newly available VIIRS snow fraction, these pixels will be updated while others are not changed. Additional quality control procedures were included. General criteria of emissivity range and two split-window channel difference were established based on the historical products and spectral library. New quality control was applied to screen out data with large uncertainties. Those screened out are replaced by the neighbouring mean value or climatology. In addition, a pixel by pixel emissivity product uncertainty will be included. The product has been evaluated with limited in-situ observations and yielded satisfactory results.

Planned work

- Carry out product verification and validation at various mission stages as determined in RIMP. Conduct verification and validation activities of the ABI LST product at different stages, including beta, provisional, and validated stages. This includes the evaluation/validation of the ABI LST with multiple ground in-situ measurements and cross-satellite comparison
- Continue the algorithm maintenance and update for LST product, with the maintenance delivery to the GOES-R Ground Segment Project (GSP) as requested.
- Maintenance of the LST enterprise algorithm
- Continue the development and update of product routine validation tools, particular, the improvement of the validation method and the software refurbishment/optimization.
- Participate the GOESR field campaign.
- Participate in the AHI post launch activities between STAR and JMA, for testing the ABI LST algorithm.
- Continue GOES-R Ground Segment Contractor Verification Support through validating vendor products and providing vendor feedback.
- A near real time emissivity retrieval system is ready. Continue to improve and evaluate the product.
- National/international collaboration with scientists on LST algorithms, validation/evaluation, and other aspects
- Update of corresponding documents.

Publications

Yu, Y., Y. Liu, and **P. Yu**, Land Surface Temperature Product Development for JPSS and GOES-R Missions, submitted to Vol. 5, Comprehensive Remote Sensing: Earth Energy Budget.

Products

- Updated emissivity retrieval algorithm for GOES-16 ABI split-window channels
- GOES-R ABI LST validation/monitoring system
- AHI LST retrieval coefficients for both baseline and enterprise algorithm.
- HIMAWARI8 AHI LST algorithm evaluation system

Presentations

Wang, H., Y. Yu, **P. Yu**, and Y. Liu, Developing Land Surface Emissivity Product for JPSS and GOESR Missions, 2016 AGU Fall Meeting

Yu, P., Y. Yu, Y. Liu, and H. Wang, The GOES-R Land Surface Temperature Product, 2016 CICS Annual Meeting.

Yu, Y., Y. Liu, **P. Yu**, H. Wang, Y. Rao, and Z. Song, Status of Land Surface Temperature Product Development at NOAA/STAR/NESDIS --- towards an enterprise LST algorithm and production, GlobTemperature 4th User Consultation Meeting.

Yu, Y., Y. Liu, **P. Yu**, and H. Wang, Developing Enterprise Algorithm for Land Surface Temperature Product, STAR Enterprise Algorithms Workshop.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	1
# of NOAA technical reports	
# of presentations	4
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

GOES-R Land Surface Temperature Data Field Validation	
Task Leader:	Peng Yu
Task Code:	PYYR_GLST_16
NOAA Sponsor:	Yunyue Yu
NOAA Office:	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%):	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic:	Scientific Support for the GOES-R Missions
Contribution to NOAA goals (%):	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

This report summarizes the ongoing NOAA project titled "GOES-R LST Data Field Validation". The goal of this work is to perform the tasks determined at land team LST schedule and Validation Plan. The major works for FY16 will be on the pre-launch validation for the GOES-R LST product, including the ground station LST data collection and calibration via national and/or international collaboration and ground campaign and the improvement on current validation method. The validation method improvement includes the investigation of up-scaling model and two-measurement analysis. The ground/field campaign data will be compared to Himawari-8 AHI data in the GOES-R LST validation tool environment. Cross-satellite LST product comparison between different sensors will be carried out.

The GOES-16 was launched in November 2016, the focus of this period was to test the baseline and enterprise LST retrieval algorithms with different sensor data as proxy. Multiple tools were modified to be ready for the operational product validation and monitoring.

Accomplishments

1. Enterprise LST algorithm development for Himawari-8 AHI data

The coefficients for enterprise LST algorithm has been derived for Himawari-8 AHI data with the most up-to-date simulate database including more atmospheric profiles from Thermodynamic Initial Guess Retrieval (TIGR). By applying this set of coefficients to Himawari-8 AHI data, LST has been derived from April 2016 to March 2017 with emissivity data developed at NOAA STAR and ancillary total precipitable water (TPW) from NCEP.

2. Validation of AHI LST comparing with ground measurements

To validate AHI LST data, ground station measurements have been collected from networks in China (1 station) and Australia (20 stations). Ground station measurement has been preprocessed to account for data quality and observation time differences (local time and UTC time). Due to lack of cloud mask data for AHI, cloud mask data from JPSS VIIRS, TERRA MODIS and AQUA MODIS are used to filter AHI data for validation. As presented in Figure 1, the AHI LST has shown good agreement with ground measurements. The performance of AHI LST is comparable with other current operational satellite LST products (i.e., S-NPP VIIRS, TERRA/AQUA MODIS).

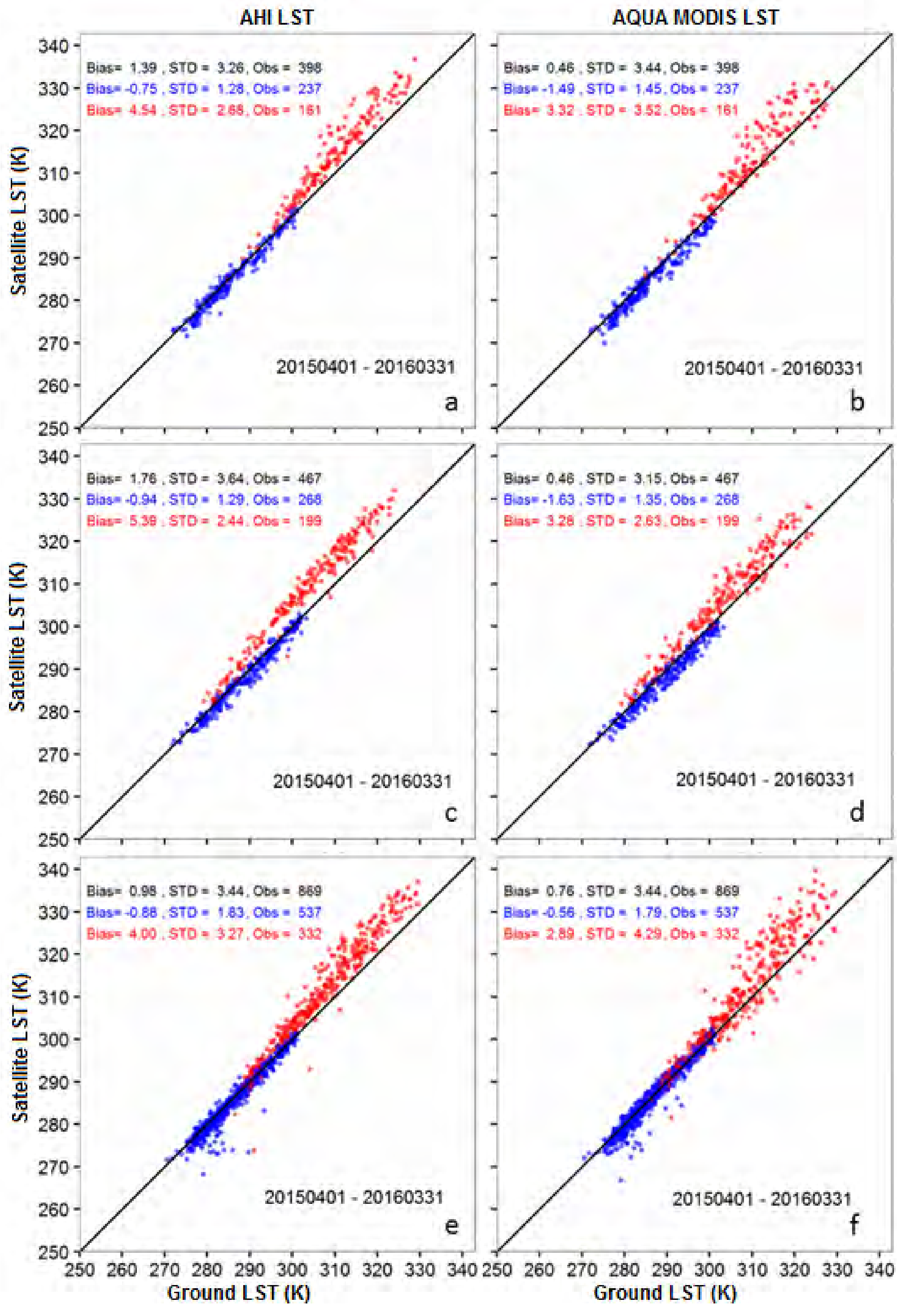


Figure 1. The comparison of validation results for Himawari-8 AHI, S-NPP VIIRS, TERRA/AQUA MODIS LST. The red dots represent daytime observations while blue dots indicate nighttime observations. (a, c, e) AHI LST with same/similar observation time (less than 5 minutes) with AQUA/TERRA MODIS, and S-NPP VIIRS respectively; (b, d, f) LST for AQUA/TERRA MODIS, and S-NPP VIIRS respectively.

In general, the bias of AHI LST is slightly larger than polar orbiting satellite LST products, while the precision of AHI LST is comparable or slightly better than other LST products. For nighttime LST observations, AHI LST has shown better performance comparing S-NPP VIIRS and TERRA/AQUA MODIS with smaller biases and standard deviations. For daytime cases, all satellite LST retrievals have notable overestimation comparing to ground measurements, which is a phenomenon that has not been reported in previous validation efforts in other continents. Among four LST data, AHI LST has larger biases than others but smaller standard deviations for daytime LST retrieval. This result indicates that enterprise AHI LST algorithm has more robust performance over Australia than others. However, the overestimation over daytime should be further investigated to improve LST products performance over Australia. The LST differences between satellite and ground measurements have been analyzed with different factors, including brightness temperature at 11 microns, brightness temperature differences between split window channels, solar and viewing geometries as well total precipitable water.

The analysis demonstrates that large daytime biases are strongly correlated with brightness temperature and solar zenith angle, indicating potential limitations of current algorithm over high temperature cases. The AHI LST has also been compared with ground measurements from a desert ground station located in northwestern China (2015.04-2015.11). The comparison has shown good agreement between satellite LST and ground measurements with small bias (-1.60 K) and standard deviation (1.82 K). This has demonstrates the effectiveness of enterprise LST algorithm over large view zenith angle areas (60.4 degree for the Chinese station).

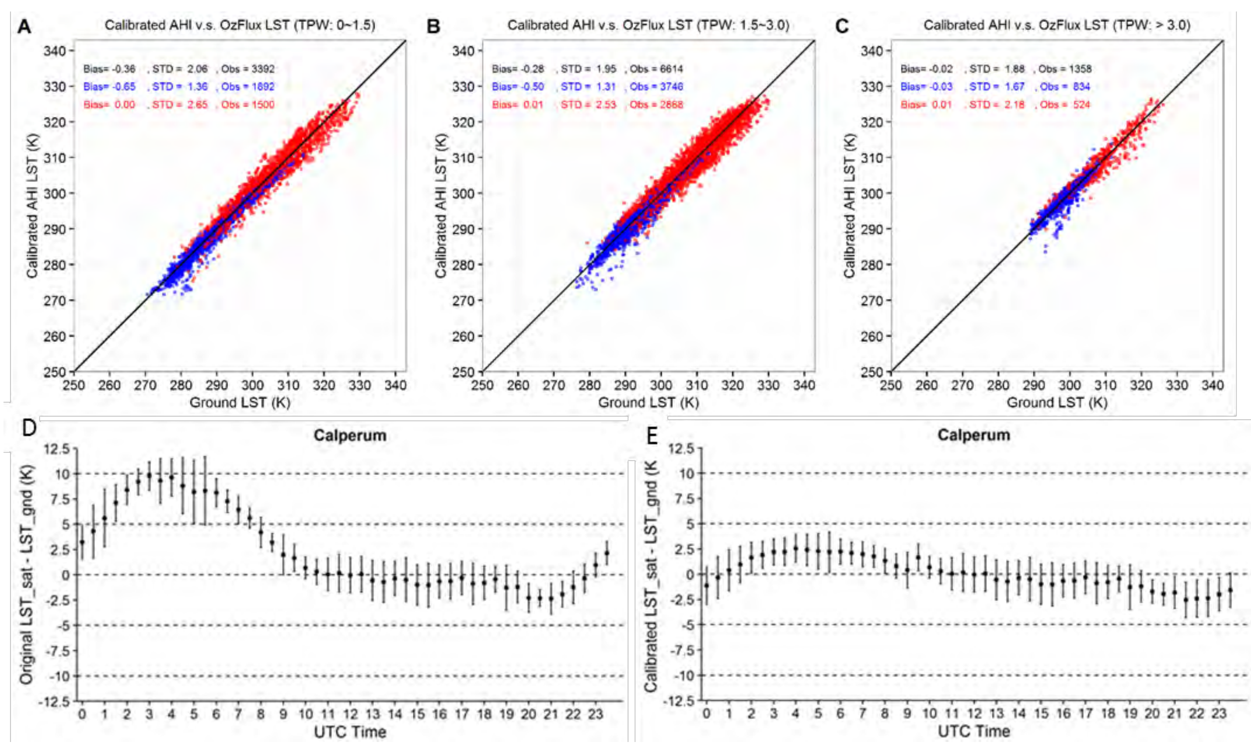


Figure 2. Validation results for calibrated AHI LST using ground measurements (A-C) for different total precipitable conditions (dry, moderate, and moist). (D-E) Example of the diurnal pattern of original and calibrated LST differences for ground station Calperum in Australia.

3. Algorithm coefficients calibration using ground measurements

To improve the performance of enterprise LST algorithm over Australia, coefficients has been calibrated using available ground measurements. Based on previous analysis, LST differences are strongly correlated with brightness temperature and brightness temperature differences of split window channels. Thus, a linear model is fitted using AHI LST and ground measurements data pairs. The dependent variable is the LST difference between satellite and ground measurements, while independent variables are brightness temperature at 11 microns and brightness temperature differences between split window channels. The model is fitted for different total precipitable water and viewing zenith angle conditions. The coefficient from fitted correction model is then added to original coefficients set for correction. After correction, the validation has been significantly improved with small bias to ground measurements. As presented in Figure 2, the corrected AHI LST has eliminated daytime overestimation over Australia. In the future study, more independent validation should be conducted to evaluate the calibrated coefficients for LST retrieval.

Planned work

- GOES-16 LST validation using SURFRAD station data: GOES-16 LST will be validated using ground measurements from SURFRAD network following similar procedure performed for AHI data;
- Cross-satellite comparison: GOES-16 LST data will be compared with polar orbiting satellite LST products including S-NPP VIIRS, TERRA/AQUA MODIS LST;
- Participation in GOES-R field campaign activities
- Station measurement upscaling: To overcome the limited spatial representativeness of ground measurements, high resolution thermal data (Landsat-8 TIR) will be used to upscale station measurements to match with coarse resolution GOES-16 LST data for validation.

Products

Enterprise Land Surface Temperature algorithm coefficients for HIMAWARI-8 AHI data and GOES-R ABI data

Presentations

June 8th -10th, 2016, GlobTemperature 4th User Consultation Meeting, Lisbon, Portugal

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	1
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Development of Algorithms for Shortwave Radiation Budget from GOES-R

Task Leader	Rachel Pinker
Task Code	RPRP_DASR_14 Year 3 & RPRP_DASR_16
NOAA Sponsor	Jaime Daniels
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Scientific Support for GOES-R Mission
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: We have tested narrow-to-broadband transformation coefficients based on heritage radiative transfer simulations implemented with simulated ABI data; developed new transformation based on updated models of radiative transfer for implementation with the operational versions of ABI and H-8/AHI.

Background

Under the GOES-R activity, new algorithms are being developed to derive surface and Top of the Atmosphere (TOA) shortwave (SW) radiative fluxes from the ABI sensor. This project supports the development and testing of this STAR effort. Specifically, scene dependent narrow-to-broadband (NTB) transformations and angular distribution models (ADMs) are developed to facilitate the use of observations from ABI. Initial NTB transformations are based on theoretical radiative transfer simulations with MODTRAN-3.7 using 14 land use classifications from the International Geosphere-Biosphere Programme (IGBP). The ADMs are a combination of MODTRAN-3.7 simulations and the Clouds and the Earth's Radiant Energy System (CERES) observed ADMs. The NTB transformations and ADMs have been tested using ABI and with H-8/AHI simulated data. Updated simulations have been performed with MODTRAN4.3 and implemented with the current ABI and H-8/AHI specifications. The new simulations have been completed and implemented with the final versions of ABI and H-8/AHI filter functions.

Comparisons of fluxes at the TOA fluxes were compared to those from CERES and/or FlashFlux data Surface condition at the scale of the ABI products are needed to compute the TOA radiative fluxes. The IGBP land classification at $1/6^{o}$ resolution for 18 surface types needs to be converted to the ABI 2-km grid over CONUS and re-grouped to 12 IGBP types to match the Clouds and Earth's Radiant Energy (CERES) ADMs. The complexity of the match-ups is illustrated in **Figure 1** showing the TOA radiative fluxes using ABI proxy data for April 27, 17-18 UTC and data from FlashFlux (http://ceres.larc.nasa.gov/order_data.php).

Accomplishment

We have developed a profile selection tool to run with MODTRAN4.3. It was applied to SeeBor Version 5.0 profiles (*Borbas et al.,* 2005; 2011) that consists of 15704 global profiles of temperature, moisture, and ozone at 101 pressure levels. The profiles are taken from NOAA-88, ECMWF 60L training set, TIGR-3, ozone-sondes from 8 NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) sites , and radiosondes from 2004 in the Sahara desert; a technique to extend the profiles above the level of existing data was also implemented by the University of Wisconsin-Madison, Space Science and Engineering Center, CIMSS.

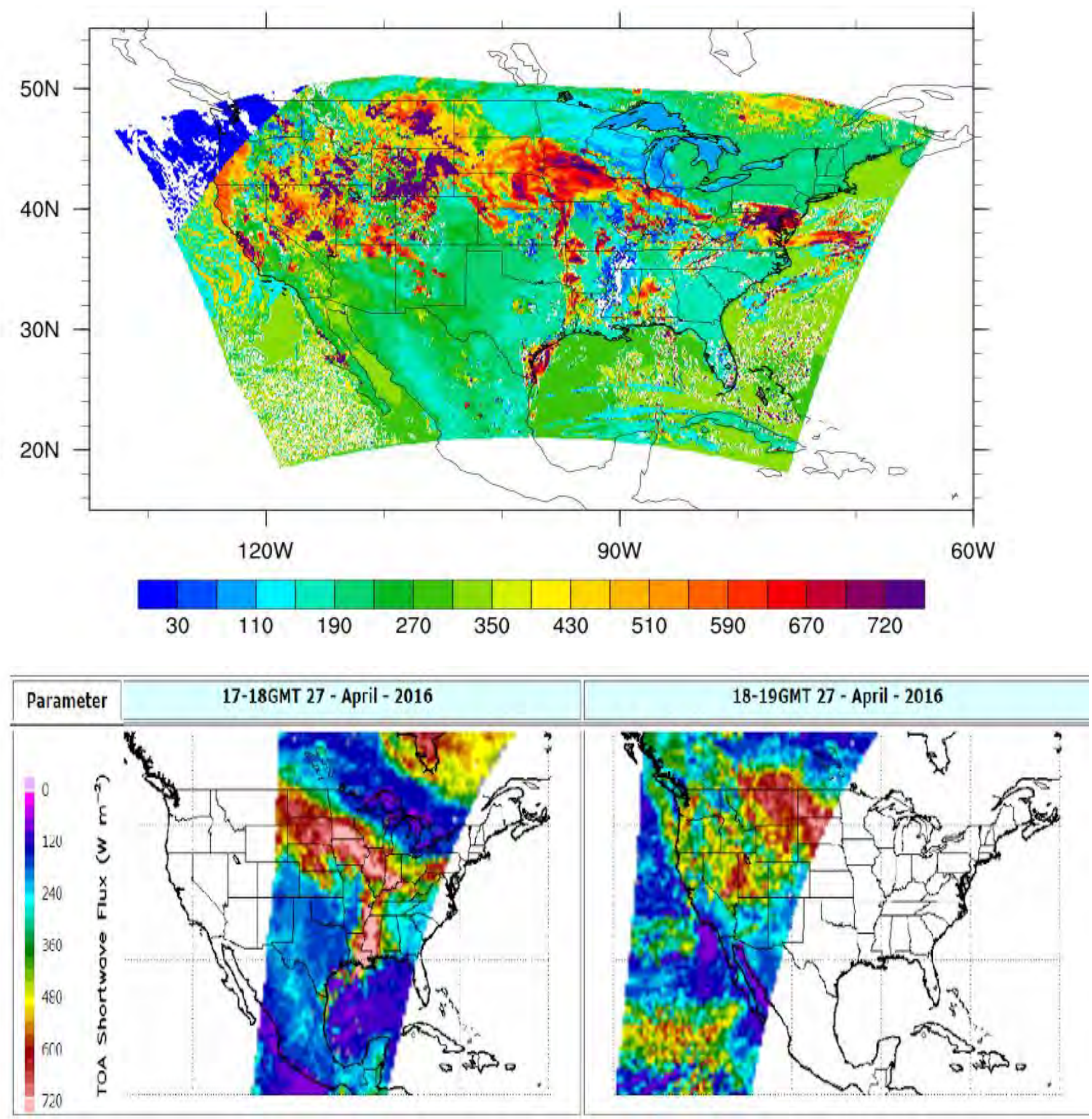


Figure 1.Top: Calculated ABI TOA fluxes at 2-km grid, 2016-04-27, 17:00 UTC; Middle and Lower: TOA hourly shortwave fluxes from Terra and Aqua from CERES website (http://ceres.larc.nasa.gov/order_data.php) FlashFlux data. Both Terra and Aqua observations are at the satellite Field-of-View (FOV) instantaneous footprint.

MODTRAN4.3 provides three multiple scattering models (Isaacs, DISORT, and Scaled DISORT) and three band model at resolutions (1 cm^{-1}, 5 cm^{-1}, and 15 cm^{-1}). The DISORT model (*Stamnes et al.,* 1988) provides the most accurate radiance simulations but the runs are time consuming. The Isaacs (*Isaacs et al*. 1987) algorithm with 2-stream is fast whereas oversimplified. The Scaled DISORT method performs radiance calculations at a small number of atmospheric window wavelengths. The multiple scattering contributions in each method are identified and ratios of the DISORT and *Isaacs* methods are computed. This ratio is interpolated over the full wavelength range, and finally, applied as a multiple scattering scale factor in a spectral radiance calculation performed with *Isaacs* method.

We performed various sensitivity tests with the simulation options (**Table 1**). The most computation demanding option is DISORT 8-stream with 1 cm^{-1} resolution; the fastest is Scaled DISORT with 15 cm^{-1}

Table 1. MODTRAN simulation speed test (CPU MHz 2099.929).

Algorithm	Stream	Band Resolution (cm^{-1})	Speed (~seconds)
Isaacs	2	1	40
DISORT	2	1, 5, 15	280, 70, 30
	4	1, 5, 15	560, 120, 40
	8	1, 5, 15	930, 300, 110
Scaled DISORT	2	1, 5, 15	30, 10, 6.67
	4	1, 5, 15	30, 10, 6.67
	8	1, 5, 15	30, 10, 6.67

We also compared DISORT simulated radiances with three band resolutions in spectral range of 0.4 – 0.5 µm and 1.5 – 2.0 µm. We have also compared radiance simulation from different multiple scattering models with 1 cm^{-1} resolution. In **Figure 2** compared are radiances simulated by *Isaacs* 2 stream, Scaled DISORT, and DISORT-4 stream with DISORT-8 stream for one case; scaled DISORT provides the smallest differences with DISORT-8.

It was learned that the Scaled DISORT method provides near-DISORT accuracy with the speed of *Isaacs.* Thus, we have set up MODTRAN4.3 simulations with Scaled DISORT 8-stream with 1 cm^{-1} band resolution. All the simulations to be performed for ABI and H-8 use this setting.

Under clear sky, multiple scattering from aerosols is also important. We have included 6 aerosol types to cover a range of possible conditions under clear sky. Aerosol models are selected base on the type of extinction and a default meteorological range for the boundary-layer aerosols models as listed below:

Aerosol Type 1: Rural extinction, visibility = 23 km
Aerosol Type 4: Maritime extinction, visibility = 23 km
Aerosol Type 5: Urban extinction, visibility = 5 km
Aerosol Type 6: Tropospheric extinction, visibility = 50 km
Aerosol Type 8: Advective Fog extinction, visibility = 0.2 km
Aerosol Type 10: Desert extinction, visibility based on wind speed

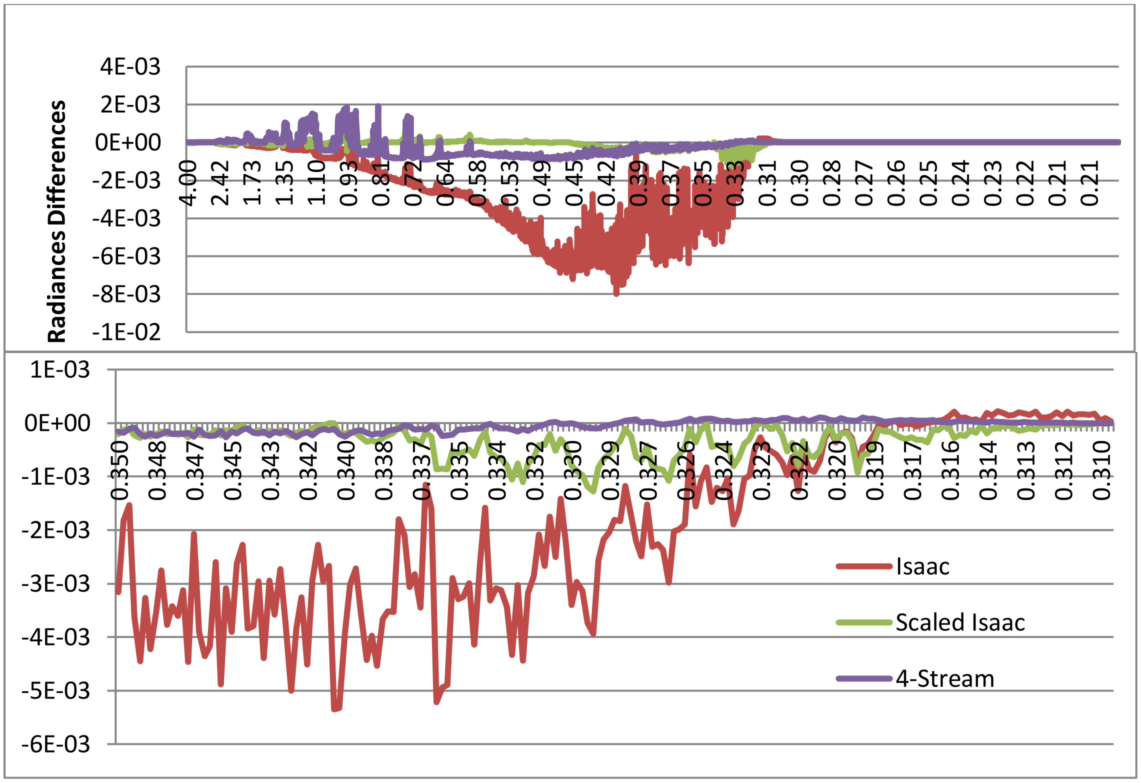


Figure 2.Radiance differences between various multi-scattering algorithms and DISORT-8 stream. The upper figure is for the whole simulated spectrum of 0.2-4 µm, the bottom figure is zoomed in to 0.3-0.35 µm (relative azimuthal angle=1.9, view angle=103.685, solar zenith angle=87.2).(This one long chart split in the middle to fit on the page.)

Narrow to broad band coefficients are built through multiple linear regression procedure. We developed a software that can perform all the necessary calculations (e.g. calculate reflectance from radiance, calculate narrow and broadband albedo etc.) and finally output N/B coefficients. Using H-8 as an example, we compared coefficients based on various methods as shown in **Figure** 3 for one particular case..

Our current selection for simulations is Scaled DISORT and use of 1 cm^{-1} band model. Including the 6 aerosol types; the total MODTRAN4.3 simulation number for each surface type is 288,000 (= 6 aerosol X 100 profiles X 10 sun angles X 48 satellite angles). *We have completed all the necessary simulations for ABI and H-8/AHI with this setting and developed the required regressions.*

Planned Work

- Modification of product validation "tools", as necessary, to accommodate content of GOES-16 datasets received from the GOES-R ground system.

- Perform intensive validation of L2 products during the GOES-R Post-Launch Test (PLT) and Extended Validation periods. Execute the validation activities defined in the GOES-R L2 Product Readiness, Implementation and Management Plan (RIMP) aimed at achieving Beta and Provisional levels of product maturity. Prepare and deliver presentations for Peer-Stakeholder Product Validation Reviews (PS-PVR).

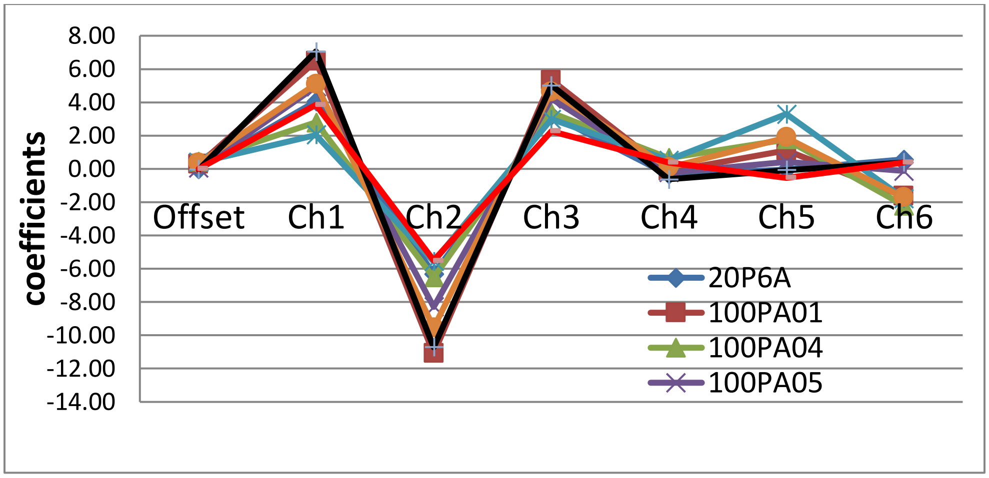


Figure 3.N/B coefficients for AHI during clear sky, based on various methodologies. The "100P6A" case is run with MODTRAN4.3 with 100 profiles, and aerosol option 6. The "Previous" stands for coefficients based on MOD-TRAN3.7 simulations. These results are for the case of surface snow, SZA of 12.9°, VZA of 11.4°, and AZ of 7.1°.

- Develop and test L2 algorithm updates, as necessary, to address any potential product performance issues in the GOES-R ground system. Work with the AIT to transition any updates to the GOES-R ground system.
- Update of documentation, as necessary, for routine product validation tools and/or ATBD.
- Coordinate updates to product algorithm software and/or data interfaces with the AIT.
- Support the GOES-R Ground Segment Project with the reviewing of applicable GOES-R Product User Guide (PUG) documents.

Products

All the simulation for ABI and H-8/AHI have been completed for clear and cloudy sky conditions. They have been delivered to STAR AWG.

Publications

Stamnes, K., S.-C. Tsay, W. Wiscombe, and K. Jayaweera, 1988. Numerically Stable Algorithm for Discrete-Ordinate-Method Radiaative Transfer in Multiple Scattering and Emitting Layered Media. *Applied Optics*, **27**. 2502-2509.

Isaacs, R. G., W. C. Wang, R. D. Worsham, and S. Goldenberg, 1987. Multiple Scattering LOWTRAN and FASCODE Models. *Applied Optics.* **26**, 1272-1281.

Borbas, E., S. W. Seemann, H.-L. Huang, J. Li, and W. P. Menzel, 2005. Global profile training database for satellite regression retrievals with estimates of skin temperature and emissivity. *Proc. Int. ATOVS Study Conf. XIV,* Beijing, China, CIMSS/ University of Wisconsin—Madison, 763–770 http://cimss.ssec.wisc.edu/itwg/itsc/itsc14/proceedings/2_9_Borbas.pdf).

Borbas, E. E., S. W. Seemann, A. Kern, L. Moy, J. Li, L. Gumley, and W. P. Menzel, 2011. MODIS Atmospheric Profile Retrieval-ATBD. Collection 006.http://modis-atmos.gsfc.nasa.gov/_docs//MOD07_atbd_v7_April2011.pdf

2.4b Scientific Support for the JPSS Mission

CUNY-CREST Ocean Color LISCO (AERONET Site) Cruise Data and Matchup

Task Leader	Alex Gilerson
NOAA Sponsor	JPSS Calibration and Validation Program Members
NOAA Office	NESDIS/ STAR
Task Code	AGSA_LISC_16
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Scientific Support for the JPSS Mission
Contribution to NOAA goals (%)	Goal 3: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight The Project has continued to provide a consistent stream of data from the SeaPRISM instrument on the Long Island Sound Coastal Observatory (LISCO) to NASA – AERONET. This quality assured in-situ OC data stream permitted evaluation of the quality of VIIRS retrieved OC products for coastal waters conditions, statistical analysis of VIIRS, MODIS and AERONET-OC data, and the impacts of the different processing schemes NASA and NOAA MSL12. Reflectance data from VIIRS validation cruises 2014, 2015 and 2016 are analyzed and compared with satellite data demonstrating good performance of CCNY instruments on board.

Background

The reliability of Ocean Color (OC) satellite observations of the open ocean and coastal zones need to be regularly assessed and validated against actual *in situ* measurements, along with related atmospheric corrections and error trends. This need is recognized by worldwide efforts devoted to acquiring accurate *in situ* time series measurements in open ocean and coastal waters, in conjunction with OC satellite imagery, to produce high quality data records which can be used both in support of operations and in climate studies. AERONET-OC sites with SeaPRISM instruments provide continuous data streams, which through the use of established algorithms are converted to multi-spectral, normalized water leaving radiances (nLw), and remote sensing reflectances (Rrs), and successfully used for the validation of SeaWiFS, MODIS, MERIS and now the JPSS/NPP/VIIRS sensor.

Our system, the Long Island Coastal Observatory (LISCO) established by the City College of the City University of New York (CCNY), supports JPSS/VIIRS cal/val activities through satellite – in situ and satellite – satellite data matchups. It provides a good representation of typical coastal water and atmospheric conditions, with a reasonable dynamic range of parameters for validation purposes. With the use of data acquired at LISCO and other coastal AERONET-OC sites in US and European waters, the validity of the VIIRS's OC and atmospheric data has been scrutinized and findings have been reported to the OC satellite remote sensing community, for better interpretation of physical or biogeochemical VIIRS data in coastal areas.

Additional data for the validation of satellites were acquired during three VIIRS validation cruises in Nov 2014, Dec 2015 and Oct 2016 on R/V Nancy Foster where underway hyperspectral measurements were made using a customized HyperSAS-POL system installed at the front of the ship, which also includes

HyperSAS radiometers sensitive to polarization. These data were compared with standard above and below water Rrs measurements of CCNY and other groups demonstrating very high quality of the HyperSAS data.

Accomplishments

The Cimel SeaPRISM instrument at LISCO (Long Island Sound Coastal Observatory) was recalibrated in April/May 2015 at the Goddard facility, and reinstalled on the platform on June 10th 2015. It was operational till mid-January 2017 and was removed from the platform in Feb 2017 due to the malfunction of the transmitter Satlink-2 (Sutron, VA). In the following we report comparisons between normalized water leaving radiance (nLw) measured at the LISCO AERONET site and those derived after the atmospheric correction from VIIRS and MODIS (both NASA and MSL12 processing), comparing for full years of 2015 and 2016.

The satellite data are averaged over a 3x3 pixel grid to minimize spatial inhomogeneities, retaining only pixels exempt from the following flags: Land, Cloudy, Bad navigation quality, High/moderate glint, High viewing/solar zenith angle. Scenes where nLw exhibits negative values are also excluded.
Temporal coincidence of ±2h was then sought with the SEAPRISM measurements. Most of valid data points (i.e., nearly-simultaneous measurements) come from the late winter/early spring period and the fall, a fact already observed for many AERONET-OC stations (e.g. WaveCIS, USC Seaprism).

Figure 1 shows the time series resulting from the filtering procedure. The comparison is generally good for green – red bands and worse for the blue bands.

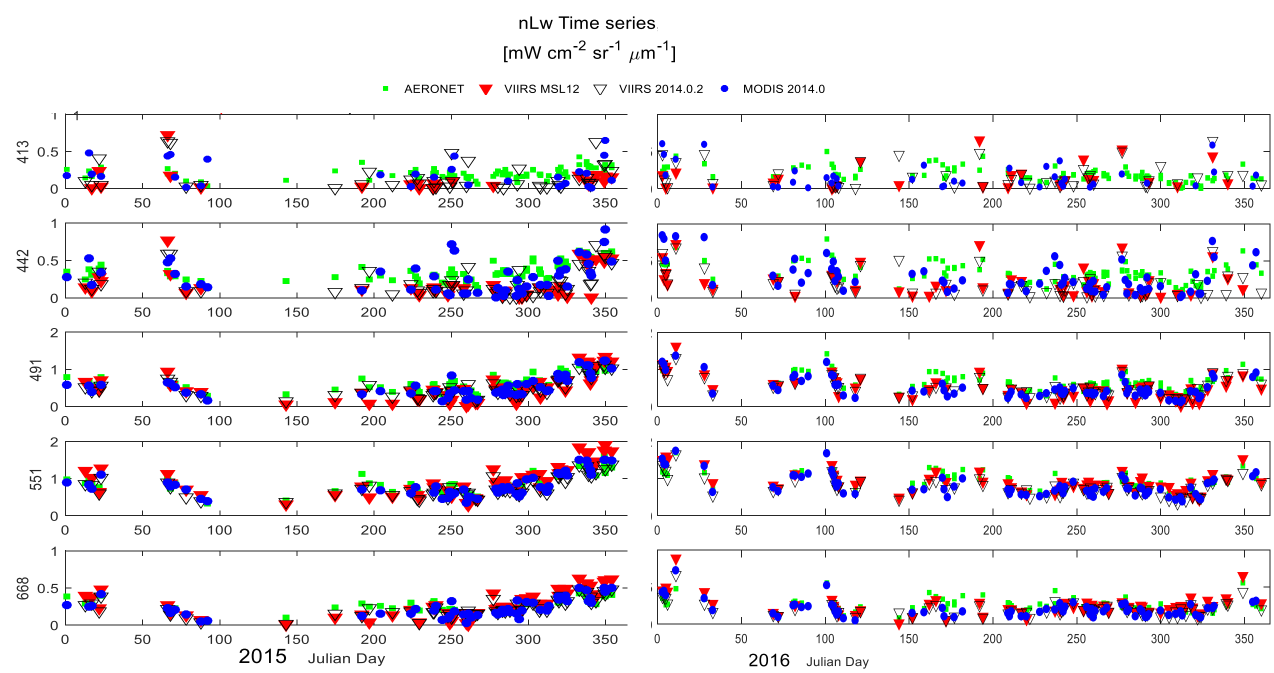


Figure 1: a) Coincident measurements of Water-leaving radiance by the AERONET-OC instrument at LISCO and either MODIS or VIIRS, for years 2015, 2016.

The goodness of the match-ups can be quantified by running linear regressions (not shown here) at each wavelength of these time series. For the longest wavelengths (≥490nm) and combined for all bands, the NASA processing scheme applied to both MODIS and VIIRS and NOAA MSL12 processing of VIIRS data show similar results with small slopes and biases. Correlations for 413 and 442 bands are quite low.

To characterize variability of spectra from water near LISCO platform which can affect the accuracy of comparison between satellite and AERONET-OC data field measurements were conducted in June 2016 at 13 stations in the area of the site in the radius of 2-3km from the platform. For the day of the cruise at the LISCO area reflectance spectra for most of the stations located at the distances 0-3 km from the platform matched well the spectra from the SeaPRISM and VIIRS. Larger differences occurred at the stations closer to the shore which are more than 2 km away from the platform and are not included in the processing scheme.

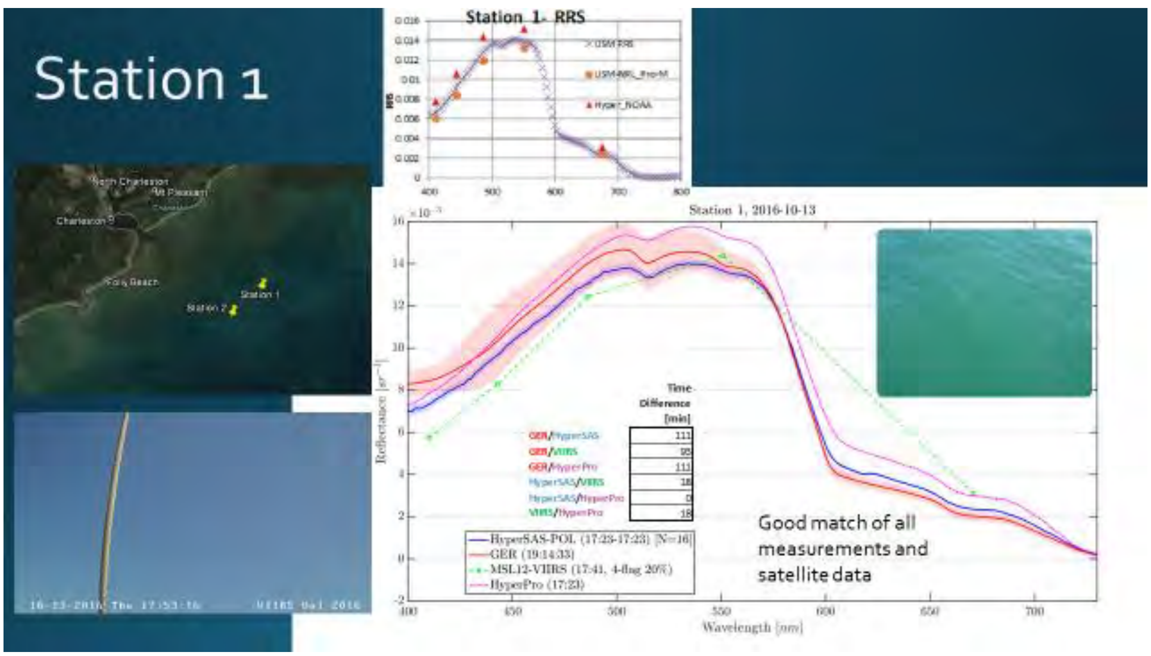


Figure 2. Match-up among HyperSAS, GER and other in-situ measurements together with VIIRS MSL12 data at station 1, 2016 cruise.

HyperSAS-POL collects hyperspectral measurements at 180 wavelengths in the 305-905 nm range at a single azimuthal angle, and at viewing zenith angles of 40◦ and 140◦. The system is outfitted for shipborne operations. Based on the ship GPS location and instantaneous heading, an automated script enables azimuthal rotation via a stepper motor, so that the observations can be maintained at 90◦ (or 270◦) azimuth relative to the Sun. If this configuration is impeded by the limits of rotation or the guy-wires supporting the mast, a 135◦ (or 225◦) relative azimuth is instead chosen. A tilt sensor records the platform attitude at high temporal resolution which allows correction of the measured parameters for the instantaneous attitude of the vessel in the post-processing stage. In addition remote sensing reflectance was measured by handheld GER spectroradiometer (SpectraVista, NY). Both instruments showed good performance in the recent NOAA cruises. Comparison of measurements by HyperSAS-POL, GER, instruments of other groups participated in the cruise and satellite data are shown in Figure 2.

Planned work

- Provide a continuous data stream of high quality from the LISCO site to NASA AERONET group including instrument calibration at NASA to ensure traceability to NIST standards.
- Matchups between satellite data (MODIS, VIIRS, OLCI on Sentinel3a) for the area of the platform and SeaPRISM data. Comparison of different processing schemes from MSL12 and NASA. Evaluation of data errors and uncertainties of the AERONET /SeaPRISM data stream.
- Field measurements in the area of the platform and other areas of opportunity, and matchup with SeaPRISM data.
- Participation in the validation cruises, analysis of cruise data.
- Assessment of impact of atmospheric conditions on the retrieval accuracy and evaluation of approaches to minimize uncertainties in satellite OC retrievals for coastal waters.
- Deliverable: characterization of the quality of the satellite data in coastal areas, possible suggestions for algorithm improvements.

Publications

R. Foster, A. Gilerson, "Polarized Transfer Functions of the Ocean Surface for Above-Surface Determination of the Vector Submarine Light Field," Applied Optics, 55, 9476-9494, 2016.

R. Foster, A. Gilerson, M. Ottaviani, A. Ibrahim, C. Carrizo, A. El-habashi, W. Slade, M. Twardowski, N. Stockley, D. Gray, I. Cetinic, "Polarized Remote Sensing Reflectance Retrieval through Wind-Driven Oceans and Validation with in-situ Polarimetry," Ocean Optics XXIII, Victoria, Canada, 2016.

R. Foster, A. McGilloway, M. Ottaviani, C. Carrizo, A. Gilerson, A. El-Habashi, and S. Ahmed, "Retrieval of the polarized submarine light field from above surface

Presentations

Matteo Ottaviani, Alex Gilerson, Robert Foster, Carlos Carrizo, Jacek Chowdhary, Sam Ahmed, "Accuracy of radiometric calibration of ocean color satellite sensors using AERONET-OC data", AGU Ocean Science Meeting, New Orleans 2016

Alex Gilerson, Samir Ahmed, Matteo Ottaviani, Robert Foster, Ahmed El-Habashi, Carlos Carrizo, Eder Herrera, Calibration/validation for Ocean Color satellites (LISCO and Ocean Cruises, JPSS meeting, MD, Aug 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of NOAA technical reports	2
# of presentations	0
# of graduate students supported by your CICS task	0
# of graduate students formally advised	2
# of undergraduate students mentored during the year	3

OSU JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color Products for the Coastal and Open Ocean

Task Leader	Curtiss Davis (Nicholas Tufillaro beginning FY 2017)
Task Code	CDCD_JPSS_16
NOAA Sponsor	Menghua Wang
NOAA Office	JPSS/IPO
Contribution to CICS Themes (%)	Theme 1: 10%; Theme 2: 80%; Theme 3: 10%.
Main CICS Research Topic	Scientific Support for the JPSS Mission
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 0%; Goal 3: 80%;

Strategic Research Guidance Memorandum: 2. Environmental Observations

Highlight: We developed new algorithims and documented protocols for above water reflectance measurements and validated it against HyperPRO data in the JPSS Ocean Color Validation Cruise in December 2016 and Platform Eureka SeaPRISM data in the Southern California bight. We also analyzed a two year time series of VIIRS data for the Southern California Bight using Platform Eureka SeaPRISM for validation and the data was used to help debug NOAA JPSS processing codes. Lastly, we processed and provided all *in situ* ocean data from US West Coast Cruises, and Hawaiian HOT cruises for use by NOAA.

Background

This report summarizes the work supported through CICS of the ongoing NOAA project entitled "JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color products for the coastal and open ocean" for activities in FY 2016. This activity is part of the JPSS Ocean Environmental Data Record (EDR) calibration and product validation team effort led by Menghua Wang (NOAA/STAR) and Bob Arnone (U. Southern Mississippi (USM)). As part of that team we are working with NOAA/STAR, Bob Arnone and others to establish and execute a plan for maintaining the on-orbit calibration of the VIIRS Visible and Near IR (VNIR) channels and for validation of ocean products. Experience with SeaWiFS, MODIS and MERIS makes it clear that ocean products must be validated in the open ocean and in diversity of coastal regions.

Our work at OSU focuses on the validation of ocean color products (water-leaving radiances and chlorophyll) for the coastal (West Coast of the US) and open ocean (Hawaii) waters. We validate VIIRS ocean color products using: (1) the Hawaii Ocean Time-series (HOT) HyperPRO data set at station Aloha in the North Pacific Gyre, and (2) Platform Eureka (a new SeaPRISM site off Southern California operated by Burt Jones (USC)) which is cross calibrated with the HyperPRO and above water remote sensing reflectance measurements. These time series are continuing and overlap with VIIRS on-orbit data collection.

Accomplishments

We are working with VIIRS data from STAR covering the entire Southern California Bight, and validating the VIIRS products using matchups with the Platform Eureka SeaPRISM data. During its first few years of operation, the SeaPRISM at Platform Eureka off the Los Angles Coast has shown consistently lower radiances than the VIIRS product data with the NOAA Star MSL12 processing. To track down the source of the bias we worked with NOAA and NASA to install a second SeaPRISM for comparisions in late 2015. After some initial instillation issues, the second side-by-side SeaPrism was functioning nominally by the

Spring of 2016. In the same time period the original SeaPrism was recalibrated by NASA, and both Sea-PRISM's where functioning nominally by the summer of 2016. A timeline of events related to the two instruments at Platform Eureka in the Southern California bight is shown in Table 1:

Table 1: Instruments Timeline

Date	Status of Instruments at Platform Eureka
2016-02-11	CIMEL #612 (Original SeaPrism) sent to GSFC for calibration
2016-04-27	New Access Agreement to site (Oil Platform) requested after rule changes
2016-06-20	CIMEL #612 reinstalled after NASA Calibration
2017-01-06	CIMEL #058 (Loaner SeaPrism) removed and returned to GSFC

To compare the two instruments we analyzed time series from 1 September to 31 December 2016. The Fall weather tends to be freer of coastal fog facilitating more match ups. We created a code to automatically identify 'outliers' (often due to quickly passing clouds or other itermittent events), and found 119 L2 in situ match ups with about 10% outlier rejections. The ideal result when comparing data from the two instruments is that the intercept is zero, and the slope (gain) 1.

To first compare instruments we looked at regressions to Sky Pointing data, so called 'Li' Sky Radiance across all visible bands shown in Figure 1.

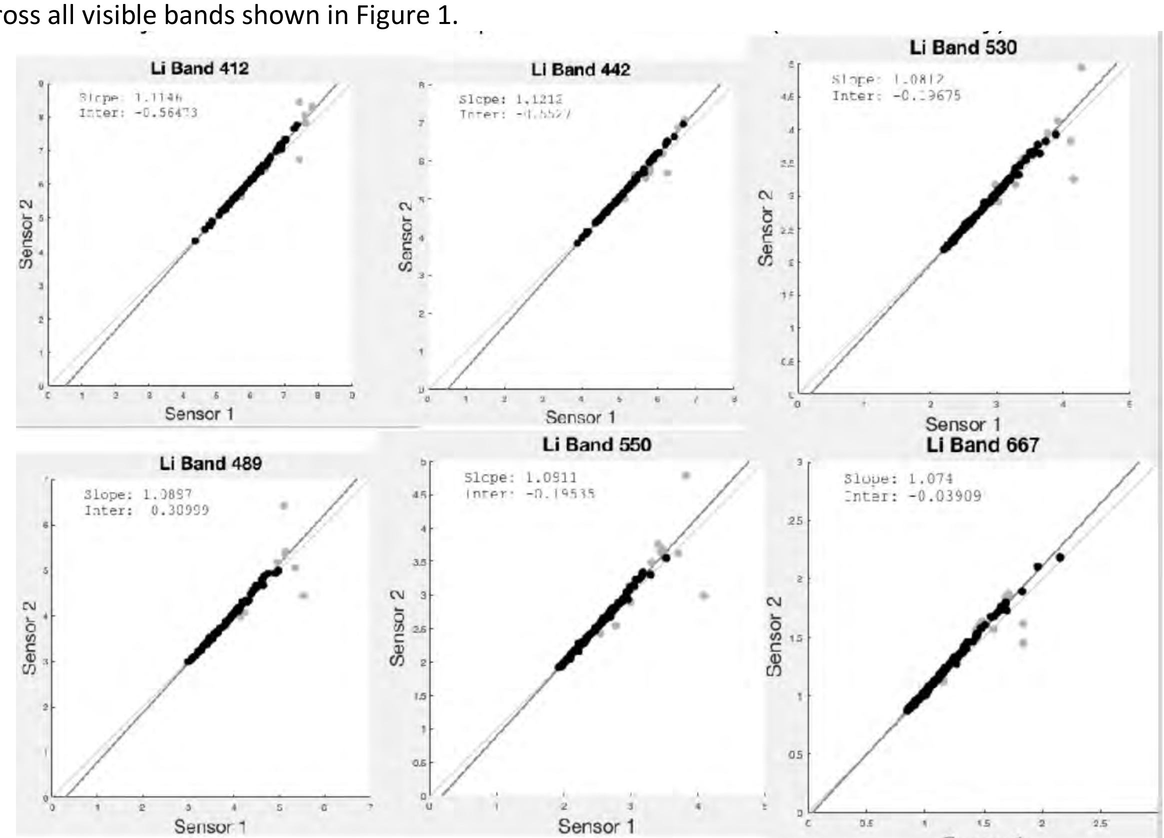


Figure 1. Regressions on all visible bands of 'L2' Sky Radiance data between CIMEL 058 (original) and 612 (loaner) during the fall and winter of 2016 at Platform Eureka in the Southern California Bight. Gray dots show outliers identified automatically due to transitory events such as rapid cloud overpasses. The measurements between the two instruments of the sky are not simulatenous but generally within 3 minutes.

Next, we compare all bands as shown in Figure 2. As hoped, the two sensors are in close agreement, with both the slope and intercept showing about ~3% discrepancy or less. The uncertainty indicated by the comparison of Sky Radiance also provides a rough indication of the any bias or errors that result from differences in field instiallation measurements as compared to Lab Calibrations. Such difference can be caused by (1) slight differences in Fields of View (FOV) of the sensor heads, differences of in reflections or shadowing off of the installation structure, (3) instrument changes (e.g. from transport) after lab calibrations. Individual bands can show more variation as indicated by Table 2. We can correct for any of these bias by a 'vicarious calibration' based on a subset of the field data (2 month out of 4) which essentially removes all bias and shows that the bias is stable over time and is probably due to slight differences in the instillations of each SeaPRISM.

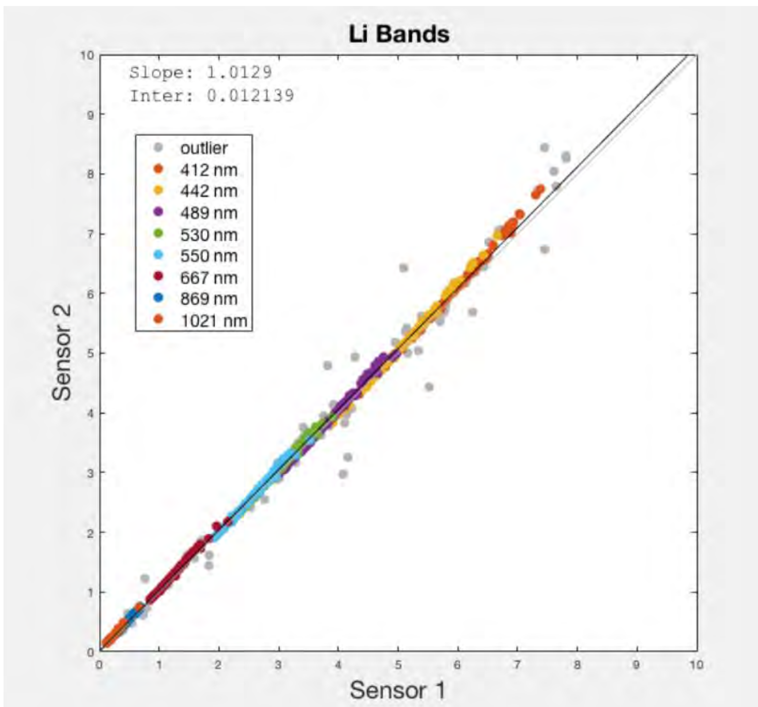


Figure 2. Regressions of 'L2' Sky Radiance data between CIMEL 058 (original) and 612 (loaner) during the fall and winter of 2016 at Platform Eureka in the Southern California Bight. Gray dots show outliers identified automatically due to transitory events such as rapid cloud overpasses. This 'field' comparison against a fixed sky radiance generally shows any bias of measurements between the two instruments possibly due to slight differences in their instillation. Here the differences are < ~3%.

Sky Radiance Li Comparisons (Relative Percentage Difference)

Slopes

Band	Original	No Outliers	Vicarious Calibration	All Bands No Outliers	All Bands Vicarious Calibration
412	-11.5273	-11.4626	0.0000	-1.2902	-0.0000
442	-10.0523	-12.1213	0.0000		
489	-6.1801	-8.9727	0		
530	-4.9339	-8.1161	0.0000		
550	-5.3406	-9.1051	0.0000		
667	-2.8839	-7.4025	0.0000		
869	-7.8416	-10.1915	-0.0000		
1021	-13.3642	-12.2349	0		

Intercepts

Band	Original	No Outliers	Vicarious Calibration	All Bands No Outliers	All Bands Vicarious Calibration
412	-9.5153	-9.3822	0.0000	0.2017	-0.0000
442	-8.9785	-10.8110	0.0000		
489	-5.4266	-8.1265	-0.0000		
530	-3.8859	-6.9171	0.0000		
550	-4.2666	-7.8579	0.0000		
667	0.7373	-3.2753	0.0000		
869	0.6734	-0.9867	0.0000		
1021	3.6319	4.2829	0		

Formulas

$y = m*x + b$

Slope Difference

$Es = 100*(1 - m)$

Intercept Difference

$Ei = 100*(b/mean(yi))$

Table 2. (Normalized) Percentage difference of individual bands between CIMEL 058 and 612. A 'vicarious' calibration can be performed which essentially zeros out any of these bias resulting from the after instilaltion in the field.

Next we compare the Normalize Water Leaving Radiances shown in Figures 3, all individual bands, and Figure 4, the aggregate. The result shows considerably more spread than the Sky Radiance measurements and can be taken as rough estimate of the uncertainties of both field measurements and processing uncertainties for radiance measurements of water, a much darker target. The errors and bias, though, are still less than ~10%, and *are not sufficient to explain the consisent observed bias of ~20% or more in the pre-2016 field measurements*. Based on these and other comparisions a re-examination of the satellite processing found evidence that the source of the discrepancies was in the UV-Blue processing steps in the MSL12 code. Initial reprocessing by NOAA looks like it has resolved the anomaly, and NOAA is now undertaking a reprocessing of the VIIRS historical data with the revised code.

After consulting with Giuseppe Zibordi, we confirmed that the dual SeaPrism data set is unique and we are now using it to study, and prepare a publication, on the uncertainties associated with SeaPRISM field meaurements as well field based methods of vicarious calibration. Progress on our validation efforts was presented at the 2016 STAR JPSS Team Meeting in College Park, MD.

Nick Tufillaro trained Ivan Lalovic on measurement protocols, and Ivan participated in the annual NOAA VIIRS Validation cruise on the R/V Nancy Foster, out of Charleston, SC in Fall of 2016 (Figure 6). Ivan operated two instruments (the OSU Satlantic HyperPRO and Spectral Evolution handheld Spectrometer) and participated in cross calibration and product validation activities on the cruise. Ivan also assisted Mike Ondrusek with pre- and post-calibration activities at Mike's NOAA calibration lab.

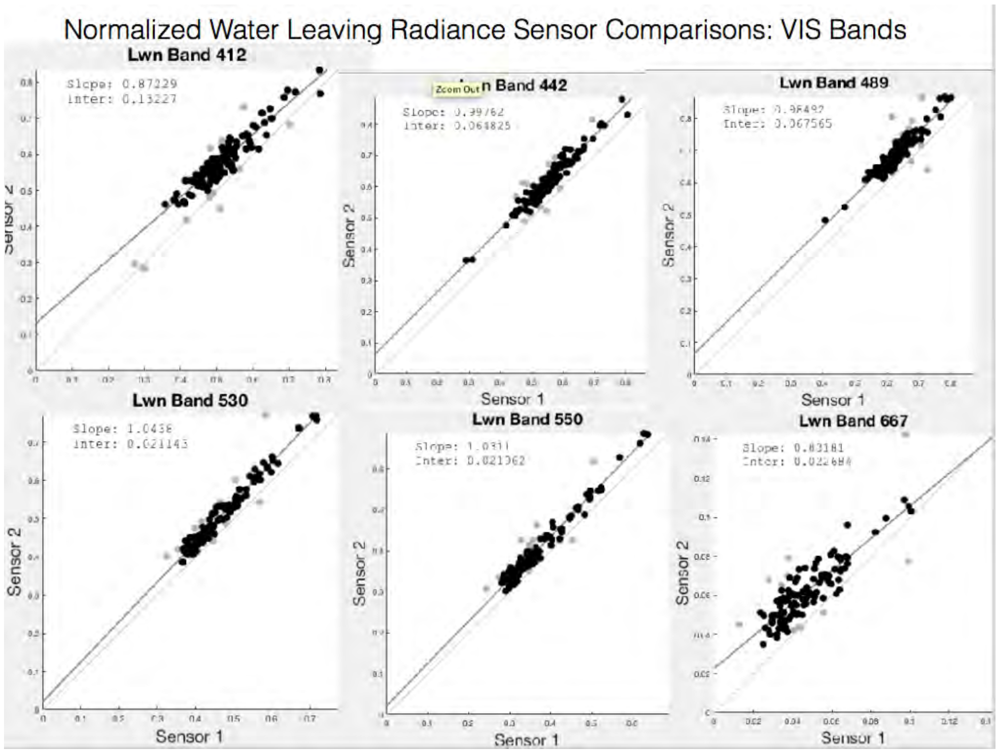


Figure 4. Comparisons of Normalized Water Leaving Radiaces for two SeaPRISM (CIMEL Sensor 058 and 612) on the oil Platform Eureka in the Southern California Bight.

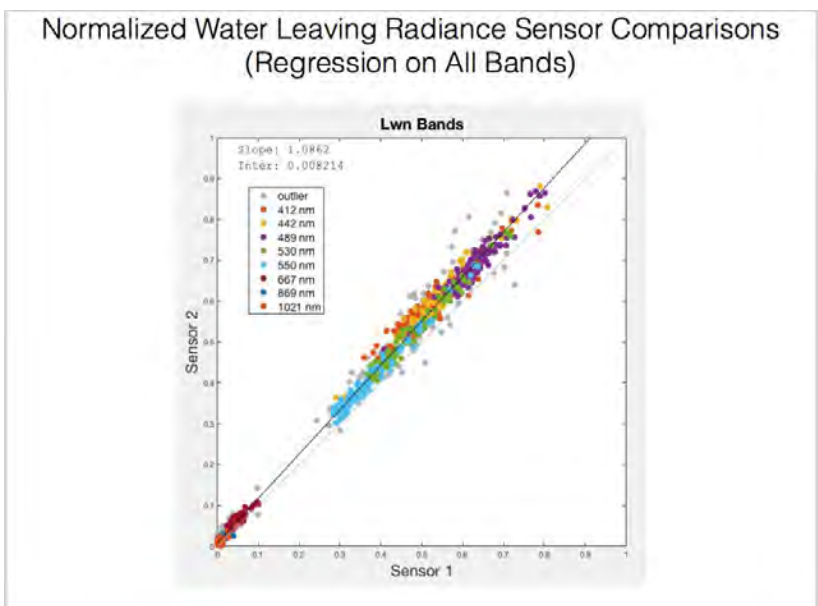


Figure 5. Comparisons of Normalized Water Leaving Radiaces for two SeaPRISM (CIMEL Sensor 058 and 612) on the oil Platform Eureka in the Southern California Bight with all bands aggregated.

Figure 6. Team picture of NOAA Nancy Foster Cruise 2016. Ivan Lalovic is front, 2nd from right.

During the cruise, we compared our above water measurements with the new Spectral Evolution (SE) spectrometer with the more common ASD spectrometer using standard white and gray plaques from the Naval Research Labs and NIST. Initial on board results showed good agreement with our measurements and those from NOAA and NRL. Following the team suggestions from 2016 cruise, we provided a new surface correction for the SE above water reflectance measurements based on the work of Lee et. al, “Removal of surface-reflected light for the measurement of remote-sensing reflectance from an above surface platform (OSA 2010). An automated code was developed for processing the SE reflecatance data to Rrs which takes care of all steps of processing from outlier rejections, to resampling based on statistical criteria. We also assisted both NRL and UMass with the operation of the SE, including the design and fabrication of a new probe head holder design. The group also compared the in-water measurements among the Satlantic HyperPROs during casts coordinated by Mike Ondrusek. We have finished processing our data and sent it to Mike Ondrusek at NOAA for detailed comparisons. An example of the OSU HyperPRO data is shown in Figure 7.

During the past year and a half we worked with NOAA (Mike Ondrusek) and the instrument manufacturer Satlantic to refine our methods for the HyperPRO data collection and processing including incorporating the multicast method for the surface waters at HOT to obtain the best possible remote sensing reflectance from this data. This work resulted in a HOT training manual for making the HyperPRO measurements and approved procedures and processing software that is identical to that used by NOAA and others. NOAA PI Mike Ondrusek is currently preparing a publication for overall hyperpro protocols for use by NOAA. Dr. Curtiss Davis also retired this year and the OSU project work is being lead by Dr. Nicholas Tufillaro going forward.

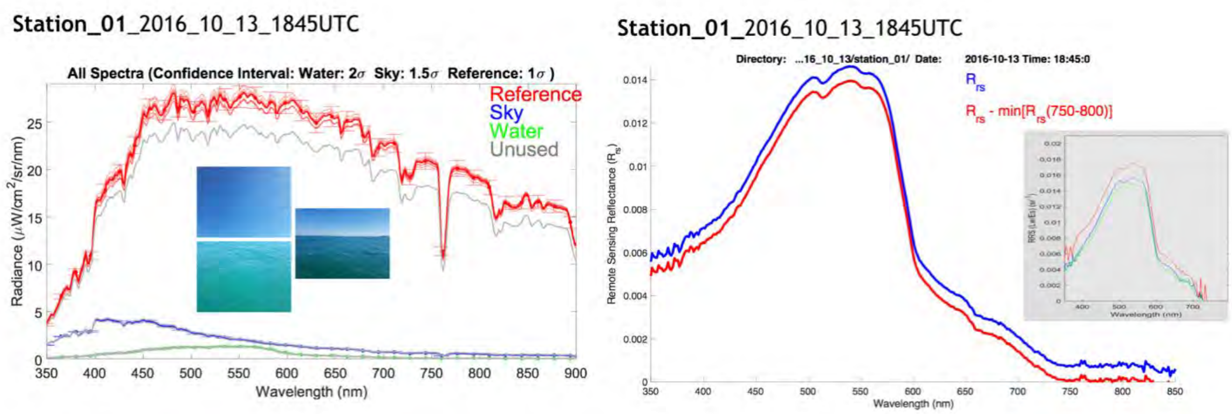


Figure 7. Automated processing application to compute Remote Sensing Reflectance from Spectral Evolution above water radiance measurements. Statistical procedures are used to remove outliers and data is resampled and binned to a standard grid. Data from2016 “Hurricane Matthew” Nancy Foster Cruise is shown.

Planned work

- Continue processing and analysis of Station Aloha HOT HyperPRO including match ups with VIIRS data for product validation
- Continue analysis of time series of VIIRS data for the Southern California Bight
- Participate in and present results at NOAA teleconferences and the NOAA STAR/JPSS Annual Meeting in August 2017.
- Participate in the 2017 NOAA VIIRS science cruise for cross calibration of instruments and methods for:
  - Above Water Rrs
  - HyperPRO optical profiles
- All *in situ* data provided to NOAA STAR for VIIRS data product validation
- Publication on above water reflectance methods
- Publication on the validation of VIIRS data with the Platform Eureka SeaPRISM time series including comparisons with other SeaPRISM sites
- Publication on uncertainties for ocean measurements with Hyperspectral Instruments
- Delivery of all processed *in situ* data to NOAA.

Publications

R. Basnayake, E. Bollt, N. Tufillaro, J. Sin and M. Gierach, Regularization Destriping of Remote Sensing Imagery, Nonlinear Processing in Geophysics, 2016 (in review).

Products

- Monthly time series of HOT HyperPRO data delivered to NOAA/STAR;
- *In situ* data from the NOAA VIIRS Science Cruises, HOT HyperPRO data and Platform Eureka Validation cruises provided to NOAA STAR;
- Publication on above water remote sensing reflectance measurement method; and

- Publication on the VIIRS time series analysis for the Southern California Bight

Presentations

Tufillaro, N. and C. Davis, Validation of VIIRS Ocean Color Products for the West Coast, STAR JPSS Team Meeting Talk 8-12 August 2016, College Park, MD.

Jenkins, J. Goes, Gomes, A. Chekalyuk, R. Arnone and N. Tufillaro, 2016, Community composition, biomass and photosynthetic competency of phytoplankton associated with microscale features and frontal zones of the Gulf Stream, ME54C-0940, Ocean Sciences Meeting, 26 February, 2016, New Orleans, LA.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	1
# of NOAA technical reports	0
# of presentations	1
# of graduate students supported by your CICS task	0
# of graduate students formally advised	2
# of undergraduate students mentored during the year	0

This project was previously supported through CIOSS at Oregon State University and has been supported through CICS for the last 30 months. Focus has been on developing a new above water reflectance measurement method and the validation of that method against the HyperPRO method particularly during the VIIRS Ocean Color Validation Cruises. We are using these improved methods to continue our validation of VIIRS open ocean products from station Aloha using the Hawaii Ocean Time series (HOT) HyperPRO data and validation of coastal products for the Southern California Bight using data from the Platform Eureka SeaPRISM.

Validation of Cryospheric EDRs GCOM AMSR2

Task Leader	Cezar Kongoli
Task Code	CKCK_AMSR_14 Year 3 & CKCK_AMSR_16
NOAA Sponsor	Paul Chang
NOAA OFFICE	NESDIS/STAR
Percent contribution to CICS Themes	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Scientific Support for the JPSS Mission
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%; Goal 3: 0%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: A blended AMSR-2 snow depth algorithm using optimal interpolation of in-situ surface Snow Depth has been developed.

Background

A suite of AMSR2 operational snow algorithms have been developed for operational implementation at NOAA as Option 2 products. The suite of snow products includes snow cover, snow depth and Snow Water Equivalent (SWE).

Accomplishments

The snow algorithms – snow cover extent, snow depth and snow water equivalent – have been developed for operational use. Figure 1 presents statistical measures of accuracy for the snow depth product with respect to in-situ data.

	STD (cm)	Bias (cm)	Number of samples
All data	17.97	0.39	130,036
ff=0	17.20	-3.69	69,139
0.0<ff<=0.5	18.26	6.14	35,232
ff>0.5	16.78	3.46	25,665

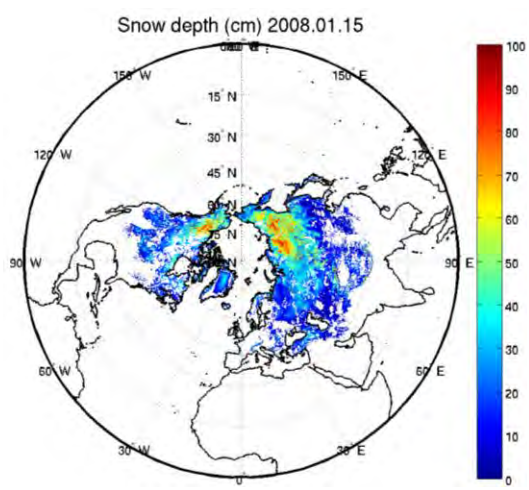


Figure 1. Snow Depth algorithm statistics with respect to in-situ stations (left) and a map of retrieved Snow Depth (right)

As shown in the table, although the overall bias is small, regional biases can be substantial, e.g., over 30% of the mean snow depth in forested areas.

To reduce regional biases, ***a method has been developed based on optimal interpolation of in-situ data.*** In this application, the satellite snow depth is the first guess, and a correction factor is computed for each valid AMSR2 snow depth value using surrounding in-situ snow depth (in a box approx. 300 km in size) for days prior to the analysis day. Adjustments are thus computed dynamically from the in-situ data collected in the previous days and applied to satellite snow depth at analysis time.

Station snow depth measurements are extracted from the Global Historical Climatology Network (GHCN). Figure 2 shows an AMSR2 snow depth map over Northern Hemisphere (top) on January 1, 2017 and the bias-corrected AMSR2 snow depth (bottom). Overall the AMSR2 product shows a reasonable large-scale snow depth distribution. The largest corrections and improvements occur over Northern Europe, western Siberia, along the north-west coast of US/ Canada and over Alaska.

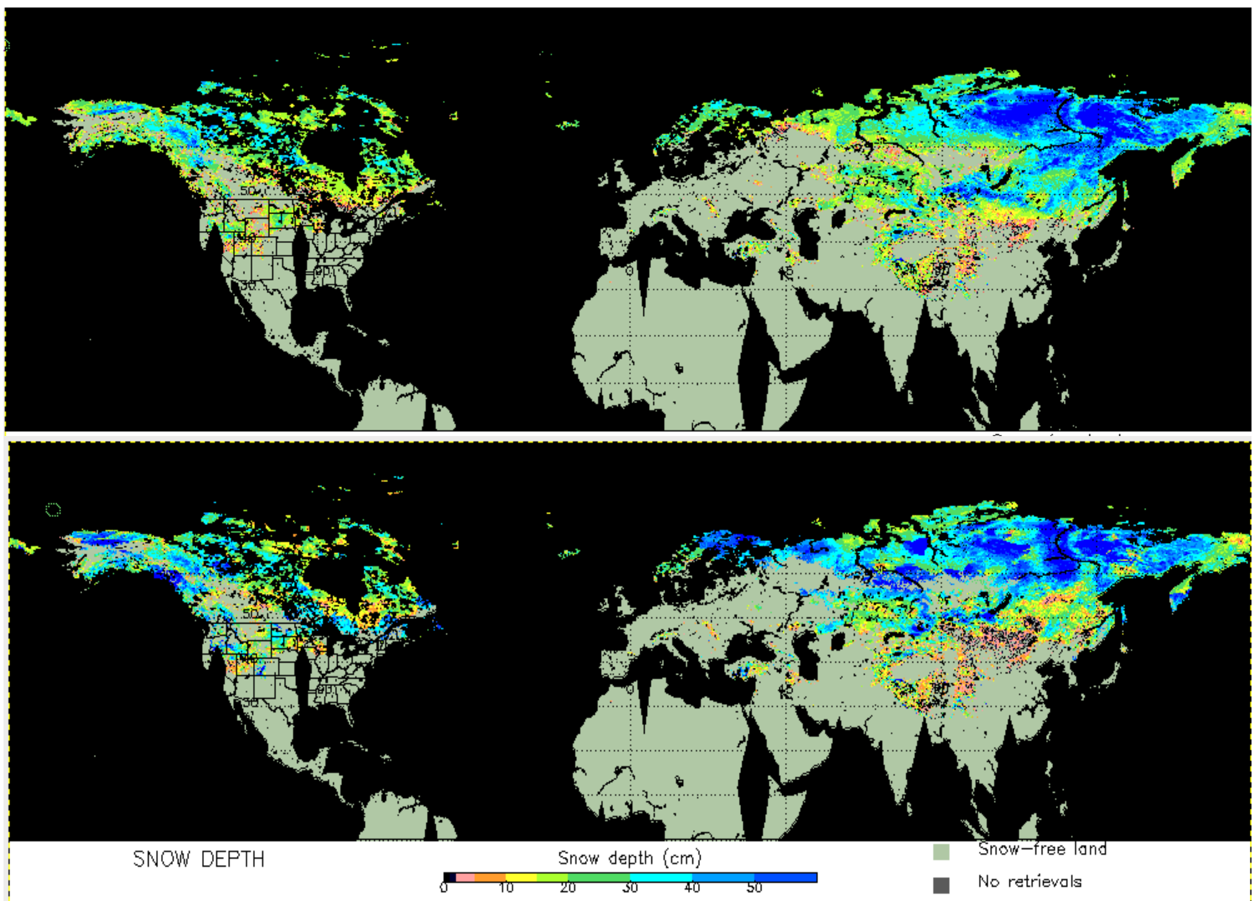


Figure 2. AMSR-2 Snow Depth before (top) and after (bottom) bias correction applied to in-situ data from GHCN-Daily using optimal interpolation.

Planned work

- Test the new bias-correction method
- Downscale snow products to 4-km resolution

Publications

Lee, Y-K**,** C. Kongoli, and J. Key, 2015. An in-depth evaluation of NOAA's snow heritage algorithms, *J. Atmos. Oceanic Technol.*, 32, 2319–2336

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	3
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Three AMSR2 snow products have been transitioned to operations improved (3) and one operational product (snow depth) improved.

Science and Managerial Support to Global Space-Based Inter-Calibration System (GSICS)	
Task Leader	Manik Bali
Task Code	EBMB_GSIC_15 Year 2
NOAA Sponsor	Fuzhong Weng/Lawrence E Flynn
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%)	Theme 1:100%
Main CICS Research Topic	Scientific Support for the JPSS Mission
Contribution to NOAA goals (%)	Goal 1:100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

The GSICS (gsics.wmo.int) Coordination Center (GCC) hosted by NOAA Star is lead by NOAA lead Lawrence E. Flynn who serves as Director of GCC. Manik Bali, the Task Leader of this task supports the NOAA lead as Deputy Director of GCC, Editor of GSICS Newsletter and Member of GSICS Data Working Group.

The main aim of GCC is to facilitate the sharing of inter-calibration activities across 15 satellite agencies (members of GSICS) and to lead the scientific discourse on application of inter-calibration data and algorithms for monitoring and maintaining in-orbit satellite accuracy and stability. A major GCC also helps members decide on choosing in-orbit references and making them aware of expectations from user community. GCC also publishes quarterly newsletters that are vetted by WMO and member agencies.

As member of GSICS Data Working group, Manik Bali supports identification of Meta data standards for GSICS products, Mirroring of GSICS Products and routine activities of GSICS Product generation such as supporting threads migration.

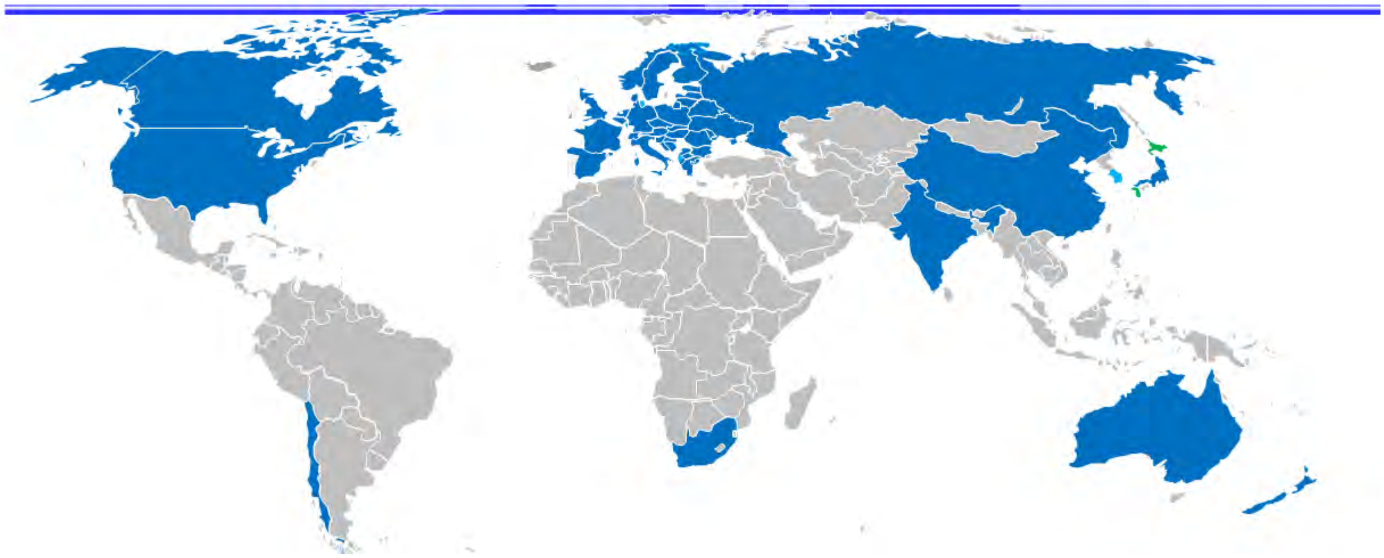
Accomplishments

Past year has seen several accomplishments. These accomplishments have been presented in international conferences.

1. GCC enhanced the capabilities of GSICS Procedure for Product Acceptance and new products from EUMETSAT were included in the Product Catalog.
2. GCC built a new Google Cloud based Action Tracker used by WMO members (see here)
3. GCC published four newsletters in the past year. Subscription has crossed 320 members worldwide and journals have started connecting with the Newsletter
4. Organized the GSICS Users Workshop 2016 (see here).

Newsletter Readers across the world

Subscribed to by over 320 members across the world



1. For the first time proposed in-orbit references for Microwave Instruments

Monitoring of in-orbit microwave instruments is critical to all downstream services that use the Micro-wave instruments for purposes such as weather forecasting, geophysical retrievals of water vapor and temperature etc. We proposed that Fundamental Climate Data Record developed by Cheng-Zhi Zou can act as vital in-orbit reference because of its high stability and long term record (~ 40 Yrs).

Using a set of collocations between SATMS and MSU-AMSU-A FCDR developed by Cheng Zhi Zou , GCC showed that this FCDR is nearly as good as Pre-launch reference.

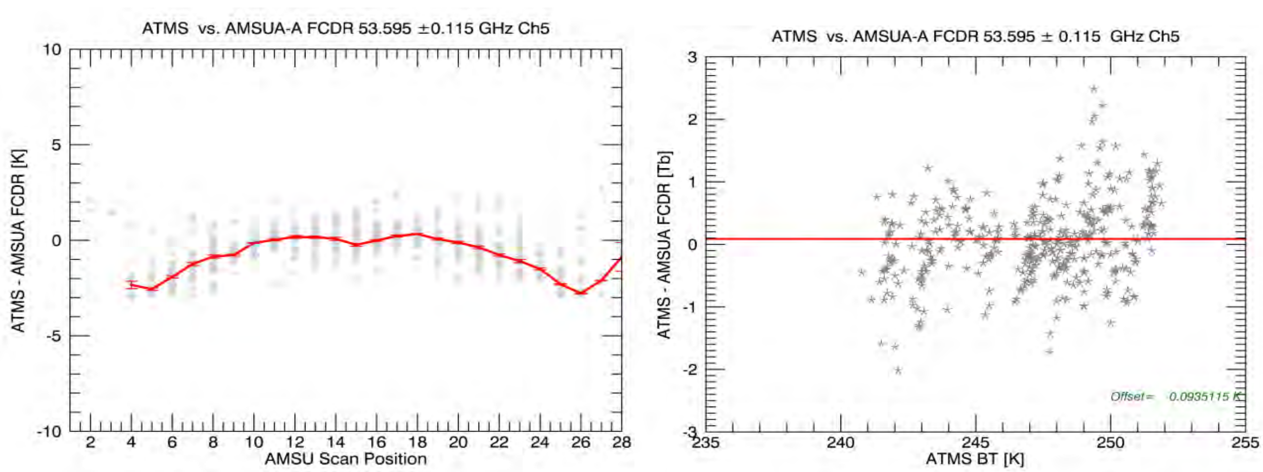


Figure 1. Shows inter-comparison of FCDR with ATMS-SDR. Shows a small Scan angle dependence. The figure on the right shows a nearly zero bias between FCDR and ATMS thereby it is nearly as good as a pre-launch reference

2. **GCC applied algorithms to produce Spectral Response Function by inter-comparison with Hyper Spectral Instrument to new instruments.**

The spectral response function is retrieved by using de-convolution. This technique gives a deterministic solution to the system linear equations that are used to fit the representative radiances. GSICS wishes to include this as a product.

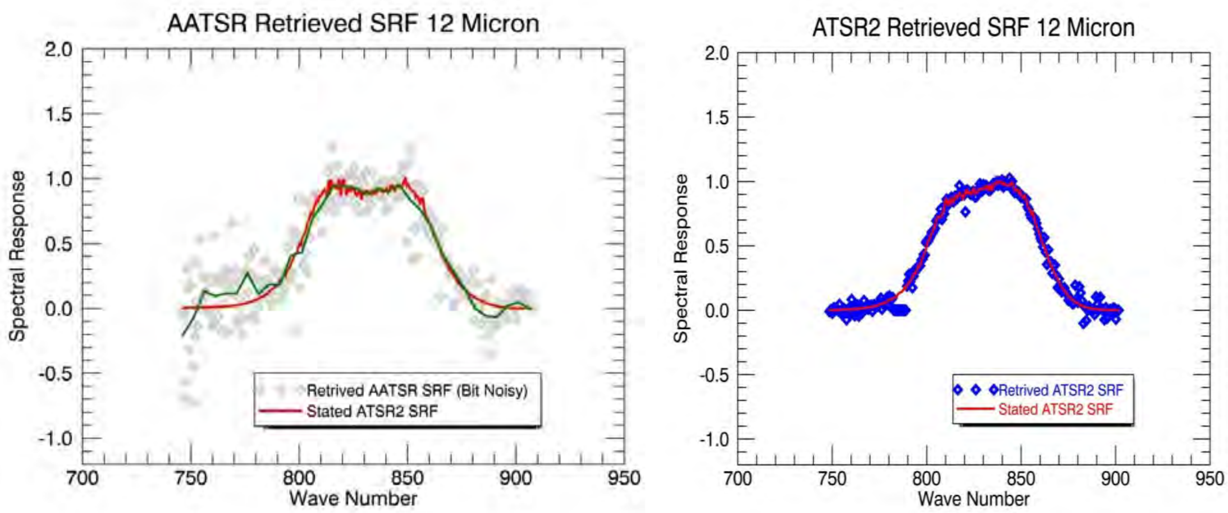


Figure 2. (left) AATSR SRF retrieved from collocations with IASI-A; (right) ATSR-2 SRF retrieved from collocations with AIIRS.

3. **Performance Summary of GSICS GEO instruments**

The GSICS Coordination Center recently developed capabilities to monitor the member states GEO instruments by producing monitoring summaries. These summaries are bias monitoring over time at standard scene temperature (265 K). The standard scene temperature bias is a variable included in the GSICS bias monitoring product.

Summaries were presented at the GSICS Annual meeting and GCC received action to further maintain an instrument monitoring database. It is being currently discussed to include these summaries in the ICVS.

4. **NOAA- GSICS Data Working Group duties**

- Established the GSICS Microwave metadata standards. These have been accepted by the microwave subgroup. Implemented the metadata into the FCDR
- Developed scripts to download the GSICS products from thredds server (see here)
- Maintain a mirror site for GSICS product . The mirror of the products can be visited here .

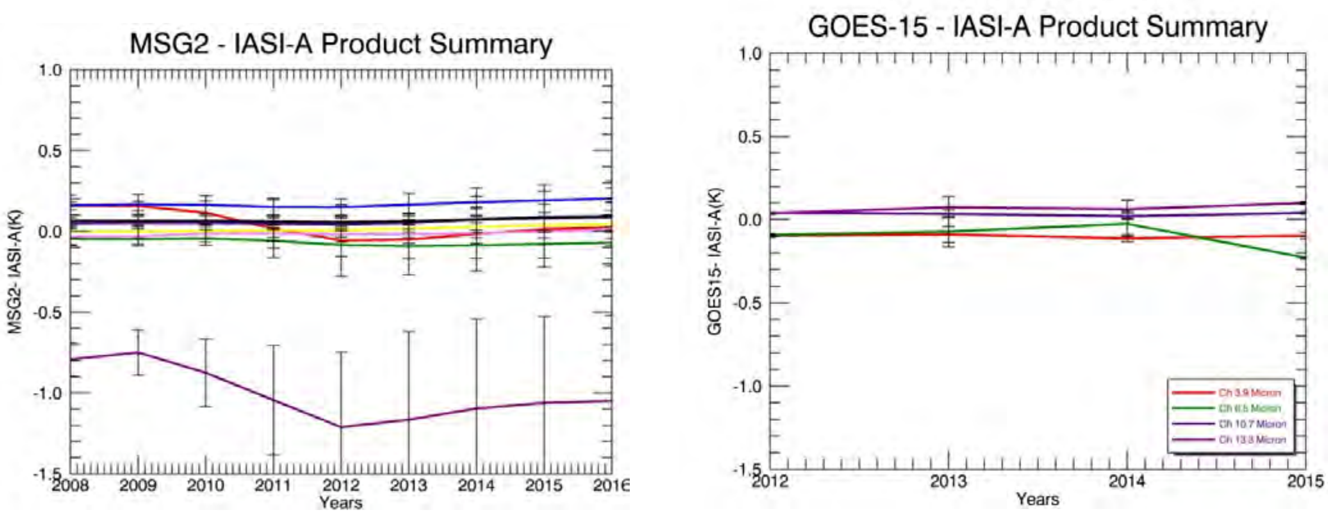


Figure 3. Shows the bias monitoring of GOES-15 and MSG2 done by GCC. All instruments are performing well within specs. The MSG2 13 Micron channel anomaly has been reported to EUMETSAT and they are investigating it currently.

Planned work

1) Perform duties as the Editor of the GSICS Quarterly Newsletter, co-ordinate and Manage web meeting of various GSICS subgroups, help to co-ordinate and organize international workshops on GSICS topics

2) Prepare reports and track action items for GCC and subsidiary working groups, assist the GCC Director in establishing the GRWG sub-working research groups, assist the GSICS director in identification of new Satellite products to promote.

3) Design and maintain the GSICS data working group website and wiki pages, design and develop a GSICS product acceptance plan as well as product taxonomy, file naming conventions and meta data conventions for all the subgroups of GSICS (IR MW VIS UV).

4) Establish trust-worthiness of GSICS community reference instruments such as CrIS/IASI/AIRS and use them for re-constructing post launch status of Spectral Response Functions of GEO instruments such as GOES.

5) Confirmation of requirements and development of acceptance procedures for GSICS measurements, prepare reports and track action items for GCC and subsidiary working groups, publish work in international journals of repute.

6) Conduct original research on calibration for space-based measurement systems operating in the visible and ultraviolet, including on-orbit refinement of spectral response functions and development of vicarious calibration methods.

7) Support GSICS/WMO to develop a Document Management System.

Publications

Bali, M., Mittaz, J. P and Goldberg, M. D.: How good are GSICS References, IASI-A and AIRS ?. GSICS Quarterly: Summer Issue 2016 Volume 10, No. 2, 2016 doi:10.7289/V5GT5K7S

Bali, M., Mittaz, J. P., Maturi, E., and Goldberg, M. D.: Comparisons of IASI-A and AATSR measurements of top-of-atmosphere radiance over an extended period, Atmos. Meas. Tech., 9, 3325 -3336, doi:10.5194/amt-9-3325-2016, 2016

Products

e.g., documented instrument development, algorithm development, numerical model development and data set generation

Presentations

Bali M, et al, Selection of in-orbit references for Global Space Based Inter-Calibration System, 2016 AGU Meeting San Francisco (Dec 2016)

Bali M et al, In-orbit references for Global Space Based Inter-Calibration System , CICS 2016 Science Meeting, (Nov 2016)

Bali M et al, GSICS Products and their Applications, 2016 EUMETSAT Satellite Conference, Darmstadt, Germany(Sept 2016)

Bali M et al, GSICS User Survey, 2016 GSICS Users Workshop (Sept 2016), College Park , MD (Sep 2016)

Bali M et al, Using AIRS and IASI as in-orbit references in GSICS , NASA Sounder Science Team Meeting (Sep 2016, **invited talk**)

Bali M et al, Instrument landing pages OSCAR , 2016 GSICS Users Workshop (Sept 2016), College Park , MD (Aug 2016)

Flynn L and M Bali. GCC Annual Report , GSICS Executive Panel Meeting, Sophia France, June 2016

Bali M and L Flynn, GSICS Users Requirements, Sophia , France (June 2016)

Bali M et al, GSICS Procedure for Product Acceptance, GSICS Annual Meeting, (March 2016)

Bali M et al, Selecting GSICS References: IR, VIS and MW, GSICS Annual Meeting, Tsukuba Japan (March 2016)

Bali M et al, Mirroring GSICS Products, GSICS Annual Meeting, Tsukuba Japan (March 2016)

Other

NOAA STAR Award
Global Satellite Inter Calibration System (GSICS):
For outstanding service to WMO's Global Satellite Inter Calibration System (GSICS) community and Leadership of the NOAA GSICS Coordination Center

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of NOAA technical reports	2
# of presentations	1
# of graduate students supported by your CICS task	1
# of graduate students formally advised	
# of undergraduate students mentored during the year	1

Continued Monitoring and Day-2 Algorithms of AMSR2 EDRs

Task Leader	Patrick Meyers
Task Code	EBPM_AMSR2_14 Year 3 & EBPM_AMSR2_16
NOAA Sponsor	Paul Chang and Ralph Ferraro
NOAA Office	NESDIS/STAR/CRPD/SCSB
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Scientific support for the JPSS Mission
Contribution to NOAA goals (%)	Goal 1: 70%; Goal 2: 30%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: GCOM-W/AMSR2 rain rate product achieved "Validated Maturity" under the JPSS program**.**
Website: http://www.ospo.noaa.gov/Products/atmosphere/gpds/

Background

In November 2015, the NOAA Office of Satellite and Product Operations (OSPO) commenced operational production of the Day-1 Environmental Data Records (EDRs) for the Advanced Scanning Microwave Radiometer 2 (AMSR2) on the Global Change Observation Mission – Water (GCOM-W) satellite. CICS-MD is responsible for the rain rate EDR, and providing support as-needed for the sea surface temperature (SST), total precipitable water (TPW), cloud liquid water (CLW), and wind speed (WSPD) algorithms. The rain rate algorithm is an adapted version of the Goddard Profiling Algorithm 2010 (GPROF2010; Meyers et al. 2016), which uses a Bayesian retrieval method over oceans and an empirical brightness temperature relationship over land.

The AMSR2 rain rate EDR meets product requirements as established by the Joint Polar Satellite System (JPSS) program. Continued monitoring and validation efforts identify nuances of the algorithm under different atmospheric and environmental conditions. For instance, routine comparisons between the AMSR2 EDR and ground-based radars identified frequent false detection of rainfall in semi-arid regions during overnight hours. Recurring issues can then be addressed in future versions of GPROF2010 for AMSR2. In addition to monitoring the current AMSR2 algorithm, the next generation of GPROF developed for the Global Precipitation Measurement (GPM) Mission is under evaluation as a potential upgrade to the operational NOAA product.

Accomplishments

In October 2016, the Day-1 AMSR2 EDRs reached the "Validated" maturity level under the JPSS program. To reach this stage, the algorithm must meet accuracy requirements and have extensive documentation, including a ReadMe, Algorithm Theoretical Basis Document, user manuals, and peer-reviewed publications. The AMSR2 rain rate EDR was approved with several recommendations for further analysis.

Additionally, the AMSR2 rain rate was incorporated into the NOAA/STAR Blended Rain Rate (bRR) product. Rain rate observations from passive microwave sensors are combined into a single product with the most recent satellite observations, which are delivered to NOAA operational forecasters. As part of the product evaluation, routine monitoring of the bRR product was established in support of OSPO. Every 6 hours, the latest bRR analysis is compared to the Multi-Radar Multi-Sensor rain rate product (Fig. 1).